Interference in Academic and Non-academic Expressions of Academicians as a Threat to Professional Immunity: A Legal Research Specially Focused on Bangladeshi Universities

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Abstract

It requires no reference all over the world to claim that where there is a duty, there is a right. But sometimes, exceptions are found unexpectedly. Though the concept of Intellectual Property Law is not very ancient in nature, but it covers a great part of rights of meritorious people over intangible assets. It has been observed by the researchers that some sorts of IP are yet overlooked by the lawmakers while making a focused area of IP. It has been found through analysis that the question of recognition of reflection of personal thoughts of a university teacher in a classroom is not irrelevant in Bangladesh perspective. And a mentionable number of unexpected events have been experienced like copying and publishing papers which could easily be called plagiarism if were done from a written research. The level of interference is so frustrating that some teachers even have been victimized physically and socially. Such humiliating harassment is expanded even up to police arrest. It has been found inconsistent that there are available examples of non-recognition of personal thought as IP, but abusing interpretations are available as to sufferings. This seems a threat to education system of Bangladesh as professional immunity is hampered in a mentionable manner in this process which is easily exercisable in other professions. This research bonafidely attempts to unveil some hidden issues and recommend a relevant solution.

Keywords: Academic Freedom, Academicians, University, Professional Immunity

1.0. Introduction

Though the need of time creates the urge of professionalism all over the world and the universities are not also exceptional, even then, it is apprehended that the facilities which other professionals enjoy, are not so frequent in the University teachers of Bangladesh. In the private universities, the concept of academic freedom for betterment of professionalism seems a myth. Even in the public universities, there are mentionable number of cases where academic freedom has been challenged in a frustrating manner. The authors think that "teaching" is the only profession which supervises all other professions all over the world. But, sorry to say, the question of dignity, the

question of security, the question of professionality all are ignored in Bangladesh. While a judge gives his/her judicial decision, is being provided professional immunity, as judicial decisions can never be wrong, though can be changed over review-revision-appeal-second appeal etc. While a doctor makes an operation and cannot save the patient even after having proper caution, the law itself provides him/her professional immunity as it is necessary for professional safeguards. Such immunities are provided also for the lawyers, tailors, engineers, contractors, police, defence forces, executive organs of government etc. But, the teachers, who are the nurses of all such professions, are not being provided such immunity. Such ill treatment of a parent profession risks enough to create more disable professions in future, if only once the teachers decide to do so. This is the right time to stop ignoring and start taking care of academic freedom in Bangladesh.

1.1. Statement of Problem/ Sorts of Interferrence the Academicians Usually Face

i. Sacking, suspension from job
ii. Making official pressure
iii. Social harrassment
iv. State responsibility: Police arrest, remand, custodial torture
v. Life threat, killing, extradition, driving away from country

2.0. Methodology

2.1. Research Approach

Though the proposed study is primarily qualitative in nature, both qualitative and quantitative approaches have been used for validity and reliability. In order to find out an adaptable legal solution as means of accelerating strategies comparative study has been held.

2.1.1. Sources of Data

Necessary data has been collected from both primary and secondary sources. The secondary data has been collected from relevant books, journal articles, research reports, official publications, thesis, dissertations etc. and primary data has been collected from judges, advocates, litigant peoples, members of law commissions, secretary of Law and Justice division of Ministry of Law and Parliamentary Affairs, relevant laws for disposal of civil cases and reports, monthly and yearly statements of the Supreme Court, Law Commission, Law Ministry and District Judge Courts.

2.1.2. Research Questions

In what perspective the current practice of professionality of University teachers of Bangladesh is objectionable?

Is academic freedom totally absent, or partially challenged?

Is the law itself, or practices liable for the negative situation?

What sort of amendments are necessary?

Is legislative amendment sufficient to remove the problem from society?

2.2. Definition of Academic Freedom

Academic freedom is that freedom of members of the academic community, assembled in colleges and universities, which underlies the effective performance of their functions of teaching, learning, practice of arts and research. The right to academic freedom is recognized in order to enable faculty members and students to carry on their roles. (Academic Freedom in e-dictionary)

Academic freedom is the belief that the freedom of inquiry by faculty members is essential to the mission of the academy and that scholars should have freedom to teach or communicate ideas or fact including those that are inconvenient to external political groups or to authorities without being targeted for repression job less or imprisonment.

In the opinion of Mr. Justice Douglas, "when suspicion fills the air and holds scholars in line for fear of their jobs, there can be no exercise of the free intellect." In *Sweezy vs New Hampshire* (Sweezy Vs New Hampshire case, 354. U.S. 234 1957, accessed on 12/12/2015), the decision reached by four concurring Justices turned in the end on a denial of due process through failure to show that the questions asked of a visiting lecturer at the University of New Hampshire about his lectures and party affiliations, during an official investigation, came within the authorized scope of the inquiry. The opinion of these four Justices, by Chief Justice Warren, expressed special concern over academic freedom. "The essentiality of freedom in the community of American universities is almost self-evident," he wrote: "No one should underestimate the vital role in a democracy that is played by those who guide and train our youth. To impose any strait jacket upon the intellectual leaders in our colleges and universities would imperil the future of our Nation. No field of education is so thoroughly comprehended by man that new discoveries cannot yet be made. Particularly is that true in the social sciences, where few, if any, principles are accepted as absolutes. Scholarship cannot flourish in an atmosphere of suspicion and distrust. Teachers and students must always remain free to inquire, to study and to evaluate, to gain new maturity and understanding; otherwise our civilization will stagnate and die. Here, "We believe that there unquestionably was an invasion of petitioner's liberties in the areas of academic freedom and political expression-areas in which government should be extremely reticent to tread." The same view was elaborated in a concurring opinion by Justices Frankfurter and Harlan, basing the decision on the freedom issue. As a result, in the later *Barenblatt* case (Barenblat V. United States case, 360 U.S. 109 1959), the majority of the Court stated in an

opinion by Mr. Justice Harlan that, broadly viewed, inquiries cannot be made into the teaching that is pursued in any of our educational institutions. When academic teaching-freedom and its corollary learning freedom, so essential to the well-being of the Nation, are claimed, this Court will always be on the alert against intrusion by Congress into this constitutionally protected domain. In the eyes of the Court majority in this case, however, the coercive effect of investigations into communist associations and activities of students and teachers is outweighed by the public interest in discovering such conduct, where there is reason to suspect it. A broad scale disclosure of all organizational affiliations cannot, however, be required of teachers in public institutions.

2.3. Development of Academic Freedom

European universities began during the Middle Ages as self-constituted communities of scholars, whether teachers or learners. The institutions they founded came under the sponsorship of the medieval church and to some degree under its authority; and the faculties, of course, were composed largely of clerics. Before the eighteenth century the Roman church and in some areas its protestant successors exerted sporadic controls against which the universities or members of their faculties found it necessary at times to contend. Scholars outside of the universities, including early scientists, engaged in the same struggles, however, and the total story is one of the efforts of the human intellect to escape from bondage, rather than simply of university faculties and students to be free of external control. Within the universities, a considerable censorship by dominant groups, giving rise to internal controversies, prevailed for a long time. The boundaries to learning maintained by this censorship receded on the whole, even though vestiges remained for long. At Oxford and Cambridge religious tests and restrictions for students were not removed until the latter half of the nineteenth century. In the eighteenth and nineteenth centuries, the political state became the sponsoring authority for most universities throughout the world-although some under religious auspices remained and in the United States particularly independent private colleges and universities have continued to exist alongside the public ones. Instances of actual or attempted political interference with public institutions have continued to arise in various countries down to the present time.' In the United States, political control by state governments remains a danger which assumes reality under demagogic governors from time to time,'" despite the generally good record of the states in relation to the colleges and universities they maintain. In Europe dictatorships of several varieties have supplied object-lessons of the extent to which political control can regiment and distort intellectual endeavor even while stimulating the development of learning along selected lines.' In some other countries, political influence may play a significant although immeasurable role in the

appointment of staff members. There is a genuine interaction between academic freedom and healthy political democracy, causing each to strengthen the other. It would be too much to say, however, that the former is wholly dependent upon the latter; for given enlightenment on the part of an autocratic government, academic freedom in a genuine sense may coexist with it, as it did in nineteenth century Germany.' It was, indeed, in nineteenth century Germany that the modern conception of academic freedom came to be formulated. The idea of the university as a place where scholars are to pursue truth, as well as to formulate and transmit it to students, who at the same time learn to pursue truth for themselves, came to be dominant there. Especially in an age of science, knowledge grows as individuals ferret it out; and the free interplay of ideas is the means of purifying it. Intellectual discipline over the members of the university community is excluded, lest it distort their search. Attracted by this conception and its results, distinguished young scholars from abroad, especially from the United States, went to the German universities in numbers. There they were imbued with the conception, an enlargement of which has since been dominant in this country. Professor Friedrich Paulsen of the University of Berlin formulated systematically in 1902, in his book on The German Universities and University Study, the conception of academic freedom which had arisen in his country during the preceding decades. "It is no longer, as formerly," he wrote," the function of the university teacher to hand down a body of truth established by authorities, but to search after scientific knowledge by investigation, and to teach his hearers to do the same. ...For the academic teacher and his hearers there can be no prescribed and no proscribed thoughts. There is only one rule for instruction: to justify the truth of one's teaching by reason and the facts. Paulsen, however, introduced a qualification. The professor of philosophy must be absolutely free; but the professor of theology "must assume a positive relation to religion and the church in general," and the professor of political and social science in a state institution must do so toward "the people and the state." The professor "who can find absolutely no reason in the state and in law, who, as a theoretical anarchist, denies the necessity of a state and legal order ... may try to prove his theory by means of as many good arguments as he can, but he has no call to teach the political sciences at a state institution." The state, for example, is not bound to tolerate adherence to the "principles of the social-democracy" on the part of professors of political science. To permit such theories to be taught would indicate that "the authorities regarded the lectures of professors as harmless and insignificant. So long as the state takes the universities seriously, such a form of political science as has been described will be impossible in its institutions of learning."'. Paulsen also expressed the view that political partisanship on the part of a faculty member is a disqualification, notwithstanding the fact that professors may be

"men of noble discontent" who sow "the thoughts for future acts." The things which universities "are called upon to cultivate transcend the boundaries of countries and nations. The German universities dwell in their own world, outside of politics, and their highest achievements are in science." Hence the professors, "the representatives of science, should not engage in politics, but should reflect upon the state and the law." Academic freedom, in other words, is internal to institutions of higher education, and does not apply to external activities of academic personnel. The conception of academic freedom which is dominant in American colleges and universities and in other countries today has discarded the limitations that remained in nineteenth century Germany. It accepts, rather, another statement of Paulsen's that "a people," who establish and maintain a university, cannot as such have an interest in the preservation of false conceptions. Its ability to live depends in no small measure upon its doing that which is necessary from a proper knowledge of actual conditions. And hence the people and the state ...can have no desire to place obstacles in the way of an honest search for truth in the field of politics and social science, either by forbidding or favoring certain views. It follows that a society will be strengthened by permitting honest condemnation as well as defense of the state in institutions of higher learning, whether publicly or privately maintained. As to participation by professors in politics, specialization and attention to duty will ordinarily keep the faculty member from an active role; but he cannot be barred from testing his views or gathering data in action, or from urging his conclusions in the world of affairs, whether relevant to his academic subject or not, by joining organizations or by other means. In addition to "full freedom" in research and publication and "freedom in the classroom in discussing his subject," the faculty member in any field of study, speaking or writing as a citizen, "should be free from institutional censorship or discipline. (Robert P. Ludlum, Academic Freedom and Tenure: A History: The Antioch Review, Vol. 10, No.1)

2.4. Academic Freedom in United State

The conception of academic freedom which is dominant in colleges and universities in the United States today rests mainly on three foundations:

a. The philosophy of intellectual freedom, which originated in Greece, arose again in Europe, especially under the impact of the Renaissance, and came to maturity in the Age of Reason;
b. The idea of autonomy for communities of scholars, which arose in the universities of Europe.
c. The freedoms guaranteed by the Bill of Rights of the federal constitution as elaborated by the courts. Here institutional integrity and individual self-direction both stand in need of

protection-not from hostile action but from temptation.' Notwithstanding the increasingly broad reach of academic freedom and the current emphasis on the essentiality of autonomy for academic institutions, the freedom of individual faculty members against control of thought or utterance from either within or without the employing institutions remains the core of the matter. If this freedom exists and reasonably adequate academic administration and methods of faculty selection prevail, intellectual interchange and pursuit of knowledge are secured. A substantial degree of institutional autonomy is both a usual prerequisite and a normal consequence of such a state of affairs. Student freedom will follow unless, indeed, individual faculty members or departmental, are permitted to tyrannize over particular students, as occasionally happens. Hence the main concern over developing and maintaining academic freedom in this country has focused upon encouragement and protection of the freedom of the faculty member. Institutional autonomy, constitutional freedoms, and the basic ideology of intellectual freedom have been invoked mainly to this end. Academic freedom is generally taken as the notion of academic freedom defined by the "1940 Statement of Principles on Academic Freedom and tenure ", jointly authored by the American Association of University Professors and the Association of American College. These principles state that, "Teachers are entitled to freedom in the classroom in discussing their subject."

The statement also permits institutions to impose "limitation of academic freedom because of religious or other aims," so on as they are "clearly stated in writing at the time of the appointment." The principles have only the character of private pronouncement, not that of binding law.

2.5. Academic Expression in UK

Academics at the universities of Oxford and Cambridge enjoy far more freedom to participate in - and criticize - their governance than academics at most other UK institutions.

It is a model of self-governance that some such as Terence Karran, who studies issues of academic freedom, would like to see adopted more widely. Given that Harvard University has a similar model, perhaps it is actually part of the fabric of what makes a world-beating institution, he contends.

As established by their own 1923 Act of Parliament, the universities' supreme governing bodies are their Congregation (Oxford) and Regent House (Cambridge). Each consists of all of their 4,000 or so permanent academic staff. And each act almost like a mini-parliament, giving scholars both the capacity to speak truth to power and to democratically stop their administrations dead in

their tracks if they don't like what they are doing. Of course, the bodies are not involved in the day-to-day administration - mostly their approvals are just a rubber-stamp process. But if they desire, academics can speak their minds and flex their muscles.

Imagine standing up in public to your deputy vice-chancellor as a matter of routine and without an ounce of fear and saying the following, as Andrew Aitchinson, a young computer officer in the department of pure mathematics and mathematical statistics at the University of Cambridge, did in November last year. His comments were part of a four-hour debate on proposed changes to weaken disciplinary, dismissal and grievance procedures (so-called Statute U) and which Cambridge's administration and its Regent House are currently locked in battle over.

"Mr Deputy Vice-Chancellor," he began, after stating his name and his department. "I can't tell you what I really feel about the report, since I am unwilling to use what Westminster calls 'unparliamentarily language'. (But) I believe that this proposal, if enacted, will make the university a less good employer, put an unproductive division between academic and academic-related staff, and dilute our academic freedom, so I wanted to be able to stand here and tell you how to make the proposal work better for the interests of the university. I struggled for ages; in the end the best improvement came to me: drop the proposal and stick with what we already have."

Terry Hoad is vice-president of the University and College Union and an Oxford academic. "Ultimately, we do have this power, which is very precious to us. We are not the worst off (when it comes to academic freedom in UK institutions), but we are not immune from the creeping threat either."

2.6. Academic Freedom in France

Professors at public French universities and researchers in public research laboratories are expected, as are all civil servants, to behave in a neutral manner and to not favor any particular political or religious point of view during the course of their duties. However, the academic freedom of university professors is fundamental principle recognized by the laws of the Republic, as defined by the Constitutional Council; furthermore, statute law declares about higher education that ''researchers and teachers are fully independent and enjoy full freedom of speech in the course of their research and teaching activities, provided they respect, following university traditions and the dispositions of this code, principles of tolerance and objectivity''. The nomination and promotion of professors is largely done through a process of peer review rather than through normal administrative procedures.

2.7. In Germany

The German Constitution (German: Grundgesetz) specifically grants academic freedom: "Art and science, research and teaching are free. Freedom of teaching does not absolve from loyalty to the constitution" (Art. 5, para. 3). In a tradition reaching back to the 19th century, jurisdiction has understood this right as one to teach (Lehrfreiheit), study (Lernfreiheit), and conduct research (Freiheit der Wissenschaft) freely, although the last concept has sometimes been taken as a cover term for the first two. Lehrfreiheit embraces the right of professors to determine the content of their lectures and to publish the results of their research without prior approval. Since professors through their Habilitation receive the right to teach (Latin : venia docendi) in a particular academic field, academic freedom is deemed to cover at least the entirety of this field. Lernfreiheit means a student's right to determine an individual course of study. Finally, Freiheit der Wissenschaft permits academic self-governance and grants the university control of its internal affairs. Through the introduction of disciplinary curricula, Lernfreiheit has become a rather empty concept.

2.8. In Philippines

The 1987 Philippine Constitution states that, "Academic Freedom shall be enjoyed in all institutions of higher learning." Philippine jurisprudence and courts of law, including the Philippine Supreme Court tend to reflexively defer to the institutional autonomy of higher institutions of learning in determining academic decisions with respect to the outcomes of individual cases filed in the courts regarding the abuse of Academic Freedom by professors, despite the individual merits or demerits of any cases. A closely watched case was the controversial case of University of the Philippines at Diliman Sociology Professor Sarah Raymundo who was not granted tenure due to an appeal by the minority dissenting vote within the faculty of the Sociology Department. This decision was sustained upon appeal by the dissenting faculty and Professor Raymundo to the University of the Philippines at Diliman Chancellor Sergio S. Cao; and though the case was elevated to University of the Philippines System President Emerlinda R. Roman, Roman denied the appeal which was elevated by Professor Raymundo to the University's Board of Regents for decision and the BOR granted her request for tenure. A major bone of contention among the supporters of Professor Raymundo was not to question the institutional Academic Freedom of the Department in not granting her tenure, but in asking for transparency in how the Academic Freedom of the department was exercised, in keeping with traditions within the University of the Philippines in providing a basis that may be subject to peer review, for Academic decisions made under the mantle of Academic Freedom.

2.9. In South Africa

Section 16 of the 1996 Constitution of South Africa offers specific protection to academic freedom. However,

there have been a large number of scandals around the restriction of academic freedom at a number of universities with particular concern being expressed at the situation at the University of KwaZulu-Natal.

2.10. Sources of Academic Freedom

As there is no specific law regarding academic freedom and it is not included within the arena of intellectual property law, we may mention some indirect sources of academic freedom such as:

2.10.1. Constitutional Law

Though academic freedom is not directly mentioned in the Constitution of Peoples Republic of Bangladesh, article 39 protects freedom of expression as fundamental right subject to any reasonable restrictions imposed by law in the interests of the security of the state, friendly relation with foreign states, public order, decency or morality, or in relation to contempt of court, defamation or incitement to an offence. According to article 44 and 102 this right is enforceable by the court. Article 17 mentioned right to free and compulsory education as fundamental Principle of state policy. For the purpose of establishing universal system of education academic freedom is *sine qua non.* (The Constitution of the People's Republic of Bangladesh)

2.10.2. Human Rights

Academic freedom can be asserted as a human right in two ways. One is to defend it as a human right to free expression; the other is to defend it as a human right to education. Freedom of opinion and expression are protected as human right by article 19 of the International Covenant on Civil and Political Rights, a treaty ratified by most of the countries, including Bangladesh. The right to education is guaranteed by article 13 of the International Covenant on Economic, Social and Cultural Rights which Bangladesh has ratified (International Covenant on Civil and Political Rights, 1966).

2.10.3. Contractual Rights

Internal sources of contractual obligations may include institutional rules and regulations, letters of appointment, faculty handbooks, and, where applicable, collective bargaining agreements. Academic freedom rights are often explicitly incorporated into faculty handbooks, which are sometimes held to be legally binding contracts.

2.10.4. Academic Custom and Usage

Academic freedom is also protected as part of "academic custom" or "academic common law.

2.10.5. Judicial Decision

Article 111 of the constitution of Bangladesh declares that the judgment of higher courts shall be binding on the lower courts. In this way, judicial decision may be a source of academic freedom. (The Constitution of the People's Republic of Bangladesh)

2.10.6. Specific Cases

While some controversies of academic freedom are reflected in proposed laws that would affect large numbers of students through entire regions, many cases involve individual academicians that express unpopular opinions or share politically unfavorable information. These individual cases may receive widespread attention and periodically test the limits of, and support for, academic freedom.

The Bassett Affair at Duke University in North Carolina in the early 20th century was an important event in the history of academic freedom (Exhibits).

In October 1903, Professor John Spencer Bassett publicly praised Booker T. Washington and drew attention to the racism and white supremacist behavior of the Democratic Party, to the disgust of powerful white Southerners. Many media reports castigated Bassett, and many major newspapers published opinion pieces attacking him and demanding his termination. On December 1, 1903, the entire faculty of the college threatened to resign en masse if the board gave into political pressures and asked Bassett to resign (Exhibits).

President Teddy Roosevelt later praised Bassett for his willingness to express the truth as he saw it. In 1929, experimental psychology Professor Max Friedrich Meyer and sociology assistant Professor Harmon O. De Graff were dismissed from their positions at the University of Missouri for advising student Orval Hobart Mowrer regarding distribution of a questionnaire which inquired about attitudes towards divorce, "living together", and sex. (Nelson, Lawrence J. 2003. Rumors of Indiscretion: The University of Missouri "Sex Questionnaire" Scandal in the Jazz Age.) The university was subsequently censured by the American Association of University Professors in an early case regarding academic freedom due a tenured professor. (A.J. Carlson February 1930. "Report on the Dismissal of Professor De Graff and the Suspension of Professor Meyer). In a famous case investigated by the American Association of University Professors, President Hamilton Holt of Rollins College in March 1933 fired John Andrew Rice, an atheist scholar and unorthodox

teacher, whom Holt had hired, along with three other "golden personalities" (as Holt called them), in his push to put Rollins on the cutting edge of innovative education. Holt then required all professors to make a "loyalty pledge" to keep their jobs. The American Association of University Professors censured Rollins. Rice and the three other golden personalities, all of them dismissed for refusing to make the loyalty pledge, founded the innovative Black Mountain College. (Mary Seymour, "The Ghosts of Rollins and Other Skeletons in the Closet", Rollins)

In 1978, Nobel Prize-winner William Shockley was concerned about relatively high reproductive rates among people of African descent, because he believed that genetics doomed black people to be intellectually inferior to white people. He stated that he believed his work on race to be more important than his work leading to the Nobel Prize (William B. Shockley, 79, Creator of Transistor and Theory on Race).

He was strongly criticized for this stand, which raised some concerns about whether criticism of unpopular views of racial differences suppressed academic freedom. (Kilgore, William J.; Sullivan, Barbara 1975). In the aftermath of the September 11, 2001 attacks, some public statements made by some university faculty were criticized. Most prominent among these were these comments made in January 2005 by University of Colorado professor Ward Churchill. He published an essay in which he asserted that the attack on the United States, while unjustified, was provoked by American foreign policy. On news and talk programs, he was criticized for describing the World Trade Center victims as "little Eichmanns", a reference to Hannah Arendt's Eichmann in Jerusalem. The university fired Churchill in 2007 for research misconduct, and despite initially winning US $1 in damages from a jury, Churchill ultimately lost his wrongful termination lawsuit on appeal. (Paulson, Steven K., September 10, 2012). At the beginning of the 21st century, Lawrence Summers, while president of Harvard University, led a discussion that was intended to identify the reasons why fewer women chose to study science and mathematics at advanced levels. He suggested that the possibility of intrinsic gender differences in terms of talent for science and mathematics should be explored. He became the target of considerable public backlash ("Summers' remarks on women draw fire").

His critics were, in turn, accused of attempting to suppress academic freedom. (Stephan Thernstrom, George Mason University). The 2006 scandal in which several members of the Duke Lacrosse team were falsely accused of rape raised serious criticisms against exploitation of academic freedom by the university and its faculty to press judgment and deny due process to the three players accused. In 2006 trade union leader and sociologist Fazel Khan was fired from the University of

KwaZulu-Natal in Durban, South Africa after taking a leadership role in a strike. (Fight for Fazel Khan – An archive of documents on the dismissal of Fazel Khan)

In 2008 international concern was also expressed at attempts to discipline two other academics at the same university –Nithiya Chetty and John van der Berg – for expressing concern about academic freedom at the university. (Letter from foreign academics to Mac Mia, Chair of Council, and Malegapuru Makgoba, Vice Chancellor Letter from David William Cohen and 35 others). J. Michael Bailey wrote a popular science style book, The Man Who Would Be Queen, which promotes Ray Blanchard's theory that trans women are motivated by sexuality, and dismisses the "woman trapped in a man's body" concept of trans sexuality. Blanchard's theory divides trans women into two groups: autogynephilics and homosexual transsexuals according to their sexual orientation. In an effort to discredit his book, some trans activists filed formal complaints with Northwestern University accusing Bailey of conducting regulated human research by talking informally to trans women without first obtaining written proof of informed consent. They also filed a complaint with Illinois state regulators, requesting that they investigate Bailey for practicing psychology without a license. Bailey, who was not licensed to practice clinical psychology in Illinois, had provided some trans women with free case evaluation letters, saying that he believed they were good candidates for sex-reassignment surgery. Regulators dismissed the complaint. Andrea James, a Los Angeles-based transgender activist, posted photographs of Bailey's children, taken when they were in middle and elementary school, with sexually explicit captions that she provided. (Carey, Benedict, 21 August 2007, "Criticism of a Gender Theory, and a Scientist Under Siege.")

Thio Li-ann withdrew from an appointment at New York University School of Law after controversy erupted about some anti-gay remarks she had made, prompting a discussion of academic freedom within the law school. ("Rights for some people". Inside Higher Ed. 8 June 2009). In 2009 the University of California at Santa Barbara charged William I. Robinson with anti-Semitism after he circulated an email to his class containing more than two dozen photographs of Jewish victims of the Nazis, including those of dead children, juxtaposed with nearly identical images from the Gaza Strip. It also included an article critical of Israel's treatment of the Palestinians and a note from Robinson stating "Gaza is Israel's Warsaw -- a vast concentration camp that confined and blockaded Palestinians," the professor wrote. "We are witness to a slow-motion process of genocide" (Helfand, Duke, 30 April 2009; "Professor's comparison of Israelis to Nazis stirs furor"; Los Angeles Times). The charges were dropped after a worldwide campaign against the management of the university.

9 SPME statement on the disposition of the case of William Robinson at UCSB, SPME Board of Directors, June 29, 2009. The University of the Philippines at Diliman affair where controversy erupted after Professor Gerardo A. Agulto of the College of Business Administration was sued by MBA graduate student Chanda R. Shahani for a nominal amount in damages for failing him several times in the Strategic Management portion of the Comprehensive Examination. Agulto refused to give a detailed basis for his grades and instead invoked Academic Freedom while Shahani argued in court that Academic Freedom could not be invoked without a rational basis in grading a student ("DILIMAN DIARY").

During the interwar years (cir. 1919-1939) Canadian academics were informally expected to be apolitical, lest they bring trouble to their respective universities who, at the time, were very much dependent upon provincial government grants. As well, many Canadian academics of the time considered their position to be remote from the world of politics and felt they had no place getting involved in political issues. However, with the increase of socialist activity in Canada during the Great Depression, due to the rise of social gospel ideology, some left-wing academics began taking active part in contemporary political issues outside of the university. Thus, individuals such as Frank H. Underhill at the University of Toronto and other members or affiliates with the League for Social Reconstruction or the socialist movement in Canada who held academic positions began to find themselves in precarious positions with their university employers. Frank H. Underhill, for example, faced criticism from within and without academia and near expulsion from his university position for his public political comments and his involvement with the League for Social Reconstruction and the Co-Operative Commonwealth Federation. (Horn, Michiel, "Professors in the Public Eye: Canadian Universities, Academic Freedom, and the League for Social Reconstruction." History of Education Quarterly.)

According to Michiel Horn this era marked, "...a relaxation of the unwritten controls under which many Canadian professors had previously worked. The nature of the institutions, natural caution and professional pre-occupation had before the Depression inhibited the professoriate. None of these conditions changed quickly, but even at the provincial universities there were brave souls in the 1930s who claimed, with varying success, the right publicly to discuss controversial subjects and express opinions about them." (Horn, Michiel, "Professors in the Public Eye:Canadian Universities, Academic Freedom, and the League for Social Reconstruction" History of Education Quarterly.

3.0. Case Studies

In Rajib Hasnat Shakil *vs* State, u/s 16(2) of The Special Powers Act, 1974, one Mr. Ahmad

Anwar, lodged an FIR alleging that on 03/07/2014, at 11.05 AM, he came to know through a secret source that there was an agitation among teachers and students at Northern University Bangladesh (NUB), Khulna campus. With the permission of the OC he went to the place of occurrence. There he heard from the people that on 26/01/2014 at 02.30 PM, the accused Rajib Hasnat Shakil (an Assistant Professor of Department of Law, NUB) commented objectionably regarding honorable president, honorable PM and the father of the nation Bangabandhu Sheikh Mujibur Rahman in classroom. Students informed the matter to the campus in charge, Professor Dr. Anwarul Karim. Accompanying with three or four other teachers, the accused Assistant Professor called the father of the nation as "FERAUN" (A tyrant ruler during the period of Musa Ah., the prophet), honorable PM Sheikh Hasina as "NASTIK" (Atheist), honorable president as "BAT TALAR UKIL" (In BD, the less qualified advocates are satire with such name). From 26/01/2014 to 03/07/2014 they criticized trial of war criminals, state, present govt. which harmed the image of Bangladesh abroad.

The accused was arrested on 03/07/2014 from the place of occurrence (NUB, Khulna Campus). His bail prayer was rejected on 07/07/2014. On the same day, police submitted FRT (the occurrence has been committed, but the accused was not involved). Now, this case is under investigation by CID (Rajib Hasnat Shakil VS State, u/s 16(2) of The Special Powers Act, 1974).

Professor Syedur Rahman Khan VS Bangladesh, M.G.R.-738/07 u/r 3(4) - {3} & 8(2) of Joruri Kshomota Bidhimala, 2007.

During the emergencies of 2007, there was a clash between armies and students of Dhaka University. The clash was followed by student revolution all over the country and unpredictable rush took place at Rajshahi and other Universities. Some teachers gave their speeches towards the students on their own ethics. On 24 August, the joint forces hauled in Dhaka University Teachers Association (DUTA) General Secretary Professor Anwar Hossain and Social Science Dean Prof. Harun-or-Rashid at about 12:30 a.m. from their campus residences on the Fuller Road. In Rajshahi, Prof. Saidur Rahman Khan, Prof. Abdus Sobhan and Moloy Kumar Bhowmik were arrested. Later, the names of Dulal Chandra Biswas, Sayed Selim Reza Newton, and Abdullah Al Mamun were included among the condemned. On 16 September Prof. Sadrul Amin and on 17 September Prof. Neem Chandra Bhoumik, both DU academicians, surrendered to the court and the court sent them to jail. Later, police remand was given to them. Even it was claimed that the teachers have been victim of custodial torture during remand. Though all the teachers are bailed, but the cases are not dismissed yet. (Sajib Bala, Student Demonstration: The Case Study of 2007 Demonstration in Dhaka University, Bangladesh)

4.0. Negativity in Over Freedom

In the case of Md. Abdul Mannan Bhuiyan vs. University of Rajshahi & Others. 25 BLD (2005) (HCD) 138, the petitioner was a student of Rajshahi University. Being aggrieved of the arbitrary marking decision of two examiners of Deprtment of Law & Justice, filed a writ petition where respondent was the Rajshahi University. Here, Rajshahi University was directed to re-examine the examination paper of Md. Abdul Mannan Bhuiyan. It was the 13th Paper of LLB (Hons.) Part-IV of 1999. Direction was further given to re-examine the paper impartially, in accordance with relevant provisions of re-examination and in accordance with law. Finally, in 2004, the petitioner got the verdict of the High Court Division directing the University of Rajshahi to provide new result of First class instead of Second class and punishing the teachers with fine as well as prohibition of participation in exam related duties. (25 BLD 2005 HCD 138)

5.0. Recommendation

a. Academic expressions should be included within the definition of intellectual property.
b. Specific law is needed to protect academic freedom and fix limitations for exercising this right.
c. Job security for academicians must be ensured in case of academic expression and research.
d. The financial, social, professional academic environment should be reviewed with a positive focus to upgrade for the academicians.
e. The Government should read the relevant laws thoroghly and take the criticism of researchers with a positive view.

6.0. Conclusion

The reasearchers strongly belive that academic freedom is must to upgrade professionality of Bangladeshi academicians. This is also belived that, such professionalism shall result positively not only to the academicians, but also to all other professionals, as teaching plays a guardian role over the other professions.

References

"Academic Values and the Jensen-Shockley Controversy". Journal of General Education.

"Exhibits". Retrieved 3 May 2015.

"Rights for some people". Inside Higher Ed. 8 June2009. Retrieved 11 June 2009.

"Summers' remarks on women draw fire" .Boston.com. Retrieved 3 May 2015.

Barenblat V. United States. 360 U.S. 109 (1959) available at https://supreme.justia.com/cases/federal/us/360/109/case.html accessed on 08/01/2016

Carey, B. (21 August 2007) Criticism of a Gender Theory, and a Scientist Under Siege, The New York Times.

Carlson, A.J. (1930) Report on the Dismissal of Professor De Graff and the Suspension of Professor Meyer, Bulletin of the American Association of University Professors, XVI (2): 2–35.doi: 10.2307/40218216.

Dana L. C. (April 30, 2009) The McCarthyism That Horowitz Built: The Cases of Margo Ramlal Nankoe, William Robinson, Nagesh Rao and Loretta Cape heart, Counter Punch.

Dredger A.D. (June 2008) The controversy surrounding "The man who would be queen": a case history of the politics of science, identity, and sex in the Internet age, Arch Sex Behave 37 (3): 366–421.doi: 10.1007/s10508-007-9301-1. PMC 3170124 .PMID 18431641.

Fight for Fazel Khan – An archive of documents on the dismissal of Fazel Khan

Helfand, Duke (30 April 2009). "Professor's comparison of Israelis to Nazis stirs furor". Los Angeles Times.

http://www.yourdictionary.com/academic-freedom, accessed on 15/11/2015

International Covenant on Civil and Political Rights, 1966

Kilgore, William J.; Sullivan, Barbara (1975).

Letter from foreign academics to Mac Mia, Chair of Council, and Malegapuru Makgoba, Vice Chancellor Letter from David William Cohen and 35 others

Mary Seymour, "The Ghosts of Rollins (and Other Skeletons in the Closet)", Rollins Magazine , fall 2011,available at http://www.rollins.edu/magazine/fall2011/ghostsofrollins2.htmlhttp://www.jstor.org/stable/40218822

Nelson, L.J. (2003) Rumors of Indiscretion: The University of Missouri "Sex Questionnaire" Scandal in the Jazz Age. Columbia, MO: University of Missouri Press. ISBN 0-8262-1449-5

Paulson, Steven K. (September 10, 2012). "Ward Churchill loses appeal to win back CU job". Denver Post Retrieved 2012-09-10.

Robert P. Ludlum, Academic Freedom and Tenure: A History: The Antioch Review, Vol. 10, No. 1 (Spring, 1950), pp. 3-34Published by: Antioch Review Inc.DOI: 10.2307/4609390 available at http://www.jstor.org/stable/4609390

Stephan Thernstrom. "In Defense of Academic Freedom at Harvard". History News Network, George Mason University.

Sweezy Vs New Hampshire. 354. U.S. 234 (1957) available at https://supreme.justia.com/cases/federal/us/354/234/case.html accessed on 12/12/2015

Tay Shi'an (22 July 2009). "She's not against gay people, just against gay agenda. The New Paper, Retrieved 24 July 2009.

The Constitution of the People's Republic of Bangladesh.

William B. Shockley, 79, Creator of Transistor and Theory on Race.

Seismic Performance Assessment of Laminated Rubber Bearing on Kadamtaly Flyover

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Abstract

This study is dedicated towards conducting seismic performance assessment is Laminated Rubber Bearing of kadamtali flyover. The flyover isolated by elastomeric rubber bearing subjected to earthquake ground motion records. The isolation system considered in this study consists of a elastomeric rubber bearing, which provides lateral flexibility while supplying high vertical load-carrying capacity. This study describes a technique to estimate the seismic performance on laminated rubber bearing by calculating its strength and deformation from a dynamic time-history analysis using the software Seismostruct. A 3-D model of Kadamtoli Flyover has been constructed and the strength and deformation of rubber bearing has been found. The analytical results show that the seismic responses of rubber bearing are significantly affected by the characteristics of the earthquake ground motion records.

Keywords: Bilinear Model, Dynamic Time History Analysis, Link Hysteretic Curve, Rubber Bearing, Seismic Isolation, Seismic Performance.

1.0. Introduction

1.1. Background

Rubbers are usually considered as incompressible materials. Hence in mechanical testing, the true stress can be readily calculated under the incompressibility assumption to predict the deformed cross section of the specimen. However, there are cases where rubbers under large strains can suffer considerable volumetric change. Although natural rubbers and high damping rubber were used as specimens in this study to display the capability of the device, the device will also be useful in measuring the deformed cross section of other types of highly deformable solids subjected to uniaxial loading (Amin et al., 2003). A study of rubber bearings with thick rubber layers to be used for three-dimensional (3-D) base isolation system is developed. Design parameters of the rubber bearings are determined to effectively reduce both horizontal and vertical seismic loads especially for equipment in the system; horizontal and vertical natural frequencies of the system supported by the rubber bearings are 0.3 Hz and 3 Hz, respectively. Furthermore, primary and secondary shape factors and design vertical pressure of the rubber bearings are determined to give stable mechanical

properties. Using scale models of the rubber bearings, static, dynamic and failure tests were carried out to evaluate the mechanical characteristics and the performance of the rubber bearings. From these tests, it is shown that the developed rubber bearings are efficient as 3-D base isolation devices (Yabana et al., 2000). Another study for developing the rubber bearing as 3-D isolators, design targets were reduction of horizontal and vertical seismic loads and good horizontal performances as well as conventional (2-D) rubber bearings. It was determined that horizontal natural frequency and vertical natural frequency of the 3-D base isolation system were about 0.3 Hz and 3 Hz in design to reduce seismic loads. Considering creep of a thick rubber layers, selecting natural rubber and the rubber material was compounded to provide shear modulus of 4.0 kgf/cm^2 (0.39 MPa). From the horizontal tests, it was found that the hysteresis loop was stable and horizontal stiffness relatively agreed with the design value (Ravari et al.).

The laminated rubber bearings (LRB) should be protected from failure or instability because the instability of rubber bearings may result in serious damage to superstructure. Predicting of behavior of LBR usually are obtained from Haringx's theory and have been developed by many researchers and they have proposed nonlinear mechanical model for multilayer elastomeric bearings. Comparisons of theoretical and experimental results show that the present analysis model has good accuracy for analyzing LBR. Examples are presented to demonstrate the validity of the develop method in predicting the horizontal stiffness of laminated elastomeric bearings with different geometric parameters. It has been found that the horizontal stiffness of laminated rubber bearing will increase or decrease according different boundary conditions. An analytical model of multilayer elastomeric isolation bearings has been developed based on the Haringx's theory. By using the initial rotations of bearing as new boundary condition, the movement and rotation equations of bearings have been formulated and the variations of horizontal stiffness of LBR have been investigated. A series of cyclic loading tests under seismic conditions (i.e., axial loading) and worn conditions (i.e., 300 cycles) were conducted to clarify the effect of tensile axial loading on plastic shear deformation of a LBR. Each LRB specimen was subjected to three cycles of lateral deformation that was gradually varied from a global shear strain of 50% to 250%. Hysteretic loops between lateral force and lateral displacement were evaluated to compare hysteretic energy dissipation and equivalent stiffness between an LRB under tensile axial loading and under compressive loading (Shoji et al., 2004). Another study is devoted towards evaluating the seismic responses of a base-isolated highway bridge with different isolators. The mechanical behavior of the bearings as observed is characterized by nonlinear elasto-plastic, strain-rate dependence and strain-hardening features at high strain levels

as documented in published papers of the authors. However, the equivalent linear and the bilinear models are used in the analysis for idealizing the mechanical behavior without considering the strain-rate dependence of the bearings. The mechanical behavior of the bridge pier is approximated using the Takeda tri-linear model and the remaining parts of the bridge are idealized using simple elastic model. Two design earthquake ground motions as recommended by codes and specifications, applied in the longitudinal direction, are used in the analysis. The seismic responses of the bridge are evaluated by solving the equations of motion of the bridge system using a standard direct integration method. The parametric studies are conducted for different system configurations and isolation systems. The seismic response of base-isolated bridge is seen to be considerably altered due to the dissimilarity in the isolator properties. Finally, a comparative assessment of the bridge responses shows the sensitivity of isolation bearings" mechanical properties in evaluating seismic responses of the bridge (Haque et al.). The LBR, which provides lateral flexibility while supplying high vertical load-carrying capacity and an auxiliary device made of multiple loops of SMA wires. The SMA device offers additional energy dissipating and re-centering capability. Numerical simulations of abridge are conducted for various near-field ground motions that are spectrally matched to a target design spectrum. The normalized forward transformation strength, forward transformation displacement and pre-strain level of the SMA device, ambient temperature and the lateral stiffness of the rubber bearings are selected as parameters of the sensitivity study. The variation of the seismic response of the bridge with the considered parameters is assessed. Also, the performance of the SRB isolation system with optimal design parameters is compared with an SMA based sliding isolation system (Ozbulut et al. 2010). Moreover, a study is analyzed for two suites near and far field earthquake ground acceleration records. The nonlinearity of the bridge pier is considered by employing a bilinear force-displacement relationship, whereas a visco-elasto-plastic rheology model is employed to evaluate the mechanical behavior of LRB under seismic excitations. The numerical results have revealed that the seismic responses of the bridge system are significantly affected by the characteristics of the earthquakes ground motion records (Bhuiyan et al.).

2.0. Bridge Bearings

2.1. Kadamtaly Flyover

Chittagong Development Authority has undertaken the 940-meter-long and 15-meter-wide project at the cost of Tk 499.787 million to ease traffic congestion at Kadamtali area. The area faces severe traffic jam because of haphazard parking of the inter district buses including the Dhaka-bound coaches. It will be the 3rd flyover of the port city. With construction of the around one kilometer-

long and four-lane flyover to be connected between city's old Railway. Station and Dhaniala para over Kadamtali level crossing, it would perform as the alternative of Dewanhat Over Bridge which life-time has already expired and need to be re-constructed. the construction of the flyover will take 15 months to complete.

2. 2. Elastomeric Bearings

Laminated bearings are either fabricated as plain bearing pads (consisting of elastomer only) or as laminated (steel reinforced) bearings (consisting of alternate layers of steel reinforcement and elastomer bonded together). These bearings are designed to transmit loads and accommodate movements between a bridge and its supporting structure. Performance information indicates that elastomeric bearings are functional and reliable when designed within the structural limits of the material. For several years plain elastomeric bearing pads have performed well on prestressed girder structures. Prestressed girders using this detail are fixed into the concrete diaphragms at the supports and the girders are set on 1/2" (13 mm) thick plain elastomeric bearing pads .The design is based on service loads without impact.

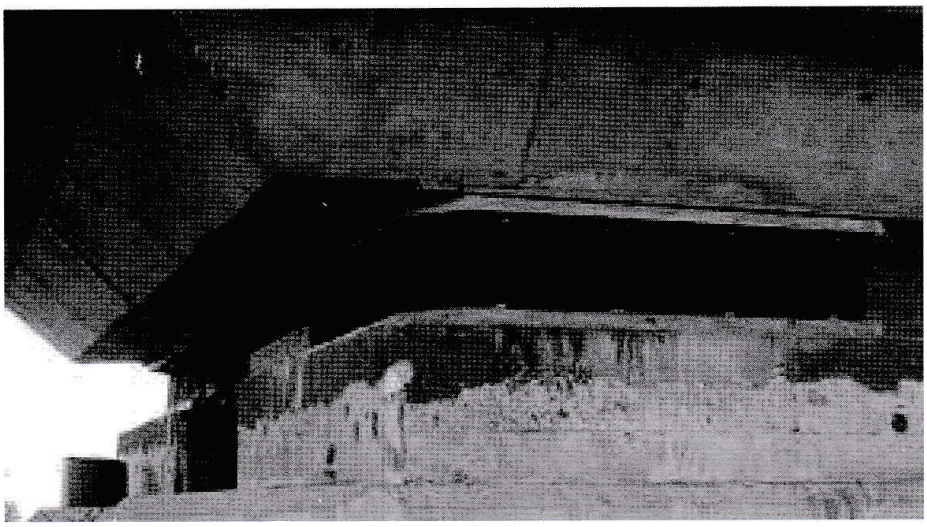


Fig. 1. Laminated rubber bearing.

3.0. Methodology

3.1. Modelling Software (SeismoStruct)

SeismoStruct is an award-winning Finite Element package capable of predicting the large displacement behavior of space frames under static or dynamic loading, taking into account both geometric nonlinearities and material inelasticity. Concrete, steel, frp and sma material models are available, together with a large library of 3D elements that may be used with a wide variety of pre-defined steel, concrete and composite section configurations. The program has been extensively

quality-checked and validated, as described in its verification report.

It is recognized that the isolation bearing has generally nonlinear inelastic hysteretic property. Some specifications have specified guidelines for using the bilinear model in order to represent the nonlinear inelastic hysteretic property of elastomeric rubber bearing. In this case, three parameters are required to represent the hysteresis loop of the bearing, initial stiffness k1, post yield stiffness k2 and the yield strength of the bearings.

Table 1. Parameters of the Bilinear model for Laminated Rubber Bearing.

Initial Stiffness, K1(N/mm)	Post yield ratio	Yield Strength(N)
20000	0.005	1000

3.2 Seismic Performance Analysis

Engineers need to know the quantified level of the actual or anticipated seismic performance associated with the direct damage to an individual building subject to a specified ground shaking. Such an assessment may be performed either experimentally or analytically. Experimental evaluations are expensive tests that are typically done by placing a (scaled) model of the structure on a shake-table that simulates the earth shaking and observing its behavior. Such kinds of experiments were first performed more than a 7 century ago. Only recently has it become possible to perform 1:1 scale testing on full structures. Due to the costly nature of such tests, they tend to be used mainly for understanding the seismic behavior of structures, validating models and verifying analysis methods.

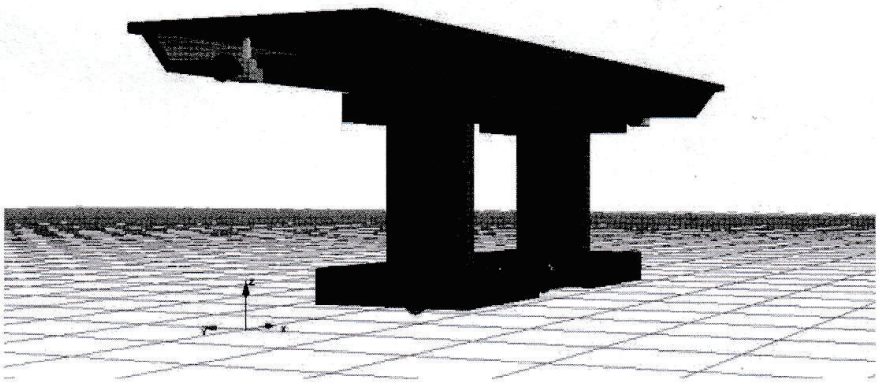


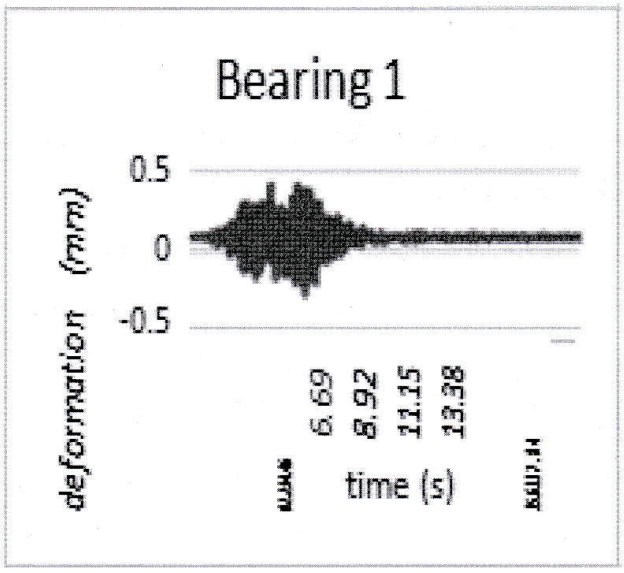
Fig. 2. A 3-D model of Kadamtaly flyover.

The dynamic time history response analysis is conducted on the bridge with elastomeric pads subjected to the ground motions. At each end, a massless rigid link preserves the skewed geometry of the bridge and serves as the connecting element between the bridge deck and the end. In

the model, the damping of the bridge deck, pier, pier cap and footing is approximated with the Rayleigh damping approximation, where the parameters are computed by assuming a 4% modal damping ratio in the first and the second modes. In the bearing, it is taken as stiffness proportional damping approximation, where the parameters are computed by assuming a 4% modal damping ratio in the first and the second modes.

4.0. Numerical Result

The time vs deformation curve of bearing 1 is presented in Fig. 3. A bilinear symmetric model for describing the mechanical behavior of rubber bearing is employed with an initial stiffness of 20000N/mm, yield force of 1000N, post yield hardening ratio of 0.005. Damping is not taken into consideration. Here the peak deformation of the bearing is 0.425 mm at the time of 4.10 sec.



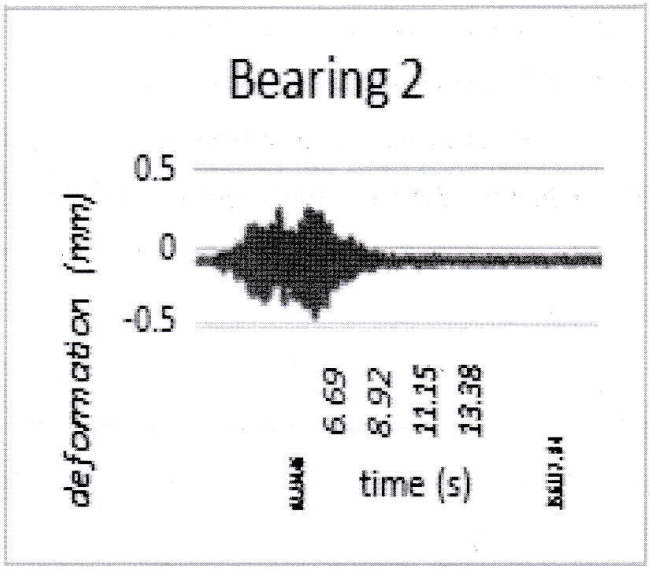


Fig. 3. Time Deformation Curve of Bearing 1. **Fig. 4.** Time Deformation Curve of Bearing 2.

The time vs deformation curve of bearing 2 is presented in Fig. 4. A bilinear symmetric model for describing the mechanical behavior of rubber bearing is employed with an initial stiffness of 20000N/mm, yield force of 1000, post yield hardening ratio of 0. 005.damping is not taken into consideration. Here the peak deformation of the bearing is .425 mm at the time of 4.10 sec.

Constitutive force-displacement response plots are provided in Fig 4 and Fig. 5. Bearing 1 and 2 exhibited stable hysteretic response at high shear strains, with modest degradation of slip force levels upon increasing numbers of slip cycles.

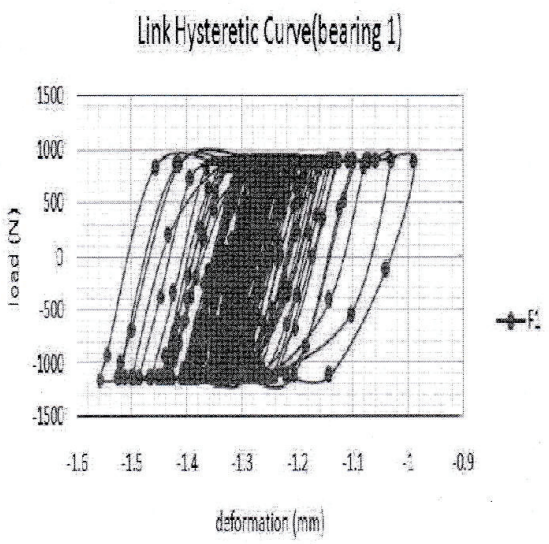


Fig. 5. Link Hysteretic curve of Bearing 1.

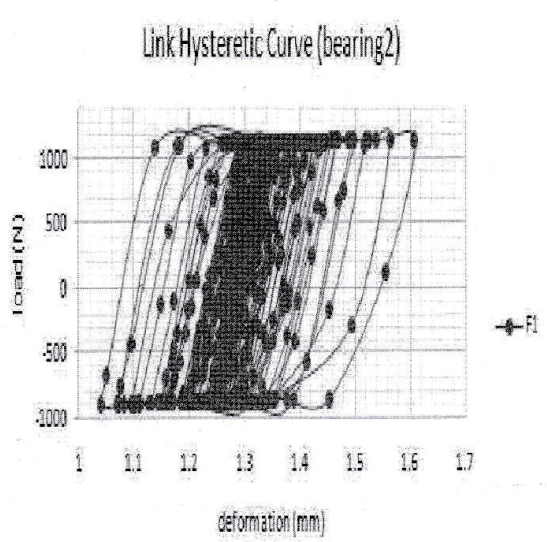


Fig. 6. Link Hysteretic curve of Bearing 2.

5.0. Conclusions and Discussions

Effect of modeling of bearings on the seismic responses of the isolated bridge is evaluated by conducting dynamic time history analyses. The bilinear model is employed for elastomeric bearing. The numerical results have revealed that the seismic responses of the bridge system are significantly affected by the characteristics of the earthquakes ground motion. The consequence effect of this phenomenon has been reflected in seismic responses considered in the current study motion records. From the numerical analysis conducted in the current study it can be concluded that not only the magnitude but the other characteristics of earthquake ground motions also have significant effect on the seismic responses of the bridge which should be carefully considered in the design phase of bridge system. It should be also noted that the selection of the type and modeling approach of isolation bearings may have a remarkable effect on the seismic performance evaluation of highway bridges, which should be carefully considered in the analysis and design steps of any bridge project. The elastomeric bearings satisfactorily restrained the deck displacement and the relative displacement between the deck and the pier for strong ground motion. From the present study, the conclusions may be drawn are (i) The Elastromeric bearing provides stiff connection between the pier and the deck for small external loading, (ii) The Elastromeric bearing satisfactorily restrained the deck displacement and the relative displacement between deck and pier for strong ground motions. (iii) The response quantities of the seismically isolated bridge by the isolator are found to be quite satisfactory. The influence of seismic isolation on the reduction in pier shear in the bridge was impressive for the isolator, (iv) A little isolation can go a long way in reducing seismic

forces in simple span bridges. Generally, there was a substantial reduction in deck accelerations and displacement for isolated bridge (compared to the non-isolated case). Within the range of the parametric study of this paper, it is observed that a careful selection of the models of isolation bearings is very important for seismic design of an isolated bridge system.

6.0. Acknowledgement

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References

Amin, A.F. M.S.; Alam, M.S.; Okui, Y. (2003) Measurement of lateral deformation in natural and high damping rubbers in large deformation uniaxial tests, Journal of testing and evaluation , Vol. 31,pp 524-532.

Bhuiyan, A.R.; Alam, R.; Haque, N. Seismic performance assessment of a continuous highway bridge seismically isolated by leas rubber bearings, ICACE, CUET.

Haque, M.N.; Bhuiyan, A.R. Alam, M.J. Seismic response analysis of base isolated highway bridge: Effectiveness of using laminated rubber bearings, ICACE, CUET.

Ozbulut, O.E.; Zachry, S.H. (2010) Seismic assessment of bridge structures isolated by a shape memory alloy/rubber-based isolation system, Department of Civil Engineering, Texas A&M, University, Published 2 December .

Ravari A.K.; Othman, I.B. Variations of Horizontal Stiffness of Laminated Rubber Bearings with Different Boundary Conditions, Dept. of Civil Engineering, University of Malaya (UM), Kuala Lumpur, Malaysia.

Shoji, G.; Saito, k.; Kameda T.; Fueki, T. (2004) Seismic performance of a laminated rubber bearing under tensile axial loading", 13th World Conference on Earthquake Engineering, Augest1-6, 2004, Vancouver, Canada.

Yabana, S.; Matsuda, A. (2000) Mechanical properties of laminated rubber bearings for three-dimensional seismic isolation, Proc. of the 12th WCEE.

Development and Potentials of Pharmaceutical Industry in Bangladesh: A Synopsis

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Abstract

Bangladesh has made impressive economic and social progress and is now honoured globally as an emerging economy. The average GDP growth over the last five years was over 6%, which is enviable one. In Bangladesh, the pharmaceutical industry is one of the most developed hi-tech one within the country's economy. This sector is also providing about 97% of the total medicine requirement of the local market. Like Readymade Garments, this industry is also potential for the growth of the economy.

Keywords: Pharmaceutical Industry, hi-tech industry, Active Pharmaceutical Ingredient (API), (Multi-National Corporations (MNCs), etc.

1.1. Introduction

The pharmaceutical sector is one of the thrust sectors in Bangladesh. Before liberation, there was hardly any remarkable pharmaceutical enterprise in Bangladesh (the then East Pakistan). Even after several years of liberation, the government could not increase (in relative terms) budgetary allocations for the improvement of health sector. At that time, most of the people had little access to the essential lifesaving medicines. This sector started to improve since 1980s.

The pharmaceutical industry has grown in the last two decades at a considerable rate. After the promulgation of Drug Control Ordinance-1982, the development of pharmaceutical industry has accelerated. The skills and knowledge of the professionals and innovative ideas of the people involved in this industry are the key factors for the developments. Due to recent development of this sector, the country is exporting medicines to global market including European countries and on the top of it; the industry has been supplying about 97 per cent of the present domestic demand for medicines.

The industry has been experiencing robust growth over the last few years. A local industry supporting drug policy and effective regulatory framework, along with Trade Related Intellectual Property Rights (TRIPs) relaxations are the key reasons for the success of the industry.

While the industry is achieving self-sufficiency, it yet procures 70% of raw materials from abroad. But developments are already taking place, with a number of firms now manufacturing raw

materials locally. In addition, an Active Pharmaceutical Ingredient (API) project has already been undertaken to accelerate the vertical integration within the industry.

The industry has been expanding locally and internationally. Local market grew at 23% in 2010, while import reached USD 50 Million landmark. A number of firms got accreditations from USA, UK, Australia, etc. developed markets, and are underway toward expansion into the developed markets. Locally, firms are preparing themselves for post 2016 scenario, now 2030 when TRIPs will be implemented. Almost all the firms are upgrading their facilities and taking up precautions for post 2016 scenario, while aggressively expanding in both local and export markets. This deadline has been extended to 2030. Like Readymade Garments (RMG), this industry is going to be very potential for the economy of the country and hence deserves comprehensive research for its further growth.

1.2. Objectives of the Study

The study aims at representing the development history and potential for pharmaceutical industry in Bangladesh and to highlight the necessity for patronization of the government.

1.3. Methodology of the Study

The study is a desk research. Different literatures have been reviewed to summaries the developments in this area. Customer's choice or perception has been collected and summarized.

2.0. Background of Pharmaceutical Industry in Bangladesh

Pharmaceuticals industry is the core of healthcare sector of Bangladesh. Being part of healthcare sector, its performance is related to demographic variables like population growth as well as economic growth and healthcare policy. In our country, with improving demographic characteristics, recent economic growth and favorable policy, the industry has seen good growth.

The history of pharmaceuticals industry dates back to 1950s. Over the years, the industry has gone through some significant changes. After liberation in 1971, the industry was largely dominated by MNCs, and the country was very much import-dependent one. In 1982, through the formulation of National Drug Policy, and Drug Control Ordinance, a defined guideline for the development of the industry was given. By then, 75% of the market was dominated by the MNCs, whereas the rest were shared by some 133 local firms. Since then, the local firms have established a stronger foothold, and the country has become from an import-dependent to an active exporter of pharmaceuticals products. At 2010, top 5 MNCs have approximately 9.05% of the market share and 97% of total local demand is met through local production.

Nowadays globally, Bangladesh pharmaceutical market has demonstrated the highest growth among all countries in 2013. Whereas Global market and Afro-Asian market is growing at a

rate of 6.70% and 15.70% only, our country is demonstrating an annualized growth of 24.58%. As a result of such significant growth along with a consistent economic growth of around 6%, recently Bangladesh was included on the Goldman Sach's "Next Eleven" list as well as the JP Morgan "Frontier Five". As per their observation, Bangladesh represents significant potentials to become an important global manufacturer of pharmaceuticals, joining China, India, Brazil and Russia.

3.0. Classification of Products in Pharmaceutical Industry:

From the perspective of business nature, the industry can be classified as-

i. High-End products (Anti-Cancer, Insulin, Vaccines, etc.),

ii. Branded generics (Products with a brand presence),

iii. Low End generics,

iv. Contract manufacturing (domestic and export).

3.1. High End Generics

These are essentially products specific to market niches, i.e. Anti-cancer, Diabetic products, Vaccines, etc. these products are usually high priced and represent a small portion of the market. Profit margins in such products are very high. Historically, these were import-dependent, and MNCs were the key provider. Recently, domestic firms have been entering into this field, and competition is expected to drive prices and import dependency down. Especially, in Anti-cancer, Insulin and several vaccine productions, several local firms have made significant progress.

3.2. Branded Generics

This represents broadest segment of the market, comprising products with relatively stable margin and brand orientation. This segment is dominated by local manufacturers, and due to high brand loyalty observed in our market, market share of manufacturers is usually moves rarely. Competition is branding oriented, and firms try to improve market share and relationships with doctors and related parties to increase market presence. Anti-Gastric and Anti-Biotic are the two-dominant product category in this segment.

3.3. Low-end Branded Generics

This segment is small, often for products with low branding possibility, and price war is most evident here. The number of competitors is very high, and market share of each competitor depends on success of marketing strategy.

3.4. Contract Manufacturing

Locally, this segment is small as almost every firm manufactures its own products. The business usually comes from health organizations like SMC (Social Marketing Company), UNICEF,

etc. to provide products such as saline, contraceptives, etc. However, there is a good market for foreign contract manufacturing. As per observation of Bangladesh Pharmaceuticals Society, our industry can earn approximately BDT 200 billion (USD 2.9 Billion) each year.

Presently, a number of top firms engage in contract manufacturing. Competition is very low, as each firm engages based on foreign counterpart relations. Manufacturing technologies and accreditations play a vital role in developing contract manufacturing capability.

4.0. Present scenario of Pharmaceutical Industry in Bangladesh

i. Bangladesh pharmaceutical industry is the largest (in volume) among the Least Development Countries (LDCs) with a market size of USD 600 million & an average annual growth rate of 12%.

ii. The industry is primarily a generic one. There are about 8,000 different brands which meet 97% of the domestic demand.

iii. The local companies have 86% share of the market. Out of 245 registered companies the top ten companies account for almost 70% of the total market.

iv. The LDCs are exempted from "Patent Protection" according to the WTO TRIPS policy. This agreement allows legal reverse engineering and sale of patented product until 2016.This gives the local pharmaceutical industry an advantage over India and China who do not come under the exemption agreement.

v. After entering the global market, Bangladesh pharmaceutical industry has made great progre ss in export. Between 2003 and 2006 pharmaceutical exports increased to about 61 countries from 51 and quadrupled in value from USD 7.9 million to USD 36.5 million.

vi. Many Bangladeshi companies have acquired international certifications like US FDA, UK MHRA and TGA; these allows them to penetrate regulated and unregulated markets.

vii. Bangladeshis in a position to emerge as one of the regional R&D centers for pharmaceutical research as reverse engineering has ended in China and India. There is an opportunity to emulate the Contract Research and Manufacturing Services (CRAMS) model of India.

viii. Currently 80% of the APIs are imported from abroad. But with the establishment of adequate reverse engineering and API manufacturing facilities the local demand for raw materials can be met without import.

ix. Bangladesh can provide a strong platform for off-shoring/outsourcing generic bulk and formulation drugs due to a cheap labor force and established infrastructure. With more and more western companies looking to cut cost in their manufacture of bulk drugs as they focus

more on the high-cost patented drugs, Bangladesh can present itself as an attractive destination for off-shoring.

x. With the establishment of modern technical facilities, the industry can emerge as a regional hub for pre-clinical testing and clinical trials. The Contract Research Organization (CRO) model success of India can act as a template to emulate as subject cost will be very low in Bangladesh compared to that of western countries.

xi. There is an opportunity for substituting import of vaccines, injectables through manufacturing it locally.

xii. Many local entrepreneurs are now looking to expand their operations beyond the country borders. Some are looking to emulate the buying of distressed companies in the west to gain immediate market access.

5.0. Customer Perception & Reputation

Customer is a person who buys the products as well as consumes the products and consumer only consumes the products (Chowdhury, 2000). Pharmaceutical industries are dealing with lifesaving drugs; here customer choice does not change so rapidly. People may prefer one brand to another. But the medicine may carry the same compound/same ingredients. Customer choice depends on the customers' reliance upon the company. For example, Beximco's Napa, and Glaxo's Parapirol carry the same compound and used for the same purpose. But, the customer purchases one of them. Customers usually prefer some foreign medicine in case of sensitive problem. However, our local pharmacies do not produce all the sensitive drugs, especially injections. This research also conducted a small survey over the customer of medicinal product and their choices. The sample was taken from different hospitals and pharmacy that came to buy the products. The above chart represents the scenario of customer choice toward the brand name. Most of the customers choose their medicine

Table 1. Customer's choice of brand name.

Brand Name	Respondent (%)
Square	38
Beximco	24
Incepta	16
Glaxo SmithKline	8
Acme	6
SK-F	4
Others	4

Source: Habib et al., (2011).

produced by square pharmaceuticals limited. According to the customer choice, no organization can play dominant role in the market.

6.0. Size of the Market

There are several sectors on which Bangladesh can be proud of and undoubtedly the pharmaceutical sector is one of these sectors, rather it is the sector, which is the second-largest contributor to the government exchequer. There are about 231 companies in this sector and the approximate total market size is about Taka 76,500 million per year of which about 97% of the total requirement of medicines is produced by the local companies and the rest 3% is imported. The imported drugs mainly comprise of the cancer drugs, vaccines for viral diseases, hormones, etc. Bangladesh pharmaceutical industry is now heading towards self-sufficiency in meeting the local demand. The industry is the second highest contributor to the national exchequer after garments, and it is the largest white-collar intensive employment sector of the country. There are about 450 generics registered in Bangladesh. Out of these 450 generics, 117 are in the controlled category, i.e., in the essential drug list. The remaining 333 generics are in the decontrolled category. The total number of brands/items that are registered in Bangladesh is currently estimated to be 5,300, while the total number of dosage forms and strengths are 8,300. Bangladesh pharmaceutical industry is mainly dominated by domestic manufacturers. Of the total pharmaceutical market of Bangladesh, the local companies are enjoying a market share reaching around 80%, while the MNCs are having a market share of 20%.

7.0. Marketing Strategies

There are different forms of marketing and promotional activities done by pharmaceutical companies. Those are as follows:

7.1. Relationship Building with Doctors

A major part of marketing pharmaceutical products is building strong relationship with the doctors. The opinion of the physicians matters a lot in consumer's decisions and preferences. Hence, the sales representatives go a long way to build strong relationships with leading doctors, whose prescription and suggestions would promote sales of drugs.

7.2. Providing Samples to Doctors

The pharmaceutical companies promote their products indirectly by supplying physician's sample to the doctors. This process includes the companies sending sales representatives to different doctors and providing the doctors with free samples of their products. This allows the pharmaceutical companies to introduce and expose their products to the doctors. Due to the absence of any media

promotion combined with the fact that the Bangladeshi market is a generics market, it is imperative to get prescription share of the leading doctors.

7.3. Providing Doctors with Gifts

Code of Pharmaceutical Marketing Practices (CRMP) strictly regulates the marketing tools and states that any gift given to the doctors has to benefit the end patients in some way. Any household or entertainment purpose related gifts like cards, prescription pads can't be given as these are considered as promotional items. These gifts can also include items like refrigerators for storage of drugs in a certain clinic or hospital. The main function of these gifts is the same as of any other PR gifts – to create exposure and eventually generate share of mind.

7.4. Discounts and Other Sales Promotion Tools

Promotional discounts are given for over the counter (OTC) products. This is the primary promotion tool used for OTCs to increase consumer demand. The price plays a very important role as mentioned above in creating consumer preference and eventually brand loyalty.

7.5. Sponsoring Events/Conferences

Sponsoring conferences and other medical related events and activities are often done by pharmaceutical companies to improve brand image.

7.6. Innovative and Other Techniques

Some companies imply other innovative techniques. For example, Renata once financed cancer treatment for a doctor who in turn regularly prescribed Renata's brands.

8.0. Nature of Channel of Distribution in Pharmaceutical Industry

The distribution channel is a key aspect for a pharmaceutical company. To ensure the widespread availability of pharmaceutical products throughout the country, it is necessary to include effective and efficient channels of distribution within the marketing channels. Because, as the aim of most pharmaceuticals is to cover the majority of the geography of a country, so the distribution process becomes a major ground of expenditure. Hence companies should not only focus on their functioning distribution channels but also on their distribution costs as well. There are institutions however which perform outsourced distribution for other companies. The price on average that these distribution agencies charge pharmaceutical companies is 10% - 15% of sales, whereas internally, this cost is generally less than 10%. An example of a distribution agency is Transom which charges 12%. The cost of distribution for Renata, which performs the distribution themselves, is around 6%. The factors that are included in the cost determination of maintaining an efficient distribution chain are:

8.1. Economies of Scale

The predominant system of circulating pharmaceutical products outside Dhaka involves the following pattern; the small-town chemists place orders according to their requirements of products of a particular company. The same company later supplies the products to them according to their demands listed. But this does pose a seemingly insignificant but in reality, quite a considerable problem. Quite often, as it happens, the transporting vehicle is not used to its optimum delivery amount if the order size is too small thus leading to inefficiencies. Large production volumes help to reduce this problem.

8.2. Efficiency of the Staff

As we know, as equally important as the distribution channel is the quality of the sales personnel. The productivity and efficiency of these very crucial staff members is essential to the success of a company in semi-urban and rural areas. The sales force generally receives adequate training but it is always difficult to maintain and monitor the required standard of skill of people employed by the organization. Inefficiencies among the sales force leads to cost inefficiencies in the distribution chains as well.

9.0. Government Regulation

The industry is regulated by Drug Regulatory Authority (DRA) through the Drug Control Ordinance of 1982, and National Drug Policy 2004.

9.1. Pricing

Under the present regulatory structure, government fixes the Maximum Retail Prices (MRP) of 209 essential drug chemical substances. Other drugs, listed as non-essential, are priced through an indicative price system. For imported finished products, whether they fall in the category of vital or non-vital drugs, a fixed percentage of markup is applied to the C&F price to obtain the MRP. For local distribution, all drugs must be registered with DRA. However, for export purpose, such registration is not mandatory. (Source: National Drug Policy 2004).

9.2. Key Registration Areas

i. Combination drugs (other than vitamins, nutritional preparations or therapeutically useful) are not allowed.

ii. For imported drugs, GMP validation, bioavailability and bio-equivalency are important registration criteria.

9.3. Drug Production Regulations

i. Firms are required to upgrade their productive facilities to ensure cGMP (Current Good Manufacturing Practice) is followed.

ii. Foreign and MNCs are allowed to manufacture drugs in Bangladesh only if at least three of their original research drug products are registered in at least two of the following countries: USA, UK, Switzerland, Germany, France, Japan, and Australia.

iii. Drugs not in British Pharma Copea (BP), US Pharma Copea (USP). Indicative Price (IP), International Non-propreitery Name (INN) or Bangladesh Pharmacy Council (BPC) will not be allowed to be manufactured.

iv. Foreign firms can produce drugs in Bangladesh under licensing agreement following certain conditions.

v. For export purpose, only, any drug can be produced in Bangladesh.

9.4. Drug Distribution, Storage and Sale

i. Only registered drugs are allowed for sale,

ii. Other than OTC drugs, no drugs should be sold without prescriptions,

iii. Advertisements are not allowed.

10.0. Current Market Scenario of Pharmaceutical Industry

Bangladeshi Pharmaceutical companies are not allowed to do any direct promotion of their products since the regulatory policies prohibit it. The policy frame work for promotion of pharmaceutical products is guided by Directorate of Drug Administration (DDA). DDA has a detailed CRMP that regulates the promotion of pharmaceutical products and this excludes any form of direct marketing through media tools. To illustrate this, the pharmaceutical companies cannot promote their products or their company through the Television, Radio, Newspaper or any other form of printed media. The primary means of promotion for pharmaceuticals is through personal selling and trade marketing. The companies try to identify key opinion leaders namely the reputed doctors and convincing them to prescribe and promote the companies' products.

Currently there are 245 registered pharmaceutical companies in Bangladesh, out of which 200 companies are still in operation. These 245 companies together have 5,300 registered brands. The market is largely dominated by local companies and there are only 5 multi-national companies currently in operation.

11.0. Factors Affecting Development of Pharmaceutical Industry

There are some factors which are affecting the pharmaceutical industry, these are given below -

11.1. Political Factors

Within Bangladesh political ambitions and, is fissiparous tendencies are on the rise and may well continue for quite some time to future. Therefore, it is expected that the Pharmaceutical Industries might consider inclusion of political risk coverage also. The only area where Bangladesh Pharmaceutical industrialists consider giving cover is with regard to TRIPS under certain conditions. Certain type of political risk at the international level has serious implications for exporters & importers. The term 'political risk' has a wider connotation than commonly understood or assumed. It covers events raising not just from politics, but risks in the course of international transactions. In this connection, it may be noted that export has evolved out of uncertainties relating to international trade, particularly due to problems arising out of foreign legal jurisdiction, political changes and currency exchange difficulties faced by many developing countries.

11.2. Economical Factors

Bangladesh has a very small economy and the contribution of pharmaceutical industry in the economy as a sector is also very low. Moreover, unlike other industries and financial institutions, Pharmaceutical Industries concentrate heavily on the urban market. This also reduces the actual size of the market. Interest rate at bank and interest rate of P. F. variation very much affect to pharmaceutical industry. Inflation also affects Pharmaceutical Industry. Because of the inflation, the price of the raw materials increases. Volatile stock market position has also an impact upon Pharmaceutical industry.

11.3. Socio-Cultural Factors

Socio-Cultural factors affecting pharmaceutical industry are as follows:

a. Population
b. Life style
c. Educational level
d. Level of earning
e. Societal benefits
f. Level of consciousness

These are the major social factors, which affect the pharmaceutical industry sector.

11.4.0. Dynamics of Marketing

Since the pharmaceutical market of Bangladesh is generic, there is not much difference in the composition of different products. As a result, a consumer will find several brands which will serve the same purpose. In such a situation, the primary three reasons for a consumer to have any preference towards any particular brand of drug are:

11.4.1. Price

Being a generic market, the content differentiation of different brands of same drugs is not very high. Invariably, there will be several drugs that will be able to meet the needs of a certain problem. In such a case, the price of the different brands becomes an important decision criterion for the consumer, especially in the case of OTC drugs.

11.4.2. Physician's Opinion

As in most situations, the physician's opinion is of imperative importance to any consumer. The case is not different for the Bangladeshi market. In fact, if anything, it is probably even more so. The influence of the physician's opinion probably stretches more on people who have limited medical knowledge and thus they heavily rely on the doctor's opinion.

11.4.3. Overall Brand Image of Drug / Manufacturer

This element is particularly applicable for OTC drugs. The overall brand image of the drug / drug manufacturer can have significant impact on the consumer's choices of purchasing drugs. The consumers might even be willing to incur a cost disadvantage to attain a trusted product. Such brand equity often provides the consumer with quality assurance.

12.0. Conclusion

Pharmaceutical Industry is now an export-oriented industry of the country. The export earnings already exceeded Tk. 500 crores and a number of countries including Srilanka and Russia imports medicine from Bangladesh at present. This is also a labor-intensive industry, conducive to highly populated country like Bangladesh. At present pharmaceutical industry is very much important in the business sector of any country. There are many companies that produce high quality medicines in Bangladesh. New company comes to this sector and produces quality medicines. For this reason, competition in this industry is increasing day by day. Not all firms in this sector do well, but most of them perform well. A new era has begun for Bangladesh pharmaceutical sector with the TRIPs agreement from 2005 and was to continue up to 2016, which has been extended another 15 years, up to 2030. These extended periods will be very crucial and important for the pharmaceutical industry. New technology should be developed so that some new kinds of medicines are added in the

product line and it can be used in various establishments. Progress in Pharmaceutical industry means progress in economy. The progress of pharmaceutical industry depends on the progress of economic condition. Pharmaceutical industry also faces many problems. So, if government develops policies to support this industry as well as to overcome its problems, this industry will flourish and its contribution to employment, other sectors of the economy and enhancement of export earnings from present level of Tk. 5,000 million would more in our country.

References:

Annual Reports of Selected Pharmaceutical Companies.

Bangladesh Bank website: http://www.bangladesh-bank.org.

Bhuiyan, M.A.R.M.; Sultana, S. (2011) Bangladesh Research Publication Journal: Analysis of Pharmaceutical Industry of Bangladesh (Its Challenges & Critical Success Factor), Vol. 5.

Bodie Z.; Kane, A.; Marcus, A.J. (2009). Investments, 8th Edition, McGraw-Hill Publishing Company Limited, Inc.

Habib, M.D.; Alam, M.D. (2011) Business Analysis of Pharmaceutical Companies in Bangladesh: Problems & Prospects, Vol. 6.

Internship Report (unpublished): Trend Analysis of Generic Shifting in Bangladesh Pharmaceutical Market (2006-2010).

Islam, M.D.; Mili, S.A. Department of Accounting & Information Systems, Comilla University, Comilla, Bangladesh. European Journal of Business & Management: Financial Diagnosis of Selected Listed Pharmaceutical Companies in Bangladesh [Online].

Reilly, F.K.; Brown, K.C. (2010-11) Investment Analysis and Portfolio Management. 8th edition, Thompson- Southwestern Publishing, NY, USA.

Robinson, T.R.; Greuning, H.V.; Henry, E.; CFA. Broihahn, M.A. (2009) International Financial Statement Analysis, 1st edition, John Wiley & Sons.

Shawon, S.A. (2011) Management Trainee, Research Report: Pharmaceutical Industry of Bangladesh, 28th June 2011.

www.dsebd.org.

www.finance.schoolfbd.com.

www.stock Bangladesh.com.

Ship Motion Prediction in Regular Head Waves

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Abstract

Ship motions are defined by the six degrees of freedom that a ship, boat or any other craft can experience. Heave and pitch are linear and rotational ship motions which are very important in case of regular head waves. This paper presents the prediction of heave and pitch motion of ship in regular head waves. The heaving and pitching motions of a typical ship model are predicted theoretically. Comparison is made between theoretical prediction and experimental results for each vessel. For the validation of the result, a model of series 60 ship has been taken. Heave and pitch motion results have been compared with experimental and other numerical results. A reasonable prediction has been found for this model. A fine destroyer and fuller bulk carrier have been taken also to check their motion results at various Froude numbers. It has been found that the predicted result computed by the present program gives very close to experimental results for the ship with wide range of block coefficient from 0.5 to 0.8.

Keywords: Ship Motion, Regular Waves, Linear Strip Theory, Destroyer.

Nomenclature

a-e, A-E, g, G	Coefficient of equation of motion	ωe	Frequency of encounter
Fr	Froude Number	τ	Phase angle of pitching moment
F0	Amplitude of time-varying heaving force	$\ddot{z}$	Heaving acceleration of center of gravity of ship or model
$\overline{F}$	Complex vertical (heaving) force	z0	Amplitude of heaving motion.
Gw	Gravitational acceleration	$\overline{z}$	Complex heaving motion
CB	Block Coefficient	δ	Theoretically computed heaving phase angle
T	Time	Δ	Displacement of ship or model
P	Density of Water	ε	Theoretically computed pitching phase angle
L	Length of ship or model	θ	Pitching displacement
M	Total pitching moment	$\dot{\theta}$	Pitching velocity

		$\ddot{\theta}$	Pitching accelerations
M0	Amplitude of time-varying pitching moment	θ0	Amplitude of pitching motion
$\overline{M}$	Complex pitching moment	$\overline{\theta}$	Complex pitching motion
N(ζ)	Sectional damping coefficient	λ	Wavelength
Z	Heaving motion of C.G of ship or model	V	Speed of ship or model
$\dot{z}$	Heaving velocity of C.G of ship or model	σ	Phase angle of heaving force

1.0. Introduction

Ship motion prediction is important because it is directly related to the safe and economic operation of the ships. An accurate assessment of ship motions is crucial importance in the process of initial design stage. One important concern is the problem of capsizing in extreme weather conditions. Other concerns include the economic fuel consumption, efficient transfer of pay-loads between marine vehicles, improved performance of tracking devices, improved missile launching capability etc. In the design stage of ships design engineers must consider ship motion. Design engineers can save time and resources by being able to anticipate the ship's performance in early stages.

2-D based theoretical and computational methods of ship motion computations have been under development for over the past 40 years by various researchers such as rational strip theory of Ogilvie et al. (1969) and the new strip theory of Salvesen et al. (1970). One main difference between the different strip theories is the dependence of the coefficients on the forward speed and the treatment of the boundary conditions. In general, all of the strip-theory calculations give satisfactory results for slender-body ships with small amplitude motions, where the nonlinear and three-dimensional effects are insignificant. Many attempts have been made to overcome some of the shortcomings of strip theory. Wang (1976) combined the strip-theory approximation and the dynamic theory to derive the hydrodynamic coefficients of ship motions. The dynamic theory treats the fluid and the body together as one dynamical system. The classical dynamic theory treats the fluid as an unbounded medium, while Wang's formulation takes into account the existence of the free surface. The results of this approach were very similar to those derived by Salvesen et al. (1970). As a matter of fact, the two methods become identical when the interaction between the body and the free surface is neglected. Troesch (1981) used the slender-body theory to derive formulae for the sway, roll, and yaw motion coefficients. Liu et al. (1997) tried to extend the strip theory and apply it to large-amplitude motions. An attempt was done to include some nonlinear effects by taking into account the instantaneous variations of the wetted hull surface during motion and its effects on the ship

hydrodynamic characteristics. The method is a quasi-steady approach, which does not take into account the memory effects. Crossland et al. (1993) conducted a series of experiments to measure the heave and pitch decay-time histories of a model ship. The aim of these experiments was to explain the over prediction of the sectional damping obtained using a strip-theory program. The over prediction of the sectional damping creates poor predictions of free decay motions. This issue has not been resolved completely and it has been concluded that strip theory should be used only in low-amplitude motions when making sea keeping predictions. As mentioned before, many research works are devoted to improving strip-theory predictions, including the applicability to situations where the 3D and nonlinear effects are significant. Earlier prediction methods followed the pioneering works of Korvin-Kroukovsky (1957) and were based on 2D theories. A number of 2D strip-theory based methods of computations were subsequently developed by various researchers.

In this research work 2D linear strip theory by Korvin-Korvosky et al. (1957) has been used to predict hydrodynamic coefficients such as added mass, damping, and exciting force. A computer program has been developed to solve the hydrodynamic coefficients. Then these coefficients were used to solve the motion equations.

2.0. Methodology

2.1. Prediction of Ship Motion Using Linear Strip Theory

Strip theory given by Korvin-Korvosky et al. (1957) has been used for determining the parameters of the ship-motion equations. The predictions are based on 2D evaluations of the ship parameters, whereby the ship is divided into several 2D transverse sections (strips) along the ship's longitudinal axis. These sections are assumed not to interact with each other. The 2D parameters are usually evaluated using potential-flow theories. In strip theory, the 3D-ship-motion coefficients are expressed in terms of integrals of 2D sectional coefficients. These coefficients are then calculated with the assumption that the 2D sections do not interact with each other. To calculate the 2D coefficients Lewis-forms method has been used. In this method, a velocity potential is determined for a cylinder oscillating in an undisturbed free surface in the sway, heave, and roll motions. Bernoulli's equation is then applied to the velocity potential to calculate the pressure distribution on the cylinder. Integration of the pressure yields the added mass and damping forces.

2.2. Analytical details of the Linear Strip theory of ship motions

The coupled set of linear differential equations can be expressed as:

$a\ddot{z} + b\dot{z} + cz + d\ddot{\theta} + e\dot{\theta} + g\theta = \overline{F} exp(i\omega_e t)$ (1) $A\ddot{\theta} + B\dot{\theta} + C\theta + D\ddot{z} + E\dot{z} + Gz = \overline{M} exp(i\omega_e t)$ (2)

Where,

z and θ are the complex heave and pitch vectors,

F and M are wave induced exciting force and moments,

ω_e the frequency of encounter,

a,b,c,d,e,g and A,B,C,D,E,G are the coefficients of the equation of motion.

The above equations result from equilibrium considerations of the hydrodynamic forces and moments called equation of motion, when meeting head or astern regular waves. Following the principles of classical dynamics, these forces and moments are obtained by applying Newton's Second Law of Motion to both translatory and rotational displacements of the body's center of gravity. The wave induced excitation force and moment may be defined as:

$$\overline{F} exp(i\omega_e t) = F_0 exp(-i\sigma)\ exp\ (i\omega_e t) = F_0 exp[i(\omega_e t - \sigma] \qquad (3)$$

$$\overline{M} exp\ (i\omega_e t) = M_0 exp(-i\tau)\ exp\ (i\omega_e t) = M_0 exp[i(\omega_e t - \tau)] \qquad (4)$$

The differential exciting force acting on a control section distant ζ from the origin of the moving coordinate system (ship's C.G.), can be expressed in the simplified form,

$$\frac{dF}{dx} = \frac{dF_1}{dx} cos\ \omega_e t + \frac{dF_2}{dx} sin\ \omega_e t = [\{ \phi_1 sin \frac{2\pi\zeta}{\lambda} + \phi_2 \frac{2\pi h C_W}{\lambda} cos \frac{2\pi\zeta}{\lambda} \} exp\ (-\frac{2\pi y}{\lambda})]\ cos\ \omega_e t + [\{\phi_1 cos \frac{2\pi\zeta}{\lambda} + \phi_2 \frac{2\pi h C_W}{\lambda} sin \frac{2\pi\zeta}{\lambda} \} exp\ (-\frac{2\pi y}{\lambda})]\ sin\omega_e t \qquad (5)$$

Where,

$$\phi_1 = h\rho g\ B - \frac{4\pi^2 h C_W}{\lambda^2}(\rho S k_2 k_4) \qquad (6)$$

$$\phi_2 = N(\zeta) - V\frac{d(\rho S k_1 k_2)}{d\zeta} \qquad (7)$$

While the differential exciting moment of this force about the C.G. is given by $\frac{dF}{d\zeta} d\zeta$. Integration of the above two quantities over the ship length results in the values of the total time-varying exciting force and moment, which are considered as the real parts of the Eq. (3) and Eq. (4).

Thus, $F = F_1 cos\ \omega_e t + F_2 sin\ \omega_e t = \sqrt{F_1^{\,2} + F_2^{\,2}} cos\ [\omega_e t - arctan\frac{F_2}{F_1}] = F_0 cos(\omega_e t - \sigma)$ (8)

and, $M = M_1 cos\ \omega_e t + M_2 sin\ \omega_e t = \sqrt{M_1^{\,2} + M_2^{\,2}} cos\ [\omega_e t - arctan\frac{M_2}{M_1}] = M_0 cos(\omega_e t - \tau)$ (9)

The analysis of the forces and moments which correspond to the ship's free oscillations in calm water yields terms which appear on the LHS of the Eq. (1) and Eq. (2). The final expressions

for the coefficients of the equation of motion used in the computations can be found in reference Al Amin et al. (2013).

After algebraic manipulation, the complex heave and pitch amplitude becomes

$$\bar{z} = z_1 - iz_2 = \sqrt{z_1^2 + z_2^2}\exp\left[-i\arctan\frac{z_2}{z_1}\right] \tag{10}$$

$$\bar{\theta} = \theta_1 - i\theta_2 = \sqrt{\theta_1^2 + \theta_2^2}\exp\left[-i\arctan\frac{\theta_2}{\theta_1}\right] \tag{11}$$

Finally $z=R_e\bar{z}\ exp(i\omega_e t) = R_e\sqrt{z_1^2 + z_2^2}exp\ [i(\omega_e t - arctan\frac{z_2}{z_1})] = z_0\cos(\omega_e t-\delta)$ (12)

$$\theta=R_e\bar{\theta}\ exp(i\omega_e t) = R_e\sqrt{\theta_1^2 + \theta_2^2}exp\ [i(\omega_e t - arctan\frac{\theta_2}{\theta_1})] = \theta_0\cos(\omega_e t-\varepsilon) \tag{13}$$

3.0. Validation

For the validation of numerical results given by developed computer program, a Series 60 ship of C_B=0.7 has been taken. The principal particulars of the ship are shown in Table 1. Body plan is shown in Fig.1. Test results have been taken from Gerritsma et al. (1967).

Table 1. Model characterization of series 60 ship.

LWL	2.479m
LBP	2.438m
Beam	0.3481m
Draft	0.139m
LCG	0.0119m (forward of amidships)
C_B	0.70

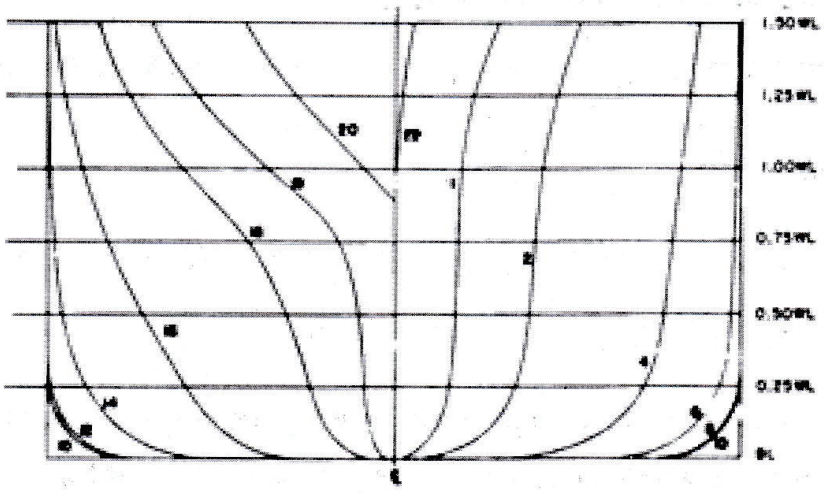

Fig. 1. Body plan of series 60.

Fig. 2, shows the comparison between the calculated results with experimental and other numerical results for heave added mass at Fr = 0.2. From this graph, it is seen that the non-dimensional heave added mass decreases gradually with the increasing value of $\omega_e(L/g)^{1/2}$. The calculated results deviate more at the higher value of $\omega_e(L/g)^{1/2}$ from the experimental results because of increasing wave frequency.

Fig. 3, shows the comparison between the calculated results with experimental and other numerical results for pitch added mass at Fr = 0.2. From this graph, it is seen that the non-dimensional pitch added mass decreases gradually with the increasing value of $\omega_e(L/g)^{1/2}$. But this time the calculated results is too close to the experiment results than the previous one.

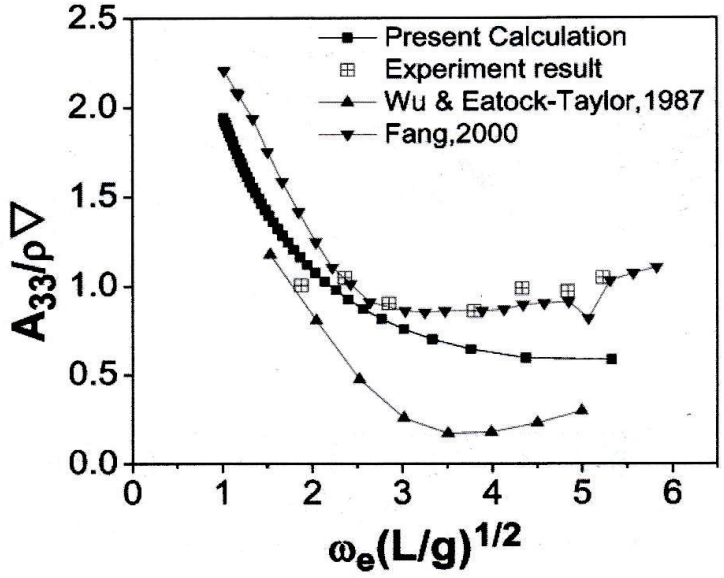

Fig. 2. Heave motion at F_n=0.2 in head sea.

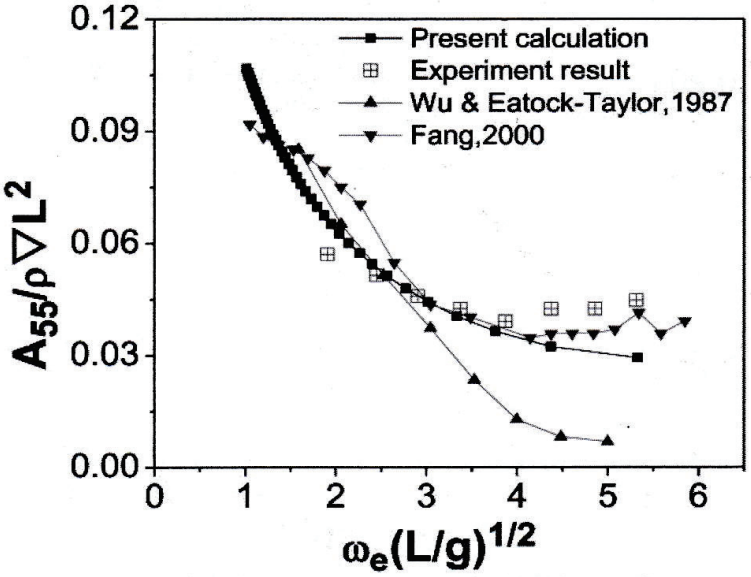

Fig. 3. Pitch motion at F_n=0.2 in head sea.

Fig. 4, shows the comparison between the calculated results with experimental and other numerical results for heave damping at Fr = 0.2. From this graph, it is seen that the non-dimensional heave damping increases gradually with the increase of the value of $\omega_e(L/g)^{1/2}$ and the calculated value deviates more at higher value of $\omega_e(L/g)^{1/2}$ from the experimental value, because of increasing value of wave frequency of encounter.

Fig. 5, shows the comparison between the calculated results with experimental and other numerical results for pitch damping at Fr = 0.2. From this graph, it is seen that the non-dimensional pitch damping increases gradually with the increase of the value of $\omega_e(L/g)^{1/2}$ but the experimental value decreases with increasing wave frequency value.

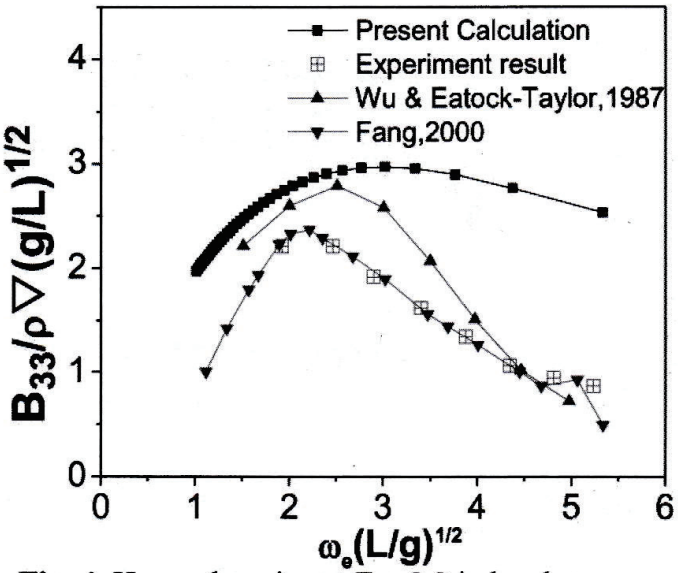

Fig. 4. Heave damping at Fn=0.2 in head sea.

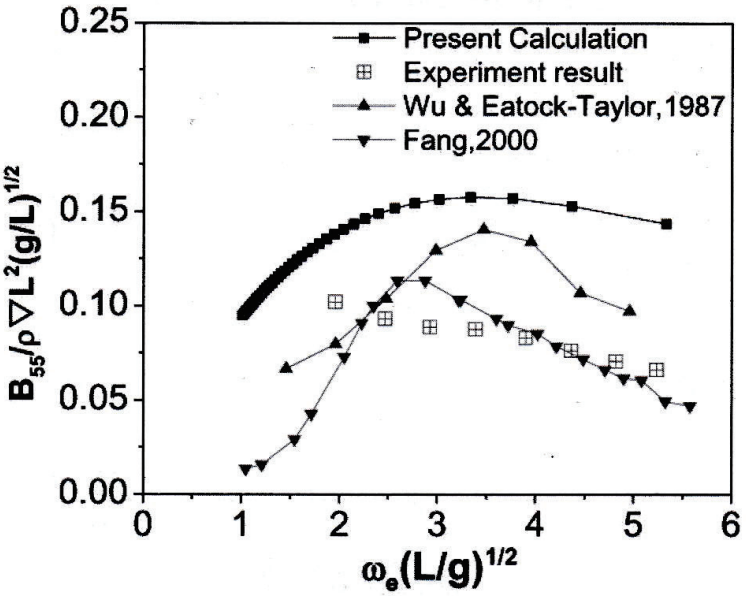

Fig. 5. Pitch damping at F_n=0.2 in head sea.

Fig. 6, shows the comparison between the calculated results with experimental and other numerical results for heave exciting force at Fr = 0.2. From this graph, it is seen that the non-dimensional heave exciting force decreases gradually with the increase of the value of $\omega_e (L/g)^{1/2}$ and the calculated value is very close to the experimental value.

Fig. 7, shows the comparison between the calculated results with experimental and other numerical results for pitch exciting moments at Fr = 0.2. From this graph, it is seen that the non-dimensional pitch exciting moments increases and then decreases gradually with the increase of the value of $\omega_e(L/g)^{1/2}$ and the calculated value is slightly deviates from the experimental value because of resonance.

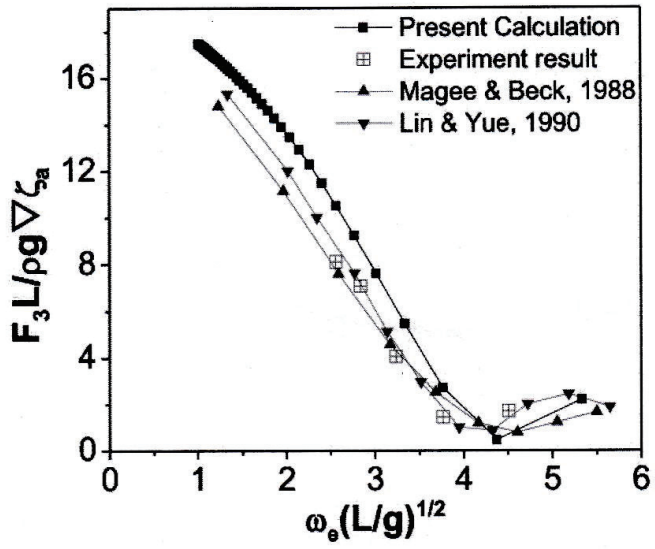

Fig. 6. Heave exciting force at F_n=0.2 in head sea.

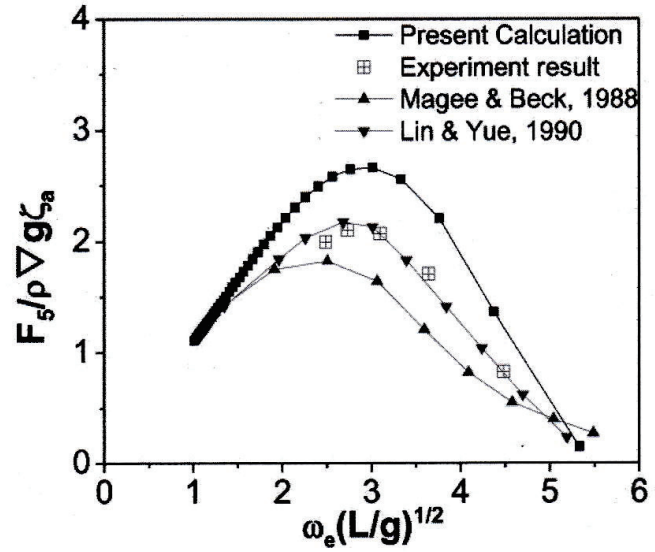

Fig. 7. Pitch exciting force at F_n=0.2 in head sea.

Fig. 8, shows the comparison between the calculated results with experimental and other numerical results for heave motion at Fr = 0.2. From this graph, it is seen that the non-dimensional heave motion increases at a certain limit and then decreases gradually with the increase of the value of $\omega_e(L/g)^{1/2}$ and the calculated value is slightly lower from the pick because of resonance to the experimental value.

Fig. 9, shows the comparison between the calculated results with experimental and other numerical results for pitch motion at Fr = 0.2. From this graph it is seen that the non-dimensional pitch motion increases at a certain limit and then decreases gradually with the increase of the value of $\omega_e(L/g)^{1/2}$ and the calculated value is slightly lower from the pick because of resonance to the experimental value.

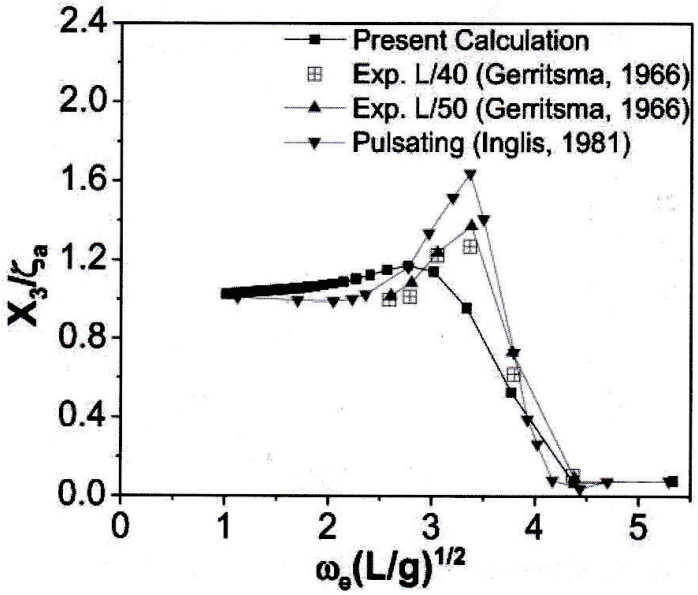

Fig. 8. Heave motion at at F_n=0.2 in head sea.

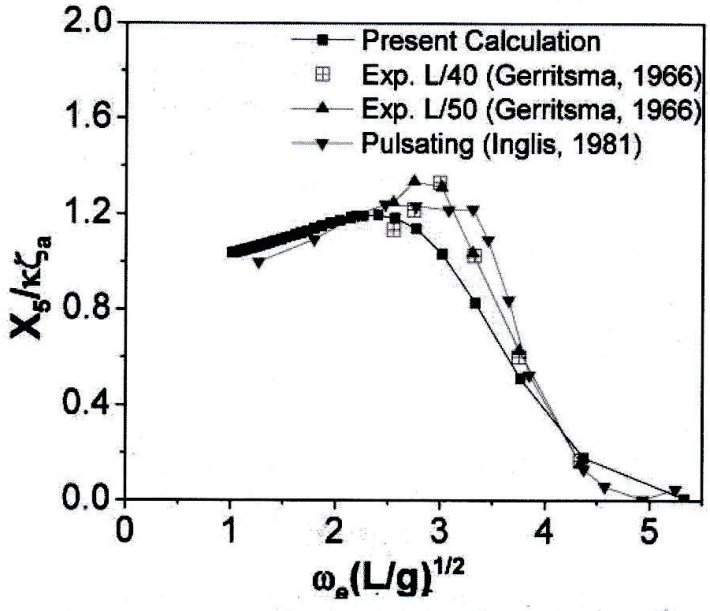

Fig. 9. Pitch motion at at F_n=0.2 in head sea.

4.0. Case Study

For case study two ship of different hull form such as Destroyer and Bulk Carrier have been chosen as follows:

4.1. Case study-1: Destroyer

For the validation of numerical results given by developed computer program, a Destroyer of C_B=0.5374 has been taken. The principal particulars of the ship are shown in Table 2. Body plan is shown in Fig.10. Test results have been taken from Salvesen et al. (1970).

Table 2. Model characteristics of destroyer.

LWL	5.307m
LBP	5.307m
Beam	0.565m
Draft	0.194m
LCG	0.0856m (forward of amidships)
C_B	0.5374

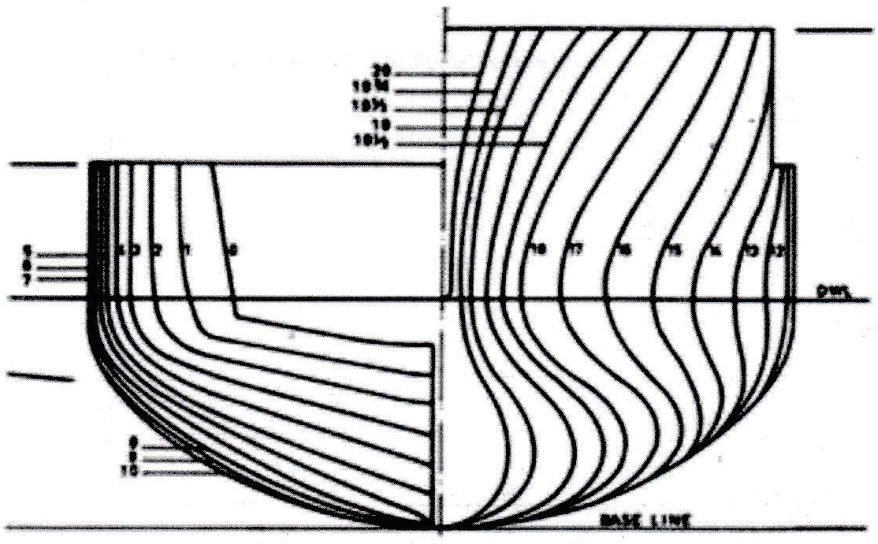

Fig. 10. Body plan of destroyer.

Fig. 11, shows the comparison between the calculated results with experimental results for heave motion at Fr = 0.25. From this graph, it is seen that the non-dimensional heave motion increases at a certain limit and then decreases gradually with the increase of the value of L/λ and the calculated value is slightly lower from the pick because of resonance to the experimental value.

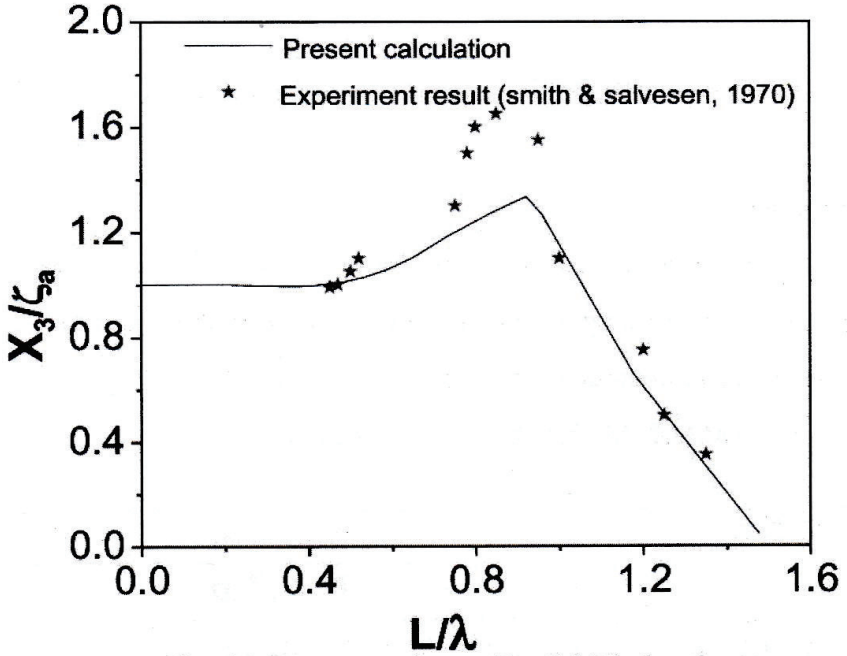

Fig. 11. Heave motion at Fn=0.25 in head sea.

Fig.12, shows the comparison between the calculated results with experimental results for pitch motion at Fr = 0.25. From this graph, it is seen that the non-dimensional pitch motion increases at a certain limit and then decreases gradually with the increase of the value of L/λ and the calculated value is as like as previous.

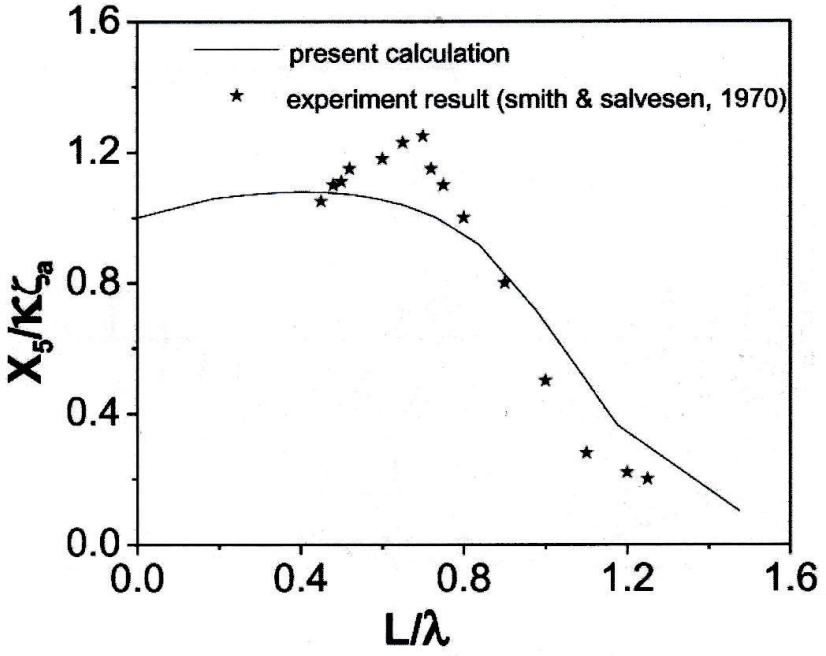

Fig. 12. pitch motion at at Fn=0.25 in head sea.

Fig. 13, shows the comparison between the calculated results with experimental results for heave motion at Fr = 0.35. Fig.14, shows the comparison between the calculated results with experimental results for pitch motion at Fr = 0.35.

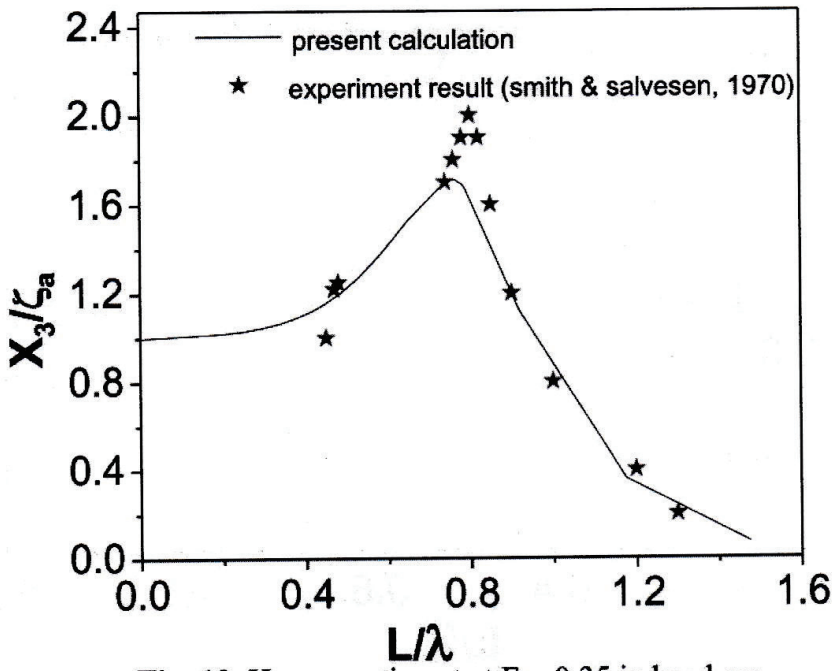

Fig. 13. Heave motion at at Fn=0.35 in head sea.

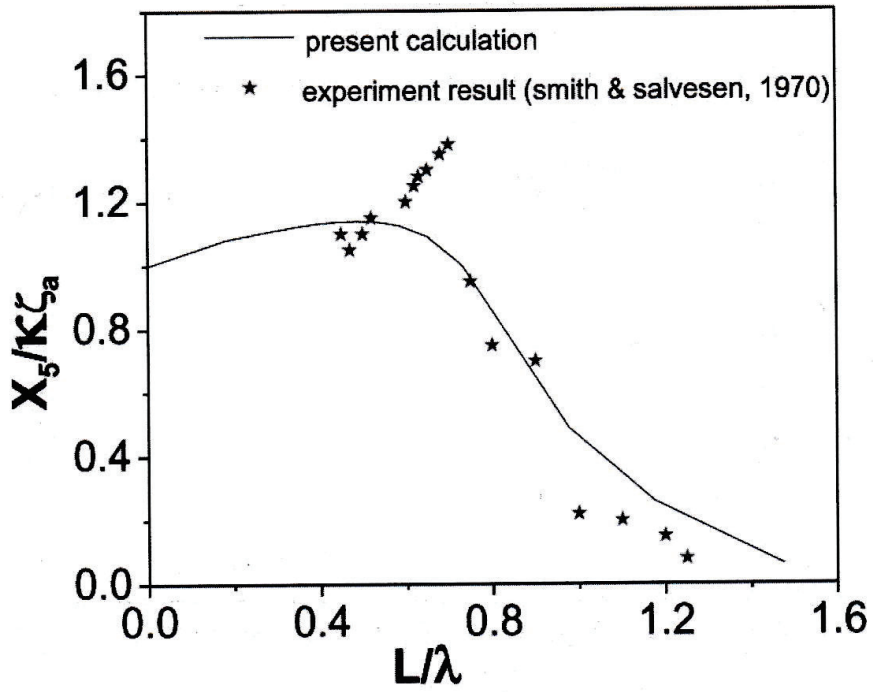

Fig. 14. Pitch motion at at Fn=0.35 in head sea.

Fig. 15, shows the comparison between the calculated results with experimental results for heave motion at Fr = 0.45. From this graph, it is seen that the non-dimensional heave motion increases at a certain limit and then decreases gradually with the increase of the value of L/λ and the calculated value is close to the pick of the experimental value.

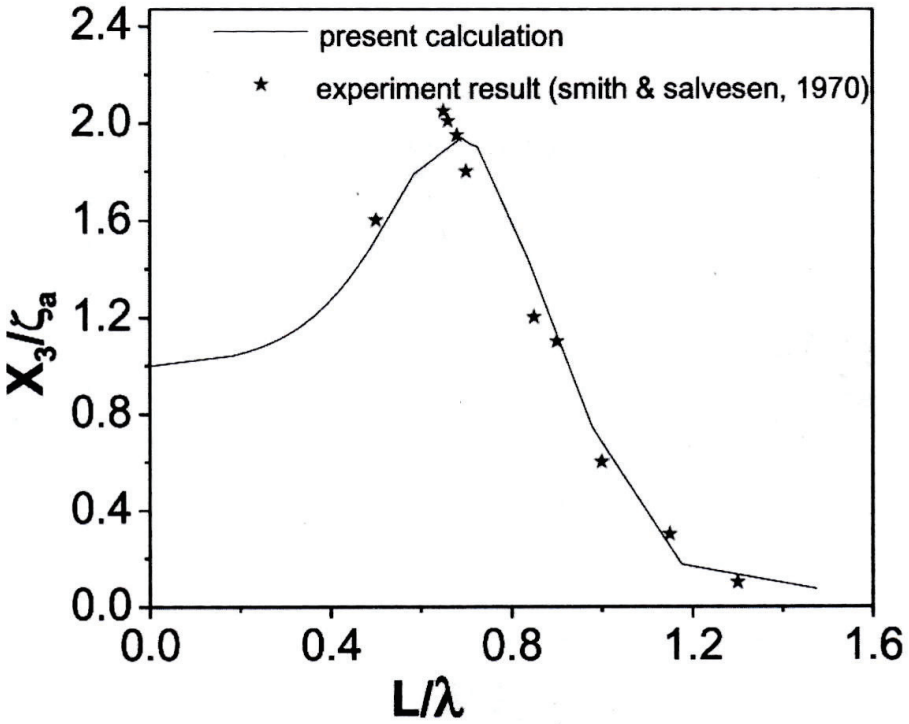

Fig. 15. Heave motion at Fn=0.45 in head sea.

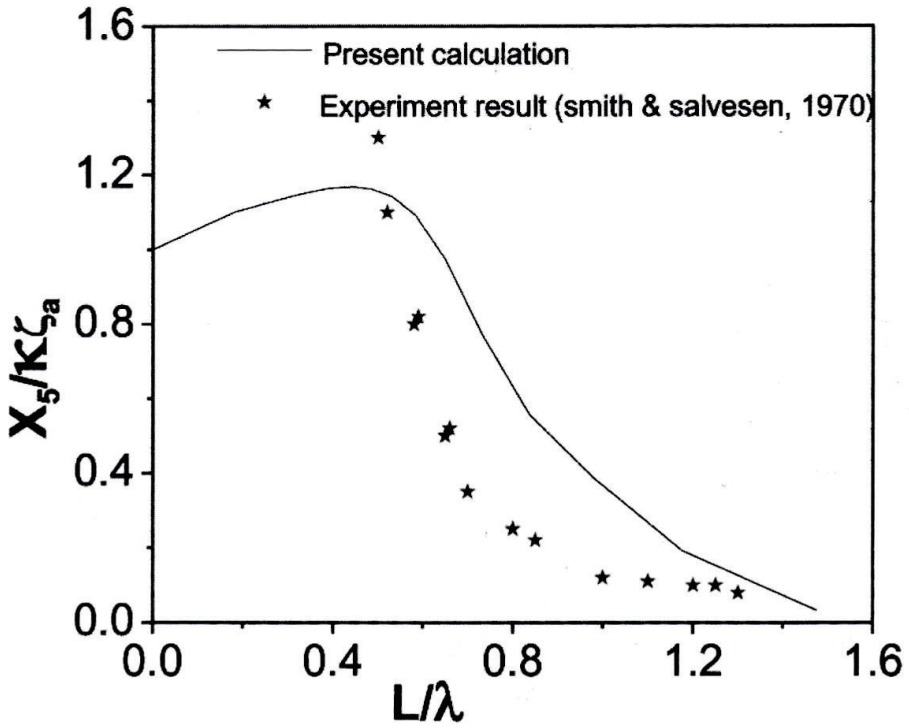

Fig. 16. Heave motion at F_n=0.45 in head sea.

Fig. 16, shows the comparison between the calculated results with experimental results for pitch motion at Fr = 0.45. From this graph it is seen that the non-dimensional pitch motion increases at a certain limit and then decreases gradually with the increase of the value of L/λ and the calculated value is slightly deviates from the experimental value.

value is close to the experimental value except at higher value of λ/L where the wave length is too high.

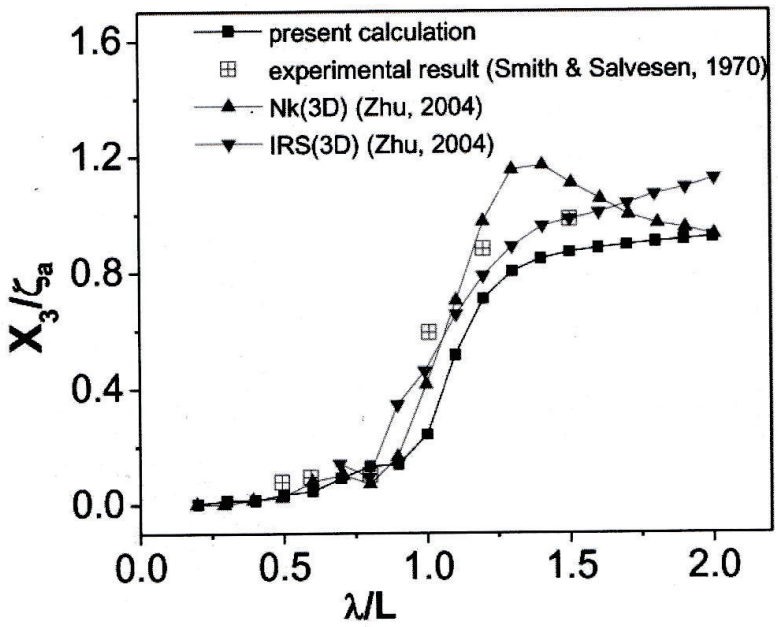

Fig. 18. Heave motion at F_n=0.131 in head sea.

Fig.19, shows the comparison between the calculated results with experimental and numerical results for pitch motion at Fr = 0.131 in head sea. From this graph, it is seen that the non-dimensional pitch motion increases gradually with the increase of the value of λ/L and the calculated value is close to the experimental value except at higher value of λ/L.

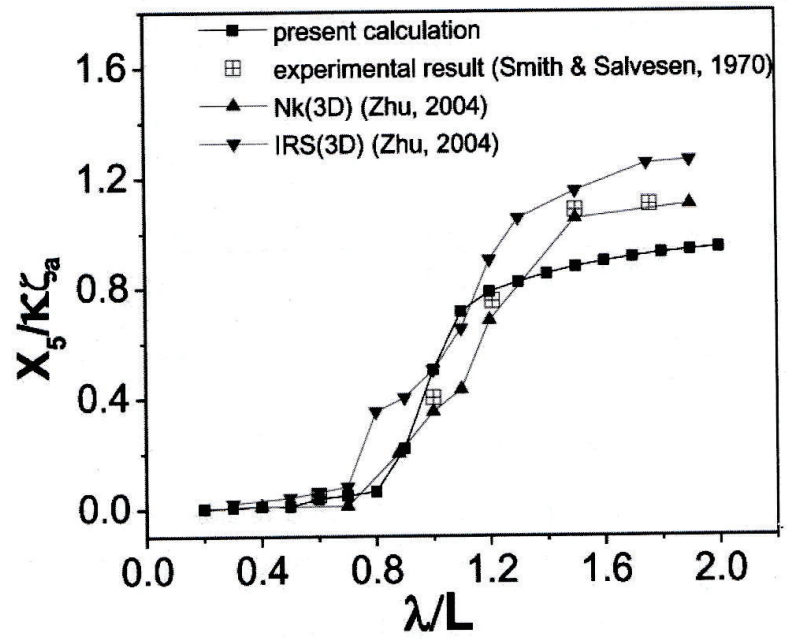

Fig. 19. Peach motion at F_n=0.131 in head sea.

4.2. Case study-2: Bulk Carrier

For the validation of numerical results given by developed computer program, a Bulk Carrier of C_B=0.804 has been taken. The principal particulars of the ship are shown in Table 3. Body plan is shown in Fig. 17. Test results have been taken from Salvesen et al. (1970). The NK(3D) and IRS(3D) data have been taken from Zhu et al. (2004).

Table 3. Model Characteristics of bulk carrier.

LWL	4.5m
LBP	4.5m
Beam	0.793m
Draft	0.285m
LCG	0.144m (forward of amidships)
C_B	0.804

shows the comparison between the calculated results with experimental and other numerical results for heave motion at Fr = 0.131 in head sea. From this graph, it is seen that the non-dimensional heave motion increases gradually with the increase of the value of λ/L and the calculated value is close to the experimental value except at higher value of λ/L where the wave length is too high.

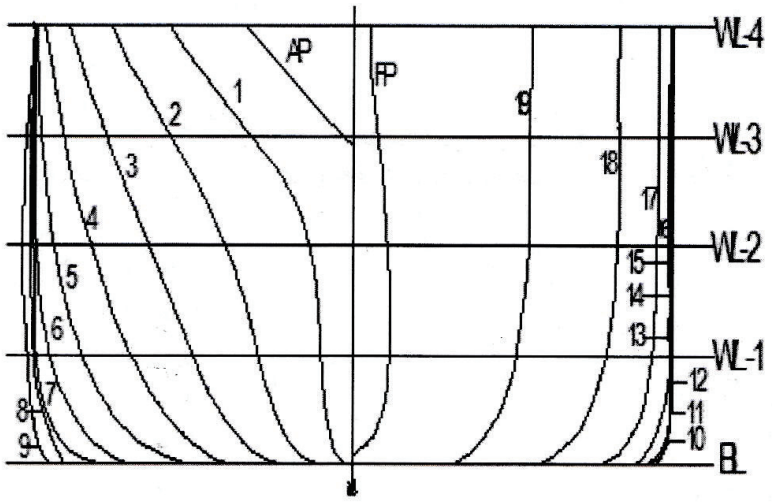

Fig. 17. Body plan of Bulk Carrier.

Fig. 18, shows the comparison between the calculated results with experimental and other numerical results for heave motion at Fr = 0.131 in head sea. From this graph, it is seen that the non-dimensional heave motion increases gradually with the increase of the value of λ/L and the calculated

5.0. Conclusion

From the numerical results calculated by the present computer code, the following conclusion may be drawn:

i. The present numerical result slightly deviates from the experimental results, but overall prediction is quite reasonable.

ii. The program gives reasonable results for a wide range hull form ($C_B = 0.50 \sim 0.80$).

iii. As the experimental work is very costly, so this program might be useful for the prediction of ship motion at initial design stage.

References

Al Amin, M.; Masudur, R. (2013). Prediction of Ship Motion in Regular Head Waves, UG thesis, Bangladesh University of Engineering & Technology, Dhaka, Bangladesh.

Crossland, P.; Wilson, P. A.; Bradburn, J.C. (1993) The Free Decay of Coupled Heave and Pitch Motions of Model Frigates, Transactions of the Royal Institution of Naval Architects.

Gerritsma, I.J.; Beukelman, W. (1967) Analysis of the Modified Strip Theory for Calculation of Ship Motions and Wave Bending Moments, Report No. 96S.

Korvin-Kroukovsky, B.V.; Jacobs, W.R. (1957) Pitching and Heaving Motions in Regular Waves, Transactions, Society of Naval Architecture and Marine Engineers.

Liu, Y. L.; Miao, G.P. (1997) An Engineering Prediction Method for Large Amplitude Motions of Ships in Waves, 6th International Offshore and Polar Engineering Conference, vol. 3.

Ogilvie, E.O.; Tuck, T.F. (1969) A Rational Strip Theory of Ship Motions, University of Michigan, Report No. 013.

Salvesen, N.; Tuck, E.O. (1970) Ship Motion and Ship Loads, Transactions, Society of Naval Architecture and Marine Engineers.

Troesch. (1981) Sway, roll and yaw motion coefficients based on a forward-speed slender-body theory-part 1, Journal of Ship Research.

Wang. (1976) Dynamical Theory of Potential Flows with a Free Surface, A Classical Approach to Strip Theory of Ship Motions, Journal of Ship Research.

Zhu, T.; Xu, L.; Singh, SP.; Ha, TB. (2004) A Comparative Study of 3-D Methods with Experimental Results for Seakeeping Analysis, ICHD Conference, Australia.

Corporate Liquidity and Profitability Patterns of Some Selected Textile Manufacturing Companies Listed with Dhaka Stock Exchange Limited

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Abstract

Liquidity and profitability management are very important issues in the growth and survival of business entity. The ability to hold the trade-off between the two elements concerns the financial managers because either inadequate liquidity or excess liquidity may be damaging to the smooth operations of the organization as well as profitability. The primary aim of this paper is to see empirically the overall liquidity and profitability condition of textile industry and finding out whether there is any significant relationship between liquidity and profitability based on performance ofsome selected manufacturing companies in textile industry listed with Dhaka Stock Exchange Limited. The analysis is based on a sample of five manufacturing companies of textile industry listed with Dhaka Stock Exchange Limited for the period 2009-2012, i.e., fifteen firm years. Correlation analysis and descriptive statistics were used in the analysis. Findings suggest that there is no statistically significant relationship between liquidity and profitability and have a relatively weak liquidity conditions among listed manufacturing companies of textile industry. Besides, the study suggests that the liquidity has low degree of influence on the profitability and there exist an inconsistency in liquidity and profitability management among the selected manufacturing companies.

Keywords: Cash Conversion Cycle (CCC), Receivables Collection Period (RCP), Payables Repayment Period (PRP), Inventory Conversion Period (ICP), Current Ratio (CR), Liquidity Ratio (LR).

1.0. Introduction

Profitability and liquidity can be considered as most high up issues that management of every organization should take these as their major business decision areas. Liquidity refers to the ability of a firm to meet its short-term obligations. The liquidity of an asset means how quickly it can be transformed into cash. When referring to company's liquidity one usually means its ability to meet its current liabilities and is usually measured by different financial ratios. A study of liquidity is of major importance to the financial analysts because of its close relationship with day to day operations of a business (Bhunia at al., 2011). A weak liquidity position poses a threat that business firm faces

when paying their short-term liabilities that ultimately leads to a negative impact to the profitability of the concerned firms.

Profitability is a measure of the amount by which a firm's revenues exceeds its relevant expenses (Niresh et al., 2012). Potential investors are interested in dividends and appreciation in market price of stock. So, they pay more attention on the profitability ratios. Managers on the other hand are interested in measuring the operating performance in terms of profitability. Hence, a low profit margin would suggest ineffective management of resources that company has and also demotivate investors to invest in the company.

The liquidity and profitability goals are contradictory to each other in most of the decisions which the finance manager takes. For example, the firm by following a lenient credit policy may be in a position to increase its sales, but its liquidity may tend to worse. In addition to this, referring to the risk return theory there is a direct relationship between risk and return. Thus, firms with high liquidity may have low risk and then low profitability (Falope et al., 2009). Conversely, firm that has low liquidity may face high risk results to higher return. Consequently, a firm is required to maintain a balance between liquidity and profitability in its day-to-day operations.

Cash is the lifeblood of organizations. An organization having a proper set of liquidity management policies and procedures will improve profits, reduce the risk of corporate failure and significantly improve its chances of survival. It also provides a strategic advantage especially in difficult economic times. Effective liquidity management will enable an organization to derive maximum benefits at minimal cost. As early stated, the survival of a business entity depends extensively on its ability to meet its current obligations as they fall due. This study has shown overall liquidity and profitability condition of textile industry and further shown the degree of relationship between liquidity management and profitability in the selected manufacturing companies listed with Dhaka Stock Exchange Limited (DSE).

2.0. Literature Review

Liquidity and profitability are the two main purposes of Working Capital Management (WCM) and relates to the matching of assets and liabilities movements over time. The general claim in literature centers on liquidity/profitability tradeoff hypothesis which posit that these two financial terms pose conflicting ends to an organization. Hence, a pursuit of one will mean a tradeoff of the other (Mihir et al., 2009). However, the other side of thinking holds that managers can pursue both liquidity and profitability goals as these two objectives have a direct relationship. These two views were observed by Mihir et al. (2009) in their works: liquidity and profitability model of WCM. They

pointed out that there were two distinct schools of thought on this issue. Firstly, that working capital is not a factor of improving profitability and there may be a negative relationship between them. Secondly, as investment in working capital plays a vital role to improve corporate profitability, so unless there is a minimum level of investment in working capital, output and sales level cannot be maintained.

Specifically, Rahman (2011) studied 9 companies in textile industry covering the periods of three years from 2005 to 2008 where he concluded that profitability and working capital position of textiles industry is not satisfactory. The study further revealed that working capital management has a positive impact on Profitability. Sayaduzzaman (2006) in his article on "Working Capital Management: A study on British American Tobacco Bangladesh Company Limited" mentions that the efficiency of working capital management of British American Tobacco Bangladesh Company Ltd. is highly satisfactory due to the positive cash inflows and planned approach in managing the major elements of working capital. He found that working capital management helps to maintain all around efficiency in operations. Another study conducted by Rasul (2012) attempted to analyze liquidity impact on Islamic banks' profitability in Bangladesh during the period 2001 to 2011, where he showed that there is greater dependency of bank's profitability on liquidity as cash & dues from banks to total assets (CDTA), cash & dues from banks to total deposits (CDDEP), investment to total assets (INVSTA) and investment to total deposits (INVSDEP) are depended on independent variables like return on assets (ROA), return on equity (ROE) and return on deposits (ROD) suggested by adjusted R squares profitability variables ROA, ROE and ROD are respectively 17.1%, 4.5% and 24.6% dependent on independent variables. Most recent study conducted by Akter and Mahmud (2014) based on twelve banks in four different sectors (Government banks, Islami banks, multinational banks and private commercial banks) where they tried to figure out how much liquidity (CR) of a bank can explain its profitability (ROA) and conclusion was that there is no significant relationship between CR and ROA.

Shin et al. (1998) studied a sample of 58,985 listed companies in America for a period of twenty years and found a strong negative relationship between the net trade cycle (cash conversion cycle, CCC) as a measure of liquidity and ROA as a measure of corporate profitability. On the basis of this finding, they concluded that managers can increase the value for their shareholders by reducing the cash conversion period to a reasonable minimum. In the same vein, Deloof (2003) also reached the same conclusion when he investigated this relationship on a sample of 1009 large Belgian non-financial firms. A similar study was carried out in Athens by Lazaridis et al. (2006)

studying a sample of 131 listed firms for the period 2001 to 2004. They found a strong negative relationship between profitability and CCC and advised that managers handle correctly the CCC and keep each of its components at optimal level in order to enhance profitability.

Most recent studies have also confirmed the existence of the tradeoff between liquidity and profitability. For instance, Manohar et al. (2010), did a case study of Cement Industry in Tamilnadu and found significant negative relation between the firm's profitability and its liquidity level. Also, Bhunia et al. (2011) studied the importance of liquidity management on profitability and found a significant negative relationship between the profitability Measured by Return on Capital Employed (ROCE) and all the independent variables (CR, LR, ALR, DER, AOI, AOD, and AOC) except for CR which indicated a positive influence on profitability. An explanation to some of these results could be gleaned from the asserting that shortening the CCC releases liquidity and impacts directly on the company's financial position as well as the company's returns.

Contrary to the above-mentioned literature, some researchers found positive and mixed (both positive and negative) association between liquidity and profitability. Narware (2004) in his study of working capital management and profitability of NFL, a fertilizer company found both positive and negative association. Also, Deloof (2003) asserts that, a longer CCC might increase profitability because it leads to higher sale.

3.0. Objectives of the Study

The purpose of this study is to examine the liquidity and the profitability pattern of textile industry and the relationship between them in order to predict whether liquidity predicts profitability. The study further attempted to generate evidence on whether firm's profitability measured by ROE and ROA depend on liquidity variables is significant or not. Specifically, the study tested empirically the association between CR, LQ and TCR on the one hand with ROE and ROA on the other hand. So, the objectives are as follows:

i. Examine the liquidity and profitability condition of textile industry and to determine whether profitability and liquidity variables show satisfactory liquidity and profitability patterns of textile industry.

ii. To identify the nature and the extent of the relationship between liquidity and profitability variables through correlation coefficient.

iii. To provide appropriate policy recommendations for the managers of the concerned companies.

iv. To suggest some measures to enhance the liquidity and profitability condition of listed manufacturing companies.

4.0. Methodology

4.1. Data Source

The present study used secondary data for the analysis. Data were extracted from the annual financial statements of the sampled companies for three years period, 2009-10, 2010-11 and 2011-12, making a total of 15 firms' years observations. In addition to this, articles from academic journals and relevant textbooks were also used.

4.2. Sampling and Research Design

The population of this study is confined to the textile sector consists of 32 firms listed with the DSE. For the purpose of this paper, the study has selected a sample of five (5) manufacturing companies out of 32 companies in textile sector listed with DSE Limited on random basis. Selected five companies listed with DSE are Malek Spinning Mills Ltd; Square Textiles Ltd; Makson Spinning Ltd; Saiham Cotton Ltd and Generation Next Ltd.

Both descriptive statistic and Pearson's Correlation analysis were applied for the data analysis. The choice of variable used in this study was influenced by previous studies. The dependent variable in this study is corporate profitability which is measured by the ROE and ROA. For the independent variables, the paper adopts traditional liquidity variables namely CR, LR and TCR. On the other hand, different efficiency variables like RCP, PRP, CCC and Operating Cash Flows Ratio (OCFR) have also been used for descriptive analysis to find out whether there is any relationship between these independent variables with ROE and ROA as dependent variables.

5.0. Liquidity

Liquidity is defined as the ability of a firm to meet its financial obligations as they fall due. The balance sheet (defined as "a structured statement of assets and liabilities") measures these resources and claims against these resources, describes the liquidity of the firm. Different liquidity measures like CR, acid test ratio, quick ratio, net working capital, operating cash flow ratio or cash ratio, working capital ratio, CCC as a combination of three activity variables: debtor collection period, creditor payment period, inventory conversion period are most often used in different research papers on corporate profitability and liquidity to measure the operating efficiency of the company. Among these variables following are used as liquidity variable for this paper:

5.1. CCC

The CCC is used as a comprehensive measure of working capital as it shows the time lag

between expenditure for the purchase of raw materials and the collection of sales of finished goods (Padachi, 2006). The day to day management of firm's short term assets and liabilities plays an important role in the success of the firm. Firms with long term prospects and healthy bottom lines do not remain solvent without good liquidity management. The CCC is calculated thus:

CCC = (Days of Sale Outstanding + No. of Day in Inventories - Days of Payable Outstanding)

In the formula, above, the three variables to which CCC is dependent are defined as follows:

- Days of Sales Outstanding/Receivables Collection Period (RCP) = $\frac{Accounts\ Receivables}{\frac{Sales}{365}}$

This ratio shows number of days it takes an organization to recover its credit sales. Shorter period is better for the organization. Account receivable with a longer recovery period possesses occurrence of bad debt for the company and also affects liquidity in the short run.

- Days of Sales in Inventory/ Inventory Conversion Period (ICP) = $\frac{Inventory}{\frac{COGS}{365}}$

The inventory conversion period represents the number of days inventory is held before being sold and replaced. Shorter inventory conversion period is better because the faster we will convert our inventory into sales, there will be less chance of obsolescence and paying of over-stocking cost.

- Days of Payables Outstanding/Payable Repayment Period (PRP) = $\frac{AccountsPayable}{\frac{COGS}{365}}$

This ratio shows the number of days the company is required to settle its short-term obligations. The longer the period the better for the company, as it gives the company leverage to recover it receivables.

Together with these variables, CCC is likely to be negative as well as positive. A positive result indicates the number of days a company must borrow or tie up capital while awaiting payment from a customer. A negative result indicates the number of days a company has received cash from sales before it must pay its suppliers (Drever, M, & Hutchinson, P, 2007). Of course, the ultimate goal is having low CCC, if possible negative, because the shorter the CCC, the more efficient the company is in managing its cash flow.

5.3. OCFR or TCR

An important measure of the overall financial health of a company is the level of cash it

generates through normal business operations. As a company operates, cash flows into the business as income and out as expenses. These activities, known as cash flows, are at the heart of all businesses and determine the ability of the company to generate profits and continue its operations. The formula for the operating cash flow ratio can be written as:

$$OCFR = \frac{Cash\ Flow\ from\ Operations}{Current\ Liabilities}$$

5.4. CR or QR

The CR is a financial ratio that shows the proportion of current assets to current liabilities. The CR is used as an indicator of a company's liquidity. In other words, a large amount of current assets in relationship to a small amount of current liabilities provides some assurance that the obligations coming due will be paid.

5.5. LR

LR measures the ability of a company to use its near cash or quick assets to extinguish or retire its current liabilities immediately. Quick assets include those current assets that presumably can be quickly converted to cash at close to their book values. It excludes inventory.

$$LR = \frac{Cash\ and\ Cash\ equivalents + Marketable\ Securities + Accounts\ Receivable}{Current\ Liabilities}$$

6.0. Corporate Profitability

Profitability is the ability to make profit from all the business activities of an organization, company, firm, or an enterprise. It measures management efficiency in the use of organizational resources in adding value to the business. Profit is the ultimate 'output' of a company, and it will have no future if it fails to make sufficient profits. Different profitability measures like ROCE, earnings before interest and taxes (EBIT), earning before tax (EBT), gross profit margin, net profit margin, ROA, ROE, return on investment (ROI), return on net assets (RONA) are most often used in different research papers on corporate profitability and liquidity to measure the operating efficiency of the company. Among these profitability measures we have used following two measures because these two effectively relates a profit figure (from the Profit and Loss Account) to a resources figure (from the Balance Sheet).

6.1. ROE

Common or ordinary shareholders are entitled to the residue profits. The rate of dividend is not fixed; the earnings may be distributed to shareholders or retained in the business. Nevertheless, the net profit after tax represents their return. A return on shareholder's equity is calculated to see the

profitability of owners' investment. The shareholders' equity or net worth will include paid up share capital, share premium and reserves and surplus less accumulated losses. Net worth can also be found by subtracting total liabilities from the total assets. The ROE is net profit after taxes divided by shareholders' equity which is given by net worth.

$$\text{ROE} = \frac{Profit\ after\ tax}{Net\ Worth\ (equity)}$$

6.2. ROA

ROA expresses the net income earned by a company as a percentage of the total assets available for use by that company. ROA measures management's ability to earn a return on the firm's resources (assets). The income amount used in this computation is income before the deduction of interest expense, since interest is the return to creditors for the resources that they provide to the firm. The resulting adjusted income amount is thereby the income before any distribution to those who provided funds to the company. ROA is computed by dividing net income plus interest expense by the company's average investment in asset during the year.

$$\text{ROA} = \frac{Net\ Income\ After\ Tax + Interest\ Expense}{Average\ total\ Asset\ during\ the\ year}$$

7.0. Data Analysis and Discussion on Findings

The results and findings of the study are based on the empirical results that begins by looking at the-

- ❖ Descriptive statistics
- ❖ Pearson's Correlation.

7.1. Descriptive Statistics Analysis

A sample of five manufacturing companies for the year 2009-2012 in the textile sector quoted on the DSE was selected and used to determine the liquidity and profitability performances and to determine relationship between liquidity management and corporate profitability. The combined descriptive statistics for all the companies show (Table 1& 2) a relatively weak liquidity management. The average debtor's collection period of the companies (152 days) is larger than the average payment period (48 days). Account receivables with longer recoverable period possess the risk of bad debt for the company and also affect liquidity in the short run. Standard deviation for the Debtor Collection Period is also high (51.05). That means all the companies operating within the industry are not in the same track. Debtor Collection Period (DCP) for the companies significantly differs from each other that are also same for the Creditor Payment Period (CPP). ICP for the

companies (182 days) indicates inefficiencies also by standard deviation of 79.31 represents inconsistencies among companies in dealing with the inventory. That means companies on an average need 182 days to hold inventory before being sold and replaced. Actually, these activity ratios help us to predict companies' operating efficiency and effectiveness in dealing with its day to day operation. But together these activity ratios help us to draw conclusion about companies' liquidity in the form of CCC which in this case indicates a value of 286 days mean companies on an average spend 286 days to regain its investment in raw material.

Table 1. Descriptive statistics of selected five companies.

Particulars	Mean μ (AM)	Standard Deviation (α)
Receivables Collection Period (RCP)	152	51.05
Payable Repayment Period (PRP)	47.8	54.55
Cash Conversion Cycle (CCC)	286	151.57
Inventory Conversion period (ICP)	181.8	79.31
Operating Cash Flow Ratio (OCF Ratio)	2.44%	19.42%
Liquid Ratio (LR)	1.19	0.14
Current Ratio (CR)	1.896	0.54
Return on Assets (ROA)	7.55%	4.3%
Return on Equity (ROE)	9.04%	5.5%

Source: Figures are calculated using the information provided in the annual report of the respective companies

The companies could settle only 2.44%of their current liability from their operating activities with high standard deviation (19.42%) which is not desirable. They have an average time lag of 286 to turn their investment in raw material to cash as indicated by CCC. This period seems too long and could have a negative impact on liquidity. Normally higher the debtors turnover ratio better it is. Higher turnover signifies speedy and effective collection. On the other hand, lower turnover indicates sluggish and inefficient collection leading to the doubts that receivables might contain significant doubtful debts. For the above case RCP is not in the satisfactory level for the companies on an average because 152 days in RCP indicates that companies within the industry are not efficient in managing their debtor. If we see PRP, companies have to pay their creditor within 48 days of purchase indicating huge mismatch between RCP and PRP. ICP also indicates inefficient performance and liquidity crisis in the overall industry. CR of 1.90 indicates companies have

availability of current assets that is approximately equal to double of current liabilities. Although it may be considered as satisfactory but liquid ratio score of 1.19 dictates companies' current assets consist significant portion of inventory and prepaid expenses that cannot be considered as most liquid assets create liquidity crisis in the company. Also, standard deviation for LR (0.14) and CR (0.54) indicates deviation in the liquidity management among the companies. Again, significant deviation in different variables indicates some form of inconsistency among companies operating within the industry. So overall, liquidity ratio for our concerned industry is not satisfactory.

On an average, all the companies ROA are 7.55% which is quite low. Common rule is that higher the ROA the better it is, because the company is earning more money on its assets. A low ROA compared with the industry average indicates inefficient use of company's assets. In case of ROE; higher values are generally favorable, meaning that the company is efficient in generating income by using shareholder wealth. Here average ROE is quite low (9.04%). One thing should be mentioned that the deviation in ROE (5.5%) and ROA (4.3%) among different companies in the industry is also significant meaning that all the firms in the industry are not able to get profit. However, relying solely on ROE for investment decisions is not safe. It can be artificially influenced by the management.

Table 2. Summary of Companies Liquidity Management and Profitability (Average for the year 2009-2012).

Ratios Companies	RCP	PRP	ICP	CCC	CR	LR	OCF Ratio	ROA	ROE
Malek Spinning	112 days	17 days	195 days	290 days	2.54	1.13	-11.30%	2.18%	0.3%
Square Textile	136 days	100 days	114 days	149 days	1.95	1.05	34.09%	10.88%	15.57%
Makson Spinning	228 days	2 days	312 days	538 days	2.12	1.18	-15.24%	12.89%	9.27%
Saiham Cotton	178 days	114 days	127 days	191 days	1.79	1.16	03.98%	6.78%	10.06%
Generation Next	106 days	6 days	161 days	262 days	1.08	1.43	0.65%	5%	10%

Source: Figures are calculated using the information provided in the annual report of the respective companies.

If we see Table 2, CCC is lower (149 days) for Square Textile among five (5) companies that means square is most efficient in collecting their invested amount in the production process back to them among concerned companies. Again, CR and LR for Square Textile is also satisfactory matching with the standard for CR (2:1) and LR (1:1). The thing is that CR and LR should not be more or less; rather it should be matched with standard in order to avoid both liquidity crises and excess liquidity. In case of OCF ratio, square also leads among the companies because it is able to repay 34.09% of its current liabilities from its operating cash flows also highest among the companies. ROA is highest for Makson Spinning (12.89%) followed by Square Textile (10.88%) that means both companies effectively manage their liquidity and profitability within industry. ROE is highest for Square Textile (15.57%) followed by Saiham Cotton (10.6%) indicating effective liquidity profitability tradeoff for Square Textile.

7.2. Pearson's Correlation Analysis

7.2.1. Research Model:

Pearson correlation analysis was carried out to identify the trade-off between liquidity and profitability. Here, liquidity variables are independent and profitability variables are dependent. It can be represented as follows;

$$P = f(L)$$

Which shows profitability is the function of liquidity.

Where, P = Profitability; L = Liquidity

In the present study, profitability is measured by using two ratios namely ROA and ROE as suggested by J. Aloy Niresh(2011) and Monika Bolek(2013), whereas liquidity is measured by using CR, TCR and LR. Further some of the liquidity variables discussed earlier like DCP, CPP, ICP and CCC are also used.

7.2.2. Hypotheses of the Study

The following hypotheses were formulated for the study.

H_0: Liquidity Management and Profitability are not significantly correlated.

H_1: Liquidity Management and Profitability are significantly correlated.

8.0. Result and Analysis

Through conducting correlation analysis this study was able to identify the degree of association among the variables. Table 3 indicates the relationship between the various independent and dependent variables used in the study. As it is observed in the table, the correlation values were found to be mixed (both positive and negative) between the independent and dependent variables.

The ' r' values were found to be negative between ROE & liquidity variables as measured by CR, LR and TCR consisting the correlation values of -0.52, -0.06 and -0.90. Correlation between ROE and CR is negative because as company invests more in the current asset its ability to invest in the long-term asset decreases that has an impact on profitability through lowering the investment in productive activities of business. Again, correlation

Table 3. Correlation Matrix.

Variables	CR	LR	TCR	RCP	PRP	ICP	CCC	ROE	ROA
CR	1.0000								
p-value	-								
LR	-0.7878	1.0000							
p-value	(0.9869)	-							
TCR	0.7078	-0.2549	1.0000						
p-value	(0.9992)	(1.000)	-						
RCP	0.2305	-0.2719	-0.3737	1.0000					
p-value	(1.000)	(1.000)	(1.000)	-					
PRP	-0.0016	-0.5455	-0.3271	0.0503	1.0000				
p-value	(1.0000)	(1.0000)	(1.0000)	(1.0000)	-				
ICP	0.3346	0.0893	0.1472	0.6165	-0.7325	1.0000			
p-value	(1.000)	(1.000)	(1.000)	(1.000)	(0.9981)	-			
CCC	0.2506	0.1558	0.0688	0.6403	-0.7288	0.9953*	1.0000		
p-value	(1.000)	(1.000)	(1.000)	(1.000)	(0.9983)	(0.0137)	-		
ROE	-0.5195	-0.0611	-0.9035	0.2181	0.5223	-0.3461	-0.2973	1.000	
p-value	1.000	1.000	0.7224	1.000	1.000	1.000	1.000	-	
ROA	0.0086	-0.3163	-0.6579	0.7490	0.1585	0.3582	0.3805	0.6973	1.000
p-value	1.000	1.000	0.9999	0.9965	1.000	1.000	1.000	.9995	-

Correlation is significant at the 0.05 level (2-tailed)

Source: Figures are calculated using the information provided in the annual report of the respective companies

between ROE and LR is justified to be negative for the same reasons. But RO Eand TCR is significantly correlated as negative because TCR consists of only more liquid asset such as cash and cash equivalent and current liabilities. As company are holding more cash it does not invest neither in long term asset nor in other current assets rather than cash and cash equivalent, so it creates negative impact on profitability.

Now if we see correlation between profitability variable ROA and liquidity variable as measured by CR, LR and TCR we see 'r' value are 0.0086, -0.32 and -0.66 respectively. The correlation between ROA and CR is insignificantly positive meaning that there is no relation or insignificant relationship between them. Again, correlation between ROA and LR is -0.32 meaning that as company increases its investment in more liquid asset its ability to invest in the productive long term asset decreases as investment decreases. So it is negatively correlated following insignificant relation. Finally, ROA and TCR is correlated as negative indicated by the figure -0.66 meaning that as company holds more cash in their daily operation its ability to invest in the profitable opportunity decreases.

Besides the descriptive analysis above, it can be deduced by correlation that there exist positive relationship between the value of ROA and the company's RCP, PRP, ICP and CCC (Table 3). Higher RCP & CCC mean that companies have flexible credit policy that encourages its customers to purchase their product comparatively higher price which ensures more profitability in the company's financial statement. That is way result shows positive correlation. PRP is positively correlated with ROA (0.16), meaning that fund is used in the investment purpose rather as a payment to creditors. ROE has positive relationship with RCP (0.22) and PRP (0.52) for the same reasons as

ROA is positively correlated with RCP and PRP. But ROE has negative correlation with ICP (-0.35) because companies do not have available finished good to ensure sale at the same time profitability. Finally, it is apparent from the table that, without ICP and CCC correlation values were found to be statistically insignificant between all the independent and dependent variables used in the study as indicated by the probability (P) values.

8.1 Hypothesis Testing

Table 4. Hypotheses testing result.

No.	Hypotheses	Results	Tools
H_0	Liquidity Management and Profitability are not significantly correlated	Accepted	Correlation
H_1	Liquidity Management and Profitability are significantly correlated.	Rejected	Correlation

8.2. Overall Findings and Recommendations

This study examined the trade-off between liquidity and profitability in the manufacturing sector of Bangladesh. The major findings with recommendations of the study are summarized below:

i. Although pair correlation among most of the variables does not show statistically significant relationship between liquidity and profitability, it can be said that changes in the liquidity position of selected firms exerts moderate or in some extent low level of changes in the profitability. It is suggested that further research can be conducted on the same topic with all the companies in the same sector as well as with different sectors and extending the years of the sample.

ii. The 'r' values were found to be negative between ROA & liquidity variables as measured by TCR and LR, consisting the correlation values of -0.66 and -0.52 but positive between ROA and CR consisting the correlation values of + 0.009. Again, 'r' values were found to be negative between ROE & liquidity variable as measured by CR, LR and TCR, consisting the correlation values -0.52, -0.06 and -0.90. So, the correlation values were found to be mixed (both positive and negative) between the independent and dependent variables although negative correlation is dominating.

iii. Average DCP 152 days compared with CPP 48 days, pointing poor level of management in the operation of the business because companies collect amount due to their debtors within 152 days of sale whereas pay amount due to creditors within 48 days of purchase indicating a mismatch between collection and payment period reflected in CCC of 286 days. It should therefore be the burning desire to make prudent liquidity decision, which is part of working capital financing in order to remain profitable and competitive.

iv. A cash ratio (operating cash flow ratio) of 1.00 and above means that the business will be able to pay all its current liabilities in immediate short term. Here, the value is 1.7, which is quite satisfactory (Table 1).

v. As average TCR, LR and CR for the industry are in a satisfactory position (Table 1). Better liquidity position of the companies to some extent makes it difficult for the companies to enjoy greater profitability. So, the candid recommendation of this paper is that overall state of liquidity should be made optimal so as to have a favorable impact on the profitability of the firms and also, reduction of cash conversion period which has the potential to improve profitability by utilizing the fund that may be increased through gearing up CCC.

vi. This paper has empirically established that a number of some key liquidity variables affect corporate profitability among selected firms in textile sector of Bangladesh. These include ICP, CCP, CR, LR and TCR. These factors will either positively affect profitability depending on how effectively and efficiently firm's liquidity management has been piloted

by corporate finance managers. So, an efficient tradeoff between liquidity and profitability should be maintained so that utility from both liquidity and profitability are in the optimum level.

vii. A cautious attention has to be paid as far as the profitability is concerned. The coefficients of variation values of profitability measures (0.58 &0.61) were found to be higher than those of liquidity measures. Thus, reveal the high volatility of profitability measures used in the study. Therefore, manufacturing firms in Bangladesh should focus on reducing the amount of volatility associated with the profitability measures.

viii. Selected manufacturing companies in textile industry of Bangladesh should concentrate on maximizing profit while preserving liquidity. Policy makers should have the interest in promoting efficient management of liquid assets to promote profitability.

9.0 Conclusion

Present declining states of many manufacturing companies in Bangladesh confirm inefficiency and ineptitude in the management of liquid assets as suggested by different liquidity variables. Although ROA and ROE value of 7.55 % and 9.04% respectively indicate relatively medium level of profitability in the textile industry, it can be improved through better managing of liquidity through focusing some liquidity indicators. Hence, it becomes important to think about proper liquidity and profitability management of the country's manufacturing as well as textile industry. As liquidity and profitability both contradicts with each other, a proper tradeoff between this two is necessary to ensure proper liquidity condition which at the same time ensure profitability in the organization as many studies confirm the existence of the tradeoff between liquidity and profitability. For instance, the finding of our study is also similar to that of Narware (2004), about working capital management and profitability of NFL, a fertilizer company that found both positive and negative association. Furthermore, this study is also similar to that of Ashok kumar and Manohar (2010) who did a case study of Cement Industry in Tamilnadu and found significant negative relation between the firm's profitability and its liquidity level.

The cardinality of liquidity management in any organization cannot be over emphasized. This is because either inadequate liquidity or excess liquidity may be injurious to the smooth operations of the organization. This paper was set out to explore the seemingly controversial profitability/liquidity trade off theory. Our empirical investigation using the pair correlation analysis reveals that liquidity ratio-measures like CR, LR and TCR have a negative relationship with profitability measured by ROE. Positive relation was found between liquidity measured by CR, DCP,

ICP, CPP and profitability measured by ROA. It is worthy to mention here that the negative direction reveals with respect to CCC and ROE is very informative of the fact that the CCC needs to be shortened to engender increase in profitability.

References

Akter, k.; Mahmud, k. (2014) Liquidity-Profitability Relationship in Bangladesh Banking Industry, International Journal of Empirical Finance: Vol. 2, pp 143-151.

Bhunia, A.; Khan, I.U. (2011) Liquidity Management Efficiency of Indian Steal Companies: A Case Study, Far East Journal of Psychology and Business: Volume 3 Number 3.

Bhunia, A.; Brahma, S.B. (2011) Importance of Liquidity Management on Profitability", Asian Journal of Business Management, Volume 3 Number 2.

Deloof, M. (2003) Does Working Capital Management affects Profitability of Belgian Firms? Journal of Business Finance & Accounting, Vol.30 No. 3 & 4.

Niresh, J.A. (2011) Trade-Off Between Liquidity & Profitability: A Study Of Selected Manufacturing Firms In Sri Lanka, Researchers World -Journal of Arts, Science & Commerce-ISSN 2229-4686 ,ISSN 2231-4172.

Manohar, V.; Ashokkumar, N. (2010) Liquidity Vs. Profitability-A Case Study on Inventory Management of Cement Industry in Tamilnadu, Advances in Management.

Mihir D. and Rani R. (2009) A Liquidity-Profitability Trade-Off Model for Working Capital, Management Social Science Research Network

Mathuva, D. (2009) The influence of working capital management components on corporate profitability: a survey on Kenyan listed firms. Research Journal of Business Management, Vol. 3, pp 1-11.

Bolek, M. (2013) Profitability as a Liquidity and Risk Function Basing on the New Connect Market in Poland, European Scientific Journal October 2013 edition vol.9, No.28 ISSN: 1857 – 7881 e - ISSN 1857- 7431

Narware, P.C. (2004) Working capital and profitability-an empirical analysis, Management Accountant-Calcutta, Vol. 39, pp 491-493.

Nobanee, H.; Al Hajjar, M. (2009) A note on working capital management and corporate profitability of Japanese firms, Available at SSRN 1433243.

Falope, O.I.; Ajilore, O.T. (2009) Working Capital Management and Corporate Profitability: Evidence from Panel Data Analysis of Selected Quoted Companies in Nigeria, Research Journal of Business Management, Vol. 3, Issue:3.

Padachi, K. (2006) Trends in working capital management and its impact on firms' performance: an analysis of Mauritian small manufacturing firms, International Review of business research papers, Vol. 2, pp 45-58.

Rahman M.M. (2011) Working Capital Management and Profitability: A Study on Textiles Industry, ASA University Review, Vol. 5 No. 1

Rasul, L M. (2012) Impact of Liquidity on Islamic Banks' Profitability: Evidence from Bangladesh AUDOE, Vol. 9, pp 23-36

Shin, H.H.; L. Soenen (1998) Efficiency of working capital and corporate profitability, Finance Pract. Educ., Vol. 8, pp 37-45.

Syaduzzaman, M. (2006) Working Capital Management: A Study on British American Tobacco Bangladesh Company Limited, The Journal of Nepalese Business Studies, Vol. 3, pp 78-84.

Teruel, P.J.G.; P.M. Solano (2005) Effects of working capital management on SME profitability, Working Papers Series. Dept. Organizacion de Empresas y Finanzas, Facultad de Economia y Empresa, Universidad de Murcia, Campus Espinardo, Spain

Lazaridis, J.; D. Tryfonidis (2006) Relationship between working capital management and profitability of listed companies in the Athens stock exchange, J. Financial Manage. Anal., Vol. 19, pp 26-35.

Study on the Spirality and Shrinkage of Weft Knitted Fabric: An Impact of Tumble Drying and Line drying

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Abstract

Spirality and shrinkage are the most common problems for knitted fabric due to their asymmetrical loop formation. Spirality is a dimensional distortion in circular knitted fabrics and has an obvious influence on the aesthetic and functional performance. Shrinkage is the process in which a fabric becomes smaller than its original size while washing and drying. This study explicitly determined the theoretically approach of the causes and remedies of spirality and shrinkage and the main difference between tumble and line drying. The tumble drying was more responsible for shrinkage contrary to the line drying. Among the samples the full feeder lycra single jersey shows the best result in shrinkage and spirality and double pique shows the worst result due to more tuck loop in its structure. Finally, this study illustrated that line drying was the best for using the garments with assured quality and dimensional stability.

Keywords: Line Drying, Tumble Drying, Spirality, Shrinkage, Weft Knitted Fabric etc.

1.0. Introduction

The ever-increasing demand of knitted apparels has attracted attention in global niche market. Knitted fabrics are used in manufacturing of fashion garments and even it has the potential in the formal wear segments also (Afroz, 2012). The dimensional stability of knitted fabrics is an important factor of the knitting industry (Hossain, 2012). On the knitted fabric, it is necessary that the wale be perpendicular to the course, but Weft knitted fabrics tend to undergo certain dimensional change that causes distortion in which there is a tendency of the knitted loops to bend over, causing the wales to be at diagonal in-stead of perpendicular to the courses. However, the wales are not always perpendicular to the course and skew to the right or left, forming a spirality angle which creates a serious problem, especially in the apparel industry (Afroz, 2012). It is well known that weft knitted fabrics tend to undergo large changes in dimensions such as spirality and shrinkage. This often directed to distortion upon repeated washing. A large number of factors are responsible for

causing these dimensional changes in weft knitted fabric structures; these are all associated with the yarn twist and hardness, knitting, finishing and making-up of the knitted fabrics. The residual torque in the component yarn caused due to bending and twisting is the most important phenomenon contributing to spirality. The residual torque is shown by its twist liveliness. Hence the greater the twist liveliness, the greater is the spirality. Twist liveliness of yarn is affected by the twist factor or twist multiple. Besides the torque, spirality is also governed by fibre parameters, cross-section, yarn formation system, yarn geometry, knit structure and fabric finishing. Machine parameters do contribute to spirality. For instance, with multi-feeder circular knitting machines, course inclination will be more, thus exhibit spirality. It affects the garments as the displacement of the side seams and this causes an important quality problem. This problem is prevented during the finishing and dyeing processes by different methods, however these preventions are temporary and after washing processes, on the clothes the displacement of side seam is occurred. Spirality depends on feed density, machine cut, and loop shape, but the magnitude of spirality can be offset by the selection of yarn twist direction. In addition, reduction in yam "torque" can only partially reduce fabric spirality, but the use of plied yams and plaiting techniques may completely eliminate it (Araujo, 1989). It is also a fact that consumers are becoming increasingly concerned and aware of fabric quality and expect higher standards of performance than ever before, even after a number of wash and dry cycles. A tumble dryer is a powered household appliance that is used to remove moisture from a load of clothing and other textiles, usually shortly after they are washed in a washing machine. Clothes may also be dried by natural evaporation and, if available, sunlight on an outdoor or indoor clothes line or clothes horse. Many dryers consist of a rotating drum called a "tumbler" through which heated air is circulated to evaporate the moisture, while the tumbler is rotated to maintain air space between the articles. Using these machines may cause clothes to shrink or become less soft (due to loss of short soft fibers/lint). A simpler non-rotating machine called a "drying cabinet" may be used for delicate fabrics and other items not suitable for a tumble dryer. A clothes line or washing line is any type of rope, cord, or twine that has been stretched between two points (e.g. two sticks) outside or indoors, above the level of the ground. Clothing that has recently been washed is hung along the line to dry, using clothes pegs or clothespins. Washing lines are attached either from a post or a wall, and are frequently located in back gardens, or on balconies (Wikipedia, 2016). The dimensional stability of knitted fabrics is an important area of the knitted industry. Fabric shrinkage is the ultimate problem if the dimensional stability of the knitted fabrics is not properly taken care. There are various factors influencing the dimensional stability as well as the shrinkage of the knitted fabrics.

Though the factors such as fibre characteristics, stitch length, machine gauge, yarn twist, knitting tension causes dimensional variations, the factor mostly responsible is relaxation of internal stress and the swelling of the yarn (Anbumani, 2007). Knitted fabrics often never fully recover from these strains and have to withstand the considerable wear and tear due to everyday use and laundering processes. To meet the demands of an increasing market, knitters have called for increased research into the dimensional stability of knitted cotton goods. With the rising popularity of cotton, greater demands in terms of quality were required as the customer became more aware of the negative properties, e.g. shrinkage from laundering (Munsi, 1993). The properties of cotton are limited due to its natural origins, therefore, if the consumer continues to expect higher quality and dimensionally stable garments, the actual construction of the fabric needs to be investigated. Another problem manufacturers have to contend with is the factors affecting variability in customer washing processes (Thomas, 1994). When the cotton yarn and the lycra yarn are knitted parallel or side-by-side in every course, with the lycra yarn always kept on one side of the cotton yarn, the method is classified as "full plating or full feeder". When the Lycra is placed in alternating courses, the method is classified as "half plating or half feeder" (Sadek, 2012). The effect of lycra fibre on the extension-at-peak load, immediate recovery, delayed recovery, permanent set and resiliency of cotton-lycra blended knitted fabric. It was observed that the immediate recovery, extension and resiliency of lycra fabric are higher than 100% cotton fabric (Mukhopadhyay). Washing and drying technique are the most important task in weft knitted fabric finishing. It requires an in-depth knowledge of the geometry, stability and forces held within the fabric. The main aim of this work was to systematically investigate the effect of the washing and drying variables on the dimensional stability and distortion of knitted fabrics. The work demonstrated that changes occurring after laundering were largely due to alterations in the loop shape, rather than loop length. The fabrics had taken up their fully relaxed state and appropriate conditions for laundering. The major aims of this study are to find out dimensional changes of weft knitted fabrics due to different washing techniques.

2.0. Materials and Method

For this study seven types of fabric have been produced from the same yarn of count and same lot. Yarn from the same lot is placed in the creels carefully for knitting with single jersey machine specification given (Table 1). The fabrics were produced by using the parameters (Table 2) and the yarn specification has been mentioned (Table 3). After knitting 2kg of each seven samples were taken and then swung to make rope form for scouring, bleaching and dyeing. The fabric was pre-treated and dyed in Fong's sample dyeing machine (Actual capacity up to 18kg). The name of

chemicals and dyes were used in scouring, bleaching and dyeing mentioned separately (Table 4). Then washed at 40°C for 18 min. The whole washing was done by the ISO: 6330 method. Then the

Table 1. Knitting machine specification.

Brand name of machine	Jiung Long
Origin of machine	Taiwan
Model	JSL
Diameter of machine	26"
Number of feeder	60
Number of needle	1960T
Machine gauge	E-24G
Machine speed	23 RPM

Table 2. Description of different fabric with yarn.

Fabric Type	Combed Yarn count (Ne)	GSM	Stitch length (mm)
Plain S/J	30/1	115	2.80
Plain S/J (Lycra 4%: full feeder)	30/1 with 40D Lycra	220	2.55
Plain S/J (Lycra 2%: half feeder)	30/1 with 40D Lycra	200	2.62
Single lacoste	30/1	140	2.74
Double lacoste	30/1	160	2.65
Single pique	30/1	120	2.75
Double pique	30/1	155	2.70

Table 3. Yarn specification Ne 30/1 combed yarn used in the fabric manufacturing process.

Properties	Test results
Twist factor	3.60
Tenacity (mN/tex)	169
Elongation at break (%)	4.2
Unevenness (U%)	10
Thick place/1000m (+50%)	23
Thin place/1000m (-50%)	1
Neps/1000m (200%)	40

Table 4. Chemicals and dyes were used in scouring, bleaching and dyeing.

Chemicals for scouring and bleaching		Chemicals and dyes for dyeing	
Name	Amount	Name	Amount
Wetting agent	1 gm/L	Glauber salt	40 gm/L
Sequestering agent	1 gm/L	Soda ash	10 gm/L
Detergent	1 gm/L	Acetic acid	1 gm/L
Caustic soda	5 gm/L	JintexalateEco SQ- 1175CA (R/D*)	1 gm/L
Hydrogen per oxide	6 gm/L	Jinlev-CL 225 (R/D*)	1 gm/L
Stabilizer	2 gm/L	pH	8.5
Temperature	90°C	Temperature	Up to 110°C
Time	1 hour	Time	1.5 hour

samples were dried with line and tumble system for 4 hours at room temperature and 30 min at 60 °C temperature respectively (Anand, 2002). After that the samples were fully conditioned for 48 hours in a standard atmosphere of 20 ± 2 °C temperature and 65 ± 2% relative humidity. Then those samples were tested to measure the dimensional stability or shrinkage and spirality percentage by ISO:16322 method. Thus, all the experimental data has been derived and discussed consecutively.

3.0. Measurement of Shrinkage and Spirality

3.1. Materials

Template, Scissor, sewing machine, washing machine, washing Chemicals, dryer, tape.

3.2. Procedure

For calculating the shrinkage percentage samples were cut into 20 cm × 20 cm, then a rectangular area was marked 15 cm × 15 cm on each. Then the fabric is treated with 0.5% owf wetting agent for 2 hours at 30 to 35°C with a liquor ratio of 1:50. Then after drying the fabric the distance of the mark length and width are measured and shrinkage percentage is calculated by the following formula:

Shrinkage % = [100 x (a-b)]/a

where, a = Distance between two ends before treatment,

b = Distance between two ends after treatment (Islam, 2014).

In this way both the lengthwise and widthwise shrinkage percentage is calculated and they are shown in the Table 4. Spirality or twisting in a garment is appeared after washing. As a result, one of the

side seams comes at front of the garment when wearer wears it. Spirality percentage depends on fabric torque and garment structure.

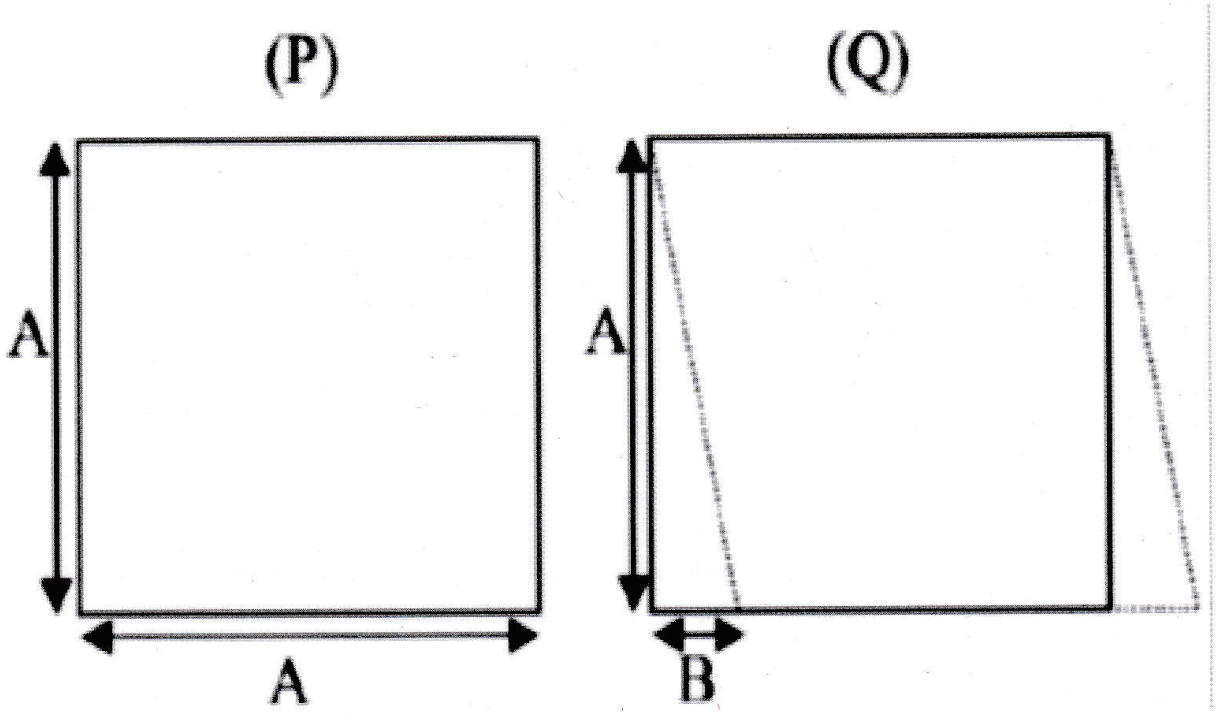


Fig. 1. (P) Before wash sample, (Q) After wash sample.

For spirality check, two fabric samples are taken which are 30 cm×30cm in dimension. They are stitched at three sides and one side is open. Then the fabric is washed in a washing machine and after that dried both in line and tumbler.

Then the Spirality of fabric is measured using the formula- Spirality% = 100* B/ A

Where, B= Displacement of side seam at bottom after wash

A= Side seam length (Islam, 2014).

The results obtained from this experiment are shown in Table 4.

4.0. Result and discussion

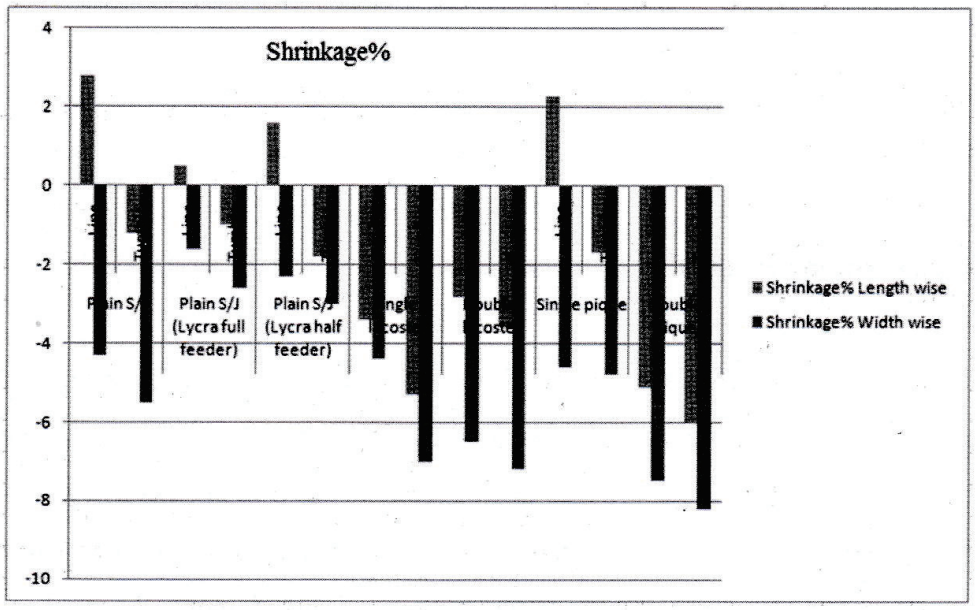
By testing spirality and shrinkage percentage of the samples according to the mentioned procedure and formula results are presented in Table 5. It was expected that the results obtained for the dimensional stability tests carried out would be significantly different for the fabric structures, due to the distinct nature of each structure. A positive value indicates extension of tested fabrics and negative value represents shrinkage.

It was expected that the results obtained for the dimensional stability tests carried out would be significantly different for the fabric structures, due to the distinct nature of each structure. A positive value indicates extension of tested fabrics and negative value represents shrinkage.

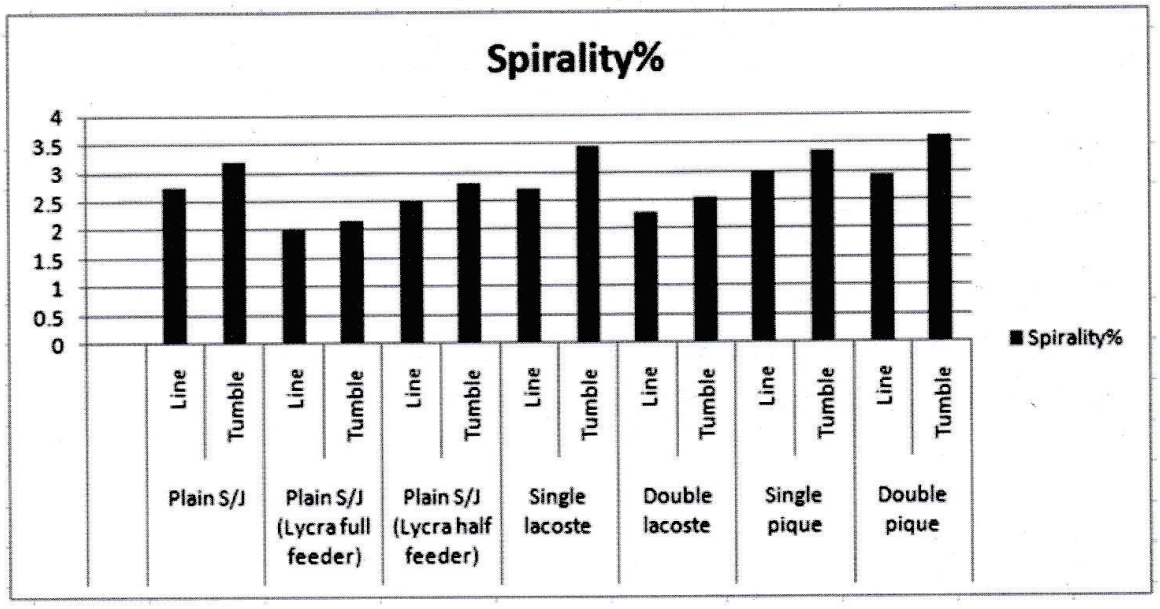
Table 5. Tested results of shrinkage and spirality percentage of fabric samples.

Fabric Type	Drying	Shrinkage%		Spirality%
		Length wise	Width wise	
Plain S/J	Line	+2.80	-4.30	2.75
	Tumble	-1.20	-5.50	3.20
Plain S/J (Lycra 4%: full feeder)	Line	+0.50	-1.60	2.00
	Tumble	-1.00	-2.60	2.15
Plain S/J (Lycra 2%: half feeder)	Line	+1.60	-2.30	2.50
	Tumble	-1.80	-3.00	2.80
Single lacoste	Line	-3.40	-4.40	2.70
	Tumble	-5.30	-7.00	3.45
Double lacoste	Line	-2.80	-6.50	2.30
	Tumble	-3.60	-7.20	2.55
Single pique	Line	+2.30	-4.60	3.00
	Tumble	-1.70	-4.80	3.35
Double pique	Line	-5.10	-7.50	2.95
	Tumble	-6.00	-8.20	3.60

From the above test result it is seen that the overall shrinkage and spirality percentage of the fabric samples were better in case of line drying system than tumble drying. If we separate the results and placed in graph of the following graph may be appeared.



From the graph of shrinkage percentage test result, it's clear that there only length wise positive shrinkage or extension has occurred in case of plain single jersey, single pique and plain single jersey with half Feeder lycra fabric samples for line drying and the rest of shows the negative value. Among these the double pique, double lacoste and single lacoste has the worst shrinkage to with wise in case of tumble drying. This is the result of presence of tuck loop in fabric structure. In the fabric structure of plain single jersey has the greater number of knit loop which is comparatively more stable or uniform in structure thus it shows the positive result. Additionally, the present of more lycra in fabric structure the amount of shrinkage percentage lower this is the result for elastic behavior of lycra which tends to recover it's original position after releasing applied force due to line or tumble drying system



It is seen that the percentage of spirality is more for double pique, single lacoste and single pique consecutively due to more number of tuck loops are present in the fabric structure. These loops are less stable than knit loop which are present in plain single jersey fabric structure. Additionally, the lycra fabric has the lower spirality percentage, the full feeder lycra fabric has lower spirality percentage than half feeder lycra fabric.

Finally, it is noted that the overall result is better in all type of fabric structure in case of line drying technique than the tumble drying due to amount of applied force for machine spin in tumble drying is more and on the other hand for line drying system there is not needed to apply force for fabric drying. For this reason, the loop deformation on tumble drying system is more than line drying and the course and wales displacement of knitted fabric occurred more. Thus, the spirality and shrinkage percentage is more in tumble drying system.

5.0. Conclusion

This study illustrated that the effect of various drying system used on garments washing made of weft knitted fabric of different structure. It is observed that the line drying system shows overall better result in case of spirality and shrinkage percentage of the dimensional stability of knitted fabric. The knitted structure of different loops such as knit and tuck have also a great effect on fabric spirality and shrinkage. More number of tuck loop present in fabric structure shows worse result in case of pique fabric. There is a slight impact of lycra percentage on spirality and shrinkage of weft knitted fabric. The larger amount of lycra prevent in fabric shows better result on spirality and shrinkage though fabric structure is same of single jersey plain fabric. So, the designer of garments manufacturer of knitted fabric should be informed that the accurate selection of definite structured fabric may help a lot to design the garments for specific purpose while need to wash for further use. The users also need to wash their garments and should prefer to dry in line drying system. Dimensional stability of knitted fabric results for the various structures indicated that there was a significant difference between tumble and line drying. The tumble-dried samples were found to shrink and spiral of loops (course and wales) to a greater extent. The effect of tumble drying was evident throughout the investigation. It would appear that this method of fabric drying tends to cause the most displacement of courses and wales change in the fabric due to a combination of knit and tuck loops along with lycra. So, from this study it can be noted that to get acceptable shrinkage and spirality wash with line drying is better than tumble drying system.

References:

Afroz, N.; Alam, A.K.M.M.; Mehedi, H. (2012) Analysis on the Important Factors Influencing Spirality of Weft Knitted Fabrics", Institutional Engineering and Technology (IET), Vol. 2, pp 8-14.

Anand, S.C.; Brown, K.S.M.; Higgins, L.G.; Holmes, D.A.; Hall, M.E.; Conrad, D. (2002) Effect of laundering on the dimensional stability and distortion of knitted fabric, AUTEX Research Journal, Vol. 2, No.2, © AUTEX

Anbumani, D.N. (2007) Knitting Fundamentals, Machines, Structures and developments, 1st edition, 2007.

Araujo, M.D.D.; Smith, G.W. (1989) Spirality of Knitted Fabrics Part I: The Nature of Spirality, Textile Research Journal, Vol. 59, pp 247-256.

Hossain, M.M.; Jalil, M.A.; Saha, J.; Mia, M.M.; Rahman, M.M. (2012) Impact of Various Yarn of Different Fiber Composition on the Dimensional Properties of Different Structure of Weft Knitted Fabric", International Journal of Textile and Fashion Technology, Vol. 2, pp 34 -44.

https://en.wikipedia.org/wiki/Clothes_dryer, 2016.

Islam, M.A.; Haque, A.N.M.A. (2014) Selection of suitable machine gauge by considering the GSM, shrinkage and spirality of single jersey knit fabric", Research Journal of Science and IT Management, Vol. 03, pp 50-55.

Mukhopadhyay, A.; Mohanty, A. (2004) Impact of lycra filament on extension and recovery characteristics of cotton knitted fabric, Indian J Fibre Text Res, Vol. 28, pp 423-430.

Munshi, V.G.; Ukidve, A.V.; Raje, C.R.; Basker, P.; Pai, S.D. (1993) The Effect of Laundering on the Mechanical Properties of Apparel Fabrics, Colourage, part 1 March 1993, part 2 June 1993.

Sadek, R. (2012) Journal of Engineered Fibers and Fabrics, Vol. 7, pp 11-16.

Thomas, K. (1994) From Liable to Stable: Dimensionally Stable Knitted Fabrics Today, Knitting Technique, Vol. 16, pp 360-361.

Study of Hybrid Photovoltaic Solar Thermal Systems During Summer Months in Bangladesh

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Abstract

A hybrid photovoltaic (PVT) solar system combines simultaneous conversion of the absorbed solar radiation into electricity and heat. In this study the design of an experimental PVT/dual system, both air and water circulation with modifications in the air channel is presented. A thin metallic sheet (TMS) inside the air channel and painted black ribbed surfaces at the bottom of the air channel are placed. For observing the variations of heat transmittance with change of the shape of the ribs four experimental setups with a Trapezoidal, a Saw tooth forward, a Saw tooth backward ribbed surfaces and a flat plate have been used, Natural convection is applied instead of forced convection to increase the system net electrical output & thereby the overall system efficiency. All setups are of the same capacity, projected area and water heat extraction method and average depth. Performance study is carried out during the months of March to June, 2012 at IUT campus, Gazipur, Bangladesh. Significant performance has been obtained with the above stated modifications. Natural convection is allowed to take place instead of fluid convection. Results obtained in this study have been compared with available information in the literature.

Keywords: Hybrid Thermal System, Solar Energy, Thin Metallic Sheet (Tms), Painted Black Ribbed Surfaces.

1.0. Introduction

The need for alternative energy sources is getting urgent, hence, the development of renewable energy is moving fast. Nationally and internationally various individuals and research companies are creating new and exciting energy systems. Some of these apparatuses are great works and need improving for massive use. Politician's world-wide are drafting policies and are making agreements to make greater use of these energy sources.

A wide use of fossil fuels today is very harmful for the environment. In the early seventies and eighties there were people and even scientists who preach otherwise, but today the negative effects are showing. The earth is warming up and climates are changing. There are parts in the world where there will be more rain and sunshine and others parts will become dryer than they already are. Another negative effect is that the ozone layer is getting thinner which also leads to a warming up of

the earth. These two effects complement each other and make it even more crucial to make another step in a different direction. This step will lead us to the use of renewable energy.

Renewable energy is derived from an energy source that is rapidly replaced, or renewed by a natural process. It is the energy which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable in nature. Some of the renewable energy are solar energy, Wind and Wave energy, Hydropower, Bio-mass, geothermal energy etc. Solar energy is an important clean, cheap and abundantly available renewable energy. The earth receives an incredible supply of solar energy.

There is a good prospect of harnessing solar power in Bangladesh. In a recent study conducted by Renewable Energy Research Centre, it is found that average solar radiation varies between 4 to 6.5 $kWhm^{-2}$ day^{-1}. Maximum amounts of radiation are available in the month of March-April and minimum in December-January.

Mainly there are two ways to collect solar energy: Natural collection and Technological collection.

There are also two methods for technological collection of solar energy.

i. Photovoltaic conversion method
ii. Thermal conversion method

Different photovoltaic cell convert only 5-15% of the incoming solar radiation into electricity, with the greater percentage converted into heat. The solar radiation converted into heat increases the temperature of the PV modules, resulting in the drop of their electrical efficiency. This undesirable effect can be partially avoided by applying a suitable heat extraction mode with a fluid circulation, keeping the electrical efficiency at a satisfactory level. Furthermore, this extracted heat can be utilized for heating air and/or water. For this purpose, the concept of hybrid photovoltaic/thermal (PV/T or PVT) solar systems have been developed.

From the above discussion, it is found that a number of survey works have been carried out in hybrid PVT solar systems using air and water as heat carrier's fluid. But only a few works have been carried out on PVT/dual (both air and water) system. However, both air and water are used as heat carriers.

2.0. Experimental setup & test procedures

2.1. Experimental setup

Four experimental setups are fabricated with similar design and dimensions except the shape of the ribs. The whole setup is constructed in a wooden box. PV panels are set at the top of the

box. Thin Metallic Sheet (TMS) is placed at the middle part of the box on top of which pipes are set for water circulation. Air channel of 0.1m height is kept under the water heat exchanger. Different ribbed plates (Trapezoidal, Saw tooth forward, Saw tooth backward and Flat plate) of same height and dimension are placed on opposite wall of the air channel. The whole inner portion of the box is insulated. TMS and Ribbed plates are painted black for better heat absorption. Fig. 1 shows the schematic diagram of each experimental setup with different ribbed surfaces. Photograph of the installed setup at IUT campus, shows in Fig. 2.

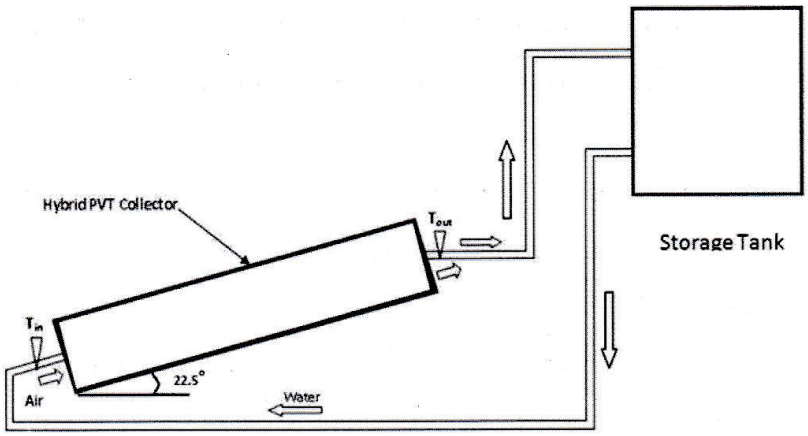


Fig. 1. Schematic diagram of each experimental setup.

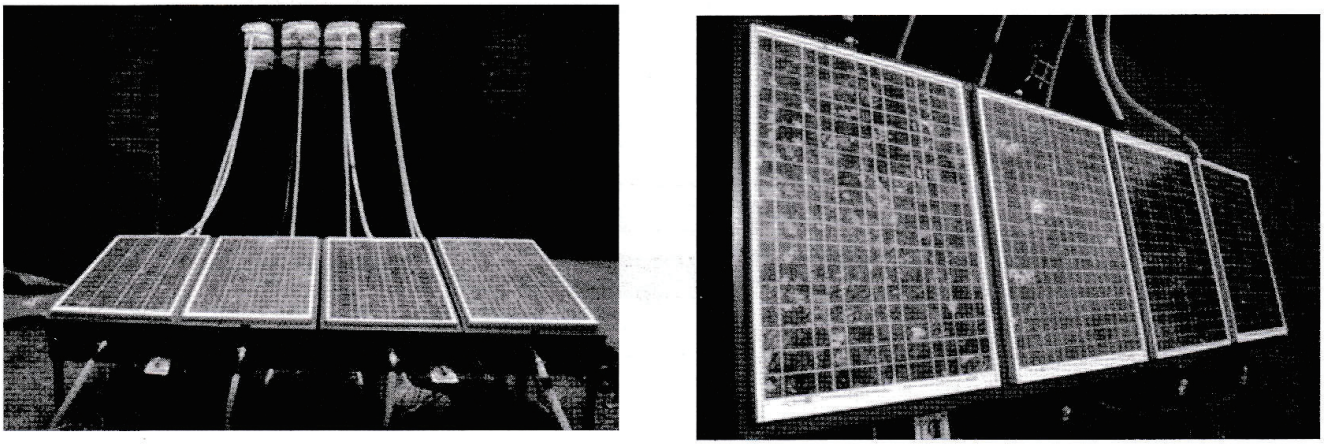


Fig. 2. Photograph of the installed setup at IUT campus.

The main components of each setup consist of a PV panel, a wooden box, a water heat exchanger (WHX), a TMS and the absorber plate, ribbed plates at the opposite of air channel, water storage tank, insulation, steel frame and stand. For this project, Polycrystalline-Silicon (pc-Si) PV panels are used with a rating of 50 watts and 0.45m^2 aperture area having approximate dimensions of (839 ×

537 × 50) mm. For circulating water copper tubes were used in this project, as copper has got higher thermal conductivity which is a necessary requirement of the project. The optimum diameter 1.25 cm (½″) is selected to facilitate the high rate of heat transfer and sufficient rate of flow.

For the header portion, copper pipe of diameter 3.8 cm (1.5") is used. The diameter of the header is found by calculating the cross-sectional area of the copper tubes corresponding to header cross-sectional area to maintain a uniform flow rate through all the tubes. For water flow to and from the storage tank nylon tube of diameter 2.5 cm is used. Nylon tubes are flexible and don't bend to interrupt the flow.

Glass wool is used as insulation for its low conductivity (K) of 0.04 W/mK, and of moderate cost. Insulation of 2.5 cm height is applied at the inner surface of the wooden box to avoid any kind of heat transfer to and from the setup which may decrease the efficiency of the PVT system. A supporting steel structure is made for the collectors and storage tanks. The collectors are set at an inclination angle of (β) 23.5^0 and directed towards south.

3.3. Test Procedures

All the collectors are installed in front of the IUT workshop where there is no obstacle to sunshine and faced towards south with an inclination angle of 23.5^0 which is the best angle to collect as much as available radiation. Photograph of which are shown in Fig. 2. All storage tanks are filled

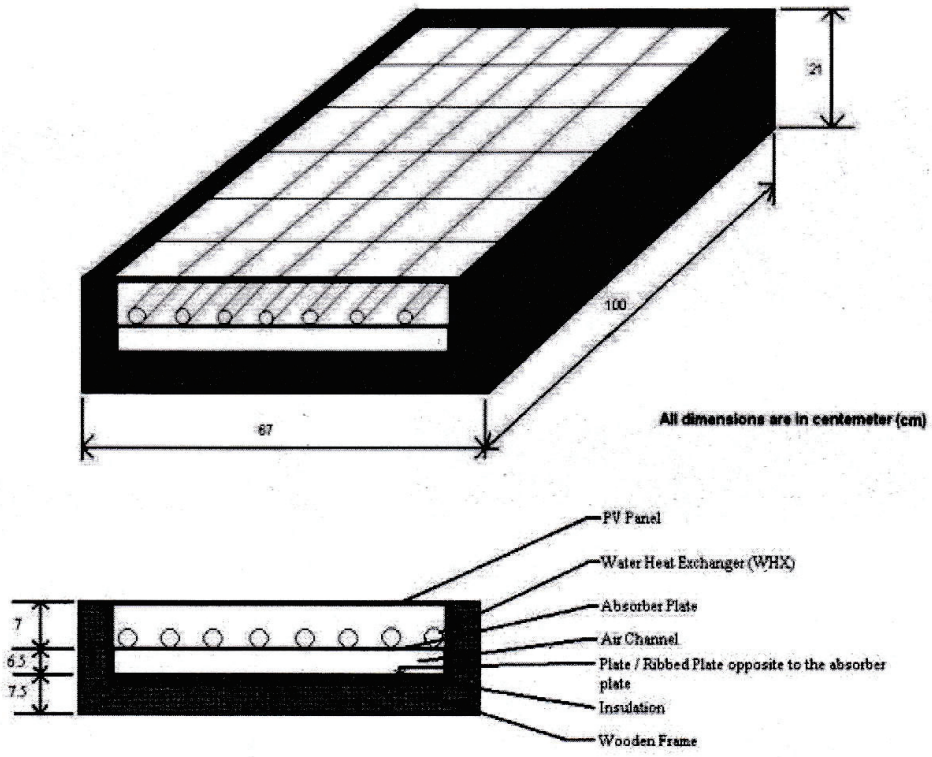


Fig. 3. Details of Hybrid Collector (All dimensions are in cm).

early in the morning with fresh water. Temperatures are measured for PV panel (T_{PV}), Water heat exchanger (T_{WHX}), Inlet and Outlet of water (T_i and T_O), Air in the channel (T_{air}) and the rib temperature (T_{rib}) in air channel by using seven 36 S.W.G. Chromel-Alumel thermocouples. Selector switches are used to switch among the thermocouples.

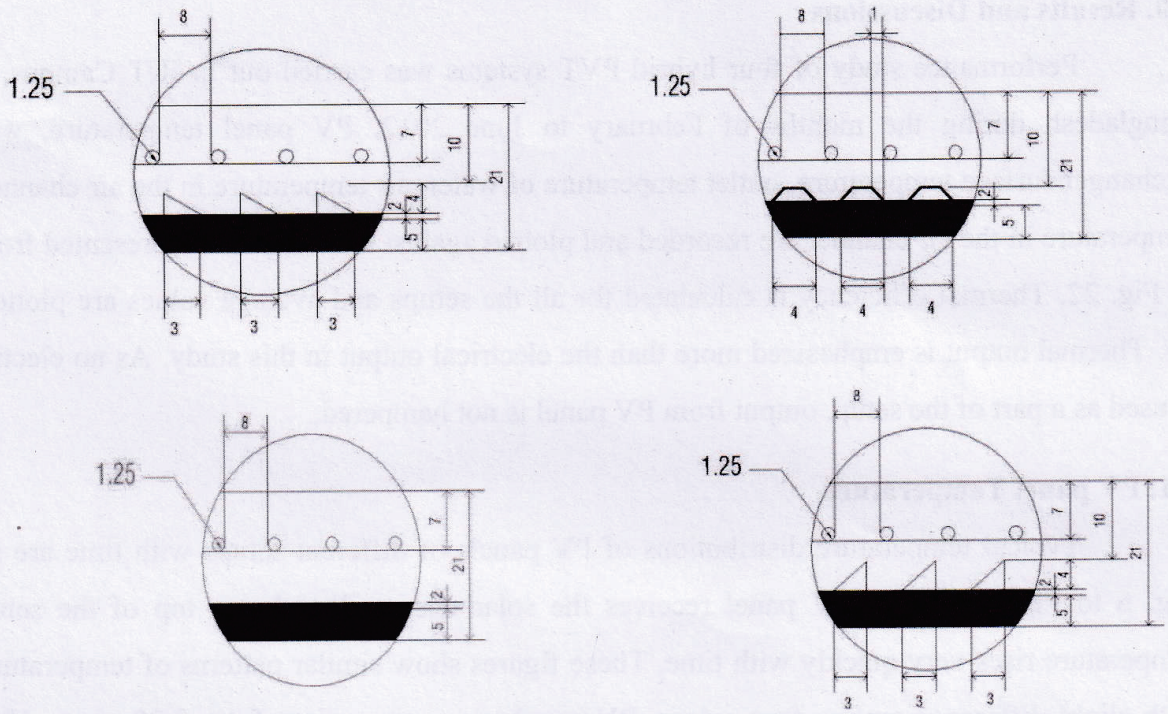


Fig. 4. Test specimens (a) Trapezoidal rib; (b) Saw tooth forward rib; (c) Saw tooth backward rib; (d) Flat plate (All dimensions are in mm).

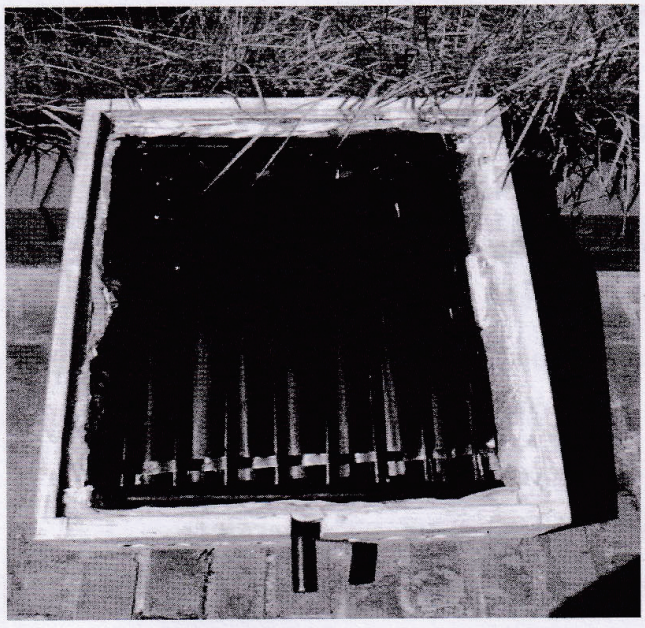


Fig. 5. Photograph of the Interior view showing the TMS with water heat exchanger.

Ambient temperature (T_{amb}), solar radiation (G) are recorded hourly every day from at 8 AM up to 6 PM. All readings are recorded in data sheets. Details of hybrid collector and test specimens used in this study are shown in Fig. 3. and in Fig. 4. Photograph of the Interior view showing the TMS with water heat exchanger shows in Fig. 5.

4.0. Results and Discussions

Performance study of four hybrid PVT systems was carried out in IUT Campus, Gazipur, Bangladesh during the months of February to June 2012. PV panel temperature, water heat exchanger surface temperature, outlet temperature of water, air temperature in the air channel and rib temperature in the air channel are recorded and plotted against time. These are presented from Fig. 6. to Fig. 22. Thermal efficiency is calculated for all the setups and average values are plotted in Fig. 23. Thermal output is emphasized more than the electrical output in this study. As no electrical load is used as a part of the setup, output from PV panel is not hampered.

4.1. PV panel Temperature

Typical temperature distributions of PV panels of different setups with time are shown in Fig. 6 to Fig. 8. As the PV panel receives the solar energy directly on top of the setup, panel temperature rises very quickly with time. These figures show similar patterns of temperature survey with slight difference among four setups. PV panel temperature rises from 8:00 am to 12:00 noon and then decreases after 2:00 pm rapidly. In an intense sunny day of 15March2012, the maximum temperature of PV panel is found to be 62°C for flat plate, 56°C for trapezoidal, 57°C for Saw tooth forward and 59°C for Saw tooth backward plate. In a sunny day of 30/April/2012, the maximum temperature of PV panel is found to be 61°C for Flat plate, 54°C for trapezoidal, 56°C for Saw tooth forward and 59°C for saw tooth backward plate. In a rainy day of 30/May/2012, the maximum temperature of PV panel is found to be 40°C for flat plate, 41°C for trapezoidal, 40°C for saw tooth forward and 39°C for saw tooth backward plate.

Setup with saw tooth forward and saw tooth backward ribs setups give lower temperature of the panel which shows better cooling of PV. Trapezoidal ribbed plate gives moderate cooling better than that of flat plate setup. In flat plate setup PV temperature is found always high, which shows inadequate heat transfer for PV cooling.

4.2. Water Heat Exchanger (WHX) Surface Temperature

Typical water heat exchanger surface temperature distributions of different setups with time are shown in Fig. 9 to Fig. 11. Water heat exchanger with TMS is placed below the PV panel at the middle section of the setup. Heat energy is absorbed here from the PV rear surface and water is

heated flowing through it. It is evident from these figures that the temperature of this heat exchanger also rises with time from 8:00 am to 12:00 noon and then decreases after 2:00 pm rapidly. In a sunny day of 30/March/2012, the maximum temperature of WHX is found to be 48°C for Flat plate, 46°C for Trapezoidal, 49°C for saw tooth forward and 48°C for Saw tooth backward plate. In a sunny day of 30/April/2012, the maximum temperature of WHX is found to be 49°C for flat plate, 47°C for trapezoidal, 51°C for saw tooth forward and 49°C for saw tooth backward plate. In a rainy day of 30/May/2012, the maximum temperature of WHX is found to be 34°C for flat plate, 37°C for trapezoidal, 36°C for saw tooth forward and 35°C for saw tooth backward plate. Average good temperature is found in case of setup with saw tooth forward rib. Average temperature difference between PV panel and WHX is around 10-12°C.

4.3. Water outlet Temperature

Typical distribution of Water outlet temperatures of different setups with time are shown from Fig. 12 to Fig. 14. Water is one of the heat removal fluids of these hybrid PVT systems and is also important for meeting thermal needs. Water temperature is raised by taking absorbed heat from heat exchanger. On intense sunny day of 15/March/2012, the maximum temperature of water is found to be 39°C for Flat plate, 41°C for trapezoidal, 40°C for saw tooth forward and 59°C for Saw tooth backward plate. On sunny day of 15 April 2012, the maximum temperature of water is found to be 40°C for flat plate, 43°C for Trapezoidal, 42°C for saw tooth forward and 41°C for saw tooth backward plate. On a rainy day of 30May2012, the maximum temperature of water outlet is found to be 35°C for flat plate, 37°C for trapezoidal, 36°C for saw tooth forward and 35°C for saw tooth backward plate.

Temperature of the water in supply lines varies between 23°C to 26°C. The maximum temperature rise is found to be 43 ° C using hybrid PVT systems. Average temperature of water is found to be around 40°C. Water at this temperature is very much suitable for household activities, in kitchens, in bathrooms for washing purpose and for taking bath etc. This water also can be used as pre-heated water in many chemical industries.

4.4. Air temperature in the air channel

Typical distributions of air temperature in the air channel of different setups with time are shown from Fig. 15 to Fig. 17. Air is one of the heat removal fluids of these hybrid PVT systems. As natural circulation of air is preferred, air flows inside the channel are found to be insufficient for heat extraction. As a result, the air temperature inside the channel is found to be only a few degrees above the ambient temperature and sometimes remains same. On a sunny day of 30/March/2012, the

maximum temperature of air is found 32°C for Flat plate, 37°C for Trapezoidal, 36°C for Saw tooth forward and 35°C for Saw tooth backward plate. On a sunny day of 30 April 2012, the maximum temperature of air is found to be 33°C for flat plate, 36°C for Trapezoidal, 35°C for Saw tooth forward and 35°C for saw tooth backward plate. In a rainy day of 30/May/2012, the maximum temperature of Air channel is found 33°C for flat plate, 35°C for trapezoidal, 34°C for saw tooth forward and 34°C for saw tooth backward plate.

Maximum air temperature in the air channel is found to be maximum 4°C to 5°C higher than the ambient temperature. Although this temperature rise is much lower than water, air as heat removal fluids of hybrid PVT system can be used for natural ventilation of buildings. In winter when the inside/room temperature.

4.5. Ribbed Surface Temperature

Variations of ribbed surface temperature with time for different setups with time are typically shown from Fig. 18 to Fig. 20. Ribbed surface is placed at the bottom of the setup in the air channel. It receives heat from the WHX. Temperature on the ribbed surface gives idea about heat transfer to air in the channel. On an intense sunny day of 15 March 2012, the maximum temperature of rib surface is found 33°C for flat plate, 36°C for Trapezoidal, 35°C for Saw tooth forward and 34°C for Saw tooth backward plate. On a sunny day of 30 March 2012, the maximum temperature of rib surface is found to be 34°C for Flat plate, 37°C for Trapezoidal, 36°C for Saw tooth forward and 35°C for Saw tooth backward plate. On a sunny day of 15/April/2012, the maximum temperature of rib surface is found to be 35°C for flat plate, 38°C for Trapezoidal, 37°C for Saw tooth forward and 36°C for saw tooth backward plate. In a partly cloudy day of 15 May 2012, the maximum temperature of ribbed surface is found to be 33°C for Flat plate, 36°C for trapezoidal, 34°C for saw tooth forward and 34°C for Saw tooth backward plate at 02:00 PM. Maximum air temperature in the ribbed surface is found to be maximum 3°C to 4°C higher than the ambient temperature.

4.6. Temperature Distribution

A hybrid PVT/dual system has several heat exchanging surfaces. PV panel, WHX, water, air and rib temperature varies accordingly. Fig. 21 to Fig. 22 show typical temperature distributions in four hybrid PVT systems with ambient temperature. It is found from these figures that temperature of the PV panel is highest as it receives heat from PV rear surface and temperature is found to be 36 °C -48 °C in this region. Water acts as a heat carrier fluid here and the temperature of water is rises with rising of WHX temperature. Water temperature is found to be within 34 °C to 50 °C. After WHX, air in the channel is receiving heat from TMS and WHX. Air temperature varies in between 35 °C to 45

°C. The last portion is the ribbed surfaces placed at the bottom of air channel of the setup. Temperature of ribbed surface varies in between 32 °C to 39 °C.

4.7. Thermal Efficiency Comparison

Thermal efficiency regarding water is compared as a function of $\Delta T/G$ ($KW^{-1}m^2$). ΔT is the temperature difference between input fluid and the ambient temperature. Efficiency of all four setups are compared along with the work of Tripangnostopoulos et al. (2007) and Karim et al. (2011) in Fig. 18 for comparison. Tripangnostopoulos et al. (2007) studied a hybrid PVT/dual system having corrugated rib on opposite air channel with WHX placed just under the PV panel in 2007 at the University of Patras, Greece. Karim et al. (2011) studied hybrid photovoltaic thermal solar system using three different ribbed surfaces (Triangular, Semicircular, Square) and flat plate in 2011 at IUT, Bangladesh.

In the present study, a hybrid photovoltaic solar thermal system using three different ribbed surfaces (Trapezoidal, saw tooth forward, saw tooth backward) and a flat plate have been carried out from March to June in 2012. The efficiency of Trapezoidal is 36% to 73%, Saw tooth forward is 37% to 70%, Saw tooth backward is 36% to 67% and Flat plate is 33% to 59%. Tripangnostopoulos et al. (2007) PVT system is found to vary from 45% to 62% and Karim et al. (2011) is found to vary from 35% to 70%. The average efficiency from all calculated values is found to be 67% for Trapezoidal, 62% for Saw tooth forward, 61% for Saw tooth backward and 54% for flat plate setup.

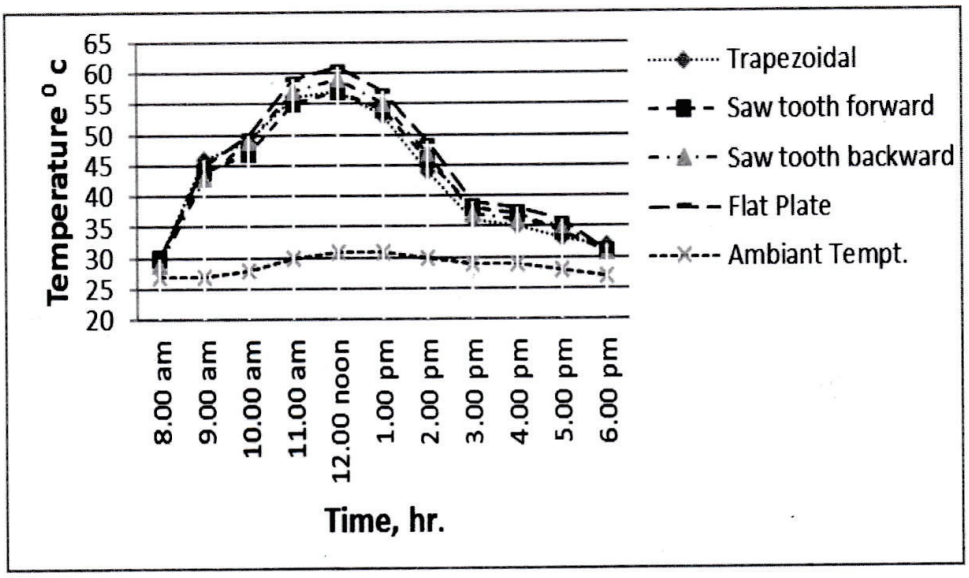


Fig. 6. Temperature distribution of PV panel temperature on 15/03/2012.

The range of efficiency varies with the operating temperature of the system. The thermal efficiency of PVT/dual system for water heat extraction is extended in negative $\Delta T/G$ axis, as some

experiments were performed for ambient temperature being higher than the water temperature at system input. Data taken for comparisons of setups are similar with ΔT/G values, to make the comparison more correct.

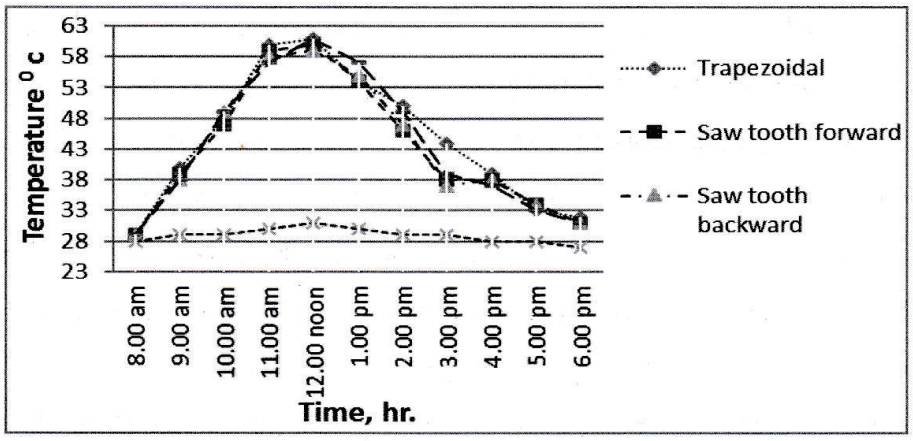


Fig. 7. Temperature distribution of PV panel temperature on 30/04/2012.

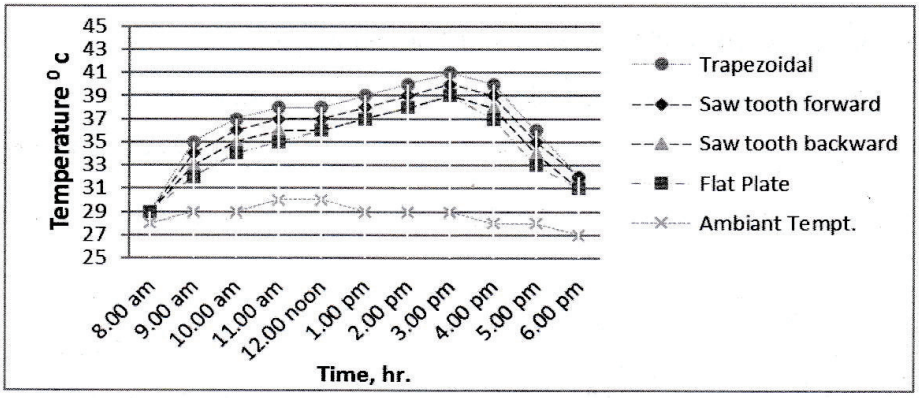


Fig. 8. Temperature distribution of PV panel temperature on 30/05/2012.

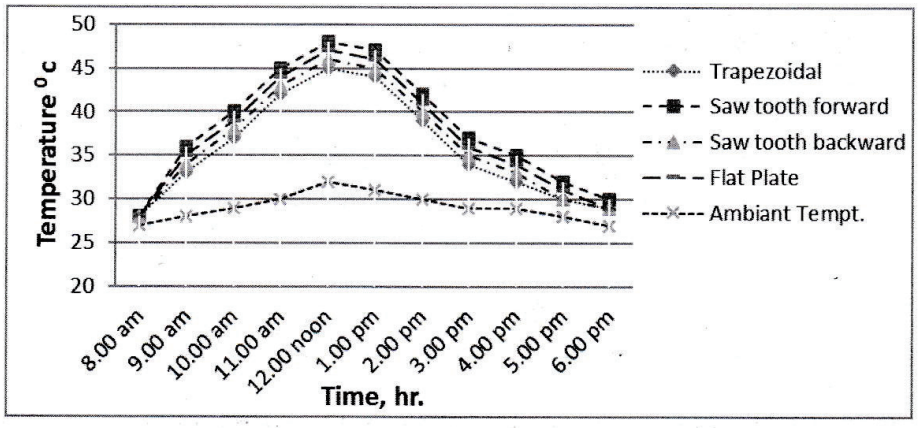


Fig. 9. Temperature distribution of water heat exchanger temperature on 30/03/2012.

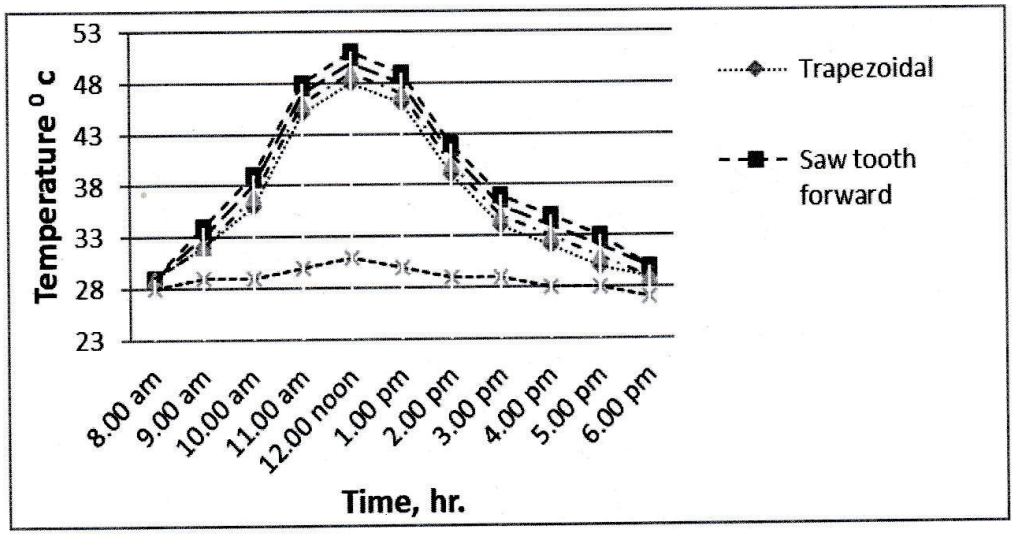


Fig. 10. Temperature distribution of water heat exchanger temperature on 30/04/2012.

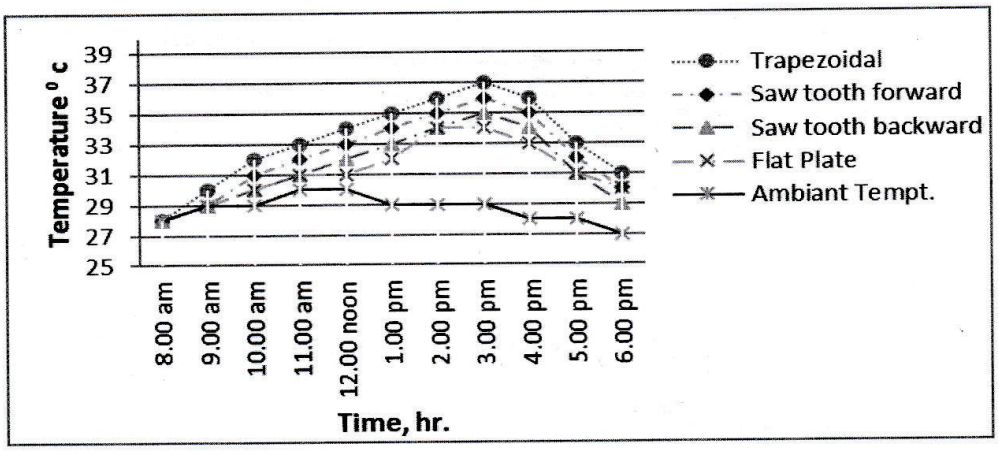


Fig. 11. Temperature distribution of water heat exchanger temperature on 30/05/2012.

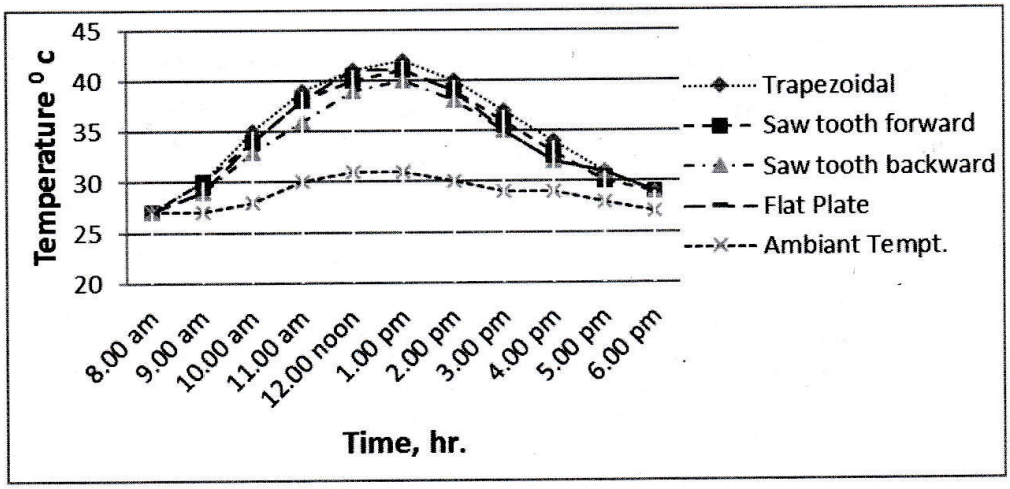


Fig. 12. Temperature distribution of water outlet temperature on 15/03/2012.

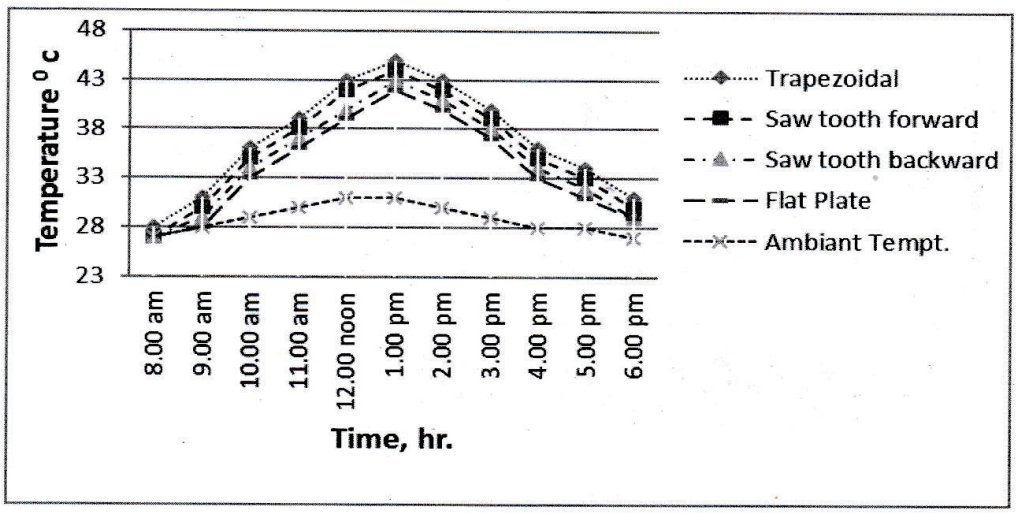


Fig. 13. Temperature distribution of water outlet temperature on 15/04/2012.

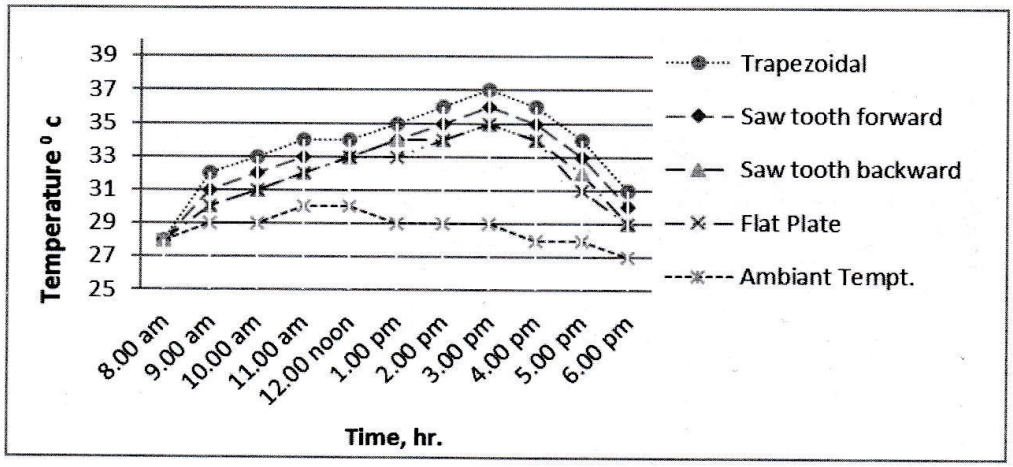


Fig. 14. Temperature distribution of water outlet temperature on 30/05/2012.

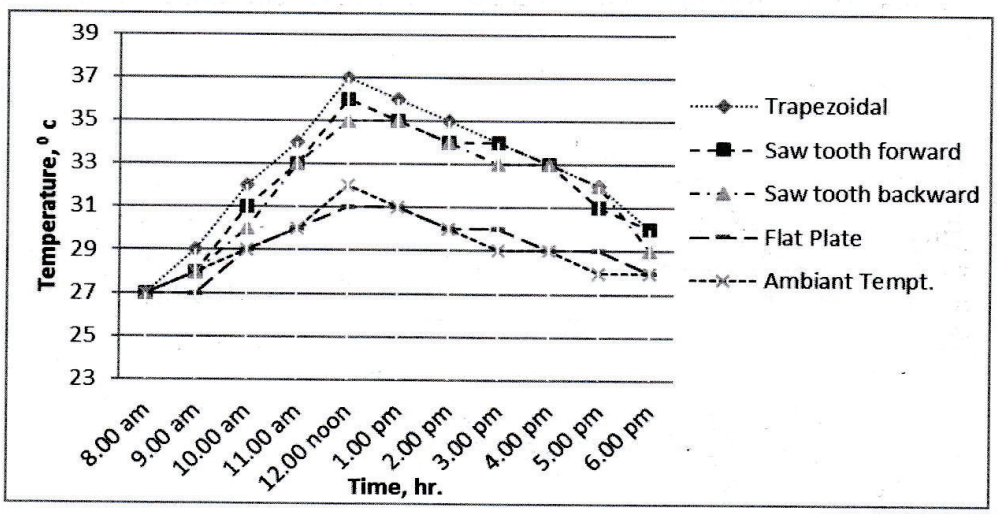


Fig. 15. Temperature distribution of Air Channel temperature on 30/03/2012.

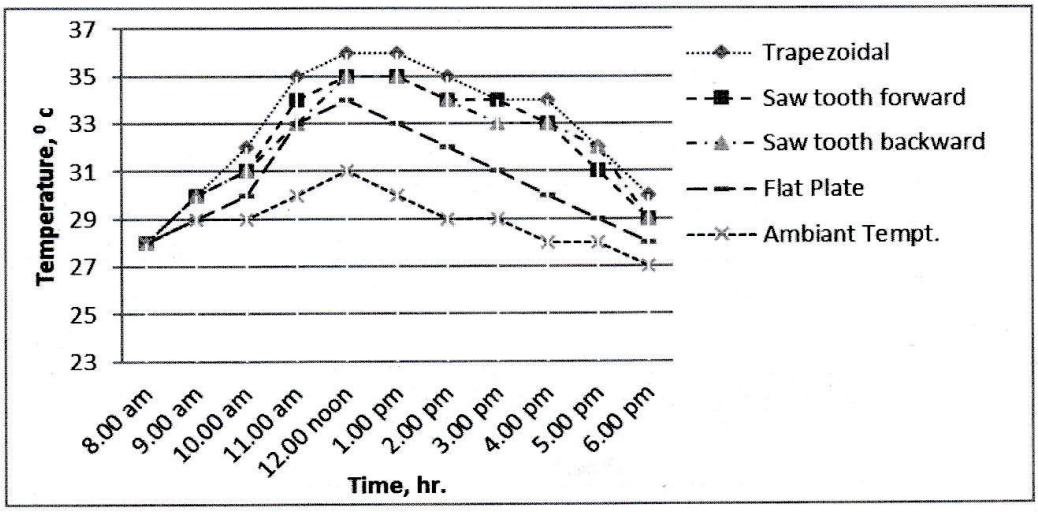


Fig. 16. Temperature distribution of Air Channel temperature on 30/04/2012.

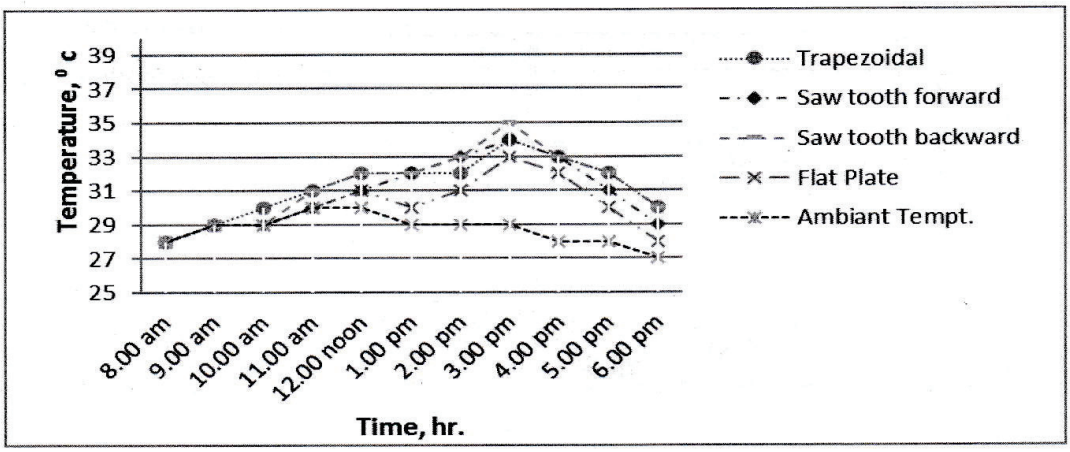


Fig. 17. Temperature distribution of Air Channel temperature on 30/05/2012.

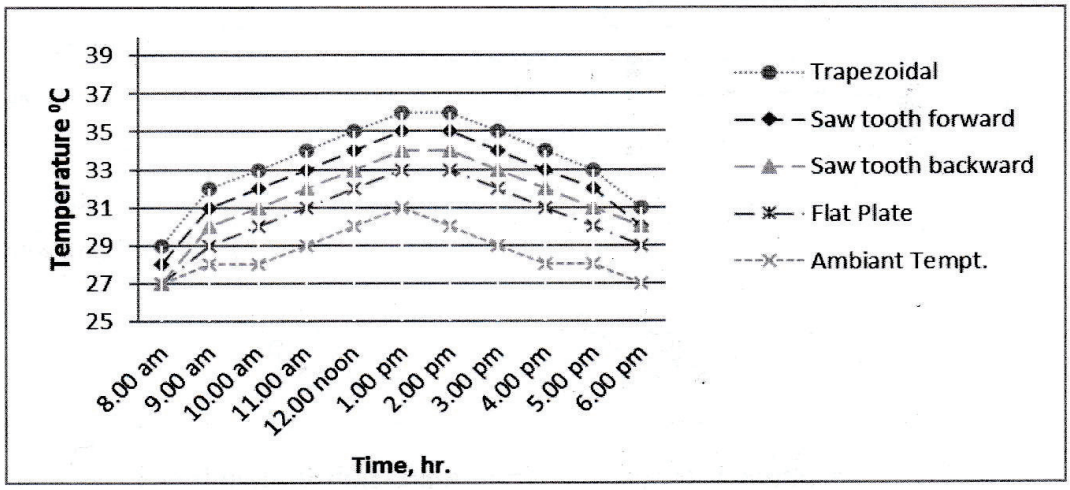


Fig. 18. Temperature distribution of Ribbed surface temperature on 15/03/2012.

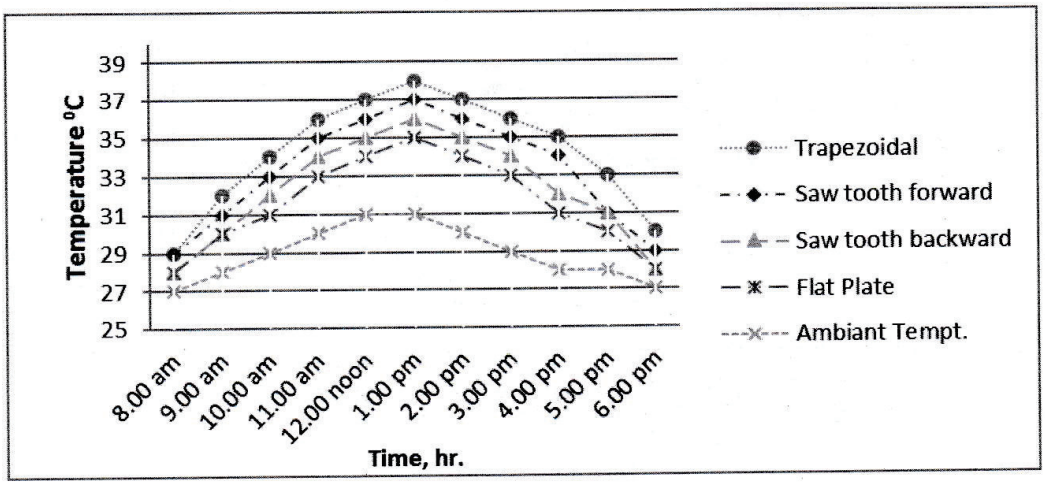


Fig. 19. Temperature distribution of Ribbed surface temperature on 15/04/2012.

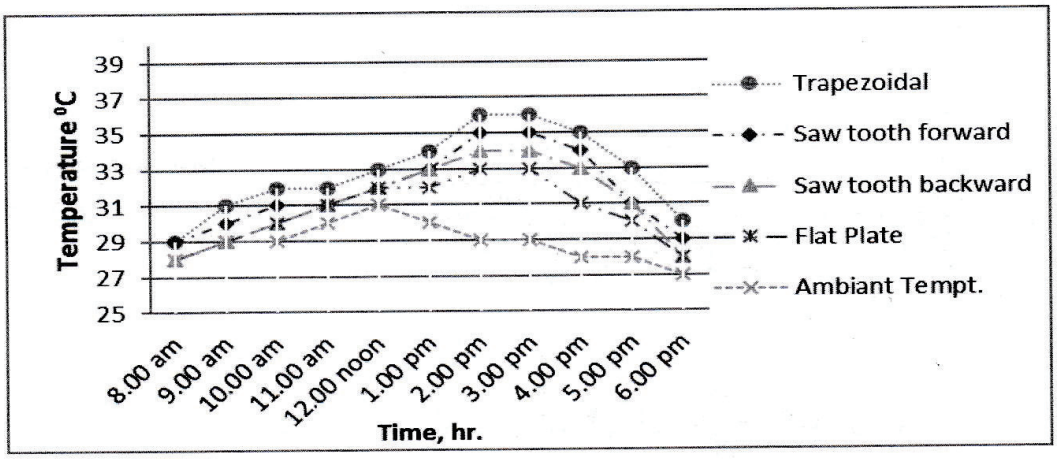


Fig. 20 Temperature distribution of Ribbed surface temperature on 15/05/2012.

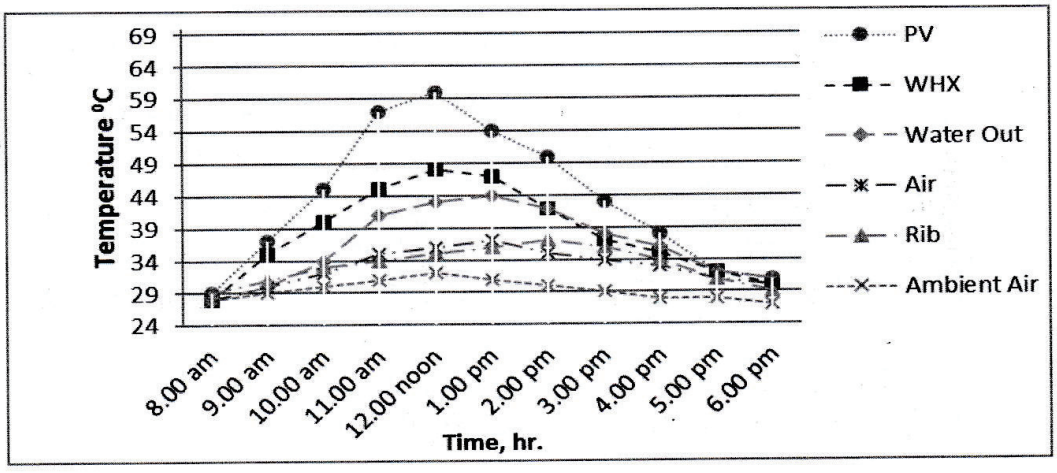
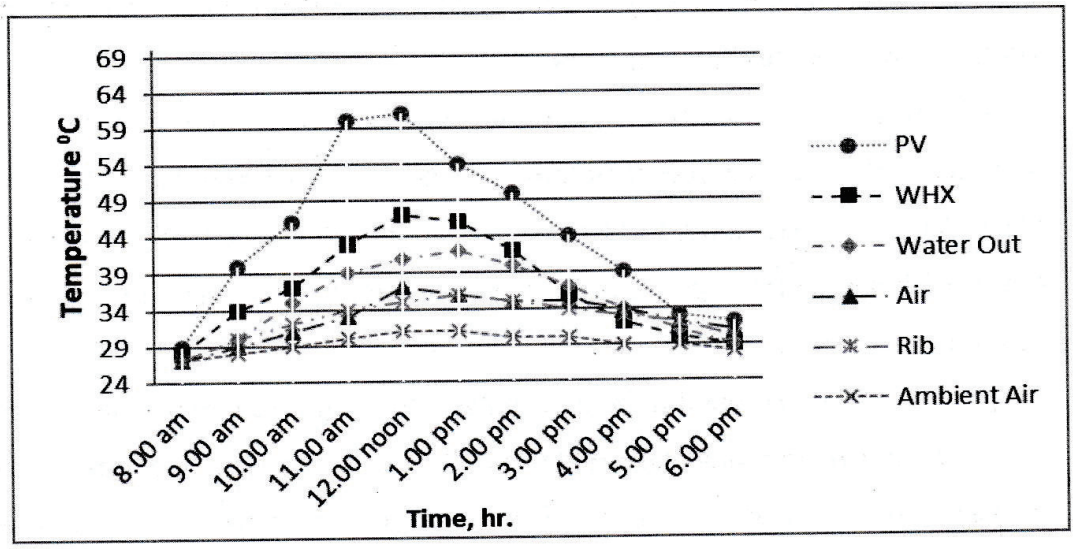


Fig. 21. Temperature distribution in Trapezoidal ribbed setup in March,2012.



22. Temperature distribution in Saw tooth backward ribbed setup in April, 2012.

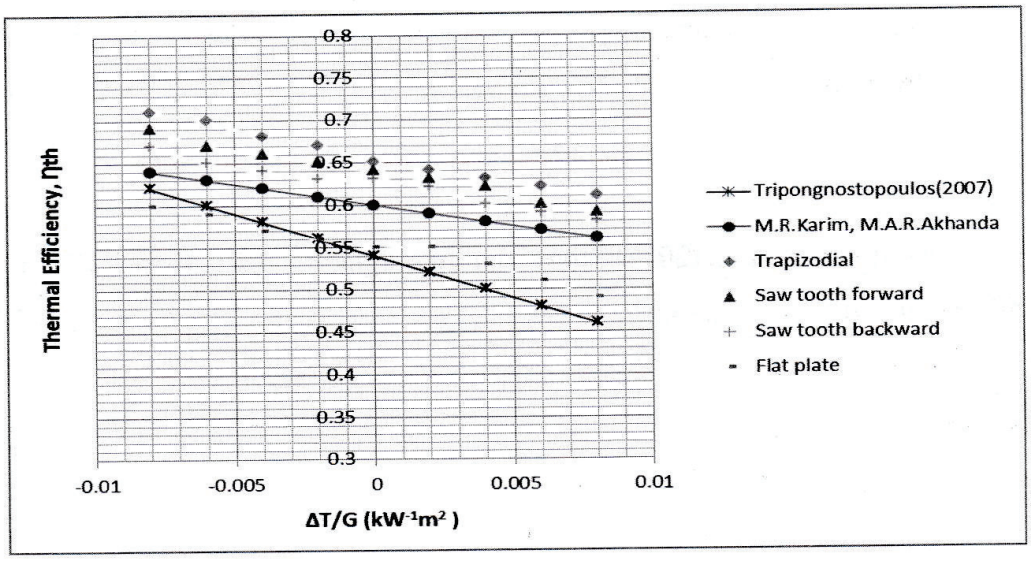


Fig. 23. Comparison of Thermal efficiencies of all four systems.

5.0. Conclusions

From this experimental study the following conclusions may be drawn:

i. With increasing of PV panel temperature, the water and air temperatures also increase and reach a maximum value at a maximum PV temperature around noon. Water and air temperature then decrease slowly with the ambient temperature also.

ii. The energy absorbed in the system from 8AM to 12 Noon is faster than that absorbed in the afternoon for all systems, tested in this study.

iii. Average water and air temperatures rise is found to be better in a Trapezoidal and in a Saw tooth forward ribbed surfaces then those of surfaces with a Saw tooth backward and a Flat plate. Setup with Saw tooth forward ribbed surfaces shows better performance than that of Flat plate but its average performance is lower than that of setup with a Trapezoidal and a Saw tooth forward ribbed surface.

iv. Thermal efficiency is found to be best in the setup with Trapezoidal ribs among all setups, applying similar experimental conditions. Efficiency of Saw tooth forward, saw tooth backward and flat plate is also found to be satisfactory within the range of experimental conditions.

v. PVT/dual system can be used either to heat water or to heat air depending on the weather conditions and building needs. The water heat extraction part could operate mainly during periods of higher ambient temperature and the air heat extraction part to operate mainly when the ambient temperature low. In mild weather conditions (like Bangladesh) it is possible to operate both heat extraction modes, if it is considered useful for the application.

References

Karim, M.R.; Akhanda, M.A.R. (2011) Study of a hybrid photovoltaic thermal (PV/T) solar systems using different ribbed surfaces opposite to absorber plate. Journal of Engineering and Technology, Vol. 09, No.01, June 2011.

Tripanagnostopoulos, Y. (2007) Aspects and Improvements of Hybrid Photovoltaic/Thermal Solar Energy Systems. Solar Energy, Vol. 81, pp 1117–1131.

Augmentation of Heat Transfer in a Circular Pipe by Means of Twisted Vane Inserts

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Abstract

Heat transfer characteristics for swirl flow of water in a circular pipe are studied numerically. The pipe is fitted with heat resistant vanes. The performance of this pipe is compared with that of an empty pipe under similar conditions. The three-dimensional Navier-Stokes equations for incompressible Newtonian fluid flow are used. This investigation reveals that the swirl flow increases heat transfer. The effects of various parameters such as Reynolds number, inlet pressure, twisting angle, surface heat flux, surface temperature, pipe length etc. are also studied.

Keywords: Swirl Flow; Steady State; Incompressible Fluid; Heat Transfer; Uniform Heat Flux; Stationary Vanes

1.0. Introduction

Laminar flow heat transfer in a circular pipe has various applications such as heating of circulating fluids in solar collectors, heating or cooling of viscous fluids (oils, liquids in process industry). There are considerable challenges in designing a heat exchanger. The main purpose is to make the equipment compact and achieve a high heat transfer rate using minimum pumping power. Since the laminar flow heat transfer coefficients are predominantly low various types of heat transfer augmentation techniques are used. These augmentation techniques (passive, active or a combination of passive and active methods) are discussed in several published literatures. The active techniques demand external power input for the enhancement of heat transfer and do not possess as much potential as the passive techniques for being complex in design. In the passive techniques, no external power input is required. Inserts are used in the flow passage to increase the heat transfer rate. They are beneficial compared to active techniques because these techniques can be easily employed in an existing heat exchanger. They are also inexpensive.

Bergles (1985) discussed almost all types of heat transfer augmentation technique with external inserts up to 1985. Swirl flow can be generated by different kinds of swirl generators.

Recently injection, vanes (tangential, radial), twisted tape, axial blades, a helical screw, wire coil, ribs, fins, dimples and other types of passive heat transfer augmentation techniques are being used.

An extensive literature review on swirl flow was discussed by Gupta et al. (1984) and Bergles et al. (1996). In a swirl flow, there is a spiral motion in the tangential direction in addition to the axial and radial directions. Swirl flows can be categorized into two types: non-decaying (steady) and decaying (unsteady). In non-decaying swirl flow, the swirl is continuous in the flow direction, i.e. the flow maintains its characteristics throughout the whole length of the pipe. In decaying swirl flow, the swirl is introduced to the flow by inserting a flow guide in the entrance of the pipe only and the effect of swirl decays in the axial direction of flow. These flows can be generated by means of insertion of various swirl generators. According to Razgaitis et al. (1976) swirl flows may be classified into three groups depending upon characteristic velocity profiles: (i) curved, (ii) rotating and (iii) vortex flow. These velocity profiles are different, depending upon the particular flow geometry and swirl generation methods. Curved flow is produced by a stationary boundary. It causes a continual bending of the local velocity vector. Also, complex secondary flows with an appreciable velocity component normal to the instantaneous osculating plane are generated. Curved flows can be generated by inserting coiled wires, twisted tapes and helical vanes into the pipe, by coiling the tube helically or by making helical grooves in the inner surface of the duct. Curved flow is also called "continuous swirl flow". Rotating flow is generated by a rotating boundary, either confining the flow (as for a rotating tube) or locally influencing the flow field (as for a spinning body in a free stream). Vortex flow arises when a flow with some initial angular momentum is allowed to decay along the length of a tube. Vortex flow is also called, "decaying swirl flow". Decaying swirl flows are generated by the use of tangential entry swirl generators and guided vane swirl generators. According to Yapici et al. (1992) by using a single tangential inlet duct or more than one tangential entry, tangential entry of the fluid into a duct stream can be achieved. Guided vane swirl generators may be categorized into two types: radial guide vane and axial guide vane. Axial vane swirl generators consist of a set of vanes fixed at a certain angle to the axial direction of the duct, which give a swirling motion to the fluid. Commonly, the vanes are mounted on a central hub and they occupy space in an annular region. Even one single helical vane or twisted tape can be used as a means of generating decaying swirl flow. Radial guide vane swirl generators are generally mounted between two disks and the vanes are so constructed as to be adjustable to obtain the desired initial degree of the swirl. Radial generators are capable of generating much more intense swirls and they cause more complex velocity profiles than axial generators. Because the flow direction must change from

radially inward to axial downstream which can occur either abruptly or by means of a fairing section. An inserted center body (deflecting element) can be used in radial generators whose function is to deflect the flow into the pipe as smoothly as possible.

Experiment on test sections with different diameters was conducted by Binnie et al. (1975). They examined the pressure and velocity distributions inside a convergent nozzle that discharges water downward under pressure. In the test section, a volute for the swirling flow was used. Results show two large departures from inviscid flow because of permanganate injection into the nozzle with a hyperdermic tube inserted through pressure tapping. The decay process of swirling flow in an axially symmetrical, cylindrical pipe in relation to the flow pattern was analyzed by Ito et al. (1978). They also derived an empirical equation for the dimensionless decrease in circulation. Hong et al. (1976) correlated heat transfer and pressure drop data for twisted-tape inserts. They used twisted tape with different twisted ratio to reduce the size of the heat exchanger. They showed that the friction factor is affected by tape twist only at high Reynolds numbers in accordance with analytical predictions. Akpinar et al. (2004) studied swirling flow generated by injection experimentally. The authors studied the effect of holes diameter, holes number and angle of injection on the heat transfer rate and the pressure drop. They found that use of injector to create swirling flow enhances heat transfer rate but it increases the pressure drop and requires more pumping power.

From the above discussion, it can be understood that very few numerical studies have been done on swirl flow. So, there are scopes for further numerical investigations. So, in the present study, a three-dimensional numerical code is developed and validated with theoretical data. The code is then used for numerical simulation to understand the heat transfer characteristics of swirl flow.

Nomenclature

D	Outer diameter of the pipe [m]
L	Length of the pipe [m]
Q	Heat transfer rate [W]
R	Inner radius of the pipe [m]
V	Radial velocity component [m/s]
W	Tangential velocity component [m/s]
d	Inner diameter of the pipe [m]
f	Friction factor
k	Thermal conductivity [W/m K]
q	Heat flux at the outer surface [W/m^2]
r	Local radius of the pipe [m]
$\dot{m}$	Mass flow rate [kg/s]
μ	Dynamic viscosity [Ns/m^2]

ρ	Density [kg/m^3]
C_p	Specific heat at constant pressure [J/kg K]
T_0	Outlet water temperature [^{0}C]
T_i	Inlet water temperature [^{0}C]
U(r)	Axial velocity component [m/s]
U_{max}	Maximum axial velocity of pipe [m/s]
U/ U_{max}	Velocity ratio
Re	Reynolds number

Table 1. Material properties.

Parameters	Water	Copper
Density, ρ (kg/m3)	997.13	8930
Dynamic viscosity, μ (Pa s)	8.9×10-4	–
Thermal conductivity, K (W/m K)	0.58	401
Specific heat at constant pressure, Cp (J/kg K)	4.18×103	380

2.0. Numerical models

The study is carried out to investigate the effects of twisted vanes on heat transfer characteristics of a circular pipe. Two models are considered. In one model, the pipe is fitted with heat resistant vanes and in another model, there are no vanes inside the pipe. In both models, the pipe is made of copper and the working medium is

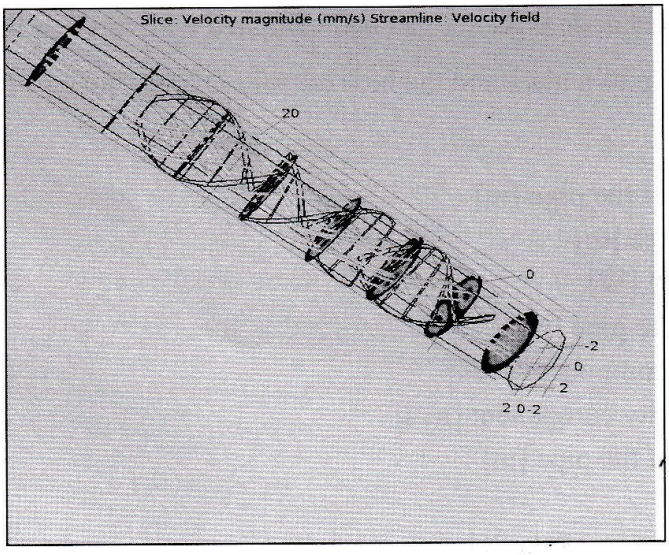

Fig. 1. Streamlines in the pipe fitted with twisted vanes.

water. The pipe for both models has a length of 42mm, an internal diameter of d = 3mm and an outer diameter of 3.5mm. Twisting angles of 22^0, 26^0, 30^0 and 35^0 are used to determine its effects on heat

transfer. Pipe length is varied to obtain the L/d ratios of 11, 12 and 13. The initial temperature and pressure are 298 K and 1atm. respectively. The inlet velocity is varied from 0.01m/s to 0.5m/s to determine the effects of Reynolds Number on heat transfer characteristics. Inlet pressure and surface heat flux are varied from 100 Pa to 700 Pa and 2000 W/m^2 to 14000 W/m^2 respectively.

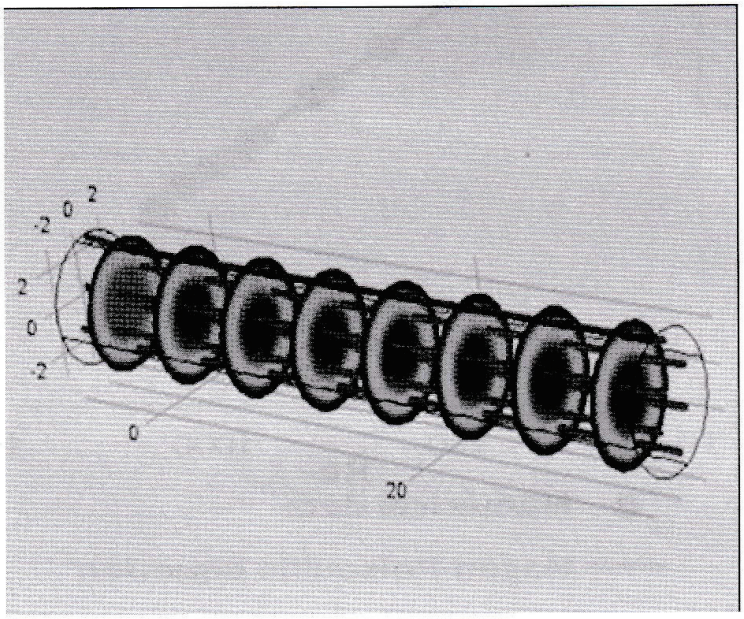

Fig. 2. Streamlines in steady state condition in different sections of the pipe without any vane.

3.1. Mathematical modeling

The governing equations are:

$$\frac{\partial U}{\partial x}+\frac{\partial V}{\partial r}+\frac{V}{r}=0 \quad \text{..... (1)}$$

The amount of heat carried away by the water,

$$Q = \dot{m}C_p(T_0-T_i) \quad \text{.....} \quad (2)$$

Heat supplied to the outer surface of the pipe,

$$Q = (\pi DL)*q \quad \text{.....} \quad (3)$$

Heat transfer efficiency

$$= \frac{\text{Amount of heat carried away by the water}}{\text{Heat supplied to the outer surface of the pipe}}$$

$$= \frac{\dot{m}Cp(T0-Ti)}{(\pi DL)*q} \quad \text{.....} \quad (4)$$

$$\text{Reynolds Number, } Re = \frac{\rho vd}{\mu} \quad \text{.....} \quad (5)$$

3.2. Code validation

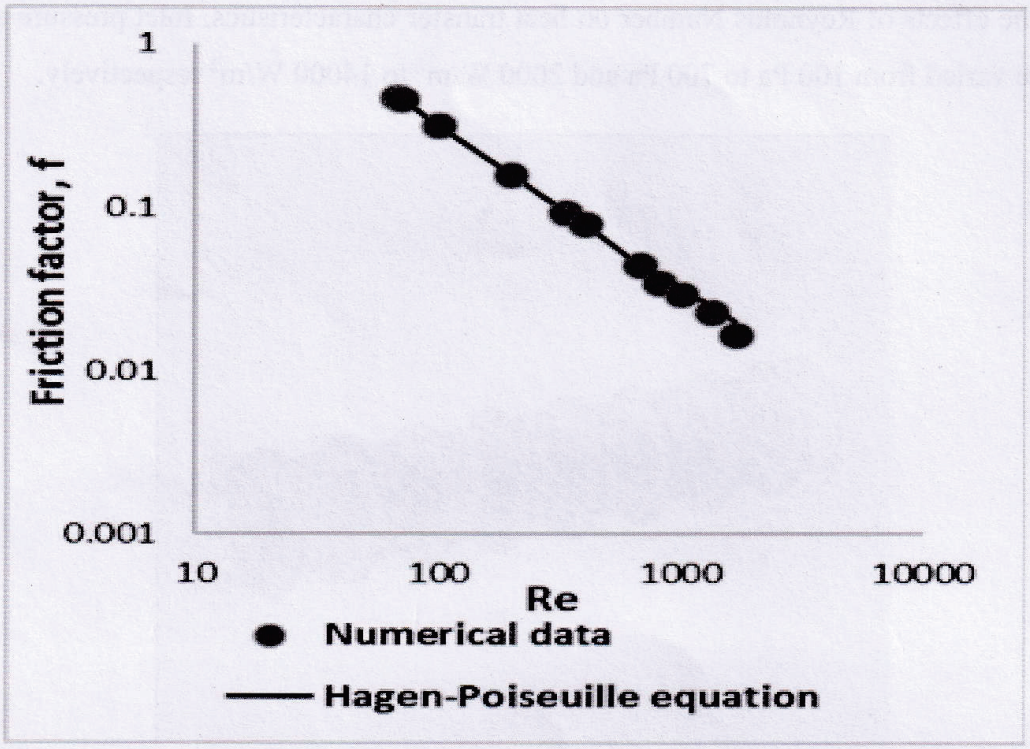

Fig. 3. Numerical and theoretical friction factor in a straight, circular pipe without vanes.

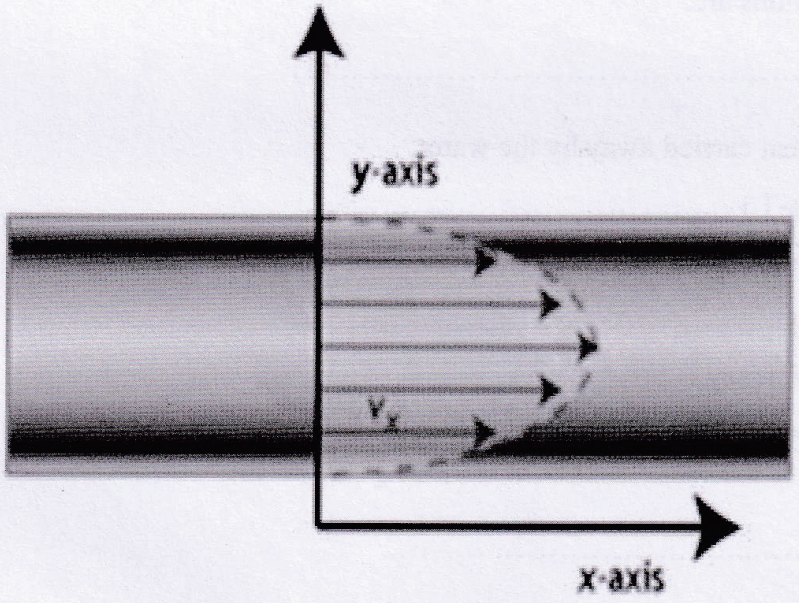

Fig. 4. Theoretical velocity profile for laminar flow.

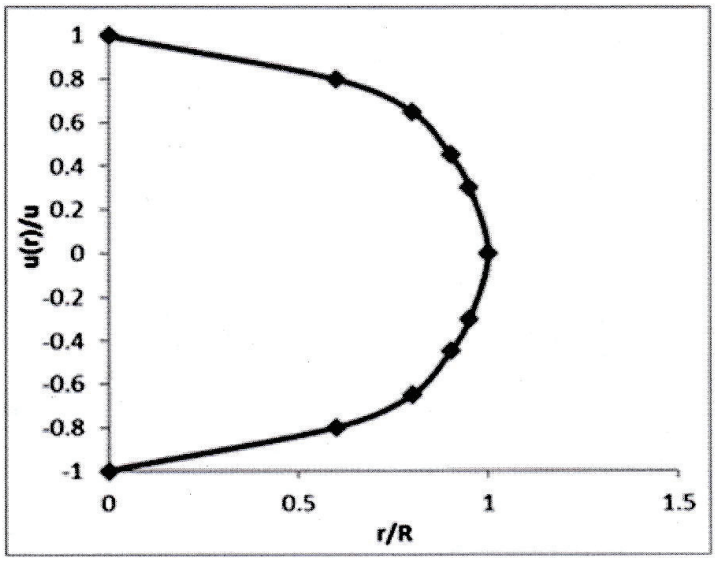

Fig. 5. Velocity profile obtained from numerical study.

To validate the numerical code, laminar flow friction factors in a straight, circular pipe without vanes are calculated from measured pressure drops and flow rates and compared with those given by the Hagen–Poiseuille equation. The comparison shown in Fig. 3 reveals a good agreement between numerical and theoretical results. Furthermore, for fully developed laminar flow, the velocity profile is parabolic as shown in Fig. 4. Fig. 5 shows the velocity profile obtained from the study and it has similar parabolic shape.

4.0. Results and Discussion

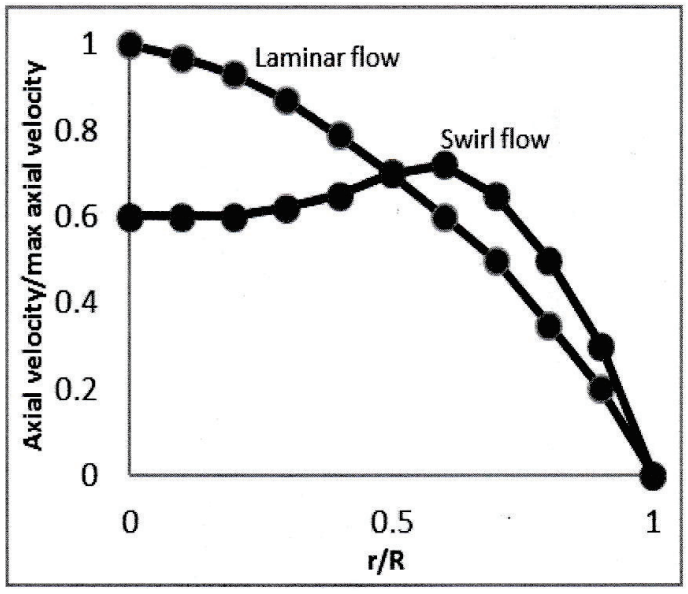

Fig. 6. Radial velocity distribution for x/d=5.

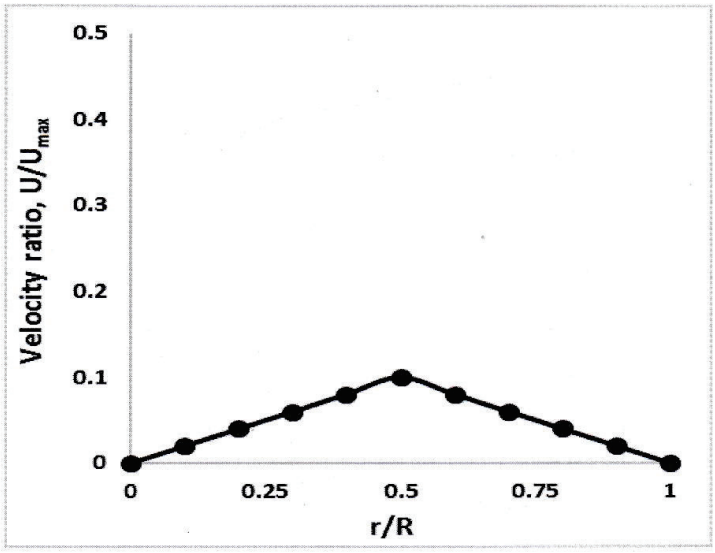

Fig. 7. Tangential velocity distribution for x/d=5.

The axial velocity distribution in the pipe is presented in Fig. 6, where it is revealed that the fully-developed velocity distribution of laminar flow is altered due to the introduction of the swirl. This is due to the destabilizing effect of the swirl. The actual fully-developed profile of laminar flow will be recovered if the vanes are completely removed and the swirl completely disappears. Fig. 7 shows the distribution of the tangential velocity. The tangential velocity is measured along the tangent of the spiral vanes. Due to the presence of this velocity flow rate is increased for swirl flow. This trend of tangential velocity was also reported by Chang et al. (1995) and Bali (1998) for turbulent swirling flow.

4.1 Effects of Swirl Flow

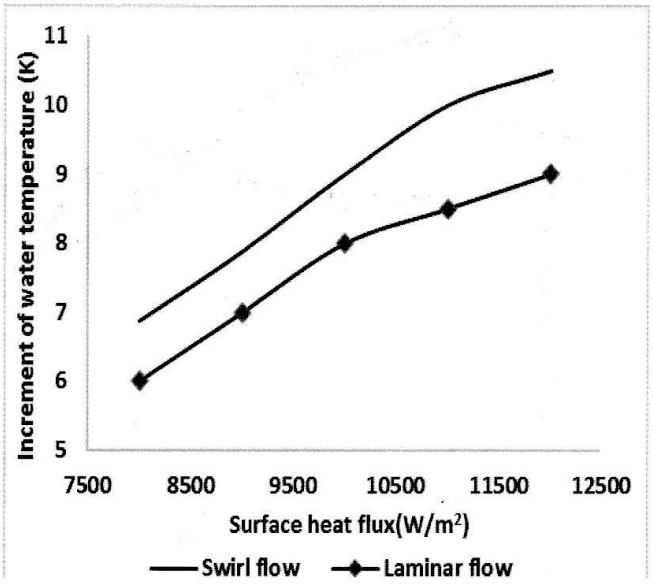

Fig. 8. Increment of water temperature with respect to surface heat flux.

For laminar flow, the maximum local temperature is occurring at the pipe outlet and is greater than that of swirl flow. This is due to the fact that for laminar flow the water layer adjacent to the pipe has higher temperature than that of swirl flow. So, this layer absorbs the highest amount of heat. But for swirl flow different layers of water comes in contact with the pipe at different times. No single layer remains in contact with the pipe at all times. So, no water layer of swirl flow can absorb the same amount of heat as that of laminar flow. Swirl increases the heat transfer due to its stirring effect on water. That is why the average water temperature of swirl flow is greater than that of laminar flow as observed from Fig. 8. It shows that for low heat flux, difference between laminar and swirl flow for the increment of water temperature is low. The difference is higher for high heat flux.

4.2 Effects of Surface Temperature and Surface Heat Flux

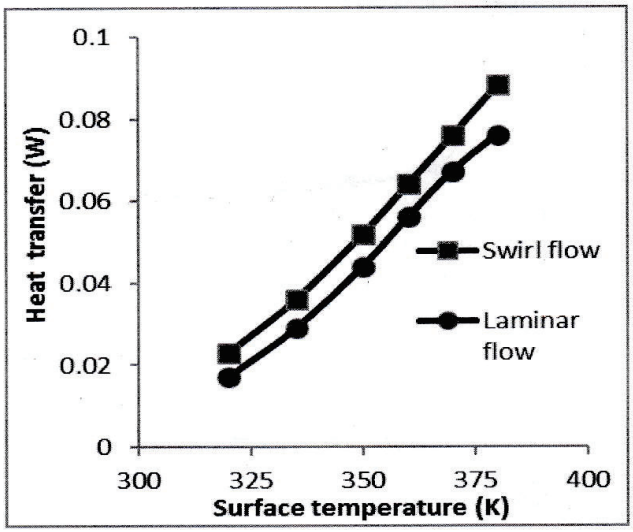

Fig. 9. Heat transfer with the variation of surface temperature.

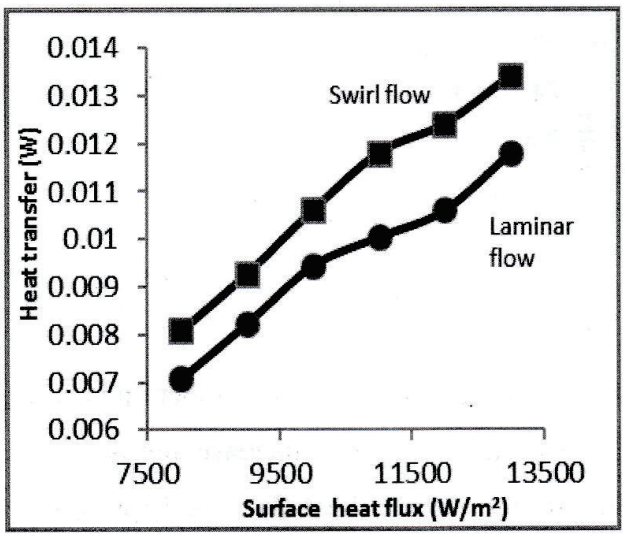

Fig. 10. Heat transfer with surface heat flux.

With the increase of surface temperature and surface heat flux outlet water temperature increases which indicates an increase in heat transfer as shown in Fig. 9 and Fig. 10. In Fig. 9 for different constant surface temperature heat transfer varies almost linearly. However, in swirl flow heat transfer is always higher than that of laminar flow. As the mass flow rate and C_p of water are constant, heat transfer is proportional to temperature increase.

4.3. Effects of Reynolds Number

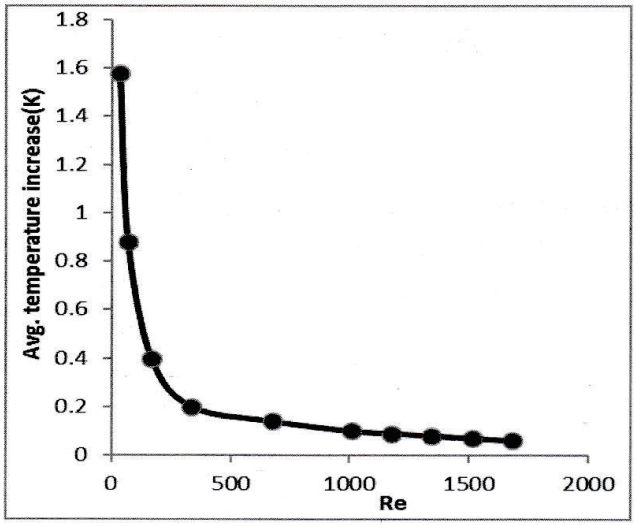

Fig. 11. Effects of Reynolds Number on flow temperature.

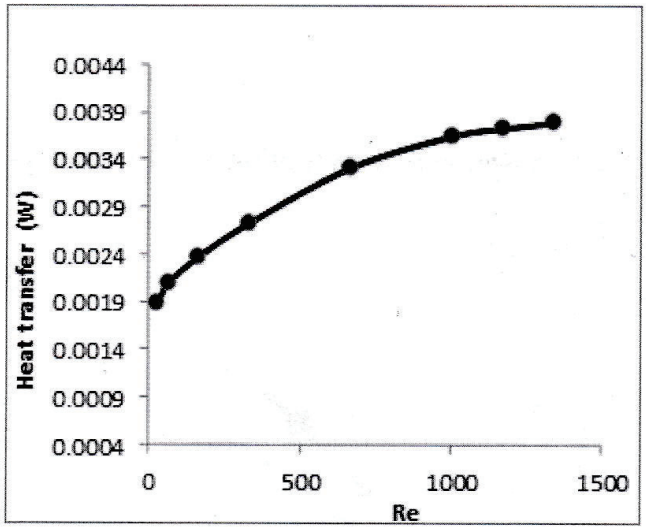

Fig. 12. Effects of Reynolds Number on heat transfer.

The effects of Reynolds Number on temperature increase and heat transfer are shown in Fig. 11 and Fig. 12. The inlet temperature and surface heat flux are kept constant at 298 K and 2000 W/m^2 respectively. With the increase of Reynolds Number, the outlet water temperature decreases because

the water has less time to flow through the pipe and absorb heat. This results in a decrease of the temperature difference. However, heat transfer increases with the Reynolds number due to an increase of mass flow rate. The increase of mass flow rate is greater than the decrease of temperature difference. As a result, heat transfer increases.

4.4. Effects of Inlet Pressure

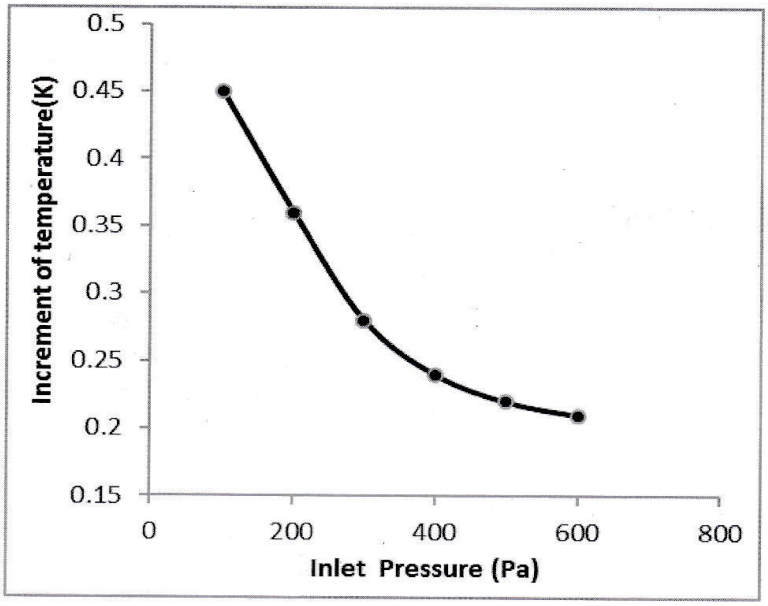

Fig. 13. Effects of inlet pressure on temperature increase.

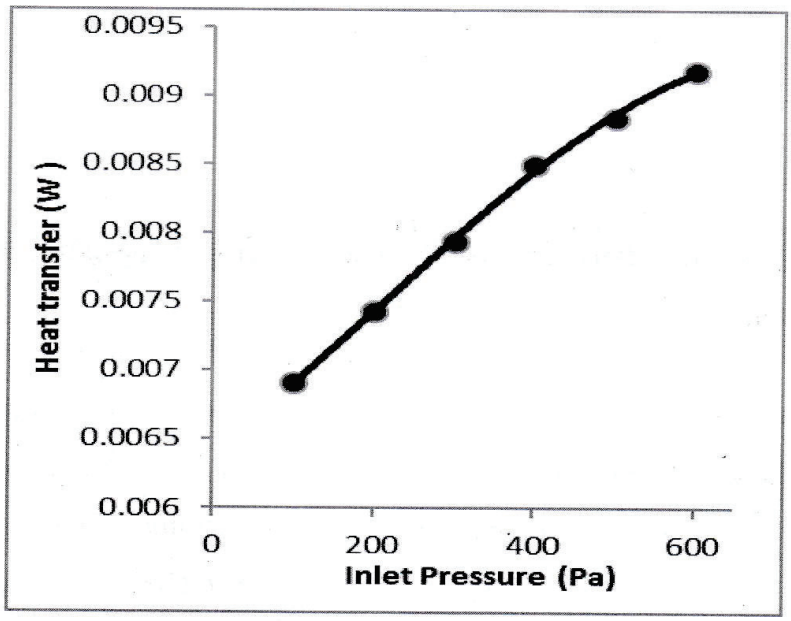

Fig. 14. Effects of inlet pressure on heat transfer.

The effects of inlet pressure are similar to the effects of Reynolds number. This is due to the fact that with the increase of inlet pressure, velocity increases. As a result, flow rate increases and thus heat transfer increases.

4.5. Effects of Twisting Angle

The effects of twisting angles from 22^0 to 35^0 are studied. As shown in Fig. 15, the heat transfer increases with increasing twisting angle. The increase is negligible at first, but after 25^0, heat transfer increases rapidly. With the increase of twisting angle, the tangential velocity increases at nominal constant values of axial velocity.

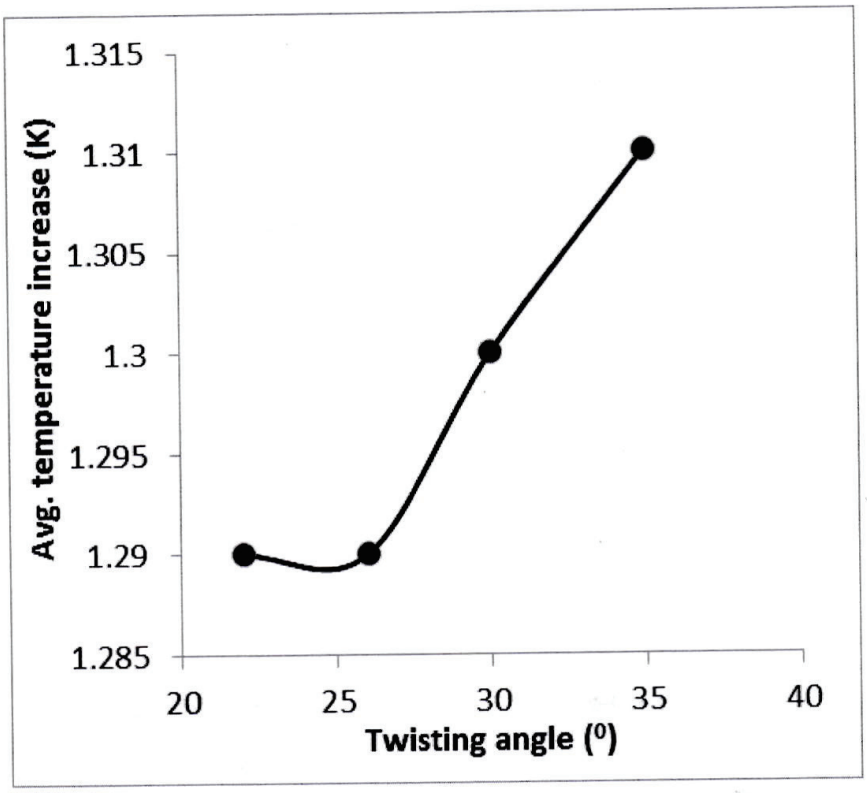

Fig. 15. Effects of twisting angle on average temperature increase.

5.0. Conclusion

The present study is a numerical investigation of heat transfer characteristics of laminar swirling flow through a pipe with continuous vanes. The swirl changes the usual parabolic velocity profile of fully developed laminar flow in the pipe. It is found that swirl flow increases the amount of heat transfer for both surface heat flux and surface temperature. The heat transfer increases with Reynolds Number due to the increase of mass flow rate. The effects of inlet pressure follow a similar pattern. The increase of twisting angle increases the heat transfer due to the increase of stirring effect of the swirl.

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References

Akpinar, E.K.; Bicer, Y.; Yildiz, C.; Pehlivan, D. (2004) Heat Transfer Enhancements in a Concentric Double Pipe Exchanger Equipped with Swirl Elements, Int. Commun. Heat Mass Transfer, Vol. 31, pp 857–868.

Bali, T. (1998) Modeling of Heat Transfer and Fluid Flow for Decaying Swirl Flow in a Circular Pipe, Int. Commun. Heat Mass Transfer, Vol. 25, pp 349–358.

Bali, T.; Ayhan, T. (1999) Experimental Investigation of Propeller Type Swirl Generator for a Circular Pipe Flow, Int. Commun. Heat Mass Transfer, Vol. 26, pp 13–22.

Bergles, A.E.; Jensen, M.K.; Shome, B. (1996) The Literature on Enhancement of Convective Heat and Mass Transfer, J. Enhanced Heat Transfer, Vol. 4, pp 1–6.

Bergles. A.E. (1985) Techniques to Augment Heat Transfer. In Handbook of Heat Transfer Applications, McGraw-Hill, New York.

Binnie, A.M.; Teare, J.D. (1957) Experiments on The Flow of Swirling Water Through a Pressure Nozzle and Open Trumpet, Quart J. of Mech. And applied Math., Vol. 10, pp 78-89.

Chang, F.; Dhir, V. K. (1995) Mechanisms of Heat Transfer Enhancement and Slow Decay of Swirl in Tubes Using Tangential Injection. Int. J. Heat Fluid Flow, Vol. 16, pp 78–87.

Gupta, A.K.; Lilley, D.G.; Syred, N. (1984) Swirl Flows, Abacus Press, Cambridge.

Herman, C.; Kang, E. (2002) Heat Transfer Enhancement in a Grooved Channel with Curved Vanes, Int. J. Heat Mass Transfer, Vol. 45, pp 3741–3757.

Hong, S.W.; Bergles, A.E. (1976) Augmentation of Laminar Flow Heat Transfer in Tube by Means of Twisted-tape Inserts, J. Heat Transfer, Vol. 99, pp 251–256.

Ito, S.; Ogawa, K.; Kuroda, C. (1978) Decay process of swirling in a circular pipe, Proc. Soc. Chem. Eng., Vol. 4, pp 247–251.

Mostafa, A.A. (1980) Effect of Swirl Angle and Geometry on Heat Transfer in Turbulent Pipe Flow, M.Sc. Thesis, Faculty of Engineering, Cairo University.

Razgaitis, R.; Holman, J.P. (1976) A Survey of Heat Transfer in Confined Swirl Flows. Heat Mass Transfer Processes, Vol. 2, pp 831–66.

Saraç, B.A.; Bali, T. (2007) An Experimental Study on Heat Transfer and Pressure Drop Characteristics of Decaying Swirl Flow through a Circular Pipe with a Vortex Generator, Exp. Thermal Fluid Science, Vol. 32, pp 158–165.

Yapici, S. (1992) Electrochemical Mass Transfer in Annular Swirl Flow, PhD Thesis, University of Exeter, Exeter, U.K.

Zaherzadeh, N.H.; Jagadish, B.S. (1975) Heat Transfer in Decaying Swirl Flows, Int. J. Heat and Mass Transfer, Vol. 18, pp 941–944.



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