Online ISSN : 2249-4596
Print ISSN : 0975-5861

GLOBAL JOURNAL

OF RESEARCHES IN ENGINEERING: A

Mechanical & Mechanics Engineering

Liquid Fuel Production

Thermal Analysis of Concrete

Highlights

Energy Storage Application

Chamfering Machine Operations

Discovering Thoughts, Inventing Future

VOLUME 14 ISSUE 5 VERSION 1.0

Global Journal of Researches in Engineering: A
Mechanical and Mechanics Engineering

Global Journal of Researches in Engineering: A
Mechanical and Mechanics Engineering
Volume 14 Issue 5 (Ver. 1.0)

Open Association of Research Society

Incorporation No.: 0423089
License No.: 42125/022010/1186
Registration No.: 430374
Import-Export Code: 1109007027
Employer Identification Number (EIN):
USA Tax ID: 98-0673427

Global Journals Inc.

*(A Delaware USA Incorporation with "Good Standing"; **Reg. Number: 0423089**)*

Sponsors: Open Association of Research Society
Open Scientific Standards

Publisher's Headquarters office

Global Journals Headquarters
301st Edgewater Place Suite, 100 Edgewater Dr.-Pl,
Wakefield MASSACHUSETTS, Pin: 01880,
United States of America
USA Toll Free: +001-888-839-7392
USA Toll Free Fax: +001-888-839-7392

Offset Typesetting

Global Journals Incorporated
2nd, Lansdowne, Lansdowne Rd., Croydon-Surrey,
Pin: CR9 2ER, United Kingdom

Packaging & Continental Dispatching

Global Journals
E-3130 Sudama Nagar, Near Gopur Square,
Indore, M.P., Pin:452009, India

Find a correspondence nodal officer near you

To find nodal officer of your country, please email us at *local@globaljournals.org*

eContacts

Press Inquiries: *press@globaljournals.org*
Investor Inquiries: *investors@globaljournals.org*
Technical Support: *technology@globaljournals.org*
Media & Releases: *media@globaljournals.org*

Pricing (Including by Air Parcel Charges):

For Authors:
22 USD (B/W) & 50 USD (Color)
Yearly Subscription (Personal & Institutional):
200 USD (B/W) & 250 USD (Color)

Integrated Editorial Board
(Computer Science, Engineering, Medical, Management, Natural Science, Social Science)

Dr. Bart Lambrecht
Director of Research in Accounting and FinanceProfessor of Finance
Lancaster University Management School
BA (Antwerp); MPhil, MA, PhD (Cambridge)

Dr. Carlos García Pont
Associate Professor of Marketing
IESE Business School, University of Navarra
Doctor of Philosophy (Management), Massachusetts Institute of Technology (MIT)
Master in Business Administration, IESE, University of Navarra
Degree in Industrial Engineering, Universitat Politècnica de Catalunya

Dr. Fotini Labropulu
Mathematics - Luther College
University of ReginaPh.D., M.Sc. in Mathematics
B.A. (Honors) in Mathematics
University of Windso

Dr. Lynn Lim
Reader in Business and Marketing
Roehampton University, London
BCom, PGDip, MBA (Distinction), PhD, FHEA

Dr. Mihaly Mezei
ASSOCIATE PROFESSOR
Department of Structural and Chemical Biology, Mount Sinai School of Medical Center
Ph.D., Etvs Lornd University
Postdoctoral Training,
New York University

Dr. Söhnke M. Bartram
Department of Accounting and FinanceLancaster University Management SchoolPh.D. (WHU Koblenz)
MBA/BBA (University of Saarbrücken)

Dr. Miguel Angel Ariño
Professor of Decision Sciences
IESE Business School
Barcelona, Spain (Universidad de Navarra)
CEIBS (China Europe International Business School).
Beijing, Shanghai and Shenzhen
Ph.D. in Mathematics
University of Barcelona
BA in Mathematics (Licenciatura)
University of Barcelona

Philip G. Moscoso
Technology and Operations Management
IESE Business School, University of Navarra
Ph.D in Industrial Engineering and Management, ETH Zurich
M.Sc. in Chemical Engineering, ETH Zurich

Dr. Sanjay Dixit, M.D.
Director, EP Laboratories, Philadelphia VA Medical Center
Cardiovascular Medicine - Cardiac Arrhythmia
Univ of Penn School of Medicine

Dr. Han-Xiang Deng
MD., Ph.D
Associate Professor and Research
Department Division of Neuromuscular Medicine
Davee Department of Neurology and Clinical NeuroscienceNorthwestern University
Feinberg School of Medicine

Dr. Pina C. Sanelli
Associate Professor of Public Health
Weill Cornell Medical College
Associate Attending Radiologist
NewYork-Presbyterian Hospital
MRI, MRA, CT, and CTA
Neuroradiology and Diagnostic Radiology
M.D., State University of New York at Buffalo,School of Medicine and Biomedical Sciences

Dr. Roberto Sanchez
Associate Professor
Department of Structural and Chemical Biology
Mount Sinai School of Medicine
Ph.D., The Rockefeller University

Dr. Wen-Yih Sun
Professor of Earth and Atmospheric SciencesPurdue University Director
National Center for Typhoon and Flooding Research, Taiwan
University Chair Professor
Department of Atmospheric Sciences, National Central University, Chung-Li, TaiwanUniversity Chair Professor
Institute of Environmental Engineering, National Chiao Tung University, Hsin-chu, Taiwan.Ph.D., MS The University of Chicago, Geophysical Sciences
BS National Taiwan University, Atmospheric Sciences
Associate Professor of Radiology

Dr. Michael R. Rudnick
M.D., FACP
Associate Professor of Medicine
Chief, Renal Electrolyte and Hypertension Division (PMC)
Penn Medicine, University of Pennsylvania
Presbyterian Medical Center, Philadelphia
Nephrology and Internal Medicine
Certified by the American Board of Internal Medicine

Dr. Bassey Benjamin Esu
B.Sc. Marketing; MBA Marketing; Ph.D Marketing
Lecturer, Department of Marketing, University of Calabar
Tourism Consultant, Cross River State Tourism Development Department
Co-ordinator , Sustainable Tourism Initiative, Calabar, Nigeria

Dr. Aziz M. Barbar, Ph.D.
IEEE Senior Member
Chairperson, Department of Computer Science
AUST - American University of Science & Technology
Alfred Naccash Avenue – Ashrafieh

Contents of the Volume

Global Journal of Researches in Engineering: A
Mechanical and Mechanics Engineering
Volume 14 Issue 5 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

A Correlation for the Pool Boiling Enhancement Factor from Low Finned Tubes

By Ali Hussain Tarrad & Damiaa Saad Khudor
Al-Mustansiriya University, Jordan

Abstract- The present work is devoted to formulate the enhancement factor of single enhanced, integrally machined finned tube boiling pure liquids in terms of active measures related to the boiling process. A new suggested correlation for the estimation of the nucleate pool boiling heat transfer coefficient was developed. The effects of the convective term due to the phase density differences and operating pressure on the boiling process were considered to stand independently. Eleven liquids, R-11, R-12, R-22, R-113, R-114,R123, R124, 134a, n-pentane, ethanol, water, boiling on the low finned tube, at different pressure for a heat flux in the range between (10) and (50) kW/m^2 were considered. The total mean absolute error of the enhancement factors was (13.3%) for the whole range of data points. It was improved to be (10.8 %) for more than (95 %) of the data points. The correlation revealed its sensitive dependency for the enhancement factor on the parameters selected for its formulation. Most of the predicted enhancement factor values fell within (± 25) %deviation from the experimental data.

Keywords: *nucleate boiling, machined tubes, enhancement factor, correlation, refrigerant.*

GJRE-A Classification : *FOR Code: 091399*

Strictly as per the compliance and regulations of:

A Correlation for the Pool Boiling Enhancement Factor from low Finned Tubes

Ali Hussain Tarrad [α] & Damiaa Saad Khudor [σ]

Abstract- The present work is devoted to formulate the enhancement factor of single enhanced, integrally machined finned tube boiling pure liquids in terms of active measures related to the boiling process. A new suggested correlation for the estimation of the nucleate pool boiling heat transfer coefficient was developed. The effects of the convective term due to the phase density differences and operating pressure on the boiling process were considered to stand independently. Eleven liquids, R-11, R-12, R-22, R-113, R-114,R123, R124, 134a, n-pentane, ethanol, water, boiling on the low finned tube, at different pressure for a heat flux in the range between (10) and (50) kW/m^2 were considered. The total mean absolute error of the enhancement factors was (13.3%) for the whole range of data points. It was improved to be (10.8 %) for more than (95 %) of the data points. The correlation revealed its sensitive dependency for the enhancement factor on the parameters selected for its formulation. Most of the predicted enhancement factor values fell within (± 25) %deviation from the experimental data.

Keywords: nucleate boiling, machined tubes, enhancement factor, correlation, refrigerant.

I. Introduction

The surface structure has been proved either experimentally or theoretically to have a vital role on the heating element performance during the boiling process, Kurihara and Myers (1960) and Griffith and Wallis (1960). Ahmad (2012) investigated saturated pool boiling of R-123 from five horizontal copper surfaces modified by different treatments. He has found that significant enhancement of heat transfer was demonstrated with increasing surface roughness. Fig. 1shows a schematic diagram of one of the available commercial surfaces implemented in boiling process known as a low finned tube.

Marto and Lepere (1981) showed that the pool boiling heat transfer coefficient when boiling R-113 and FC-72 was strongly related to the liquid-surface combination factor, the past history of the surface and the operating liquid properties. Yilmaz et al. (1981) found that the enhancement in the boiling heat transfer coefficients of p-xylene and isopropyl alcohol depends on the operating conditions and boiling liquid type. Marto and Hernandez (1983) reported an enhancement factor of about three times when boiling R-113 on the Gewa-T surface at atmospheric pressure. Hahne and Muller (1983) have found an improvement in the boiling heat transfer coefficient of R-11 when compared the finned tubes with that of the smooth one.

Kandikar and Howell (1996) reported an increase in bubble activity on a micro fin surface when compared to a plain surface for flow boiling investigation. Yuming et al. (2003) made a comparison between the smooth and enhanced tubes for bubble nucleation characteristics. These are assigned as growth rate, departure diameter, frequency, active site density and rise velocity. The effects of physical properties on the bubble dynamics were clear especially the departure diameter and the nucleation site density.

Yilmaz and Westwater(1981) concluded that the enhancement in heat transfer performance depends on the enhanced surface structure and liquid properties. In addition to these factors, Tarrad (1991) has concluded that the enhancement factor of the enhanced tubes is also a strong function of whether the boiling fluid was a pure or mixture substance. Ricardo (1984) has concluded that the enhancement shows a dependency on the vapor density, latent heat and thermal conductivity of the boiling fluid.

The operating heat flux, pressure, surface condition and thermal physical properties will be incorporated in a simple correlation to predict the enhancement factor. Eleven pure fluids boiling on a low finned tube, possessing quite a good range of thermal properties and operating pressure will be implemented to establish the present correlation.

Author α, σ: Department of Mechanical Engineering, College of Engineering, Al-Mustansiriya University, Baghdad, Iraq.
e-mails: dr.alitarrad@yahoo.com, damiaasaad@yahoo.com

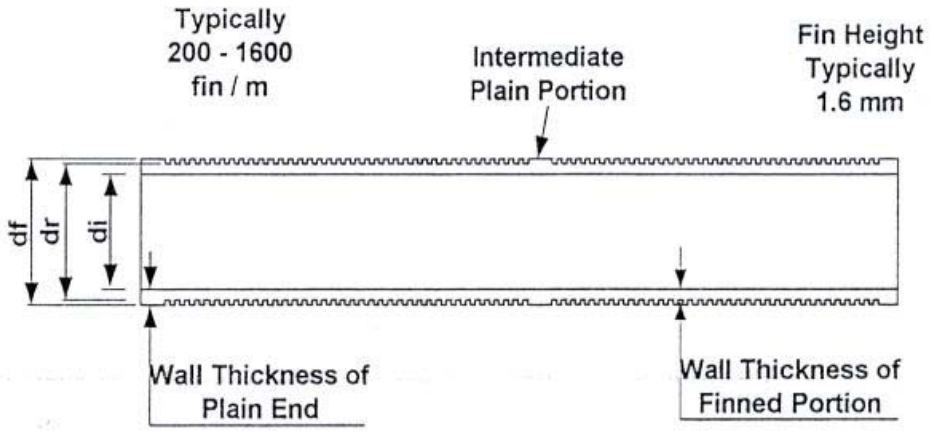


Figure 1 : A schematic diagram for a typical low finned tube

II. Available Correlations

The available correlations in the open literature are either semi-empirical or they require a large number of parameters to be determined prior to the application of such correlations, Tarrad (2011). This of course will exhibit an additional difficulty of handling the enhanced surface effect on the boiling heat transfer performance prediction.

Palen and Yang (1983) proposed a correlation for the prediction of the boiling heat transfer coefficient on low finned tube in the form:

$$\alpha_{L-F} = F_c F_e \eta \alpha_{pla.} + \alpha_{nc} \quad (1)$$

Where ($\alpha_{pla.}$) is the boiling heat transfer coefficient achieved by a plain tube and (α_{nc}) is the natural convection part of the heating surface which is usually small; of the order of (250) W/m^2 K for hydrocarbons. The mixture correction factor (F_c), and the fin efficiency (F_e) were given a specified numerical values. They represented a formula for the surface factor (η) in the form:

$$\eta = C_1 \left(\frac{q}{q_{ref}}\right)^{m_1} \left(\frac{p}{p_c}\right)^{m_2} F_c^{\,m_3} \quad (2)$$

The authors postulated that this expression has been found by the (HTRI) organization and no numerical values for the exponents and the empirical constant were specified.

Xin and Chao (1987) presented a model to describe the boiling heat transfer coefficient of flat *Gewa-T* surfaces. The resultant correlation has the form:

$$Nu = 3.76 \left(\frac{2H+L}{2D}\right) {Ar_D}^{1/3}\, {Re_l}^{-0.15} We^{0.29} {Pr_l}^{0.76} \quad (3)$$

Where:

$$Nu = \frac{q\,s}{\Delta T_s k_l} = \frac{h\,s}{k_l} \quad (4.a)$$

$$Ar_D = \frac{g\,D^3}{{V_l}^2} \frac{\rho_l - \rho_g}{\rho_l} \quad (4.b)$$

$$Re_l = \frac{2\,q\,s}{h_{fg}\,\mu_l} \quad (4.c)$$

$$We = \frac{{q_{ev}}^2 s^2}{\sigma\,\rho_g {h_{fg}}^2\, D} \quad (4.d)$$

$$Pr_l = \frac{V_l}{a_l} \quad (4.e)$$

The authors tested the general formula, eq. (3), with many types of the Gewa-T surface boiling water, ethanol and R-113. The fin shape and structure has a variable fin gaps, pitches, and heights. They concluded that the expression presented in eq. (3) correlated the experimental data within accuracy of (±30%). Thome (1990) tested this correlation with data of different refrigerants (R-11, R-12, R-22, and R-113), isopropanol and p-xylene boiling on Gewa-T tubes. He concluded that this formula showed a poor agreement with the experimental data for the tested refrigerants.

Chen et al. (1989) proposed a model to predict the boiling heat transfer coefficients ofR-11from copper single and twin finned tube arrangements for the heat flux range (20) to (50) kW/m^2. Their correlation involved three empirical constants to be determined for each surface. Tarrad (1991) correlated his own results for boiling on the plain and enhanced surfaces at the atmospheric pressure as:

$$q = C_1 \Delta T^{\,n} \text{ for5} \le q \le 60 \text{ kW/m}^2 \quad (5)$$

Where the empirical constant *(C_1)* and the wall superheat index *(n)* were given for each liquid - surface combination. These values showed a great dependence on the liquid properties and surface structure considered.

Tarrad (2007) attempted to formulate the enhancement factor for externally integral machined finned tubes boiling different liquids for a heat flux range between (10) kW/m^2 and (50) kW/m^2. The liquids considered were R-113, n-pentane, ethanol, water, p-xylene and R-11. The general form of his correlation can be expressed as follows:

$$\eta = C_{S,F}\left(\frac{\rho_l h_{fg}^{3/2}}{q}\right)^{0.1856}\left(\frac{cp_l\sigma}{k_l h_{fg}^{0.5}}\right)^{0.3}\left(\frac{p}{p_c}\right)^{-0.2} \quad (6)$$

The coefficient *($C_{S,F}$)* was given a different numerical value for each of the surface-liquid combination considered in the formulated correlation as tabulated values. This correlation showed a total absolute mean errors for the boiling heat transfer coefficient of (8%) and (9%) for the *low finned* and *Gewa-T* tubes respectively. For the same heat flux range and *R-113, n-pentane, ethanol, water* and R-11 boiling fluids, Tarrad (2011) has postulated a more comprehensive formula for the prediction of the pool boiling enhancement factor of *low finned* and *Gewa-T* tubes. His correlation had the form:

$$\eta = C_{S,F}\left(\frac{\rho_l h_{fg}^{3/2}}{q}\right)^{0.1806}\left(\frac{cp_l\sigma}{k_l h_{fg}^{0.5}}\right)^{1.7} \quad (7)$$

The coefficient *($C_{S,F}$)* was given a different numerical value for each of the considered surfaces as (0.389) and (0.48) for the *low finned* and *Gewa-T* tubes respectively. This correlation has showed a total mean absolute errors of the boiling heat transfer coefficients of (9.5%) and (13.5%) for the low finned and *Gewa-T* tubes respectively. A thoroughly inspection for this equation reveals that the predicted enhancement factor of *Gewa-T* surface is about 24% higher than that of the *Low finned* tube for the same test fluids and operating conditions.

III. The Present Correlation

a) Theoretical Background

The present correlation represents an extension to Tarrads' previous correlations, (2007) and (2011) as shown in equations (6) and (7) respectively, for the integrally machined enhanced tubes. It has been proved previously that the enhancement factor is directly proportional to the boiling liquid physical properties, operating pressure and heat flux, and enhancement structure, Marto and Lepere (1981), Yilmaz and West water (1981), Tarrad (1991) and many other investigators. The physical specification effect of the external enhancement of the boiling tube can be demonstrated by the surface area. It is suggested to formulate this parameter as a surface area ratio. This can be expressed as the ratio of the finned surface area to the fin root area of the tube, λ. As a matter of fact, this includes the effect of fin density defined as number of fins per inch; fin spacing, shape and height. The above argument can be expressed as:

$$\eta = \eta\left(h_{fg}, \rho_l, \rho_v, k_l, cp_l, \sigma, q, \lambda, p_r\right) \quad (8)$$

Where (η) refers to the enhancement factor defined by:

$$\eta = \frac{\alpha_{enh.}}{\alpha_{pla.}} = \frac{\Delta T_{pla.}}{\Delta T_{enh.}} \quad (9)$$

The enhanced surface nucleate boiling heat transfer coefficient is therefore has the form:

$$\alpha_{enh.} = \eta\alpha_{pla.} \quad (10.a)$$

In terms of the wall superheats in the form:

$$\Delta T_{enh.} = \frac{\Delta T_{pla.}}{\eta} \quad (10.b)$$

The plain nucleate pool boiling heat transfer coefficient, α_{pla}, is predicted by the available correlations such as Gorenflo (1993) equation in the following expression:

$$\alpha_{pla.} = \alpha_0 F_{PF}\left(\frac{q}{q_0}\right)^{nf}\left(\frac{R_p}{R_{p0}}\right)^{0.133} \quad (11.a)$$

The pressure correction factor (F_{PF}) is

$$F_{PF} = 1.2\,p_r^{0.27} + 2.5\,p_r + \frac{p_r}{1-p_r} \quad (11.b)$$

And

$$nf = 0.9 - 0.3\,p_r^{0.3} \quad (11.c)$$

Equations (11.b) and (11.c) are applied for all of the tested fluids in his correlation except water and Helium; for water the corresponding equations are:

$$F_{PF} = 1.73\,p_r^{0.27} + \left(6.1 + \frac{0.68}{1-p_r}\right)p_r^{2} \quad (11.d)$$

And

$$nf = 0.9 - 0.3\,p_r^{0.15} \quad (11.e)$$

In this method, R_{p0}=0.4 μm and q_0= 20000W/m^2. The value of the surface roughness R_p is set to (0.4) μm when unknown. The correlation is applicable for a reduced pressure range from about 0.0005 to 0.95. The reference heat transfer coefficient α_0 is listed in table (1) for the fluids considered in the present work.

For fluids which are not covered with the above correlation, it is suggested to use Mostinski (1963) correlationin the form:

$$\alpha_{pla.} = 0.1 p_c^{0.69} q^{0.7} F(p_r) \quad (12.a)$$

Where

$$F(p_r) = 1.8 p_r^{0.17} + 4 p_r^{1.2} + 10 p_r^{10} \quad (12.b)$$

In this formula, (p_c) is in bar, (q) in W/m^2 and ($\alpha_{pla.}$) in W/m^2 K. This correlation has been tested for a long time with different liquids and showed acceptable agreement with the experimental data.

b) Correlation Formulation

In performing a dimensional analysis from the independent variables, the four dimensions will be considered for these variables (M, L, T, θ) together with four selected repeating variables (h_{fg}, ρ_l, k_l and cp_l). There are ten variables expressed in terms of four fundamental dimensions. Therefore, the equation relating the variables will contain six independent dimensionless groups including the reduced pressure group in the forms:

$$\pi_1 = \eta \quad (13.a)$$

$$\pi_2 = \frac{\rho_l h_{fg}^{3/2}}{q} \quad (13.b)$$

$$\pi_3 = \left(\frac{\sigma}{k_l}\right) \frac{cp_l}{h_{fg}^{0.5}} \quad (13.c)$$

$$\pi_4 = \frac{\rho_v}{\rho_l} \quad (13.d)$$

$$\pi_5 = \lambda \quad (13.e)$$

$$\pi_6 = \frac{p}{p_c} = p_r \quad (13.f)$$

Therefore, the suggested correlation has the following expression:

$$\pi_1 = \phi(\pi_2, \pi_3, \pi_4, \pi_5, \pi_6) \quad (14.a)$$

$$\eta = \phi\left\{\left(\frac{\rho_l h_{fg}^{3/2}}{q}\right), \left(\frac{cp_l \sigma}{k_l h_{fg}^{0.5}}\right), \left(\frac{\rho_v}{\rho_l}\right), (\lambda), (p_r)\right\} \quad (14.b)$$

This function may be represented in an equation with the form:

$$\eta = C_{S,F} \left(\frac{\rho_l h_{fg}^{3/2}}{q}\right)^m \left(\frac{cp_l \sigma}{k_l h_{fg}^{0.5}}\right)^n \left(\frac{\rho_v}{\rho_l}\right)^i \lambda^j \left(\frac{p}{p_c}\right)^\kappa \quad (14.c)$$

The independent groups (π_2) and (π_3) are reflecting the effect of the enhancement structure on the ability of bubble nucleation activity and departure parameters, the bubble size and frequency. The first group, (π_2), represents the rate of vaporization of the boiling liquid at the vicinity of the heating element. In fact it represents the intensity of bubble generation in the liquid layer penetrating through the tunnels of the surface structure. The second group, (π_3), corresponds to the effect of the surface tension force during the bubble detachment for the heating surface and the force implemented by the vapor generation and its movement in the structure tunnels at the heating surface.

The effect of the density difference between the vapor and liquid phases, which represents the effect of convective term during bubble nucleation and growth rate, is shown by (π_4). This will induce a momentum effect on the bubble nucleation and its intensity at the enhanced surface. The effect of the available finned tube surface area including the fin specifications on the heat transfer process is stated by the ratio (λ) as (π_5). The last group, (π_6), represents the effect of the operating pressure on the enhancement factor, hence the predicted nucleate boiling heat transfer coefficient.

The experimental data published in the open literature shown in table (2) is used in creation of the present correlation. More than (400) data points for the heat flux range between (10) and (50) kW/m^2 at different pressure were used. The thermal physical properties of the pure liquids tested by the present correlation are shown in table (3). These values are deduced from Tarrad (1991), Incropera and Dewitt (1990), Sinnott (1986) and Du Pont technical information catalogue.

Hence the best prediction of the enhancement factor for the whole range of the experimental data was obtained by:

$$\eta = 0.2411 \left(\frac{\rho_l h_{fg}^{3/2}}{q}\right)^{0.0864} \left(\frac{cp_l \sigma}{k_l h_{fg}^{0.5}}\right)^{1.40} \left(\frac{\rho_v}{\rho_l}\right)^{0.115} \lambda^{1.125} \left(\frac{p}{p_c}\right)^{-0.271} \quad (15)$$

The standard deviation of the fitted data was within (0.308) and the average absolute residual of the data points was (0.237) for this correlation. It showed a total mean absolute error of (13.3 %) for the whole ranges of heat flux and operating pressure implemented with the test fluids in the present work. Fig. 2. shows the residual versus the predicted values for the whole range of data points implemented by the present suggested correlation.

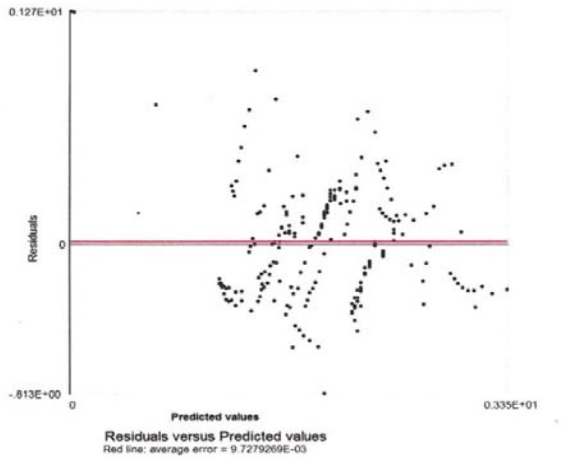


Figure 2 : A distribution diagram of the residual versus predicted values by the present correlation

The numerical values of *(m), (n), (i), (j)* and *(κ)* conclude that the enhancement factor shows a decrease as the operating heat flux, liquid surface tension, and the operating system pressure increase. This behavior is perfectly corresponds to the experimental data tested in the present work from the point of view of the effect of the heat flux and other physical properties on the predicted enhancement factor. The effect of (λ) is mainly revealed by increasing the exposed surface area of the tube to accomplish heat transfer and increasing the intensity of bubble nucleation.

With increase in the operating pressure, increase in reduced pressure, the enhancement in heat transfer achieved by the finned tube structure over the plain surface tends to decrease. This is exactly coinciding with the results obtained by different investigators such as Aniruddha and Yogendra (2006) and Yilmaz etal. (1981) when boiling fluids on enhanced surfaces. Palen and Yang (1983) concluded that the reduced pressure exponent, m_2, has a negative value in an enhancement correlation presented in the form of Eq.(2). However, no numerical values for all of the coefficients in the above equation were given in the open literature.

c) Boiling Heat Transfer Coefficient Formula

The final form of the suggested correlation of the present work is obtained by applying the above formula of the enhancement factor correlation, eq. (15), to the plain tube prediction equation either eq. (11) or eq.(12). The choice of implementation of the plain tube nucleate boiling heat transfer coefficient correlation depends on the accuracy and limitations of the considered equation. Gorenflo (1993) correlation has been used to predict the plain tube heat transfer coefficient for all of the test liquids in the present work. Thus, the general form of the present correlation is represented by eq. (16) as:

$$\alpha_{enh} = 0.2411\ \alpha_{pla.}\left(\frac{\rho_l h_{fg}{}^{3/2}}{q}\right)^{0.0864}\left(\frac{cp_l\,\sigma}{k_l h_{fg}{}^{0.5}}\right)^{1.40}\left(\frac{\rho_v}{\rho_l}\right)^{0.115}\lambda^{1.125}\left(\frac{p}{p_c}\right)^{-0.271} \quad (16)$$

IV. Results and Discussion

The present formula was tested against different liquids boiling on the plain and low finned surfaces at different pressures. The errors percentage of the predicted enhancement factor by eq.(15),is defined by the following expression:

$$(Err\%)_{\eta} = \frac{\eta_{pred.} - \eta_{meas.}}{\eta_{meas.}} \times 100 \quad (17)$$

The mean absolute error of the above expression is also calculated by:

$$(Err\%)_{abs.} = \Sigma\,|Err\%|\ /\ N \quad (18)$$

The correlation showed a quite high accuracy for the enhancement factor of the test surface. The total mean absolute error of the enhancement factor was within (13.3 %) for the whole range of data points. If the data points those located out of range were ignored, then the total mean absolute error will be improved to be (10.8 %) for more than (95 %) of the implemented data points. More than (95 %) of the experimental data fell within the zone bounded by the margin lines of (± 25 %). Fig. 3 shows the predicted and measured enhancement factors of the boiling liquids on the low finned tube structure. It is obvious that the predicted values of (η) by the form of eq.(15) showed a good agreement with those of the measured values and bounded within the limit of (±25%) for more than (95 %) of the data points considered in this work.

It is worthwhile to point out that the accuracy and limitation error margin of the present correlation of the nucleate boiling heat transfer coefficient is directly related to the plain tube prediction values. Therefore, it is recommended to select the most appropriate correlation for this object. We may conclude that the plain tube heat transfer coefficient correlations implemented in the present work are quite acceptable for the test fluids.

The present correlation for the prediction of the enhancement factor of the integral machined heating element showed a good response to the surface and liquid combination type. This concludes that the shape of enhancement and the boiling fluid combination has a great interaction effect on the behavior of the bubble

nucleation in the machined tunnels where the flow of the boiling liquid is very high there. Further, the boiling liquid properties account for the higher part of the influence on the enhancement expected from a specified surface.

For example at atmospheric pressure, the enhancement factor produced by boiling n-pentane was ranged between (2) and (2.6) for the whole range of heat fluxes. The corresponding values of ethanol were bounded between (1.6) and (2). Whereas, boiling of water on this surface didn't show any augmentation for the boiling heat transfer coefficient. On the contrary, this surface showed deterioration for the performance of the heating element for most of the heat flux range. Further, it exhibited the same nucleate pool boiling heat transfer as that of the plain tube at a heat flux of (10) kW/m^2.

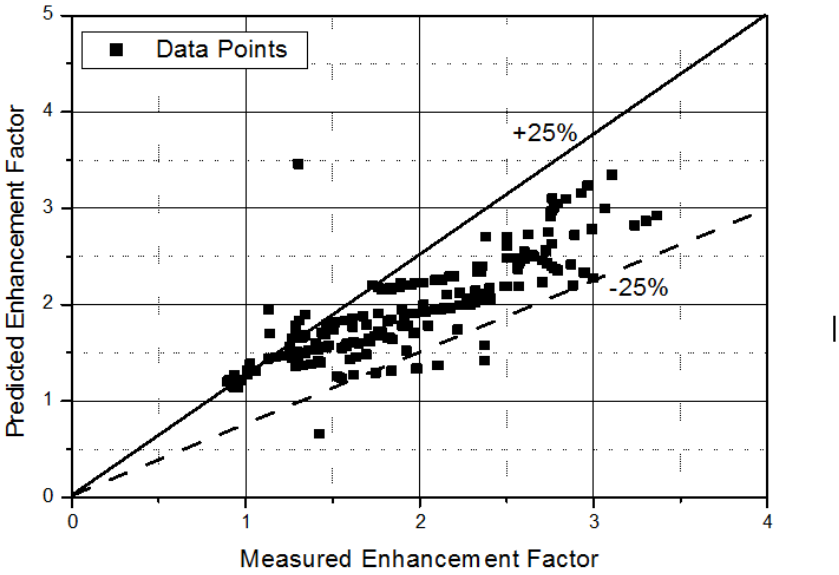


Figure 3 : A Comparison for the predicted enhancement factor with experimental data of the low finned surface

When boiling R-113; the enhancement factor was ranged between (1.8) and (2.6) for the entire range of the heat flux applied in the present work. This behavior of the variation was also exhibited by the present formula for the prediction of the enhancement factor of the enhanced surface.

V. Conclusions

A general form of correlation for the enhancement factor exhibited by the enhanced low finned surface was developed in the present investigation. The formula showed a good response to the variation of (η) when compared with the experimental data during boiling on the integral machined heating surface. The total mean absolute error of the correlation of the enhancement factor is within (13.3 %) for the data points used in the present work.

The suggested equation of the enhancement factor prediction exhibited an acceptable range of accuracy to be within (±25%) for the heat flux range (10 – 50) kW/m^2 and tested range of the operating pressure for more than (95 %) of the data point.

Although the present correlation has included some of the halocarbon refrigerants those to be at the phase out stage of application, but it will give an excellent indication for the substitutes to be used for existing refrigeration units. Further, it can be incorporated with models used for the design of the kettle reboilers and pool boiling evaporators used in a variety of industrial applications.

VI. Nomenclature

a: Thermal Diffusivity (m^2/s)

$C_{S,F}$: Liquid-Surface Contribution Factor in eq.(13.c), (Dimensionless)

C_1 : Empirical Constant in Equations

cp : Specific Heat of Fluid, (kJ/kg K)

d : Tube Diameter, (m)

h_{fg}: Heat of Vaporization, (kJ/kg)

k : Thermal Conductivity of Fluid, (W/m.K)

m : Constant in eq. (13.c), (Dimensionless)

n : Constant in eq.(13.c), (Dimensionless)

N : Number of Data Points, (Dimensionless)

p : Process Operating Pressure, (kPa)

q : Heat Flux Density, (kW/m2)

q_{ref}: Reference Heat Flux in eq.(2), (kW/m^2)

T : Temperature, (C^o)

ΔT: Wall Superheat, (deg C)

a) Greeks

α : Nucleate Boiling Heat transfer Coefficient, (kW/m^2 K)

η : Enhancement Factor of Boiling Heat Transfer Coefficient, (Dimensionless)
μ : Viscosity of Fluid, (Pa.s)
ν : *Kinematic Viscosity* (m^2/s)
ρ: Density of Fluid, (kg/m^3)
σ : Surface Tension, (N/m)

b) Subscripts

c : Critical Value
enh.: Enhanced surface Value
exp.: Experimental Value
l : Liquid
L-F: Low Finned Surface
o : Outside
pla.: Plain Tube Value
pred.: Predicted Value
r: Reduced or Measured at Fin Root

References Références Referencias

1. Ahmad, S., W., "Combined Effect of Electric Field and Surface Modification on Pool Boiling of R-123", PhD. Thesis, School of Engineering and Design, Brunel University, May 2012.
2. Aniruddha, P. and Yogendra, J., "Boilingat Sub-Atmospheric Conditions with Enhanced Structures", G. W. Woodruff School of Mechanical Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332 U.S.A., IEEE 2006.
3. Bertsch, G., M., "Nucleate Pool Boiling Characteristics of R-124", MSc. Thesis, Naval Postgraduate School, Monterey, California, March 1993.
4. Chen, Q.,R. Windisch, E. Hahne, "Pool Boiling Heat Transfer on Finned Tubes", Eurotherm Seminar no. 8, Advances in Pool Boiling Heat Transfer, pp. 126-141, Paderborn, Federal Republic of Germany, 1989.
5. Du Pont-Suva Refrigerants, "Du Pont HCFC-123", Properties, Uses, Storage and Handling, Technical Information Manual P123.
6. Du Pont-Suva Refrigerants, "Du Pont R-22", Properties, Uses, Storage and Handling, Technical Information Manual P22.
7. Griffith, P.,J. and Wallis, D.," The Role of the Surface Condition in Nucleate Boiling", Chem. Eng. Prog.Symp. Ser., Vol. 56, no. 49, pp. 49-63, 1960.
8. Gorenflo, D., "Pool Boiling", VDI-Heat Atlas, VDI-Verlag, Disseldorf (English Version), 1993.
9. Hahne, E. and Muller, J.," Boiling on a Finned Tube and Finned Tube Bundle", Int. J. Heat Mass Transfer, Vol. 26, no. 6, pp. 849-859, 1983.
10. Incropera, F. P. and Dewitt, D. P. "Introduction to Heat Transfer", 2nd edition, John Wiley Publications, New York, 1990.
11. Kurihara, H., M. and Myers, J. E.," The Effect of Superheat and Surface Roughness on Boiling Coefficients", AIChE. J., Vol. 6, no. 1, pp. 83-91, 1960.
12. Kandlikar, S., G. and Howell,M. J., "Investigation of Nucleation and Heat Transfer for Subcooled Flow Boiling on Microfin Surfaces", 2nd European Thermal-Sciences and 14th UIT National Heat Transfer Conference, Vol. 1, pp. 241-247, 1996.
13. Kedzierski, M., A., "Calorimetric and Visual Measurements of R123 Pool Boiling on Four Enhanced Surfaces", National Institute of Standards and Technology, Building and Fire Research Laboratory Gaithersburg, Maryland 20899, 1995.
14. Marto P. J. and Lepere V. J., "Pool Boiling Heat Transfer from Enhanced Surfaces to Dielectric Fluids", In: Webb, R. L., editor. Advances in Enhanced Heat Transfer, ASME.Publ., HTD-Vol. 18, pp. 93-102, 1981.
15. Marto,P., J. and B. Hernandez," Nucleate Pool Boiling Characteristics of Gewa-T Surface in Freon-113", AIChE. Symp.Ser., no. 225, Vol. 79, pp. 1-10, 1983.
16. Mostinski,I. L.," Application of the Rule of Corresponding States for Calculation of Heat Transfer and Critical Heat Flux to Boiling Liquids", British Chemical Engineering Abstracts: FOLIO no. 150, pp. 580, 1963.
17. Palen, J., W. and Yang, C., C.," Circulation Boiling Model for Analysis of Kettle and Internal Reboiler Performance", Heat Exchangers for Two Phase Applications, 21st Nat. Heat Transfer Conf. ASME., HTD-Vol. 27, pp. 55-61, Seattle, Wa., 1983.
18. Palm, B., E.," Pool Boiling of R-22 and R-134a on Enhanced Surfaces", 19th Int. Congress of Refrigeration Proc. Iva: 465-471, 1995.
19. Ricardo, J., P., O.," Nucleate Pool Boiling Characteristics of Gewa-T Finned Surfaces in Freon-113", MSc. Thesis, Naval Postgraduate School, Monterey, California, Sept. 1984.
20. Sinnott, R. K.," Chemical Engineering", Vol. 6, Pergamon Press, New york, 1986.
21. Sugiyama, D., C., "Nucleate Pool Boiling of R-114 and R-114/Oil Mixtures From Single Enhanced Tubes", MSc. Thesis, Naval Postgraduate School, Monterey, California, Sept. 1991.
22. Tarrad, A., H., " Pool Boiling of Pure Fluids and Mixtures on Plain and Enhanced Surfaces", Ph.D. Thesis, Mech. Eng. Dept., Heriot-Watt University, Edinburgh, U.K., 1991.
23. Tarrad, A., H., " A Correlation for the Prediction of Nucleate Pool Boiling Performance of Pure Liquids from Enhanced Tubes", Jordan Journal of Mechanical and Industrial Engineering (JJMIE), Volume 5, Number 2, pp. 139 – 144, April 2011.
24. Tarrad, A., H., "A Simplified Correlation for the Prediction of Nucleate Pool Boiling Performance of Single Integral Enhanced Tubes Boiling Pure Liquids at Atmospheric Pressure", Journal of Engineering

and Development, Vol. 11, No. 3, pp. 131-148, December (2007).
25. Thome, J., R, "Enhanced Boiling Heat Transfer", Hemisphere Publishing Corporation, 1990.
26. Webb, R., L, "Principles of Enhanced Heat Transfer", John Wiley and Sons Inc.,1994.
27. Webb, R., L., and Pais, C., "Nucleate Pool Boiling Data of Five Refrigerants on Plain, Integral-fin and Enhanced Tube Geometries", Int. J. Heat Mass Transfer, Vol. 35, No. 8, pp. 1893-1904, 1992.
28. Xin, M., D. and Chao, Y., D., "Analysis and Experiment of Boiling Heat Transfer on T-Shaped Finned Surfaces", Chem. Eng. Comm., Vol. 50, pp. 185-199, 1987.
29. Yilmaz, S., Palen, J. W. and Taborek, J., "Enhanced Boiling Surface as Single Tubes and Bundles", In: Webb, R. L., editor. Advances in Enhanced Heat Transfer, ASME. Publ., HTD-Vol. 18, pp. 123-129, 1981.
30. Yuming, C., Manfred, G., Rainer, M. and Rudi, K.," Bubble Dynamics of Boiling of Propane and Iso-butane on Smooth and Enhanced Tubes", Institute of Nuclear Technology and Energy Systems (IKE), University of Stuttgart, Germany, 2003.
31. Yilmaz, S., and West water, J. W., "Effect of Commercial Enhanced Surfaces on the Boiling Heat Transfer", In: Webb, R. L., editor. Advances in Enhanced Heat Transfer, ASME. Publ., HTD-Vol. 18, pp. 73-91, 1981.

Table 1 : Coefficients used with Gorenflos' correlation

Fluid	Chemical Formula	Molecular Weight (M) kg/kmol	α_0 (W/m^2 K)
R-11	CCl_3F	137.4	2800
R-12	CCl_2F_2	120.9	4000
R-22	$CHClF_2$	86.47	3900
R-113	$Cl_2FCCClF_2$	187.4	2650
R-114	$CClF_2CClF_2$	170.9	2800
R-123	CF_3CHCl_2	152.9	2600
R-124	$CHClFCF_3$	136.48	------
R-134a	CH_2FCF_3	102	4500
n-Pentane	C_5H_{12}	72.15	3400
Ethanol	C_2H_5OH	46.07	4400
Water	H_2O	18.02	5600

Table 2 : The structure characteristics of the surfaces tested in the present correlation

Surface Type	Source of Data	Tube d_o (in)	FPI	d_o/d_r (mm)	Fluid	Pressure (bar)
Plain	Hahne& Muller (1983)	3/4	-----	19/19	R-11	1.013
	Tarrad(1991)	3/4	-----	19/19	n-pentane, water, Ethanol, R-	1.013
	Webb (1994)	3/4	-----	19/19	113	1.013
	Palm (1995) *	3/4	-----	15.9/15.9	R-22	3 & 5
	Sugiyama (1991)	5/8	-----	15.9/15.9	R-22, R-134a	1.013
	Bertsch (1993)	5/8	-----	--------	R-114	1.77
	Gorenflo Correlation (1993)				R-124	-----
Low Finned	Hahne& Muller (1983)	3/4	19	18.9/15.9	R-11	1.013
	Tarrad(1991)	3/4	19	18.8/15.8	n-pentane, water, Ethanol, R-	1.013
	Webb (1994)	3/4	19	19/15.8	113	1.013
	Webb and Pais(1992)*	3/4	26	18.9/15.9	R-22	0.4-5.73
	Palm (1995)	3/4	26	18.9/15.9	R-11, R-12, R-22,R-123, R-	3 & 5
	Sugiyama (1991)	5/8	26	15.9/12.9	134a	1.013
	Bertsch (1993)	5/8	26 & 19	15.9/12.9	R-22, R-134a	1.77
	Kedzierski(1995)	5/8	19	15.9/12.9	R-114	0.391
					R-124	
					R-123	

* The pressure depends on the type of the boiling fluid

Table 3 : Selected physical properties of the correlated liquids at their normal boiling point

Liquid	$T_{Boiling}$ (C)	ρ_l (kg/m^3)	ρ_v (kg/m^3)	cp_l (kJ/kgK)	k_l (W/m K)	h_{fg} (kJ/kg)	$\mu_l \times 10^3$ (Pa. s)	σ (N/m)	P_c (bar)
R-11	23.805	1479.4	5.853	0.8703	0.08898	180.33	0.405	0.018	44.1
R-12	-29.49	1486.67	6.343	0.8824	0.0882	165.69	0.360	0.0159	41.36
R-22	-40.8	1409.1	4.705	1.0916	0.1142	233.79	-----	0.01818	49.9
R-113	47.44	1507.42	7.419	0.98	0.07	147	0.5015	0.0159	34.15
R-114	3.763	1518.28	7.826	0.9621	0.0657	135.97	0. 3519	0.01332	32.6
R-123	27.85	1455.6	6.504	0.7191	0.076	170.4	0.408	0.0158 @ 25 C	36.68
R-124	-12.09	1473.76	6.652	1.0618	0.07963	165.93	0.4066	0.0142	36.243
R-134a	-26.1	1374.4	5.26	1.268	0.1055	214.94	0.406	0.01554	40.6
n-Pentane	36	610.598	2.9741	2.376	0.1096	356.3	0.1944	0.0143	33.7
Ethanol	78.3	736.45	1.50	3.0202	0.15147	823.83	0.4376	0.0177	63.8
Water	100	958.4	0.598	4.219	0.681	2257	0.2817	0.0589	221.2

Global Journal of Researches in Engineering: A
Mechanical and Mechanics Engineering
Volume 14 Issue 5 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Thermal Analysis of Concrete Bed for Energy Storage Application

By Adeyanju A. A. & Manohar K.
Ekiti State University, Nigeria

Abstract- This study analyzed theoretically the temperature distribution and energy storage ability of a simultaneous charging and discharging concrete bed Storage System.

This was achieved by first modeled a single spherical shaped concrete which was used to represent a sequence of points along the axis of the beds.

A one dimensional finite difference formulation was used in modeling the single spherical shaped concrete material, where heat conduction to neighboring spherical concrete was ignored.

Using this assumption reduced the spherical shaped concrete model to that of an isolated sphere in cross flow, where the total surface area of the sphere was exposed to convection. The thermal properties of the materials within the bed accounted for temperature dependence.

Comparisons were made between charging and discharging mode of the storage system for air flow rates of 0.0094m^3/s, 0.013m^3/s, and 0.019m^3/s. It was discovered that the difference of the temperature response between the charging and fluid to solid heat transfer process at the initial period of the packed bed was large and the heat recovered by the cool air flowing inside the copper tube was fairly high (larger inlet–outlet temperature difference compared with the later period indicates larger heat recovery).

The energy storage efficiency was also analyzed and it was discovered that spherical shaped concrete of 0.11m diameter has the highest storage efficiency of 60.5% at 0.013 m3/s airflow rate.

Keywords: thermal analysis, concrete-bed, charging, discharging, storage efficiency.

GJRE-A Classification : FOR Code: 290501p

Strictly as per the compliance and regulations of:

Thermal Analysis of Concrete Bed for Energy Storage Application

Adeyanju A. A.[α] & Manohar K.[σ]

Abstract- This study analyzed theoretically the temperature distribution and energy storage ability of a simultaneous charging and discharging concrete bed Storage System.

This was achieved by first modeled a single spherical shaped concrete which was used to represent a sequence of points along the axis of the beds.

A one dimensional finite difference formulation was used in modeling the single spherical shaped concrete material, where heat conduction to neighboring spherical concrete was ignored.

Using this assumption reduced the spherical shaped concrete model to that of an isolated sphere in cross flow, where the total surface area of the sphere was exposed to convection. The thermal properties of the materials within the bed accounted for temperature dependence.

Comparisons were made between charging and discharging mode of the storage system for air flow rates of 0.0094m^3/s, 0.013m^3/s, and 0.019m^3/s. It was discovered that the difference of the temperature response between the charging and fluid to solid heat transfer process at the initial period of the packed bed was large and the heat recovered by the cool air flowing inside the copper tube was fairly high (larger inlet–outlet temperature difference compared with the later period indicates larger heat recovery).

The energy storage efficiency was also analyzed and it was discovered that spherical shaped concrete of 0.11m diameter has the highest storage efficiency of 60.5% at 0.013 m^3/s airflow rate.

Keywords: thermal analysis, concrete-bed, charging, discharging, storage efficiency.

I. Introduction

Heat transfer in concrete beds is used to describe a variety of phenomena, namely: (1) the convective heat transfer from the walls of the concrete bed to the fluid; (2) the convective heat transfer from the particles to the fluid flowing through the bed, which can be referred to as the fluid-particle mode; (3) the conduction heat transfer from the walls of the bed to the particles constituting the bed; (4) the conduction heat transfer between the individual particles in the bed; this can also be referred to as the particle-particle mode; (5) radiant heat transfer; and (6) heat transfer by mixing of the fluid (Adeyanju and Manohar 2009). These modes are described schematically in Figure 1.0. The fourth mode, namely the conduction between the particles, can be further subdivided into the axial and radial directions.

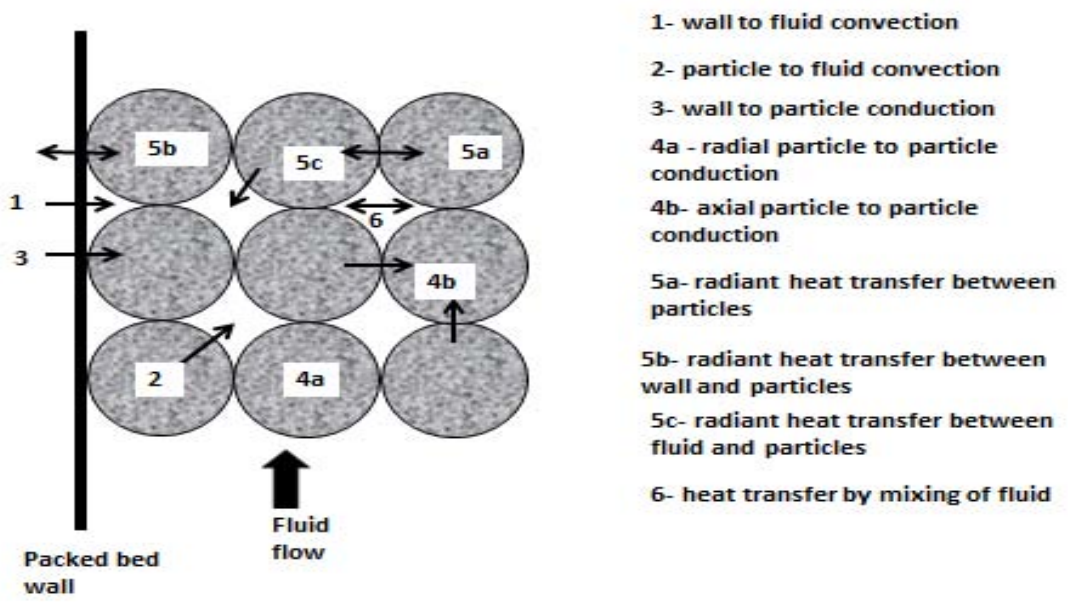


Figure 1.0 : Schematic showing the modes of heat transfers in concrete bed

Author α: Mechanical Engineering Department, Ekiti State University, Ado-Ekiti, Nigeria. e-mail: anthonyademolaadeyanju@yahoo.co.uk
Author σ: Mechanical and Manufacturing Engineering Department, University of West Indies, St. Augustine, Trinidad and Tobago.

Moreover, at high temperatures heat transfer by radiation will also be an important mode. In many industrial applications, it is found that two or more of the modes cited above take place simultaneously. For example, the conduction between the particles may be affected by the convection between the particles and the fluid. This interaction among the different modes is one of the main reasons for the difficulty in correlating the total heat transfer and analyzing the experimental data in this field (Balakrishnan and Pei 1974).

This study analyzed theoretically the temperature distribution and energy storage ability of a simultaneous charging and discharging concrete bed Storage System.

II. Review of Literature

The first work on heat transfer in packed beds was published by Anzelius et al. (1926), although Schumann (1929) is usually the first reference cited in most literature (Adeyanju and Manohar 2009). Each of them made a number of simplifying assumptions and solved the heat transfer equations for an incompressible fluids passing uniformly through a bed of solid particles with perfect conductivity. The derived heat transfer equations were:

$$\frac{\left(T_s - T_{s,0}\right)}{\left(T_s - T_{s,0}\right)} = 1 - e^{-Y-Z}\Sigma Y^n M^n\left(yz\right) = e^{-Y-Z}\Sigma Z^n M_n \quad (1)$$

$$\frac{\left(T_f - T_s\right)}{\left(T_{f,0} - T_{s,0}\right)} = 1 - e^{-Y-Z}\Sigma\left[Y^n M^n\left(yz\right)\right] = e^{-Y-Z}\Sigma\left[Z^n M_n\left(yz\right)\right] \quad (2)$$

Where T is the temperature (of fluid and solid) and Y and Z are dimensionless quantities. The solutions of these equations were presented in graphical form, called Schumann curves. Thus to evaluate volumetric coefficients of heat transfer using these curves, it was only necessary to measure exit air temperature and the bed temperature. These curves could be used to evaluate the heat transfer coefficients for a given packed bed undergoing heat exchange with a fluid provided the following conditions which were the simplifying assumptions made by Schumann were satisfied:

1. The solid particles were so small or have such a high thermal conductivity that no temperature gradients exist within the solid particles. This means that the solids offer a negligible resistance to heat transfer.
2. The resistance to heat transfer by conduction in the fluid was also negligible.
3. The rate of heat transfer from fluid to solid or vice versa at any point in the bed was directly proportional to the average temperature differential between them at that point.
4. The densities of solid and fluid and other transport properties were independent of temperature.

Upholding the above conditions, Furnas (1930) extended the Schumann curves to wider coverage temperatures. He also postulated an empirical relation for the evaluation of the heat transfer coefficient as shown in equation (3):

$$h_v = \frac{BG^{0.7}T^{0.3}10^{1.68\varepsilon - 3.56\ \varepsilon 2)}}{d_p^{0.9}} \quad (3)$$

Where, h_v is the volumetric heat transfer coefficient. B is a constant dependent on the bed material, G is the mass velocity of the fluid, T is the average air temperature, d_p is the particle diameter and ε is the porosity.

Saunders and Ford (1940) used dimensional analysis to derive correlations to calculate heat transfer coefficient. The work was, however, limited to spheres and cannot directly be applied to other geometries of solid particles.

Kays and London (1964) presented another correlation for evaluating heat transfer coefficient between gases and randomly packed solid spheres. Using the Colburn j-factor, the correlation was given as:

$$j_h = \frac{0.23}{Re_p^{0.3}} \quad (4)$$

where, $j_h = St.Pr^{2/3}$

$$200 < Re_p < 50,000 \text{ and } 0.37 < \varepsilon < 0.39$$

Löf and Hawley (1948) investigated heat transfer between air and packed bed of granitic gravel. Unsteady state heat transfer coefficients were correlated with the air mass velocity and particle diameter to obtain the equation:

$$h = 0.652\left(G/d_p\right)^{0.7} \quad (5)$$

This was evaluated for 8mm $< d_p <$ 33mm; 50 $<$ Rep 500 and temperature range of 311K to 394K. They also concluded that the temperature of the entering air had no appreciable effect on the coefficient.

Leva (1948) determined heat transfer coefficient between smooth spheres of low thermal conductivities and fluids (air and carbon dioxide) in packed beds and tubes of 50.8 and 6.4mm diameters, respectively. The ratio of particles to tube diameters was varied from 0.08 to 0.27; gas flow rate was of Reynolds number range 250 to 3,000. Correlation of film coefficient was found to be:

$$h = 3.50 \left(\frac{k}{D_t} \right) e^{-4.6\frac{Dp}{Dt}\left(\frac{DpG}{\mu}\right)0.7} \quad (6a)$$

By approximation, this reduced to

$$h = 0.40 \left(k / D_t\right) \left(DpG / \mu\right) 0.7 \quad (6b)$$

$$\text{Or}, N = 0.4\ Re^{0.7} \quad (6c)$$

Maximum film coefficient was predicted and verified at a value of Dp/Dt equal 0.153.

Riaz (1977) and Jefferson (1972) studied the dynamic behavior of beds undergoing heat exchange with air using single and two phased modes. By incorporating factors of axial bed conduction and intra-particle resistance, which Schumann ignored, the heat transfer coefficients were evaluated and found to be 1 + Bi/5 times smaller than those predicted using Schumann curves.

Ball (1958), Norton (1946), Meek (1961), Bradshaw and Meyers (1963), Harker and Martyn (1985) and also, Bouguettaia and Harker (1991) have all researched on various packed beds using air and other gases as fluids and have developed correlations involving the heat transfer coefficient.

III. Methodology

a) Heat Transfer Model for a Spherical Shaped Concrete Packed Bed

A numerical heat transfer model was developed for the spherical shaped concrete packed bed.

This was achieved by first modeled a single spherical shaped concrete which was used to represent a sequence of points along the axis of the beds.

A one dimensional finite difference formulation was used in modeling the single spherical shaped concrete material, where heat conduction to neighboring spherical concrete was ignored.

Using this assumption reduced the spherical shaped concrete model to that of an isolated sphere in cross flow, where the total surface area of the sphere was exposed to convection. Also, the thermal properties of the materials within the bed accounted for temperature dependence.

b) Finite Difference Formulation of a Single Spherical Shaped Concrete Material

Since conduction to other spherical shape concrete has been neglected, the geometry allows the concrete to be reduced to one dimension along its radius.

To model this numerically, a finite difference approach was employed (Lanz 1998). For this approach, the spherical shaped concrete can be characterized by three different nodal equations:

(i) a general, interior node
(ii) the center node
(iii) the surface node

All exposed to convection as shown in Figure 2.0.

For the general and interior node within the spherical shaped concrete model, the conduction equation for $T_{(r,t)}$ is:

$$\rho_c C_c \frac{\partial T}{\partial t} = \frac{1}{r^2}\frac{\partial}{\partial r}\left(K_c r^2 \frac{\partial T}{\partial r} \right) + \dot{q}_{(r,t)} \quad (7)$$

Where C_c= Specific heat of concrete

K_c = Thermal conductivity of concrete

$\dot{q}$ = Heat generation

And this equation was represented in finite difference form.

The specific heat, thermal conductivity, and the heat generation, are temperature dependent and varied with the temperature along the radial direction.

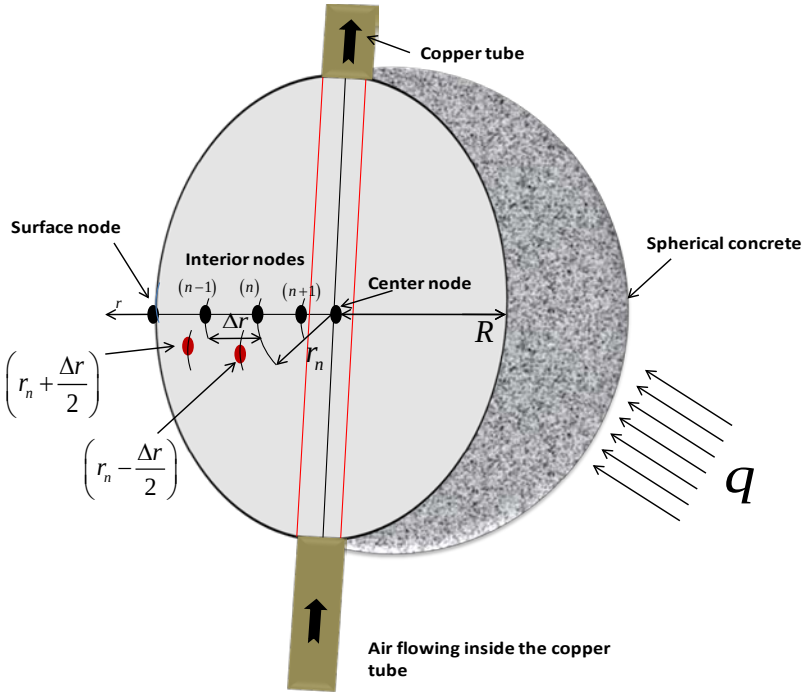


Figure 2.0 : Schematic showing the cross-section of the spherical shaped concrete materials imbedded with copper tube

Because the thermal properties are functions of temperature, and consequently functions of the spherical shaped concrete radius, the finite difference equations are derived by the volume integration over a finite difference node.

Multiplying equation (7) by r^2 and integrating both sides of the equation from $r_n - \Delta r/2$ to $r_n + \Delta r/2$ resulted to:

$$\rho_c C_c \frac{\partial T}{\partial t}\int_{r_{n-\frac{\Delta r}{2}}}^{r_{n+\frac{\Delta r}{2}}} r^2 dr = \int_{r_{n-\frac{\Delta r}{2}}}^{r_{n+\frac{\Delta r}{2}}} \frac{\partial}{\partial r}\left(K_c r^2 \frac{\partial T}{\partial r}\right)dr + \int_{r_{n-\frac{\Delta r}{2}}}^{r_{n+\frac{\Delta r}{2}}} r^2 \dot{q}_{(r,t)} dr \tag{8}$$

Since the specific heat is not as strong a function of temperature as the thermal conductivity, it was assumed constant with respect to *r,* and thus brought outside the integral.

By evaluating the integrals in equation (8) and representing the derivatives in finite difference form using the fully implicit method gives:

$$\rho_c C_c \left(\frac{T_n^{Z+1}-T_n^Z}{\Delta t}\right)\left(\frac{r_{n^+}^3 - r_{n^-}^3}{3}\right) = \int_{r_{n-\frac{\Delta r}{2}}}^{r_{n+\frac{\Delta r}{2}}} 2K_c r dT + \dot{q}\int_{r_{n-\frac{\Delta r}{2}}}^{r_{n+\frac{\Delta r}{2}}} r^2 dr \tag{9}$$

$$\rho_c C_c \left(\frac{T_n^{Z+1}-T_n^Z}{\Delta t}\right)\left(\frac{r_{n^+}^3 - r_{n^-}^3}{3}\right) = \left[\frac{2K_c r^2}{2}\frac{dT}{\Delta r}\right]_{r_{n-\frac{\Delta r}{2}}}^{r_{n+\frac{\Delta r}{2}}} + \dot{q}_n \left[\frac{r^3}{3}\right]_{r_{n-\frac{\Delta r}{2}}}^{r_{n+\frac{\Delta r}{2}}} \tag{10}$$

$$\rho_c C_c \left(\frac{T_n^{Z+1}-T_n^Z}{\Delta t}\right)\left(\frac{r_{n^+}^3 - r_{n^-}^3}{3}\right) = K_{c(n^+)} r_{n^+}^2 \left(\frac{T_{n+1}^{Z+1}-T_n^{Z+1}}{\Delta r}\right) - K_{c(n^-)} r_{n^-}^2 \left(\frac{T_n^{Z+1}-T_{n-1}^{Z+1}}{\Delta r}\right) + q_n \left[\frac{r_{n^+}^3 - r_{n^-}^3}{3}\right]_{r_{n-\frac{\Delta r}{2}}}^{r_{n+\frac{\Delta r}{2}}} \tag{11}$$

Where T_n^Z and T_n^{Z+1} indicate temperatures for an arbitrary node at times t^Z and t^{Z+1} respectively.

Also, $W_n = W$ at T_n^{Z+1} (12)

$$and, K_{n^+} = \frac{K\left[T_{n+1}^{Z+1} + K\right]}{2}, \text{at} T_n^{Z+1} \quad (13)$$

$$also, r_{n^+} = r_n + \frac{\Delta r}{2} \quad (14)$$

$$r_{n^-} = r_n - \frac{\Delta r}{2} \quad (15)$$

Equation (11) can be rearranged and solved for plus a known quantity which resulted to:

$$\rho_c C_c \left(\frac{T_n^{Z+1} - T_n^Z}{\Delta t}\right) = \frac{3K_{c(n^+)} r_{n^+}^2}{r_{n^+}^3 - r_{n^-}^3}\left(\frac{T_{n+1}^{Z+1} - T_n^{Z+1}}{\Delta r}\right) - \frac{3K_{c(n^-)} r_{n^-}^2}{r_{n^+}^3 - r_{n^-}^3}\left(\frac{T_n^{Z+1} - T_{n-1}^{Z+1}}{\Delta r}\right) + \dot{q}_n\left[\frac{3r_{n^+}^3 - r_{n^-}^3}{3r_{n^+}^3 - r_{n^-}^3}\right] \quad (16)$$

$$\rho_c C_c \frac{T_n^{Z+1}}{\Delta t} - \rho_c C_c \frac{T_n^Z}{\Delta t} = \frac{3K_{c(n^+)} r_{n^+}^2}{r_{n^+}^3 - r_{n^-}^3}\left(\frac{T_{n+1}^{Z+1} - T_n^{Z+1}}{\Delta r}\right) - \frac{3K_{c(n^-)} r_{n^-}^2}{r_{n^+}^3 - r_{n^-}^3}\left(\frac{T_n^{Z+1} - T_{n-1}^{Z+1}}{\Delta r}\right) + \dot{q}_n \quad (17)$$

Multiply equation (17) by Δt and divide by $\rho_c C_c$ resulted to:

$$T_n^{Z+1} - T_n^Z = \frac{3K_{c(n^+)} r_{n^+}^2 \Delta t}{\rho_{c(m)} C_{c(m)} \Delta r\left(r_{n^+}^3 - r_{n^-}^3\right)}\left[T_{n+1}^{Z+1} - T_n^{Z+1}\right] - \frac{3K_{c(n^-)} r_{n^-}^2 \Delta t}{\rho_{c(m)} C_{c(m)} \Delta r\left(r_{n^+}^3 - r_{n^-}^3\right)}\left[T_n^{Z+1} - T_{n-1}^{Z+1}\right] + \frac{3\Delta t \dot{q}_n}{\rho_{c(m)} C_{c(m)}} \quad (18)$$

$$\therefore T_n^Z + \frac{3\Delta t \dot{q}_n}{\rho_{c(m)} C_{c(m)}} = T_n^{Z+1} - \left[\frac{3K_{c(n^+)} r_{n^+}^2 \Delta t}{\rho_{c(m)} C_{c(m)} \Delta r\left(r_{n^+}^3 - r_{n^-}^3\right)}\right]\left[T_{n+1}^{Z+1}\right] + \left[\frac{3K_{c(n^+)} r_{n^+}^2 \Delta t}{\rho_{c(m)} C_{c(m)} \Delta r\left(r_{n^+}^3 - r_{n^-}^3\right)}\right]\left[T_n^{Z+1}\right] + \left[\frac{3K_{c(n^-)} r_{n^-}^2 \Delta t}{\rho_{c(m)} C_{c(m)} \Delta r\left(r_{n^+}^3 - r_{n^-}^3\right)}\right]\left[T_n^{Z+1}\right] + \left[\frac{3K_{c(n^-)} r_{n^-}^2 \Delta t}{\rho_{c(m)} C_{c(m)} \Delta r\left(r_{n^+}^3 - r_{n^-}^3\right)}\right]\left[T_{n-1}^{Z+1}\right] \quad (19)$$

Collecting the like terms from equation (19) yielded:

$$\therefore T_n^Z + \frac{3\Delta t\dot{q}_n}{\rho_{c(m)}C_{c(m)}} = \left[\left(\frac{3\Delta t}{\rho_{c(m)}C_{c(m)}\Delta r}\right)\frac{K_{c(n^-)}r_{n^-}^2}{\left(r_{n^+}^3 - r_{n^-}^3\right)}\right]\left[T_{n-1}^{Z+1}\right] +$$

$$\left[1+\left\{\left(\frac{3\Delta t}{\rho_{c(m)}C_{c(m)}\Delta r}\right)\frac{\left(K_{c(n^-)}r_{n^-}^2 + K_{c(n^+)}r_{n^+}^2\right)}{\left(r_{n^+}^3 - r_{n^-}^3\right)}\right\}\right]\left[T_n^{Z+1}\right] - \tag{20}$$

$$\left[\left(\frac{3\Delta t}{\rho_{c(m)}C_{c(m)}\Delta r}\right)\frac{K_{c(n^+)}r_{n^+}^2}{\left(r_{n^+}^3 - r_{n^-}^3\right)}\right]\left[T_{n+1}^{Z+1}\right]$$

This resulting equation is valid for any general, interior node within the spherical shaped concrete $0 < r_n < R$.

At the center node, where $r_n = 0$ the temperature profile is axisymmetric, and $\frac{\partial T}{\partial r} = 0,$ when $r = 0$ thus, the temperature on either side of the node is equal.

$$T_{n-1}^{Z+1} = T_{n+1}^{Z+1}$$

$$likewise, K_{c(n^-)} = K_{c(n^+)}$$

$\therefore$ Equation (20) simplified to:

$$\therefore T_n^Z + \frac{\Delta t\dot{q}_n}{\rho_{c(m)}C_{c(m)}} = T_n^{Z+1} - \left(\frac{6\Delta t}{\rho_{c(m)}C_{c(m)}\Delta r^2}K_{c(n^+)}\right)T_{n+1}^{Z+1} \tag{21}$$

This occur at $r_n = 0$.

This simplified form of equation (20) was used to represent the center node.

The conduction through the surface of the spherical concrete is equal to the convection at the surface.

$$\therefore -K\frac{\partial T}{\partial r}_{at,r=R} = -U_C\left(T_{r=R} - T_\infty\right) \tag{22}$$

However, this boundary condition cannot be directly represented in finite difference form, since such formulation requires a volume element and equation (22) applies at a point.

Instead a first law energy balance was utilized to obtain the nodal equation for the surface of the spherical concrete. This energy balance can be written as:

$$\dot{E}_{in} - \dot{E}_{out} + \dot{E}_{gen} = \dot{E}_{st} \tag{23}$$

where,

$$\dot{E}_{in} = -KA\frac{\partial T}{\partial r} \tag{24}$$

$$\dot{E}_{out} = U_C A\left(T - T_g\right) \tag{25}$$

$$\dot{E}_{gen} = \dot{q}V \tag{26}$$

$$\dot{E}_{st} = \rho CV\frac{\partial T}{\partial t} \tag{27}$$

Representing equation (23) in a finite difference form consistent with equation (20) and (21) resulted to:

$$-KA\frac{\partial T}{\partial r} - U_C A\left(T - T_g\right) + \dot{q}V = \rho CV\frac{\partial T}{\partial t} \tag{28}$$

This can be written in finite difference form to give:

$$-4\pi r_{n^-}^2 K_{n^-}\frac{T_n^{Z+1} - T_{n-1}^{Z+1}}{\Delta r} - 4\pi r_n^2 U_C\left(T_n^{Z+1} - T_\infty\right) + \frac{4}{3}\pi\left(r_n^3 - r_{n^-}^3\right)\dot{q}_n =$$

$$\frac{4}{3}\pi\rho C_n\left(r_n^3 - r_{n^-}^3\right)\frac{T_n^{Z+1} - T_n^Z}{\Delta t} \tag{29}$$

Where, U_c = convection coefficient.

Solving for T_n^Z plus known quantities involving $\dot{q}$ and U_c, in a similar manner to equation (20) and (24) resulted to:

$$\frac{-4\pi r_{n^-}^2 K_{n^-} T_n^{Z+1}}{\Delta r} + \frac{-4\pi r_{n^-}^2 K_{n^-} T_{n-1}^{Z+1}}{\Delta r} - 4\pi r_n^2 U_C T_n^{Z+1} - 4\pi r_n^2 U_C T_\infty + \frac{4}{3}\pi\left(r_n^3 - r_{n^-}^3\right)\dot{q}_n = \frac{4}{3}\pi\rho C_n \frac{\left(r_n^3 - r_{n^-}^3\right)}{\Delta t} T_n^{Z+1} - \frac{4}{3}\pi\rho C_n \frac{\left(r_n^3 - r_{n^-}^3\right)}{\Delta t} T_n^Z \tag{30}$$

Multiply equation (30) by Δt and divide by $\frac{4}{3}\pi\rho\left(r_n^3 - r_{n^-}^3\right)$ resulted to:

$$T_n^Z - T_n^{Z+1} = \frac{3\Delta t}{\Delta r \rho C_n}\left(\frac{r_{n^-}^2 K_{n^-}}{r_n^3 - r_{n^-}^3}\right) T_n^{Z+1} - \frac{3\Delta t}{\Delta r \rho C_n}\left(\frac{r_{n^-}^2}{r_n^3 - r_{n^-}^3}\right) T_{n-1}^{Z+1} + \frac{3\Delta t U_C}{\rho C_n}\left(\frac{r_{n^-}^2}{r_n^3 - r_{n^-}^3}\right) T_n^{Z+1} + \frac{3\Delta t U_C}{\rho C_n}\left(\frac{r_n^2}{r_n^3 - r_{n^-}^3}\right) T_\infty - \frac{\dot{q}_n \Delta t}{\rho C_n} \tag{31}$$

$$T_n^Z + \frac{\Delta t}{\rho C_n}\dot{q}_n + \frac{3\Delta t U_C}{\rho C_n}\left(\frac{r_{n^-}^2}{r_n^3 - r_{n^-}^3}\right) = -\left(\frac{3\Delta t}{\Delta r \rho C_n}\frac{r_{n^-}^2 K_{n^-}}{r_n^3 - r_{n^-}^3}\right) T_{n-1}^{Z+1} + \left[1 + \frac{3\Delta t}{\rho C_n \Delta r}\left(\frac{r_{n^-}^2 K_{n^-}}{r_n^3 - r_{n^-}^3}\right) + \frac{3\Delta t U_C}{\rho C_n}\left(\frac{r_n^2}{r_n^3 - r_{n^-}^3}\right)\right] T_n^{Z+1} \tag{32}$$

$$T_n^Z = -\left(\frac{3\Delta t}{\Delta r \rho C_n}\frac{r_{n^-}^2 K_{n^-}}{r_n^3 - r_{n^-}^3}\right) T_{n-1}^{Z+1} + \left[1 + \frac{3\Delta t}{\rho C_n \Delta r}\left(\frac{r_{n^-}^2 K_{n^-}}{r_n^3 - r_{n^-}^3}\right) + \frac{3\Delta t U_C}{\rho C_n}\left(\frac{r_n^2}{r_n^3 - r_{n^-}^3}\right)\right] T_n^{Z+1} - \frac{\Delta t}{\rho C_n}\dot{q}_n - \frac{3\Delta t U_C}{\rho C_n}\left(\frac{r_{n^-}^2}{r_n^3 - r_{n^-}^3}\right) \tag{33}$$

Equation (20), (21) (32) and (33) constitute a system of algebraic equations for heat transfer modeling in spherical shaped concrete.

IV. Result and Discussion

The values of equation (33) are obtained from the values in Tables 1.0. Since the thermal properties are constant, average temperatures could therefore be used to determine thermal properties of bed materials.

Table 1.0 : Parameters used in Modeling

Parameters	Values
Airflow rate	0.01316 m^3/s (28cfm)
Density of Air	1.07154 Kg/m^3
Specific heat capacity of air	1008 J/KgK
Density of Concrete	2400 Kg/m^3
Specific heat capacity of Concrete	1130 J/KgK
Density of Copper tube	8900 Kg/m^3
Specific heat capacity of copper tube	384J/KgK
Area of spherical shaped concrete	0.013m^2
Area of copper tube + Header	0.664m^2
Volumetric heat transfer coefficient	106.5 W/m^3K

The following data were obtained from the mathematical model carried out on thermal performance of packed bed energy storage system as shown in Figure 3.0

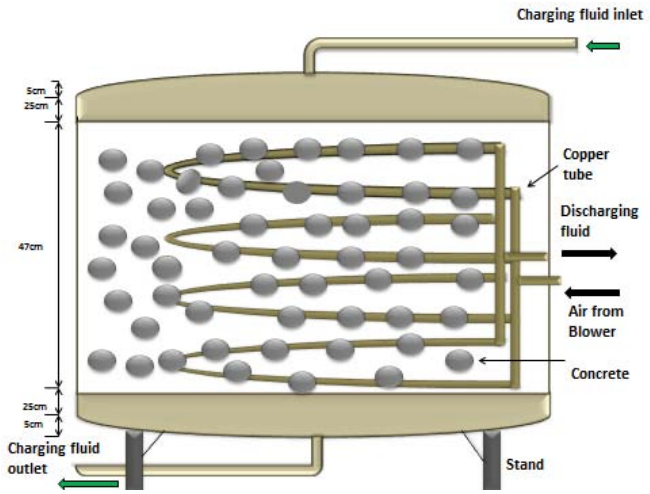


Figure 3.0 : Schematic of the storage tank dimensions

The definitions of the symbols are:

- **Time** represents the interval time of measurements, in minutes
- $T_{s\text{-}in}$ represents the inlet air temperature to the packed bed storage tank in °C
- $T_{s\text{-}ount}$ represents the outlet air temperature from the packed bed storage tank in °C
- $T_{t\text{-}in}$ represents the inlet air temperature to the copper tube in °C
- $T_{t\text{-}out}$ represents the outlet air temperature from the copper tube in °C
- T_{A1}, T_{A2}, T_{A3}, and T_{A4} represent the air stream temperatures (°C) through the bed at different heights of the storage tank 117.5cm, 235cm, 352.5cm, and 470cm, respectively.
- T_{ci1}, T_{ci2}, T_{ci3}, and T_{ci4} represent the core temperatures of the Spherical shaped concrete (°C) through the bed at different heights of the storage tank 117.5cm, 235cm, 352.5cm, and 470cm, respectively.
- T_{ti1}, T_{ti2}, T_{ti3}, and T_{ti4} represent the temperatures of air flowing inside the copper tube (oC) through the bed at different heights of the storage tank 117.5cm, 235cm, 352.5cm, and 470cm, respectively.
- T_{ct1}, T_{ct2}, T_{ct3}, and T_{ct4} represent the temperatures of the contact made between Spherical shaped concrete and imbedded copper tube (°C) through the bed at different heights of the storage tank 117.5cm, 235cm, 352.5cm, and 470cm, respectively.
- T_{t1}, T_{t2}, T_{t3}, and T_{t4}represent the surface temperatures of the copper tube (°C) through the bed at different heights of the storage tank 117.5cm, 235cm, 352.5cm, and 470cm, respectively.

The results of the temperature measurements of a simultaneous charging and discharging packed bed energy storage system were shown in Figures 4.0, 6.0 and 8.0 for spherical shaped concrete of size 0.11m; 0.08m and 0.065m diameter respectively while the discharging only temperature measurements were shown in Figures 5.0, 7.0 and 9.0 respectively for air flow rate of 0.0094m^3/s, 0.013m^3/s, and 0.019m^3/s.

Figure 10.0 present the comparison of the temperature variations with time at $T_{s\text{-}in}$, $T_{s\text{-}out}$, $T_{t\text{-}in}$, $T_{t\text{-}out}$, T_{A1}, T_{A2}, T_{A3}, T_{A4}, T_{ci1}, T_{ci2}, T_{ci3}, T_{ci4}, T_{ti1}, T_{ti2}, T_{ti3}, T_{ti4}, T_{ct1}, T_{ct2}, T_{ct3}, T_{ct4}, T_{t1}, T_{t2}, T_{t3}, and T_{t4} during the simultaneous charging and discharging while Figure 11.0 present for discharging only. The comparisons were presented for air flow rates of 0.0094m^3/s, 0.013m^3/s, and 0.019m^3/s.

These Figures show that the difference of the temperature response between the charging and fluid to solid heat transfer process at the initial period (< 30 min) of the packed bed was large (large inlet–outlet temperature difference means large heat supply), and the heat recovered by the cool air (approximately 27 °C) flowing inside the copper tube was fairly high (larger inlet–outlet temperature difference compared with the later period indicates larger heat recovery).

Therefore, a relatively large part of the heat supplied by the simulated air heater was used to heat the air flowing inside the copper tube through conduction and convection and also stores the rest for continuous usage.

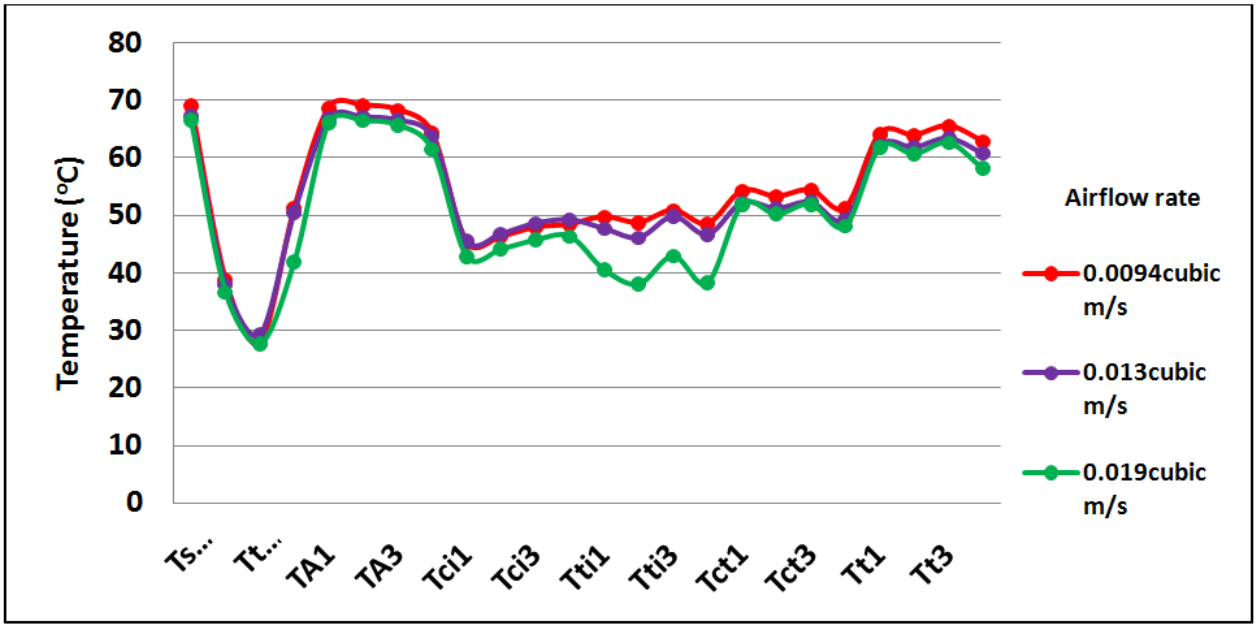


Figure 4.0 : Average temperature measurement of charging packed bed storage system for spherical shaped concrete of size 0.11m diameter and flow rate of 0.0094, 0.013, and 0.019m^3/s

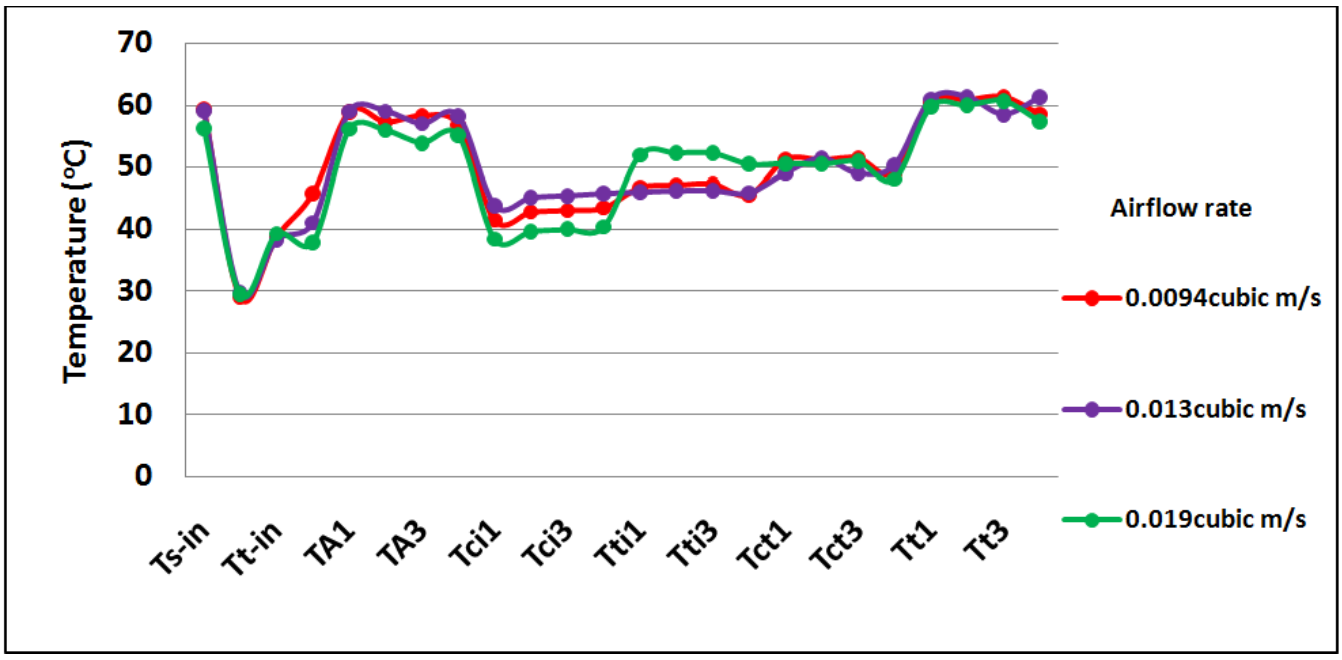


Figure 5.0 : Average temperature measurement of discharging packed bed storage system for spherical shaped concrete of size 0.11m diameter and flow rate of 0.0094, 0.013, and 0.019m^3/s

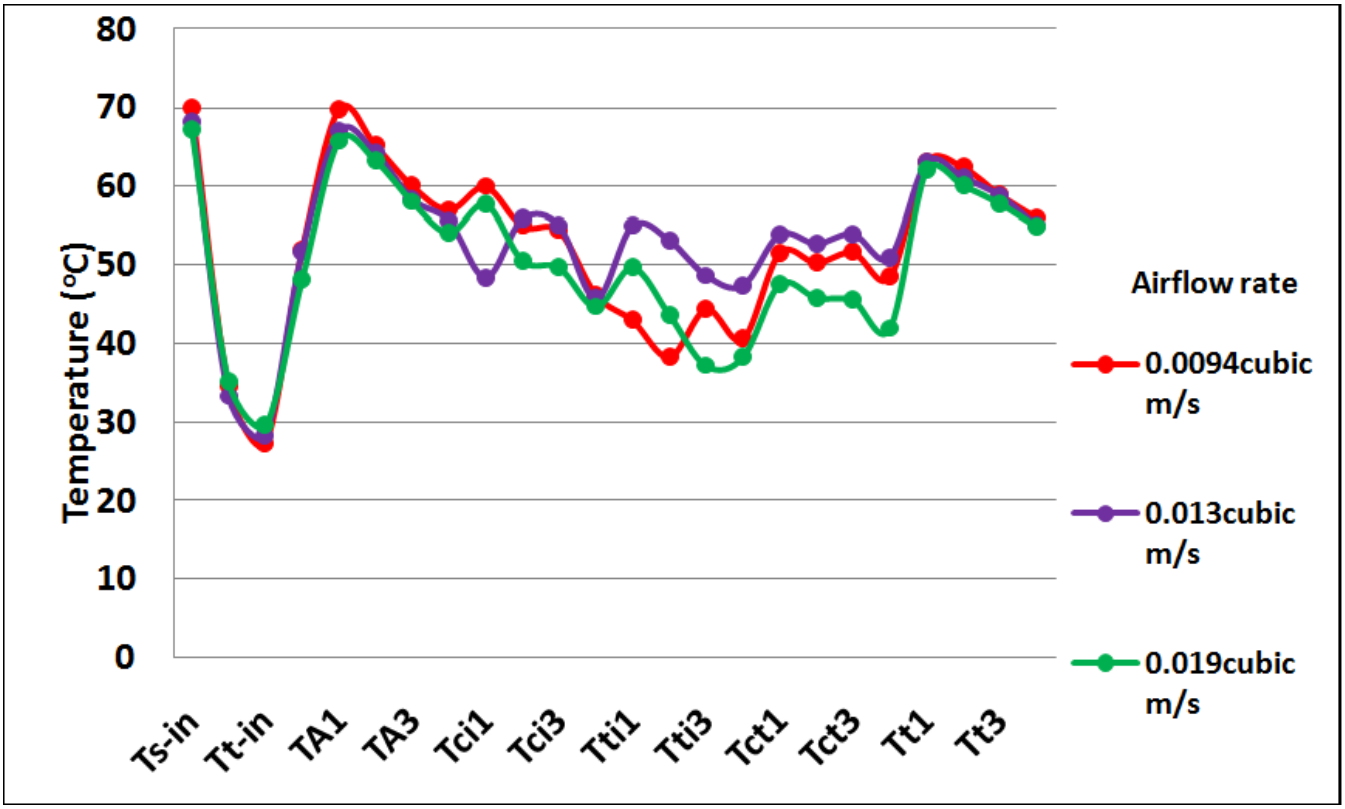


Figure 6.0 : Average temperature measurement of charging packed bed storage system for spherical shaped concrete of size 0.08m diameter and flow rate of 0.0094, 0.013, and 0.019m^3/s

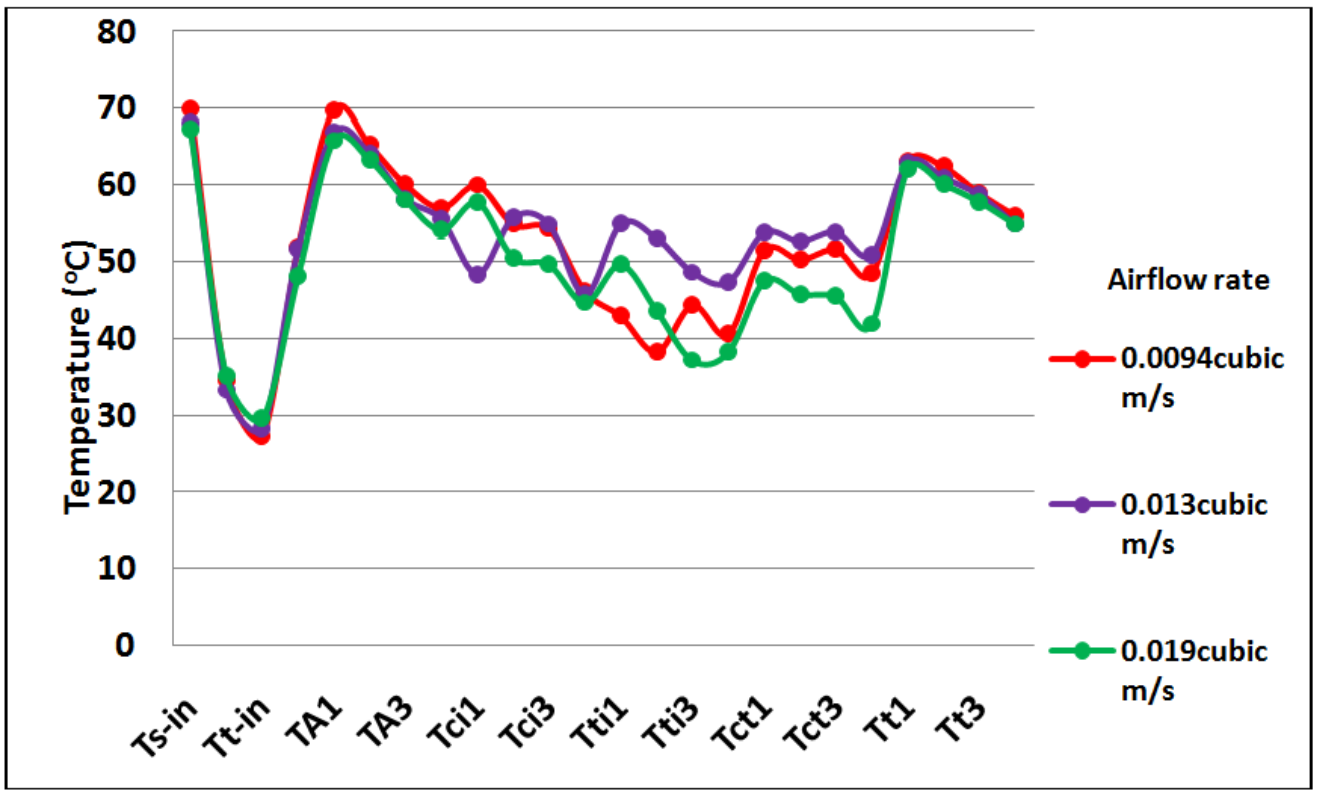


Figure 7. 0 : Average temperature measurement of charging packed bed storage system for spherical shaped concrete of size 0.08m diameter and flow rate of 0.0094, 0.013, and 0.019m^3/s

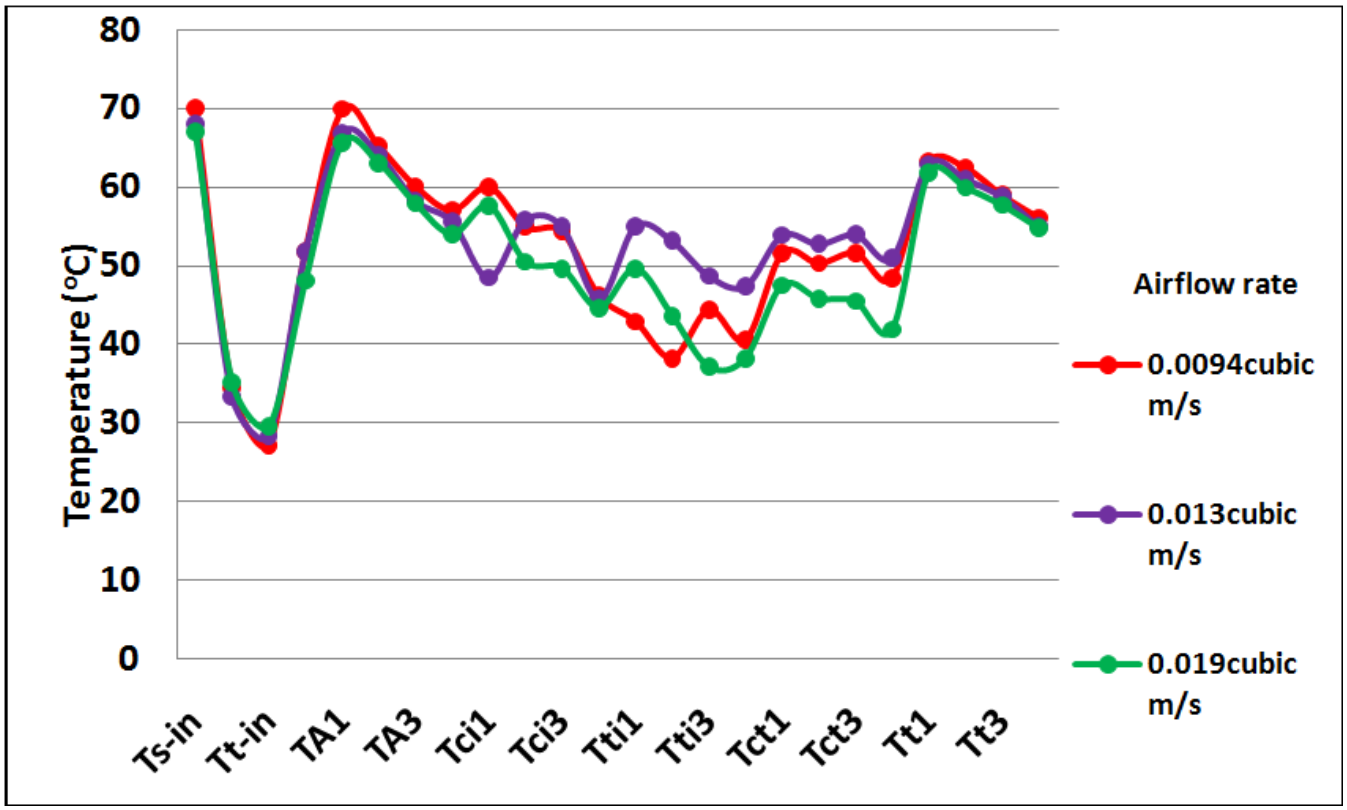


Figure 8.0 : Average temperature measurement of discharging packed bed storage system for spherical shaped concrete of size 0.08m diameter and flow rate of 0.0094, 0.013, and 0.019m^3/s

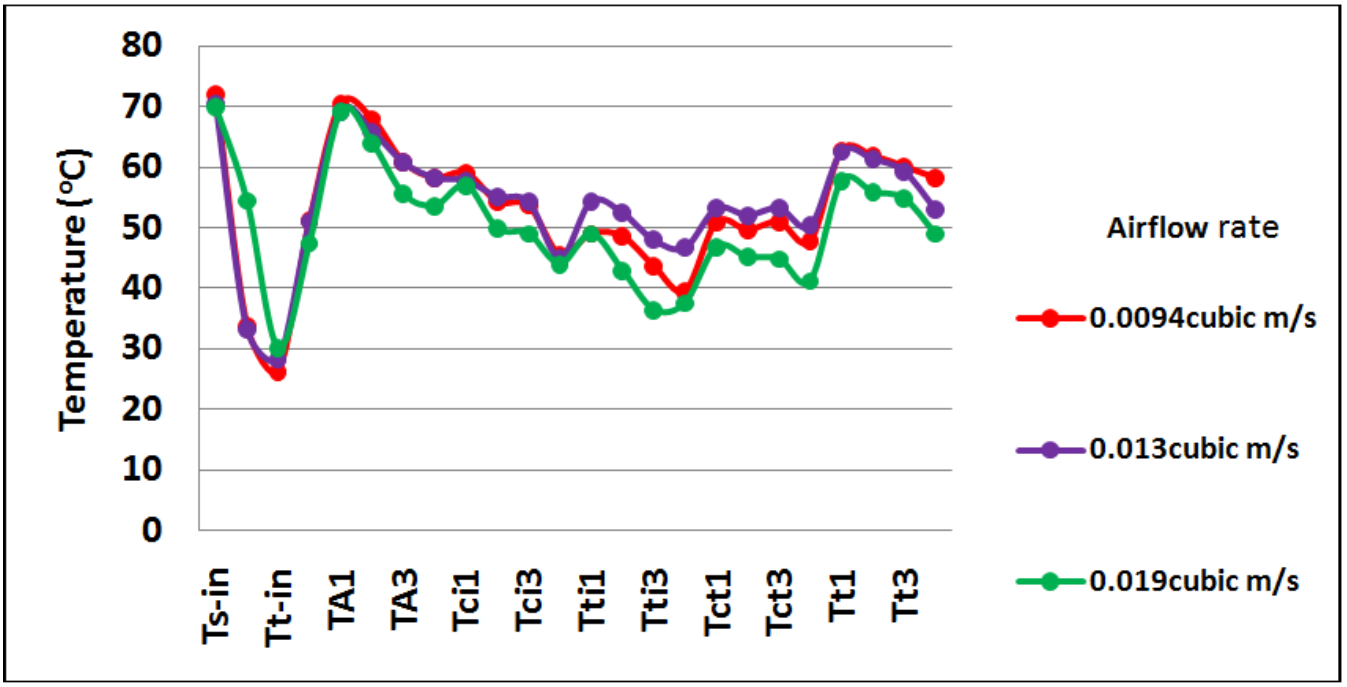


Figure 9.0 : Average temperature measurement of charging packed bed storage system for spherical shaped concrete of size 0.065m diameter and flow rate of 0.0094, 0.013, and 0.019m^3/s

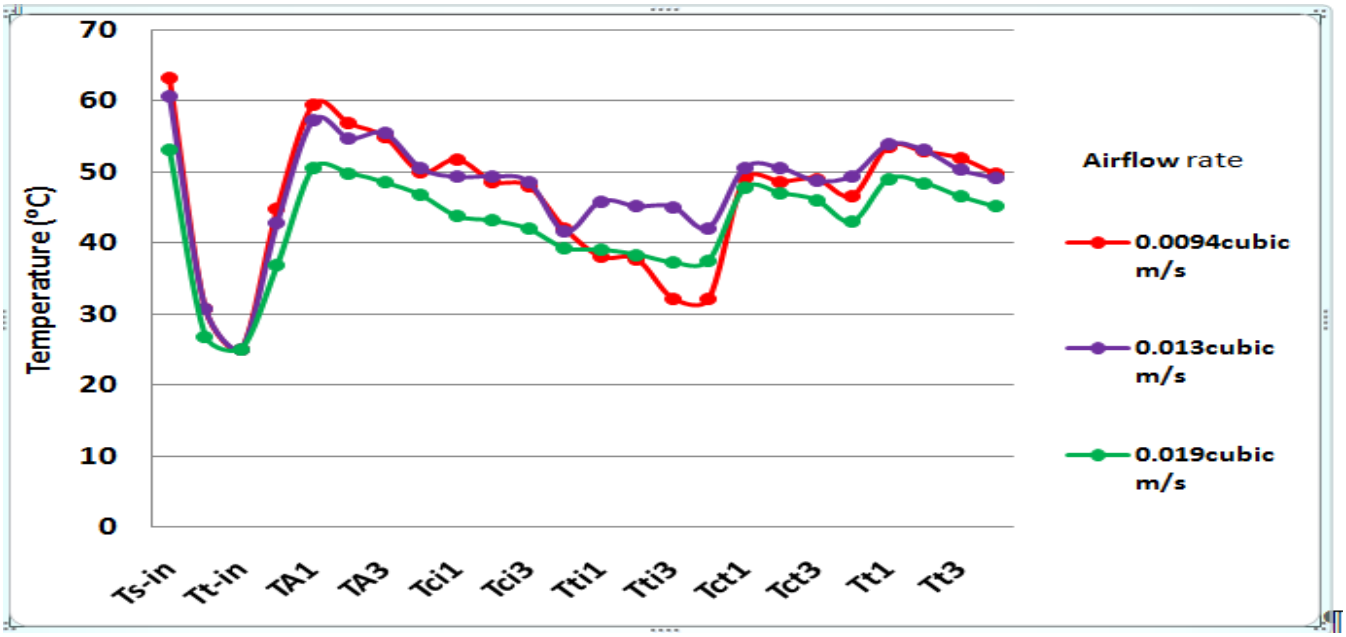


Figure 10.0 : Average temperature measurement of discharging packed bed storage system for spherical shaped concrete of size 0.065m diameter and flow rate of 0.0094, 0.013, and 0.019m^3/s

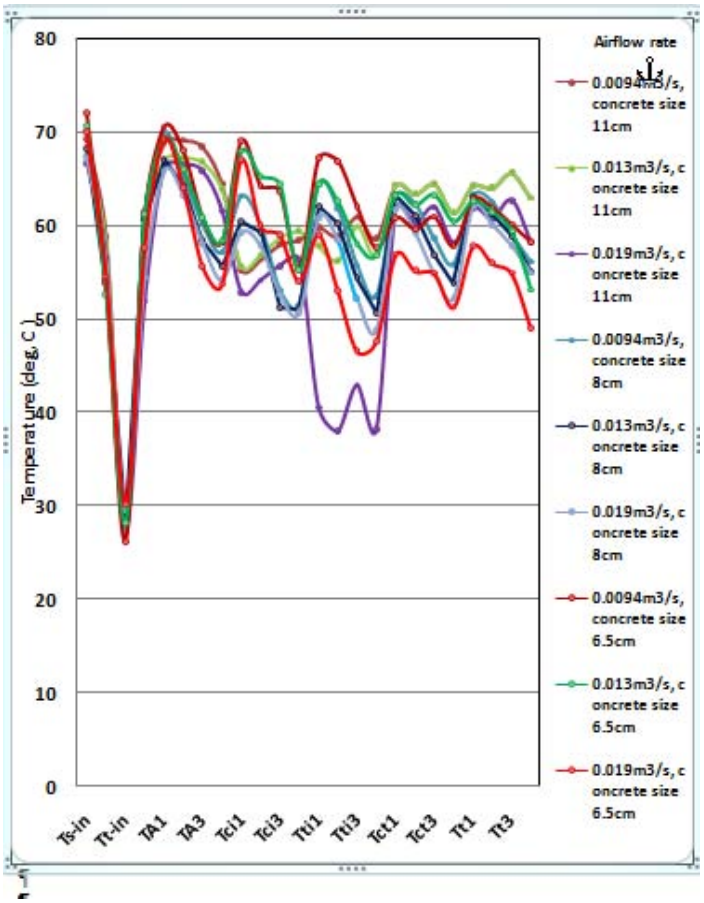


Figure 11.0 : Comparison of Average Temperature measurement of charging packed bed storage system for spherical shaped concrete of size 0.065, 0.08, 0.11m in diameter and flow rate of 0.0094, 0.013, and 0.019m^3/s

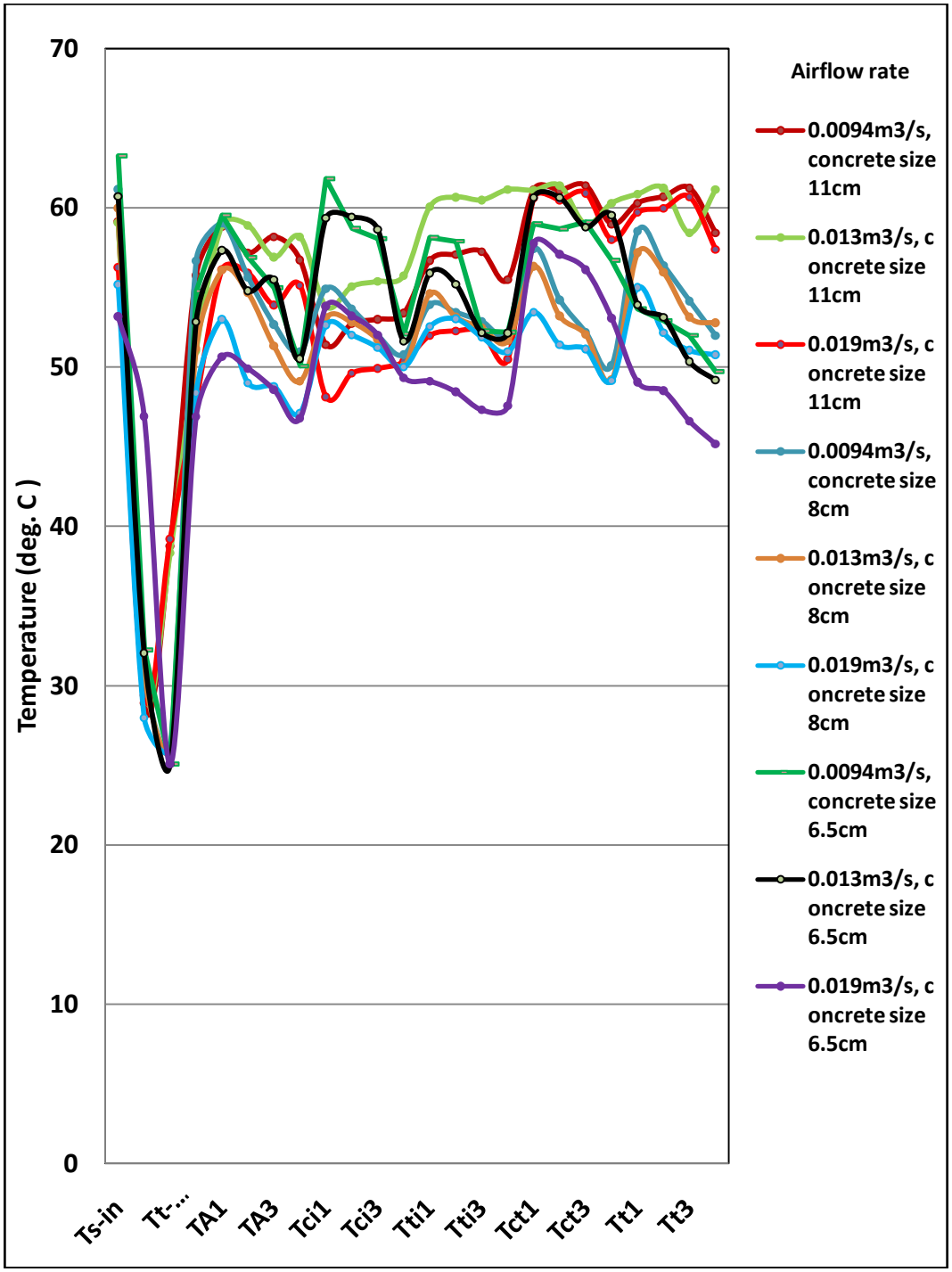


Figure 12.0 : Comparison of Average Temperature measurement of discharging packed bed storage system for spherical shaped concrete of size 0.065, 0.08, 0.11m in diameter and flow rate of 0.0094, 0.013, and 0.019m^3/s

The following are the storage efficiency for spherical shaped concrete of size 0.11m, 0.08m and 0.065m diameter at airflow rate of 0.0094, 0.013 and 0.019 m^3/s (Figure 12.0):

For 0.11m diameter spherical shaped concrete:

- Storage efficiency at air flow rates of 0.0094 m^3/s = 40.7%
- Storage efficiency at air flow rates of 0.013 m^3/s = 60.5%
- Storage efficiency at air flow rates of 0.019 m^3/s = 57.5%

For 0.08m diameter spherical shaped concrete:

- Storage efficiency at air flow rates of 0.0094 m^3/s = 23.5%
- Storage efficiency at air flow rates of 0.013 m^3/s = 51.3%
- Storage efficiency at air flow rates of 0.019 m^3/s = 50.2%

For 0.065m diameter spherical shaped concrete:

- Storage efficiency at air flow rates of 0.0094 m^3/s = 14.8%
- Storage efficiency at air flow rates of 0.013 m^3/s = 35.06%
- Storage efficiency at air flow rates of 0.019 m^3/s = 40.3%

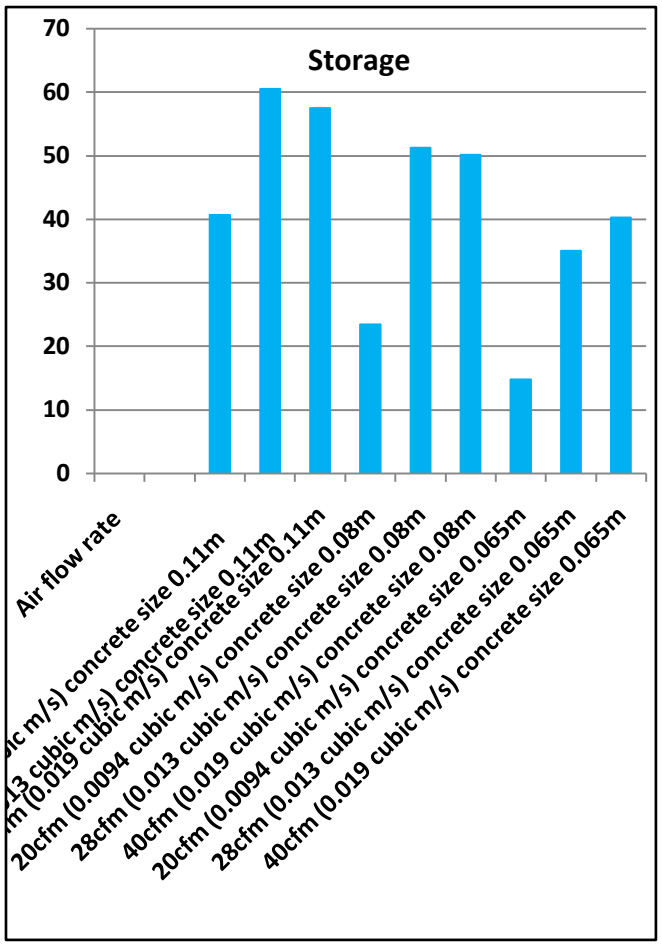


Figure 13.0 : Storage Efficiency of Simultaneous Charging and Discharging Packed Bed Storage System for Spherical Shaped Concrete of diameter 0.065, 0.08, 0.11m and Air Flow Rate 0.0094, 0.013, and 0.019m^3/s

V. Conclusion

The study led to the following findings and conclusions:

1. The mathematical model developed can accurately predict the temperature within the concrete bed for energy storage purpose.
2. The steady intermittent input temperature variation actually led to continuous discharge temperature at the copper tube outlet.
3. The mathematical model may be extended to specify the packed bed storage system dimensions.
4. Spherical shaped concrete of 0.11m diameter has the highest storage efficiency of 60.5% at 0.013 m^3/s airflow rate.

References Références Referencias

1. Adeyanju, A. A and K. Manohar 2009. Theoretical and Experimental Investigation of Heat Transfer in Packed Beds. Research Journal of Applied Sciences 4 (5): 166 - 177.
2. Anzelius, A. 1926. Heating by means of Percolating Media. Journal of Mechanical and Agriculture, ASAE, 41st Edition 6:291-296. AE 1996.
3. Balakrishnan, A. R. and D. C. T. Pei. 1974. Heat transfer in Fixed Bed. Industrial and Engineering Chemical Process Design Development. ACS Publication 13: 441-446.
4. Ball, W. E 1958. "Heat Transfer Properties of a Packed Bed: Determination by a Frequency

Response Technique." Dissertation Abstract. 19:494.
5. Bouguettaia, H. and J. H. Harker. 1991. Energy Storage in Packed Beds of Spheres Containing Palm Oil. Journal of Institute of Energy 64:89-94.
6. Bradshaw, R. C. and J. E. Myers. 1963. Heat and Mass Transfer in Fixed and Fluidized Beds of Large Particles. AICh E-Journal 9: 590- 599.
7. Furnas, C. C. 1930. Heat Transfer from a Gas Stream to a Bed of Broken Solids. Journal of Chemical Engineering 22: 26 and 721.
8. Harker, J. H and E. J. Martyn. 1985. Energy Storage in Gravel Beds. Journal of Institute of Energy 58:.94-99.
9. Jefferson, C. P. 1972. Prediction of Break through Curves in Packed Beds: Applicability of Single Parameter Models. AIChE Journal.18 (2):409-416.
10. Kays, W. M and A. C. London. 1964. Compact Heat Exchangers. New York: McGrawHILL.
11. Lanz, J. E. 1998. "A Numerical Model of Thermal Effects in a Microwave Irradiated Catalyst Bed." M. Sc Thesis Virginia Polytechnic Institute and State University, Virginia, U. S. A.
12. Leva, M.and M. Grummer. 1948. Concentration and Temperature Profiles in a Tubular Reactor. Industrial and Chemical Engineering Fundamental. ACS Publication 40:747-753.
13. Löf, G. O. G. and Hawley, R.W. 1948. Unsteady State Heat Transfer between Air and Loose Solids. Journal of Industrial Engineering.40 (6):1061-1070.
14. Meek, R. M. G. 1961.The Measurement of Heat Transfer Coefficients in Packed Beds by the Cyclic Method. International Heat Transfer Development. ASME 1961.
15. Norton, C. L. 1946. Pebble Heater: New Heat Transfer Unit for Industry. Journal of American Ceramic Society 29: 187-193.
16. Riaz, M.1977. Analytical Solution for Single and Two Phase Models of Packed Bed Thermal Storage Systems. Journal of Heat Transfer 99: 489-492.
17. Saunders, O.A. and Ford 1940. Heat Transfer in the flow of Gas through a Bed of Solid Particles. Journal of Iron and Steel 141: 291-296.
18. Schumann, T. E. W. 1929. Heat Transfer: A Liquid Flowing Through a Porous Prism. Journal of Heat Transfer 5: 208-212.

This page is intentionally left blank

Global Journal of Researches in Engineering: A
Mechanical and Mechanics Engineering
Volume 14 Issue 5 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Design, Fabrication and Performance Study of a Biomass Solid Waste Pyrolysis System for Alternative Liquid Fuel Production

By Md. Akram Hossain, Md. Raquibul Hasan & Md. Rofiqul Islam
Rajshahi University of Engineering & Technology, Bangladesh

Abstract- Now-a-days production of Bio-fuel is a prime concern in the world due to decrease other fuel source. The conversion of devdaru seeds into pyrolytic oil by fixed bed reactor has been taken into consideration in this study. A fixed bed pyrolysis system has been designed and fabricated for obtaining liquid fuel from biomass solid wastes. The major components of the system are: fixed bed reactor, liquid condenser and liquid collectors. The devdaru seeds in particle form is pyrolized in an externally heated 7.6 cm diameter and 46 cm high fixed bed reactor with nitrogen as the carrier gas. The reactor is heated by means of a cylindrical biomass source heater. Rice husk, cow dung and charcoal are used as the energy source. The products are oil, char and gas. The parameters varied are reactor bed temperature, running time and feed particle size. The parameters are found to influence the product yields significantly. The maximum liquid yield is 51 wt% at 5000C for a feed size of <1.18 mm at a gas flow rate of 5 liter/min with a running time of 90 minute. The pyrolysis oil obtained at these optimum process conditions are analyzed for some of their properties as an alternative fuel. We get the higher heating value of devdaru seeds oil is 24.22 MJ/kg. The heating value of the oil is moderate.

Keywords: *biomass, polylthia longifolia seeds, pyrolysis, fixed bed reactor.*

GJRE-A Classification : *FOR Code: 850499p, 091399*

Strictly as per the compliance and regulations of:

Design, Fabrication and Performance Study of a Biomass Solid Waste Pyrolysis System for Alternative Liquid Fuel Production

Md. Akram Hossain [α], Md. Raquibul Hasan [σ] & Md. Rofiqul Islam [ρ]

Abstract- Now-a-days production of Bio-fuel is a prime concern in the world due to decrease other fuel source. The conversion of devdaru seeds into pyrolytic oil by fixed bed reactor has been taken into consideration in this study. A fixed bed pyrolysis system has been designed and fabricated for obtaining liquid fuel from biomass solid wastes. The major components of the system are: fixed bed reactor, liquid condenser and liquid collectors. The devdaru seeds in particle form is pyrolized in an externally heated 7.6 cm diameter and 46 cm high fixed bed reactor with nitrogen as the carrier gas. The reactor is heated by means of a cylindrical biomass source heater. Rice husk, cow dung and charcoal are used as the energy source. The products are oil, char and gas. The parameters varied are reactor bed temperature, running time and feed particle size. The parameters are found to influence the product yields significantly. The maximum liquid yield is 51 wt% at 5000C for a feed size of <1.18 mm at a gas flow rate of 5 liter/min with a running time of 90 minute. The pyrolysis oil obtained at these optimum process conditions are analyzed for some of their properties as an alternative fuel. We get the higher heating value of devdaru seeds oil is 24.22 MJ/kg. The heating value of the oil is moderate.

Keywords: biomass, polylthia longifolia seeds, pyrolysis, fixed bed reactor.

I. Introduction

Biomass has been recognized as a major renewable energy source to supplement declining fossil fuel sources of energy. It is the most popular form of renewable energy and currently biofuel production is becoming very much promising. Transformation of energy into useful and sustainable forms that can fulfill and suit the needs and a requirement of human beings in the best possible away is the common concern of the scientists, engineers and technologists. From the view point of energy transformation, fixed bed pyrolysis is more attractive among various thermo chemical conversion processes because of its simplicity and higher conversion capability of biomass and its solid wastes into liquid product. In South Asian developing countries, especially in Bangladesh the generation of biomass waste is quite high. Along with other residues these waste accumulated is creating disposal problems. Also direct burning of these wastes creates a serious environmental problem. As carbonaceous solid wastes are the source of energy, therefore, the potential of recovering these wastes into useful form of energy by pyrolysis into liquid fuel should be considered. In this way the waste would be more readily useable and environmentally acceptable. This liquid of high heating value can easily be transported, can be burnt directly in the thermal power plant; can easily be injected into the flow of conventional petroleum refinery, can be burnt in a gas turbine or upgraded to obtain light hydrocarbon transport fuel. The solid char can be used for making activated carbon. The gas has high calorific value, sufficient to be used for the total energy requirements of the pyrolysis plant.

a) Thermochemical Conversion Process

Due to high calorific value and ultimate analysis of plant based agro wastes it implies that these agro wastes are potentially useful for energy utilization in the form of combustible gas, tar oil (liquid fuel), char (solid fuel), steam or electricity when they are processed by using thermo chemical technologies for biomass conversion. There are four main thermo chemical methods of converting biomass. Such as (1) pyrolysis (2) liquefaction (3) gasification (4) direct combustion. Pyrolysis is one of the most important thermo-chemical conversion processes.

b) Pyrolysis

Pyrolysis is a thermal decomposition process that occurs at moderate temperature with a high heat transfer rate to the biomass particles and a short hot vapor residence time in the reaction zone. Several reactor configurations have been shown to assure this condition and to achieve yields of liquid products as high as 75% based on the starting dry biomass weight [16]. Pyrolysis of biomass produces a liquid product, pyrolysis oil or bio-oil that can be readily stored and transported. Pyrolysis oil is a renewable liquid fuel and can also be used for production of chemicals. Pyrolysis has now achieved a commercial success for production of chemicals and is being actively developed for producing liquid fuels. Pyrolysis oil has been successfully tested in engine, turbines and boilers, and been upgraded to high quality hydrocarbon fuels although at a presently unacceptable energetic and financial cost.

Author α σ ρ : Department of Mechanical Engineering, Rajshahi University of Engineering & Technology, Rajshahi, Bangladesh.
e-mail: akram190188@gmail.com

c) Direct Combustion

Direct combustion of biomass solid waste produces heat energy by direct burning of them. The products and applications of various biomass solid waste converting method are mentioned in Table 1.1

d) Solid Particle Pyrolysis

Pyrolysis is the heating of any fuel particle, droplet or gaseous molecule in the absence of oxygen and for solids it can be presented by the following equation:

Table 1.1 : Thermal conversion technologies, products and applications [4]

Technology	Primary product	Example application
Combustion	Heat	Heating
Gasification	Gas	Fuel gas
	Gas	Fuel gas
Pyrolysis generally	Liquid	Liquid fuel & chemical
	Char	Solid fuel/ fuel slurry
Very slow pyrolysis	Solid charcoal	Solid fuel
	Liquid	Liquid fuel
Fast pyrolysis (low temperature)	Gas	Gaseous fuel and chemical
Fast pyrolysis(high temperature)		

$$C_aH_bO_3 + \text{heat} \longrightarrow H_2O + CO_2 + H_2 + CO + CH_4 + C_2H_6 + CH_2O + \ldots + \text{Tar} + \text{char}.$$

There are three classes of products of pyrolysis; they are volatiles, tar and char. The volatiles may or may not be condensable at ambient condition; however, in all practical combustion systems these component remains in the gas phase. The tar is generally a heavy hydrocarbon substance with an atomic H/C ratio > 1.0[15]. The char generally is a carbon rich solid with only minor fractions of hydrogen and heteroatom present in the fuel or waste. Although there are exothermic regions associated with some pyrolysis reaction, the overall solid particle pyrolysis is endothermic. This equation presents a summary of pyrolysis; however, it makes fundamental chemical process involved. Pyrolysis involves both chemical and physical changes. The physical changes include the potential for particle shrinkage. Further, pyrolysis changes the thermodynamic and transport properties of the fuel particles resulting in a material which is more isolative.

II. Objectives and Scope of the Project

The aim of the project is to design and fabricate an externally heated fixed bed pyrolysis system for the production of alternative liquid fuel from devdaru seeds.

The project work is carried out with the following objectives:

- To simplify the design a fixed bed pyrolysis system,
- To fabricate the pyrolysis system,
- To produce liquid from biomass solid waste(Devdaru seeds) by pyrolysis process,
- To analyze the liquid product obtained from the pyrolysis system.

The scope of the work is as follows:

- Only Devdaru seeds are considered as feed materials for their availability at cheap price.
- The emphasis of the study is on the production of liquid. The char product is also quantified. The gas is flared to atmosphere.

a) Selected Biomass Waste

Devdaru seeds were selected as the feed material for this study. **Polylthia Longifolia** (Devdaru) in the genus Switenia, is extensively cultivated in India, Sri Lanka, Bangladesh etc as avenue tree. It is a semi evergreen tree, about 30-35m tall. Fruit shape is oval, fruit length is 1 to 3 inches, fruit covering dry or hard, the fruit color is brown. In Bangladesh, a large amount (250000 tons/yr) of devdaru seeds are not utilized but the production of oil from it may provide the use of a

renewable resource along with adding value to agricultural products.

Adapted from a number of literature an indicative picture of the chemical composition of the devdaru seed has been collated in the Table 1.2:

Table 1.2 : Approximate composition of devdaru seeds [16]

Moisture	5%
Crude Protein	31.6%
Oil	10-12%
Soluble sugar	5.15%
Fat	44.9%
Ash	4.5%

Figure 2.1 : Photograph of devdaru seeds

III. Theory and Principles

a) Pyrolysis

Pyrolysis is the process of thermal decomposition to produce gases, liquids (tar), and char (solid residue). These pyrolysis products can be used as fuels, with or without prior upgrading, or they can be utilized as feed stocks for chemical or material industries. The types of materials which are candidates for pyrolysis processing include coal, plant biomass, animal and human waste, food scraps, paper, cardboard, plastics, and rubber. AFR has developed novel pyrolysis experiments (Series 101 TG/Plus Analyzer) and modeling techniques (FG-DVC Modeling Software).Pyrolysis is generally described as the thermal decomposition of the organic components in biomass wastes in the absence of oxygen at mediate temperature (about 500° C) to yield tar (bio oil, bio fuel, bio crude), char (charcoal) and gaseous fractions (fuel gases)[18]. For convenience, there are two approaches to the conversion technology. The first approach referred to as conventional or traditional pyrolysis, is to maximize the yields of fuel gas at the preferred conditions of high temperature, low heating rate and long gas residence time or to enhance the char production at the low temperature and low heating rate. Another approach referred to as flash or fast pyrolysis is to maximize the yields of liquid product at the processing conditions of low temperature, high heating rate and short gas residence time. The heating approaches are as follows

Type 1: Part of the raw material burns inside the reactor to provide heat needed to carbonize the remainder.

Type 2: Direct heat transfer from hot gases produced by combustion of one or more of the pyrolysis products or any other fuel outside the reactor.

Type 3: Direct heat transfer from inert hot material (hot gases or sand introduced into the reactor.

Type 4: Indirect heat transfer through the reactor walls (i.e. external heat source due to combustion of one of or more pyrolysis products or any other fuel)

Due to the poor thermal stability and corrosivity in the use of the bio crude, the liquid products still need to be upgraded by lowering the oxygen content and removing residues by means of hydrogenation and catalytic cracking. Eventually the purified bio oil can be used as fuel in boilers, engines, turbines or processed into refineries as a feed stock is also being considered.

b) Pyrolysis Conversion

Among the various thermal conversion processes, pyrolysis has received much more attention, since the process conditions could be optimized to produce high energy density pyrolysis oils and chemicals in addition to derived char and gaseous products [4]. Research have been carried out on different stages of the process, from the pretreatment of the feed stock, the pyrolysis conversion process and technology, the utilization and the upgrading of the products and to the techno-economic assessment of the whole process. Different types of pyrolysis process have been studied and developed either in laboratory-scale or a pilot plant units and a small number of commercial-scale pyrolysis plants are installed. The results of this research have proved the feasibility of this technology and strongly suggested that pyrolysis is the most promising technology for solid waste treatment. Pyrolysis conversion of other organic solid wastes to liquid hydrocarbon have also been studied and reported extensively. Pyrolysis of municipal waste has been studied much earlier where initially the emphasis was on the waste disposal but gradually attention was shifted towards the liquid hydrocarbon recovery from the

process, as reported by Pober and Bauer (1977)[13]. Pyrolysis of sewage sludge to liquid hydrocarbon was also reported in literature and among the recent studies was demonstrated by Bellman et al. (1989) and Boocock et al. (1993)[2].

A possible reaction pathway of pyrolysis process is shown below:

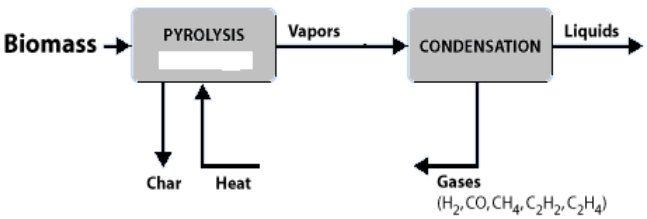


Figure 1.3 : A possible reaction pathway of pyrolysis of organic solid waste

c) Fixed Bed Pyrolysis

Pyrolysis may be either fixed bed pyrolysis or fluidized bed pyrolysis. In fixed bed pyrolysis, a fixed bed pyrolyser is used. The feed material in the reactor is fixed and heated at high temperature. As the feed is fixed in the reaction bed (reactor), it is called fixed bed pyrolysis. In this process, the feed material is fed into the reactor and heat is applied externally. Liquid petroleum or other inert gas is used for making inert condition and for helping the gaseous mixture to dispose of the reactor. The losses in fixed bed pyrolysis are relatively less than fluidized bed pyrolysis. Moreover, fluidized bed pyrolysis is more complex. This project work is based on fixed bed pyrolysis.

IV. Design and Fabrication of the Pyrolysis System

The design and fabrication of the fixed bed pyrolyser is the major part of this project work and maximum time has been spent to design, construct and assemble the experimental setup. The main parts of the system are fixed bed reactor and condenser. The pyrolysis system has been designed based on the following considerations:

- Short vapor residence time in the reactor.
- Rapid condensation of the vapor product to promote high yield of pyrolysis liquid product.
- Reliable heat supply for heating the system.
- Rapid heat transfers into the reactor so that less heating material is required
- Adequate gas flow rate to dispose off the vapor mixture.
- Proper mass flow rate of vapor and water for proper condensation.
- Size of the system is such that sufficient amount of pyrolysis liquid can be produced.

a) Simplification of the design

For simplifying the fixed bed pyrolysis system the following factors may be considered:

- To eliminate leakage problem liquid gasket may be used.
- Passing of the Nitrogen gas through a heated pipe situated in the biomass heater may save fuel for preheating.
- Using ice instead of huge amount of water may be a better substitution for condensation.

b) Description of work

Due to corrosive nature of pyrolysis liquid, especially derived from biomass and high operating temperature of the process (400°C to 550°C), stainless steel of grade ASTM A 240 and AISI 340 has been selected as the material for the major component of the system. Oxy-acetylene gas welding has been used for joining the parts of each component using brass as filler metal in the fabrication of the rig. Lathe machine has been used for cutting the stainless steel pipes and sheets . Drilling operation has been done by the drill machine for drilling various sizes of holes in the steel pipes and flanges. Gas welding has been used for various joints in the setup. Oxygen and acetylene gas has been used here for welding. Grinding machine has been used for smooth surface finishing of the flanges.

c) Fixed Bed Reactor

The selection of the size of the fixed bed reactor depends primarily on the fixed bed. The gas flow rate and the volume of the reactor determine the apparent vapor residence time in the reactor and this vapor residence time is an important parameter in fast pyrolysis process for maximizing liquid product. For fast pyrolysis the residence time should not exceed 5 sec. For the ease of fabrication, a cylindrical reactor has been considered for the system using stainless steel pipe.

i. *Design of Reactor*

Let, Apparent vapor residence time, t = 4 sec

Diameter of reactor, d = 7.6 cm (Commercially available)

Reactor area, $A = \pi d^2/4 = 45.56\ cm^2$

Gas flow rate, Q = 12.5 lit/min

= (12.5*1000 cc)/60 sec

= 208 cm^3/ sec

Effective volume for gas flow = Q*T =208*4 = 833 cm^3

However it is about 40% of the total reactor volume.

As about 60% of the volume of the reactor is occupied by the feed, the total volume of the reactor, V = 833+1.5*833 = 2082.5 cm^3

Length of the reactor, L = V/A

= 2082.5/45.35

= 45.96 cm

= 46 cm

Thus the reactor length, L = 46 cm

ii. *Design of Condenser*

A rapid quenching of pyrolysis vapor products promotes high liquid yield. The pyrolysis condensate, especially biomass derived liquid contains tarry substance, which rapidly forms and deposits in the condenser and pipelines.We have constructed a condenser which is made by copper pipe. The copper pipe is winded like a spring and placed within a plastic bottle. It is joint with the reactor by a joint connector nut.

Length of copper pipe = 14 ft

Diameter of copper pipe=0.25 in

V. Necessary Apparatus and Equipment

a) Pyrometer

A pyrometer is used for taking the temperature reading. Temperature is measured between 400°C-600°C. The maximum temperature range of the thermometer was 1000°C.

b) Biomass Heater

The biomass heater system is used to heat the reactor externally. A body of cylindrical shape biomass heater is used to heat the reactor at desired temperature.

c) Electric Blower

The necessary oxygen required to burn the heating fuel in the biomass heater is supplied trough an electric blower.

d) N_2 gas flow meter

This flow meter measures the flow of gas in liter per minute. Maximum rating of
this flow meter is 40 liter per minute.

e) N_2 gas cylinder

A N_2 gas cylinder is used to supply N_2 gas.

VI. Argument of Material Selection

With the anticipation of corrosive nature of pyrolysis liquid, especially liquid derived from organic solid and high operating temperature of the process, problems of corrosion has been envisaged. The material of various parts (reactor and their joining pipes) is stainless steel for its less corrosiveness and higher metallurgical limit. In condenser, copper pipe is used for its better work as a condensing device. As it is widely used is refrigerator for its good condensing quality. Plastic bottle is used to hold the copper pipe. Wolf bottle is used as liquid collector.

VII. Assembly of the Rig

The rig is assembled on a frame structure made of mild steel angle bar. The rig is mounted by making rack in frame, so that the position of the rig is fixed. They are joined with each other or with reactor and condenser by locking screw with flange. Liquid gasket is used to seal various joints. The biomass heater is set in a rack of frame, which supplied heat uniformly to the reactor externally. The assembly is shown in Figure 4.6. At the bottom of the reactor is connected a gas (inert) cylinder and there is a condenser also for cooling vapors. The schematic diagram and photograph of the setup is shown in Figure 1.4 and 1.5.

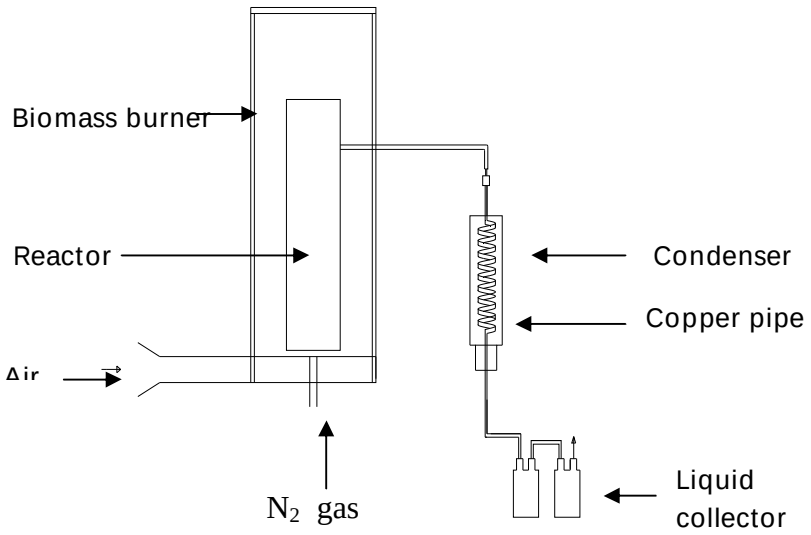


Figure 1.4 : Schematic Diagram of Fixed Bed Pyrolysis System

Figure 1.5 : Photograph of the pyrolysis system

a) Feed Preparation

The devdaru seed is collected and dried. It is then crushed into smaller sizes. These are <1.18mm, 1.18mm, 2.36mm, and 4.75mm in dia. It is dried with the help of oven. Thus the feed material is prepared.

b) Process Flow Chart

The flow path of the fixed bed pyrolysis of devdaru seed is given in Figure 1.6. The prepared feed material is taken into the reactor and heated. The gaseous vapor is passed through the condenser to separate the products into liquid and gas.

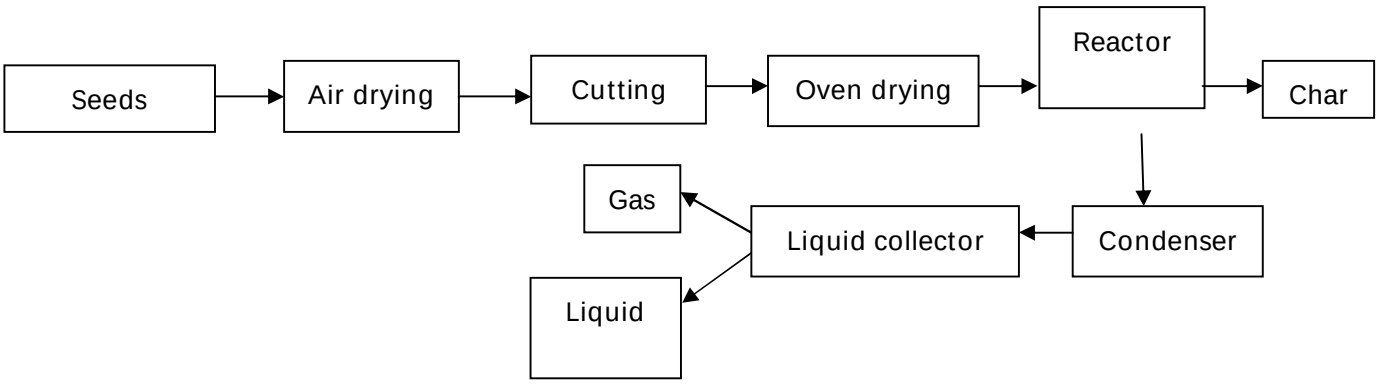


Figure 1.6 : Process flow chart for fixed bed biomass pyrolysis

VIII. Experimental Procedure

At first, Feed material was weighed and filled into the reactor. The experimental set-up was assembled. High temperature adjustable gaskets were used to seal the joints and fittings of the hot parts of the connecting pipe, reactor and condenser. Ice was placed into the condenser. The reactor was heated externally by a biomass heater at different temperatures and these temperatures were measured by pyrometer. The N_2 gas was passed through reactor through a heated pipe and this flow was controlled by the use of a gas flow meter valve. The operation time was recorded by means of a stopwatch. When the operation was completed a small flow of N_2 gas was allowed to pass Seeds Air drying through the system to prevent back flow of air which might react with hot gases when the reactor was still hot. It is dismantle when the rig was cooled enough to be handled. The char was collected from the reactor bed and weighed. All data are recorded in tabular form. All the parts of the system were cleaned and the heating value of the liquid and char was measured by a bomb calorimeter before reassembling for the next run.

a) Gas flow rate

Nitrogen gas is metered from gas cylinder. A multi-stage nitrogen gas pressure regulator of model MUREX N-10 is used to regulate the pressure of the gas from the cylinder. During the study, the outlet gage reading is set at atmospheric pressure. The gas entered at the bottom of the reactor through the heated pipe. Nitrogen gas is used in the study for its inertness and ease of availability and cheapness in cost. A nitrogen gas flow-meter of model MUREX 0011 with a variable control valve of capacity 0-40 liter/min is used to control

and measure the gas flow rate. The flow rate is varied between 4-12 liter/min.

b) Temperature Measurement

The reactor temperature of the rig is measured by a pyrometer. Its capacity for measuring temperature range is 0°C to 1000°C. The pyrometer is inserted into the reactor from the side to the almost bottom of the reactor where the pyrolysis conversion has taken place.

IX. Study of Physical Properties of Pyrolysis Oil

a) Higher Heating Value

The higher heating value is a measure of the quantity of the heat released in the total combustion and therefore the energy content of a fuel. It is the most important fuel properties of any liquid fuel. The higher heating value of the derived oil is determined by using Parr adiabatic bomb calorimeter according to the test method of DIN 51 900. The test is conducted in the Heat Engine Laboratory of the Department of Mechanical Engineering of Rajshahi University of Engineering and Technology.

By using a Bomb calorimeter

H.C.V. = $(TW-E_1-E_2-E_3)/M$ in the unit of MJ/kg

Where, M = Weight of the liquid fuel = 1 gm

W = 2426 cal/gm k water equivalent

T = Temperature difference

E_1 = Correction in calories for heat of formation of nitric acid (HNO_3) = 23.9 Cal

E_2 = Correction in calories for heat of formation of sulfuric acid (H_2SO_4) = 13.9 Cal

E_3 = Correction in calories for heat of combustion of fuse-wire = 17.5 Cal

b) Density

The density of oil is a measure of aromatics in hydrocarbon oils, but not in biomass derived oils. It is a necessary parameter used to calculate the volumetric output of pumps and injectors needed to supply a given rate of delivered energy, because the heat of combustion is determined on a weight basis. Mass density means mass per volume.

c) Kinematic Viscosity

Kinematic viscosity is a measure of the resistance to gravity flow of a fluid. Viscosity of oil is an important property, since it affects for example the flow of the liquid through pipelines. The lower the viscosity of the liquid, the easier it is to pump and to atomize and achieve finer droplets. This is the major criterion upon which the oils are graded. The kinematic viscosity of the pyrolysis liquids was determined using Glass Capillary Kinematic Viscometer, according to ASTM D445- IP 71-BS 2000 Part 71 test methods. This test was carried out at the Laboratory of the Department of Chemistry.

By using a glass capillary kinematic viscometer

Viscosity, $\mu = [(t*\rho) / (t_o*\rho_o)]*\mu_o$

At 35°C, for water

t_o = 90 sec

ρ_o = 994.1 kg/m³

μ_o = 0.723 Pa.s

d) Flash Point

This measure the liquid temperature necessary for the vapors above a pool of the fuel to ignite by passing flame through the vapor. This is a measure of volatility of the oil as oil as its ease of ignition. The higher value is the safer the oil is to handle because the risk of accidental vapor ignition is reduced. Pyrolysis oil has a reported flash point of between 30°C and over 100°C, reflecting a wide variation in the content of volatiles. However, above temperature of 70°C to 75°C, water vapor from the pyrolysis oils start to disturb the analysis and a reproducible value is difficult to obtain. The flash point of the liquid was determined using Cleveland open cup tester, according to ASTM D 92-IP36 test methods.

e) Fire Point

Fire point is the temperature at which the oil, if once lit with flame, will burn steadily at least for 5 seconds. The fire point of the liquid was determined using Cleveland open cup tester, according to ASTM D 92-IP36 test method.

X. Results and Discussion

a) Experimental run

A total of 12 experimental run has been taken in this study. Four sizes of devdaru seeds are used here. The sizes are <1.18 mm, 1.18 mm and 2.36 mm and 4.75mm. The experimental results of the run at different conditions with their effects are presented here.

i. *Effect of feed particle size*

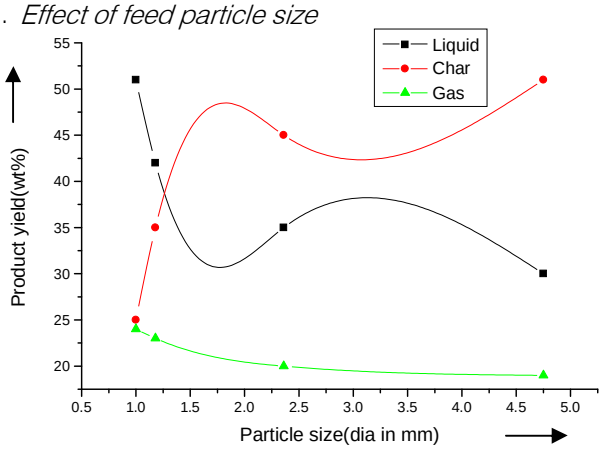


Figure 1.7 : Effect of feed particle size on product yield (<1.18 mm,1.18 mm, 2.36 mm and 4.75mm) for reactor temperature 450~550°C

Figure 1.7 represents the percentage weight of liquid and solid char products for different particle size of feed at a bed temperature of 500°C and an operating time of 90 minutes. It is observed that at 500°C the percentage of liquid collection is a maximum of 51% of total biomass feed for particle size of <1.18 mm. A less amount of liquid is obtained from the larger particle size feed. This may be due to the fact that the larger size particles are not sufficiently heated up so rapidly causing incomplete pyrolysis that reduced liquid product yield.

ii. *Effect of reaction temperature*

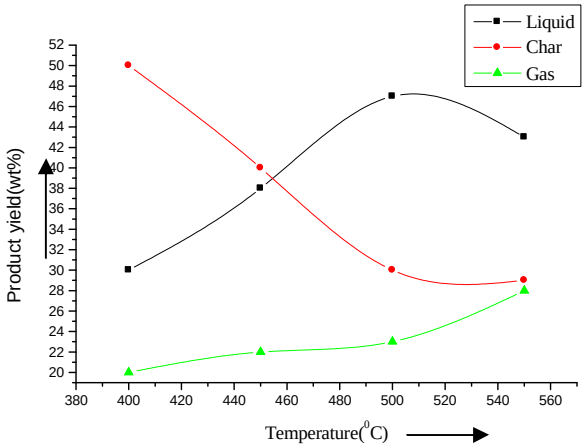


Figure 1.8 : The effect of operating temperature on product yield

Figure 1.8 shows the variation of percentage weight of liquid, char and gaseous products at different bed temperature with particle size of < 1.18mm. From this it is found that the maximum liquid products yield is obtained at a temperature of 500°C, and this is 47%wt of total biomass feed. At lower temperature the liquid product yield is decreasing while with the increase of temperature above 500°C, the liquid product yield is again deteriorating. With the increase of temperature the solid char yield is decreasing above 500°C and increasing below 500°C. It may be caused at lower temperature less than 500°C, complete reaction cannot be taken place.

iii. *Effect of Running Time*

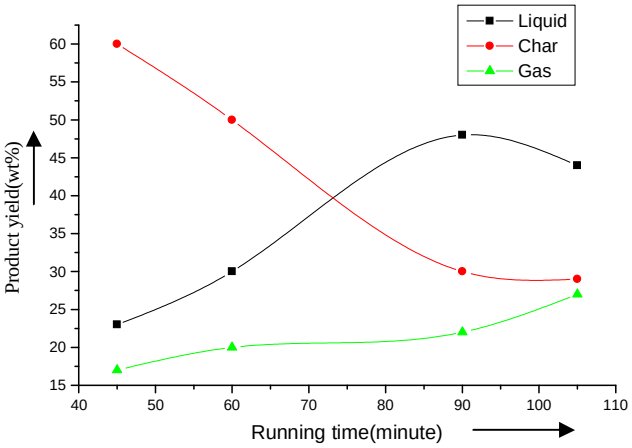


Figure 1.9 : Effect of running time on product yield for reaction bed temperature 450~500°C and for feed particle size 1.18 mm

Figure 1.9 shows the variation of product yield (wt%) of liquid, solid char and gas products at a temperature of 500° C solid char product is 30wt% of < 1.18mm. The maximum liquid product is 48 wt% of biomass feed while the for feed particle of size of dry feed at 90 minutes. It is observed that lower and greater running time than of that of 90 minutes the liquid product yield is not optimum that may be due to insufficient pyrolysis reaction and higher rate of gas discharge respectively. Secondary cracking reaction taken place by which the amount of permanent gas product is increased. So at temperature higher than 5000C liquid product is decreased.

b) Physical Characteristics

The physical characteristics of the pyrolysis oil are shown in Table 1.3. The energy content of the oil is 24.22 MJ/kg. The oil is found to be heavier than water with a density of 1240 kg/m²at 35°C. The flash point of the oil is 60°C and hence precautions are not required in handling and storage at normal atmosphere. The viscosity of the oil of 12.15 cSt at 35°C is a favorable feature in the handling and transportation of the liquid.

Table 1.3 : Physical characteristics of devdaru seed oil

Analysis	Devdaru seed oil
Kinematic viscosity at 35°C (cSt)	12.15
Density(kg/m^3)	1240
Flash Point(°C)	60
Fire Point (°C)	76
HHV of liquid(MJ/kg)	24.22
HHV of char(MJ/kg)	22.5
HHV of feed material(MJ/Kg)	20.7

Comparison of devdaru seed oil with petroleum products and biomass derived pyrolysis oil.

The comparison of physical characteristics of devdaru seed oil with other biomass derived pyrolysis oil and petroleum products is shown in Tables 1.4 & 1.5

Table 1.4 : Comparison of devdaru seed pyrolysis oil with biomass derived pyrolysis oil

Analysis	Devdaru Seed oil	Date Seed oil [12]	Waste paper oil [8]	Sugarcane bagasse oil [10]	Jute stick oil [9]
Kinematic viscosity at 35^{0}C (cSt)	12.15	6.63	2.00	89.34	12.8
Density (kg/m^3)	1240	1042.4	1205	1198	1224
Flash Point (^{0}C)	60	126	200	105	>70
HHV(MJ/kg)	24.22	28.636	13.10	20.072	21.091

Table 1.5 : Physical characteristics of the Devdaru seeds pyrolysis oil and its comparison

Analysis	Devdaru Seed oil	Fast Diesel [6]	Diesel [1]	Heavy Fuel Oil [14]	Wood Waste [1]
Kinematic viscosity at 35^{0}C (cSt)	12.15	1.3-3.3.3$^{\#}$	2.61*	200$^{\#}$	66.99
Density (kg/m^3)	1240	780	827.1*	980*	1180.2
Flash Point (^{0}C)	60	75	53	90-180	59
HHV(MJ/kg)	24.22	45-46	45.18	42-43	19.80

#at 500C *at 200C

From the comparison it is shown that the viscosity of devdaru seed oil is favorable than other pyrolysis oils. It has HHV of 24.22 MJ/kg.

XI. Conclusion

The objectives of the study are fulfilled by using the biomass waste in the form of devdaru seeds with fixed bed pyrolysis system made of stainless steel pipes and sheets. The fixed bed pyrolysis of solid devdaru seed has a maximum oil yield of 51wt% of biomass feed particle size of <1.18mm at a reactor bed temperature of 500^{0}C and a gas flow of 5 liter/ minute with the running time of 90 minute. With increasing reactor bed temperature, percentage weight of char production is decreasing and the gas production is increasing. The physical properties analysis showed that the oil is heavy in nature with moderate viscosity. The oil possessed favorable flash point. The heating value of the oil is moderate.

XII. Recommendation

The liquid yield of devdaru seed from the fixed bed reactor is quite satisfactory. However, the performance of the system could be improved further, to produce more reliable and better results. The following recommendations are suggested for such improvement.

a) The process bed temperature would be easier to control at uniform value if the system could be well insulated and supplied uniform rate of air by the blower.

b) If only copper pipe is used for condenser, more liquid yield will be condensed.

c) The char products from pyrolysis of devdaru seed is reasonably high. The high char yield has a potential values a solid fuel or as activated carbon or further characterization of the char are suggested. The energy content of the char could be utilized. The gaseous product may be taken into consideration.

d) The consumption of expensive inert gas (nitrogen) was high. The gas product could be recycled as fluidizing gas. However, the effect of the use of recycling gas on the pyrolysis product yield and characteristics should be studied first.

e) The external heating system (heater) should be insulated to reduce heat loss.

f) The properties of different products of this research work can be found for comparison with other conventional fuels for alternative use.

g) Finally after implementing product-upgrading process, the fuel may be tested in an internal combustion engine.

References Références Referencias

1. Andrews, R.G. and Patniak, P. C., 1996, "Feasibility of utilizing a biomass derived fuel for industrial gas turbine applications" In: Bridgwater AV, Hogan EN, editor. *Bio-Oil Production & Utilization,* Berkshire: CPL Press, pp. 236-245.
2. Bellman,U., Kummer, A.B, Ying, Y. and kaminnsky, W.(1989). "Fluidized Bed Pyrolysis of Sewage Sludge. In: Ferrero, G.L.,Buekens, A. & Bridgwater, A.V.(Eds). *Pyrolysis & Gasification.* London: Elsevier Applied Science; 190-195. Buekens.
3. Boocock, D. G. B., Konar, S. K., Leung, A.,Liu,J. and Ly, L. D., (1993). "Liquid Hydrocarbons from the Extraction and Catalytic Pyrolysis of Sewage Sludge". In: Bridgwater, A.V.,(Eds.). *Advances in Thermochemical Biomass Conversion.* Edinburgh: Blackie Academic and Professional; 986-999.
4. Bridgwater,A.V.and Bridge, S.A.(1991). "A Review of Biomass Pyrolysis Technologies. In: Bridgwater, A. V. and Grassi, G. (Eds). *Biomass Pyrolysis liquids Upgrading and Utilisation.* London: Elsevier Science; 11-92.
5. Evans, R. J. and Milne, T. (1988). "Molecular-Beam, Mass-Spectrometric Studies of Wood Vapour and Model Compounds over an HZSM-5 Catalyst". In: Soltes, E.J. and Milne, T.A. (Eds.). *Pyrolysis Oils from Biomass Producing Analysing, and Upgrading.* Washington: America Chemical Society; 311-327.
6. Harker, J.H. and Bachurst J, R., 1981, *Fuel and Energy,* London: Academic Press.
7. Islam, M. N. Islam M. N. Beg, M. R. A. (2003). "The fuel properties of pyrolysis liquid derived from urban solid wastes in Bangladesh". *Bioresourc Technology* 92, l8l-186.
8. Islam, M. N. Islam M. N. Beg, M. R .A, Islam M. R. (2004). "A work on pyrolytic oil from fixed bed pyrolysis of municipal solid waste and its characterization". *Renewable Energy* 30, 413-420.
9. Islam, M.R., Nabi, M.N. and Islam, M.N. 2001, "Characterization of biomass solid waste for liquid fuel production", *Proc. of 4'h Int. Conf. on Mechanical Engineering* (ICME2001), Bangladesh, pp.77-82.
10. Islam, M.R, Islam, M.N. and Islam, M.N. 2003, "The fixed bed pyrolysis of sugarcane bagasse for liquid fuel production", *Proc. of the Int. Conf. on Mechanical Engineering* (ICME2003), Bangladesh, pp.26-28.
11. Islam, M.N. and Ani, F. N. 2003, "Production of Bio-oil from palm oil shell", *Jurnal Kejuruteraan* 12 (2000), pp.105-116.
12. M. Uazzal Hossain Joardder and M. Montasir Iquebal, 2003: *"Design, Fabrication and Performance Study of a Biomass solid waste Pyrolysis System for Alternative Liquid Fuel Production".*
13. Pober, K. W. & Bauer, H. F. (1977). "The nature of pyrolysis oil from municipal solid waste". In: Anderson, L. L. & Tillman, D. A. (Eds). *Fuel From Waste.* N. York: Academic Press; 73-85.
14. Rick, F. and V ix, U., 1991, "Product standards for pyrolysis products for use as fuel in industrial firing plants", In: Bridgwater AV, Grassi G, editor. *Biomass Pyrolysis Liquids Upgrading and utilization,* London: Elsevier Science, pp. 177- 218.
15. Soerianegara, I, Lemmens, R. H. M. J, eds 1993: *"Ptant Resources of South East Asia No 5(1)".*
16. Web Link
    http://www.frtr.gov/matrix2/section4/4-25.html
    http://www.llnl.gov/IPandC/op96/03/3h-mol.html
    http://www.bestenergies.com/companies/bestpyrolysis.html
    http://www.DirectScience.com
    en.wikipedia.com

Global Journal of Researches in Engineering: A
Mechanical and Mechanics Engineering
Volume 14 Issue 5 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

A Case Study of Heat Treatment on AISI 1020 Steel

By Sayed Shafayat Hossain, Md. Maksudul Islam & Md. Sajibul Alam Bhuyan
Khulna University of Engineering and Technology, Bangladesh

Abstract- Proper heat treatment of steels is one of the most important factors in determining how they will perform in service. Engineering materials, mostly steel, are heat treated under controlled sequence of heating and cooling to alter their physical and mechanical properties to meet desired engineering applications. In this study we have chosen AISI 1020 steel as for our research work and we have tried to find out the mechanical properties (hardness) and micro structural properties (martensite formation, carbon self-locking region) by means of appropriate heat treatment process (annealing, normalizing & hardening). Here the steel specimens were heat treated in a furnace at different temperature levels and soaking time; and then cooled in various media (air, ash, water). After that the hardness of the specimens were rechecked for the comparison with previous data and the microstructures of the specimens were examined using metallurgical microscope equipped with camera. These results showed that the hardness of AISI 1020 steel can be changed and improved by different heat treatments for a particular application. From the microstructures we have found that the annealed specimens with mainly ferrite structure give the lowest hardness value and highest ductility while hardened specimens which comprise martensite give the highest hardness value and lowest ductility. On the other hand, normalized specimens have given the moderate hardness and ductility comparing with hardened and annealed specimens.

Keywords: heat treatment, annealing, hardening, normalizing, microstructures, austenite, ferrite, pearlite, martensite.

GJRE-A Classification : FOR Code: 091399, 091308

Strictly as per the compliance and regulations of:

A Case Study of Heat Treatment on AISI 1020 Steel

Sayed Shafayat Hossain [α], Md. Maksudul Islam [σ] & Md. Sajibul Alam Bhuyan [ρ]

Abstract- Proper heat treatment of steels is one of the most important factors in determining how they will perform in service. Engineering materials, mostly steel, are heat treated under controlled sequence of heating and cooling to alter their physical and mechanical properties to meet desired engineering applications. In this study we have chosen AISI 1020 steel as for our research work and we have tried to find out the mechanical properties (hardness) and micro structural properties (martensite formation, carbon self-locking region) by means of appropriate heat treatment process (annealing, normalizing & hardening). Here the steel specimens were heat treated in a furnace at different temperature levels and soaking time; and then cooled in various media (air, ash, water). After that the hardness of the specimens were rechecked for the comparison with previous data and the microstructures of the specimens were examined using metallurgical microscope equipped with camera. These results showed that the hardness of AISI 1020 steel can be changed and improved by different heat treatments for a particular application. From the microstructures we have found that the annealed specimens with mainly ferrite structure give the lowest hardness value and highest ductility while hardened specimens which comprise martensite give the highest hardness value and lowest ductility. On the other hand, normalized specimens have given the moderate hardness and ductility comparing with hardened and annealed specimens.

Keywords: heat treatment, annealing, hardening, normalizing, microstructures, austenite, ferrite, pearlite, martensite.

I. Introduction

In engineering similar metals are required to possess very strange combination of properties when they are subjected to different conditions of working. They may have to be subjected to, twisting, impact loading, as well as to withstand various stresses like tensile, compressive and shear in different places of their utility. Moreover for using them or their alloys as a tool material, they may require hardness, toughness, along with softer shank. In order to induce certain desirable properties in the metals, Heat treatment operations are applied to the material. For this purpose the metals may have to be heated to different temperatures, cooled and reheated in different media. The properties of metals can be improved, graded or altered practically by controlled heating and cooling *i.e.* by heat treatment [1].

Microscopic examination (microanalysis) is the study of the structured materials under a microscope at large magnification. The structure observed is called microstructure. A definite though only qualitative relationship exists between the structure of a metal observed in an optical microscope and certain properties of that metal. In many cases microanalysis shows that the variations in alloy properties are due to variations in chemical composition and conditions of treatment [1].

Polishing of specimen surface for microscopic study is done to prepare a smooth, deformation or distortion free surface for giving a clear two-dimensional view of the microstructures present. But, the polished surface of a uniform specimen appears bright without any detail under the metallurgical microscope. To make its structure apparent under the microscope it is necessary to impart unlike appearances to the constituents. This is accomplished by selectively corroding or etching the polished surface [1].

Transformation temperature is a function of chemical composition and heat treatment and quenching processes done on these alloys. In heat treatment process, the rate of quenching, exposure time and heat treatment temperature control the forward and reverse transformation temperatures of austenite to martensite and martensite to austenite [2].

Hardening is the heat treatment process which increases the hardness of a steel piece by heating it to a certain high temperature and then cooling it rapidly to room temperature. In this process a piece of steel is heated to a temperature of 30°C to 50°C above the upper critical temperature for hypo-eutectoid steels and by the same temperature above lower critical temperature for hyper-eutectoid steels. Depending upon its thickness, it is held at this temperature for a specified time and then cooled in a suitable cooling medium (quenching bath) like water, brine, oil or current of air from blower or compressor [3]. However, water is corrosive with steel, and the rapid cooling can sometimes cause distortion or cracking [4].

Annealing is that heat treatment process which softens an already hardened steel piece by heating it to a certain high temperature and then cooling it very slowly to room temperature. This process refines grain structures, softens the steel, improves its machinability

Author α ρ: Department of Mechanical Engineering, Khulna University of Engineering and Technology, Khulna-9203, Bangladesh.
e-mail: shafayathossain1005013@gmail.com, sajibul.alam.1005057@gmail.com
Author σ: Department of Industrial Engineering and Management, Khulna University of Engineering and Technology, Khulna-9203, Bangladesh. e-mail: maksudkhandakar@gmail.com

and restores its ductility by reducing hardness. It also removes internal stresses [1].

The tensile strength and hardness of steel produced by annealing are less than that produced by normalizing [5].

Normalizing is a heat treatment process to make steel moderate hard from soften steel. The normalizing of steel is carried out by heating approximately 100'F above the upper critical temperature line and then cooling in air to room temperature. It does not soften the steel to the extent it is done by annealing and also it does not restore ductility as much as done by annealing [2].

II. Various Microstructures

Prediction of microstructure transformations is prerequisite for successful prediction of mechanical properties after a heat treatment and of generation of stresses and strains during a heat treatment. Phase transformation modeling is one of the main challenges in modeling of heat treatment [6]. During annealing, softening processes are under way in the microstructure and, in some cases, recovery and recrystallization take place as well. Naturally, the morphology of carbides changes as well [7].

a) Ferrite

It is α-iron (B.C.C.) having not more than 0.025% carbon in solid solution. It is major constituent in low carbon steels and wrought iron. Its hardness varies from 50 to 100 B.H.N. Its upper tensile strength is about 330 MN per m2 and percentage elongation about 40. It can be easily cold worked [1].

b) Cementite

It is iron carbide, with 6.67% carbon. Its upper tensile strength is about 45 MN per m2 and hardness about 650 B.H.N. It is white in color and is brittle. It occurs in steels which have been cooled slowly. It is magnetic below 250°C .In steels containing carbon less than 0.8% it is present as a component of another constituent, "pearlite". In steels containing more than 0.8% carbon it exists as a grain boundary film [1].

c) Pearlite

In its microstructure it consists of alternate laminations of ferrite and cementite. It contains about 0.8% carbon in iron. It is the strongest constituent of steel. Its hardness is about 180 B.H.N., ultimate tensile strength about 920 MN per m2 and percentage elongation about 5% [1].

d) Austenite

It is a solid solution of carbon in ý-iron (F.C.C.) containing a maximum of 2% carbon at 1130°C. It is tough and non-magnetic. It exists in plain carbon steels above upper critical temperature. Elements like chromium and manganese in steel preserve all or some of austenite down to 0°C. Austenite consists of polyhedral grains showing twins [1].

e) Martensite

In plain carbon steel it is obtained by quenching from above upper critical temperature. It is the hardest constituent obtained in given steel. It shows a fine needle-like microstructure. Its hardness is about 700 B.H.N. It is unstable and disappears on reheating the steel. It is magnetic and less tough than austenite. It is considered to be highly stressed α-iron supersaturated with carbon [1].

III. Methodology

Figure 3.1 : Muffle furnace (manual)

Figure 3.2 : Muffle furnace (automatic)

Figure 3.3 : Metallurgical Microscope

Figure 3.4 : Polishing Machine

a) Material Composition

The chemical composition of AISI 1020 steel

Table 1 : Material composition of AISI 1020 steel

C	Si	Mn	Cr	Ni	P	S	Fe
0.20	0.22	0.66	0.055	0.18	0.015	0.028	Balanced

b) Working Steps

The following steps were carried out in our experimental investigation:

- Samples of AISI 1020 steel were prepared for hardness test in Brinell Hardness Tester machine.
- After that the following specimens were heat treated in the furnace for reaching the austenization temperature (850-900°C) of the following specimens.
- Then the specific heat treatment operation like hardening, annealing and normalizing had been done.
- For specific heat treated specimen, the hardness test was done for assessing the change in hardness.
- Metallographic tests were carried out to observe the changes in microstructures after heat treatment.

IV. Result and Discussion

a) For Annealing

In this case the specimen was put in the furnace for 850°C and we kept it in this situation for approximately 35 minutes. After that it was cooled in a heap of ashes so that it was cooled down at a very slow rate.

The function of annealing is to restore ductility and also removes internal stresses but its Brinell Hardness Number is less than hardening because here carbon get more time to react with oxygen in the atmosphere for slow cooling rate.

b) For Hardening

In this case the specimen was put in the furnace for 850°C and we kept it in this situation for approximately 10 minutes. After that it was cooled in water so that it was cooled down very quickly.

The function of hardening is to increase the hardness of the specimen and so its Brinell hardness number is larger than annealing and normalizing because here carbon cannot get more time to react with oxygen (for quick cooling rate), so carbon is trapped with the specimen and formed martensite.

c) For Normalizing

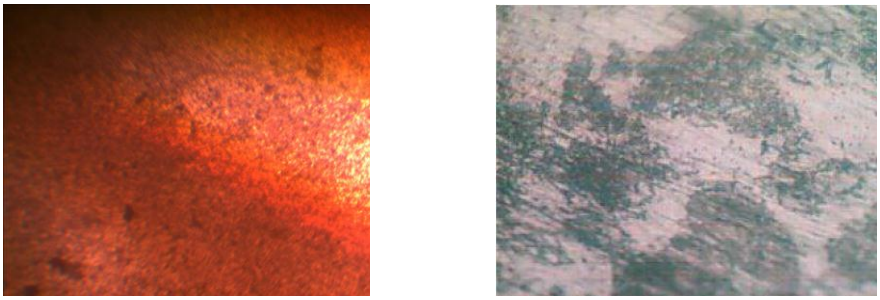
In this case the specimen was put in the furnace for 850°C and we kept it in this situation for approximately 45 minutes. After that it was cooled in room temperature.

Normalizing does not soften the steel to the extent it is done by annealing and also it does not restore ductility as much as is done by annealing. Its Brinell Hardness Number is less than hardening but greater than annealing.

Table 2 : Effect of heat treatment on hardness

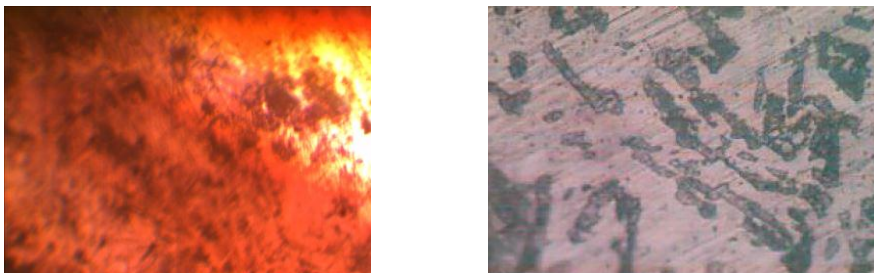
Heat treatment technique	Hardness number (B.H.N.)	
	Before heat treatment	After heat treatment
Annealing	109	127
Hardening (water quenched)	109	431
Normalizing	109	151

From the *Table 2* we can easily indicate that there is a significant change in hardness number of the hardened specimen comparing with normalizing and annealing. It is happened because of self-locking of carbon particles in the hardened specimen. In the microstructures of these specimens we have indicated the carbon-saturated region with arrow marks (*Figure 4.1, Figure 4.2, Figure 4.3*) and these help to find out the differences among the microstructures of annealed, normalized and hardened specimens comparatively. As slow cooling is done in annealing so it transforms austenite to soft pearlite and also mixed with ferrite or cementite and this cementite increases the brittleness of the steel. Normalizing converts soft steel to moderate hard steel. In this case cooling rate is faster than annealing and for this reason, when the specimen is cooled in room temperature then ferrite and cementite are formed but their quantity is less. So the specimen is enhanced with considerable ductility by reducing its brittleness. In hardening process austenite structure is directly formed into martensite structure for fast cooling. Actually the rapid cooling converts most of the austenite into martensite which is a hard constituent and more stable than austenite at ordinary temperatures.



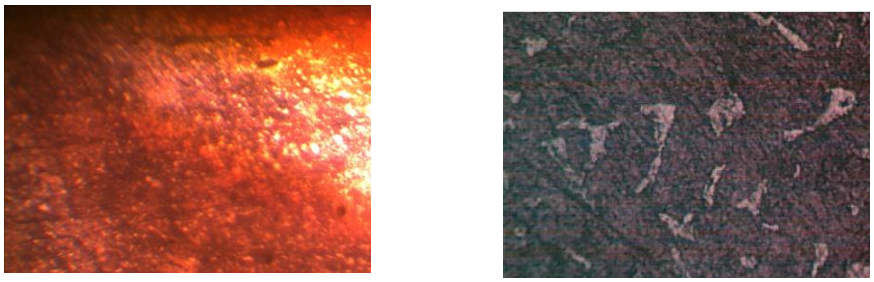
Experimental Actual

Figure 4.1 : Annealed AISI 1020 steel microstructure (100X)



Experimental Actual

Figure 4.2 : Normalized AISI 1020 steel microstructure (100X)



Experimental Actual

Figure 4.3 : Hardened AISI 1020 steel microstructure (100X)

V. Conclusion

Here we have tried to show that the different means of cooling rate are responsible to provide significant change or effect on the microhardness of steels depending on the carbon content of steel. The microhardness increases with the increasing cooling rate and carbon content due to solid solution hardening and formation of the martensite phase. Thus heat treatment is used to obtain desired properties of steels such as improving the toughness, ductility or removing the residual stresses.

References Références Referencias

1. V. K. Manchanda, G.B.S. Narang, 2005. "Materials and Metallurgy", 6th Edition, Khanna Publishers.
2. K.W.K. Yeunga, K.M.C. Cheunga, W.W. Lua, C.Y. Chungb, "Materials Science and Engineering" A, 383 (2004) 213–218.
3. Sidney H.Avner, 2010. "Introduction to Physical Metallurgy", Second Edition, Tata McGraw-Hill.
4. Htuni, G.G., M. Faccoli, and M. Roberti. 2009. "Influence of Aging on Microstructure". 198-205.
5. Herring, D.L. and V. Jenko. 2009. "Estimation of Fracture Toughness of Nitride Compound Layers on Tool Steel by Application of Vickers Indentation Method". Surface and Coating Technology. 201:182-188.
6. K. Funatani, G.E. Totten, "Present Accomplishments and Future Challenges of Quenching Technology", Proceedings of the 6th International Federation of Heat treatment and Surface Engineering Congress, IFHTSE, Kyongju, Korea, 1997, 20-27.
7. Nam W. J. & Bae C. M. (1999), "Coarsening Behavior of Cementite Particles at a Subcritical temperature in a medium Carbon Steel". *Scripta Materialia,* Vol. 41, No. 3, pp. 313-318.

Global Journals Inc. (US) Guidelines Handbook 2014

www.GlobalJournals.org

FELLOWS

FELLOW OF ASSOCIATION OF RESEARCH SOCIETY IN ENGINEERING (FARSE)

Global Journals Incorporate (USA) is accredited by Open Association of Research Society (OARS), U.S.A and in turn, awards "FARSE" title to individuals. The 'FARSE' title is accorded to a selected professional after the approval of the Editor-in-Chief /Editorial Board Members/Dean.

- The "FARSE" is a dignified title which is accorded to a person's name viz. Dr. John E. Hall, Ph.D., FARSE or William Walldroff, M.S., FARSE.

FARSE accrediting is an honor. It authenticates your research activities. After recognition as FARSE, you can add 'FARSE' title with your name as you use this recognition as additional suffix to your status. This will definitely enhance and add more value and repute to your name. You may use it on your professional Counseling Materials such as CV, Resume, and Visiting Card etc.

The following benefits can be availed by you only for next three years from the date of certification:

FARSE designated members are entitled to avail a 40% discount while publishing their research papers (of a single author) with Global Journals Incorporation (USA), if the same is accepted by Editorial Board/Peer Reviewers. If you are a main author or co-author in case of multiple authors, you will be entitled to avail discount of 10%.

Once FARSE title is accorded, the Fellow is authorized to organize a symposium/seminar/conference on behalf of Global Journal Incorporation (USA).The Fellow can also participate in conference/seminar/symposium organized by another institution as representative of Global Journal. In both the cases, it is mandatory for him to discuss with us and obtain our consent.

You may join as member of the Editorial Board of Global Journals Incorporation (USA) after successful completion of three years as Fellow and as Peer Reviewer. In addition, it is also desirable that you should organize seminar/symposium/conference at least once.

We shall provide you intimation regarding launching of e-version of journal of your stream time to time.This may be utilized in your library for the enrichment of knowledge of your students as well as it can also be helpful for the concerned faculty members.

The FARSE can go through standards of OARS. You can also play vital role if you have any suggestions so that proper amendment can take place to improve the same for the benefit of entire research community.

As FARSE, you will be given a renowned, secure and free professional email address with 100 GB of space e.g. johnhall@globaljournals.org. This will include Webmail, Spam Assassin, Email Forwarders,Auto-Responders, Email Delivery Route tracing, etc.

The FARSE will be eligible for a free application of standardization of their researches. Standardization of research will be subject to acceptability within stipulated norms as the next step after publishing in a journal. We shall depute a team of specialized research professionals who will render their services for elevating your researches to next higher level, which is worldwide open standardization.

The FARSE member can apply for grading and certification of standards of their educational and Institutional Degrees to Open Association of Research, Society U.S.A. Once you are designated as FARSE, you may send us a scanned copy of all of your credentials. OARS will verify, grade and certify them. This will be based on your academic records, quality of research papers published by you, and some more criteria. After certification of all your credentials by OARS, they will be published on your Fellow Profile link on website https://associationofresearch.org which will be helpful to upgrade the dignity.

The FARSE members can avail the benefits of free research podcasting in Global Research Radio with their research documents. After publishing the work, (including published elsewhere worldwide with proper authorization) you can upload your research paper with your recorded voice or you can utilize chargeable services of our professional RJs to record your paper in their voice on request.

The FARSE member also entitled to get the benefits of free research podcasting of their research documents through video clips. We can also streamline your conference videos and display your slides/ online slides and online research video clips at reasonable charges, on request.

The FARSE is eligible to earn from sales proceeds of his/her researches/reference/review Books or literature, while publishing with Global Journals. The FARSE can decide whether he/she would like to publish his/her research in a closed manner. In this case, whenever readers purchase that individual research paper for reading, maximum 60% of its profit earned as royalty by Global Journals, will be credited to his/her bank account. The entire entitled amount will be credited to his/her bank account exceeding limit of minimum fixed balance. There is no minimum time limit for collection. The FARSE member can decide its price and we can help in making the right decision.

The FARSE member is eligible to join as a paid peer reviewer at Global Journals Incorporation (USA) and can get remuneration of 15% of author fees, taken from the author of a respective paper. After reviewing 5 or more papers you can request to transfer the amount to your bank account.

MEMBER OF ASSOCIATION OF RESEARCH SOCIETY IN ENGINEERING (MARSE)

The 'MARSE ' title is accorded to a selected professional after the approval of the Editor-in-Chief / Editorial Board Members/Dean.

The "MARSE" is a dignified ornament which is accorded to a person's name viz. Dr. John E. Hall, Ph.D., MARSE or William Walldroff, M.S., MARSE.

MARSE accrediting is an honor. It authenticates your research activities. After becoming MARSE, you can add 'MARSE' title with your name as you use this recognition as additional suffix to your status. This will definitely enhance and add more value and repute to your name. You may use it on your professional Counseling Materials such as CV, Resume, Visiting Card and Name Plate etc.

The following benefitscan be availed by you only for next three years from the date of certification.

MARSE designated members are entitled to avail a 25% discount while publishing their research papers (of a single author) in Global Journals Inc., if the same is accepted by our Editorial Board and Peer Reviewers. If you are a main author or co-author of a group of authors, you will get discount of 10%.

As MARSE, you will be given a renowned, secure and free professional email address with 30 GB of space e.g. johnhall@globaljournals.org. This will include Webmail, Spam Assassin, Email Forwarders,Auto-Responders, Email Delivery Route tracing, etc.

We shall provide you intimation regarding launching of e-version of journal of your stream time to time.This may be utilized in your library for the enrichment of knowledge of your students as well as it can also be helpful for the concerned faculty members.

The MARSE member can apply for approval, grading and certification of standards of their educational and Institutional Degrees to Open Association of Research, Society U.S.A.

Once you are designated as MARSE, you may send us a scanned copy of all of your credentials. OARS will verify, grade and certify them. This will be based on your academic records, quality of research papers published by you, and some more criteria.

It is mandatory to read all terms and conditions carefully.

AUXILIARY MEMBERSHIPS

Institutional Fellow of Open Association of Research Society (USA)-OARS (USA)

Global Journals Incorporation (USA) is accredited by Open Association of Research Society, U.S.A (OARS) and in turn, affiliates research institutions as "Institutional Fellow of Open Association of Research Society" (IFOARS).

The "FARSC" is a dignified title which is accorded to a person's name viz. Dr. John E. Hall, Ph.D., FARSC or William Walldroff, M.S., FARSC.

The IFOARS institution is entitled to form a Board comprised of one Chairperson and three to five board members preferably from different streams. The Board will be recognized as "Institutional Board of Open Association of Research Society"-(IBOARS).

The Institute will be entitled to following benefits:

The IBOARS can initially review research papers of their institute and recommend them to publish with respective journal of Global Journals. It can also review the papers of other institutions after obtaining our consent. The second review will be done by peer reviewer of Global Journals Incorporation (USA) The Board is at liberty to appoint a peer reviewer with the approval of chairperson after consulting us.

The author fees of such paper may be waived off up to 40%.

The Global Journals Incorporation (USA) at its discretion can also refer double blind peer reviewed paper at their end to the board for the verification and to get recommendation for final stage of acceptance of publication.

The IBOARS can organize symposium/seminar/conference in their country on behalf of Global Journals Incorporation (USA)-OARS (USA). The terms and conditions can be discussed separately.

The Board can also play vital role by exploring and giving valuable suggestions regarding the Standards of "Open Association of Research Society, U.S.A (OARS)" so that proper amendment can take place for the benefit of entire research community. We shall provide details of particular standard only on receipt of request from the Board.

The board members can also join us as Individual Fellow with 40% discount on total fees applicable to Individual Fellow. They will be entitled to avail all the benefits as declared. Please visit Individual Fellow-sub menu of GlobalJournals.org to have more relevant details.

We shall provide you intimation regarding launching of e-version of journal of your stream time to time. This may be utilized in your library for the enrichment of knowledge of your students as well as it can also be helpful for the concerned faculty members.

After nomination of your institution as "Institutional Fellow" and constantly functioning successfully for one year, we can consider giving recognition to your institute to function as Regional/Zonal office on our behalf.
The board can also take up the additional allied activities for betterment after our consultation.

The following entitlements are applicable to individual Fellows:

Open Association of Research Society, U.S.A (OARS) By-laws states that an individual Fellow may use the designations as applicable, or the corresponding initials. The Credentials of individual Fellow and Associate designations signify that the individual has gained knowledge of the fundamental concepts. One is magnanimous and proficient in an expertise course covering the professional code of conduct, and follows recognized standards of practice.

Open Association of Research Society (US)/ Global Journals Incorporation (USA), as described in Corporate Statements, are educational, research publishing and professional membership organizations. Achieving our individual Fellow or Associate status is based mainly on meeting stated educational research requirements.

Disbursement of 40% Royalty earned through Global Journals : Researcher = 50%, Peer Reviewer = 37.50%, Institution = 12.50% E.g. Out of 40%, the 20% benefit should be passed on to researcher, 15 % benefit towards remuneration should be given to a reviewer and remaining 5% is to be retained by the institution.

We shall provide print version of 12 issues of any three journals [as per your requirement] out of our 38 journals worth $ 2376 USD.

Other:

The individual Fellow and Associate designations accredited by Open Association of Research Society (US) credentials signify guarantees following achievements:

- The professional accredited with Fellow honor, is entitled to various benefits viz. name, fame, honor, regular flow of income, secured bright future, social status etc.

- In addition to above, if one is single author, then entitled to 40% discount on publishing research paper and can get 10%discount if one is co-author or main author among group of authors.
- The Fellow can organize symposium/seminar/conference on behalf of Global Journals Incorporation (USA) and he/she can also attend the same organized by other institutes on behalf of Global Journals.
- The Fellow can become member of Editorial Board Member after completing 3yrs.
- The Fellow can earn 60% of sales proceeds from the sale of reference/review books/literature/publishing of research paper.
- Fellow can also join as paid peer reviewer and earn 15% remuneration of author charges and can also get an opportunity to join as member of the Editorial Board of Global Journals Incorporation (USA)
- • This individual has learned the basic methods of applying those concepts and techniques to common challenging situations. This individual has further demonstrated an in–depth understanding of the application of suitable techniques to a particular area of research practice.

Note :

"

- In future, if the board feels the necessity to change any board member, the same can be done with the consent of the chairperson along with anyone board member without our approval.
- In case, the chairperson needs to be replaced then consent of 2/3rd board members are required and they are also required to jointly pass the resolution copy of which should be sent to us. In such case, it will be compulsory to obtain our approval before replacement.
- In case of "Difference of Opinion [if any]" among the Board members, our decision will be final and binding to everyone.

"

Process of submission of Research Paper

The Area or field of specialization may or may not be of any category as mentioned in 'Scope of Journal' menu of the GlobalJournals.org website. There are 37 Research Journal categorized with Six parental Journals GJCST, GJMR, GJRE, GJMBR, GJSFR, GJHSS. For Authors should prefer the mentioned categories. There are three widely used systems UDC, DDC and LCC. The details are available as 'Knowledge Abstract' at Home page. The major advantage of this coding is that, the research work will be exposed to and shared with all over the world as we are being abstracted and indexed worldwide.

The paper should be in proper format. The format can be downloaded from first page of 'Author Guideline' Menu. The Author is expected to follow the general rules as mentioned in this menu. The paper should be written in MS-Word Format (*.DOC,*.DOCX).

The Author can submit the paper either online or offline. The authors should prefer online submission.Online Submission: There are three ways to submit your paper:

(A) (I) First, register yourself using top right corner of Home page then Login. If you are already registered, then login using your username and password.

(II) Choose corresponding Journal.

(III) Click 'Submit Manuscript'. Fill required information and Upload the paper.

(B) If you are using Internet Explorer, then Direct Submission through Homepage is also available.

(C) If these two are not conveninet , and then email the paper directly to dean@globaljournals.org.

Offline Submission: Author can send the typed form of paper by Post. However, online submission should be preferred.

Preferred Author Guidelines

MANUSCRIPT STYLE INSTRUCTION (Must be strictly followed)

Page Size: 8.27" X 11'"

- Left Margin: 0.65
- Right Margin: 0.65
- Top Margin: 0.75
- Bottom Margin: 0.75
- Font type of all text should be Swis 721 Lt BT.
- Paper Title should be of Font Size 24 with one Column section.
- Author Name in Font Size of 11 with one column as of Title.
- Abstract Font size of 9 Bold, "Abstract" word in Italic Bold.
- Main Text: Font size 10 with justified two columns section
- Two Column with Equal Column with of 3.38 and Gaping of .2
- First Character must be three lines Drop capped.
- Paragraph before Spacing of 1 pt and After of 0 pt.
- Line Spacing of 1 pt
- Large Images must be in One Column
- Numbering of First Main Headings (Heading 1) must be in Roman Letters, Capital Letter, and Font Size of 10.
- Numbering of Second Main Headings (Heading 2) must be in Alphabets, Italic, and Font Size of 10.

You can use your own standard format also.
Author Guidelines:

1. General,

2. Ethical Guidelines,

3. Submission of Manuscripts,

4. Manuscript's Category,

5. Structure and Format of Manuscript,

6. After Acceptance.

1. GENERAL

Before submitting your research paper, one is advised to go through the details as mentioned in following heads. It will be beneficial, while peer reviewer justify your paper for publication.

Scope

The Global Journals Inc. (US) welcome the submission of original paper, review paper, survey article relevant to the all the streams of Philosophy and knowledge. The Global Journals Inc. (US) is parental platform for Global Journal of Computer Science and Technology, Researches in Engineering, Medical Research, Science Frontier Research, Human Social Science, Management, and Business organization. The choice of specific field can be done otherwise as following in Abstracting and Indexing Page on this Website. As the all Global

Journals Inc. (US) are being abstracted and indexed (in process) by most of the reputed organizations. Topics of only narrow interest will not be accepted unless they have wider potential or consequences.

2. ETHICAL GUIDELINES

Authors should follow the ethical guidelines as mentioned below for publication of research paper and research activities.

Papers are accepted on strict understanding that the material in whole or in part has not been, nor is being, considered for publication elsewhere. If the paper once accepted by Global Journals Inc. (US) and Editorial Board, will become the copyright of the Global Journals Inc. (US).

Authorship: The authors and coauthors should have active contribution to conception design, analysis and interpretation of findings. They should critically review the contents and drafting of the paper. All should approve the final version of the paper before submission

The Global Journals Inc. (US) follows the definition of authorship set up by the Global Academy of Research and Development. According to the Global Academy of R&D authorship, criteria must be based on:

1) Substantial contributions to conception and acquisition of data, analysis and interpretation of the findings.

2) Drafting the paper and revising it critically regarding important academic content.

3) Final approval of the version of the paper to be published.

All authors should have been credited according to their appropriate contribution in research activity and preparing paper. Contributors who do not match the criteria as authors may be mentioned under Acknowledgement.

Acknowledgements: Contributors to the research other than authors credited should be mentioned under acknowledgement. The specifications of the source of funding for the research if appropriate can be included. Suppliers of resources may be mentioned along with address.

Appeal of Decision: The Editorial Board's decision on publication of the paper is final and cannot be appealed elsewhere.

Permissions: It is the author's responsibility to have prior permission if all or parts of earlier published illustrations are used in this paper.

Please mention proper reference and appropriate acknowledgements wherever expected.

If all or parts of previously published illustrations are used, permission must be taken from the copyright holder concerned. It is the author's responsibility to take these in writing.

Approval for reproduction/modification of any information (including figures and tables) published elsewhere must be obtained by the authors/copyright holders before submission of the manuscript. Contributors (Authors) are responsible for any copyright fee involved.

3. SUBMISSION OF MANUSCRIPTS

Manuscripts should be uploaded via this online submission page. The online submission is most efficient method for submission of papers, as it enables rapid distribution of manuscripts and consequently speeds up the review procedure. It also enables authors to know the status of their own manuscripts by emailing us. Complete instructions for submitting a paper is available below.

Manuscript submission is a systematic procedure and little preparation is required beyond having all parts of your manuscript in a given format and a computer with an Internet connection and a Web browser. Full help and instructions are provided on-screen. As an author, you will be prompted for login and manuscript details as Field of Paper and then to upload your manuscript file(s) according to the instructions.

To avoid postal delays, all transaction is preferred by e-mail. A finished manuscript submission is confirmed by e-mail immediately and your paper enters the editorial process with no postal delays. When a conclusion is made about the publication of your paper by our Editorial Board, revisions can be submitted online with the same procedure, with an occasion to view and respond to all comments.

Complete support for both authors and co-author is provided.

4. MANUSCRIPT'S CATEGORY

Based on potential and nature, the manuscript can be categorized under the following heads:

Original research paper: Such papers are reports of high-level significant original research work.

Review papers: These are concise, significant but helpful and decisive topics for young researchers.

Research articles: These are handled with small investigation and applications

Research letters: The letters are small and concise comments on previously published matters.

5.STRUCTURE AND FORMAT OF MANUSCRIPT

The recommended size of original research paper is less than seven thousand words, review papers fewer than seven thousands words also.Preparation of research paper or how to write research paper, are major hurdle, while writing manuscript. The research articles and research letters should be fewer than three thousand words, the structure original research paper; sometime review paper should be as follows:

Papers: These are reports of significant research (typically less than 7000 words equivalent, including tables, figures, references), and comprise:

(a)Title should be relevant and commensurate with the theme of the paper.

(b) A brief Summary, "Abstract" (less than 150 words) containing the major results and conclusions.

(c) Up to ten keywords, that precisely identifies the paper's subject, purpose, and focus.

(d) An Introduction, giving necessary background excluding subheadings; objectives must be clearly declared.

(e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition; sources of information must be given and numerical methods must be specified by reference, unless non-standard.

(f) Results should be presented concisely, by well-designed tables and/or figures; the same data may not be used in both; suitable statistical data should be given. All data must be obtained with attention to numerical detail in the planning stage. As reproduced design has been recognized to be important to experiments for a considerable time, the Editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned un-refereed;

(g) Discussion should cover the implications and consequences, not just recapitulating the results; conclusions should be summarizing.

(h) Brief Acknowledgements.

(i) References in the proper form.

Authors should very cautiously consider the preparation of papers to ensure that they communicate efficiently. Papers are much more likely to be accepted, if they are cautiously designed and laid out, contain few or no errors, are summarizing, and be conventional to the approach and instructions. They will in addition, be published with much less delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and to make suggestions to improve briefness.

It is vital, that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

Format

Language: The language of publication is UK English. Authors, for whom English is a second language, must have their manuscript efficiently edited by an English-speaking person before submission to make sure that, the English is of high excellence. It is preferable, that manuscripts should be professionally edited.

Standard Usage, Abbreviations, and Units: Spelling and hyphenation should be conventional to The Concise Oxford English Dictionary. Statistics and measurements should at all times be given in figures, e.g. 16 min, except for when the number begins a sentence. When the number does not refer to a unit of measurement it should be spelt in full unless, it is 160 or greater.

Abbreviations supposed to be used carefully. The abbreviated name or expression is supposed to be cited in full at first usage, followed by the conventional abbreviation in parentheses.

Metric SI units are supposed to generally be used excluding where they conflict with current practice or are confusing. For illustration, 1.4 l rather than 1.4 × 10-3 m3, or 4 mm somewhat than 4 × 10-3 m. Chemical formula and solutions must identify the form used, e.g. anhydrous or hydrated, and the concentration must be in clearly defined units. Common species names should be followed by underlines at the first mention. For following use the generic name should be constricted to a single letter, if it is clear.

Structure

All manuscripts submitted to Global Journals Inc. (US), ought to include:

Title: The title page must carry an instructive title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) wherever the work was carried out. The full postal address in addition with the e-mail address of related author must be given. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining and indexing.

Abstract, used in Original Papers and Reviews:

Optimizing Abstract for Search Engines

Many researchers searching for information online will use search engines such as Google, Yahoo or similar. By optimizing your paper for search engines, you will amplify the chance of someone finding it. This in turn will make it more likely to be viewed and/or cited in a further work. Global Journals Inc. (US) have compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Key Words

A major linchpin in research work for the writing research paper is the keyword search, which one will employ to find both library and Internet resources.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy and planning a list of possible keywords and phrases to try.

Search engines for most searches, use Boolean searching, which is somewhat different from Internet searches. The Boolean search uses "operators," words (and, or, not, and near) that enable you to expand or narrow your affords. Tips for research paper while preparing research paper are very helpful guideline of research paper.

Choice of key words is first tool of tips to write research paper. Research paper writing is an art.A few tips for deciding as strategically as possible about keyword search:

- One should start brainstorming lists of possible keywords before even begin searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in research paper?" Then consider synonyms for the important words.
- It may take the discovery of only one relevant paper to let steer in the right keyword direction because in most databases, the keywords under which a research paper is abstracted are listed with the paper.
- One should avoid outdated words.

Keywords are the key that opens a door to research work sources. Keyword searching is an art in which researcher's skills are bound to improve with experience and time.

Numerical Methods: Numerical methods used should be clear and, where appropriate, supported by references.

Acknowledgements: Please make these as concise as possible.

References

References follow the Harvard scheme of referencing. References in the text should cite the authors' names followed by the time of their publication, unless there are three or more authors when simply the first author's name is quoted followed by et al. unpublished work has to only be cited where necessary, and only in the text. Copies of references in press in other journals have to be supplied with submitted typescripts. It is necessary that all citations and references be carefully checked before submission, as mistakes or omissions will cause delays.

References to information on the World Wide Web can be given, but only if the information is available without charge to readers on an official site. Wikipedia and Similar websites are not allowed where anyone can change the information. Authors will be asked to make available electronic copies of the cited information for inclusion on the Global Journals Inc. (US) homepage at the judgment of the Editorial Board.

The Editorial Board and Global Journals Inc. (US) recommend that, citation of online-published papers and other material should be done via a DOI (digital object identifier). If an author cites anything, which does not have a DOI, they run the risk of the cited material not being noticeable.

The Editorial Board and Global Journals Inc. (US) recommend the use of a tool such as Reference Manager for reference management and formatting.

Tables, Figures and Figure Legends

Tables: Tables should be few in number, cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g. Table 4, a self-explanatory caption and be on a separate sheet. Vertical lines should not be used.

Figures: Figures are supposed to be submitted as separate files. Always take in a citation in the text for each figure using Arabic numbers, e.g. Fig. 4. Artwork must be submitted online in electronic form by e-mailing them.

Preparation of Electronic Figures for Publication

Even though low quality images are sufficient for review purposes, print publication requires high quality images to prevent the final product being blurred or fuzzy. Submit (or e-mail) EPS (line art) or TIFF (halftone/photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Do not use pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings) in relation to the imitation size. Please give the data for figures in black and white or submit a Color Work Agreement Form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution (at final image size) ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs) : >350 dpi; figures containing both halftone and line images: >650 dpi.

Figure Legends: Self-explanatory legends of all figures should be incorporated separately under the heading 'Legends to Figures'. In the full-text online edition of the journal, figure legends may possibly be truncated in abbreviated links to the full screen version. Therefore, the first 100 characters of any legend should notify the reader, about the key aspects of the figure.

6. AFTER ACCEPTANCE

Upon approval of a paper for publication, the manuscript will be forwarded to the dean, who is responsible for the publication of the Global Journals Inc. (US).

6.1 Proof Corrections

The corresponding author will receive an e-mail alert containing a link to a website or will be attached. A working e-mail address must therefore be provided for the related author.

Acrobat Reader will be required in order to read this file. This software can be downloaded

(Free of charge) from the following website:

www.adobe.com/products/acrobat/readstep2.html. This will facilitate the file to be opened, read on screen, and printed out in order for any corrections to be added. Further instructions will be sent with the proof.

Proofs must be returned to the dean at dean@globaljournals.org within three days of receipt.

As changes to proofs are costly, we inquire that you only correct typesetting errors. All illustrations are retained by the publisher. Please note that the authors are responsible for all statements made in their work, including changes made by the copy editor.

6.2 Early View of Global Journals Inc. (US) (Publication Prior to Print)

The Global Journals Inc. (US) are enclosed by our publishing's Early View service. Early View articles are complete full-text articles sent in advance of their publication. Early View articles are absolute and final. They have been completely reviewed, revised and edited for publication, and the authors' final corrections have been incorporated. Because they are in final form, no changes can be made after sending them. The nature of Early View articles means that they do not yet have volume, issue or page numbers, so Early View articles cannot be cited in the conventional way.

6.3 Author Services

Online production tracking is available for your article through Author Services. Author Services enables authors to track their article - once it has been accepted - through the production process to publication online and in print. Authors can check the status of their articles online and choose to receive automated e-mails at key stages of production. The authors will receive an e-mail with a unique link that enables them to register and have their article automatically added to the system. Please ensure that a complete e-mail address is provided when submitting the manuscript.

6.4 Author Material Archive Policy

Please note that if not specifically requested, publisher will dispose off hardcopy & electronic information submitted, after the two months of publication. If you require the return of any information submitted, please inform the Editorial Board or dean as soon as possible.

6.5 Offprint and Extra Copies

A PDF offprint of the online-published article will be provided free of charge to the related author, and may be distributed according to the Publisher's terms and conditions. Additional paper offprint may be ordered by emailing us at: editor@globaljournals.org .

You must strictly follow above Author Guidelines before submitting your paper or else we will not at all be responsible for any corrections in future in any of the way.

Before start writing a good quality Computer Science Research Paper, let us first understand what is Computer Science Research Paper? So, Computer Science Research Paper is the paper which is written by professionals or scientists who are associated to Computer Science and Information Technology, or doing research study in these areas. If you are novel to this field then you can consult about this field from your supervisor or guide.

TECHNIQUES FOR WRITING A GOOD QUALITY RESEARCH PAPER:

1. Choosing the topic: In most cases, the topic is searched by the interest of author but it can be also suggested by the guides. You can have several topics and then you can judge that in which topic or subject you are finding yourself most comfortable. This can be done by asking several questions to yourself, like Will I be able to carry our search in this area? Will I find all necessary recourses to accomplish the search? Will I be able to find all information in this field area? If the answer of these types of questions will be "Yes" then you can choose that topic. In most of the cases, you may have to conduct the surveys and have to visit several places because this field is related to Computer Science and Information Technology. Also, you may have to do a lot of work to find all rise and falls regarding the various data of that subject. Sometimes, detailed information plays a vital role, instead of short information.

2. Evaluators are human: First thing to remember that evaluators are also human being. They are not only meant for rejecting a paper. They are here to evaluate your paper. So, present your Best.

3. Think Like Evaluators: If you are in a confusion or getting demotivated that your paper will be accepted by evaluators or not, then think and try to evaluate your paper like an Evaluator. Try to understand that what an evaluator wants in your research paper and automatically you will have your answer.

4. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

5. Ask your Guides: If you are having any difficulty in your research, then do not hesitate to share your difficulty to your guide (if you have any). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work then ask the supervisor to help you with the alternative. He might also provide you the list of essential readings.

6. Use of computer is recommended: As you are doing research in the field of Computer Science, then this point is quite obvious.

7. Use right software: Always use good quality software packages. If you are not capable to judge good software then you can lose quality of your paper unknowingly. There are various software programs available to help you, which you can get through Internet.

8. Use the Internet for help: An excellent start for your paper can be by using the Google. It is an excellent search engine, where you can have your doubts resolved. You may also read some answers for the frequent question how to write my research paper or find model research paper. From the internet library you can download books. If you have all required books make important reading selecting and analyzing the specified information. Then put together research paper sketch out.

9. Use and get big pictures: Always use encyclopedias, Wikipedia to get pictures so that you can go into the depth.

10. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right! It is a good habit, which helps to not to lose your continuity. You should always use bookmarks while searching on Internet also, which will make your search easier.

11. Revise what you wrote: When you write anything, always read it, summarize it and then finalize it.

12. Make all efforts: Make all efforts to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in introduction, that what is the need of a particular research paper. Polish your work by good skill of writing and always give an evaluator, what he wants.

13. Have backups: When you are going to do any important thing like making research paper, you should always have backup copies of it either in your computer or in paper. This will help you to not to lose any of your important.

14. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several and unnecessary diagrams will degrade the quality of your paper by creating "hotchpotch." So always, try to make and include those diagrams, which are made by your own to improve readability and understandability of your paper.

15. Use of direct quotes: When you do research relevant to literature, history or current affairs then use of quotes become essential but if study is relevant to science then use of quotes is not preferable.

16. Use proper verb tense: Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

17. Never use online paper: If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. Pick a good study spot: To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

20. Use good quality grammar: Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. Think technically: Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

Title Page:

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

Administration Rules Listed Before Submitting Your Research Paper to Global Journals Inc. (US)

Please carefully note down following rules and regulation before submitting your Research Paper to Global Journals Inc. (US):

Segment Draft and Final Research Paper: You have to strictly follow the template of research paper. If it is not done your paper may get rejected.

- The **major constraint** is that you must independently make all content, tables, graphs, and facts that are offered in the paper. You must write each part of the paper wholly on your own. The Peer-reviewers need to identify your own perceptive of the concepts in your own terms. NEVER extract straight from any foundation, and never rephrase someone else's analysis.

- Do not give permission to anyone else to "PROOFREAD" your manuscript.

- Methods to avoid Plagiarism is applied by us on every paper, if found guilty, you will be blacklisted by all of our collaborated research groups, your institution will be informed for this and strict legal actions will be taken immediately.)
- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

Criterion for Grading a Research Paper (Compilation) by Global Journals Inc. (US)

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals Inc. (US).

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

INDEX

save our planet

Global Journal of Researches in Engineering

Visit us on the Web at www.GlobalJournals.org | www.EngineeringResearch.org
or email us at helpdesk@globaljournals.org

ISSN 9755861