Lecture Notes in Mechanical Engineering

Anil Kumar
Amit Pal
Surendra Singh Kachhwaha
Prashant Kumar Jain *Editors*

Recent Advances in Mechanical Engineering

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Lecture Notes in Mechanical Engineering

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Foreword

I am pleased to know that an International Conference on "Recent Advances in Mechanical Engineering" (RAME 2020) is being organized by Department of Mechanical Engineering, Delhi Technological University (DTU), on September 18 and 19, 2020. I welcome all the delegates and participants across the globe for participating in RAME 2020 conference at DTU. I am sure that RAME 2020 conference will bring together the national and international talents.

The role of mechanical engineering is inevitable to improve productivity, product quality and safe working environment in the applied fields for the society at large. The conference shall provide excellent opportunities for researchers, scientists and industrialists to share and converse on the latest developments in the areas of mechanical engineering. The publication of the conference proceedings in *Lecturer Notes in Mechanical Engineering*, Springer, will give a new benchmark and more insight to the R&D initiatives in these areas. I also hope that the conglomeration of eminent experts will highlight the importance of research and innovation and discuss the best global practices.

I congratulate the organizing team of RAME 2020 conference and wish that the conference will be a grand success and help in branding Delhi Technological University as a leading research university.

Prof. Yogesh Singh
Vice-Chancellor
Delhi Technological University
New Delhi, India

Preface

Mechanical engineering is the application of physical principles of science and engineering to the creation of useful systems, devices, objects and machines. This basic perception of mechanical engineering still holds good, while it has evolved into various new fields. Mechanical engineering is thus deep rooted in to a vast engineering canvas and is in the service of mankind at all levels. Therefore, there is also a need to understand the design principles for environment, life-cycle design and sustainable development.

It is our pleasure to present the academicians and scholars, the proceedings of the research papers scheduled for presentation at the 2nd International Conference on "Recent Advances in Mechanical Engineering" during 18–19 September 2020 at the Department of Mechanical, Production and Industrial and Automobile Engineering and Centre for Energy and Environment, Delhi Technological University (*Formerly Delhi College of Engineering*), Delhi-110 042 (India). This conference is in series with earlier international conference RAME-2016 organized by the Department of Mechanical Engineering, Delhi Technological University (Formerly Delhi College of Engineering), Delhi-110 042 (India). The conference was very well received, both by the industry and academia.

The core organizing committee for organizing RAME-2020 is:

- **Chief Patron**: Prof. Yogesh Singh, Hon'ble Vice-Chancellor
- **Patron**: Prof. Samsher; Prof. S. K. Garg
- **Chairman**: Prof. R. S. Mishra; Prof. Vipin; Prof. S. Maji
- **Co-Chairman**: Prof. Vikas Rastogi; Prof. Raj Kumar Singh; Prof. Atul Agrawal
- **Convener**: Prof. Amit Pal
- **Co-Convener**: Prof. Vijay Gautam; Prof. Quasim Murtaza and Prof. Rajesh Kumar
- **Organizing Secretary**: Dr. Anil Kumar
- **Joint Organizing Secretary**: Dr. Girish Kumar; Dr. N. A. Ansari and Dr. N. Yuvraj
- **Treasurer**: Dr. M. Zunaid

The proceeding consists of papers contributed by leading academicians, research scholars and experts from the industries. The conference papers cover both research areas and the latest trends in the industry. 96 papers from 300+ authors and about 450 participants attended the conference. In all, qualitative papers would be selected to present during the conference. The main topics of the conference have been classified into the following four categories:

- Thermal Engineering
- Energy Science and Engineering
- Design and Development
- Industrial and Production Engineering

The technical advisory committee is pleased to mention that the papers have been received on all these topics. Such a voluminous proceedings is not possible without the generous support received from various quarters. The committee would like to put on record its deep appreciation for the persistent efforts of all reviewers.

We are grateful to all the authors of the papers for having made their contributions to enrich this international conference of RAME-2020.

It is our immense pleasure to express our heartful gratitude to Prof. Yogi D. Goswami, University of South Florida, USA; Prof. H.C. LIM, Pusan National University, South Korea; Prof. Afzal Husain, Sultan Qaboos University, Oman; Dr. Nitin Upadhyay, University of Modern Science, Dubai, UAE; Dr. Ashish Shukla, Loughborough University, UK; Dr. Shyam S. Pandey, Kyushu Institute of Technology, Japan; and Dr. Jan Banout, Czech University of Life Science Czech Republic and other colleagues in India and abroad.

Special acknowledgement is made to the support of expert papers and also the generous support received from our distinguished alumnus of DTU, the leading industrialist. We also acknowledge the excellent cooperation received from our colleagues and experts on the review panel, for their painstaking efforts in reviewing the papers.

We duly acknowledge the sponsors with thanks and extend full credit to the publisher (Springer) for accepting the proposal to publish conference proceedings with the book title 'Recent Advances in Mechanical Engineering' under the series title 'Lecture Notes in Mechanical Engineering'.

We sincerely hope that engineering community would find this publication a valuable source of knowledge to profess mechanical engineering in the knowledge age.

North West Delhi, India — Anil Kumar
North West Delhi, India — Amit Pal
Gandhinagar, India — Surendra Singh Kachhwaha
Jabalpur, India — Prashant Kumar Jain

Contents

About the Editors

Dr. Anil Kumar is Associate Professor in the Department of Mechanical, Production & Industrial and Automobile Engineering, with additional charge of Additional Coordinator-Centre for Energy and Environment, Delhi Technological University, Delhi, India. He has completed his Ph.D. in Solar Energy from Centre for Energy Studies, Indian Institute of Technology Delhi, India, in the year 2007. He was Postdoctoral Researcher at Energy Technology Research Center, Department of Mechanical Engineering, Faculty of Engineering, Prince of Songkla University, Hat Yai, Songkhla, Thailand, in the discipline of Energy Technology from June 2015 to May 2017. He has also served as Assistant Professor in Energy Centre, Maulana Azad National Institute of Technology Bhopal, India, from 2010 to 2018, and the Department of Mechanical Engineering, University Institute of Technology, Rajiv Gandhi Proudyogiki Vishwavidyalaya, Bhopal, India, from 2005 to 2010. His areas of specialization are energy technology, renewable energy, solar energy applications, energy economics, heat transfer, natural rubber sheet drying and environmental issues. He has completed many research projects in these areas. He has more than 15 years of experience in the field of energy technology. He has published 135 papers in international peer-reviewed journals and 75 papers in the international/national conferences proceeding. He has received more than 3500 citations with h-index = 33. He has developed thin-layer drying model with his student in 2014. It is known as "Prakash and Kumar model". This model is being used and cited by so many researchers around the globe. He has published 10 books with international/national publishers. He has also published 3 patents—one in the solar dryer and another in the solar photovoltaic thermal collector. He has supervised 9 Ph.D. scholars and 37 master students. Dr. Kumar has visited countries, namely UK, Thailand and Malaysia. He has received various awards and appreciation from reputed sources. Some of them are provided here: "Commendable Research Award 2019" for publishing quality research paper in Delhi Technological University, Delhi, India. Research Excellence Award 2016: The researcher has Top 20 Publications from the Web of Science database, honored by Dr. Chusak Limsakul, President Prince of Songkla University, Hat Yai, Thailand. "Appreciation" for Outstanding Service in the reviewer's committee and active reviewers during the year 2015 from International Institute of Engineers, Kolkata, and Elsevier. "Best Paper Award" in Global Conference on

Energy and Sustainable Development (GCESD 2015), February 24–26, 2015, at Coventry University Technology Park, Puma Way, Coventry, West Midlands CV1 2TT.

Dr. Amit Pal is currently working as Professor at the Department of Mechanical, Production & Industrial and Automobile and Production & Industrial Engineering, Delhi Technological University (Formerly Delhi College of Engineering), Delhi. He obtained his B.E. (Mechanical Engineering) from Vikram University, Ujjain and Master of Engineering from the University of Mumbai and Ph.D. from the Faculty of Technology, University of Delhi. He has more than 23 years of experience in teaching and research with major research interest areas which include IC engines, biofuels and waste management, pollution mitigation, etc. He has published 50 papers in reputed international journals. Prof. Amit Pal received commendable research award 2018 for the paper "Experimental Studies on Utilization of Prunus armeniaca L. (Wild Apricot) Biodiesel as an Alternative Fuel for CI Engine in Waste and Biomass Vaporization." He also received the first prize for the research paper "Recent Developments in Biodiesel: Part I – Biodiesel Production Technology" and the Second prize for the research paper titled "Optimization of Solar assisted Production of Biodiesel from Cottonseed Oil". He has been an expert member in various committees of CPCB India, DTC Delhi, GGSIPU, NIOS and NBOS India, etc. Prof. Amit Pal published 3 books on Renewable Energy, Advances in Mechanical Engineering, and Heat and Mass Transfer. He wrote many chapters in "Advances in Alternate and Renewable Energy Technologies". Prof. Amit Pal has also successfully completed different research projects sponsored by the Government of Delhi, Arihant Energy Solutions, Mosarbear and DTU costing over 17 lakhs (INR). He is the life-time member of the Indian Society of Mechanical Engineers, the Indian Society of Technical Education, the Solar Energy Society of India and the Ultrasonic Society of India. Prof. Amit Pal organized many workshops, conferences and faculty development programmes and also delivered over 30 expert lectures in many reputed seminars, conferences, short-term courses, QIP and FDP programmes etc. organized at DTU and other reputed organizations.

Dr. Surendra Singh Kachhwaha is Professor, Mechanical Engineering Department, School of Technology, Pandit Deendayal Petroleum University, Gandhinagar, India. He has accomplished research projects and consultancy work worth four crores. He completed his B.E. degree in Mechanical Engineering from M.B.M. Engineering College, Jodhpur. He did his M.Tech. in Heat Power from Indian Institute of Technology, BHU Varanasi, and Ph.D. in Evaporative Cooling from IIT Delhi. He has teaching experience of more than 32 years in thermal engineering at undergraduate and postgraduate levels. Dr. Kachhwaha has around 80 technical publications in reputed national and international journals and more than 100 publications in national/international conferences. His research interests include evaporative cooling, ice slurry generation, polygeneration, offshore wind energy and biodiesel production techniques. Dr. Kachhwaha has taught various thermal engineering courses at undergraduate and postgraduate levels and guided 33 M.Tech.

dissertation and 7 PhDs. He served as Faculty in Rajasthan Technological University, Kota and Delhi Technological University, Delhi, in the past.

Dr. Prashant Kumar Jain is Associate Professor and Dean (Students) at Indian Institute of Information Technology, Design and Manufacturing Jabalpur, India. He has over 25 years of research and teaching experience at UG and PG levels. He is graduated in Mechanical Engineering from Dr. H. S. Gour University Sagar in 1995 and did Master's in Advanced Production Systems from Samrat Ashok Technological Institute (S.A.T.I.) Vidisha. He has received Ph.D. Degree in the area of Rapid Prototyping/Additive Manufacturing, particularly on Part Strength studies in Selective Laser Sintering Process from Indian Institute of Technology Delhi, (IIT Delhi) Delhi in 2009. Dr. Prashant K. Jain was previously with Delhi Technological University Delhi (formerly known as Delhi College of Engineering) as lecturer in Mechanical Engineering Department. He has also served Indian Institute of Technology Delhi as project scientist and research associate where he was engaged in research work on error compensation in CNC machines and part quality improvement in Fused Deposition Modelling. Currently he is with PDPM IIITDM Jabalpur as Associate Professor and Dean (Students). He has more than 110 publications to his credit, published in International peer reviewed journals of repute, National and International conferences in India and abroad. He has guided 5 Ph.D.'s and 27 Master's and several ongoing. He has been a resource person and delivered invited lectures, chaired scientific sessions in several National and International Conferences, STTP's and QIP programs. His research interest extends from Geometric Modelling, CAD/CAM Integration, Incremental Sheet forming, Computational geometry, Rapid Prototyping & Tooling, Incremental sheet forming to Nano Technologies in Manufacturing.

Thermal Engineering

Experimental Studies of Heat Transfer Under Natural Convection in Heat Pipe Insulated with Vacuum Chamber

Sumit Kumar Rai, Anjaney Pandey, and Alok Chaube

Nomenclature

Symbol

A	Surface area of HP (m^2)
C_p	Specific heat (J/(kg K))
$h_{\text{practical}}$	Practical value of CCHT (W/(m^2 K))
$h_{\text{theoretical}}$	Theoretical value of CCHT (W/(m^2 K))
k	Thermal conductivity (W/(m k))
$Q_{\text{practical}}$	Practical value of RHT (W)
$Q_{\text{theoretical}}$	Theoretical value of RHT (W

Subscript

CCHT	Coefficient of convective heat transfer
HP	Heat pipe
HPHE	Heat pipe heat exchanger
HPHEVC	Heat pipe heat exchanger insulated with vacuum chamber
RHT	Rate of heat transport

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1 Introduction

The heat transfer systems are commonly associated with different types of heat transfer equipment who is working based on sensible heat transfer, latent heat transfer and mixed mode of these two types [1]. The heat transfer system can be designed into single tube and multi-tube type [2], cross flow heat transfer, evaporators and condensers, hollow cylindrical type heat pipe equipment [3], etc. The motivation for making an experimental setup of heat pipe insulated with vacuum chamber is to obtain high exchanger compactness in given surface area having size, position and weight limitations [4, 5]. The heat transfer systems are normally based on the transferring heat from hot fluids to cold fluids with the help of different types of equipment which are used in a variety of engineering applications. The heap pipe system has been divided into three sections, i.e., evaporator, adiabatic and condenser section.[1] The heat transfer inside the heat pipe between hot and cold fluids is by the forced convection or natural convection. The manufacturers normally depend upon the local vendors for procurement of accessories including heat exchangers working under natural or forced convection which may not be optimally designed. Since these heat exchangers are to be acquired in a new design of model with configurations and layout, therefore, even well composition of heat exchangers in a particular configuration is subjected to change in thermal performance [6]. There are a lot of methods to amplify the transferring heat from hot fluids to cold fluids with the help of heat exchanger equipment; one may look for a solution in the given situation. If the area of heat transfer is increased, then heat transfer will be increased, and the other solution is increasing the flow rate of working fluids may be increasing the heat transfer. The first solution takes more space, so it is not helpful for minimum space area and the other solution required more pressure drop between inside section of heat pipe and atmosphere. All these types of studies are limited to forced convection because they need some external forces for transferring the heat by heat pipe in heat exchanger. Therefore, to make heat pipe, heat exchanger under natural convection is required for transferring the heat without any external forces [7] (Fig. 1).

The literature survey reported that the temperature difference between the surface and the working fluids is created natural convections without any external forces. And a model can be developed for transfer the heat through a heat pipe under natural convection conditions [7]. The size and thermo physical properties of material of heat pipe also involve transferring the heat under natural convection conditions [8]. The temperature difference between surface and fluids indicates that good working conditions under natural convection conditions and huge amount of heat transfer through the heat pipe insulated with vacuum chamber. The heat transfer through the natural convection also depends on the properties of fluids, design of heat pipe, position of heat pipe [9] and working environments [3, 9]. These all are critical parameters that affected transferring the heat under natural convective conditions.

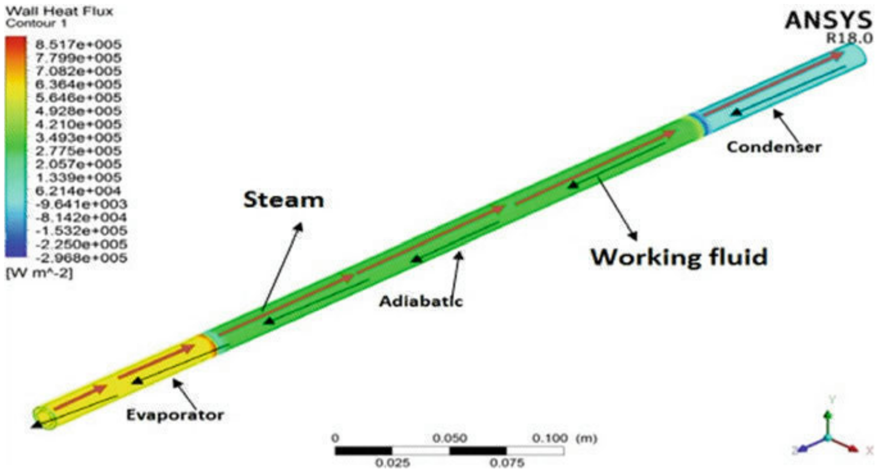

Fig. 1 Heat pipe

2 Design Considerations

The present investigation aims at low temperature application, such as cooling of transformer oil, cutting fluids and generated heat from the CPU should be dissipated, and therefore, the operating temperature range of 40–61 °C has been considered.

The availability, cost, properties and operating conditions of fluids are the basic parameters of fluids for selection as working fluids working under natural convection at low temperature range [10]. The viscosities of fluids should be low at liquid and vapor conditions. Based on all above parameters, water, ethanol, methanol and butanol are used as working fluids [11]. The maximum possible heat transfer occurs when water is used as working fluids as compared to the other working fluids.

2.1 Development of Analytical Model

An analytical model of heat pipe has been developed to calculating coefficient of heat transfer and heat transfer rate when heat pipe working under natural convection conditions at 40–61 °C inlet heating temperature range [3, 12]. The different heat transfer correlations available in the literature have been used to compute the coefficient of heat transfer, rate of heat transfer across evaporator system of the HPHE.

The analytical considerations for analyzing the HPHE are

1. Laminar flow or turbulent flow regime has been assumed in the evaporator side [2].

2. A temperature range of 40–61 °C is assumed for the heating (hot) fluid in the evaporator section for low temperature applications [3, 12].
3. The thermodynamic properties of heating fluids (water, ethanol, methanol[12] and butanol) and ambient air have been evaluated at the mean temperature of fluids [11].
4. Glass vacuum chamber is used as insulating material surrounding the heat pipe for minimum heat loss to atmosphere [13].

2.2 Mathematical Formulations

To determine the CCHT, the HPHE has been modeled as a thermal resistance network [4]. The CCHT have been computed on the internal surface of evaporator. For natural convection condition, the correlations have been taken from a text book of Engineering Thermodynamics written by G.F.C. Rogeks and Y. R. Mayhew. The calculation of CCHT and RHT across the heat pipe under natural convection is described below:

$$\mathrm{Nu} = C(\mathrm{Gr} \times \mathrm{Pr.})^n \tag{1}$$

Natural convection heat transfer from inclined tube from y-axis is computed by the correlations of

$$\mathrm{Nu} = C(\mathrm{Gr} \times \mathrm{Pr} \times \cos\theta)^n \tag{2}$$

where Gr, Pr and Nu represent the value of Grashoff number, Prandtl number [10] and Nusselt number [7, 6], respectively, C and n are constant. θ is angle of inclination of heat pipe from vertical axis or y-axis [4].

The fluid flow will be laminar flow

$$\mathrm{Nu} = 0.590 \times (\mathrm{Gr} \times \mathrm{Pr} \times \cos\theta)^{0.25}, \tag{3}$$

For $10^4 < (\mathrm{Gr} \times \mathrm{Pr} \times \cos\theta) < 10^9$.

The fluid flow will be turbulent flow

$$\mathrm{Nu} = 0.590 \times (\mathrm{Gr} \times \mathrm{Pr} \times \cos\theta)^{1/3}, \tag{4}$$

For $10^9 < (\mathrm{Gr} \times \mathrm{Pr} \times \cos\theta) < 10^{12}$

$$\mathrm{Nu} = \frac{(\mathrm{ht} \times L1)}{K} \tag{5}$$

where ht or $h_{\text{theoretical}}$ represents the theoretical value of coefficient of convective heat transfer in W/m^2 °C, L1 is the length of heat pipe in m, and K represents the thermal conductivity of fluids in (W/m °C).

The heat transport rate by HPHE has been computed by following correlations:

$$Q_{\text{theoretical}} = V.I \tag{6}$$

where V = Voltage in Volt, I = Current in ampere.

3 Experimentation

The test rig has been designed in a manner such that calculates the value of coefficient of heat transfer and heat transfer rate at different tilt angles under natural convection conditions. A test setup is shown in Fig. 2. The total length of heat pipe is 500 mm, and thickness of heat pipe is 4 mm. The evaporator, adiabatic and condenser lengths are 100 mm, 300 mm and 100 mm, respectively. The evaporator section is insulated with glass chamber when the internal pressure of glass chamber is less then vacuum pressure. The adiabatic section is insulated with glass chamber when the internal pressure of glass chamber is less than vacuum pressure. The condenser is exposed to a chamber made of glass box having length, width and height are 100 mm, 100 mm and 100 mm, respectively, which filled with flowing water at ambient temperature. The condenser removes the heat by natural convection. The working fluids (water, ethanol, methanol and butanol) heated through an electrical heater. Temperature data logger has been used to measure the value of temperature with the help of thermocouples. There are ten thermocouples used for measuring the temperature

Fig. 2 Experimental setup of heat pipe insulated with glass vacuum chamber

from different–different locations of heat pipe. Two thermocouples are mounted with the external surface of evaporator, three thermocouples are mounted with the external surface of adiabatic section, and other four is mounted with the condenser section. One thermocouple is left open in the atmosphere to take a reading of atmospheric temperature. A voltmeter is used to measure the voltage reading in volt, and ammeter is used to take the reading of current in ampere.

The coefficient of convective heat transfer under natural convection was determined with the help of experimental reading. The practical value coefficient of convective heat transfer in W/m^2 °C was computed as follows:

$$\mathrm{hp} = \frac{Q}{A * dT} \tag{7}$$

The transferring heat by the heat pipe has been calculated with the help of experimental reading. The practical heat transfer rate in W/m^2 °C was computed as follows:

$$Q_{\mathrm{practical}} = q_1 - q_2 - q_3 \tag{8}$$

q_1 = Heat input to the evaporator in W [5]

$$q_1 = \frac{m.\mathrm{cp}.\Delta t}{\mathrm{time}} \tag{9}$$

q_2 (Heat loss from adiabatic section) [5]

$$q_2 = h.\mathrm{Aa}.(T\mathrm{adiabatic} - T\mathrm{atm}) \tag{10}$$

q_3 (Heat loss from condenser) [5]

$$q_3 = h.\mathrm{Ac}.(T\mathrm{condenser} - T\mathrm{atm}) \tag{11}$$

where m represents the value of mass flow rate, cp represents the value of specific heat at given inlet heating temperature, and Δt = temperature difference between walls of heat pipe to atmosphere, Aa = area of adiabatic section, Ac = area of condenser section, h = coefficient of convective heat transfer.

4 Results and Discussions

The experimental values of CCHT and RHT of the heat pipe insulated with vacuum chamber under natural convective conditions have been calculated. The analytical values are used to validate the experimental model whether model worked under natural convection conditions or not. This paper shows the results and comparisons of experimental values of different–different working fluids.

4.1 CCHT When Water, Ethanol, Methanol and Butanol Used as Working Fluids

The practical value of CCHT has been calculated with the help of experimental setup for different–different fluids separately. The results of practical value with respect to the inlet temperature of evaporator and tilting angles of heat pipe from vertical axis [11] for water [11, 10], ethanol, methanol [12] and butanol are used as working fluids are shown in Table 1 and Figs. 3, 4, 5, 6 and 7.

Figures 3, 4, 5, 6 and 7 show the results of practical values of CCHT with respect to the inlet heating temperature for water, ethanol, methanol and butanol used as working fluids at different inlet temperature of evaporator.

The value of CCHT is influenced by angle of inclination of heat pipe from vertical axis. It has been observed that the angle of inclination of heat pipe increases from vertical axis 0° to 15°, the coefficient of convective heat transfer increases, and it starts decreasing beyond 15° tilt angles for inlet evaporator temperature 61 °C and methanol, ethanol and butanol used as working fluids.

4.2 RHT of HPHE for Water, Ethanol, Methanol and Butanol Used as Working Fluids

The practical value of RHT has been calculated with the help of experimental setup for different–different fluids separately. The results of practical value with respect to the inlet temperature of evaporator and tilting angles of heat pipe from vertical axis [4] for water [11], ethanol, methanol [12] and butanol are used as working fluids are shown in Table 2 and Figs. 8, 9, 10, 11 and 12.

Figures 8, 9, 10, 11 and 12 show the results of practical values of RHT of HPHE with respect to the inlet heating temperature for water, ethanol, methanol and butanol used as working fluids, and the arrangements of heat pipe inclined at different–different tilt angles from vertical axis of HPHE.

The result shows that the HPHE gives the maximum heat transport rate when water is used as a working fluid as compared to ethanol, methanol and butanol. In the case of inclination of heat pipe from its vertical position, it gives good thermal execution when heat pipe is inclined at 45° tilt angles at all the range of inlet temperature of the evaporator and methanol is used as a working fluid.

Table 1 Coefficient of convective heat transfer for different working fluids under natural convection

Coefficient of convective heat transfer for different working fluid under natural convection in W/m^2 °C											
Water						Ethanol					
T1	Angle of inclination					T1	Angle of inclination				
	0	15	30	45	60		0	15	30	45	60
	$h_{practical}$	$h_{practical}$	$h_{practical}$	$h_{practical}$	$h_{practical}$		$h_{practical}$	$h_{practical}$	$h_{practical}$	$h_{practical}$	$h_{practical}$
40	1254.53	1201.03	1201.03	1115.23	373.85	40	336.83	333.12	323.64	310.62	264.84
43	1334.54	1334.97	1273.70	1177.20	1046.33	43	365.13	365.13	337.20	322.60	291.13
46	1433.12	1453.80	1388.63	1303.32	1137.87	46	386.70	381.99	373.24	344.54	310.62
49	1568.00	1550.37	1473.68	1368.20	1207.53	43	408.46	413.68	387.44	376.06	325.89
52	1601.34	1581.72	1555.95	1434.13	1280.43	52	434.82	434.82	418.76	386.71	349.89
55	1705.23	1646.66	1659.28	1532.38	1350.23	55	458.20	453.55	432.39	406.09	363.27
58	1733.83	1766.17	1632.44	1584.41	1428.78	58	480.97	474.40	450.97	421.16	378.22
61	1833.22	1828.98	1768.12	1644.45	1434.67	61	486.39	434.43	476.84	435.36	336.58
Methanol						Acetone or Butanol					
T1	Angle of inclination					T1	Angle of inclination				
	0	15	30	45	60		0	15	30	45	60
	$h_{practical}$	$h_{practical}$	$h_{practical}$	$h_{practical}$	$h_{practical}$		$h_{practical}$	$h_{practical}$	$h_{practical}$	$h_{practical}$	$h_{practical}$
40	467.95	465.18	441.45	419.21	367.10	40	561.78	557.81	530.87	495.66	439.90
43	503.06	507.50	486.92	452.62	387.42	43	606.43	611.48	579.17	538.02	485.28
46	541.24	529.83	497.45	469.53	434.12	46	661.44	651.13	635.36	594.38	527.65
43	552.30	545.95	534.08	495.33	443.35	49	706.23	700.97	672.71	634.10	553.32
52	580.93	572.45	551.05	521.78	471.68	52	746.02	747.36	710.76	675.25	592.19

(continued)

Table 1 (continued)

Methanol						Acetone or Butanol					
T1	Angle of inclination					T1	Angle of inclination				
	0	15	30	45	60		0	15	30	45	60
	$h_{practical}$	$h_{practical}$	$h_{practical}$	$h_{practical}$	$h_{practical}$		$h_{practical}$	$h_{practical}$	$h_{practical}$	$h_{practical}$	$h_{practical}$
55	600.54	598.17	582.96	540.17	486.92	55	802.72	784.80	755.93	705.35	632.79
58	643.44	628.93	535.58	564.77	512.02	58	837.12	825.53	809.01	745.28	663.21
SI	849.71	654.00	640.65	587.32	516.34	61	863.11	874.32	838.73	774.85	707.37