A Literature Review on Solar Air Heater with Roughened Duct having Arc-Shaped Wire

Shailesh Kumar Ram[1], Prof. Hemant Kumar Tandan[2] & Prof. Dharmendra Rathore[3]

[1]M-Tech Research Scholar, [2]Research Guide and [3]HOD Deptt. of Mechanical Engineering

Bagula Mukhi College of Technology, Bhopal (M.P.)

Abstract:-: Solar air heater is one of the basis equipment through which solar energy is converted into thermal energy. The solar air heater has an important place among solar heat collectors. It can be used as sub-systems in many systems meant for the utilization of solar energy. Possible applications of solar air heaters are drying or curing of agricultural products, space heating for comfort regeneration of dehumidifying agents, seasoning of timber, curing of industrial products such as plastics. When air at high temperature is required the design of a heater becomes complicated and very costly. As far as the ultimate application for heating air to maintain a comfortable environment is concerned, the solar air heater is the most logical choice. In general solar heaters are quite suitable for low and moderate temperatures application as their design is simple.

Keywords: Heat strip; Acceleration cooling; Electronics Heat transfer; Numerical simulation; Power engineering and energy; Resistance Heat transfer; Numerical simulation.

I. INTRODUCTION

The sun is the greatest source of energy. The small fraction of solar irradiation received by the earth is sufficient for the existence of life. This irradiation is converted into different forms of energy that are useful in many different applications. All the other sources of energy known to exist have their origin as the sun except for nuclear energy. The advantages of the sun have led many scientists throughout the world to research on economic ways of harnessing its energy.

The sun is a renewable source of energy. It is relatively easy to harness and is environmentally friendly. These advantages make it a number one candidate for the provision of energy to the whole world. Coal and oil have been used for many years now. The burning of these fossil fuels leads to emission of carbon dioxide, sulphur and nitrous oxides. Carbon dioxide is a strong greenhouse gas that causes global warming. Sulphur and nitrous oxides are converted into acids in the atmosphere and are eventually precipitated as acid rain, which is dangerous to animals and plants. Nuclear energy is not environmentally friendly and has drawbacks since the nuclear power plants are expensive to built and maintain. Furthermore, the storage and disposal of nuclear waster has not been resolved yet. Many solar collecting devices are already in use throughout the world. These collect solar radiation and convert it into useful energy such as heat or electricity. Photo-voltaic devices use semiconducting materials to convert sunlight directly into electricity. Photo-thermal devices usually called solar collectors convert solar radiation into heat (thermal conversion). Solar collectors are used to heat water and air inside buildings at lower temperatures.

Solar collectors used for heating water and air conditioning are mainly of flat-plate type. A flat-plate solar collectors is simple and inexpensive. The most important and critical part of the flat plate collectors is the absorber surface. In order to maximize the output from the solar collectors, the absorber should be spectrally selective. It should absorb as much of the incoming solar radiation as possible and at the same time retain the collected heat. This means that it should exhibit high solar absorptance and low thermal emittance. Thermal losses due to conduction, convection and radiation have an effect on the efficiency of solar absorbers. Other desirable properties of solar absorbers are that they should not degrade significantly during the lifetime of the collector and that they should withstand harsh environmental conditions.

II. BACKGROUND

Energy is foundation for sustainable and quality life. Energy is required in various forms to fulfil our day to day requirements. The energy consumption rate is an index of prosperity or the standard of living. Broadly energy resources can be classified into two categories: conventional and non-conventional. Conventional energy resources include fossil fuels (coal, crude oil and natural gas) which are definite in amount and thus need restricted and judicious use. It is estimated that at the present pace of energy consumption, conventional energy sources shall last for 75-100 years only. This envisaged researchers across the globe to look for alternate energy resources so as to avoid exhaustion of conventional energy resources.

Non-conventional or alternate energy resources can be divided into two groups namely; renewable and non-renewable resources. Renewable energy resources have a short period of renewal (upto a few years maximum) such as solar energy, wind energy, biomass energy, hydro energy, ocean and tidal energy . Solar energy is seen to be the most promising of all these alternatives because of its inexhaustibility, abundance and non-polluting nature .

Hasatani et al. reported that a limited group of advanced industrialized countries (North American, European countries and Japan etc.) has consumed the most of the available energy. However, the demand of energy has been predicted to grow enormously in the developing countries also. It is the right of the inhabitants of this planet to develop and use natural resources but conservation of these natural resources is everyone duty. The growing energy demand and depleting natural (fossil) resources require immediate attention for a close monitoring of the present energy situation, including energy dependency, security, efficiency and their environmental concerns. There has been therefore, an ever-increasing need for more and more power generation recently in all the countries of the world. In a global perspective of the power demand, it can be said with certainty that many of the developing countries of the world are now 2 actually facing energy crisis situation and are busy in formulating strategies to explore new horizons of energy generation.

The Indian power sector has an installed capacity close to 207876 MW . Out of which 65% is harnessed from the thermal systems and the rest from hydro (large), nuclear and renewable based electricity generation systems. Power shortages in our country are estimated around 12-18% of total peak electricity requirement .

Table 1.1 shows the peak demand and shortage of electricity in India. Hence, the ever increasing gap between demand and supply of energy, growing concerns about the environmental perils associated with the use of fossil fuels and spiraling cost of energy have forced the scientific community to find and develop alternate sources of energy. The rapid depletion of fossil fuel resources on a worldwide basis has necessitated an urgent source for alternative / renewable energy to meet our demands for the immediate future and for generations to come.

Table 1.1: Peak demand and shortage scenario of electricity in India [8].

S. No.	Year	Peak Demand (MW)	Peak Met (MW)	Peak Shortage (MW)	Peak Shortage (%)
1.	2002-03	81492	71547	9945	12.2
2.	2003-04	84574	75066	9508	11.2
3.	2004-05	87906	77652	10254	11.7
4.	2005-06	93255	81792	11463	12.3
5.	2006-07	100715	86818	13897	13.8
6.	2007-08	108866	90793	18073	16.6
7.	2008-09	120109	98408	21701	18.1
8.	2009-10	118794	103816	14978	12.6
9.	2010-11	126951	111533	15418	12.1

III. RENEWABLE ENERGY

The Indian scientific establishment has been working on the development of various renewable energy systems. In 1981, the Government of India established the Commission for Additional Sources of Energy (CASE) in the Department of Science and Technology (DST). In 1982, CASE was incorporated in the newly created Department of Non-conventional Energy Sources (DNES). After a decade in 1992, DNES became the Ministry of Non-conventional Energy Sources (MNES) and in 2006, MNES was renamed as Ministry of New and Renewable Energy (MNRE). Due to continuous efforts, the country has achieved an impressive progress in development and deployment of renewable energy technologies in the last 20 years. At present renewable energy (mainly wind, biomass, small hydropower etc.) contributes more than 20,000 MW, which accounts for more than 10% of the total grid power. In the present scenario India ranks second in biogas utilization after China, fourth in wind power after Germany, Spain and US, fifth in small hydropower (SHP) and seventh in the solar photovoltaic based energy production in the world [9]. The detailed estimated potential of renewable energy based on electricity generation and installed capacity is shown in Table 1.2 .

Table 1.2: Current renewable energy scenario in India

S. No.	Sources	Approx. Potential (MW)	Potential Harnessed (MW)*
1.	Wind Power	45219	17967.15
2.	Small Hydro (up to 25 MW)	15000	3434.07
3.	Biomass Power (Agro residues)	16881	1209.60
4.	Cogeneration-bagasse	5000	2109.73
5.	Waste to Energy	2700	93.68
6.	Solar Power	$6x10^8$	1044.16
	Total	**84,776**	**25858.39**

Renewable energy is anticipated to play a pivotal role in establishing optimally good standards of living in any country. It has substantially huge potential to meet the 4 growing energy requirements of the increasing population of the world, while offering sustainable solutions to the global threats of climate change. Fortunately, India is bestowed with a substantial resource base and these non-conventional energy technologies are well suited for both grid-connected power generation and for energy supplies in those remote areas which are not yet connected to the grid. Variations in the availability of natural resources, their applications and economics will favour some over others. Appropriate policies and plans that optimize use of the available energy resources and selection of such technologies are essential to lead towards a sustainable energy future. The eco-friendly aspect and free abundant availability of solar energy are the two prime factors that have made solar energy favourite among the other alternate sources of energy. Solar energy has a potential to fulfill the energy requirements of all human made systems provided technologies are developed to harness the potential of solar energy. Considerable efforts are being made to develop the technologies to tap the enormous potential of solar energy

IV. SOLAR ENERGY

The Sun is the source of the solar energy. Knowledge of characteristics of solar radiation i.e. its intensity and variations with regard to location and time is essential for the design of solar energy equipment. The Sun is a sphere of intensely hot gaseous matter with diameter of 1.39×106 km and is about 1.5×108 km away from the earth. In its central region, the temperature is estimated to vary from 8×106 to 40×106 K and the fluid density is 80 to 100 times that of the water density [11]. The surface of the sun can be considered to be an effective blackbody with temperature of approximately 5762 K. The energy intercepted by the earth amounts to approximately 1.8×1011 MW, which is many thousands times greater than the present energy consumption rate. The solar radiation that reaches the earth's surface consists of two components [12]:

i. Direct or beam radiation, which reaches the earth without any change in its direction. 5

ii. Diffuse radiation, which reaches the earth as a result of scattering and re-radiation of solar energy by dust particles, water vapours and air molecules. On a clear sky day the diffuse component varies between 10 to 20 percent of the total radiation, while during the over cast sky; it can be up to 100 percent of the total radiation reaching the earth's surface.

Applications of Solar Energy

Solar energy can be used to supply energy demand in the form of thermal energy (solar thermal systems) as well as in the form of electricity (solar photovoltaic systems). Some of the important applications of solar energy are listed below

- *Water heating*
- *Space heating and cooling*
- *Solar cooking*
- *Solar crop drying*
- *Solar distillation*
- *Solar refrigeration*
- *Green houses*
- *Solar power generation*
- *Solar furnace*
- *Solar water pumping*

In order to make the solar energy utilization economically viable, its efficient collection and storage are very essential. The most important component of solar energy utilization system is the solar collector.

Solar Air Heaters

Air is generally used as a heat transferring fluid in various categories of energy conversion devices. Solar air heater is a type of heat exchanger where heat has been carried away by air from the heated absorber plate. The low value of convective heat transfer coefficient between the air and absorber plate is a major cause for low thermal efficiency of solar air heater. Numerous investigators [22-24] have introduced different configurations of the collector passages to enhance the heat transfer coefficient between the absorber plate and air, which involves use of corrugated surface or artificial roughness at the absorber plate, or packed bed in flow cross-section. In away to reduce the heat losses to the atmosphere, use of more than one glass covers, honeycomb, multi pass airflow passages and absorber plate with selective surface have been proposed. The details of few of such designs are briefly discussed below.

Performance Enhancement Methods For Solar Air Heaters

Thermal performance of a solar air heater is poor because of its low thermal capacity. Thermal performance of a solar air heater depends upon different parameters such as incident solar radiations, losses from the absorber plate and convective heat transfer coefficient between air and the absorber plate. Broadly performance enhancement methods for solar air heaters can be classified into following three categories.

- *Enhancement of intensity of solar incident radiation on solar collector.*
- *Reduction of thermal losses.*
- *Flow passage modifications for convective heat transfer coefficien enhancement*

Fluid Flow And Heat Transfer Characteristics of Roughened Surface

Each of these roughness geometries discussed, influences the fluid flow and heat transfer characteristics in its own particular way; the simple transverse circular or square ribs generate almost minimum level of turbulence while an arrangement that involves inclined and staggering of broken rib pieces with chamfering, wedging or grooving arrangement are obviously capable of increasing the turbulence to much higher levels. In view of the complex nature of the flow comprising separated turbulent flows developed by certain special orientations of the roughness element, it is difficult to develop analytical flow models. The effect of roughness on friction factor and velocity distribution was first investigated by Nikuradse [63], who had conducted series of experiments on pipes which was roughened by sand grains. Early studies beginning with that of Nikuradse [63] attempted to develop velocity and temperature distribution for roughened surfaces.

(i)For smooth surface

u + = y + ; for laminar sublayer, y+ ≤ 5 ……………………………………….(2.1)

u + = 5 ln (y +) + 3.5; for buffer layer, 5< y+ ≤30 ……………………………………….(2.2)

u + = 2.5 ln(y +) + 5.5; for turbulent layer, y+ > 30……………………………………(2.3)

(ii) For roughened surface A detailed study of the data on roughened surface shows that the velocity profile in the turbulent flow region is strongly dependent upon the roughness height along with the flow Reynolds number. The parameter roughness Reynolds number has been obtained by combining two parameters i.e. Roughness height and Reynolds number and has been expressed as:

$$e^{+} = \sqrt{\frac{f}{2}}\left(\frac{e}{D}\right)\mathrm{Re} \qquad (2.4)$$

The velocity distribution is then written as:

$$u^{+} = B\ln[y/e] + R(e^{+}) \qquad (2.5)$$

Where e is the roughness height and R (e+) is known as momentum transfer function and it can be written as:

$$R(e^{+}) = \sqrt{\frac{2}{f}} + 2.5\ln(2e/D) + 3.75 \qquad (2.6)$$

The non-dimensional parameter R(e+) is called by different investigators as the Roughness Parameter [64] or Momentum Transfer Roughness Function [65] or Roughness Function [39, 66] .The usual relation for this function is given as;

$$R(e^{+}) = \sqrt{2/f} + 2.5\ln(2e/D) + E \qquad (2.7)$$

The constant (E) in Eqn. (2.7) is termed as geometric parameter whose value depends on the configuration of the duct. Nikuradse [63] reported a value of this parameter as 3.75 for pipe and the same value was used by Dipprey and Sabersky [65] in their investigation. However, there is no general agreement on the value of constant (E). The plot of the Roughness Function, R(e+), against Roughness Reynolds number (e+) obtained by Nikuradse [63] is shown in Figure 2.7. The three flow regions namely, hydraulically smooth flow region, transition rough flow region and fully rough region are shown in Figure 2.7.

i. Hydraulically smooth flow (0< e+<5)

In this flow the roughness has no effect on the friction factor and for all values of relative roughness height (e/D), the values coincides with those for a smooth pipe. The measured pressure loss data in this regime were correlated by Nikuradse, [63] in the form of R (e+) as under,

R (e+) = 5.5 + 2.5 ln (e+)   …………………(2.8)

ii. Transitionally Rough flow (5 ≤ e+ ≤ 70)

In transition zone, the influence of roughness becomes noticeable to a greater degree; the friction factor increases with increase in roughness Reynolds number (e+). This zone is particularly characterized by the fact that the friction factor depends on the Reynolds number as well as on the relative roughness height. The thickness of viscous sub-layer (δ) is of the same order of magnitude as the average roughness height (e) and individual projection extends through the boundary layer which produces vortices causing additional loss of the energy. As the roughness Reynolds number increases, the number of projections passing over the viscous sub-layer increases because of reduction in its thickness with increase in Reynolds number. Thus the additional energy loss increases with increase in the roughness Reynolds number.

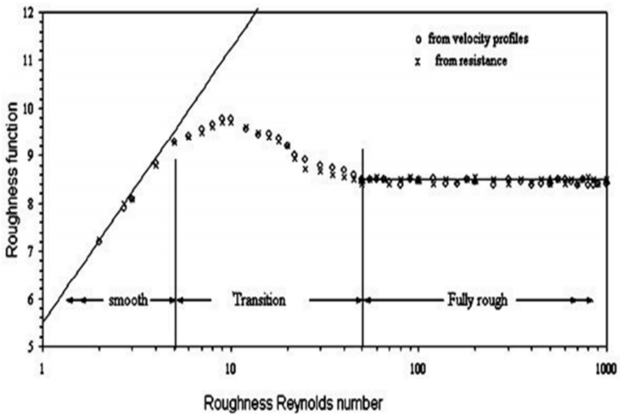

Figure Variation of Momentum Transfer Roughness Function with roughness Reynolds Number

V. LITERATURE REVIEW

D. Jansangsuk, C. Khanoknaiyakarn and P. Promvonge, The paper presents an experimental study on heat transfer and pressure drop characteristics in a rectangular channel fitted with periodic triangular v-pattern ribs. The ribs are tested for pointing downstream (v-down) to the flow. The channel has an aspect ratio (width to height ratio), AR = 10 and height, H = 30 mm; the rib-to-channel height, e/H = 0.1, 0.2, and 0.3; the rib pitch to channel height, PR=P/H = 3 and 4; the attack angle (α) of 30° relative to the flow direction. The experiment has been conducted by varying air flow velocity in order to adjust Reynolds number range from 5000 to 20,000. The upper plate of channel is uniformly heated as a constant heat flux while the whole test section is covered with insulation to reduce heat loss to surroundings. These boundary conditions correspond closely to those founded in solar air heaters. The experimental results show a significant effect of the presence of the ribs on the heat transfer rate and pressure drop over the plain channel. The measured data indicates that the triangular v-type rib with e/H = 0.3 and PR =3 yields higher heat transfer rate in terms of Nusselt number, Nu, and the pressure drop in the form of friction factor, f, than the others and also much higher than the smooth wall channel.

N. Depaiwa, T. Chompookham and P. Promvonge, The forced convection heat transfer and friction loss behaviors for turbulent airflow through a constant heat flux channel solar air heater with rectangular winglet vortex generator (WVG) are experimentally investigated in this work. The rectangular winglet pairs are considered with two different arrangements by pointing upstream (PU) and pointing downstream (PD) of the flow. Ten pairs of the WVGs with various attack angles (α) of 60°, 45° and 30° are mounted on the test duct entrance wall to create longitudinal vortex flows over the tested channel. Measurements are carried out for the rectangular channel air heater of aspect ratio, AR = 10 and height, H = 30 mm with the WVG height, b/H = 0.4 and a transverse pitch ratio, P/H = 1. The flow rate is in terms of Reynolds numbers based on the inlet hydraulic diameter of the channel ranging from 5000 to 23,000. The experimental results show that the solar air heater channel with rectangular WVG provides significantly higher heat transfer rate and friction loss than the smooth wall channel. The use of larger attack angle value leads to higher heat transfer rate and friction loss than that of lower one. The PD-WVGs performs higher heat transfer rate and friction loss than the PU one for similar operating conditions. In comparison, the largest attack angle (α = 60°) of the PD-WVGs yields the highest increase in Nusselt number and friction factor while the lowest attack angle (α = 30°) of the PU-WVGs shows the best thermal performance.

Hequan Wu, Summary form only given. In the beginning of the second decade of this century, the demand on broadband, mobile and ubiquitous application continues to increase. The proportion of number of 3G subscribers to total mobile subscribers is 7.5% up to April 2011, and 49.5% in new increased mobile subscribers during Jan to Apr 2011 in China. Global mobile data traffic in 2010 (237 PB/month) was over three times greater than the total global Internet traffic in 2000 (75 PB/month). Global mobile data traffic first exceeded voice in December 2009 and 1.5 times voice in Q2'2010. Internet of Things and ubiquitous network applications will also aggravate demand on bandwidth .For example, During the Shanghai World Expo 2010, 10,000 security cameras were installed on buses, trucks, and emergency vehicles. When live monitoring is needed, video is transmitted over the mobile network at 2 frames per second. If each frame is 0.5 MB, then an hour of this video generates 3.6 GB. If half of these vehicles transmitted 2 minutes of video over the course of a day, this would generate 18 Peta-bytes of mobile data traffic of a month, more that total global mobile data traffic in 2007. The technology progress begins to encounter bottleneck despite the optimistic market forecasts. Network development faced to some challenges, for example, scalability, ubiquitous, power consumption, security, Quality of Service, governance, etc. Firstly, the increased speed of Internet traffic exceeds Moore's law. Only a true optical layer can accommodate such traffic growth, but optical layer switching lack granulation. Core router capacity is also unable to keep pace with user traffic growth. ICANN announces that IPv4 addresses bank was sold out in Feb, 2011. Only 0.6 IPv4 address is available per user on average in China. Transition to IPv6 is inevitable. But few terminals currently in use support IPv6, and the prospect of kill application is not yet good enough for the operators and ICP to make up their m- - inds. Frequency spectrum resource is another importance challenge. In some large cities of China, the mobile communications penetration rate is over 90%. The larger number of users accessing the mobile Internet and using broadband services as 3G and LTE also adds to the burden upon urban mobile frequency spectrum. 4G cellular compared to 2G cellular needs more small cells interconnected with each other. The challenge for lower carbon on network equipments must be also considered. Energy consumption of mobile networks is growing much faster than ICT on the whole as rapid traffic growth and build-up of broadband coverage. The development of the Internet is a typical example that engineering technology walks ahead of theory, but the contin uous development of the Internet needs the theoretical support and experimental Validation. Both evolution and revolution schemes for Next Generation Internet all are worth searching well. Construction of a pure IPv6 large scale Internet core network and IPv6 source address validation mechanism for the first time in Chinese Next Generation Internet project. China Mobile has launched the TD-LTE trial in 2010 Shanghai World Expo. MIIT approved to initiate TD-LTE scale tech trial in Shanghai, Hangzhou, Nanjing, Guangzhou, Shenzhen and Xiamen, and demonstration network construction in Bei jing at end of 2010. Each city undertaking scale tech-trial will installed 200 TD-LTE base stations. Mobile communica tions will continually develop from LTE to 4G. Combining TDMA/FDMA/SDMA technologies have been used by air interface of 4G mobile system. Technologies space of physical layer will be limited for future improvement on spectrum efficiency and peak data rate. It is necessary to explore optimization of cross layers, cognitive radio and offloading to WLAN technologies etc. In a word, it will be difficult to evolve ICT along the existing technical route given the constraints imposed by frequency spectrum resources and power consumption etc.

C. S. Woei, C. K. Feng, W. Huiru, H. C. Chin and K. J. Ken,This paper presents the results of a set of numerical and experimental studies for flow and heat transfer in a spiral channel roughened by skew ribs over two opposite endwalls. The experimental Nusselt number (Nu) distributions, pressure drop coefficients (f) and thermal performance factors (η) for the spiral ribbed channel are examined along with the flow structures determined from the CFD analysis. The comparisons of Heat Transfer Enhancement (HTE) ratios measured from the ribbed spiral channel with other passive types of HTE devices confirm the favorable HTE performances for the spiral channel with the in-line skew ribs. A subsequent design and product development for the liquid cooling unit using the ribbed spiral channel is described with the pressure drops and thermal resistances presented. This study confirms the availability of the enhanced liquid cooling performance using the spiral ribbed channel for the electronic chipset(s) with higher power densities.

K. H. Dhanawade and H. S. Dhanawade, Rapid heat removal from heated surfaces and reducing material weight and cost become a major task for design of heat exchanger equipments like Cooling of I C engines. Development of super heat exchangers requires fabrication of efficient techniques to exchange great amount of heat between surface such as extended surface and ambient fluid. The present paper reports, an experimental study to investigate the heat transfer enhancement in rectangular fin arrays with circular perforation equipped on horizontal flat surface in horizontal rectangular duct. The data used in performance analyses were obtained experimentally by varying flow, different heat inputs and geometrical conditions. The experiment covered Reynolds number range from 3000-6000, based on the flow average inlet velocity and hydraulic diameter. Clearance ratio (C/H) 0.45, inter-fin spacing ratio (S/H) 0.22, duct width 150mm, height 100mm and fin size of both solid and perforated (weight reduction) were 100mm × 55mm × 3mm. For various heat inputs and flow rates values of Reynolds and Nusselt number were obtained. The results of perforated fin arrays have been compared with its external dimensionally equivalent solid fin arrays. It shows that enhancement in heat transfer of perforated fin arrays than solid fin arrays.

Faghani, M. Eskandari and E. Faghani, A study has been made of the flow and heat transfer to a circular cylinder from an isothermal impinging air jet. Numerical solutions of the governing conservation equations have been obtained utilizing a non-orthogonal curvilinear coordinate grid. The study focused on low Reynolds numbers (based on nozzle average exit velocity and cylinder diameter) in the range of 132-1315 and H/W = 2, 4, 6 and 8 which corresponds to the ratio of distance between the nozzle and cylinder to nozzle width. The flow is stable and symmetric over the range of parameters studied. The effects of buoyancy, diffusion and cooling of the cylinder, the development of the wall jet, and the recirculating bubble all affect the flow and heat transfer. The average Nusselt number increases with increasing Reynolds. Also the distance between the nozzle and the cylinder has a strong effect on the heat transfer.

P. Faghani, M. Eskandari and E. Faghani, A study has been made of the flow and heat transfer to a circular cylinder from an isothermal impinging air jet. Numerical solutions of the governing conservation equations have been obtained utilizing a non-orthogonal curvilinear coordinate grid. The study focused on low Reynolds numbers (based on nozzle average exit velocity and cylinder diameter) in the range of 132-1315 and H/W = 2, 4, 6 and 8 which corresponds to the ratio of distance between the nozzle and cylinder to nozzle width. The flow is stable and symmetric over the range of parameters studied. The effects of buoyancy, diffusion and cooling of the cylinder, the development of the wall jet, and the recirculating bubble all affect the flow and heat transfer. The average Nusselt number increases with increasing Reynolds. Also the distance between the nozzle and the cylinder has a strong effect on the heat transfer.

Table : Summary of Literature Review

SR.NO.	TITLE	AUTHORS	YEAR	METHODOLOGY
1	"Experimental study on heat transfer and pressure drop in a channel with triangular V-ribs,"	D. Jansangsuk, C. Khanoknaiyakarn and P. Promvonge,	May 2010	transfer and pressure drop in a channel with triangular V-ribs
2	Thermal enhancement in a solar air heater channel using rectangular winglet vortex generators,"	N. Depaiwa, T. Chompookham and P. Promvonge,	May 2010	enhancement in a solar air heater channel using rectangular winglet
3	Some thoughts on the transformation of information and communication technologies	Hequan Wu, "	2011	transformation of information and communication technologies
4	"Design and development of compact spiral ribbed cooling unit for electronic chipsets with high power densities,"	C. S. Woei, C. K. Feng, W. Huiru, H. C. Chin and K. J. Ken,	2011	development of compact spiral ribbed cooling unit
5	"Enhancement of forced convection heat transfer from fin arrays with circular perforation	K. H. Dhanawade and H. S. Dhanawade,	2011	heat transfer from fin arrays with circular perforation
6	"Numerical investigation of flow and heat transfer characteristics from an impinging jet on a circular cylinder,"	Faghani, M. Eskandari and E. Faghani,	*2010*	Numerical investigation of heat transfer characteristics on a circular cylinder
7	"Numerical investigation of flow and heat transfer characteristics from an impinging jet on a circular cylinder,"	P. Faghani, M. Eskandari and E. Faghani,	*2010*	Numerical investigation of heat transfer
8	"Forced convection air cooling in porous graphite foam for thermal management applications,"	K. C. Leong, L. W. Jin, H. Y. Li and J. C. Chai,	2008	convection air cooling in porous graphite foam for thermal management applications
9	"Comparative Investigation on the Cooling Effect of Swirling Impinging Jet using Experimental and Numerical Methods,"	. Jie-min, F. Yi-feng, Y. Ying, T. Juan, H. Bing-ting and C. Xiao-ling,	2007	Cooling Effect of Swirling Impinging Jet using Experimental and Numerical Methods

K. C. Leong, L. W. Jin, H. Y. Li and J. C. Chai, Rapid development in the design of electronic packages for modern high-speed computers has led to the demand for effective methods of chip cooling. The primary concerns in thermal management applications are high thermal conductivity, large specific surface area and low weight. Graphite foams which possess predominantly spherical pores with smaller openings between the cells constitute a novel highly-conductive porous material for electronic cooling applications. These foams can be produced with bulk thermal conductivities almost equivalent to dense aluminum alloys with only 1/5 the weight of solid aluminum material. Motivated by the thermal and physical properties of graphite foam, experiments were performed to assess the cooling performance of such foams for thermal management applications. A test facility was developed for experimental studies under constant heat flux heating condition. The graphite foam heat sinks were fabricated into different structures, which were designed to utilize the porous properties of the foam for heat removal. Heat transfer characteristics including local temperature and Nusselt number distributions for steady flow through the tested heat sinks were measured and a correlation of length-averaged Nusselt number in terms of Prandtl and Reynolds numbers was obtained. The findings of this study show that graphite foam heat sinks with appropriate structure can offer good heat removal with relatively low pressure drop.

Z. Jie-min, F. Yi-feng, Y. Ying, T. Juan, H. Bing-ting and C. Xiao-ling The rapid miniaturization of the electronic packaging accelerated the development of air cooling technology. In this research, both experimental and numerical methods are adopted to investigate the heat transfer between the air swirling impinging jets and an iso-heat-flux simulant chip. In the experiment scheme, the simulant chip is impacted by the swirling jet which is generated by inserting twisted strips into round nozzles. In some range of flow Reynolds number, the effects of nozzle-to-plate spacement, the geometries of the nozzle and the thread intervals of the twisted strips are examined, and then the radial distributions of Nusselt numbers on the target plate are obtained. Meanwhile, the heat transfer characteristics of the swirling jet in both the stagnation region and the wall jet region are interpreted. In order to verify its heat transfer effect, the swirling jet is compared to the ordinary straight one. Afterwards, numerical simulation is also performed to study the heat transfer effect of this cooling system, in which, a simplified axisymmetric model is built. The angular velocity of the swirling jet, the flow Reynolds number, the dimension of the nozzle and the nozzle-to-plate spacings are all examined, and then the distribution of heat transfer coefficient (Nusselt number) on the simulant chip is also obtained.

VI. CONCLUSIONS

To predict the influence of transverse rectangular cross-sectioned ribs on a solar air heater's convective heat transfer properties. A rectangular duct was constructed and numerical analysis was carried out on square and thin (high aspect ratio) rib shapes arranged in different fashion, namely single wall, staggered and in-line ribs arranged on two opposite walls including the absorber plate. Air was the working fluid and constant heat flux was applied only on the absorber plate's top surface. On comparing simulation results, pertaining to smooth duct's average Nusselt number, ϖ for different turbulent models, it was found that SST-k-omega can best predict the thermal performance of the solar air heater. For all the cases considered in this study, increase in Reynolds number leads toϖ augmentation in Nusselt number. Since, it was observed that high aspect ratio ribs allow higher convective heat transfer, hence it would be interesting to conduct research work on triangular shaped ribs having very low apex angles. The present work is expected to be very helpful for carrying out the new future project.

REFERENCES

[1] D. Jansangsuk, C. Khanoknaiyakarn and P. Promvonge, "Experimental study on heat transfer and pressure drop in a channel with triangular V-ribs," *Proceedings of the International Conference on Energy and Sustainable Development: Issues and Strategies (ESD 2010)*, Chiang Mai, 2010, pp. 1-8.

[2] N. Depaiwa, T. Chompookham and P. Promvonge, "Thermal enhancement in a solar air heater channel using rectangular winglet vortex generators," *Proceedings of the International Conference on Energy and Sustainable Development: Issues and Strategies (ESD 2010)*, Chiang Mai, 2010, pp. 1-7.

[3] Hequan Wu, "Some thoughts on the transformation of information and communication technologies," *2011 IEEE Technology Time Machine Symposium on Technologies Beyond 2020*, Hong Kong, 2011, pp. 1-1.

[4] C. S. Woei, C. K. Feng, W. Huiru, H. C. Chin and K. J. Ken, "Design and development of compact spiral ribbed cooling unit for electronic chipsets with high power densities," *2011 27th Annual IEEE Semiconductor Thermal Measurement and Management Symposium*, San Jose, CA, 2011, pp. 231-238.

[5] K. H. Dhanawade and H. S. Dhanawade, "Enhancement of forced convection heat transfer from fin arrays with circular perforation," *Frontiers in Automobile and Mechanical Engineering -2010*, Chennai, 2010, pp. 192-196.

[6] P. Faghani, M. Eskandari and E. Faghani, "Numerical investigation of flow and heat transfer characteristics from an impinging jet on a circular cylinder," *2010 12th IEEE Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems*, Las Vegas, NV, 2010, pp. 1-7.

[7] K. C. Leong, L. W. Jin, H. Y. Li and J. C. Chai, "Forced convection air cooling in porous graphite

foam for thermal management applications," *2008 11th Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems*, Orlando, FL, 2008, pp. 57-64.

[8] Jie-min, F. Yi-feng, Y. Ying, T. Juan, H. Bing-ting and C. Xiao-ling, "Comparative Investigation on the Cooling Effect of Swirling Impinging Jet using Experimental and Numerical Methods," *2007 International Symposium on High Density packaging and Microsystem Integration*, Shanghai, 2007, pp. 1-5

[9] Z. Jie-min, F. Yi-feng, Y. Ying, T. Juan, H. Bing-ting and C. Xiao-ling, "Comparative Investigation on the Cooling Effect of Swirling Impinging Jet using Experimental and Numerical Methods," *2007 International Symposium on High Density packaging and Microsystem Integration*, Shanghai, 2007, pp. 1-5.