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Research Paper

HEAT TRANSFER AUGMENTATION USING DIMPLES IN FORCED CONVECTION- AN EXPERIMENTAL APPROACH

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Over the past couple of years the use of concavities or dimples to enhance the heat transfer has been reported by several researchers. This work deals with experimental investigation of the forced convection heat transfer over circular dimpled surfaces. The various heat transfer parameters considered for study are Nusselt number, heat transfer coefficient, heat transferrate andReynolds Number. From the obtained results, novel conclusion for thedesign of compactheat exchangercan be drawn (Katkhaw, 2014).

Keywords: Forced convection, Dimples, Heat transfer augmentation, Compactheat exchanger

INTRODUCTION

In compact heat exchanger design, passive techniques are one of the most important techniques used by researchers to enhance the heat transfer (Liu *et al.*, 2013). Passive techniques are also used in solar air heaters, electronic cooling equipment's (heat sinks), biomedical devices, turbine airfoil cooling etc. In passive techniques heat transfer rate is increased by making surface modifications such as protrusions, dimples and pin fins. Among these, the dimples (surface indentations) are considered important because in dimple manufacture the material is removed whereas in pin-fin or rib tabulators extra material is added which increases weight and cost of the equipment. A variety of Numerical and experimental work has been carried out on augmentation of heat transfer.

Afanasyev *et al.* (1993) carried out an experimental investigation of heat transfer characteristics of flow over spherical dimple surfaces.

Chyu *et al.* (1997) carried out an experiment to study local heat transfer coefficient distribution in a channel having two different shaped dimples (spherical and tear drop type) at the bottom. Burgess *et al.* (2005) carried out an experiment to study the effect

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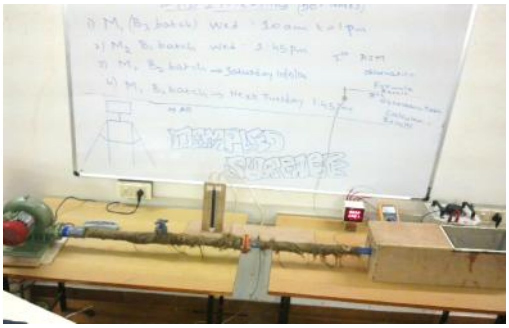
of dimple depth on friction and heat transfer characteristics in a channel. They reported an increase in local and average Nusselt number with increase in dimple depth. Wei *et al.* (2007) carried out anumerical study of laminar flow inside a micro-channel having dimples at the bottom surface. Small *et al.* (2005) carried numerical and experimental studies on heat sinks with and without dimples and concluded that the presence of dimples increase heat transfer rate considerably.

From the above literature, it is very much clear that dimples have a high potential to increase heat transfer. However, most of the researchers carried out experimental or numerical study on spherical shaped dimples in channelsand a very few studies were reported on non-spherical dimples (Chyu, 1997; and Katkhaw, 2014). Deriving motivation from this, the present study aims at investigating experimentally the effect of air flow over a flat plate with circular dimples. Theobtained results, helpsin drawing novel conclusion for thedesign of compactheat exchanger (Katkhaw, 2014).

EXPERIMENTAL SETUP

The forced convection setup required for this study is shown in Figure 1 below.

Figure 1: Experimental Setup



Data Reduction

The study was carried out under Steadylaminar external forced convection regime. Steady state value of the plate and air temperaturefor a given heat flux wereused to determine the values of the different performance parameters.

RESULTS AND DISCUSSION

Heat transfer experiment on test plate with squaredimplesfor staggered arrangement were done and the data was is used for finding parameters like Nusselt number, heat transfer coefficient and heat transfer rate. Experimental findings has been plotted in the formof graphs, mainly

- Re vs Nu
- Re vs h
- Re vs Qto facilitate a better discussion on experimental data.

Figure 2 shows the variation of Nusselt number 'Nu' with Reynolds number 'Re' for the dimple surfaces. It can be seen that the 'Nu' increases obviously with'Re' for both thecases.

Figure 2: Variation of Nusselt Number 'Nu' with Reynolds Number 'Re'

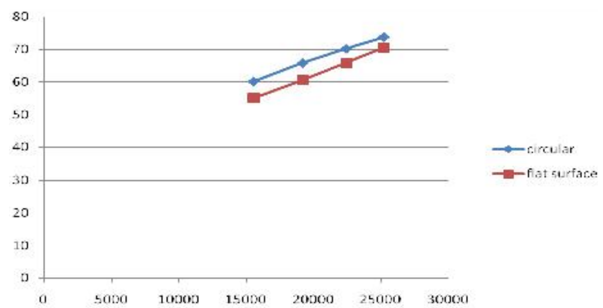


Figure 3 shows the variation of Heat transfer co-efficient 'h' with Reynoldsnumber 'Re'. It is obvious that 'h' increases with 'Re' in both the cases.

Figure 3: Variation of Heat Transfer Co-efficient 'h' with Reynolds Number 'Re'

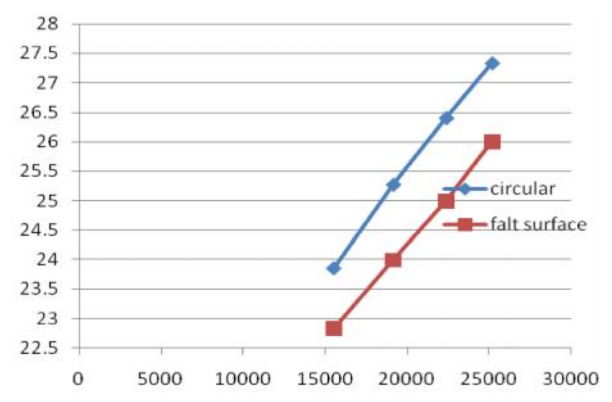
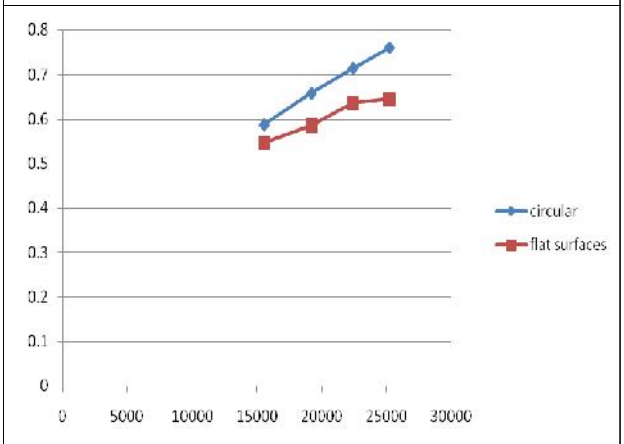


Figure 4 shows variation of Heat transfer rate 'Q' with Reynolds number 'Re' for the dimples. It can be seen that again 'Q' increases as 'Re' increases.

Figure 4: Variation of Heat Transfer Rate 'Q' with Reynolds Number 'Re'



CONCLUSION

In this study an experimentalinvestigation of the effect of air flow over a flat plate with circulardimples is carried out. The main conclusions can be summarized as follows:

1. Nusselt number 'Nu' increases with Reynolds number 'Re'.
2. Heat transfer co-efficient'h' increases with Reynolds number 'Re' in all the cases.
3. The Heat transfer rate 'Q' increases as Reynolds number 'Re' increases for both the cases.

REFERENCES

1. Afanasyev V N, Chudnovsky Y P, Leontiev A I and Roganov P S (1993), "Turbulent Flow Friction and Heat Transfer Characteristics for Spherical Cavitieson a Flat Plate", *Exp. Therm. Fluid Sci.*, Vol. 7, No. 1, pp. 1-8.
2. Burgess N K and Ligrani P M (2005), "Effects of Dimple Depth on Channel Nusselt Numbers and Friction Factors", *J. Heat Transfer*, Vol. 127, No. 1, pp. 839-847.
3. Chyu M K, Yu Y, Ding H, Downs J P and Soechting F O (1997), "Concavity Enhanced Heat Transfer in an Internal Cooling Passage", ASME Paper 97-GT-437.
4. Katkhaw N, Vorayos N, Kiatsiriroat T, Khunatorn Y, Bunturat D and Nuntaphan (2014), "Heat Transfer Behavior of Flat Plate having 450 Ellipsoidal Dimpled Surfaces", *Case Studies in Thermal Engineering*, Vol. 2, pp. 67-74.
5. Liu S and Sakr M (2013), "A Comprehensive Review on Passive Heat Transfer Enhancements in Pipe Exchangers", *Renewable and Sustainable Energy Reviews*, Vol. 19, pp. 64-81.
6. Small E, Sadeghipour S M and Asheghi M (2006), "Heat Sinks with Enhanced Heat Transfer Capability for Electronic Cooling Applications", *ASME J. Electron. Packag.*, Vol. 128, pp. 285-290.

7. Wei X J, Joshi Y K and Ligrani P M (2007), "Numerical Simulation of Laminar Flow and Heat Transfer Inside a Micro Channel with One Dimpled Surface", *ASME J. Electrn. Package*, Vol. 129, pp. 63-70.