Variation of Heat Energy Storage in Unsteady and Steady State in Porous Media During Oscillating Flow

[1]Raman Arora, [2]Dr. Beant Singh
[1,2]Dept. of Mechanical Engineering, Punjab College of Engineering & Technology, Lalru Mandi, India

Abstract
This paper deals with the variation of heat energy storage in unsteady and steady state in porous media during oscillating flow. The experiments are performed to analyze the thermal response of steel ball and glass ball in unsteady and steady state. The spherical balls of steel and glass material having diameter 6.5mm are used with water as a fluid. The experiment is carried out at Peclet number 1368. The constant head and fully saturated flow of water is maintained. The result shows the amount of energy absorbed and retrieved in unsteady and steady state and comparison of energy storage in unsteady and steady state during the oscillating flow.

Keywords
Porous Media, Unsteady and Steady State, Oscillating Flow

I. Introduction
The theory of heat transfer in a porous medium is applicable to several disciplines of science and engineering. It is an important subject in many fields of practical interest and can be found in mechanical engineering, petroleum engineering, ground water hydrology, agricultural engineering, chemical engineering, environmental science and soil mechanics. In an oscillatory flow, the cold and hot fluids flow periodically through opposite ends of a domain. These flows have a wide range of applications in the field of energy. Pascale [1] experimentally studied heat transfer in oscillating flow inside a cylindrical tube. Leong & Jin[2] studied heat transfer in oscillating flow through channel filled with aluminium foam. Chanpreet [3] studied Energy storage in fluid saturated porous media subjected to oscillating flow. Yee[4]Studied theoretical effect of viscous dissipation on forced-convection heat transfer in cylindrical packed-beds. Polyakov [5] investigate the heat transfer in envelopes made of porous material. Gazy [6] studied effect of porous media particle size on forced convection from a circular cylinder without assuming local thermal equilibrium between phases. Mishra [7] experimentally studied mass and heat transfer effect on MHD flow of a visco-elastic fluid through porous medium with oscillatory suction and heat source. Pathak[8]studied Convective heat transfer and thermal dispersion during laminar pulsating flow in porous media. Wang [9] numerically studied Three-dimensional natural convection in an inclined porous cavity with time sinusoidal oscillating boundary conditions.

II. Experimental Set Up
A schematic diagram of the experimental setup is shown in fig. 1.The experimental set up consist of PVC circular pipe in which porous material is closely packed. The PVC circular pipe has internal diameter 84 mm and 660 mm length. The total 360mm mid length of pipe is used for measurement in which five thermocouples are inserted at a distance of 90mm apart. The porous media of steel metal balls diameter 4.55 mm and 6.5mm are used. The fluid used is water, which is maintained at temperature of 42°c for hot and 20°c for cold water. The constant heat tanks of 20 litre capacity are used and constant heat is maintained. The temperature is measured by K type very sensitive thermocouple. The ADD Link NU-2213 Data Acquisition Card (DAQ) of 16 channels is used to record the reading in CPU. The DAQ card is so sensitive that it can takes five reading in one second. The flow of the water is measured by a rota meter having capacity of 5 lpm. However the fixed flow can be adjusted by setting the knob provided on the rotameter. The heat loss is avoided by putting the insulating material on the pipes.

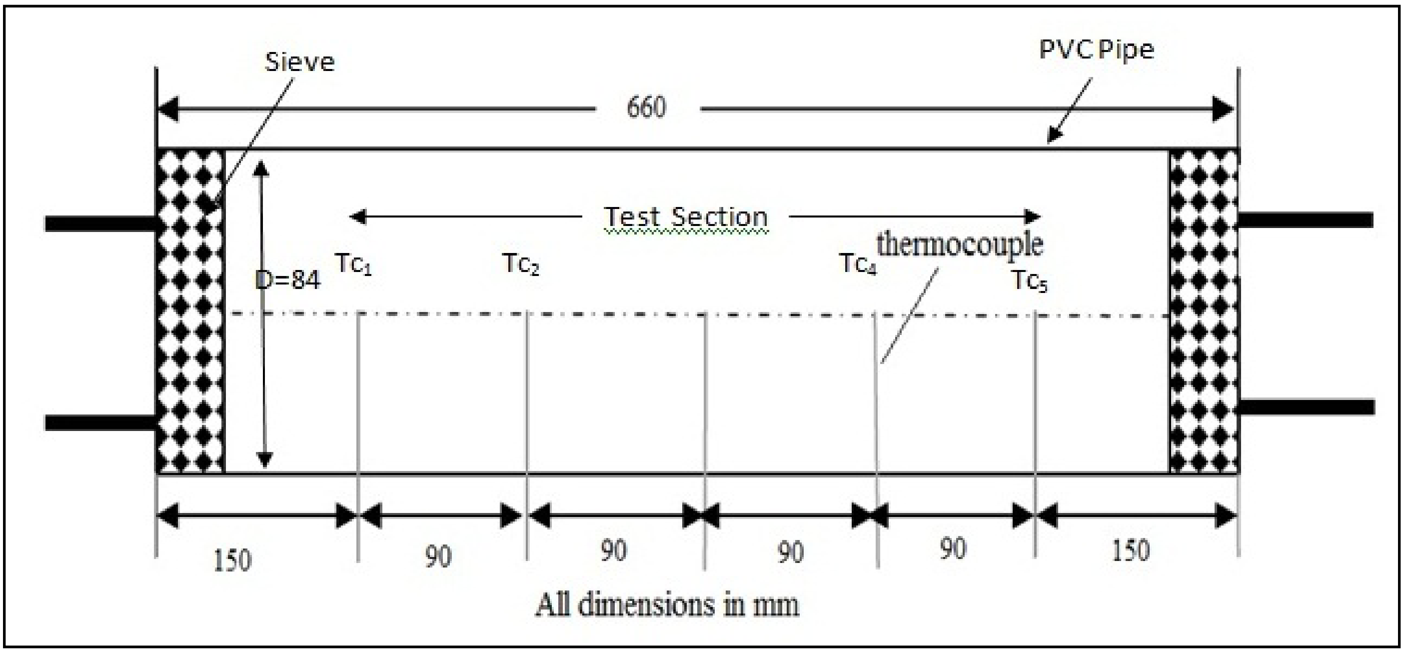

Fig. 1:

ISSN : 2249-5762 (Online) | ISSN : 2249-5770 (Print)

III. Results and Discussions

A. Variation of Front Amplitude With Location for Steel Ball (Unsteady State)

In Oscillating flow, temperature rises to maximum value in hot phase and falls to minimum value in cold phase. The difference between maximum and minimum value of temperature is called Front Amplitude. It is clear from the figure that front amplitude decreases rapidly with the distance. The front amplitude is maximum at Z0 and then it decreases. The fig. 2 shows the variation of Front Amplitude with distance at Reynolds Number 251.

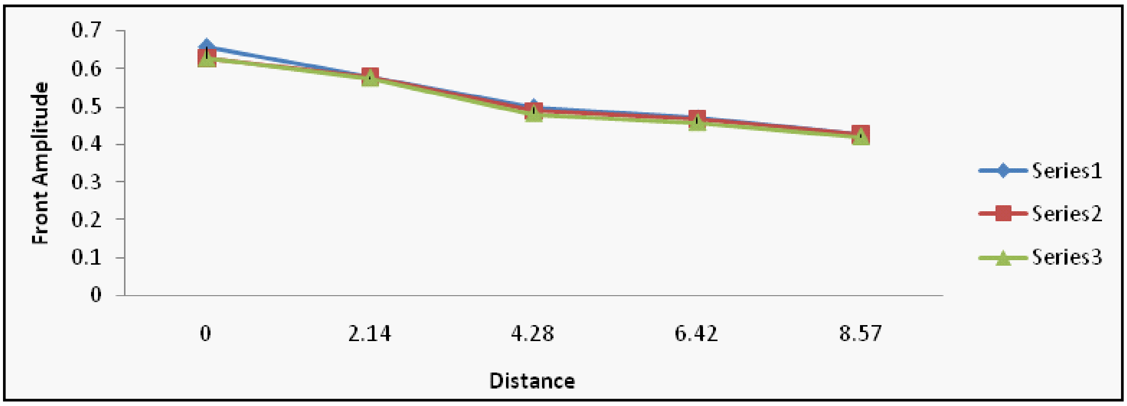

Fig. 2: Variation of Front Amplitude With Distance

B. Variation of Front Amplitude With Location for Steel Ball (Steady State)

In steady state the front amplitude decreases very slowly with distance which can be considered to be nearly constant.

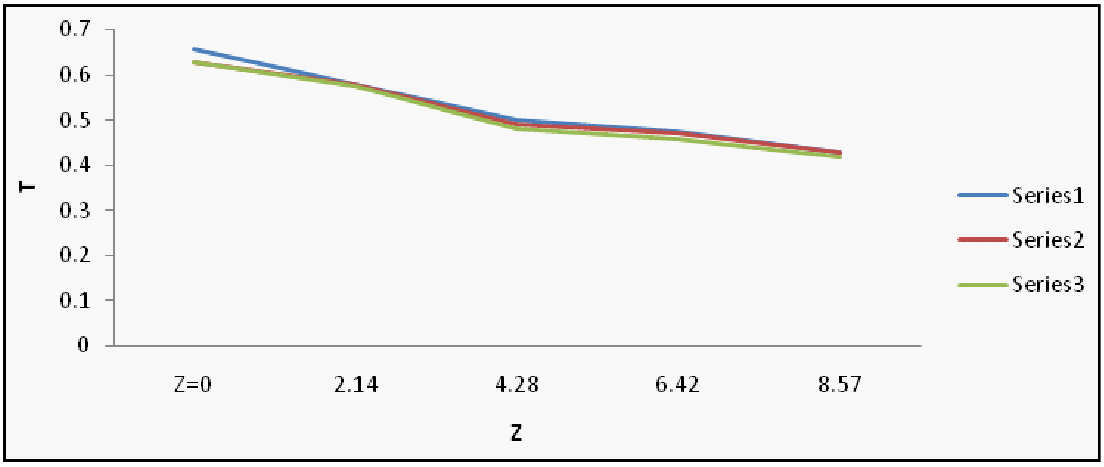

Fig. 3: Variation of Front Amplitude With Distance

C. Variation of Front Amplitude With Location for Glass Ball (Unsteady State)

It is clear from the figure that front amplitude decreases rapidly with the distance. The front amplitude is maximum at Z0 and then it decreases. It is minimum at Z4.

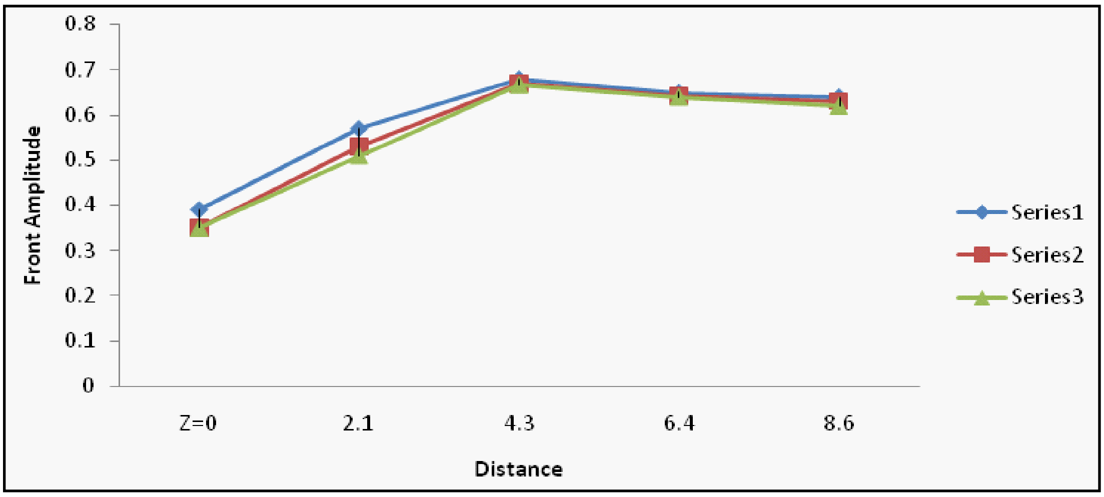

Fig. 4: Variation of Front Amplitude With Distance

D. Variation of Front Amplitude With Location for Glass Ball (Steady State)

From fig. it is clear that the variation of front amplitude with distance is more up to Z2 and after that it becomes almost constant for Z3 and Z4.

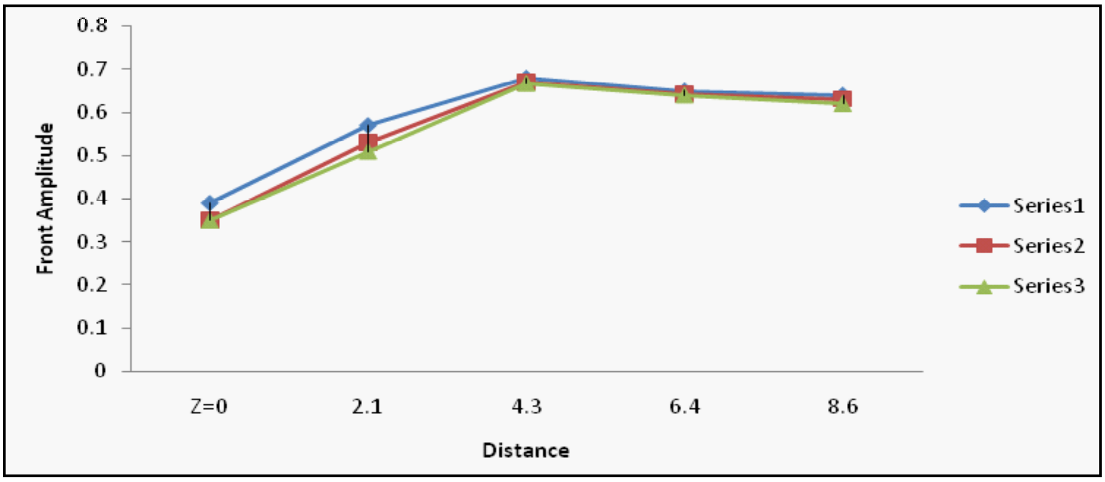

Fig. 5: Variation of Front Amplitude With Distance

E. Heat Energy Stored and Retrieved in Unsteady State for Steel Water Bed

The fig. 6 shows the amount of energy stored and retrieved in unsteady state for glass ball 6.5mm size. The difference between heat energy stored and retrieved goes on decreasing

With increase in number of cycles.

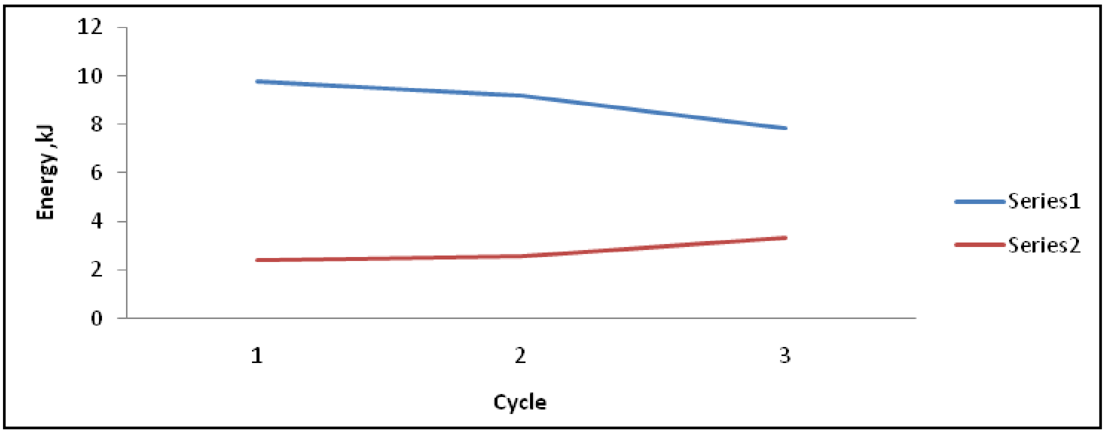

Fig. 6: Heat Energy Stored and Retrieved in Unsteady State

G. Heat Energy Stored and Retrieved in Steady State for Steel Water Bed

The fig. 6 shows heat energy stored and retrieved in steady state. The difference between heat stored and retrieved goes on decreasing in steady state.

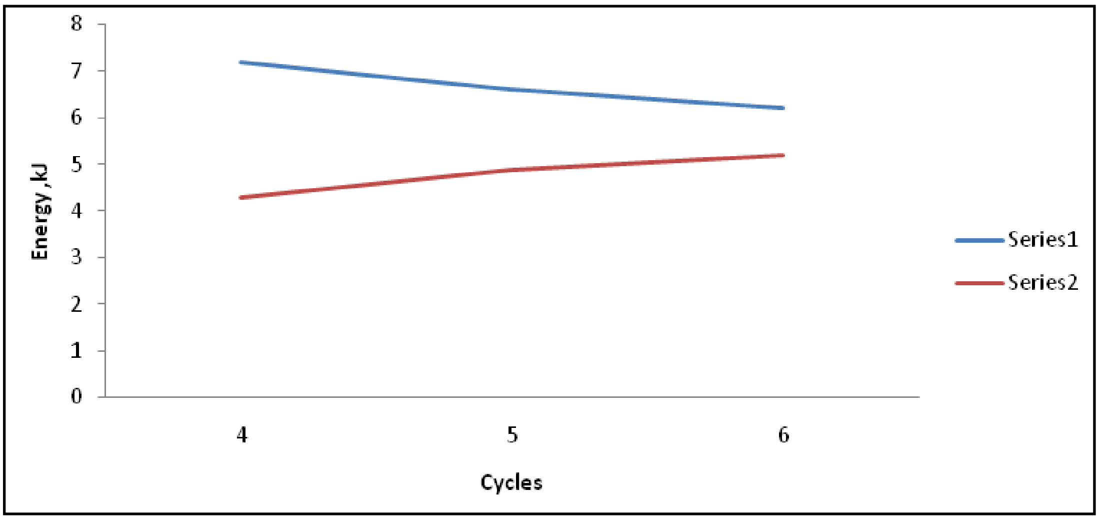

Fig. 7: Heat Energy Stored and Retrieved in Steady State (Steel Ball)

ISSN : 2249-5762 (Online) | ISSN : 2249-5770 (Print)

H. Heat Energy Stored and Retrieved in Unsteady State for Glass Water Bed

The fig. 7 shows the Heat energy stored and retrieved in unsteady state for glass water bed. The difference in heat stored and retrieved is less as compared with the steel water bed. The difference in heat stored and retrieved is maximum at 1st cycle.

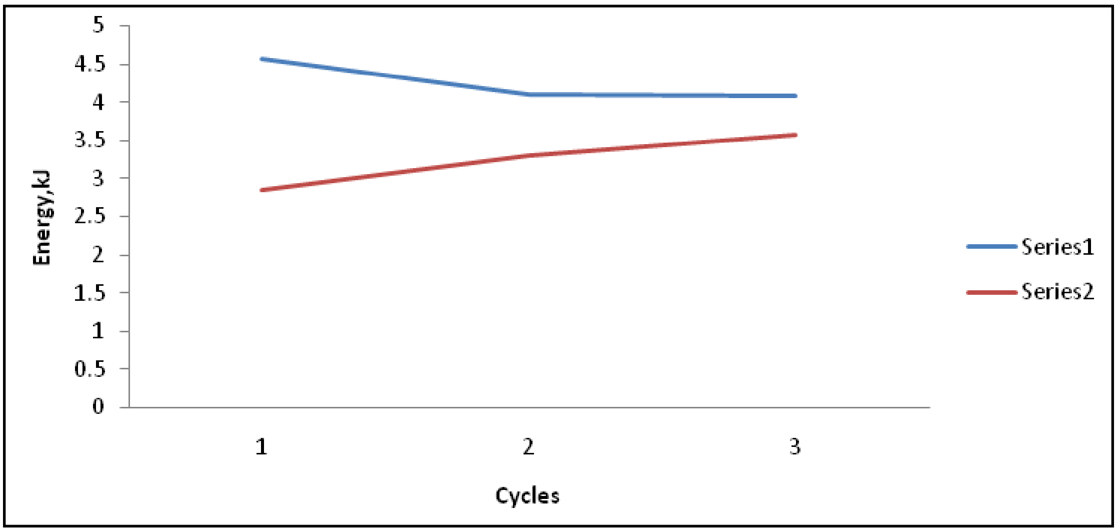

Fig. 8 Heat energy stored and retrieved in unsteady state for glass water bed.

H. Heat Energy Stored and Retrieved in Steady State for Glass Water Bed

The fig.8 shows the heat energy stored and retrieved in steady state for glass water bed.It is clear from the fig. that heat energy stored and retrieved in steady state tends to coincide each other i.e. there will be no difference in heat stored and heat retrieved.

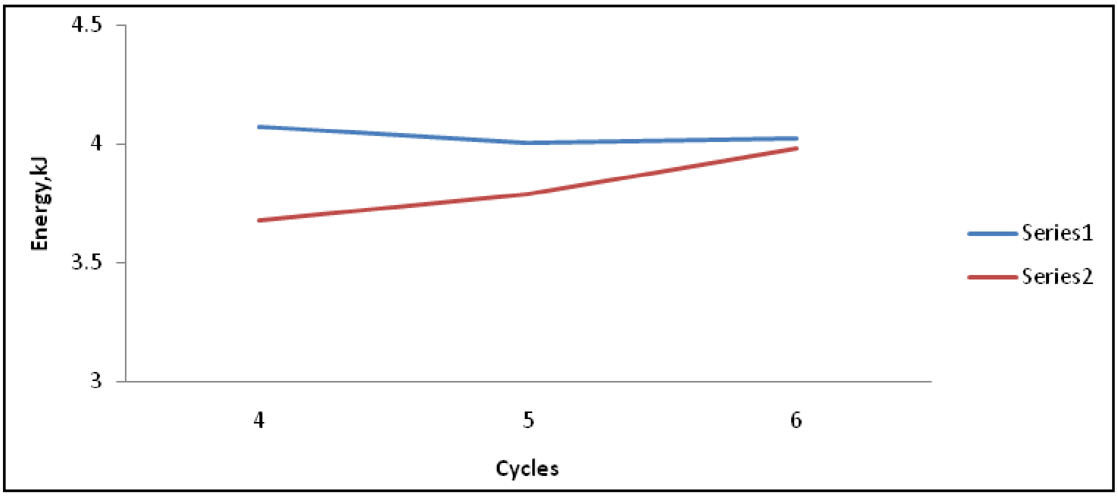

Fig. 9: Heat Energy Stored and Retrieved in Steady State for Glass Water Bed

IV. Conclusion

The oscillating flow in porous media of steel spherical balls and glass balls of diameters 6.5mm were analyzed at Reynolds Number 251 and Peclet Number 1368.The variation of front amplitude with distance is more in unsteady state as compared with steady state during oscillating flow. The front speed increases with distance for both steel and glass material. The variation in heat energy stored and retrieved is more in unsteady state as compared to steady state. Heat energy stored by steel ball is more as compared to glass ball of same size.

References

[1] Pascale Bouvier, Pascal Stouffs, Jean-Pierre Bardon "Experimentally study of heat transfer in oscillating flow", Int. Journal of Heat and Mass Transfer 48, 2005, pp. 2473-2482.

[2] K.C.Leong, L.W.J,"Characteristics of oscillating flow through a channel filled with open-cell metal form", Int.Journal of Heat & Fluid Flow 27, 2006, pp. 144-153.

[3] Chanpreet Singh, R.G.Tathgir, K.Muralidhar,"Energy storage in fluid saturated porous media subjected to oscillating flow", Journal of Heat Mass Transfer 45, 2009, pp. 427-441.

[4] San San Yee, Kouichi Kamiuto,"Effect of viscous dissipation on forced-convection heat transfer in cylindrical packed-beds", Int. Journal of Heat and Mass Transfer 45, 2002, pp. 461-464.

[5] A.F. Polyakov, V.K. Stratev, A.F. Tretyakov, Yu.L. Shekhter,"Heat Transfer in envelopes made of porous network material", Pleiades publishing 56, 2009, pp. 227-234.

[6] F.Gazy, Akira Nakayama, Mark C.Thompson,"Effect of porous media particle size on forced convection from a circular cylinder without assuming local thermal equilibrium between phases", Int. Journal of Heat and Mass Transfer 55, 2012, pp. 3366-3378.

[7] S.R. Mishra, G.C. Dash, M. Acharya,"Mass and heat transfer effect on MHD flow of a visco-elastic fluid through porous medium with oscillatory suction and heat source",

International Journal of Heat and Mass Transfer, Vol. 57, November 2012, pp. 433–438.

[8] M.G. Pathak, S.M. Ghiaasiaan,"Convective heat transfer and thermal dispersion during laminar pulsatin flow in porous media", International Journal of Thermal Sciences, Vol. 50, Issue 4, April 2011, pp. 440-448.

[9] Q.W. Wang, J. Yang, M. Zeng, G. Wang,"Three-dimensional numerical study of natural convection in an inclined porous cavity with time sinusoidal oscillating boundary conditions", International Journal of Heat and Fluid Flow, Vol. 31, Issue 1, February 2010, pp. 70-82.

Er. Raman Arora working as Lecturer in Mechanical Engineering Deptt., Punjab college of Engineering and Technology, Lalru Mandi (Punjab) since 2011, He did his B.Tech from Kurukshetra University in 2006.His area of interest are Machine Design, Theory of machines.

Dr. Beant singh working as Professor in Mechanical Engineering Deptt, Punjab college of Engineering and Technology, Lalru mandi (Punjab) since 2003. He did his P.hd in the area of Inter Phase heat transfer between solidand liquid phase for cyclic heating–cooling of porous media from PunjabiUniversity, Patiala in 2014.His area of interest are Heat transfer, Strength of material and Fluid mechanics.