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Variation Of Front Amplitude, Front Speed, Front Spread In Porous Media For Different Particle Size During Oscillating Flow

Umesh Gera[1], Beant Singh[2], Chanpreet Singh[3]
[1] Department of Mechanical Engineering, Galaxy Global Group of institution, Dinarpur, India
[2] Department of Mechanical Engineering, Punjab College of Engineering and Technology, Lalru Mandi, India
[3] Department of Mechanical Engineering, UCOE Pbi Uni Patiala, India

Abstract

This paper deals with the effect of oscillatory flow on front amplitude, front speed, front spread in porous media. The experiments are performed to analyze the response of parameters like front amplitude, front speed, front spread in porous media at Reynolds number. The solid material of 4.55mm and 6.5mm are used as spherical balls of steel material and normal water is used as a fluid. The constant head and fully saturated flow of water is maintained. The performance behavior of each parameter has also been compared at Peclet Number. The result shows the amount of energy stored in porous media of steel spherical balls diameter 4.55mm is large as compared to the porous media of steel spherical ball diameters 6.5mm.

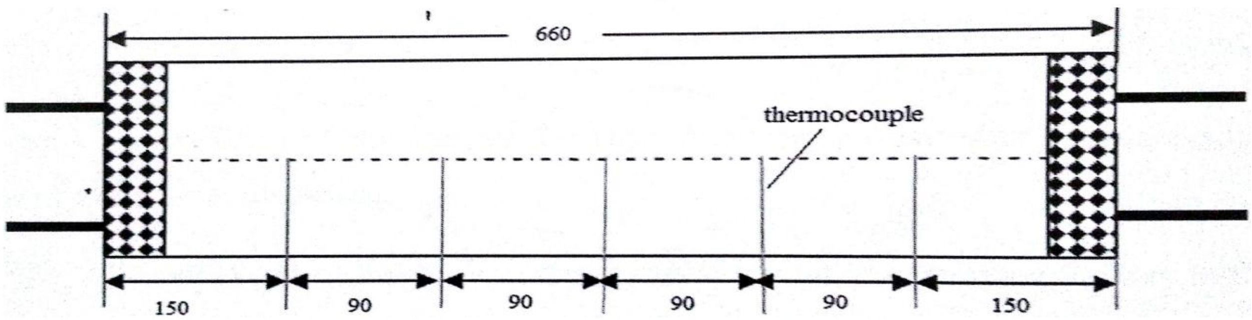
Keywords- Oscillatory, Porous media, Voids.

I. INTRODUCTION

The theory of dynamics flow and 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 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. Nield [1] invested the effects of thermal non-equilibrium on thermally developed forced convection in porous medium. Byun [2] studied analytically the thermal behavior of porous medium under oscillated flow conditions. Cimatti [3] presented method to reduce PDE system of the flow of a viscous fluid in a porous medium with boundary conditions on the pressure. Leong [4] experimentally studied the convective heat transfer in Graphite foam heat skin with baffle and stagger structures. Janzadeh and Delavar [5] investigated forced convection in a channel with solid block inside a square porous block. Polyakov [6] investigated the heat transfer in envelopes made of porous network materials. Jin [7] studied heat transfer in oscillating flow through channel filled with aluminum foam.

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 rotameter 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.



All dimensions are in mm
Fig. 1. Porous Bed with Thermocouples

III. RESULT AND DISCUSSION

1.1 Variation of Front Amplitude for particle size 4.55mm:

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. The Fig. 2 shows the variation of Front Amplitude with time on different location at Reynold Number 236.

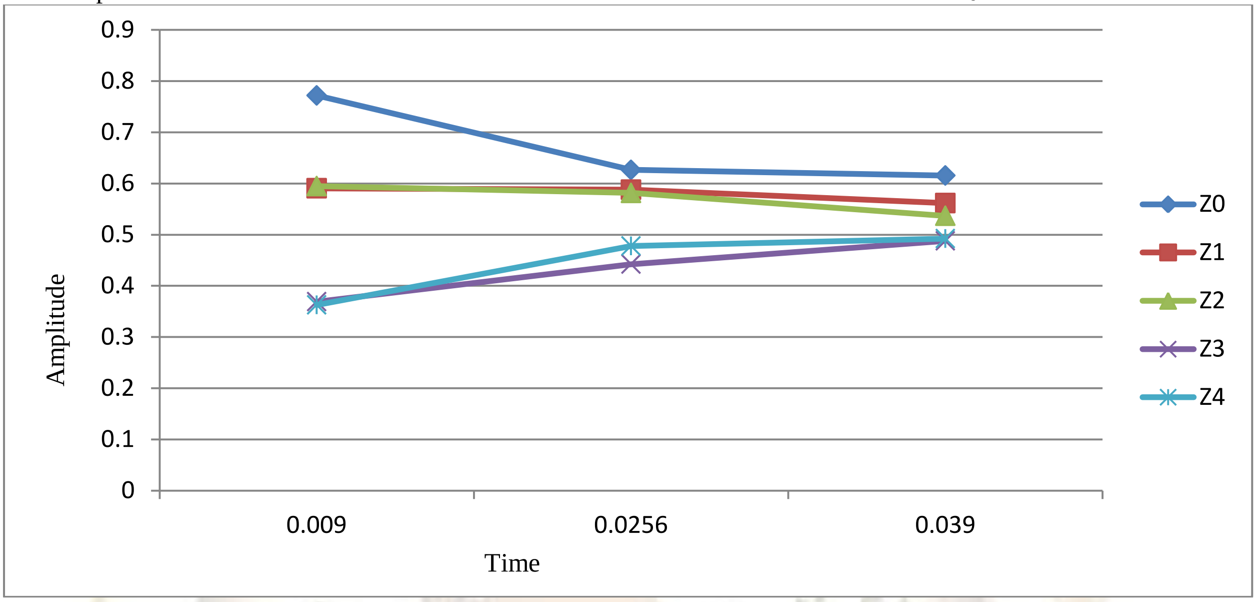


Fig. 2. Variation of Front Amplitude with Time

It has been observed that Front Amplitude decreases at location Z0 and Z1 which are near to the hot domain and increases at the thermocouples Z3 and Z4 which are near to the cold domain. The Front Amplitude decreases at location Z0 and Z1 because the lower temperature increase and increases in the Z3 and Z4 due to increase in the higher temperature whereas being nearer to cold domain the lower temperature is not much increaseing. The increase and decrease in Front Amplitude indicates that the total amount of energy observed is approximately same in all the cycles.

3.2 Variation of Front Amplitude for particle size 6.5mm:

The Fig. 3 shows the variation of Front Amplitude with Time at Reynold Number 236.

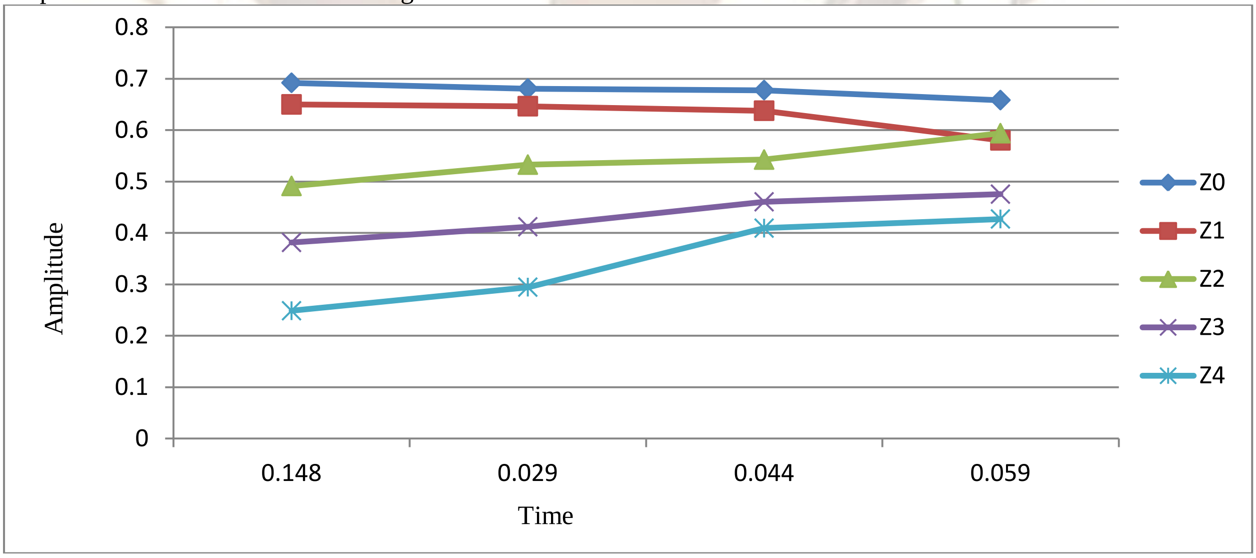


Fig. 3. Variation of Front Amplitude with Time

It has been observed that the Front Amplitude decreases at location Z0 and Z1 which are near to the hot domain and increases at the thermocouples Z3 and Z4 which are near to the cold domain. The Front Amplitude decreases at location Z0 and Z1 because the lower temperature increase and increases at Z3 and Z4 due to increase in the higher temperature whereas being nearer to cold domain the lower temperature is not much increasing. The increase and decrease in amplitude indicates that the total amount of energy observed is approximately same in all the cycles.

3.3Variation of Front Speed for particle size 4.55mm: The front speed is measured for 0.5 degree temperature rise between two locations. The non-dimensional value is calculated by equation:

Front Speed= ΔZ /Pe Δt

Where Pe is the peclet Number, ΔZ is the distance between the locations, Δt is the time.

As the front speed is a function of Peclet number, So it is evaluated at Peclet Number 1287 is shown in Fig. 4.

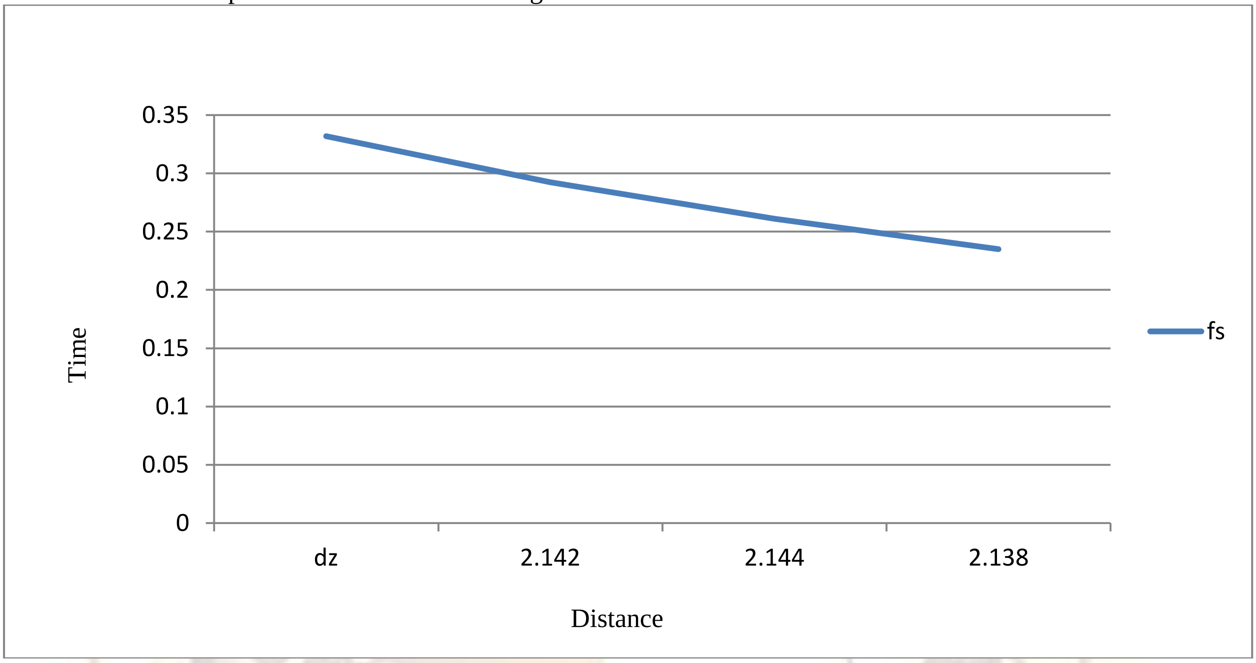


Fig. 4 Variation of Front Speed with Time

It has been observed that the Front Speed is 0.33 at Z0 located near hot domain and front speed reduces to 0.23 at Z3 located near the cold domain.

3.4 Variation of Front Speed for particle size 6.5mm: The Fig. 5 shows the variation of Front Speed with Time at Peclet Number 1287.

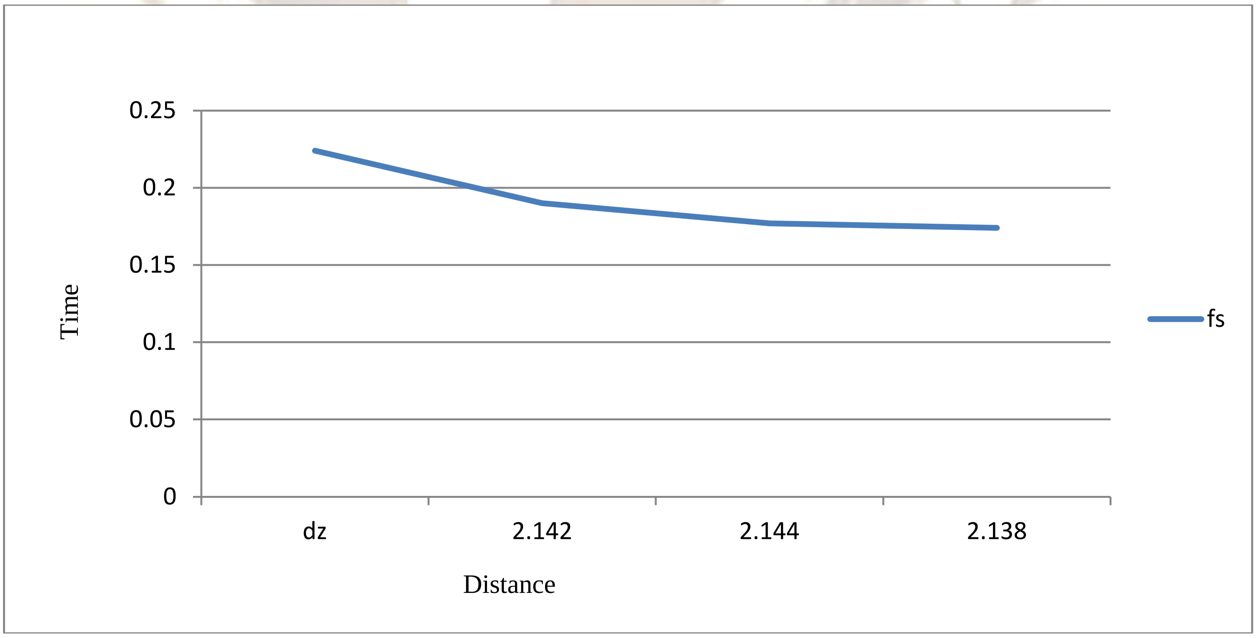


Fig. 5 Variation of Front Speed with Time

It has been observed that the Front Speed is 0.22 at Z0 located near hot domain and front speed reduces to 0.18 at Z3 located near cold domain.

3.5 Variation of Front Spread for particle size 4.55mm: Front Spread arises from flow of fluid, when it is moving in pores of porous media. It is due to spreading of fluid particals in both the directions longitudinal and transverse for dispersion. For higher dispersion and heat loss higher is the Front Spread. The Front spread at particular location indicates the role of diffusion in heat energy transfer. The non-dimensional value of Front Spread is calculated by equation:

Front Speed= $(\Delta t)Pe$

Where Pe is the Peclet Number and Δt is the time

Front Spread is function of Peclet number, Higher the value of Peclet Number, the higher is the Front spread. The Fig. 6 shows the variation of Front Spread with Locations (Distance) at Peclet Number 1287.

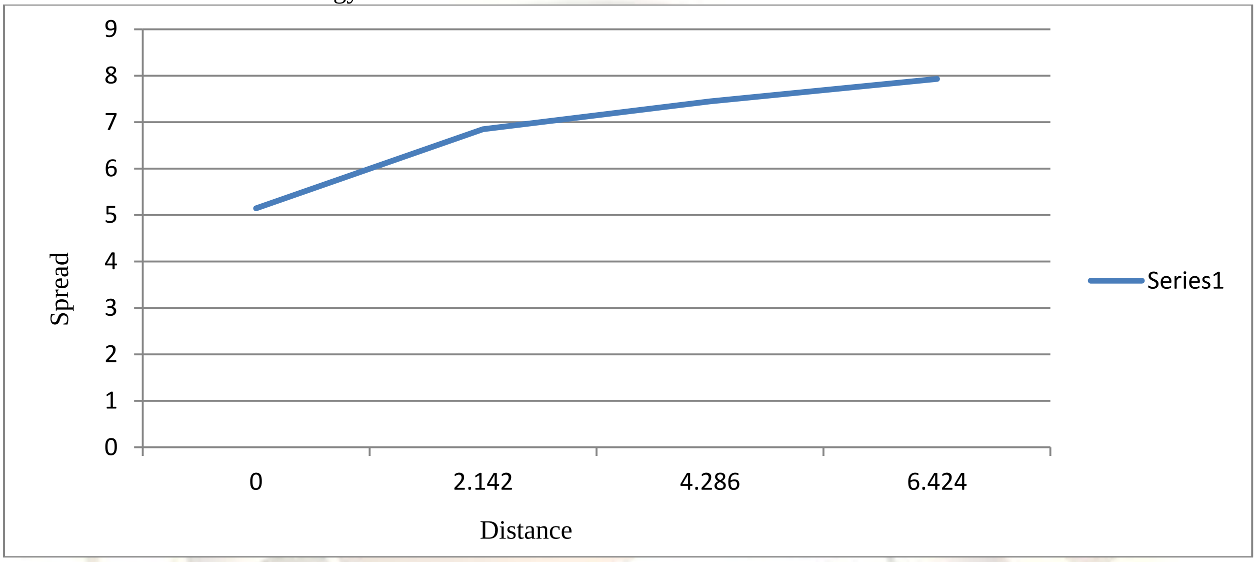


Fig. 6 Variation of Front Spread with Distance

It has been observed that the Front Spread is 5.1 at Z0 and rises to 7.9 at Z3 location. The Front Spread rises from hot domain to cold domain to downstream. As the fluid flows with distance heat dispersion increases in longitudinal and transverse direction.

3.6 Variation of Front Spread for particle size 6.5mm: The Fig. 7 shows the variation of Front Spread with Locations (Distance) at Peclet Number 1287.

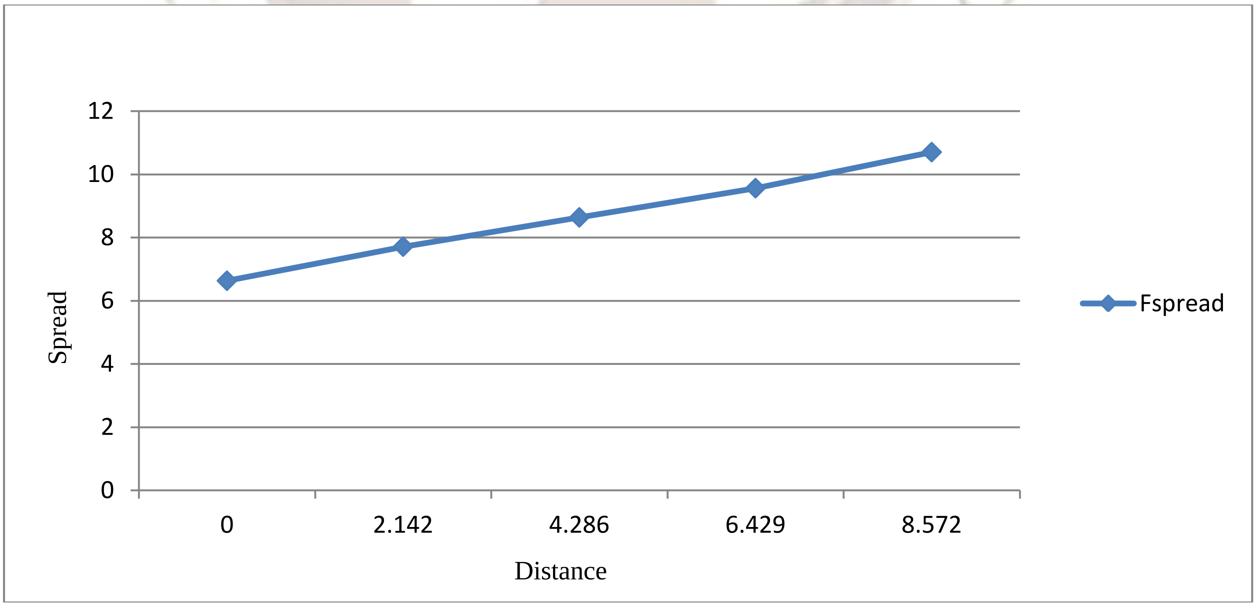


Fig. 7 Variation of Front Spread with Distance

It has been observed that the Front Spread is 6.2 at Z0 and rises to 10.2 at Z3 location. The Front Spread rises from hot domain to cold domain to downstream. As the fluid flows with distance heat dispersion increases in longitudinal and transverse direction.

IV. CONCLUSION

The oscillating flow in porous media of steel spherical balls of diameters 4.55mm and 6.5mm were analyzed at Reynold Number 236 and Peclet Number 1287. In case of Particle Size diameter 6.5mm, the Front Amplitude was found to be decreasing with distance and value is low as compared to Particle Size diameter 4.55mm. The value of Front Speed is higher for porous media of steel spherical balls diameters 6.5mm. The amount of energy stored in porous media of steel spherical balls diameter 4.55mm is large as compared to the porous media of steel spherical ball diameters 6.5mm.

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