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Variation of Front Amplitude, Front Speed, Front Spread In Porous Media for Different Solid Medium of Same Particle Size during Oscillating Flow

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Abstract
This paper deals with the effect of oscillatory flow on front amplitude, front speed, front spread in porous media for different solid medium of same particle size at different Reynolds number. The solid material of 6.5mm is used as spherical balls of steel and glass material. Normal water is used as a fluid. The size of porous bed is less than the 1/10 of diameter of the tube. The steel spherical balls of diameter 6.5 mm constitute a porous bed which will act as Steel Water Bed and glass spherical balls of diameter 6.5 mm constitute a porous bed which will act as Glass Water Bed. The front amplitude of steel water bed was found to be decreasing with distance and value was low as compared to glass water bed. The value for front speed of Steel water bed was higher in comparison to the glass water bed. Front spread is observed for hot phase. The value for front spread of steel water bed was higher in compression to the glass water bed.
Keywords- Oscillatory, Porous media, Voids.

I. INTRODUCTION

Porous medium is a material medium made of heterogeneous or multiphase matter. At least one of the considered phases is not solid. The solid phase is usually called the solid matrix. The space within the porous medium domain that is not part of the solid matrix is named void space or pore space. It is filled by gaseous and/or liquid phases. The theory of dynamics of 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. Examples can be found in mechanical engineering, petroleum engineering, ground water hydrology, agricultural engineering, chemical engineering, environmental science and soil mechanics. Porous medium is a solid with pores. The fluid flows through interconnected pores. Fluid's path through pores is quite complex, micro level treatment is not possible and a fluid continuum approach is used for analysis. The equations of fluid are solved over an ensemble of many molecules contained in a small volume. The known solutions are useful in understanding the flow and heat transfer phenomena. Lab scale experiments are efficient means for measuring global parameters like front amplitude, front speed and front spread. Lamorlette[1] numerical studied of global convective heat transfer coefficient in two-energy equation model for convection in three dimensional porous media with buoyancy effects. Nield[2] examined the effects of combined horizontal and vertical heterogeneity on the onset of convection in a porous medium. Li[3] analyzed the fluid flow and heat transfer in a channel with staggered porous blocks. Leong [4] experimentally studied of heat transfer in oscillating flow through a channel filled with aluminium foam. Mehmet[5] examined the heat transfer in porous media of steel ball under oscillating flow. Neda[6] numerically Investigated the Forced Convection in a Channel with Solid Block inside a Square Porous Block.

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 and glass metal balls of diameter 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 head tanks of 20 litre capacity are used and constant head 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.

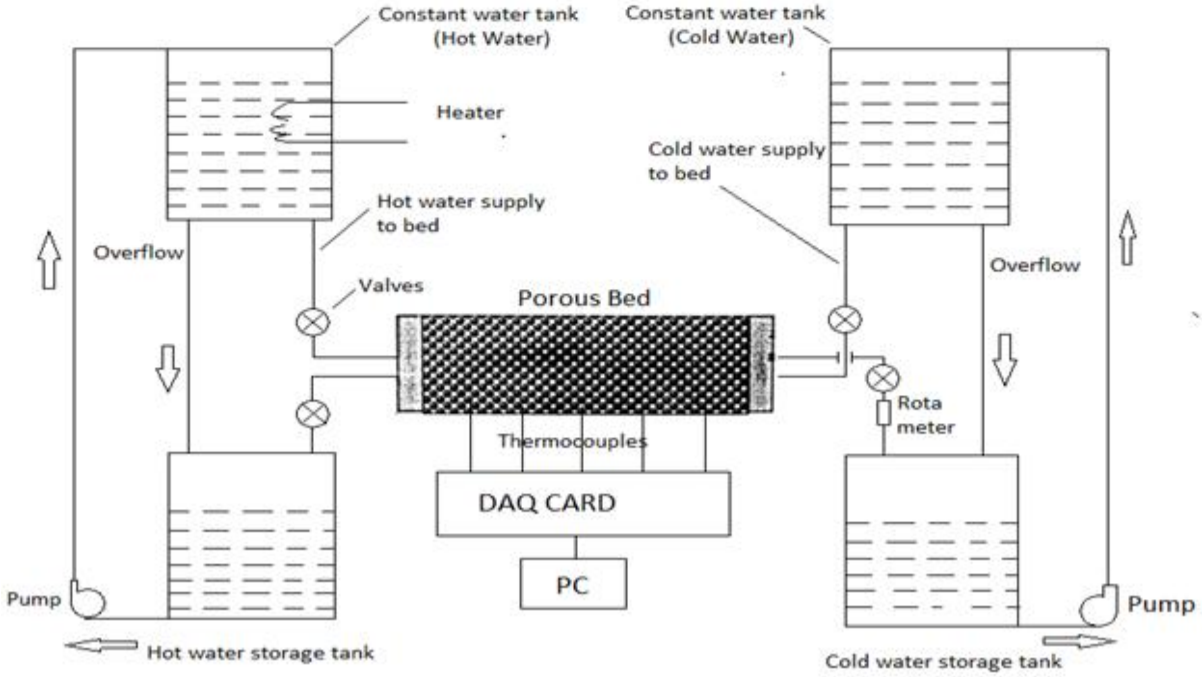

Fig. 2.1 Experimental Setup

III. RESULT AND DISCUSSION

3.1 Variation of front amplitude for Steel water bed of particle size 6.5mm:

The flow of fluid in steel water bed is oscillatory in which the hot and cold flows alternately at opposite ends. The flow of hot and cold fluid in the bed creates a maximum and minimum temperature. The difference of maximum and minimum temperature is called front amplitude. The front amplitude is analyzed at two Re. no's 346, 251.

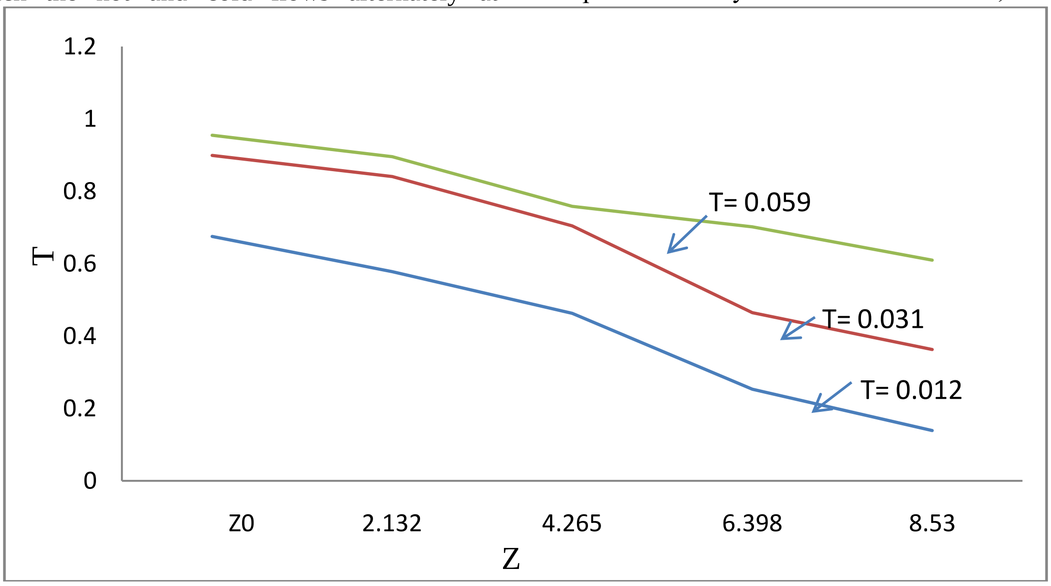

Fig 3.1 Variation of temperature at different locations at different time at Re 346

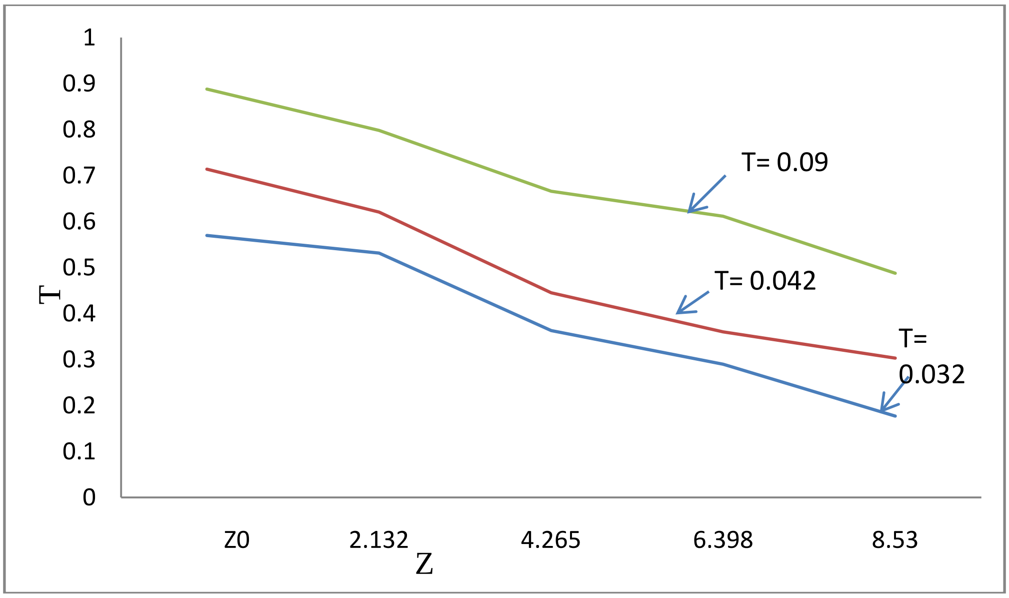

Fig. 3.2 Variation of temperature at different locations at different time at Re 251

It is observed from the above graphs that the value of temperature at Z0 (hot domain) is highest and decrease with stream. The value of maximum temperature at low Re is high as compared to high Re due to the fluid exchanges more energy with the solid material during in the same time period and the temperature increase is more. The temperature of thermocouple at exit end Z_4 is lower in case of low Re, due to maximum amount of energy is exchanged in previous locations.

3.2 Variation of front speed for Steel water bed of particle size 6.5mm: The front speed is the ratio of ΔZ and Δt, it is the change of 0.5 temperatures at various locations. It is calculated for both hot and cold phase. The fig. 3.3 and 3.4 show the variation of front speed with the location at Re 283 & 346 respectively.

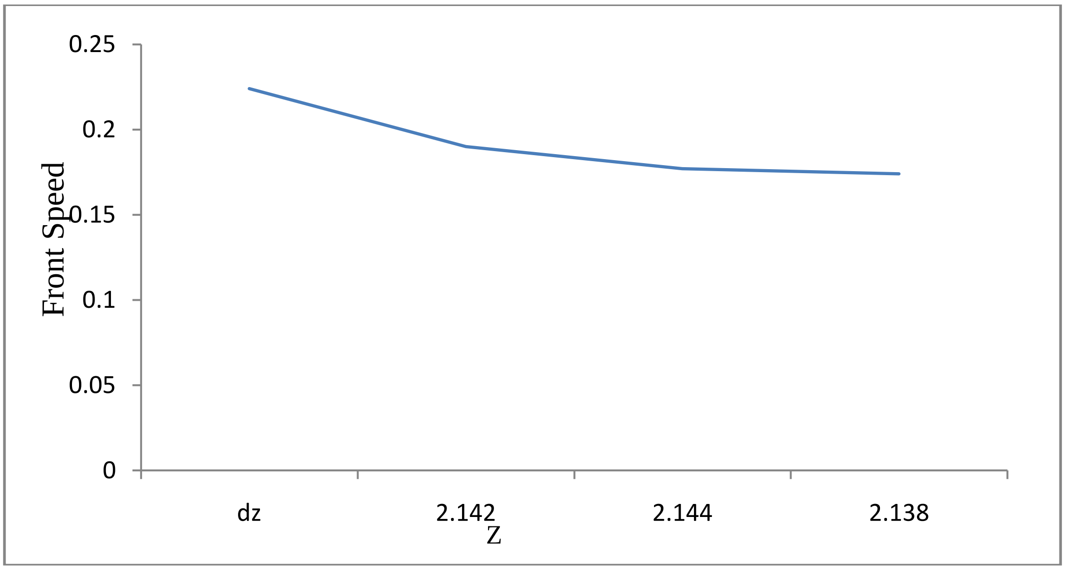

Fig. 3.3 Variation of Front Speed with location at Re 283

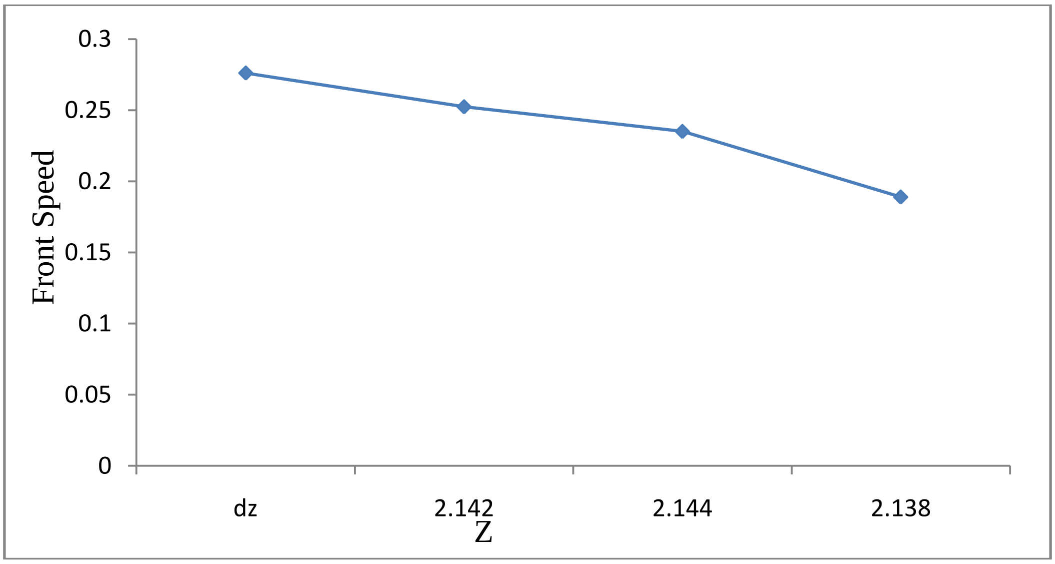

Fig. 3.4 Variation of Front Speed with location at Re 346

As per the graph the front speed decreases with the distance. The ratio of decreases of front speed at Re 346 is very less. The thermal velocity of fluid at higher Re is reducing at low rate.

3.3 Variation of Front Spread for Steel water bed of particle size 6.5mm: The **front spread** is rise of temperature from 0.25 to 0.75 at a location. The spread arises from spreading of fluid particle in both longitudinal and transverse direction. The spread increases with distance which results from spreading fluid particles in the transverse directions. Higher is the dispersion and heat less and higher is the spread. . The front spread is analyzed at two Re's 283 & 346 and shown in fig. 3.5 and 3.6.

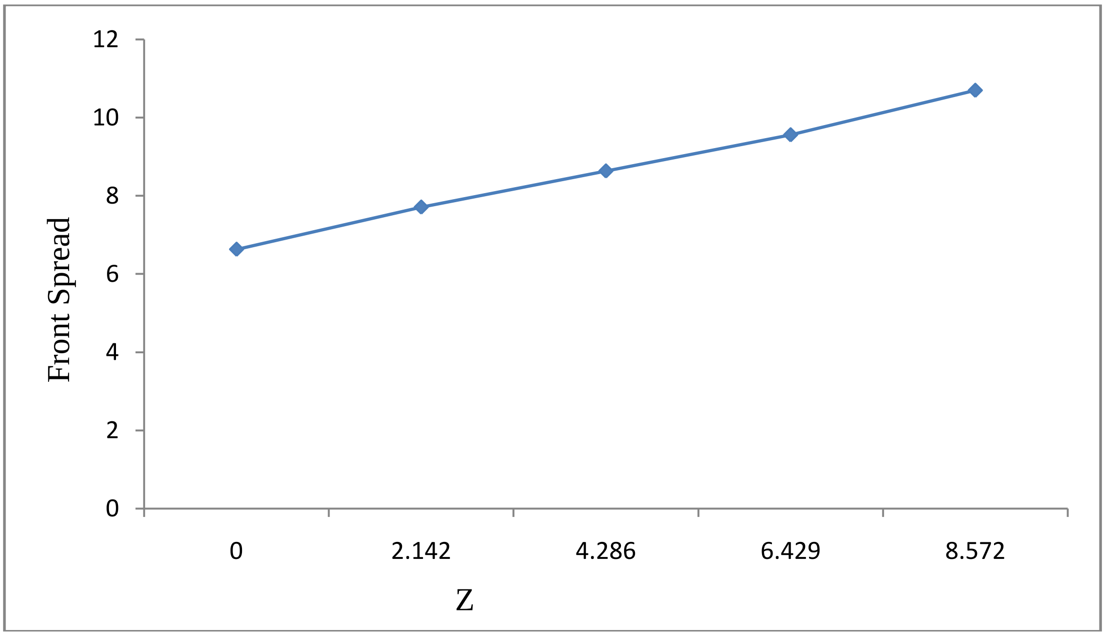

Fig. 3.5 Variation of front spread with location at Re 283

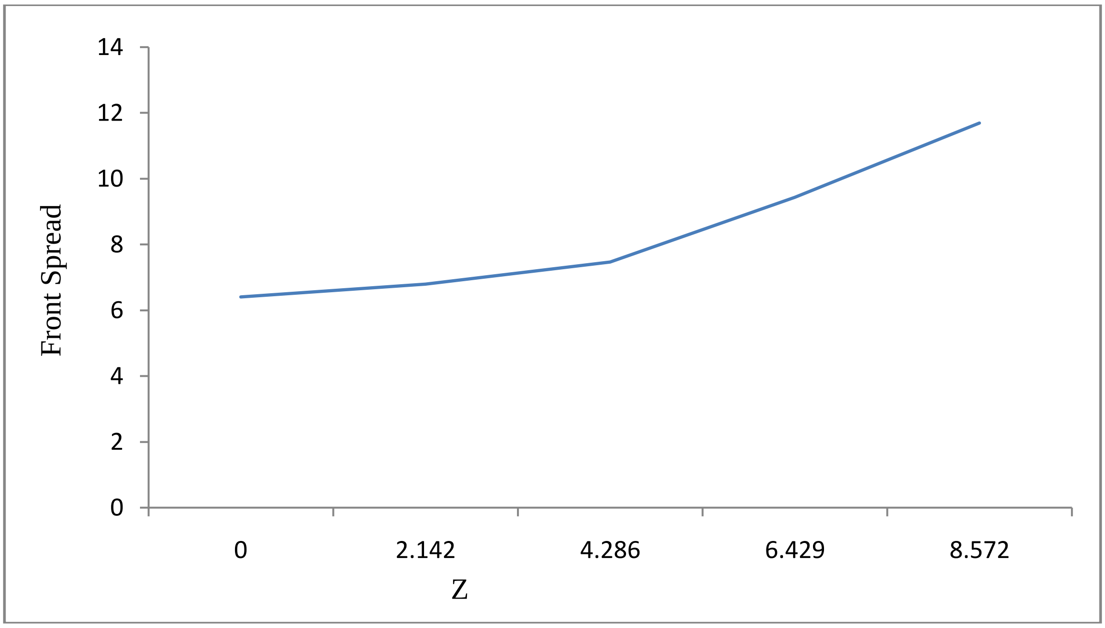

Fig. 3.6 Variation of front spread with locations at Re 346

It is observed from the graph that the front speed increases with the distance. The value of front speed at Re 283 is increasing from 6.63 in the bed and at higher Re 346 the value rises from 6.41. The value of front spread is low at higher Re number. The value increases with the distance in both the cases.

3.4 Variation of front amplitude for Glass water bed of particle size 6.5mm: The solid phase used is glass spherical beads of diameter 6.5mm. The amplitude is the difference between maximum and minimum temperature at a location. It is observed from freqyency response that during first cycle the amplitude is very high due to initially cold domain. The variation of amplitude with locations at Re 299 and 377 shown in fig. 3.7 and 3.8.

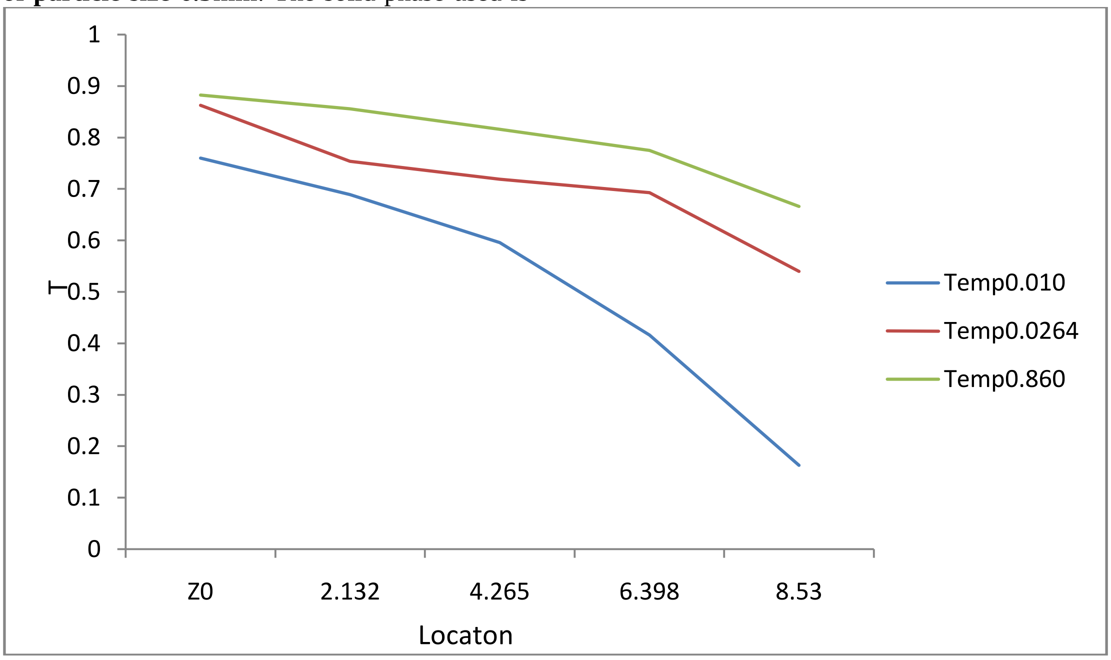

Fig. 3.7 Variation of temperature at different locations at different time Re 299

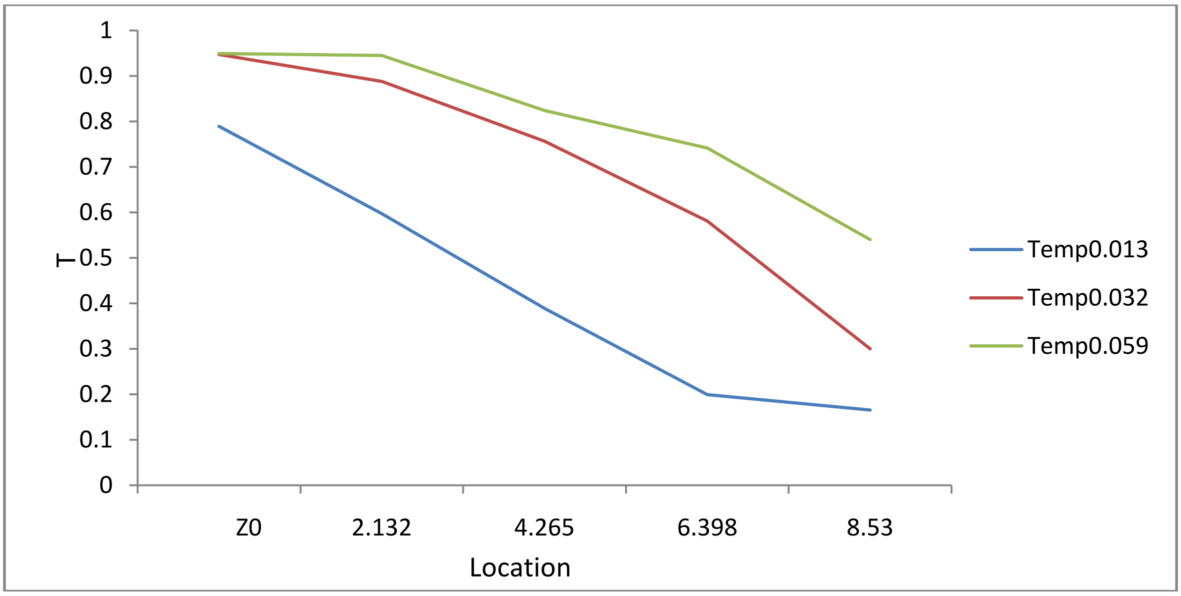

Fig. 3.8 Variation of temperature at different locations at different time Re 377

The peak value variations are shown for the different flow rate. It is observed that variation of peak at unistage is higher and slope decreases with the passage of time. The peak value increases with the time. The value of temperature at Re 377 is higher near the hot domain and decreases with downstream.

3.5 Variation of front speed for Glass water bed of particle size 6.5mm:

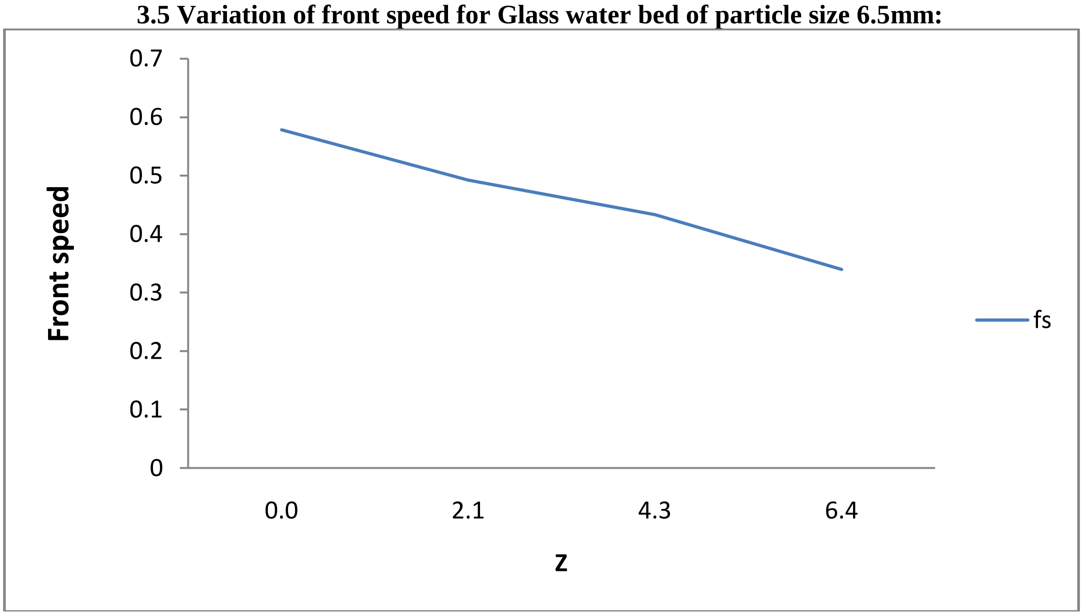

Fig. 3.9 Variation of Front Speed with Distance at Re 283

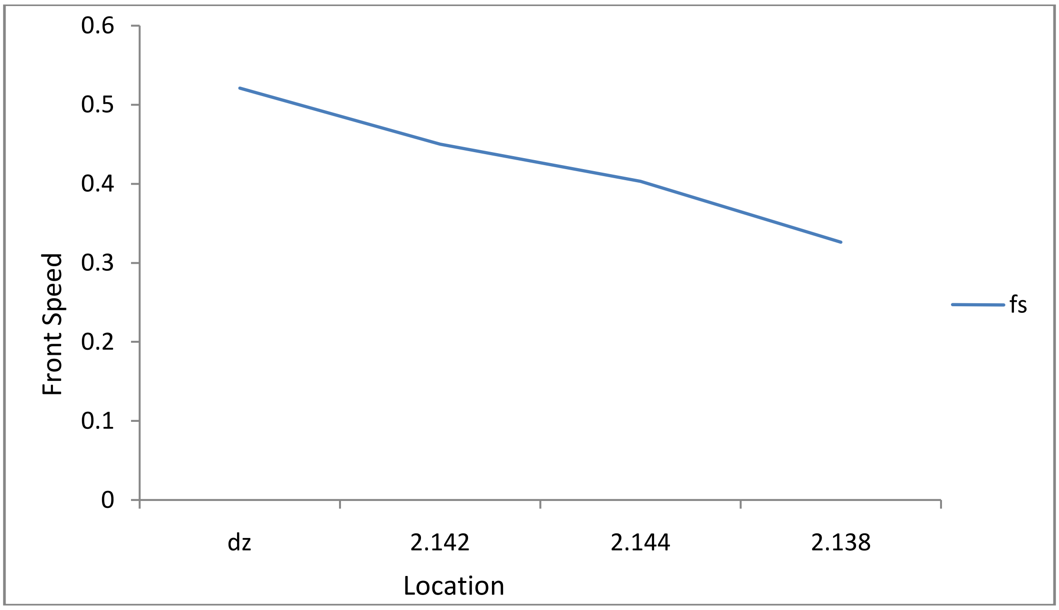

Fig. 3.10 Variation of Front Speed with Distance at Re 377

It is observed that front speed is highest at Z_0 and decrease with downstream, the non dimensional value of front speed at Z0 = 0.401 and at Z4 the value is 0.3873. The graph shows that heat dissipation decrease with the increase in distance. At Re283 the value of front speed at Z0 is 0.579 and decrease with distance. The front speed at lower Re is higher.

3.6 Variation of Front Spread for Glass water bed of particle size 6.5mm:

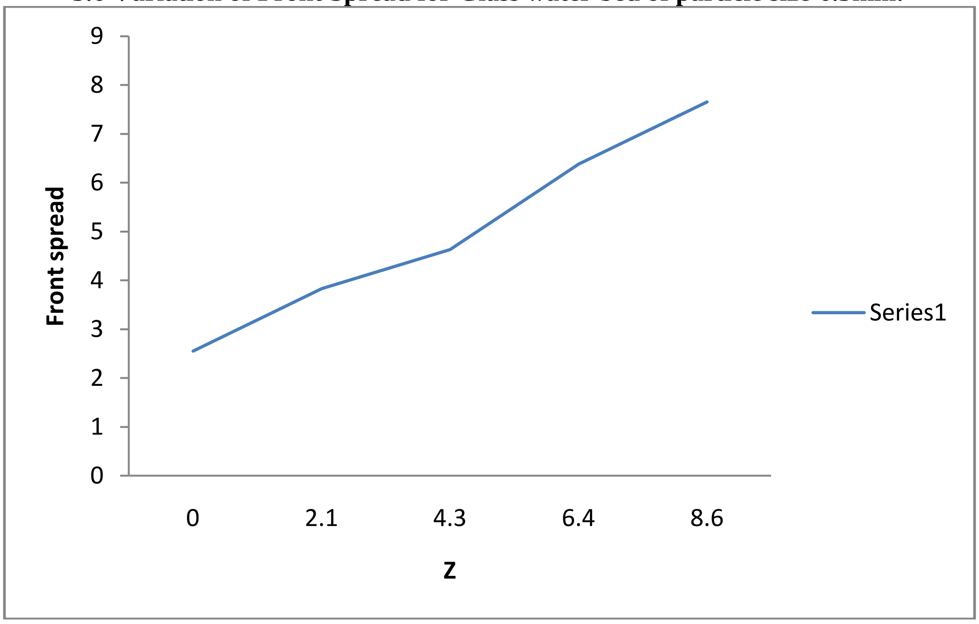

Fig. 3.11 Variation of front spread with distance at Re 283

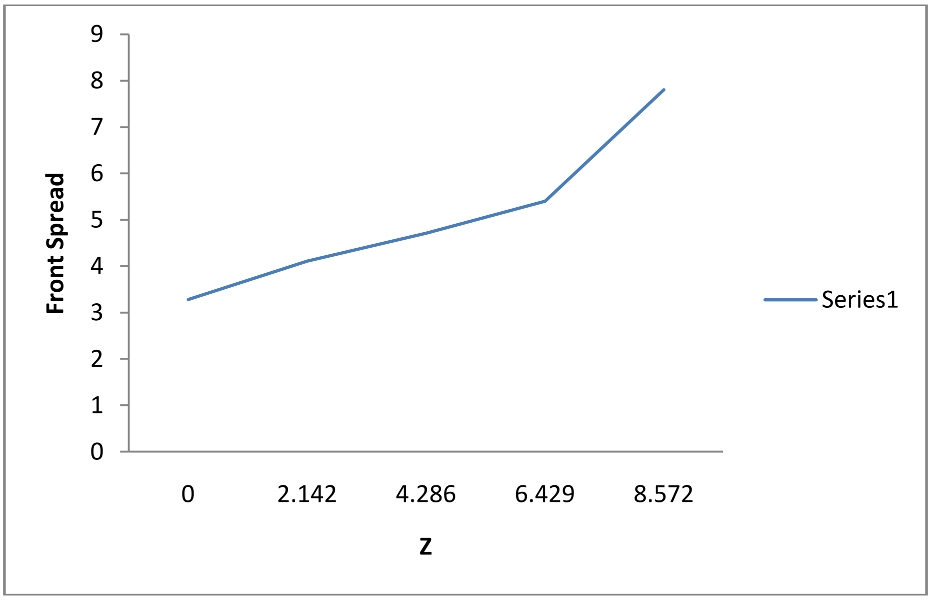

Fig. 3.12 Variation of front spread with distance at Re 377

It is observed from the graph that the front spread increase in hot phase with downstream. At Z0 the temperature rises very fast and rate of temperature decrease with distance. Also at higher Re the value of front spread is large. It gives the similar trend at higher flow rate. The front spread is largest at Z4 because it takes the maximum time to reach temperature from 0.25 to 0.75.

IV. CONCLUSION

The oscillating flow in porous media of steel and glass spherical balls of diameter 6.5mm were analyzed at different Reynold Numbers. The front amplitude of steel water bed was found to be decreasing with distance and value is low as compared to glass water bed. The decrease rate amplitude with distance is very low. The value of front speed of steel water bed was higher than glass water bed. Front spread is observed for hot phase. The value for front spread of steel water bed was higher in compression to the glass water bed.

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