Effect of Water Abstraction Ratio on Flow Behaviour in Vortex Chambers

Mohammad Athar[1], Humaira Athar[2]

[1]*Professor, Department of Civil Engineering, Zakir Husain College of Engineering & Technology, A.M.U., Aligarh, U.P.*

[2]*Scientist, 'B', CBRI, Roorkee*

Abstract **-** Water abstraction ratio is an important hydraulic parameter on which the sediment removal efficiency of vortex chambers depends. The sediment concentration as well as velocity distribution inside the chambers also highly influenced by water abstraction ratio. In this paper an attempt has been made to investigate the effect of water abstraction ratio on flow behaviour inside the vortex chamber. Data for velocity are collected in the laboratory on vortex chamber model by a Programmable Electro-Magnetic Shunt (P.E.M.S.) flow meter. Results for velocity distributions at various depths 8%, 13% and 17% water abstraction ratios are presented herein. It is found that velocity distribution depends upon water abstraction ratios. As this ratio increases from 8 to 13%, the velocity values are increasing but with further increase of discharge ratio, the velocity values at each nodal points get reduced.

Keywords -Vortex Chamber , Water Abstraction Ratio, Flow behavior, Shunt meter, Nodal points

I. INTRODUCTION

To trap the silt from the canals, many silt trapping devices such as conventional settling basin, tunnel type extractor, vortex tube are in common uses. All these devices have their inherent advantages and disadvantages. It was found after extensive literature survey that about 20 to 25 % canal discharge is needed to extract the silt from the canal. A vortex chamber type settling basin/extractor is a device which requires only about 8 to 10 % canal discharge to extract same amount of silt with same silt gradation and silt charge. Vortex chamber type silt extractors have additional advantages as occupying less space and consuming relatively small amount of canal discharge to extract same grade of silt in comparison to conventional devices. The sediment trapping efficiency of the chamber basically depends upon inside flow structure which in turn depends upon water abstraction ratios. In this study, an emphasis is given to study the effect of water abstraction ratio on the flow behavior.

II. BRIEF REVIEW

Many investigators such as Anwer (1965), Cecen (1977), Daggett and Keulegan (1977), Julien (1985 a and b), Odgaard (1986), Vasistas et al. (1989) and Hite & Mih (1994), Mujib et al. (2008, 2012) carried out theoretical and experimental studies on velocity distribution inside the vortex chambers of various geometric configuration and hydraulic parameters. Most of them studied about tangential and radial velocities. Very few of them studied the effects of water abstraction ratio on velocity distribution. The sediment removal efficiency of the vortex chambers mainly depends upon water abstraction ratio (Athar et al., 2001), hence this paper is intended to study the effects of water abstraction ratio on the velocity distribution by taking extensive data on velocity along tangential and radial directions with PEMS meter at various water abstraction ratios ranging from 8 to 17%.

III. THEORETICAL TREATMENT

Following functional relationships are assumed to hold good for the tangential and radial velocity components.

$$vt = f_2\left(V_i,\ R,\ r,\ \theta,\ Q_u,\ Q_i\right) \quad (1a$$

$$v_r = f_1\left(V_i,\ R,\ r,\ \theta,\ Q_u,\ Q_i\right) \quad (1b)$$

Here vt and v_r are the tangential and radial velocities, R is the radius of the chamber, r is the radial spacing, Q_u is the underflow discharge and Q_i is discharge in the inlet channel. Carrying dimensional analysis for above variables using Bakingham's Pi-theorem method, following equations in terms of non-dimensional variables are obtained as follows.

$$vt/V_i = \phi\left(Q_u/Q_i, \theta, r/R\right) \quad (2a)$$

$$v_r/V_i = \phi\left(Q_u/Q_i, \theta, r/R\right) \quad (2b)$$

IV. EXPERIMENTAL PROGRAMME

Circular cylinder vortex basins having internal diameter equal to 1.0 m with geometric configuration as shown in Fig.1 is used. The inlet channel used in basins is 6.5 m long, 0.20 m wide and 0.25 m deep and has adjustable slope. The inlet channel bed and walls are made-up of painted steel. The outflow outlet channels provided in the basin are 2.5 m long, 0.20 m wide and 0.25 m deep and has adjustable slope. Circular steel pipes are used as the railing in the inlet and the overflow outlet channels and they are made parallel to the channel beds by adjusting the railing screws. The straight inlet channel joined the vortex chamber tangentially at its one side. The straight outlet channel was taken off tangentially to the chamber but from the point that was diametrically opposite to the junction of the inlet channel .

1.1. Electromagnetic Liquid Velocity Meter (PEMS)

A programmable Electro-Magnetic Liquid Velocity Meter (Fig.2is used for measuring the velocity components of the flow in the vortex chamber. This instrument consists of a disc-type probe, which is placed, vertically in the flow. It sense the motion of the fluid by electric pulses. The list count of the PEMS meter is 0.001m/sec.

1.2. Measurements by P.E.M.S.

Prior to use of the PEMS meter, the nodal points were fixed by dividing whole chamber into five annular and eight sectors thus creating 40 nodal points at the base of the chamber. The PEMS meter could move in all three mutual perpendicular directions such as annular, radial and vertical directions. During observation, the PEMS was moved on each nodal points along the flow.

V. ANALYSIS OF DATA

1.3. Velocity Distributions

The data collected in the non-dimensional farm based on the functional relationships presented in Eqns. 2(a) and 2(b).

5.1.1 Effect of Water Abstraction Ratio on Tangential Velocity along Vertical direction

Figures 4, 5, 6 and 7 show the variations of tangential velocity along vertical direction at few radial locations. Here the results and graphs are shown for all θ values varying from 0^o to 315^o.It is clear from these plots that there is considerable effect of water abstraction ratio on velocity distribution. For $\theta = 0^o$, 45^0 and 315^o, the effect is not in increasing trend. For all other θ values, the effect of water abstraction ratio is consistent and always in increasing fashion. The similar trends are obtained for both radial distances ie. r = 0.2m and r = 0.4m.

5.1.2 Effect of Water Abstraction Ratio on Variation of Radial Velocity along Vertical direction

Same data have also been plotted to observe the effect of water abstraction ratio on radial velocity distribution (Figs.8 to 11). Almost for all θ , the radial velocity values are maximum and negative. This shows that velocity is pointing towards the centre of the vortex basin. Similar trends are obtained for both radial spacings ie. r = 0.2m and r = 0.4 m.

5.1.2 Effect of Water Abstraction Ratio on Tangential Velocity along Radial Direction

The all data were plotted for tangential velocity along radial directions at two z- values ie. 0.01m and 0.13m for all θ values (Figs.12 to 15). It is clear from all these plots that there is schematic trend in tangential velocity distribution along radial distance of the basin and with increase in water abstraction ratio, the velocity values always go on increasing but the mod of velocity variation is invariant. This trend is for both z- values ie. 0.01m and 0.13m. Higher water abstraction ratio increases the vortex strength which is responsible to move the silt particles faster in the vortex basins. From these plots it is also very much clear that Rankine type vortex (combination of forced and free vorticies) is formed inside the basin.

5.1.3 Effect of Water Abstraction Ratio on Radial Velocity Distribution along Radial Direction.

Radial velocity data are also plotted for two z-values and for all θ values (Figs.16 to 19). At water abstraction ratio 13 %, the radial velocity values are mostly negative and with higher magnitudes in comparison to 8 and 17 %. This is for z = 0.01m from the bottom of the basins. This indicates that at the bottom radial velocity is negative and with high magnitudes. This will facilitate the easy motion of silt particles into the underflow outlet with moderate consumption of water from the basin. However, this fact is not fully true for z = 0.13m. (Figs.18 and 19).

VI. CONCLUSIONS

Following conclusions are made**:**

1. Within the vortex chamber, the velocities in tangential and radial directions are found to vary along vertical direction but the effect is less pronounced.
2. Flow patterns are found to be different in the different segments of the vortex chamber. Segments of vortex chamber having flow pattern similar to that Rankine vortex extended only up to half diameter length of the vortex chambers.
3. Likewise tangential velocities, the radial velocities seem to follow Rankine vortex law in some segment of the chamber.
4. The higher and negative values of radial velocity show that the radial velocity will be more significant in extracting the silt from the bed of the basin.
5. The results of both geometric models are almost similar. But there is slight effect of outlet (overflow) channels on velocity distributions.

VII. REFERENCES

[1]. Anwar, H. O., 1965. Flow in a Free Vortex. Water Power, April issue, 153-161.

[2]. Athar, M., 2001. Study of Vortex Chamber type Sediment Extractor, Ph. D. Thesis, presented for the award of the Degree of Doctor of Philosophy, I.I.T. Roorkee.

[3]. Athar, M., Kothari, U. C. and Garde, R. J., 2002. Studies on Vortex Chamber type Sediment Extractor. Journal of Hydraulic Engineering, I.S.H., Vol. 8, No.2, 1-16.

[4]. Athar, M., "Experimental Studies of Flow Mechanics inside the Vortex Chamber type Sediment Extractors",Journal of Indian Water Resources Society (IWRS), September, 2007.

[5]. Ansari M. A. & Athar M.(2012) .Experimental study of flow structure inside Vortex Setling Basin, Proceeding of National Conference on Hydraulics, Water Resources, Coastal and Environmental Engineering (HYDRO-2012), Civil Engg. Department, IIT Mumbai, pp.69.

[6]. Cleland, J. David., 2001. Laboratory Measurements of Velocity Profiles in Simulated Tornado-like Vorticies, The Journal of Undergraduate Research Physics, Vol.18, No.2, 51-57.

[7]. John, E. Hite, Jr. and Walter, C. Mih, 1994. Velocity of Air-Core Vortices at Hydraulic Intakes. Journal of Hydraulic Engineering, ASCE, Vol. 120, No. 3., Paper No. 5252, 284-237.

[8]. Julien, P. Y., 1985a. Motion of Sediment Particles in a Rankine-Combined Vortex. Report CER-84 PYJ6, Colarado State University, Fort Collins, 37.

[9]. Mashauri, D. A., 1986. Modelling of a Vortex Settling Basin for Primary Clarification of Water. Ph.D. Thesis presented to the Tampere University of Technology, Finland.

[10]. Paul, T. C., Sakhuja, V.S. and Dhillon, G. S., 1991. Analytical Models for Free Surface Air-Core Vortex. Indian Journal of Power and River Valley Development, 161-170.
[11]. Rea, Q., 1984. Secondary Currents Within the Circulation Chamber Sediment Extractor M. Sc. Engg. Dissertation, presented to Faculty of Engineering and Applied Science, Department of Civil Engineering, Institute of Irrigation Studies, University of Southampton, England.
[12]. Vatistas, C. H., Lin, S. And Kwok, C.K., 1986. Theoretical & Experimental Studies on Vortex Chamber Flows. AIAA, Journal, Vol. 24, No. 4, 635-642.
[13]. Zhou, Zhu, Hou, Jie. And Tang, Yi, 1991. Flow Field Measurement of Sand Funnel and its Influence on Sediment Transport, 27th IAHR, Congress, 1-6.

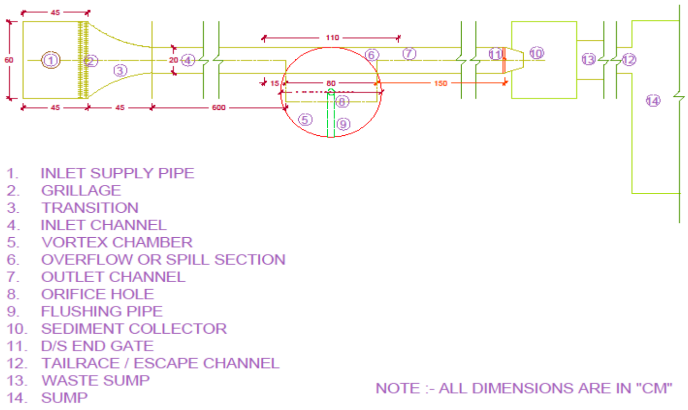

Fig.1 Plan of Experimental Set-up

Fig.2 PEMS Meter

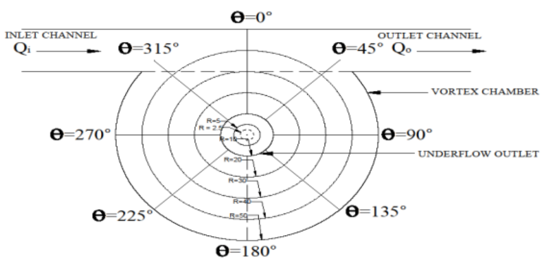

Fig.3 Secterisation of Vortex Basins

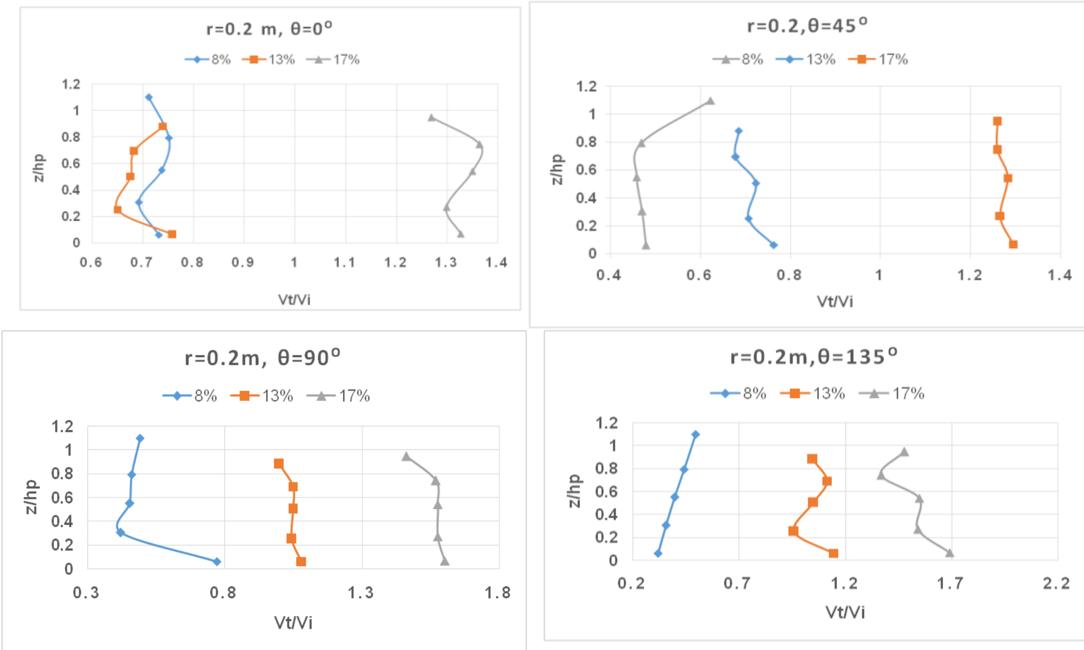

Fig.4 Variation of Tangential Velocities along Vertical Direction at r = 0.2m

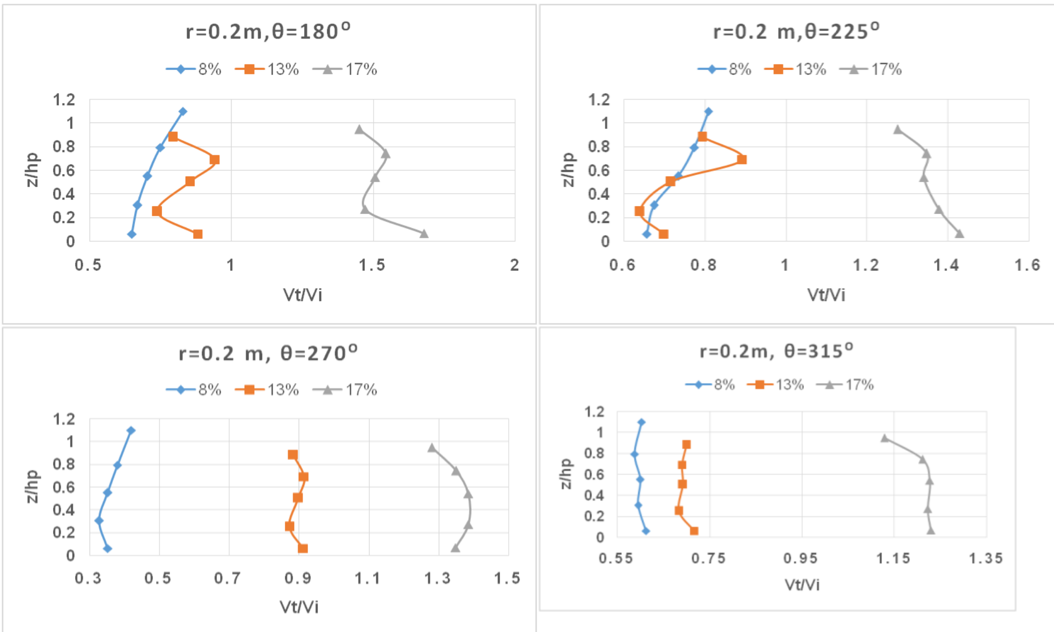

Fig. 5 Variation of Tangential Velocity along Vertical Direction at r= 0.2m

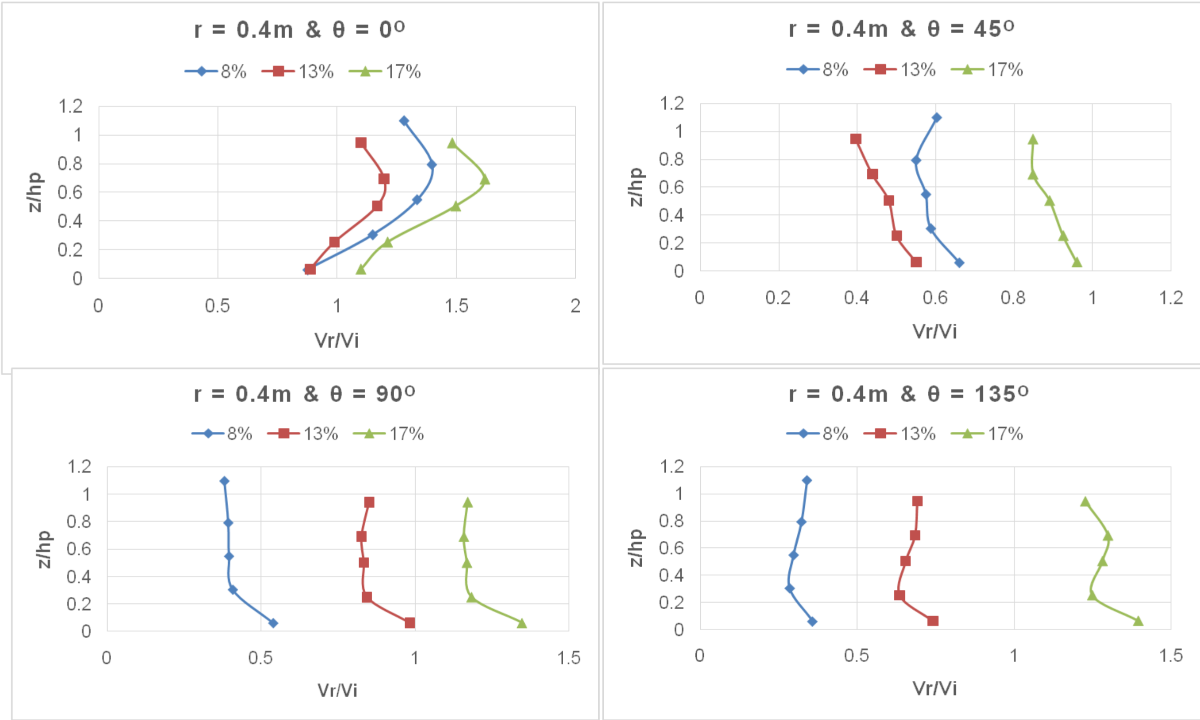

Fig.6 Variation of Tangential Velocity along vertical Direction at r = 0.4m

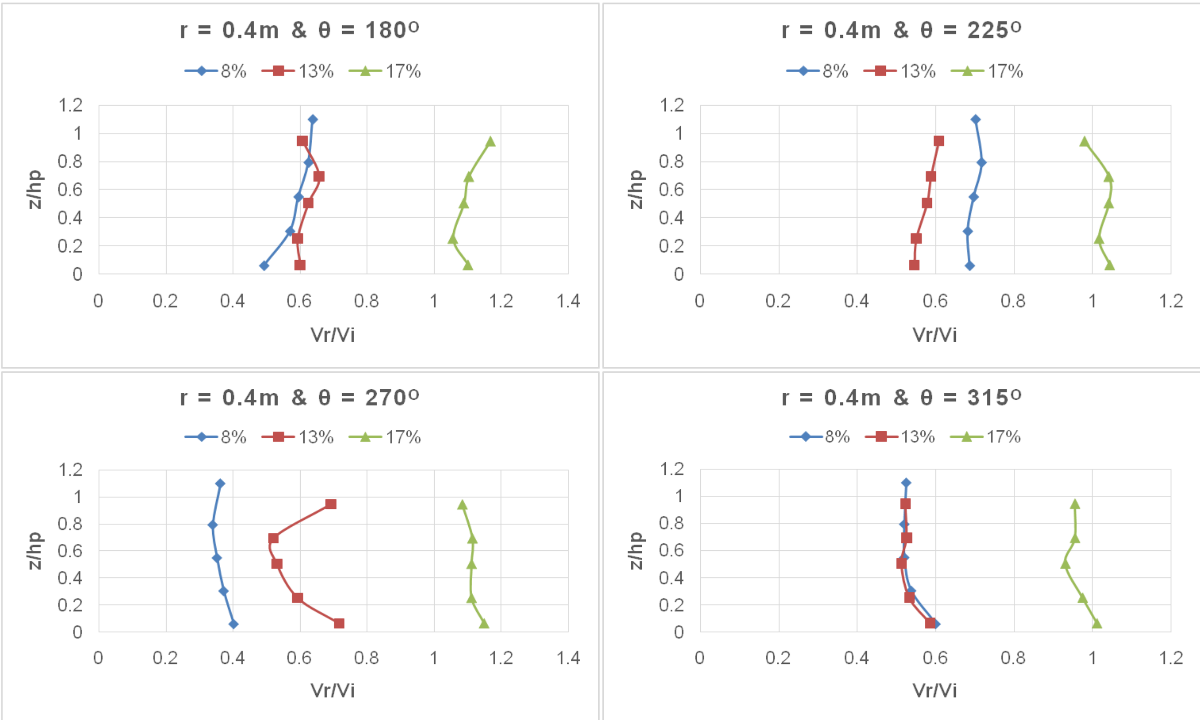

Fig.7 Variation of Tangential Velocity along vertical Direction at r = 0.4m

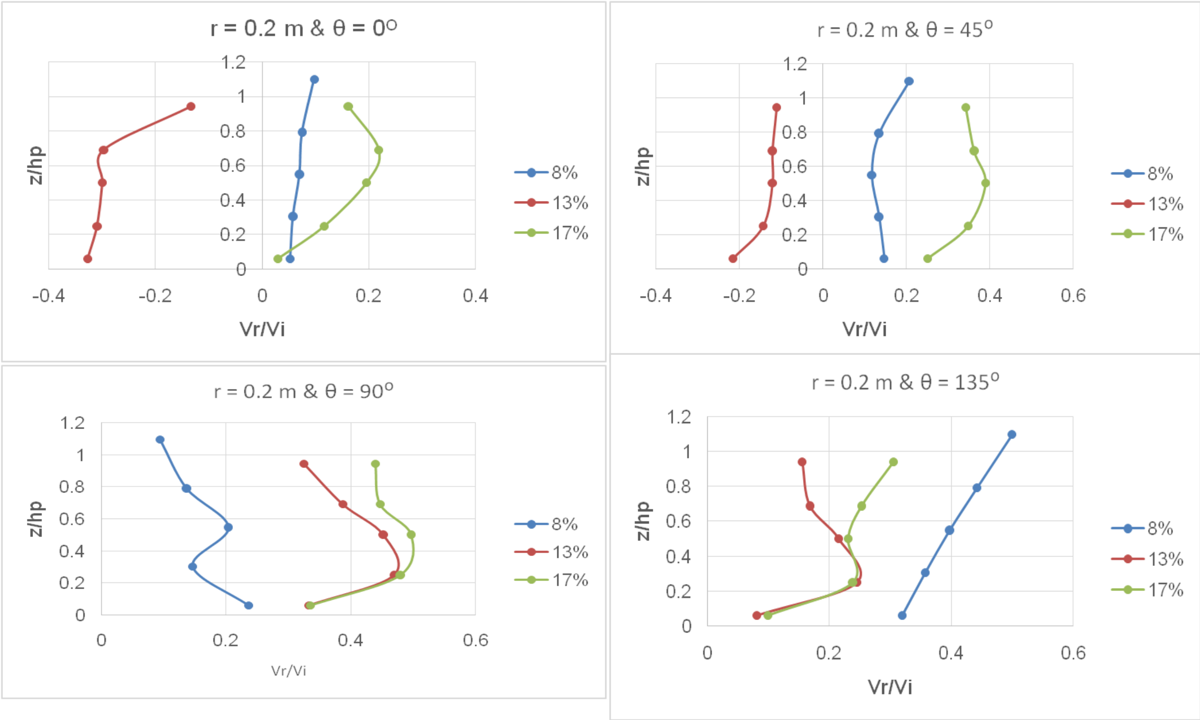

Fig.8 Variation of Radial Velocity along vertical Direction at r = 0.2m

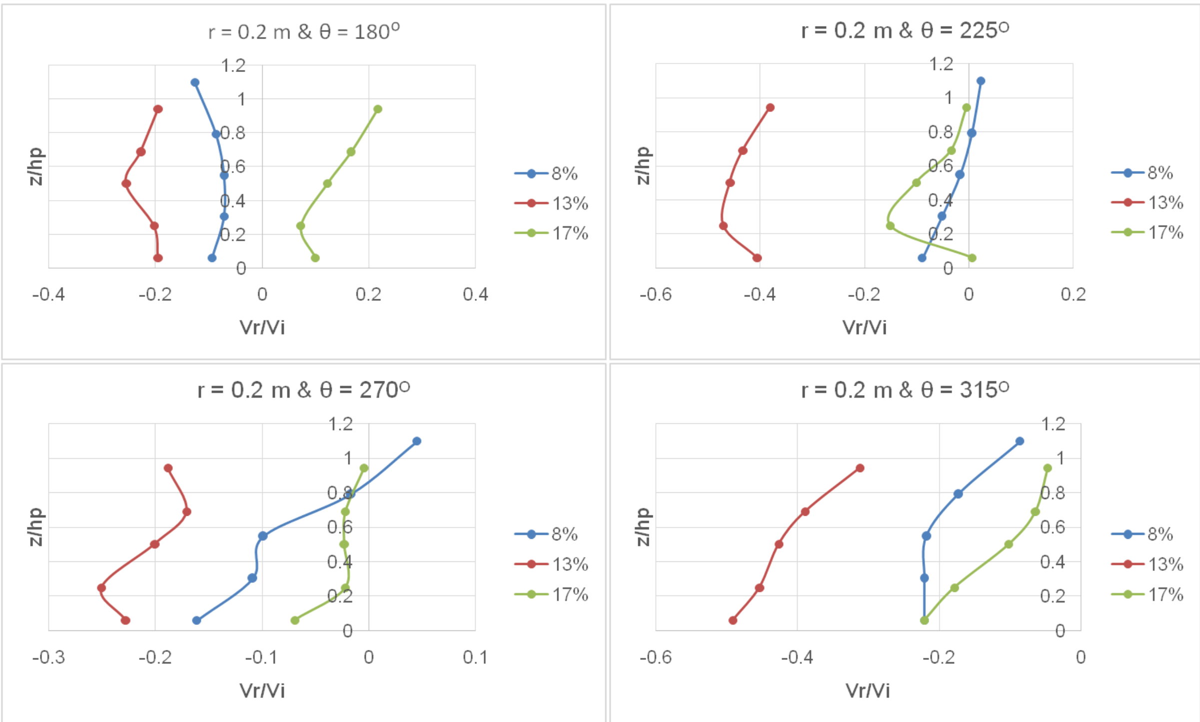

Fig.9 Variation of Radial Velocity along vertical Direction at r = 0.2m

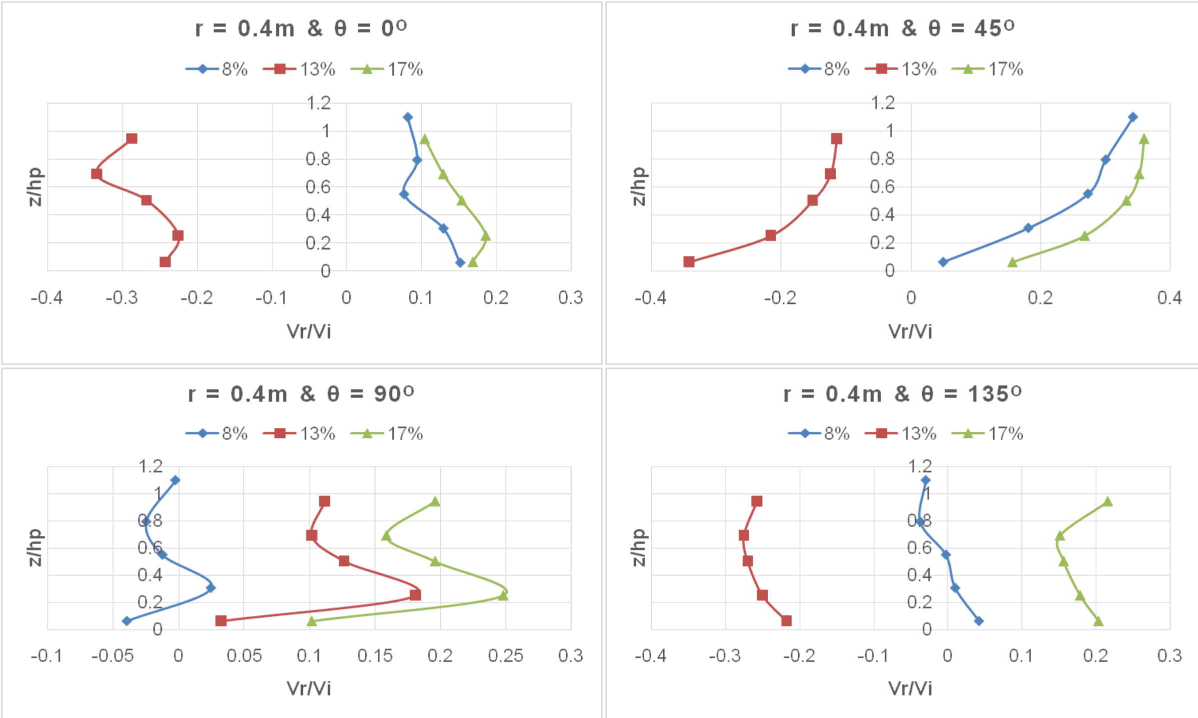

Fig.10 Variation of Radial Velocity along vertical Direction at r = 0.4m

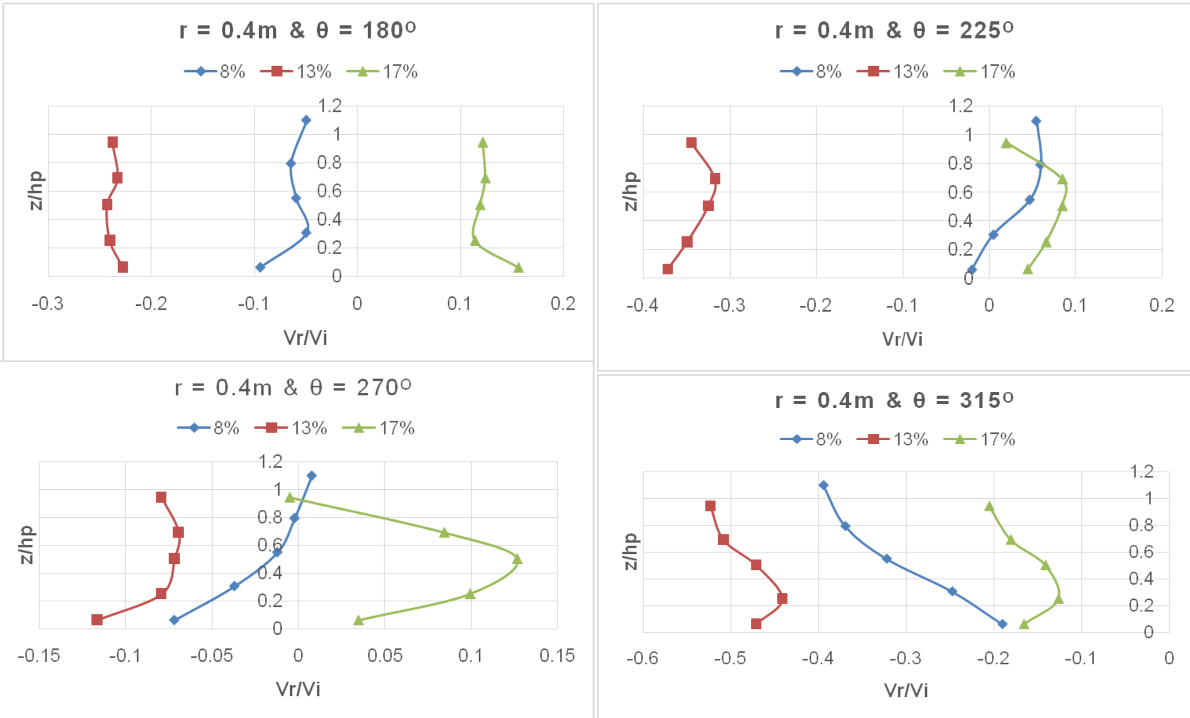

Fig.11 Variation of Radial Velocity along vertical Direction at r = 0.4m

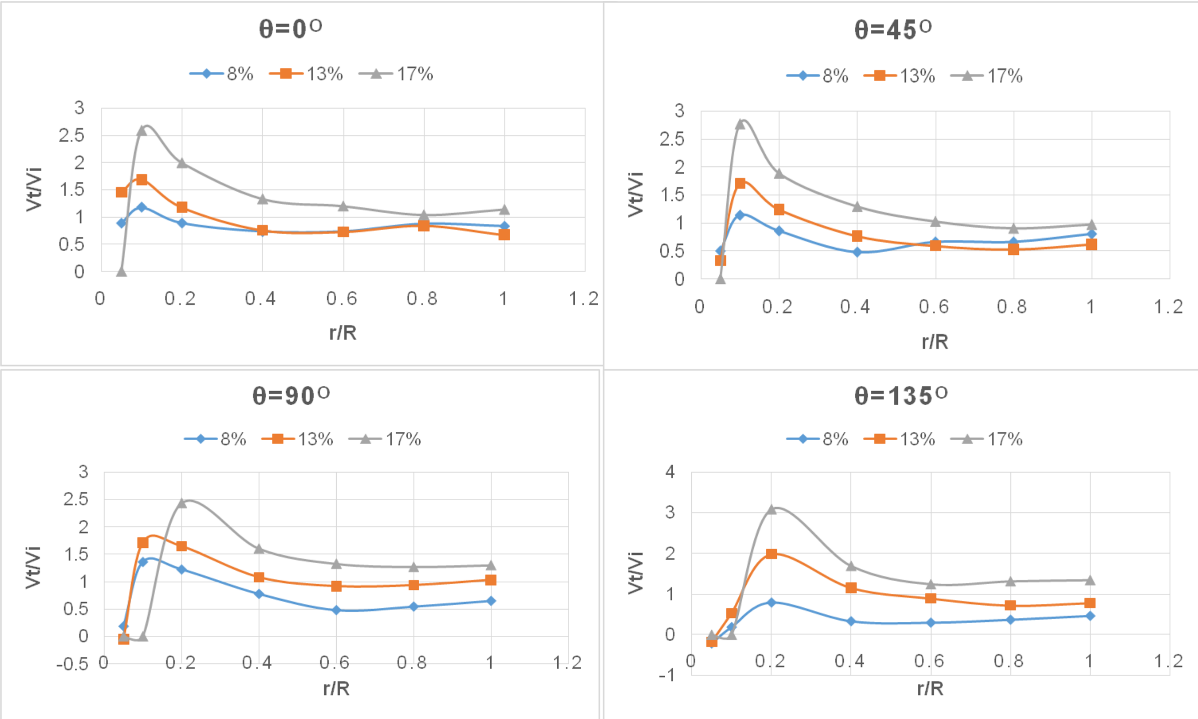

Fig.12 Variation of Tangential Velocity along radial Direction at z = 0.01m

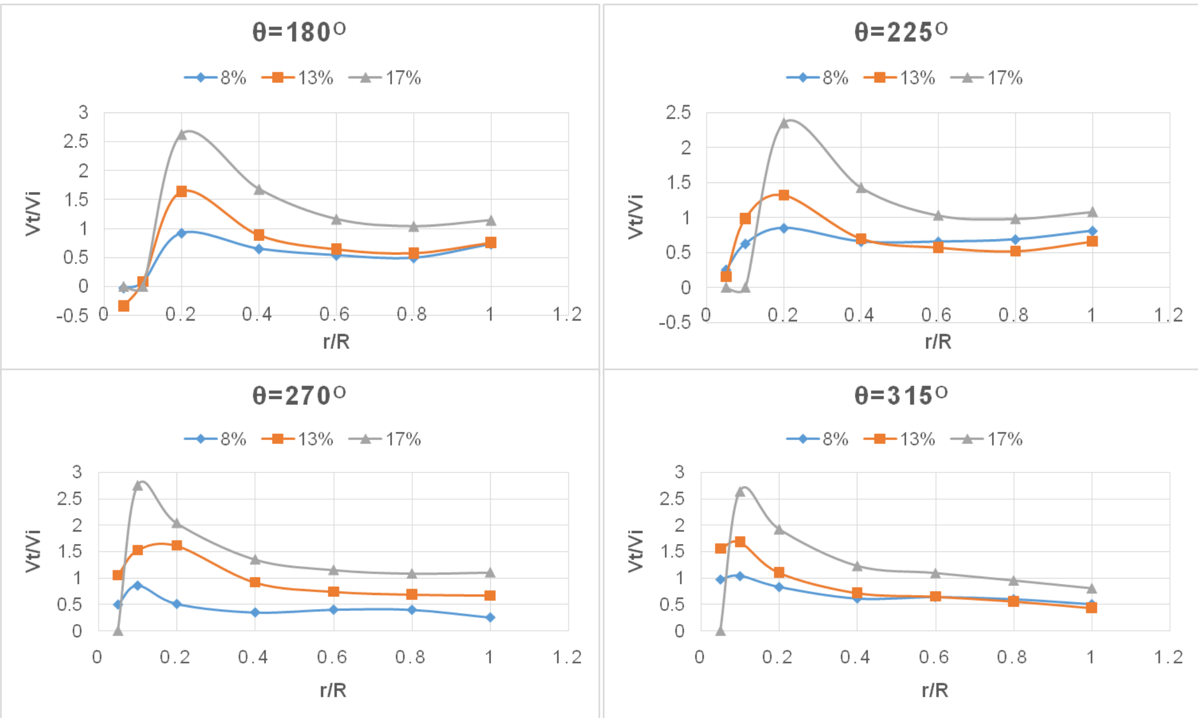

Fig.13 Variation of Tangential Velocity along radial Direction at z = 0.01m

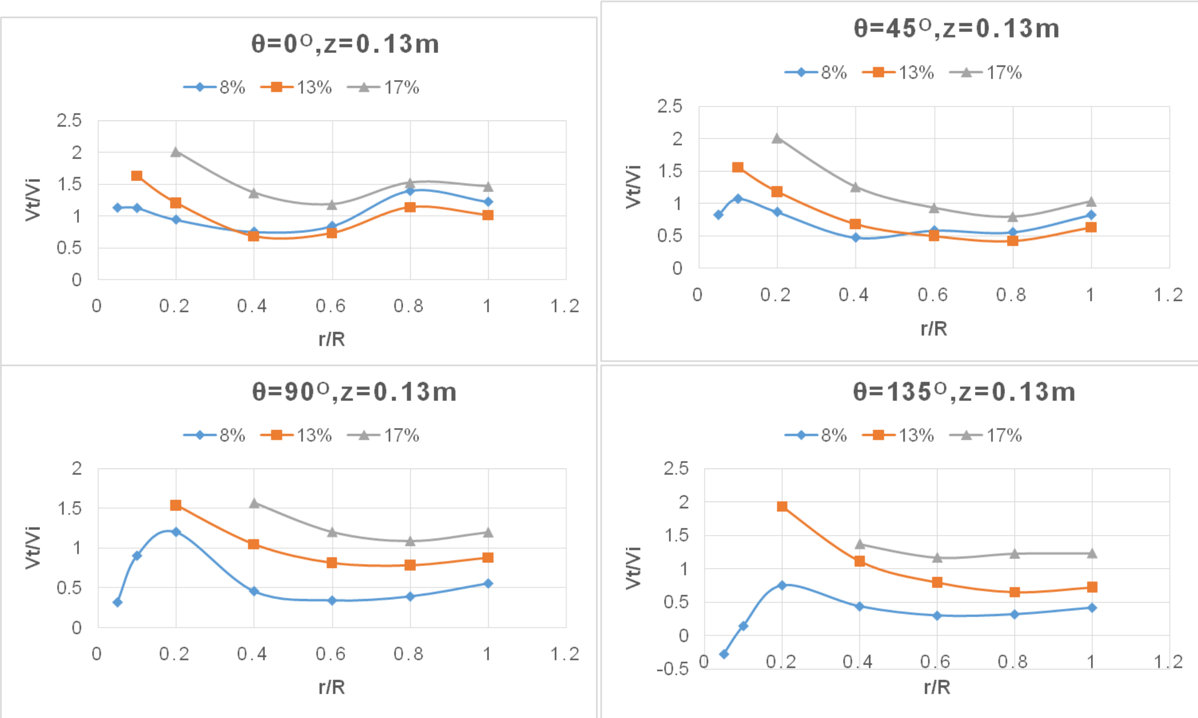

Fig.14 Variation of Tangential Velocity along radial Direction at z = 0.13m

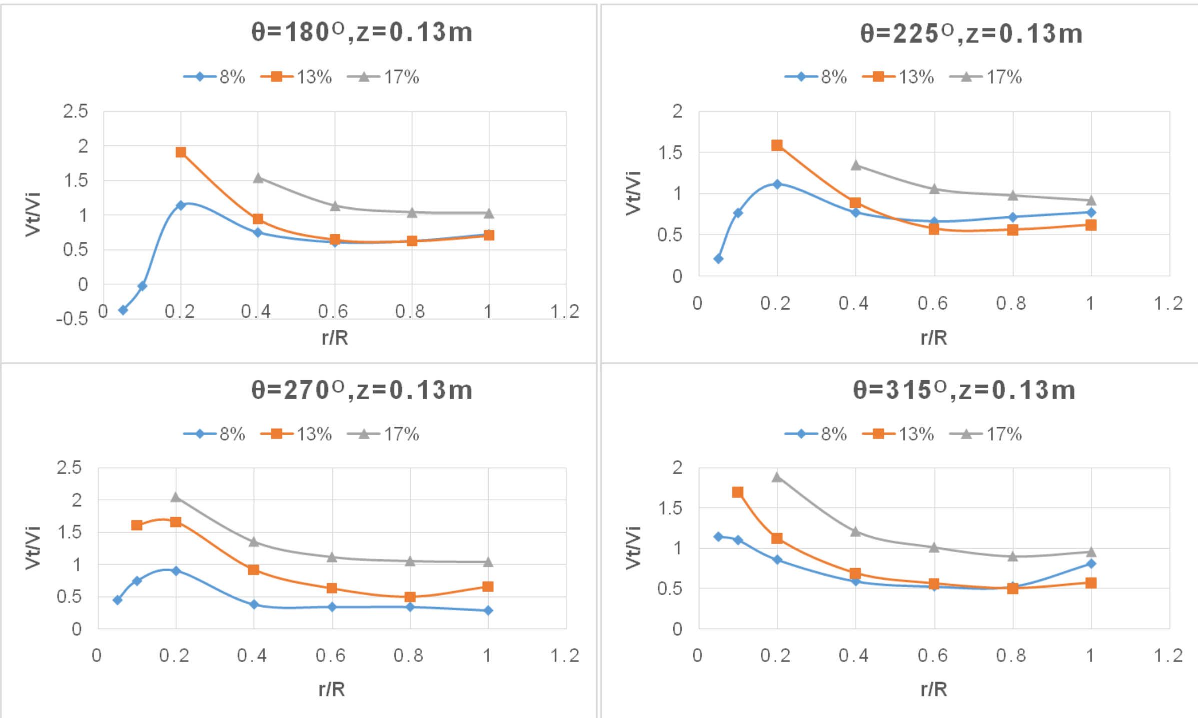

Fig.15 Variation of Tangential Velocity along radial Direction at z = 0.13m

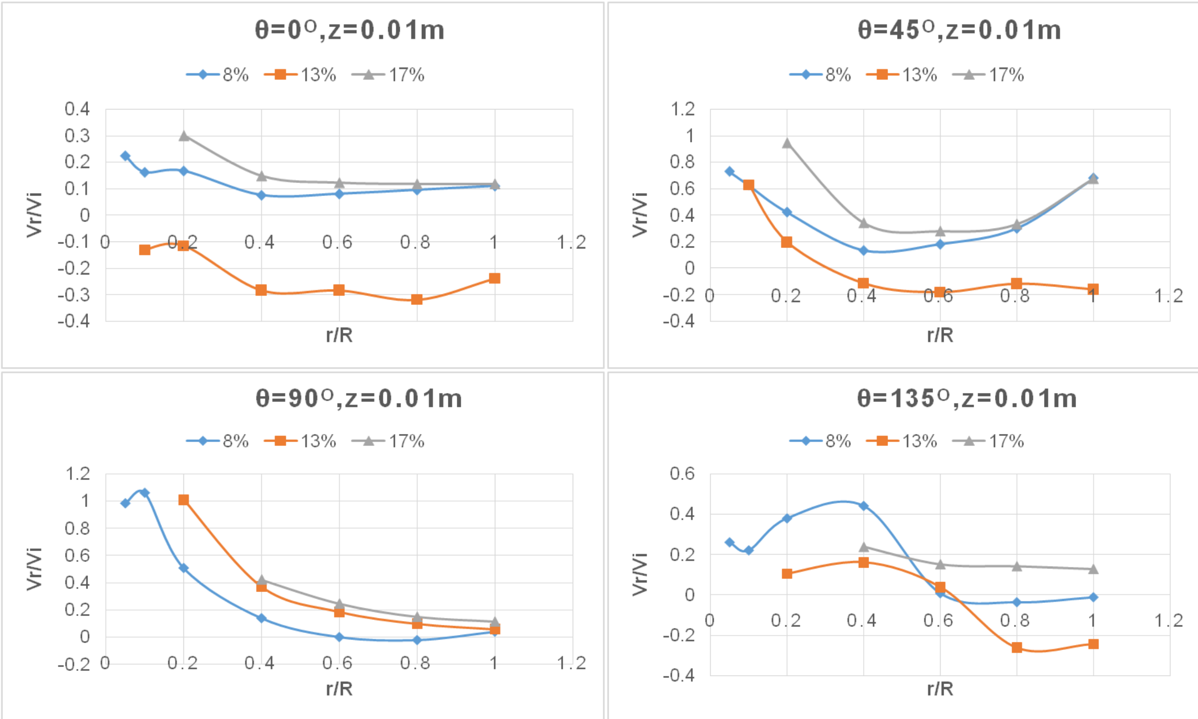

Fig.16 Variation of Radial Velocity along radial Direction at z = 0.01m

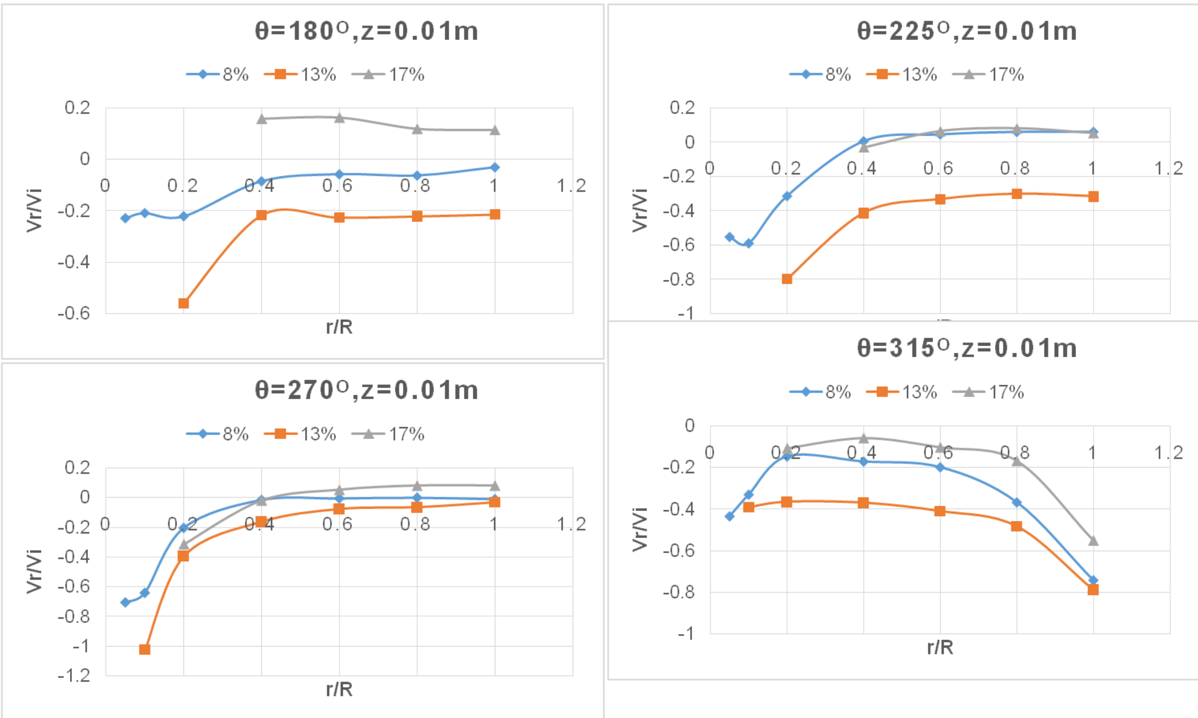

Fig.17 Variation of Radial Velocity along radial Direction at z = 0.01m

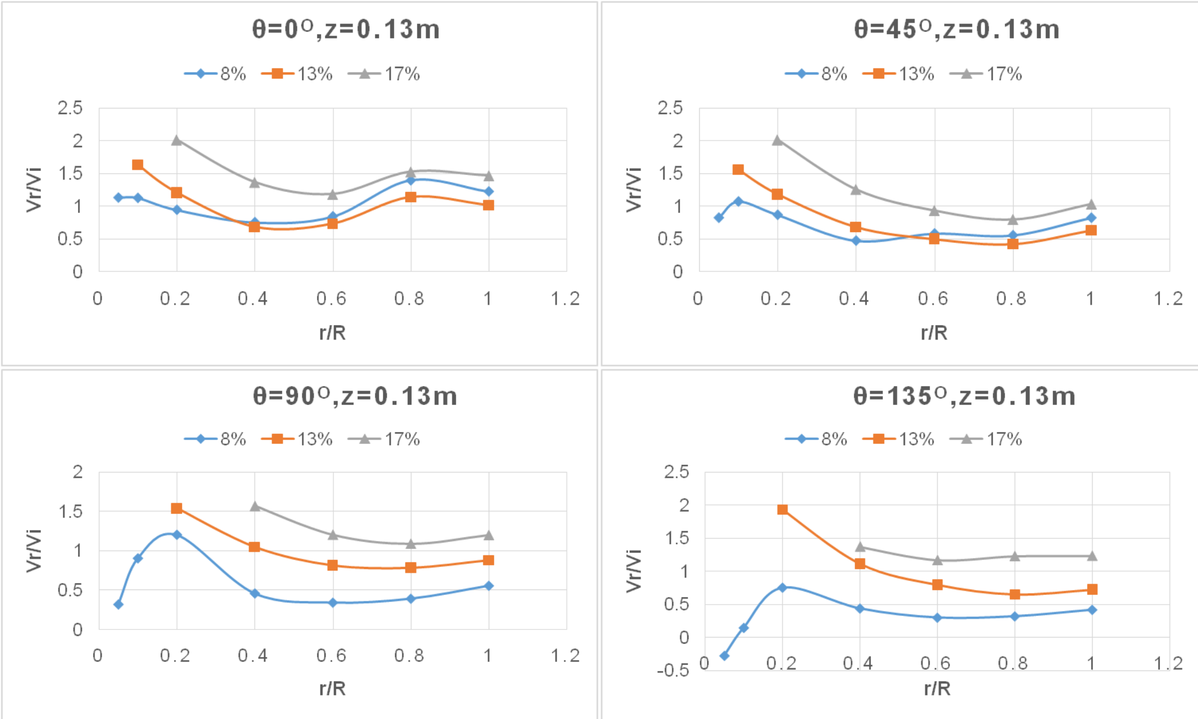

Fig.18 Variation of Radial Velocity along radial Direction at z = 0.13m

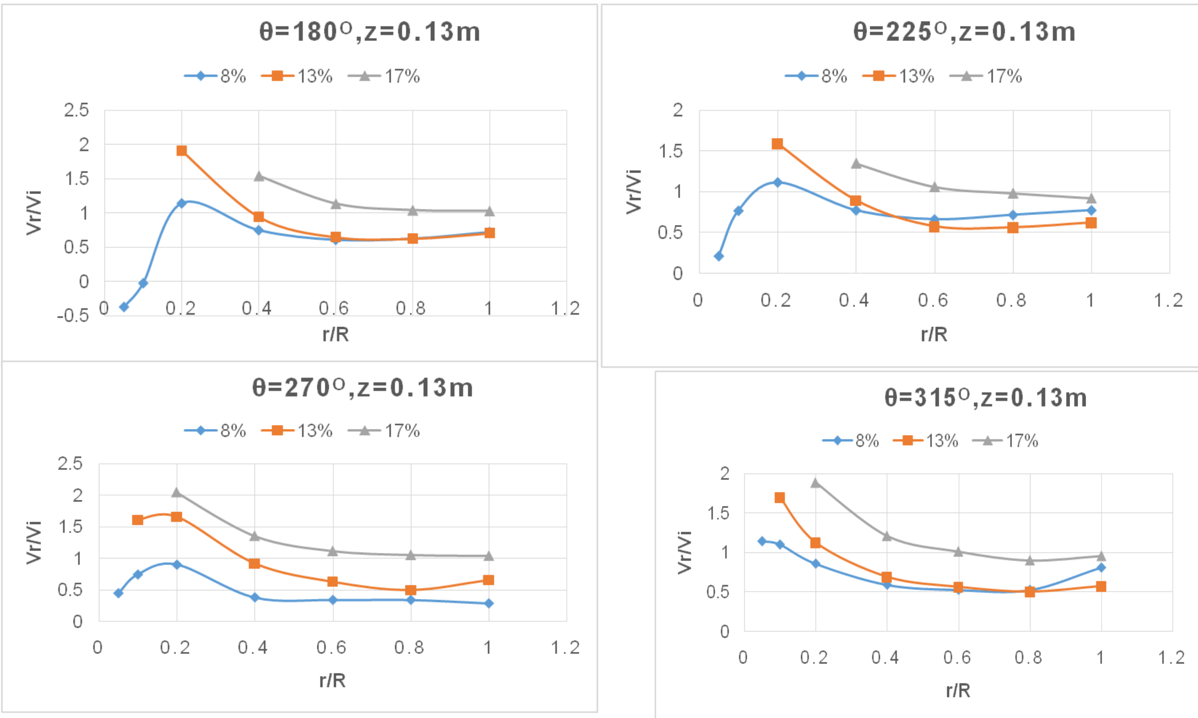

Fig.19 Variation of Radial Velocity along radial Direction at z = 0.13m