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Velocity distribution through slurry pipeline

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Abstract- Slurry pipelines are extensively used for transporting solid materials in bulk quantities over large distances in various industries. The present knowledge of the flow mechanics of solid-liquid mixtures is far from complete. The present study is aimed towards the better understanding of different facts of the flow of equi-sized mixtures. Different aspects of the work carried out are outlines. On the basis of extensive literature review, it was found that Roco & Shook *[1] model has great promise for the velocity distribution prediction. Roco & Shook *[1] model have been used to predict the velocity distribution for experimental data available in literature. It was observed that however the average velocity calculated on the basis of Roco & Shook *[1] model is similar to the measured values; the shape of velocity distribution is not according to the shape of measured velocity distribution. The reason for irregular shape of velocity distribution predicted by Roco & Shook *[1] model is attributed to the use of Peckenkin*[2] equation for liquid and solid turbulence intensities in their model. Roco & Shook [1984] model is modified by using a very recently and well tested formula for liquid and solid turbulence intensities proposed by Kaushal et al.*[3]. The proposed modified Roco & Shook *[1] model gives the average flow velocity and shape similar to that observed in experimental data. Also the location of maximum velocity is similar to that of experimental measurements.

I. INTRODUCTION

Slurry pipelines are used to transport solid material is using water or any other liquid as a carrier fluid. This mode of transportation is suited for long distances haulage of bulk materials, like mineral ore to processing plants, coal to thermal plants, disposal of waste material like fly ash, tailing material etc. Various industries have accepted slurry pipelines as an attractive mode of transport of solids because of its low maintenance and round the year availability. This mode of transportation is extremely safe besides being eco-friendly.

A] Advantages of slurry transportation

1) Tremendous economy of scale
2) Relative immunity to escalation of prices
3) High degree of efficiency and reliability
4) Simplicity of installation and small place requirements
5) Ease of crossing both natural and artificial obstacles
6) Reduced storage cost at the point of consumption
7) Scan be readily automated
8) Easy to operate.

B] Limitations of slurry transportation

1) The initial capital cost is relatively high
2)The pipelines transportation system is solely dedicated to the transportation of solids, whereas rail, road or a highway has multi-purpose utility.
3)The pipeline transportation system requires water or other liquids as the carrier fluid in large volume, which may not be easily available at all places and all the time
4)Quality control has to be very stringent for the efficient operation at the pipeline.

C] Hydraulic Design of the slurry pipeline

Important design parameters

1) Hydraulic Parameters
   a) Selection of the carrier fluid
   b) Optimum particle size
   c) Optimum concentration of solids
   d) Minimum operating velocity
   e) Pipe diameter
   f) Pressure drop
   g) Additives required for flow improvement
   h) Attrition of particles due to pumping
2) Parameters of corrosion-erosion
   a) Establish pipeline life (20 to 50 yrs)
   b) Select corrosion inhibitor and/or additives for Oxygen and pH control
   c) Select metal allowance
   d) Abrasion
3) Parameters of operational stability
   a) shutdown-start up requirements
   b) Maximum allowable slope.

II. DETAILS OF THE MODEL FOR VELOCITY DISTRIBUTION

Prediction as proposed by Roco and Shook (1984)

In a slurry pipe line, apart from the pressure drop and concentration distribution, velocity field at a cross-section is an equally important parameter for the slurry pipeline design. The interrelation between various parameters cannot be fully understood without complete knowledge about the velocity field.Roco and Shook gives formula for the prediction of velocity distribution across the pipe cross section along with the modifications incorporated to improve the accuracy of the above model.

Formula for prediction of velocity profile by Roco and Shook

$$V_m(r) = -\frac{\mu_m}{2\alpha_{md}} + sqrt\left[\left(\frac{\mu^2 m}{4\alpha_{md}^2}\right) + \left(\frac{\zeta(r)}{\alpha_{md}}\right)\right] \quad (1)$$

Test results for water-sand mixtures flowing in circular pipelines are given as-
Experimental data to be used in the present study.

Run no.	D(mm)	i(mH_2O/m_{pipe})	Cexp (%)	Vexp (m/s)
1	51.5	0.068	8.41	1.66
2		0.25	9.18	3.78
3		0.092	18.7	1.66
4		0.35	18.9	4.17
5	263	0.0312	19.0	2.9
6		0.039	18.4	3.5
7	495	0.0197	27.3	3.16
8		0.026	26.9	3.76

III. Comparison Of Measured And Predicted (By Roco And Shook (1984) Model) Velocity Distribution

The experimental data considered in the present study are tabulated in Table. The predicted velocity distribution is shown in Figures. It is observed that the experimental velocity distributions were continuous in nature. However, the predicted velocity distribution by Roco and Shook (1984) model were found to be discontinuous in nature.

Formulae used for prediction of velocity distribution given by Roco and Shook for run no 1 to 8 is given by equation no. (1)

A) Calculation of Vm(r) for run no. 1

Y’	Vm m/s
Y’ = - 0.8 R	1.1
Y’ = - 0.6 R	1.19
Y’ = - 0.4 R	1.43
Y’ = -0.2 R	1.63
Y’ = 0	1.79
Y’ = 0.2 R	2.11
Y’ = 0.4 R	2.06
Y’ = 0.6 R	1.99
Y’ = 0.8 R	1.91
Y’ = R & -R	0

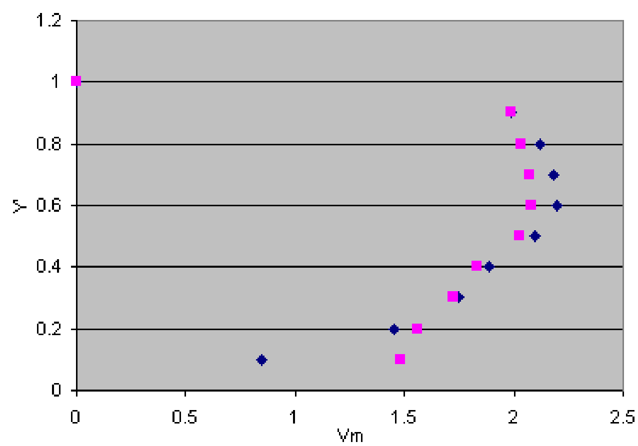

Fig.1 Predicted velocity distribution by Roco and Shook (1984) model for sand water slurry flow of volumetric efflux concentration of 8.41% and flow velocity of 1.66 m/s through 51.5 mm diameter pipe.

◆ Measured velocity distribution
■ Predicted velocity distribution by proposed model

B) Calculation of Vm(r) for run No. 2

Y’	Vm m/s
Y’ = - 0.8 R	3.18
Y’ = - 0.6 R	3.26
Y’ = - 0.4 R	3.46
Y’ = -0.2 R	3.77
Y’ = 0	3.94
Y’ = 0.2 R	4.27
Y’ = 0.4 R	4.19
Y’ = 0.6 R	4.12
Y’ = 0.8 R	4.1
Y’ = R & -R	0

C) Calculation of Vm(r) for run No. 3

Y’	Vm m/s
Y’ = - 0.8 R	1.1
Y’ = - 0.6 R	1.13
Y’ = - 0.4 R	1.26
Y’ = -0.2 R	1.43
Y’ = 0	1.57
Y’ = 0.2 R	2.04
Y’ = 0.4 R	2.03
Y’ = 0.6 R	2.03
Y’ = 0.8 R	2.02
Y’ = R & -R	0

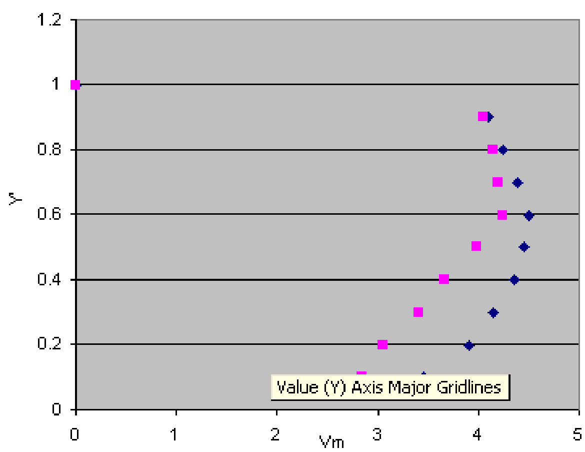

Fig.2 Predicted velocity distribution by Roco and Shook (1984) model for sand water slurry flow of volumetric efflux concentration of 9.18% and flow velocity of 3.78 m/s through 51.5 mm diameter pipe.

◆ Measured velocty distribution
■ Predicted velocity distribution by proposed model

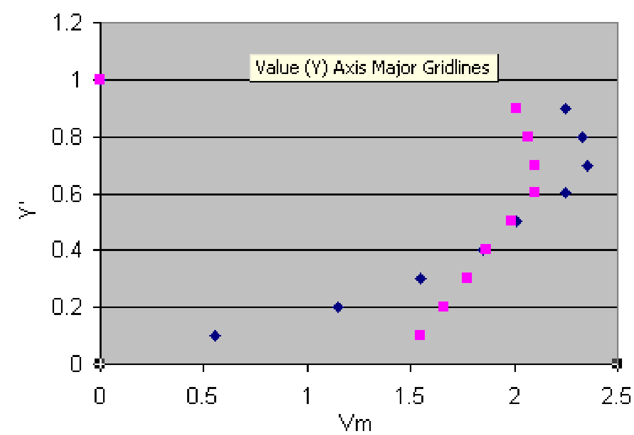

Fig.3 Predicted velocity distribution by Roco and Shook (1984) model for sand water slurry flow of volumetric efflux concentration of 18.7% and flow velocity of 1.66 m/s through 51.5 mm diameter pipe.

◆ Measured velocity distribution
■ Predicted velocity distribution by proposed model

D) Calculation of Vm(r) for run No. 4

Y’	Vm m/s

Y' = - 0.8 R	3.28
Y' = - 0.6 R	3.32
Y' = - 0.4 R	3.58
Y' = -0.2 R	3.79
Y' = 0	4.06
Y' = 0.2 R	4.52
Y' = 0.4 R	4.48
Y' = 0.6 R	4.42
Y' = 0.8 R	4.38
Y' = R & -R	0

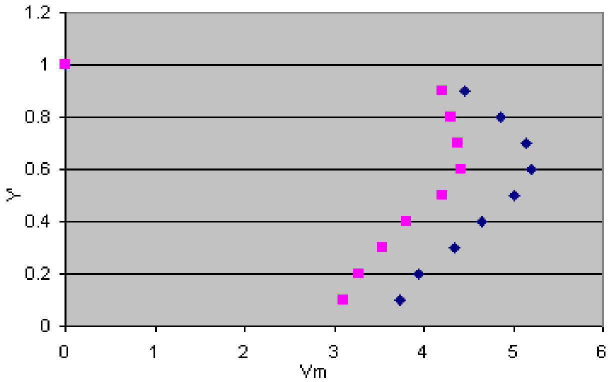

Fig.4 Prediction of velocity distribution by Roco and Shook (1984) model for sand water slurry flow of efflux concentration of 18.9% and flow velocity of 4.17 m/s through 51.5 m diameter pipe.

◆ Measured velocity distribution
■ Predicted velocity distribution by proposed model

E) Calculation of Vm(r) for run No. 5

Y'	Vm m/s
Y' = - 0.8 R	2.11
Y' = - 0.6 R	2.2
Y' = - 0.4 R	2.38
Y' = -0.2 R	2.58
Y' = 0	2.74
Y' = 0.2 R	3.69
Y' = 0.4 R	3.66
Y' = 0.6 R	3.57
Y' = 0.8 R	3.55
Y' = R & -R	0

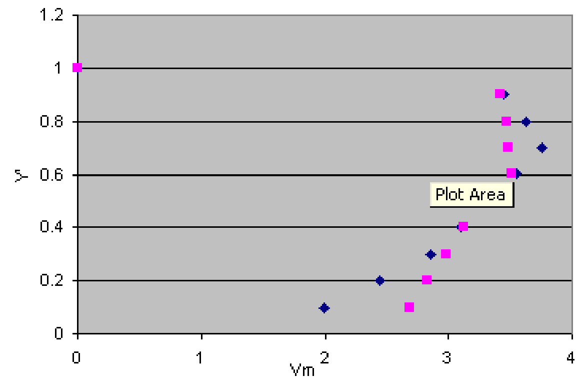

Fig.5 Predicted velocity distribution by Roco and Shook (1984) model for sand water slurry flow of volumetric efflux concentration of 19.0% and flow velocity of 2.9 m/s through 263 mm diameter pipe

◆ Measured velocity distribution
■ Predicted velocity distribution by proposed model

F) Calculation of Vm(r) for run No. 6

Y'	Vm m/s

Y' = - 0.8 R	2.5
Y' = - 0.6 R	2.55
Y' = - 0.4 R	2.79
Y' = -0.2 R	3.02
Y' = 0	3.26
Y' = 0.2 R	3.92
Y' = 0.4 R	3.99
Y' = 0.6 R	3.86
Y' = 0.8 R	3.81
Y' = R & -R	0

Y'	Vm m/s
Y' = - 0.8 R	2.55
Y' = - 0.6 R	2.71
Y' = - 0.4 R	2.82
Y' = -0.2 R	2.95
Y' = 0	3.15
Y' = 0.2 R	3.73
Y' = 0.4 R	3.91
Y' = 0.6 R	3.87
Y' = 0.8 R	3.82
Y' = R & -R	0

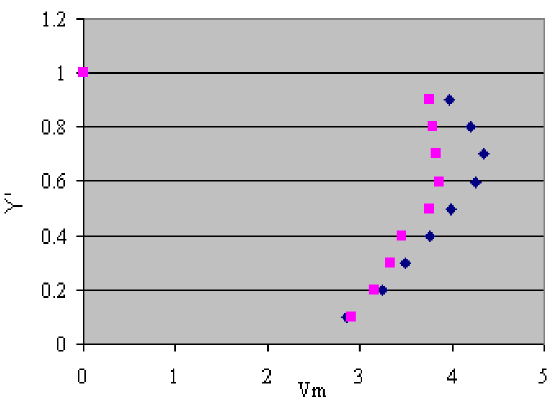

Fig 6 Predicted velocity distribution by Roco and shook (1984) model for sand water slurry flow of volumetric efflux concentration of 18.4% and flow velocity of 3.5 m/s through 263 mm diameter pipe.

◆ Measured velocity distribution
■ Predicted velocity distribution by proposed model

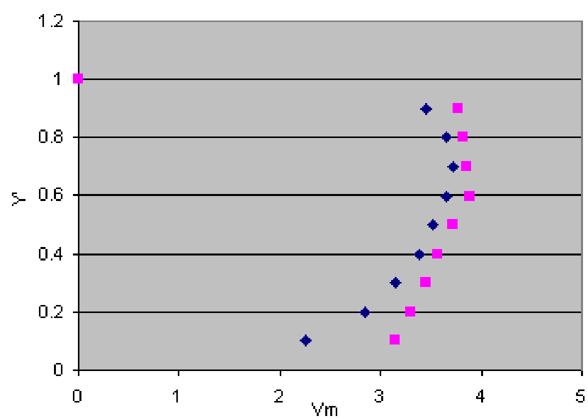

Fig.7 Predicted velocity distribution by Roco and Shook (1984) model for volumetric efflux concentration of 27.3% and flow velocity of 3.16 m/s through 495 mm diameter pipe.

◆ Measured velocity distribution
■ Predicted velocity distribution by proposed model

G) Calculation of Vm(r) for run No. 7

H) Calculation of Vm(r) for run No. 8

I)

Y'	Vm m/s
Y' = - 0.8 R	3.47
Y' = - 0.6 R	3.61

Y' = - 0.4 R	3.96
Y' = -0.2 R	4.26
Y' = 0	4.53
Y' = 0.2 R	5.11
Y' = 0.4 R	5.13

Y' = 0.6 R	4.85
Y' = 0.8 R	4.84
Y' = R & -R	0

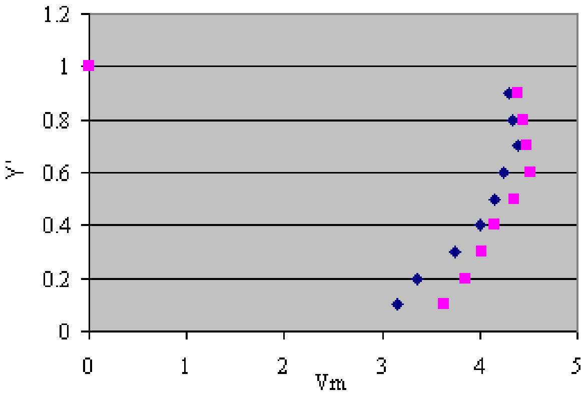

Fig.8 Predicted velocity distribution by Roco and Shook (1984) model for sand water slurry flow of volumetric efflux concentration of 26.9% and flow velocity of 3.76 m/s through 495 mm diameter pipe

◆ Measured velocity distribution
■ Predicted velocity distribution by proposed model

IV) CONCLUSIONS:

This chapter gives the broad and general observations for the overall characteristics of the flow of equi-sized particulate slurry.

1)On the basis of extensive literature review, it was found that Roco and Shook [1] model has great promise for the velocity distribution prediction.

2) Roco and Shook [1] model has been used to predict the velocity distribution for experimental data available in literature.

3)It was observed that however the average velocity calculated on the basis of Roco and Shook [1] model is similar to the measured value, the shape of the velocity distribution is not according to the shape of measured velocity distribution.

4)The reason for irregular shape of velocity distribution predicted by Roco and Shook [1] is attributed to the use of Peckenkin [2] equation for liquid and solid turbulence intensities in their model.

5)Roco and Shook (1984) model is modified by using a very recently and well tested formula for liquid and solid turbulence intensities proposed by Kaushal et.al [3].

6)The proposed modified Roco and Shook [1] model gives the average flow velocity and shape similar to that observed in experimental data. Also the location of maximum velocity in similar to that of experimental measurements.

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