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Effect of Boundary Layer Thickness on the Front Supported V-cone Flowmeter

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Introduction

- Flow measurement is an old art.
- In fluid flow measurement, accuracy is important for two reasons:
  - Precise regulation of flow for smooth operation of various components and equipments.
  - Metering the fluid flow accurately for the prospects of business.
- Selection of flow metering devices are done on the basis of application.

- Based on application, flowmeters are classified into two types:
  - Classical obstruction flowmeters which work on DP.
  - Special flowmeter having different working principles
- Classical obstruction flowmeters:

Merits:

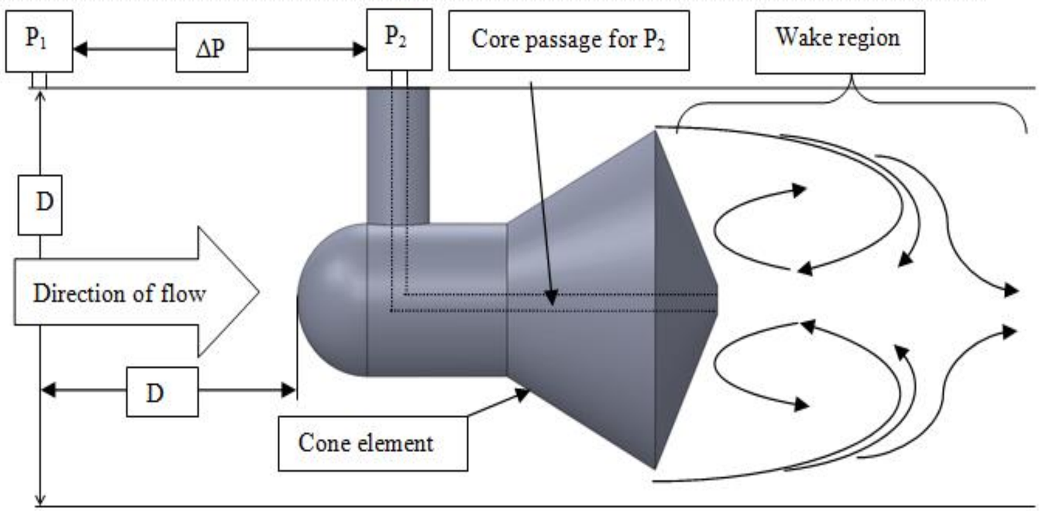
- Simple in design
- Low fabrication and maintenance cost
- Ease of operation

Drawbacks:

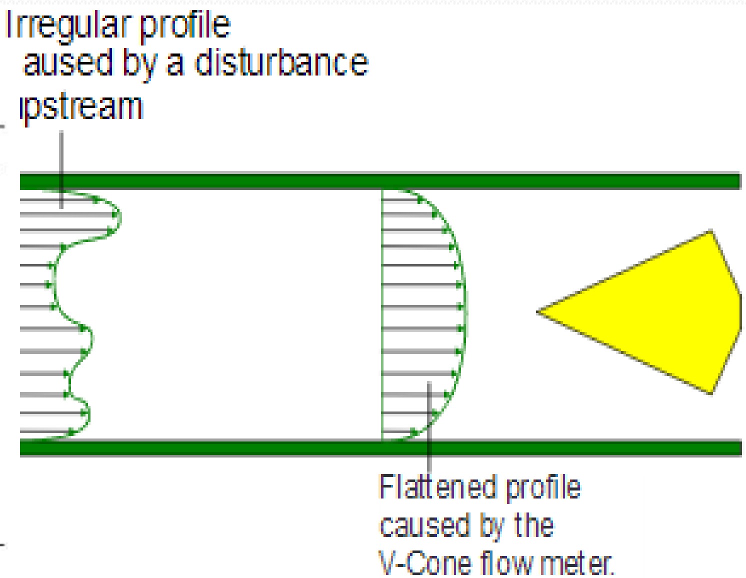
- Space requirements, Measurement accuracy and Turn-down ratio
- **Need for an alternative**

V-cone flowmeter could be one of the alternatives.

Working principle of a V-cone flowmeter



Schematic diagram of V-Cone flowmeter



Courtesy: McCrometer[1]

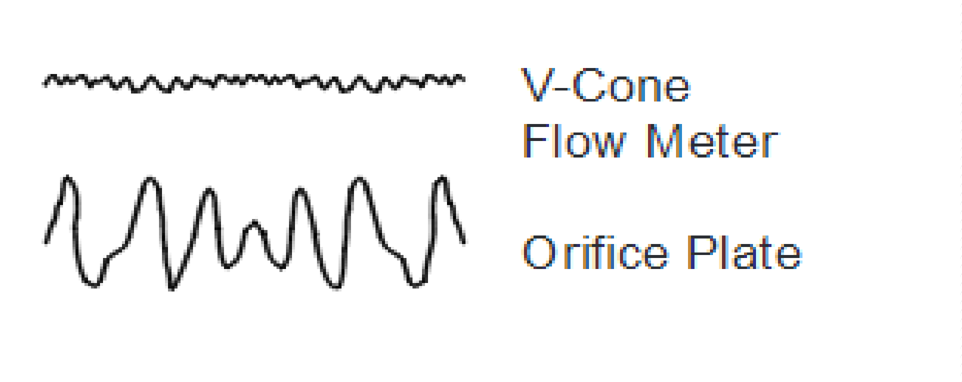
V-Cone flowmeter is a differential pressure flowmeter:

$$Q = C_d * \frac{1}{\sqrt{1-\beta^4}} * \frac{\pi}{4} * \left(D^2 - d^2\right) * \sqrt{2 * \rho * \Delta P} \quad kg/s$$

$$where \quad \beta = \sqrt{1 - \frac{d^2}{D^2}}$$

Unique Features of V-cone Flowmeter

- Requires small space for installation.
- Accuracy level is high
- Turn down ratio is high i.e. 30:1[1]
- High repeatability up to ±0.1%.
- Can measure disturbed flow accurately
- Good signal stability [1].



Review of Literature

Author	Parameter varied	Findings
Ifft et al. [2]	β= 0.5 and 0.75	▪Upstream and downstream length required are 0 to 3D and 3 to 5 D. ▪ Disturbances beyond these pipe lengths have negligibly effect on C_d.
Prabhu et al.[4]	β=0.75 Re=30,000 - 49,400	▪C_d is independent of inlet Reynolds number
Singh et al. [5]	β= 0.64 and 0.77	▪C_d is independent of inlet Re within the range of Re they studied. ▪C_d increases with increasing the closure of the valve placed at 5D upstream of the cone.
Nasiruddin et al. [7]	β =0.6 $20° \leq \phi \leq 180°$	▪Optimized vertex angle is 75°. ▪Fore-vertex tip radius has no effect.
Nasiruddin et al. [8]	β =0.6 ϕ =60°, 75° and 90°	▪Introducing curvature at the aft-cone improves the performance of the flowmeter. ▪R/d=0.55 is the optimum radius of curvature.
Nasiruddin et al. [9]	β =0.6 ϕ =60°	▪Effect of Off-set affects the performance of the flowmeter by 3%.

Objectives

- Selection of proper turbulence model for the kind of flow prevails in the vicinity of the V-cone.
- To study the effect of boundary layer thickness on the performance of the V-cone flowmeter.

Approach

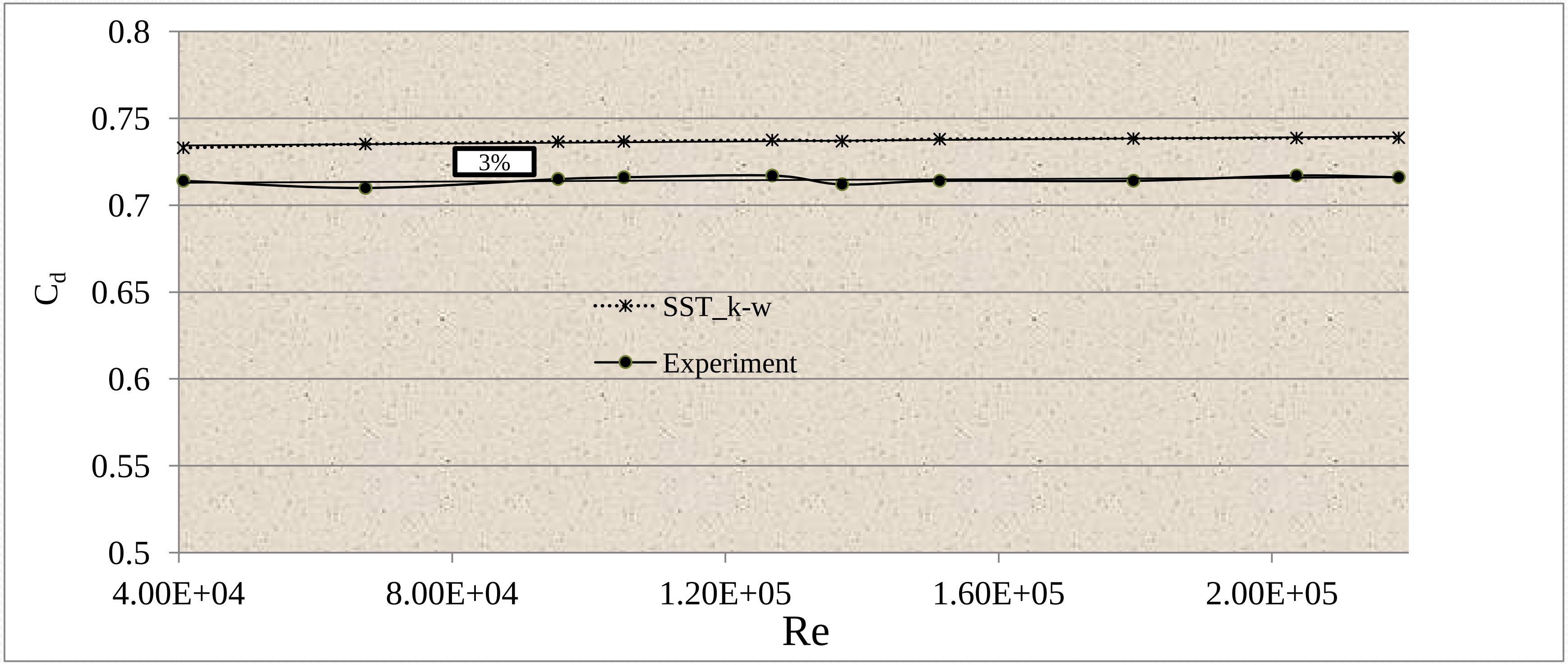
The objectives of the present work has been achieved with the help of Numerical Simulation:

- ✓ Modeling
- ✓ Grid Generation
- ✓ Chosen CFD tool - Ansys 15.0 Fluent.
- ✓ Selection of Turbulence Model
- ✓ Grid independence Study
- ✓ Results

Boundary Conditions

Inlet	Mass-flow-inlet (Uniform velocity) & Velocity profile fed
Outlet	Pressure Outlet
Pipe wall	Wall
Cone wall	Wall
Roughness height	0.5 mm
Roughness constant	0.5
y+	< 5

Validation of turbulence model

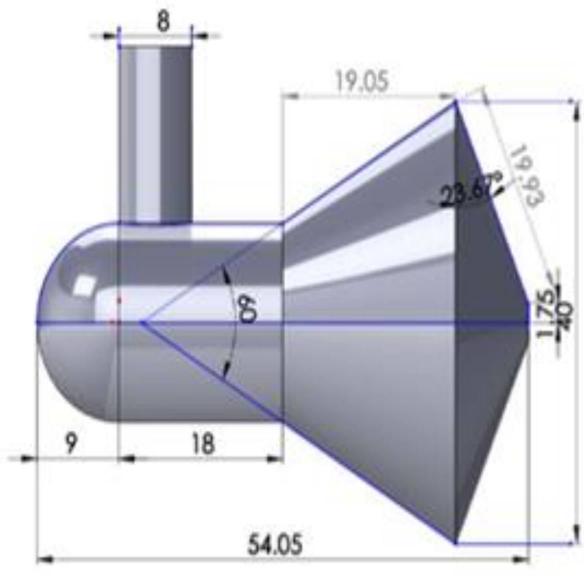


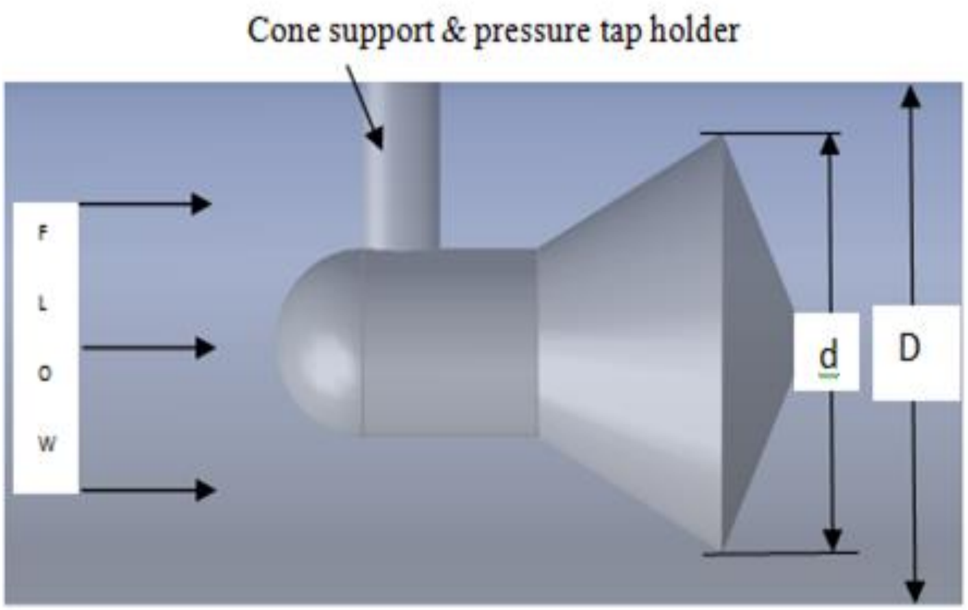
The validation studies show that the SST k-ω turbulence model predicts the performance of the V-cone flowmeter well and hence it has been used for all further parametric investigations.

Grid independence study

Rough Pipe	
Number of mixed grid elements	Value of C_d
6.26×10^5	0.7355
7.12×10^5	0.7365
8.38×10^5	0.7372
10.28×10^5	0.7374
13.31×10^5	**0.7385**
18.49×10^5	0.7385
22.58×10^5	0.7386
28.32×10^5	0.7388
49.38×10^5	0.7387

Geometrical details of the V-cone flowmeter (β=0.6 and ϕ=60°)



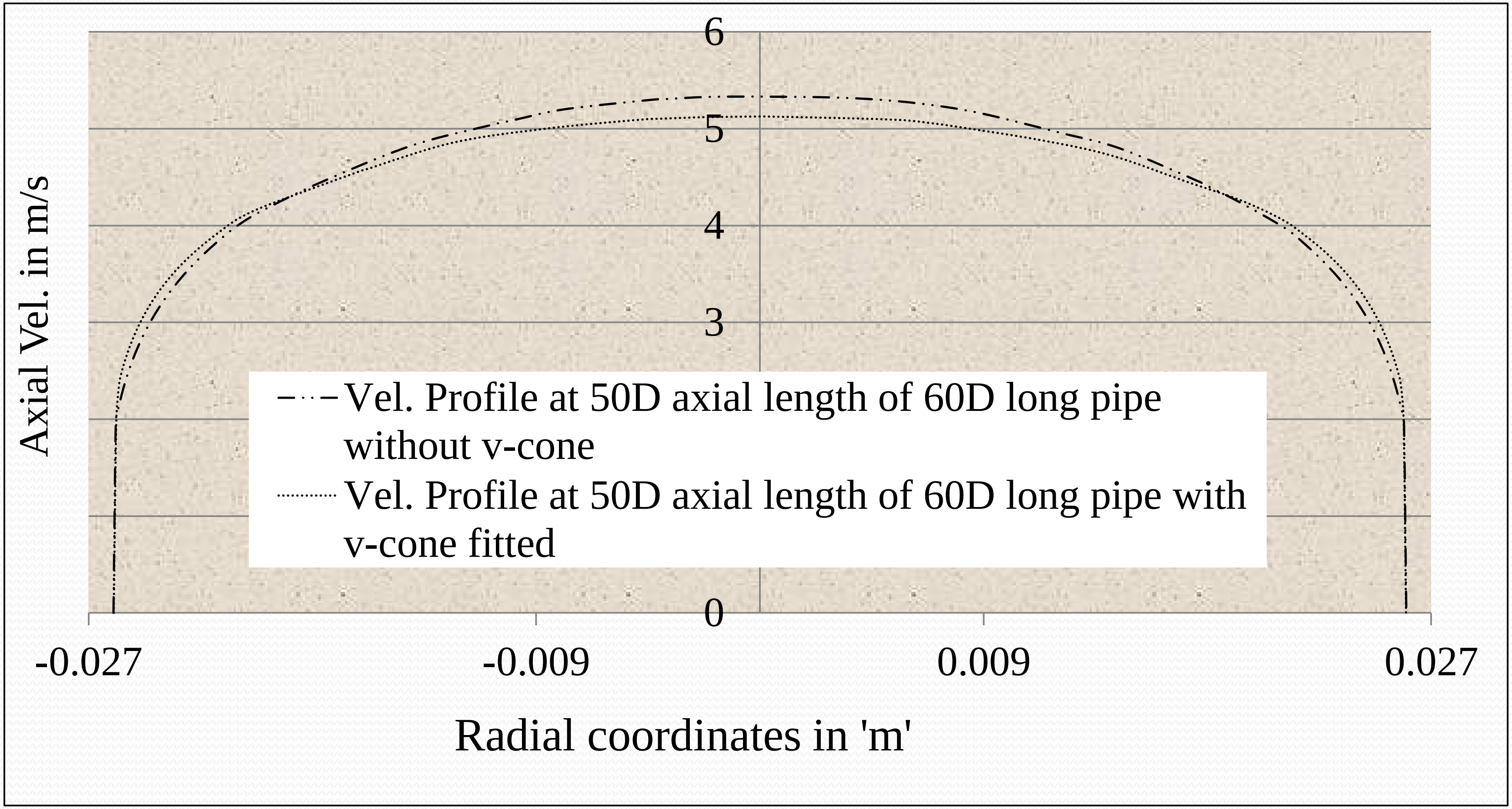


Flow and Geometrical conditions

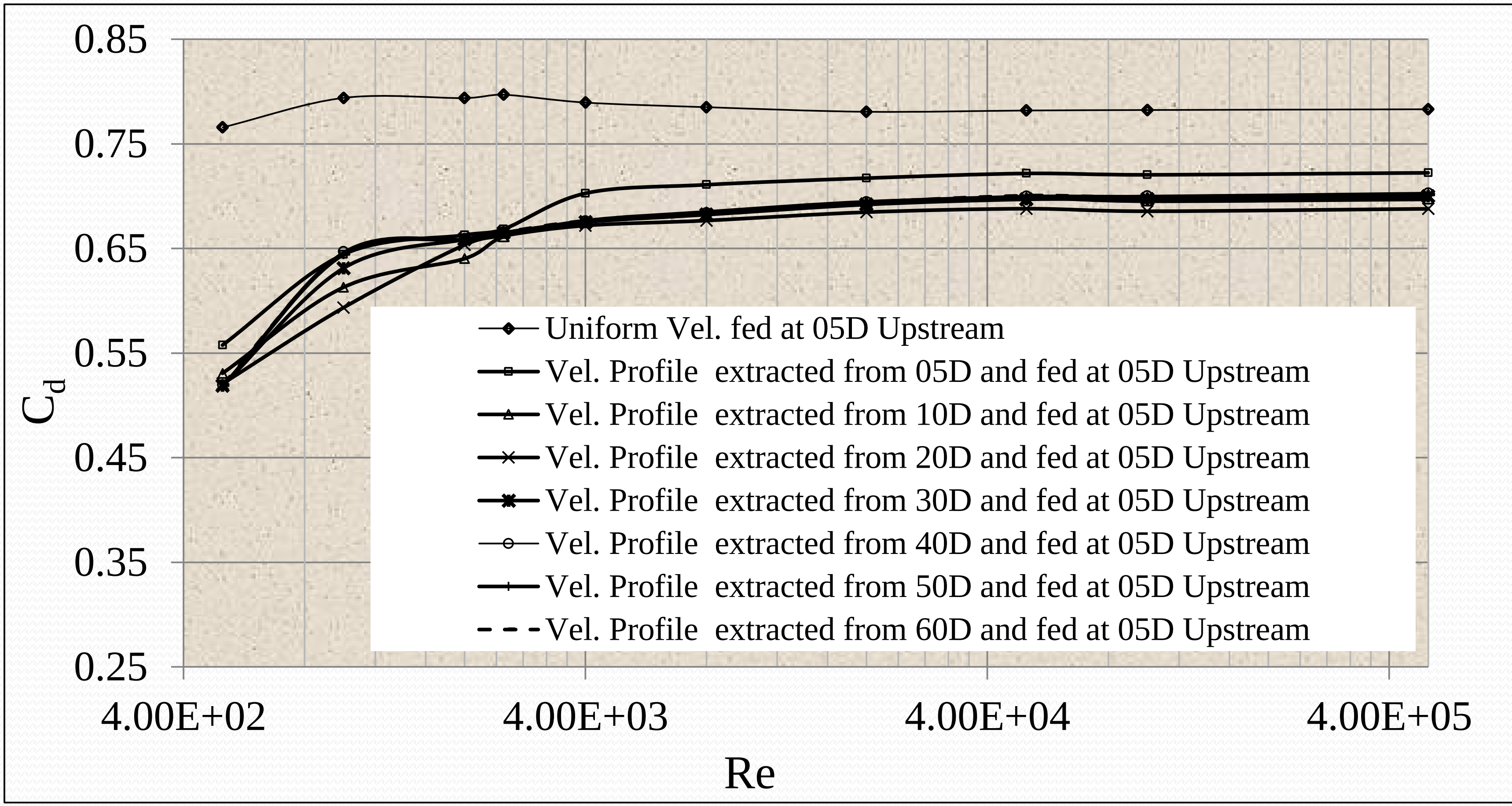
Reynolds number (Re)	Vertex angles (φ)	Equivalent Diameter Ratio(β)	Location of the velocity profile extracted from the pipe fitted without cone meter	Location of the velocity profile fed at the inlet of the pipe fitted with cone meter
500, 1000, 2000, 2500, 4000, 8000, 20000, 50000, 100000,500000	60°	0.6 and 0.7	05D, 10D, 20D, 30D, 40D, 50D and 60D	All extracted velocity profiles including uniform velocity are fed at 5D upstream of the Cone

Results & Discussion

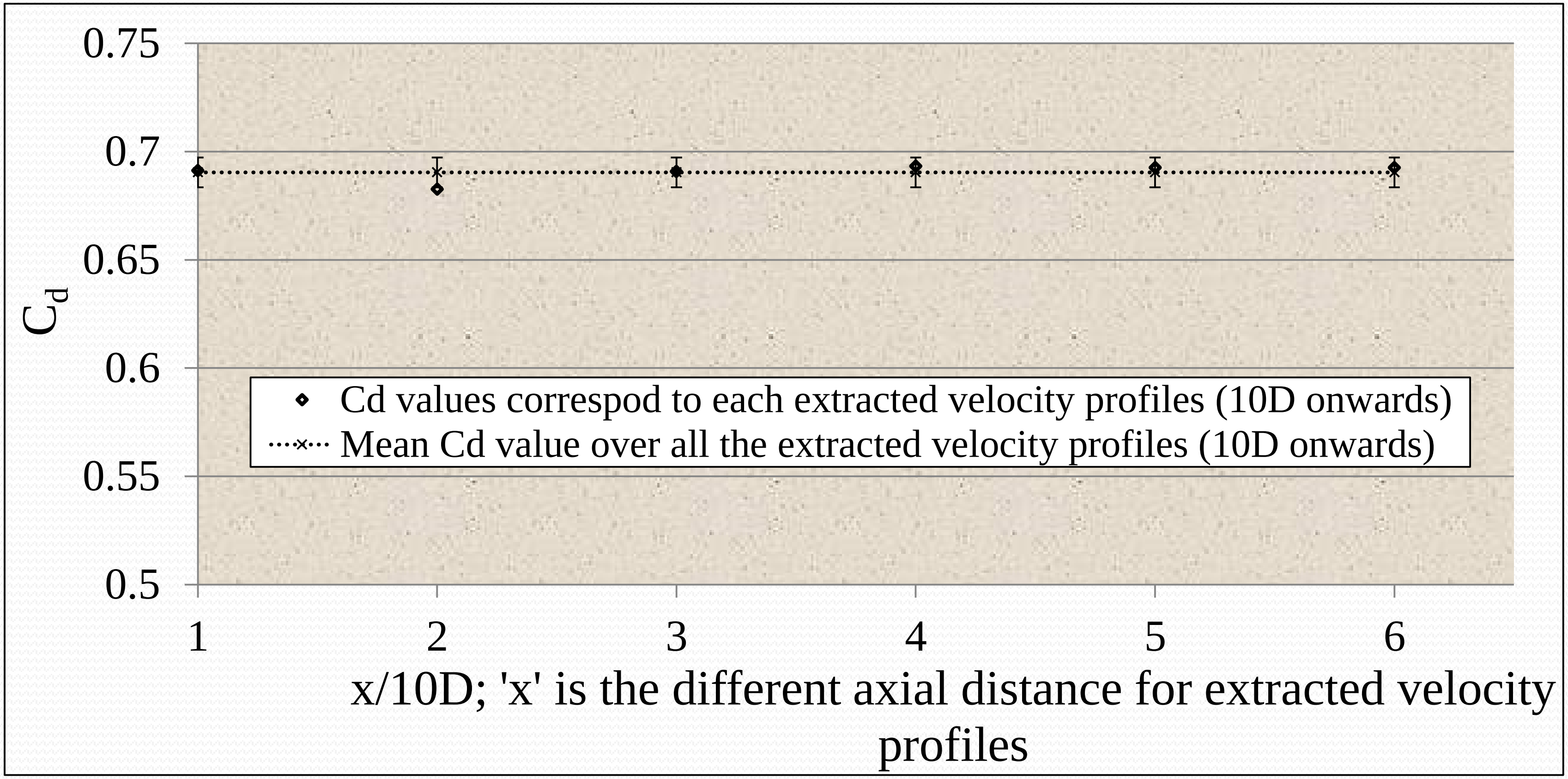
Comparison of velocity profiles for pipe flow simulation with and without V-cone



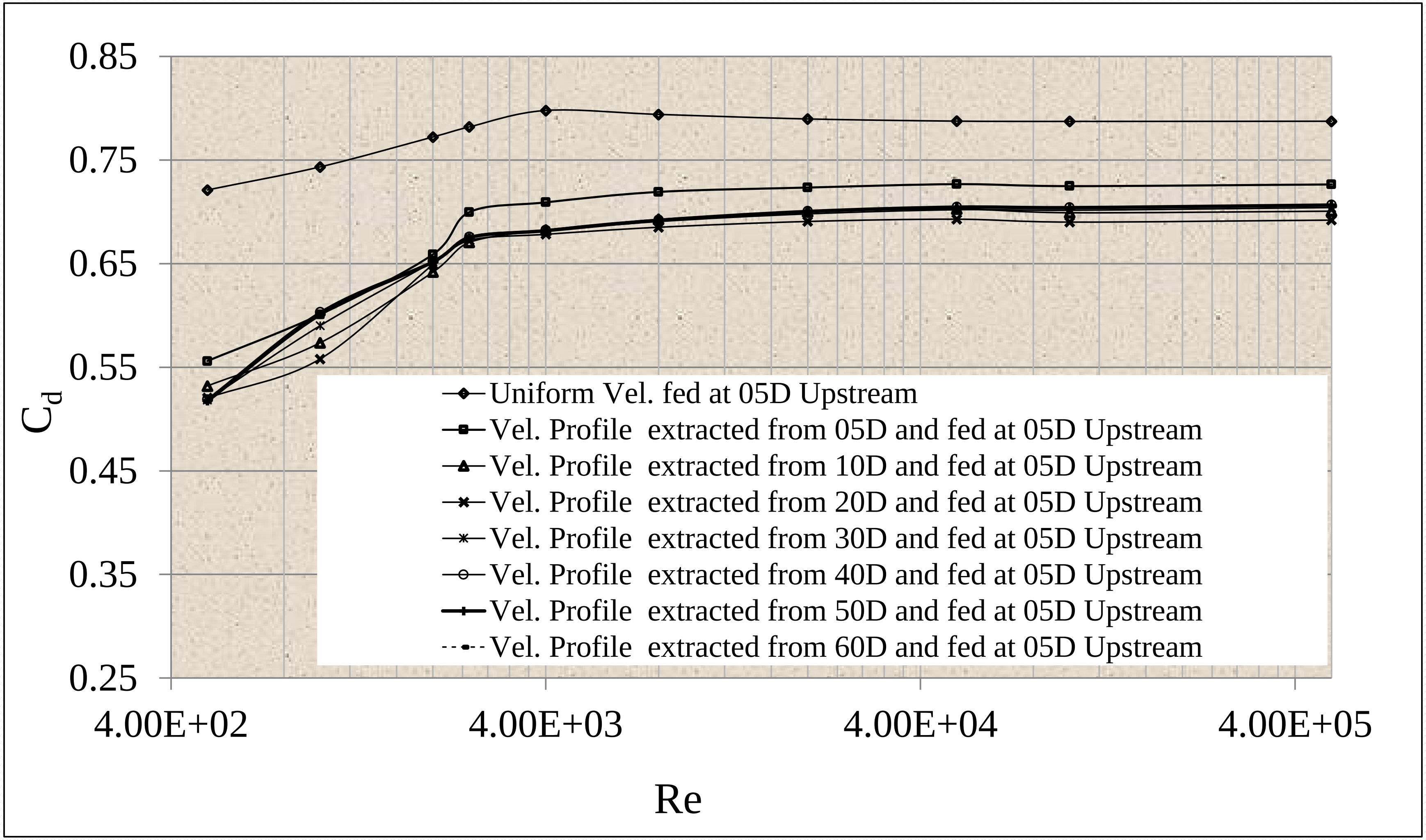
Variation of C_d with Re for β=0.6 & φ=60°



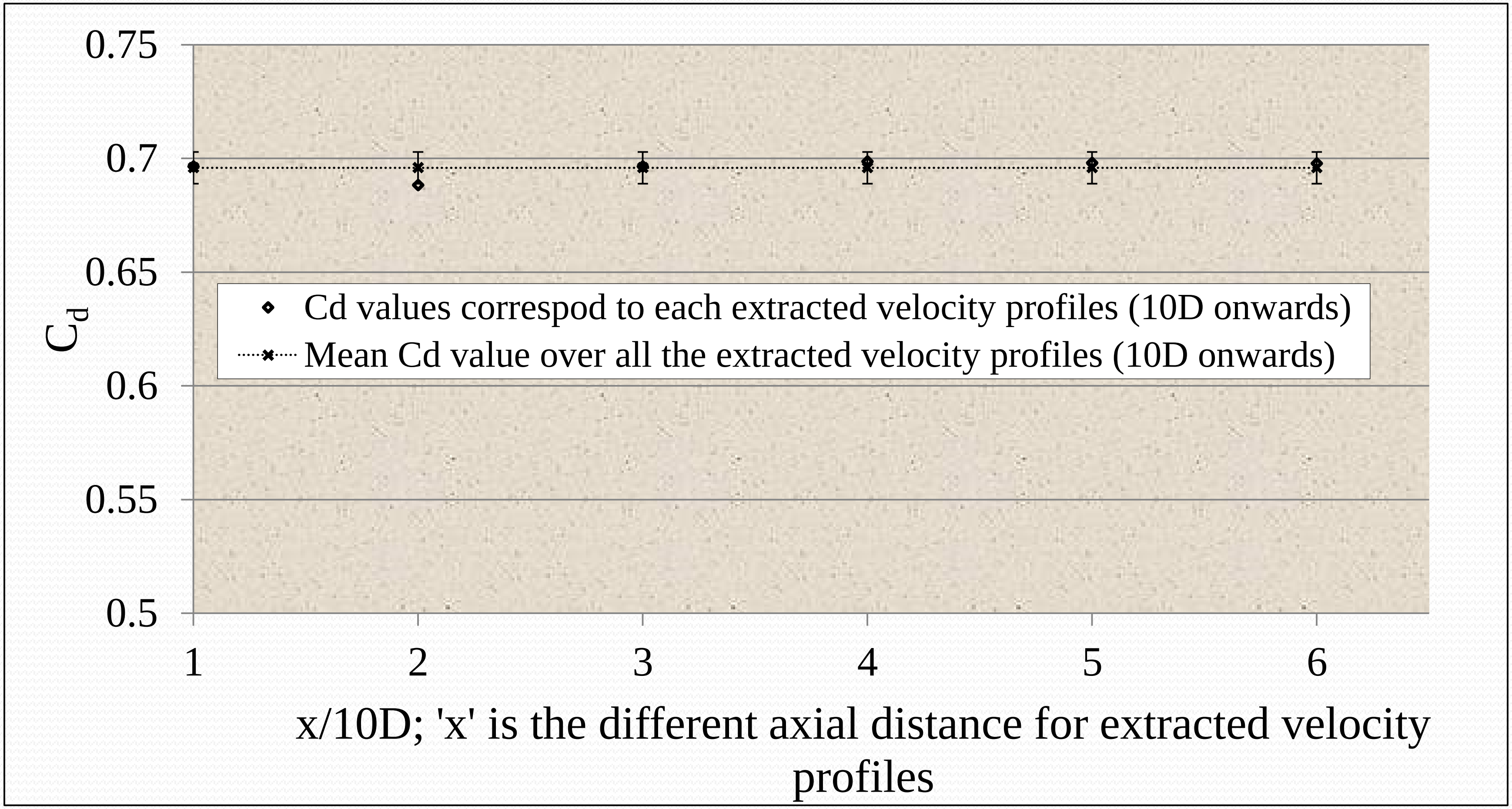
C_d value for different extracted profiles with ±1% error bar (β=0.6& φ=60°) for Re ≥ 4000



Variation of C_d with Re for β=0.7 & φ=60°



C_d value for different extracted profiles with ±1% error bar (β=0.7 & φ=60°) for Re ≥ 4000



Conclusions

- SST k-omega turbulence model is an efficient tool to predict the performance of V-cone flowmeter for various design parameters. The error is only 3% from the experimental findings.
- For the chosen β-values, C_d value is linearly dependent on Reynolds number in the laminar and transition regimes and nearly constant for turbulent flow regime beyond Reynolds number of 4000.
- The performance of the V-cone flowmeter is not affected by the B-L thickness except for the uniform flow and 5D extracted velocity profile (negligible boundary layer thickness) which were fed at 5D upstream of the meter.
- The effect as seen (for both β values) in figures for the uniform flow and 5D extracted velocity profile is the result of pressure variation in the vicinity of the cone due to its influence.

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THANK YOU

Understanding V-cone Flowmeter:Video (Courtesy: McCrometer)