

EXPERIMENTAL STUDY ON FLOW THROUGH VENTURIMETER

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Abstract - An attempt to study and prepare the computational model of a venturimeter, which can be used as an efficient and easy means for calibration of the instrument instead of costly experimental methods is done. The research covers the following aspects: to study the theory of the venturimeter and calculate the data theoretically by using Bernoulli's equation, to analyse the experimental data and to plot graphs for it. The focus here is to analyse the pressure variations across the venturi section by means of Ansys Fluent 14.5, a commercial CFD code, which explores the use of computational methods to compute the flow parameters in the tube. The study aims at comparing the results calculated by both, the computational and experimental methods. An effort is made to check the validity of Bernoulli's equation when applied to the steady flow of water in a tapered duct and to calibrate the venturi as a flowmeter by calculating the coefficient of discharge.

Key words: Computational Fluid Dynamics, Calibration, Ansys.

1. INTRODUCTION

The Venturimeter is an obstruction meter named in honour of Giovanni Venturi (1746-1822), an Italian physicist who first tested conical expansions and contractions. The original, or classical, venturi was invented by a U.S. engineer, Clemens Herschel, in 1898. It consisted of a 21° conical contraction, a straight throat of diameter d and length d , then a 7 to 15° conical expansion. The discharge coefficient is near unity, and the non-recoverable loss is very small. The modern venturi nozzle consists of an ISA 1932 nozzle entrance and a conical expansion of half angle no greater than 15°. It is intended to be operated in a narrow Reynolds-number range of 1.5×10^5 to 2×10^6 . Venturi meters consist of a short length of pipe shaped like a vena contracta, or the portion with the least cross sectional area, which fits into a normal pipe-line. The obstruction caused to the flow of liquid at the throat of the venturi produces a local pressure drop in the region that is proportional to the rate of discharge. This phenomenon, using Bernoulli's equation, is used to calculate the rate of flow of the fluid flowing through the pipe. Nowadays, it is necessary to perform the calibration tests of the flow meters in order to find out the accuracy of the instrument. These can be done by calculating the discharge coefficient of the venturi. Although experimental procedures offer a good result, they are often time consuming. Hence a more sophisticated method of testing the flow meter is through numerical methods. Due to variety of commercial CFD codes being available in the market, it is possible to obtain more accurate results which take less time. These results can then be compared with the initial experimental results to calibrate the instruments.

2. EXPERIMENTAL TEST

The flow calibration facility is set-up for the calibration of differential pressure type of flow elements by accurately measuring the weight of water passing through the flow element and collected in collection tank over a given over a given time. The water is stored in a sump tank and pumped through supply line to maintain constant head and desired flow. The calibration setup has a venturimeter and an orifice meter. The orifice meter valve is closed completely and for the venturimeter, the desired flow in supply and calibration line is achieved by control valves in supply line, calibration line and pump bypass line. Readings taken are time taken for 10cm rise in water level in the measuring tank and the manometric head indicated by the differential manometer. Readings are taken for three different values of flow rates. The observations H1 and H2 indicate the manometric deflections on both sides of the scale.

Table -1: Experimental determination of Coefficient of discharge

Sl.No	MANOMETER READING			ΔH	Time for 10cm rise in collecting tank (s)	Discharge ($\frac{m^3}{s}$)		Coefficient of discharge
	h_1 (m)	h_2 (m)	h (m)			Actual discharge	Theoretical discharge	
1	0.125	0.77	1.027	1.251	75	1×10^{-3}	1.2×10^{-3}	0.89
2	0.125	0.265	1.038	1.279	26	0.96×10^{-3}	1.06×10^{-3}	0.905
3	0.155	0.245	1.224	1.106	30	0.8×10^{-3}	0.9×10^{-3}	0.904
4	0.165	0.23	0.819	0.904	37	0.67×10^{-3}	0.75×10^{-3}	0.889

3. MODELLING

The 3D Modelling of the Venturimeter was done by using Siemens NX 11.0. It delivers a robust set of new tools and significant enhancements to existing functionality.



Fig -1: 3D Modelling

4. MESHING

The Venturimeter section for analysis is selected as the domain. The 3D geometry of the domain prepared by using Siemens NX 11.0 is imported in Ansys 14.5. The type of mesh performed was QUAD. The mesh interior was made up of 2600 Elements and 3180 Nodes.

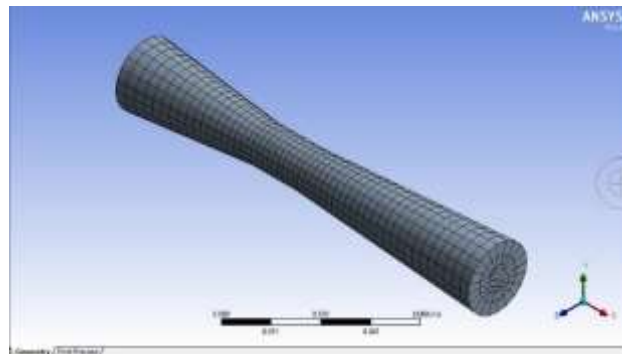


Fig -2: Meshing

5. ANALYSIS

Computational fluid dynamics (CFD) is a branch of fluid mechanics that uses numerical analysis and data structures to analyse and solve problems that involve fluid flows. Computers are used to perform the calculations required to stimulate the free-stream flow of the fluid, and the interaction of the fluid with surfaces defined by boundary conditions. Ongoing research yields software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows. In addition, previously performed analytical or empirical analysis of a particular problem can be used for comparison. CFD analysis was performed using ANSYS 14.5.

Table -2: Input Parameters

TYPE OF SOLVER	PRESSURE BASED SOLVER
ENERGY MODEL	ON
MATERIAL	WATER
DENSITY OF WATER	$1000 \frac{kg}{m^3}$
TURBULENT INTENSITY	5%
SOLUTION METHOD	SIMPLE scheme
SOLUTION INITIALIZATION	FROM INLET
NUMBER OF ITERATIONS	200

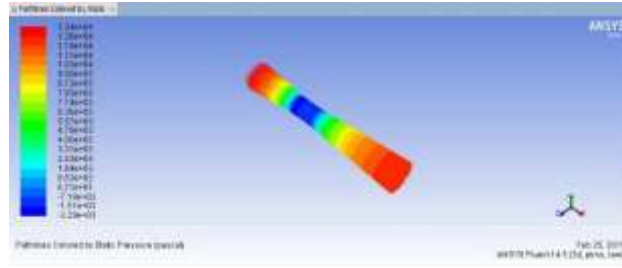


FIG-3 Analysis

6. OBTAINING COEFFICIENT OF DISCHARGE

The pressure drop across the convergent portion of the venturi was calculated using the code and these values were used to calculate the discharge coefficient using the simple Bernoulli's equation. The discharge coefficient was calculated for three different values of flow rates.

Table -3: Results from Analysis

ACTUAL MASS FLOW RATE ($\frac{kg}{s}$)	PRESSURE INLET (pascal)	PRESSURE THROAT (pascal)	THEORETICAL MASS FLOW RATE ($\frac{kg}{s}$)	CO-EFFICIENT OF DISCHARGE
1	12649	-1505	1.0053	0.994
0.96	11659	-1386	0.9652	0.995
0.81	8742	-1036	0.8360	0.968
0.67	5724	-672	0.6761	0.993

7. COMPARISON OF RESULTS

The coefficient of discharge obtained from both, the experimental tests and the CFD analysis are as follows:

Table -4: Results

CFD ANALYSIS	EXPERIMENTAL	ACCURACY (%)
0.994	0.89	11.6
0.995	0.905	9.9
0.968	0.904	7.07
0.993	0.889	11.6

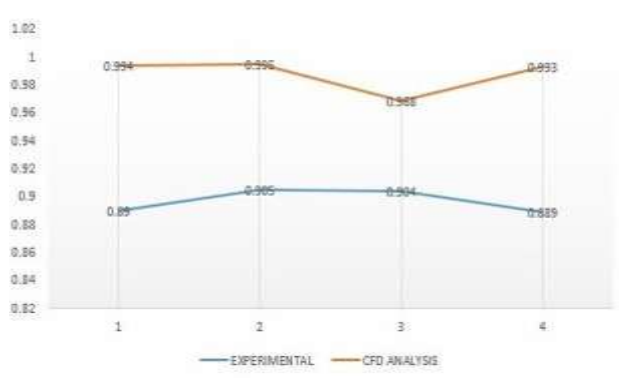


Chart -1: Comparison of experimental and Ansys Fluent results

8. CONCLUSIONS

A brief summary and various conclusions drawn from the observations and calculations are as follows:

- The values of discharge coefficient obtained from experimental tests and CFD simulation are very close to each other.

- The accuracy of results is within 15%.
- Calibration of the venturimeter was successfully carried out.
- It can be inferred that such computational models can provide an efficient and accurate method for re-calibrating flowmeters instead of employing costly and time consuming experimental methods.

9. REFERENCE

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