International Journal of Engineering Research and General Science Volume 6, Issue 6, November-December, 2018
ISSN 2091-2730

Dynamic pressure compensation analysis in pre-compensated hydraulic spool type valve

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Abstract— The main objective of the present work is to analyze the pressure compensation phenomenon and observe the variations in output flow as per change in pressure margins across the directional flow control valve. A MATLAB code is created and Simulink model is built for dynamic analysis of capturing compensator spool behavior in typical pre-compensated mobile control valve. Simulation results are compared with the test results and correlation is established.

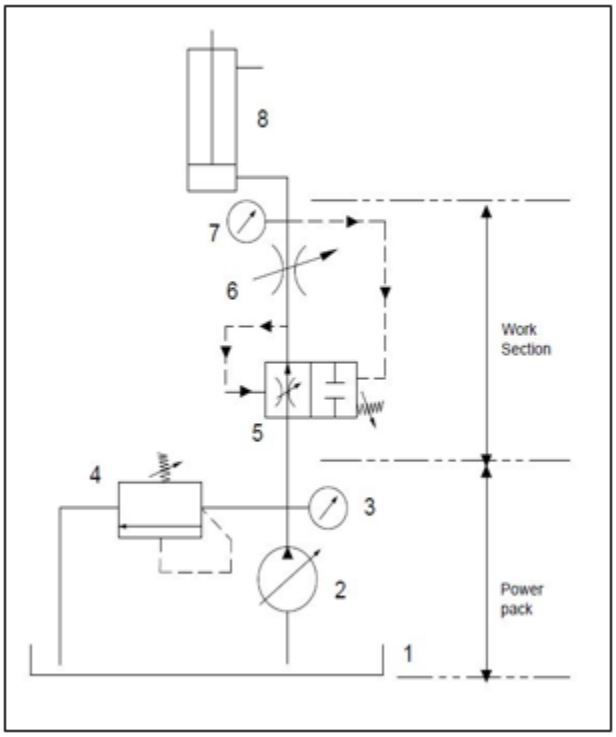
Keywords— Spool, compensator, orifice pressure drop, flow, MATLAB-Simulink, Coefficient of discharge.

INTRODUCTION:

In case of mobile valve equipments, OEMs demand precise flow control through the valve to the actuator such as hydraulic cylinder or motor irrespective of changes in load induced pressure. Therefore, development of pressure compensated control valve is today's only preferred technology in order to satisfy the demands for better flow performance. There are different types of spool valves based upon the type of actuations mechanism, number of operating positions. These spoolA valves include a shaft element called as spool which moves inside a bore of the manifold of the valve and provides the passage for oil to flow from one port to another. In order to achieve flow control irrespective of changes in load induced pressures, these spool valves are assembled with one more spool which is called as compensator spool. Depending upon the position of the compensator spool with respect to main flow spool, pressure compensated valves are classified as either pre-compensated valves or post-compensated valves. In pre-compensated valves, compensator is located upstream (before) main spool whereas in case of post-compensated valves it is located downstream (after) main spool. Furthermore, in pre-compensated valves, compensator is in normally open position which is alike to normally closed position in post-compensated valves. Overall, the function of the compensator remains same and it is to maintain constant flow through the work port of valve by varying its position for taking into account the variations in the load induced pressure. Such pressure compensated valves are usually helpful while operating sectional valves simultaneously at different pressures for controlling different functions of the machine at a time.

HOW PRE-COMPENSATED SYSTEM WORKS:

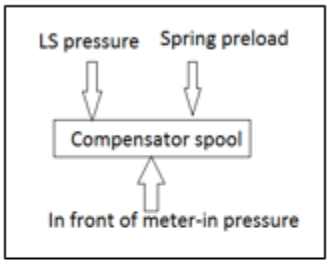
Hydraulic schematic below shows the typical circuit of pre-compensated valve. Out of the total pressure drop across the valve, part of pressure drop occurs across the compensator and remaining pressure drop occurs across the main spool. A compensator spool is similar to pressure reducing valve where it works between two pressures. On one side compensator experiences the force induced because of the pressure which is generated after compensator orifice which is known as control chamber force and on other side it experiences the force created because of pressure dropped after main spool (metering) orifice which is knows as load sense chamber force. The load sense chamber pressure is always less than control chamber pressure. Thus, the difference in two pressure values is the pressure drop occurring across main spool which is shown in free body diagram of compensator. Since the load sense pressure is lesser than control chamber pressure, a spring is installed in load sense chamber which will provide pre-load generating pressure equivalent to main spool pressure drop.

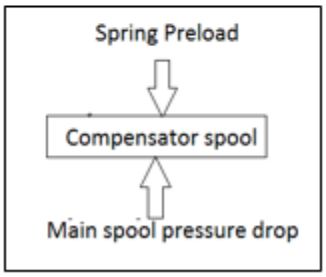


Nomenclature of the symbols in the schematic is as follows

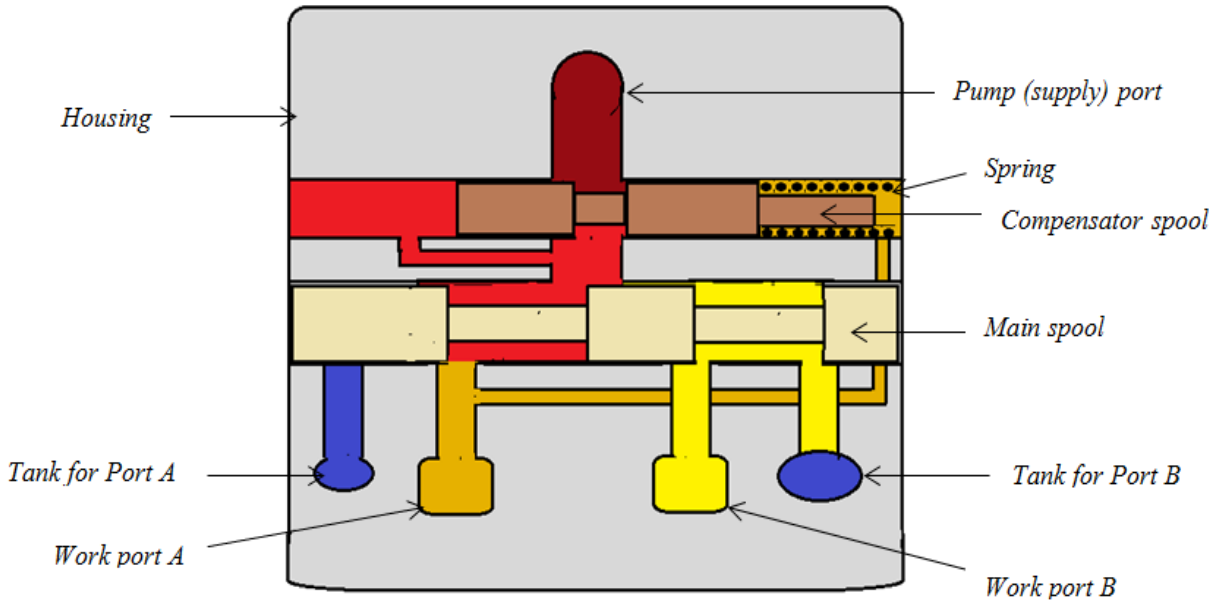
1. Reservoir (Tank)
2. Variable displacement unidirectional pump
3. Pressure gauge for measuring inlet/supply pressure
4. System relief valve
5. Compensator spool (Normally open)
6. Main spool (Metering orifice)
7. Pressure gauge for measuring load sense pressure
8. Actuator (Double acting cylinder)

Therefore, it can be concluded that the pressure created by spring pre-load on spool cross-sectional area is the amount of pressure drop occurring across main spool. When there is increase in the total pressure drop across valve then pressure acting on compensator through control chamber increases which makes compensator to shift from its normally open position by some amount and causes the excess of pressure drop across itself keeping constant pressure drop across main spool ultimately maintaining constant flow through main spool. The position which compensator will achieve is called as equilibrium position and is dependent on the amount of change in total pressure drop. Therefore pressure compensation is a dynamic phenomenon which we are going to capture in present study through simulation in SIMULINK.





TYPICAL ARCHITECTURE OF PRE-COMPENSATED VALVE:



Supply pressure

Load sense (meter-in) pressure

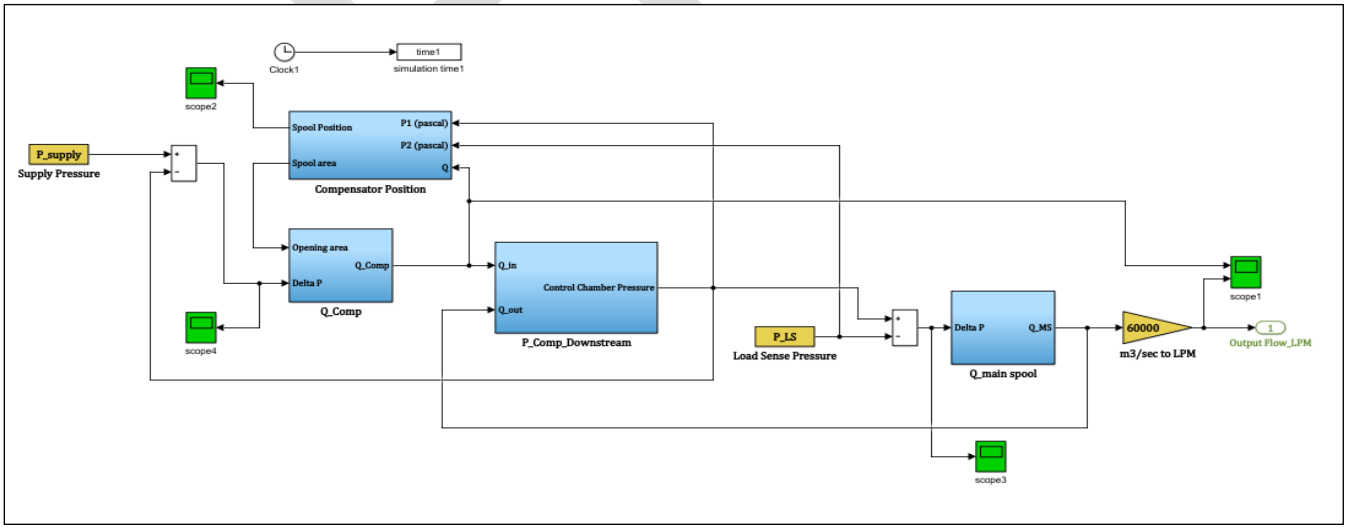
Control chamber pressure

Meter-out pressure

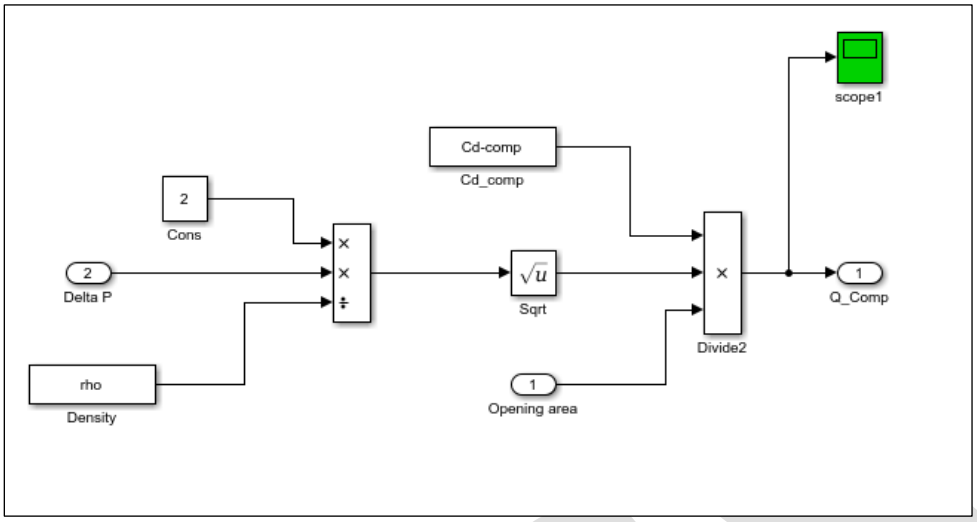
Tank pressure

DYNAMIC ANALYSIS OF PRESSURE COMPENSATION:

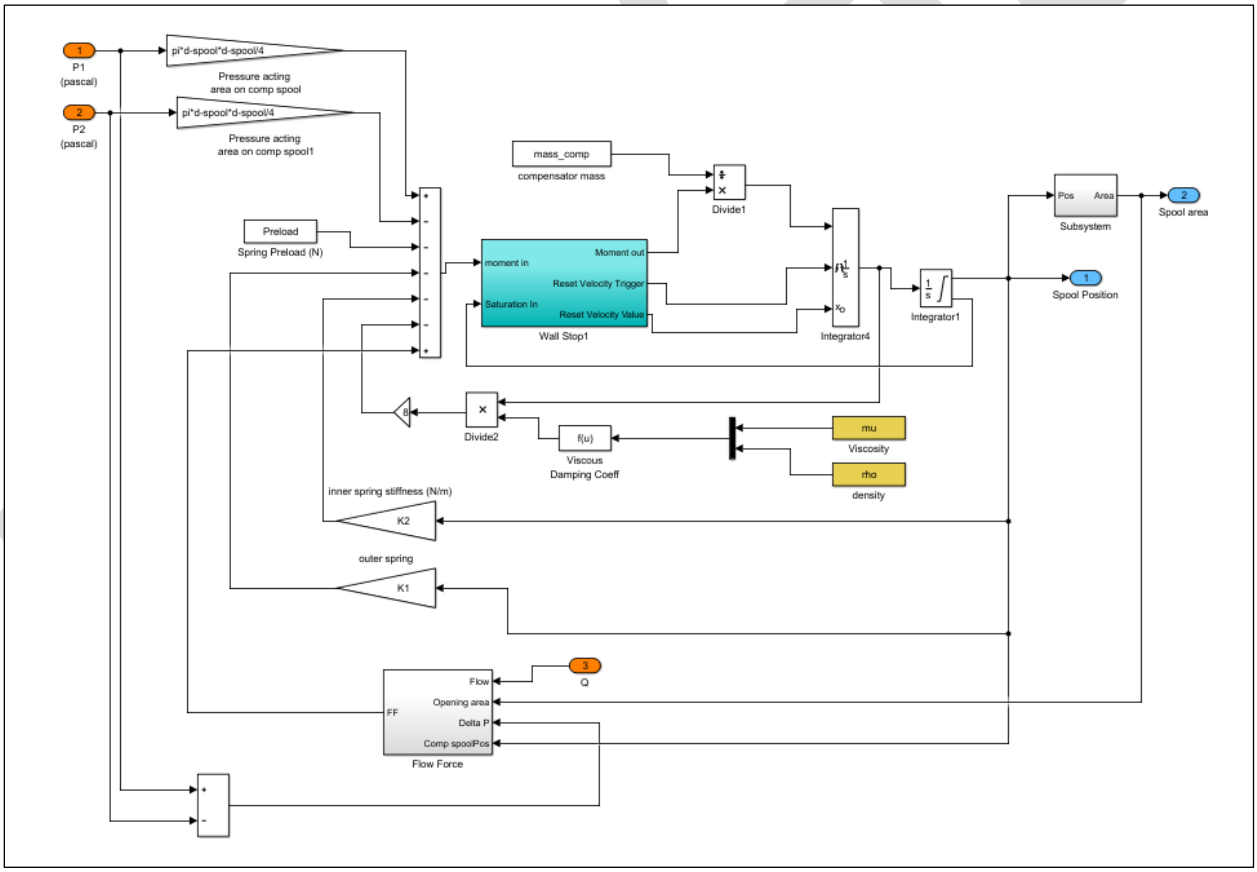
To analyze pressure compensation phenomenon, a math model in MATLAB-SIMULINK is build. It includes the analysis of compensator spool position with respect to time, main spool flow variation with respect to variation in load induced pressure. Generated math model is shown below.



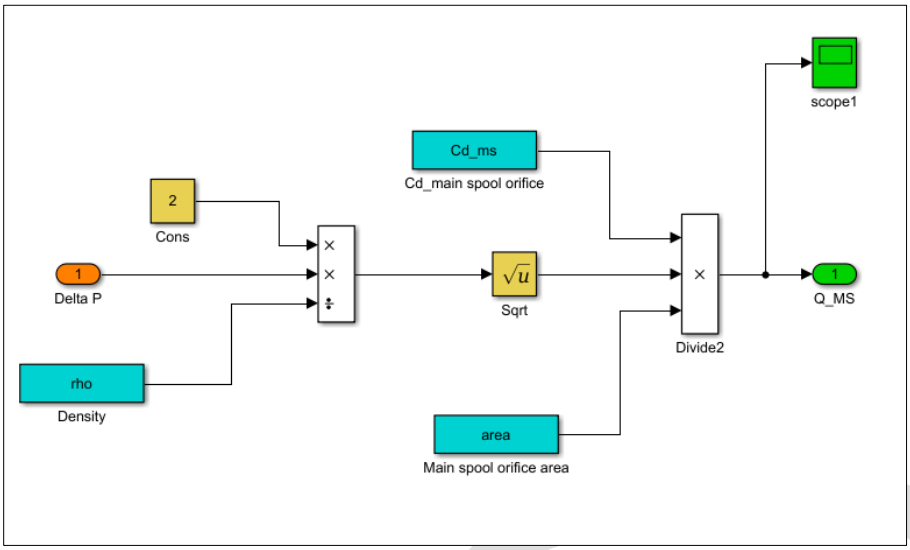
Overall valve level math model



Math model for compensator spool flow



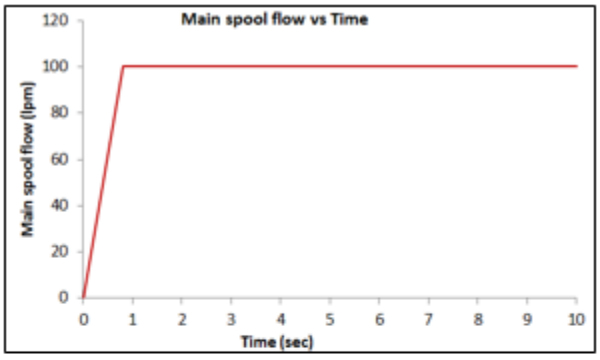
Math model for compensator spool position

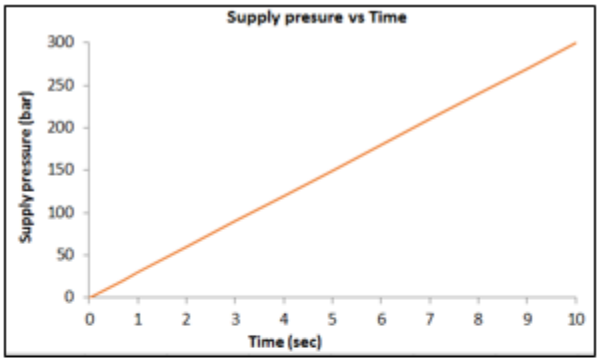


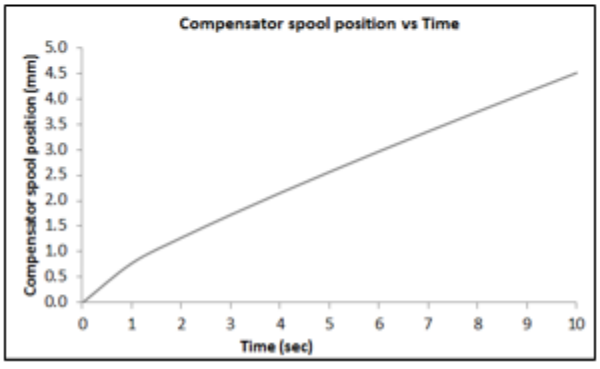
Math model for metering spool flow

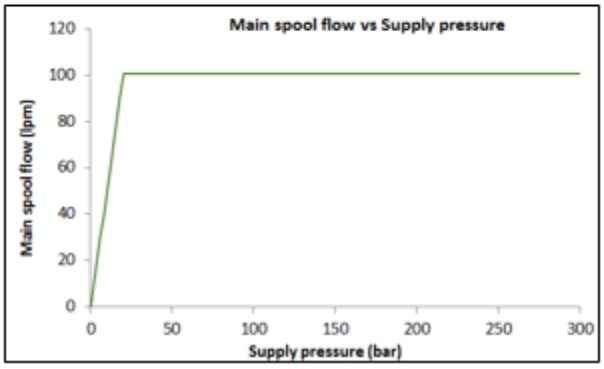
SIMULATION APPROACH AND RESULTS:

The simulation for compensation analysis is done with the assumption of some parameters such as coefficient of discharge at compensator spool, coefficient of discharge at main spool, oil density









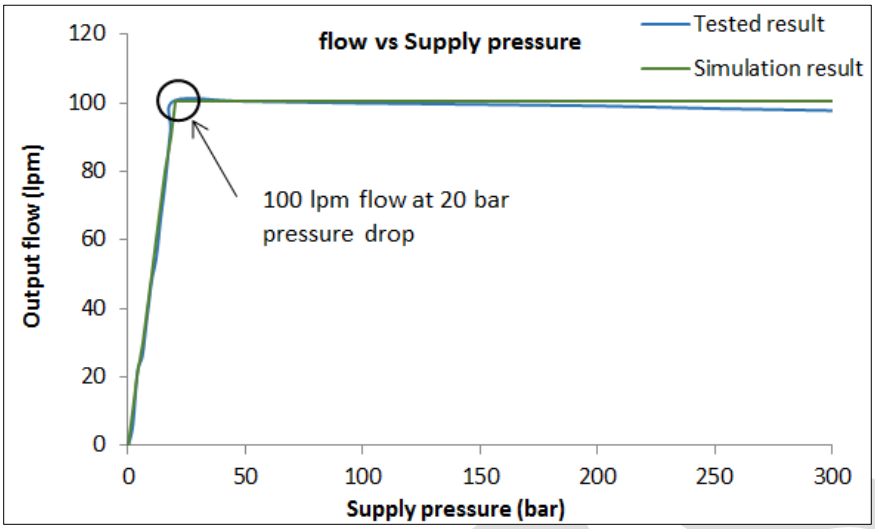
TEST CONDITIONS:

In experimental testing, supply pressure is ramped up with respect to time up to 300 bar and flow meter is connected to the hose which is passing oil coming out of the work port to reservoir. Two pressure sensors were used to sense supply pressure as well as load sense pressure. The load sense pressure was zero gauge pressure. Therefore, the variation of supply pressure replicates the variation of total pressure drop across valve with respect to time. Difference of two pressure reading is then calculated at every data point and then graph of work port flow versus total pressure drop is plotted.

As the tested valve was rated for 100 lpm flow at 20 bar pressure drop, we first compared the tested output flow value with simulated result at same pressure drop. The main spool of valve was shifted to its full displacement to allow maximum area of notch to open and thus to allow flow pass to work port. During this, pressure difference of 20 bar was maintained between supply and load sense.

Tested flow rate (lpm)	Simulated flow rate (lpm)
100.78	100.3

N	Supply pressure (bar)	Simulated flow rate (lpm)	Tested flow rate (lpm)
1	0.50	2.50	1.10
2	2.00	10.03	6.19
3	4.00	20.06	22.14
4	6.00	30.09	26.58
5	8.00	40.12	37.20
6	10.00	50.15	48.48
7	12.00	60.18	55.95
8	14.00	70.21	67.66
9	16.00	80.24	78.92
10	18.00	90.27	92.53
11	20.00	100.30	100.78
12	50.00	100.30	100.49
13	100.00	100.30	99.95
14	150.00	100.30	99.57
15	200.00	100.30	99.18
16	250.00	100.30	98.40
17	300.00	100.30	97.81



Simulated results and tested results match very well together and therefore it can be inferred that the correct physics of pre-compensation is captured in the math model.

CONCLUSION:

This paper focuses on modeling and simulation of pre-compensated hydraulic spool type valve system. Developed model can be utilized for prediction of required properties of any pre-compensated spool type valve. The simulated results of output flow are compared with tested results.

With the use of this model, it is possible for any hydro-mechanical engineer to predict the mean values of specific characteristics prior to freezing the design. Furthermore, this would assist to optimize the design for better compensation effect in valve.

REFERENCES:

[1]Marko Simic–Mihael Debevec–Niko Herakovi. 'Modelling of Hydraulic Spool-Valves with Specially Designed Metering Edges'. *Strojniški vestnik* Journal of mechanical engineering 60 (2014) 2, P-77-83

[2] Tic, V., Lovrec, D. (2012). Design of modern hydraulic tank using fluid flow simulation. International Journal of Simulation Modeling, Vol.11, no.2, p.77-88, DOI:10.2507/IJSIMM11(2)2.202.

[3]Krishna Shamra-Pranav Salunke. Prediction of pressure drop across orifice using MATLAB and 2D analysis of flow through it using CFD International Journal of Engineering Research and General Science Volume 3, Issue 6, November-December, 2015