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Experimental Results Showing Discharge Variation in Gate Valve

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ABSTRACT

Gate valve are traditionally used for controlling the discharge in pipes. The valve is operated by rotating the wheel provided on the top a rod which is also connected to circular disc on other side of it. Every single rotation of wheel produces specific linear movement of disc which in turn tends to change the area of flow. It is expected that for same disc position, the discharge should be same, but the analysis showed that the discharge varied considerably. Further analysis repeated that it is happening on account of the fluctuating separation zones formed on either side of the disc. To address this issue, it is proposed to use a flexible membrane pipe inside the gate valve. This membrane will not allow the separation zone to form, as its shape will automatically change depending upon the disc position and intensity of discharge. It is similar to that of venturimeter with dynamically changing convergent and divergent cones. With this new adaption an experimental setup is fabricated with 1 inch pipe. Thus results have shown excellent improvement in the relationship between disc position and discharge. Further it is calibrated with respect to rotation angle of wheel. The experimental study has shown that the new gate valve can also be used as flow measuring device. The paper describes the journey of gate valve from flow control device to flow measuring device.

I. Introduction

Gate valve is that which either allows or prohibit the flow of hydraulic fluid. Many industrial applications demand accurate flow control for various processes. In fact Gate Valve itself is a flow control device. But on account of its inability to precisely control the flow, it needs to be supplemented with separate flow measuring device. Traditionally 'Gate Valves' along with some flow measuring device like 'Venturimeter' or 'Orificemeter' is used for flow control.

Fig 1. Gate valve.

Mechanism of gate valve

Handwheel of gate valve is connected to vertical disc by the stem, as handwheel is rotated horizontally stem moves vertical disc in downward and upward direction depends on the clockwise and anticlockwise movement of handwheel.

Partially open gate valve forms non uniform flow which is responsible for reduction in the head and so it affects the coefficient of discharge. Due to partially open disc of gate valve wake formation takes place and leads to zone separation on either side of disc. Discharge variation takes place for same disc position of gate valve.

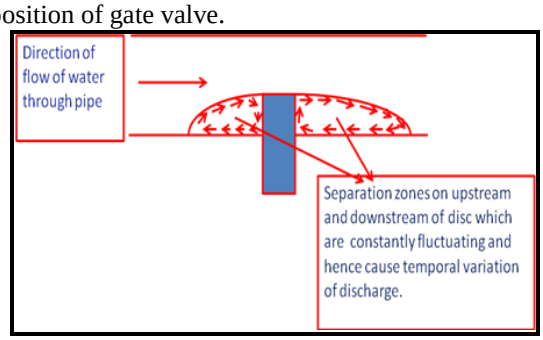

Fig 2. Zone separation on either side of disc of gate valve.

II.Literature Survey

As mentioned above, while use of gate valve foremost problem faced is discharge variation. For the same disc position discharge varies each time. Due to separation of zones discharge varies. Wake nothing but low pressure zones formed and so impinge on discharge head. To address this issue literature is reviewed.

G. A. Hinge (Hydro, 2004) has modified an experimental setup of flow through orifice by designing a novel inlet float valve. With the help of this valve the rate of inflow can be automatically controlled. The gadget works without any fluctuation over a wide range of pressure on upstream.

For setting the certain head on orifice the inlet valve as well as valve on the overflow pipe is needed to be operated simultaneously. If not, due passages of time the head will no longer remain constant.

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Fluctuations of inflow are the disturbances in flow of water created due to sudden transition at the inlet valve and the leakage through the ball valve. And hence to overcome this problem he inserted a flexible pipe in the float valve and the outlet of which was dropped in the main tank. This causes the perfectly steady uniform inflow. So for eliminating the same lacuna of gate valve use of flexible pipe will be beneficial.

III. Methodology

Project tactics includes study of mechanism of gate valve and its basics. What are the lacunas of use of gate valve for flow control and how to tackle with the problems by using innovative approach? Then it is followed by conventional model making, which consists of gate valve fixed along the pipe and the second model keeping all parameters same as in first one (like pipe and valve material, pressure of water) is made which consists of flexible pipe. For both the model various trials are taken to measure discharge for same disc position of valve. Testing of both models and the analysis is evidence for the innovative approach. By using analyzed results of model with flexible pipe mathematical equation for discharge is formulated. For the later confirmation of the innovation multiple models and their testing can be carried out. By varying parameters like diameter, material of pipe and valve these models can be framed.

IV. Experimentation and Observations

Experimentation comprises of making model and their testing. First model is consists of gate valve fixed along the pipe. On both sides of the valve providing pipe length equal to flow development length to avoid boundary layer to increase beyond the radius of the pipe. Flow development length is equal to fifty times diameter of the pipe.

Fig 3. Experimental setup of conventional model.

For the conventional model 25mm metallic gate valve is selected. Complete closing of this valve requires 8 complete and $1/3^{rd}$ of one rotation of handwheel. Mathematically it is 3000^0. Before fixing the valve 60^0 interval points are marked along the periphery of bonnet of the valve. On both the sides of valve acrylic pipe of flow development length equal to 1250mm is provided. Transparency of acrylic pipe helps to observe the flow pattern.

Fig 4. Zone formation in partially opened gate valve.

By keeping inlet pressure constant water is passed through the system. Measure discharge through complete open valve by directly taking volume per unit time. Complete opened valve is closed by rotating clockwise at an angle of 360^0 nothing but one rotation of handwheel record the discharge repeat the procedure until valve closes completely. Rotating the handwheel in anticlockwise direction (360^0). For each rotation record the discharge. Repeating this procedure again and again will give set of readings. Complete closing of gate valve from complete opened valve gives first set of readings. Following table includes various columns. First column is of angle of rotation of handwheel in degree, second column is of volume collected in ml, forth column gives the time in second for which volume collected and last column is of discharge which is calculated as volume collected per second of time.

Opening of valve gives set of readings in clockwise direction.

Table1. Readings-set 1 (clockwise rotation)

Serial No.	Volume (ml)	Angle of rotation (degree)	Time (second)	Discharge (mlps)
1	500	0	-	-
2	500	360	105.2	4.75
3	500	720	4.1	121.95
4	500	1080	3.2	156.25
5	2000	1440	10.2	196.078
6	2000	1800	8.5	235.29
7	2000	2160	7.1	281.69
8	2000	2520	6.3	317.46
9	2000	2880	5.5	363.63
10	2000	3000	5.1	392.156

Closing of valve gives set of readings in anticlockwise direction.

Table2. Readings-set 1 (anticlockwise rotation)

Serial No.	Volume (ml)	Angle of rotation (degree)	Time (second)	Discharge (mlps)
1	2000	3000	5.2	384.62
2	2000	2880	5.9	338.98
3	2000	2520	6.7	298.507
4	2000	2160	7.2	277.78
5	2000	1800	8.7	229.88
6	2000	1440	10.3	194.174
7	500	1080	3.1	161.29
8	500	720	4.3	116.28
9	500	360	92.3	5.417
10	500	0	-	-

Similarly as in first set of readings next two set of pilot readings are taken in both directions.

Table3. Readings-set 2(clockwise rotation)

Serial No.	Volume (ml)	Angle of rotation (degree)	Time (second)	Discharge (mlps)
1	500	0	-	-
2	500	360	53.4	9.36
3	500	720	4.5	111.11
4	500	1080	3.1	161.29
5	2000	1440	10.3	194.174
6	2000	1800	8.7	229.88
7	2000	2160	7.4	270.27
8	2000	2520	6.5	207.69
9	2000	2880	6.1	327.86
10	2000	3000	5.7	350.87

Table4. Readings-set 2 (anticlockwise rotation)

Serial No.	Volume (ml)	Angle of rotation (degree)	Time (second)	Discharge (mlps)
1	2000	3000	5.5	363.63
2	2000	2880	5.8	3440827
3	2000	2520	6.6	303.03
4	2000	2160	7.5	266.67
5	2000	1800	8.6	232.56
6	2000	1440	10.0	200
7	500	1080	2.9	172.41
8	500	720	4.6	108.69
9	500	360	69.9	7.15
10	500	0	-	-

Table5. Readings-set 3 (clockwise rotation).

Serial No.	Volume (ml)	Angle of rotation (degree)	Time (second)	Discharge (mlps)
1	500	0	-	-
2	500	360	94.3	5.30
3	500	720	4.4	113.63
4	500	1080	2.9	172.41
5	2000	1440	9.8	204.08
6	2000	1800	8.7	229.88
7	2000	2160	8.3	240.96
8	2000	2520	8.0	250
9	2000	2880	7.4	270.27
10	2000	3000	7.2	277.77

Table6. Readings-set 3 (anticlockwise rotation).

Serial No.	Volume (ml)	Angle of rotation (degree)	Time (second)	Discharge (mlps)
1	2000	3000	7.2	277.77
2	2000	2880	7.5	266.67
3	2000	2520	8.1	246.91
4	2000	2160	8.5	235.29
5	2000	1800	8.9	224.71
6	2000	1440	9.7	206.18
7	500	1080	2.9	172.41
8	500	720	4.7	106.38
9	500	360	100.5	4.97
10	500	0	-	-

After the 3 sets of pilot readings in clockwise and anticlockwise direction we have observed the variation of discharge for the same position of disc of gate valve. In simple words for same angle of rotation discharge is different. By keeping 60^0 as interval one more set of clockwise and anticlockwise readings is recorded as follows:

Table 7. Opening of the gate valve at an interval of 60^0 (clockwise direction).

Sr. No.	Volume (ml)	Angle of rotation (degree)	Time (sec)	Discharge (mlps)
1	500	0	0	0
2	500	60	510.3	0.97
3	500	120	278.7	1.79
4	500	180	193.1	2.59
5	500	240	112.8	4.43
6	500	300	73.4	6.81
7	500	360	46.3	8.94
8	500	420	30.4	16.42
9	500	480	13.7	36.52
10	500	540	9.8	50.76
11	500	600	5.8	86.2
12	500	660	4.8	104.17
13	500	720	4.4	113.63
14	500	780	3.9	128.20
15	500	840	3.8	131.57
16	500	900	3.7	135.135
17	500	960	3.7	135.135
18	500	1020	3.6	138.88
19	500	1080	3.5	142.85
20	500	1140	3.4	147.06
21	2000	1200	12.9	155.04
22	2000	1260	12.8	156.25
23	2000	1320	12.6	158.73
24	2000	1380	12.5	160
Sr. No.	Volume (ml)	Angle of rotation (degree)	Time (sec)	Discharge (mlps)
25	2000	1440	12.4	131.29
26	2000	1500	11.0	181.81
27	2000	1560	10.7	186.91
28	2000	1620	10.3	194.174
29	2000	1680	9.8	204.08
30	2000	1740	9.5	210.52
31	2000	1800	9.3	215.03
32	2000	1860	9.2	217.39
33	2000	1920	9.1	219.78
34	2000	1980	9.1	219.78
35	2000	2040	8.3	240.96
36	2000	2100	8.9	224.71
37	2000	2160	8.8	227.27
38	2000	2220	8.7	229.88
39	2000	2280	8.5	235.29
40	2000	2340	8.4	238.05
41	2000	2400	8.4	238.09
42	2000	2460	8.3	240.96
43	2000	2520	8.1	246.91
44	2000	2580	7.9	253.16
45	2000	2640	7.7	259.74
46	2000	2700	7.5	266.67
47	2000	2760	7.3	273.97
48	2000	2820	7.1	281.69
49	2000	2880	6.6	303.03
50	2000	2940	6.3	317.46
51	2000	3000	6.1	327.86

Table 8. closing of the gate valve at an interval of 60^0 (anticlockwise direction).

Sr. No.	Volume (ml)	Angle of rotation (degree)	Time (sec)	Discharge (mlps)
1	2000	3000	5.1	392.1
2	2000	2940	5.2	390.6
3	2000	2880	5.3	377.58
4	2000	2820	5.5	363.6
5	2000	2760	5.7	350.87
6	2000	2700	5.8	344.8
7	2000	2640	5.9	338.9
8	2000	2580	5.9	338.9
9	2000	2520	6.1	327.86
10	2000	2460	6.1	327.86
11	2000	2400	6.3	317.46
12	2000	2340	6.5	307.69
13	2000	2280	6.8	294.11
14	2000	2220	7.1	281.69
15	2000	2160	7.0	285.71
16	2000	2100	7.7	259.74
17	2000	2040	7.9	253.16
18	2000	1980	7.9	253.16
19	2000	1920	8.1	246.91
20	2000	1860	8.4	238.09
21	2000	1800	8.5	235.29
22	2000	1740	8.6	232.55
23	2000	1680	8.9	224.71
24	2000	1620	9.1	219.78
25	2000	1560	9.4	212.76
26	2000	1500	9.5	210.52
27	2000	1440	9.9	202.52
28	2000	1380	10.1	198.01
29	2000	1320	10.1	198.01

30	2000	1260	10.3	194.174
31	2000	1200	11.1	180.18
32	500	1140	2.8	178.57
33	500	1080	3.1	161.29
34	500	1020	3.2	156.25
35	500	960	3.4	147.05
36	500	900	3.7	135.135
37	500	840	3.9	128.2
38	500	780	4.1	121.95
39	500	720	4.7	106.38
40	500	660	5.9	84.74
41	500	600	7.8	64.1025
42	500	540	9.3	53.76
43	500	480	16.3	30.67
44	500	420	44.5	11.23
45	500	360	100.10	4.995
46	500	300	157.2	3.180
47	500	240	261.9	1.909
48	500	180	325.7	1.535
49	500	120	498.2	1.0036
50	500	60	540.8	0.924
51	500	0	0	0

Another model is having same parameters as that of first. . But this one is assembled with the flexible pipe. Purpose of using flexible pipe is to avoid zone separation.

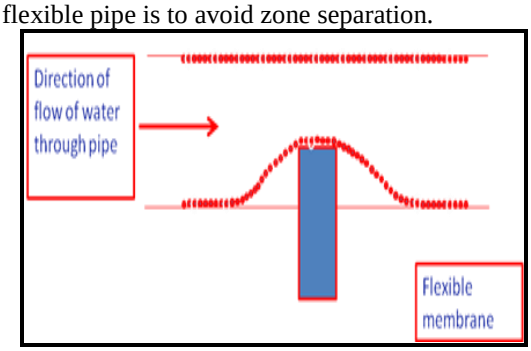

Fig 5. System with flexible membrane.

This system consists of 25mm metallic valve fixed along the acrylic pipe on either sides having flow development length of 1250mm with the same pressure at inlet. This flexible pipe is made up of nylon material which used in canopy of umbrella. Length of the flexible pipe depends on the distance of zone formation on either side of the valve which is measured from conventional model. For the present case it is 128mm on either sides of valve.

Length of flexible pipe

= length of wake on either sides + width of valve

= (128+128) +150

=406mm

To be on safer side 450 mm length is to taken for flexible pipe.

Fig 6. Experimental setup with flexible membrane.

Same procedure is followed for the recording of reading. First of all 3 set of pilot readings are taken which are having interval of one complete rotation (360^0) in clockwise and anticlockwise direction.

Table 9. Readings-set 1 (Clockwise rotation).

Serial No.	Volume (ml)	Angle of rotation (degree)	Time (second)	Discharge (mlps)
1	500	0	0	0
2	500	360	51.7	19.34
3	500	720	18.8	53.19
4	500	1080	12.9	77.51
5	2000	1440	12.2	81.96
6	2000	1800	10.1	99.00
7	2000	2160	9.9	101.01
8	2000	2520	9.5	105.26
9	2000	2880	9.1	109.89
10	2000	3000	8.9	112.36

Table10. Readings-set 1 (anticlockwise rotation)

Sr. No.	Volume (ml)	Angle of rotation (degree)	Time (second)	Discharge (mlps)
1	2000	3000	8.6	116.27
2	2000	2880	9.2	108.69
3	2000	2520	9.4	106.38
4	2000	2160	9.8	102.04
5	2000	1800	10.0	100
6	2000	1440	11.9	84.03
7	500	1080	12.8	78.125
8	500	720	18.6	53.76
9	500	360	49.9	20.04
10	500	0	0	0

Table11. Readings-set 2 (clockwise rotation).

Sr. No.	Volume (ml)	Angle of rotation (degree)	Time (second)	Discharge (mlps)
1	500	0	0	0
2	500	360	59.2	16.80
3	500	720	17.2	58.14
4	500	1080	13.2	75.75
5	2000	1440	12.8	78.12
6	2000	1800	10.5	95.23
7	2000	2160	10.0	100
8	2000	2520	9.7	103.09
9	2000	2880	9.6	104.16
10	2000	3000	9.2	108.69

Table12. Readings-set 2 (anticlockwise rotation).

Sr. No.	Volume (ml)	Angle of rotation (degree)	Time (second)	Discharge (mlps)
1	1000	3000	9.2	108.69
2	1000	2880	9.5	105.26
3	1000	2520	9.7	103.09
4	1000	2160	10.1	99
5	1000	1800	10.4	96.15
6	1000	1440	12.5	80
7	1000	1080	12.9	77.51
8	1000	720	17.9	55.86
9	1000	360	53.8	18.58
10	1000	0	0	0

Table13. Readings-set 3(clockwise rotation)

Sr. No.	Volume (ml)	Angle of rotation (degree)	Time (second)	Discharge (mlps)
1	1000	0	0	0
2	1000	360	61.2	16.33
3	1000	720	17.4	57.47
4	1000	1080	13.6	73.53
5	1000	1440	12.5	80
6	1000	1800	10.8	92.59
7	1000	2160	10.2	98.04
8	1000	2520	9.4	106.38
9	1000	2880	9.1	109.89
10	1000	3000	8.5	117.64

Table14. Readings-set 3 (anticlockwise rotation).

Sr. No.	Volume (ml)	Angle of rotation (degree)	Time (second)	Discharge (mlps)
1	2000	3000	8.8	113.63
2	2000	2880	9.2	108.69
3	2000	2520	9.5	105.26
4	2000	2160	10.3	97.08
5	2000	1800	10.5	95.23
6	2000	1440	12.3	81.30
7	500	1080	13.3	75.18
8	500	720	17.7	56.49
9	500	360	58.3	17.15
10	500	0	0	0

After the 3 sets of pilot readings in clockwise and anticlockwise direction we have observed the discharge is almost same for the same position of disc of gate valve. In simple words for same angle of rotation discharge is almost same. By keeping 60^0 as interval one more set of clockwise and anticlockwise readings is recorded as follows:

Table 15. Opening of the gate valve (clockwise).

Sr. no.	Volume (ml)	Angle of rotation (degree)	Time (second)	Discharge (mlps)
1	1000	0	0	0
2	1000	60	0	0
3	1000	120	0	0
4	1000	180	370.1	2.70
5	1000	240	141.5	7.08
6	1000	300	88.2	11.33
7	1000	360	55.3	18.08
8	1000	420	49.1	20.36
9	1000	480	35.2	28.40
10	1000	540	27.8	35.97
11	1000	600	25.2	39.68
12	1000	660	22.2	45.04
13	1000	720	17.5	57.14
14	1000	780	16.9	59.17
15	1000	840	14.9	67.11
16	1000	900	14.8	67.56
17	1000	960	14.5	68.96
18	1000	1020	13.5	74.07
19	1000	1080	13.3	75.19
20	1000	1140	12.9	77.51
21	1000	1200	12.9	77.51
22	1000	1260	12.8	78.12
23	1000	1320	12.8	78.12
24	1000	1380	12.7	78.74
25	1000	1440	12.2	81.96
26	1000	1500	12.3	81.30
27	1000	1560	12.1	82.64
28	1000	1620	11.8	84.74
29	1000	1680	11.6	86.20
30	1000	1740	11.3	88.49
31	1000	1800	10.8	92.59
32	1000	1860	10.8	92.59
33	1000	1920	10.7	93.46
34	1000	1980	10.7	93.46
35	1000	2040	10.6	94.34
36	1000	2100	10.2	98.64
77	1000	2160	10.1	99.00
38	1000	2220	10.5	95.24
39	1000	2280	10.3	97.08
40	1000	2340	10.1	99.00
41	1000	2400	9.9	101.01
42	1000	2460	9.8	102.04
43	1000	2520	9.7	103.09
44	1000	2580	9.6	104.17
45	1000	2640	9.6	104.17
46	1000	2700	9.5	105.26
47	1000	2760	9.3	107.53
48	1000	2820	9.3	107.53
49	1000	2880	9.3	107.53
50	1000	2940	9.2	108.69
51	1000	3000	9.2	108.69

Table 16. Closing of the gate valve (Anticlockwise).

Sr. no.	Volume (ml)	Angle of rotation (degree)	Time (second)	Discharge (mlps)
1	1000	0	0	0
2	1000	60	0	0
3	1000	120	0	0
4	1000	180	378.2	2.64
5	1000	240	140.4	7.12
6	1000	300	88.5	11.3
7	1000	360	56.5	17.7
8	1000	420	50.2	19.92
9	1000	480	36.8	27.17
10	1000	540	28.9	34.60
11	1000	600	26.5	37.73
12	1000	660	21.6	46.3
13	1000	720	18.1	55.24
14	1000	780	16.1	62.11
15	1000	840	15.5	64.51
16	1000	900	14.4	69.44
17	1000	960	13.9	71.94
18	1000	1020	13.7	72.99
19	1000	1080	13.5	74.07
20	1000	1140	13.5	74.07
21	1000	1200	13.3	75.19
22	1000	1260	13.3	75.19
23	1000	1320	13.1	76.34
24	1000	1380	12.9	77.51
25	1000	1440	12.6	79.36
26	1000	1500	12.1	82.64
27	1000	1560	11.9	84.03
28	1000	1620	11.7	85.47
29	1000	1680	11.5	86.95
30	1000	1740	11.3	88.5
31	1000	1800	10.9	91.74
32	1000	1860	11.0	90.90
33	1000	1920	10.9	91.74
34	1000	1980	10.8	92.6
35	1000	2040	10.5	95.24
36	1000	2100	10.3	97.08
77	1000	2160	10.3	97.08
38	1000	2220	10.3	97.08
39	1000	2280	10.7	93.46
40	1000	2340	10.5	95.24
41	1000	2400	10.3	97.08
42	1000	2460	10.3	97.08
43	1000	2520	10.5	95.24
44	1000	2580	9.9	101.0
45	1000	2640	10.1	99.0
46	1000	2700	10.0	100
47	1000	2760	9.9	101.01
48	1000	2820	9.6	104.67
49	1000	2880	9.6	104.67
50	1000	2940	9.5	105.26
51	1000	3000	9.4	106.38

V. Result and Discussion

Graphical presentation of pilot readings of conventional system shows scattered pattern as discharge varies each time due to zone separation. While in case of graph of pilot readings with flexible pipe pattern observed is in close proximity. This shows the negligible change of discharge.

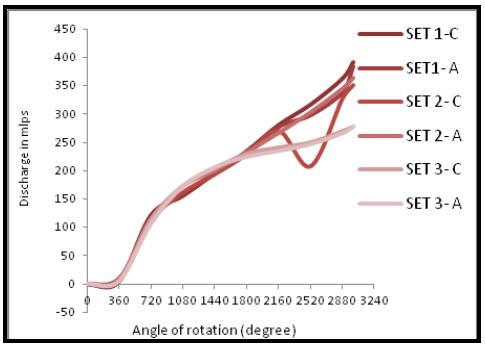

Fig 7. Graphical representation of pilot readings of conventional system.

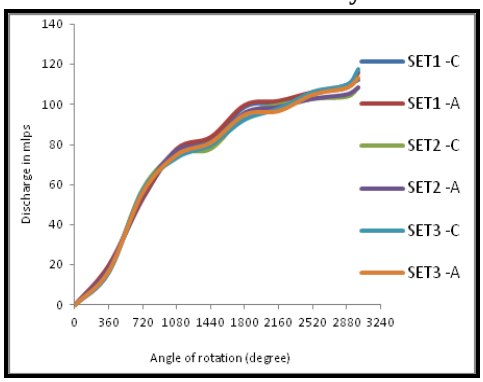

Fig 8. Graphical representation of pilot readings of system with flexible pipe.

Similarly, for the readings taken at an interval of 60^0 the graphical line with flexible pipe shows closer pattern while conventional system is scattered one.

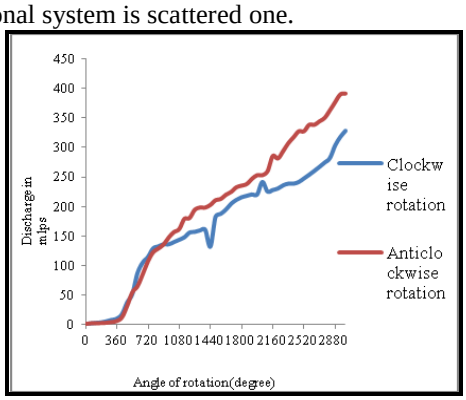

Fig 9. Graphical representation of readings of conventional system.

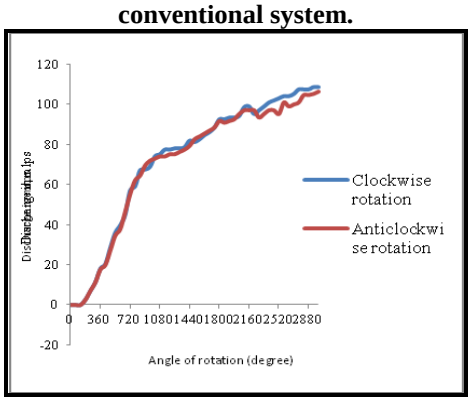

Fig 10. Graphical representation of readings of system with flexible pipe.

After complete analysis of results use of flexible pipe removes the lacuna of use of gate valve and keeps the discharge constant. So gate valve can be used as a flow measuring device.

VI. Acknowledgment

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VII. References

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