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ROLE OF VALVE OPENING RATIO IN THE DESIGN OF FOOT VALVES

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In connection with design and development of foot valves, experiments were conducted at the department of Soil and Water Conservation Engineering on different types of foot valves. It is revealed by the experimental data that the valve opening ratio $\frac{O}{a}$ varies inversely with the coefficient of resistance 'K', and the pressure head loss hf in foot valves. In this paper an attempt has been made to find out the effect of valve opening ratio on head-loss characteristics of foot valves in pumpsets.

Foot valve is a sort of check valve fitted at the base of the suction pipe. The foot valve consists of valve system and a strainer. The foot valve is to perform the following functions *viz.*, (1) to keep the centrifugal pump in primed condition and (2) to check the entry of foreign floating materials into the suction line.

Foot valve manufacturers so far have not been found to supply the headloss information of their products. Normally, some of the reputed manufacturers carry out the relevant hydraulic test of their products.

The testing of foot valves for determining their headloss values in order to identify the low resistance foot valves available in the country is drawing considerable attention from the scientists, research workers and industrialists.

Patel, (1982) conducted experiments on frictional losses in locally manufactured foot valves and found out that a head loss of 10 to 50 cm was experienced in flap type foot valves. The senior author felt that the important factors affecting the frictional loss were (a) strainer opening' (b) valve opening and (c) shape of the dome or bell mouth and that the foot valve must have strainer area about 2.5 to 3 times the cross sectional area of the suction pipe.

Patel (1984) correctly diagonised the causes of pressure loss in the foot valve. The principal factor for the loss is the flap or valve opening area. When the valve opening area is larger than the throat or suction pipe area there would be convergence of flow and for the reverse there will divergent flow. As known from the hydraulics, the loss in the divergent flow would be more than in the convergent flow. The values of the head loss were 0.1 to 0.13 m in the convergent flow and 0.22 to 0.23 m in the divergent.

Patel and Bhattacharya (1985) analysed that the total head loss in a

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foot valve would be of the one at the stainer and the loss due to sudden contration of flow at the foot valve throat.

A sample survey conducted by Government of Tamil Nadu in Chingleput district to study and identify the defects in the installation of pump sets as part of energy audit, revealed that 80 per cent of pump-sets consumed more energy than needed. The pressure loss in the conventional foot val 1 to 1.5 m. By reducing this loss to 0.4or 0.5m in about 1 lakh pump sets operating in the whole of Tamil Nadu it is possible to save energy worth of Rs. 36 million per annum. A study was, therefore, conducted with locally available foot valves to identify the important parameters that govern the pressure loss of a foot valve.

MATERIALS AND METHODS

In the course of the experiments, the water was pumped from the sump with a five horse power centrifugal pump and recirculated back. The suction pipe line was 3" in diameter and delivery 2 1/2". A pressure tapping has been made in the suction pipe line just above the foot valve and was connected the to the limb of manometer with the other end being open to atmosphere. The manometric liquid used was mercury. The discharge pumped out was metered by actually collecting in a tank. The pressure loss in the foot valve was observed on the manometer.

An equation was obtained to workout the pressure loss using the observed data. Considering two points for this purpose, one at the entrance to the foot valve and the other at the outlet of the foot valve and applying Bernoullis theroem, we get

$$Ha + x = Hs + \frac{Vs^2}{2g} + hf$$

But $Hs = Ha + H - 13.6 \Delta H - (H - \Delta H) + W' [(H - \Delta H) + y + x]$

That is $Hs = Ha - 13.6 \Delta H + \Delta H$ $(\therefore W' \simeq 0)$

Eliminating Hs and rearranging for hf

$$hf = x + 12.6 \Delta H - \frac{Vs^2}{2g}$$

Where

hf = Headloss due to foot valve, m

x = Submergence of foot valve tapping, m

Hs = Suction head, m

Vs = Suction velocity, m/sec.

W^1 = Weight density of air

ΔH = Differential head in the manometer

In this analysis the weight of the air column from the manometer to the outlet point of the valve was neglected. Hence head loss can be expressed as

$$K \frac{V^2}{2g} = h_f = x + 12.6 \Delta H - \frac{Vs^2}{2g}$$

where 'K' is the resistance coefficient. This resistance coefficient can be determined with the computation of velocity head $\frac{V^2}{2g}$ and the observed pressure head 'h_f'. The experimental details of different foot valves with their valve opening ratio $\left(\frac{O}{a}\right)$ are given in (Table 1).

Table 1. Experimental details of different foot valves with the ratio $\frac{o}{a}$

S.No.	Name	Discharge (Q) m^3/Sec	Velocity (V) m/Sec.	$\frac{V}{\sqrt{gd}}$	Head loss (hf) m	Coefficient of resistance (K)	$\frac{(O)}{a}$ ratio
1.	Fabricated	0.017	5.66	7.2	0.52	0.31	
		0.016	5.33	6.8	0.50	0.34	
		0.014	4.66	5.9	0.45	0.40	2.56
		0.012	4.00	5.1	0.38	0.46	
		0.010	3.33	4.2	0.30	0.53	
		0.009	3.00	3.8	0.26	0.57	
2.	Fabricated	0.018	6.00	7.6	0.64	0.34	
		0.017	5.66	7.2	0.61	0.37	
		0.015	5.00	6.3	0.52	0.40	
		0.013	4.33	5.5	0.50	0.52	2.50
		0.010	3.33	4.2	0.40	0.71	
		0.009	3.00	3.8	0.35	0.77	
3.	Fabricated	0.018	6.00	7.6	0.70	0.38	
		0.017	5.66	7.2	0.67	0.41	
		0.015	5.00	6.3	0.64	0.50	2.41
		0.013	4.33	5.5	0.56	0.58	
		0.011	3.33	4.2	0.50	0.73	
		0.008	2.66	3.3	0.37	1.02	
4.	Gowri	0.017	4.25	5.2	1.55	1.66	
		0.015	3.75	4.3	1.40	1.97	
		0.013	3.25	3.7	1.20	2.26	1.60
		0.010	2.50	2.9	0.94	3.03	
		0.008	2.00	2.3	0.70	3.50	
5.	Green	0.018	4.50	5.2	1.72	1.68	
		0.015	3.75	4.3	1.53	2.15	
		0.014	3.50	4.0	1.40	2.25	1.0
		0.012	3.00	3.4	1.25	2.77	
		0.009	2.25	2.6	0.95	3.80	
6.	DPF	0.018	4.50	5.2	1.90	1.84	
		0.016	4.00	4.6	1.76	2.17	
		0.014	2.50	4.0	1.60	2.58	0.99
		0.011	2.75	3.2	1.31	3.44	
		0.009	2.25	2.6	1.11	4.44	
7.	Synthetic	0.018	4.50	5.2	3.05	2.99	
		0.016	4.00	4.6	2.83	3.49	
		0.015	3.75	4.3	2.75	3.87	0.87
		0.013	3.25	3.7	2.55	4.81	
		0.010	2.50	2.9	2.27	7.32	
		0.009	2.25	2.6	2.15	8.60	

RESULTS AND DISCUSSION

It is clearly noticed from the Table 1 that the valve opening ratio $\frac{O}{a}$ Ratio of valve opening area (O)

to its suction cross section area (a), is one of the important factors affecting the presure loss in the foot valves. From the Table it is seen that the co-efficient of resistance (K) varies inversely with valve opening ratio $\frac{O}{a}$.

In Sl. No. 1, the K value varies from 0.31 to 0.57 for $\frac{O}{a}$ value 2.56 and in Sl. No. 2 it varies from 0.34 to 0.77 for $\frac{O}{a}$ valve 2.50. For $\frac{O}{a}$ value 2.41 the resistant coefficient K, ranges between 0.38 to 1.02 in Sl. No. 3. In Sl. No. 4-the Gowri foot valve, the resistance coefficient varies from 1.66 to 3.50 for value opening ratio 1.6. For the $\frac{O}{a}$ value 1.0, the Gowri foot valves register the K value in between 1.68 to 3.80 in Sl. No. 5. From the Table 1. it is clearly known that the value opening ratio is playing an important role in the determination of head loss in foot valves. As may be seen from the Table (1) the highest pressure loss was observed in synthetic foot valve and the lowest in the case of fabricated foot valve (Sl. No. 1). The increased valve opening ratio $\frac{O}{a}$ will be obtained when the valve opening area (O), is as larger as possible. The larger valve openining area (O) will facilitate smooth entry of water from strainer to the throat section of suction line. The smooth and free entry of water is subjected to less friction and this leads to lesser coefficient of resistance (K). If the valve opening ratio $\frac{O}{a}$ value is less than 1.0 it means that the flow is divergent and if it is grater than 1.0, the flow is convergent both of which are not desirable from the point of view of pressure loss. However, if the ratio is less than 1.0, then the divergent nature of flow will lead to enormous pressure loss, subsequently the K will be very high.

Due to the larger valve opening ratio (ratio of valve opening area to the suction area) the pressure loss could be reduced to 0.3 to 0.5 m from the average value of 1.25 m noticed in the conventional foot valves. By this improved valve opening ratio $\frac{O}{a}$, It is possible to achieve economy in the operation of pumpsets.

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