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'erformance evaluation of hydraulic ram by varying the weight and troke length of waste valve

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Abstract: A hydraulic ram (50 mm x 25 mm) was designed, fabricated and installed using locally available pipes and fittings and with some components which could be easily made. Test was conducted by varying the stroke length and weight of waste valve. The study revealed that the efficiency of hydraulic ram increased with decrease in stroke length of waste valve. It was also found that there is a minimum weight of waste valve corresponding to a certain weight of delivery valve, at which the hydraulic ram functions satisfactorily. The operating range of hydraulic ram was found to decrease with decrease in the weight of waste valve.

Key Words: Hydraulic ram, Stroke length, Waste valve.

ntroduction

In a developing country like India, the ifficulties in conveying electrical energy to emote hilly areas and shortage of petroleum uels have focused the importance of hydraulic am for lift irrigation and rural water supply. n mountainous regions of India, there are numerous ites where hydraulic rams could be installed, hus reducing the human drudgery in carrying ead loads of drinking water along steep hills nd improve the economic conditions of villages hrough irrigation of dry uplands.

Hydraulic ram runs itself, it needs no xternal instigating energy source, it is auomatic, pollution free, simple in construction, ontinuous in operation, requires no lubrication nd supervision, needs less maintenance and vear is minimum. Despite of these merits, hey have not been used widely for irrigation ecause in the past no serious attempt had een made to popularise the ram (Raveendra nd Sheshadri, 1981). Recently, in the wake f power crisis, many of the developed and leveloping countries are giving more importance n popularising the hydraulic ram. Only few tudies have been conducted to optimise various parameters of hydraulic ram. In this study, n attempt is made to fabricate a cheap and conomic model of hydraulic ram by using ocally available materials and also to study he performance of ram by varying the weight nd stroke length of waste valve.

Materials and Methods

The study was conducted at Kelappagi College of Agricultural Engineering and Technology, Tavanur, Kerala. A centrifugal pump was utilised to supply water from a sump to the supply tank of hydraulic ram. During the study, a constant supply head of 1.955 m was maintained. G.I.Pipes having diameter of 50 mm and 25 mm were used as supply and delivery pipes. One end of the supply pipe was connected to the supply tank and the other end to the waste valve. The delivery pipe was connected to the air chamber. A 75 mm diameter GI pipe was used as air chamber. A gate valve was provided in the delivery pipe to control the discharge. The corresponding delivery head was measured using pressure gauge fitted on the delivery pipe. Keeping the delivery head (H_d) constant, the volume of water flowing through the gate valve on the delivery discharge and waste discharge were found out by using the following formula,

$$\text{Delivery discharge } (Q_d) = \frac{V_d}{t} \text{ where,}$$

V_d is the volume of water flowing out through the gate valve on the delivery pipe for a duration of time 't'

$$\text{Waste discharge } (Q_w) = \frac{V_w}{t} \text{ where,}$$

Table 1. Minimum delivery head at which the ram functions

Weight of waste valve (g)	Stroke length of waste valve (mm)	Stroke length of delivery valve (mm)	Minimum delivery head at which ram functions (m)			
			Delivery valve weights (g)			
			185.37	285.37	385.37	485.37
		20	6.25	8.75	*	*
400	42	35	5.25	8.75	*	*
		50	4	9	*	*
		20	5	9	*	*
400	30	35	6	10.75	*	*
		50	5.5	11.5	*	*
		20	5.75	10	*	*
400	20	35	4.5	11	11.9**	12.75**
		50	4.5	11	12.5**	13.5**
		20	4.5	6	12	14.5
500	42	35	4.5	5.5	11.5	14
		50	4	5.5	11	13.5
		20	5	6	14	14.25
500	30	35	4.5	5	12	14
		50	4	4.75	10	13.75
		20	5	7.75	10.5	12.25
500	20	35	4	7	10.8	12.5
		50	3	5	8.5	12
		20	5.5	7	10	12.75
600	42	35	5	5.75	9.8	12.5
		50	4	4.75	8.5	12.25
		20	4	5	9.5	12
600	30	35	4	5	8	11
		50	4	5	8	11
		20	5	6	10.8	14.5
600	20	35	4	6	10.5	14.25
		50	3	4	10	12

* Hydraulic ram did not work

** Hydraulic ram worked for a while, then stopped

V_w is the volume of water flowing through the waste valve for a duration of time 't'.

The general layout of experimental setup is presented schematically in Fig.1 and sectional view of waste valve is given in Fig.2. Provisions were given to change the weight and stroke length of waste valve. In order to study the effect of stroke length of waste valve, three stroke lengths 42 mm, 30 mm and 20 mm were used. Totally three waste valve weights namely 400 g, 500 g and 600 g were used in the present study.

In each set up of the instrument, performance of hydraulic ram was evaluated mainly observing delivery head-delivery discharge relationships. In each case the efficiency (η) was also calculated using the D' Aubuisson's efficiency formula,

$$\text{D' Aubuisson's efficiency } (\eta) = \frac{Q_d H_d}{Q_s H_s} \text{ where,}$$

'upply discharge (Q_s) = $Q_d + Q_w$ and supply 'ead (H_s) = 1.995 m

'esults and Discussion

In order to study the effect of stroke :ngth of waste valve, observations were taken 'y keeping other parameters namely weight 'f waste valve, weight and stroke length of 'elivery valve and volume air chamber constant. Curves showing the variation of delivery discharge 'vith delivery head for different stroke lengths 'f waste valve are given in Fig (3) and Fig 4). The curves showed that there was substantial 'ecrease in delivery discharge with slight increase 1 the delivery head. It was also seen that 1e delivery discharge corresponding to a given 'alue of delivery head, increased with decrease 1 stroke length of waste valve, when all other 'rameters were kept constant. The possible 'xplanation for this is that with the reduction f stroke length, number of strokes per minute ets increased. The time during which the waste alve remained open decreased with decrease 1 stroke lengh of waste valve, which reduced 1e wastewater per each cycle of operation. 'loreover, the number of times the water forced 1to the air chamber increaed and hence the 'elivery discharge increased. The curves show-1g the relation between delivery head and fficiency (Fig.3) revealed that efficiency increased 'vith increase in delivery discharge upto a certain 'oint and after that efficiency decreased slowly 'vith increase of delivery head. It can also 'e seen that the delivery head correspnding 'o maximum efficiency for different stroke lengths 'f waste valve was more or less the same.

At higher delivery head, the time during 'vhich the wase valve off its seat increases nd hence the waste discharge increases (Gibson, 930). The increased wastage will decrease the fficiency. At one stage, when delivery head urther increases, the increase in gain due to 1crease of delivery head is less than the loss 'ue to increase in wastage resulting, a lower fficiency. Also the shock and frictional losses 1 the supply and delivery pipes increase with 1crease in the delivery head. Further, loss f energy due to resilience is proportional to 1e square of delivery head. At higher delivery ead, these losses will be large and hence efficiency ets reduced. Hence efficiency of ram was found to be maximum at moderate delivery head. However in the case of lighter waste valve, the efficiency was continued to decrease with increase in delivery head (Fig.4) upto a certain point and after that ram stopped functioning. For lower weight of waste valve, hydraulic ram stopped functioning comparatively at higher delivery head (i.e. at lower delivery discharge) and operating range of hydraulic ram was found to decrease with decrease in the weight of waste valve. Moreover, for lower weight of waste valve, as stroke length of waste valve decreases, ram was found to operate comparatively in high range of delivery heads. But for a heavier waste valve, hydraulic ram operated even for higher delivery discharge though the corresponding delivery head was small. So to have a large delivery discharge, we must use a heavier waste valve (when all other parameters are constant). The possible explanation for the stoppage of operation of the ram at lower delivery head is at lower delivery heads, the pressure developed in the air chamber will be less than the pressure generated under conditions of higher delivery heads. This means that under lower delivery heads, the delivery valve will open under relatively lower pressure.

The positive water hammer pressure generated by the sudden closure of waste valve will obtain a relief before it attains its maximum value. Magnitude of the consequent negative pressure developed will also be less. Negative pressure developed under low head conditions will not be sufficient to open the waste valve and ram will not work on its own. Under higher delivery head conditions, delivery valve opens after the positive water hammer pressure attains higher value. The consequent negative pressure developed will also be high. This will be sufficient to open the waste valve and the ram will work on its own repeating the cycle. Thus, for the same weight of delivery valve, when the weight of waste valve was increased, the negative pressure developed might be sufficient to open the heavier waste valve and hence the ram functioned smoothly even at lower delivery head and higher delivery discharge. It was also seen that efficiency increaed as the stroke length decreaed. This may be mainly due to the fact that as the stroke length decreases

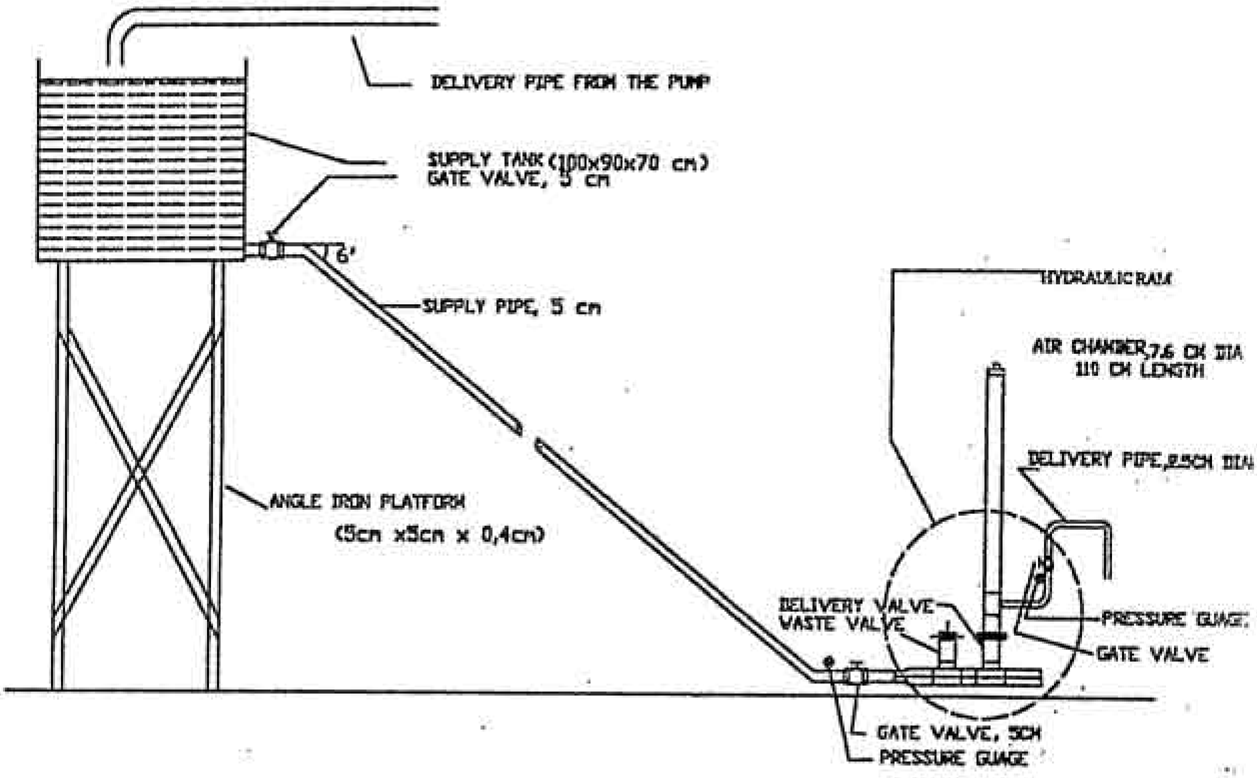


Fig.1 General layout of hydraulic ram

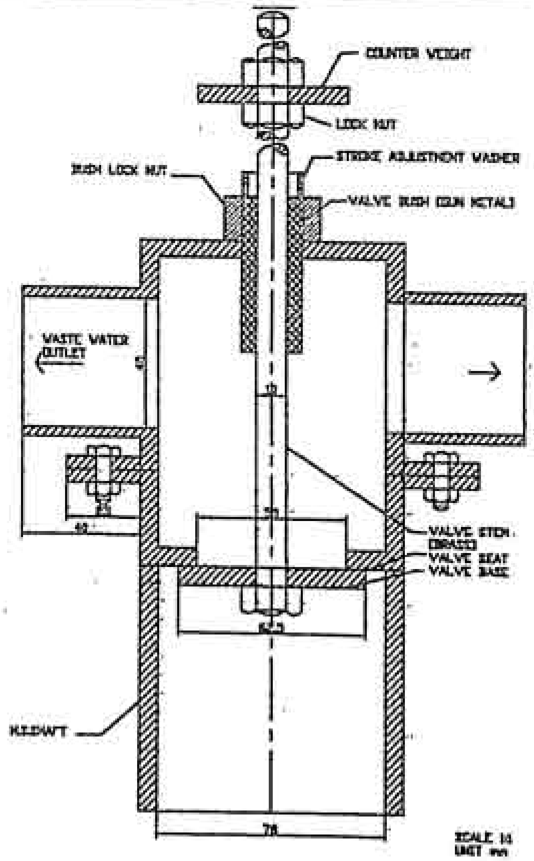


Fig.2 Sectional elevation of waste valve

number of times water forced into the ai chamber for a unit period of time increase and for a particular volume of water washe through waste valve, the delivery discharge ge increased.

From the above discussion, it can b seen that the delivery head of the ram is a important parameter affecting the efficiency Calvert (1958) found that the ratio (H_d/H_s is the most influencing dimensionless paramete on the performance of the ram. But in thi study, supply head was constant and so hea ratio is only a function of delivery head. I was found that the results obtained in the study are also consistent with the findings of Calver on the same aspect.

From the Table 1 it is clear that weigh of the waste valve had also significant effec on the performance of ram. When the weigh of delivery valve was increased from 285.87 g to 387.37g, hydraulic ram was not working smoothly with the waste valve having a weight of 400 g. By increasing the weight of waste valve to 500 g, the hydraulic ram worked

Fig.3 Effect of stroke length of waste valve on the performance of hydraulic ram

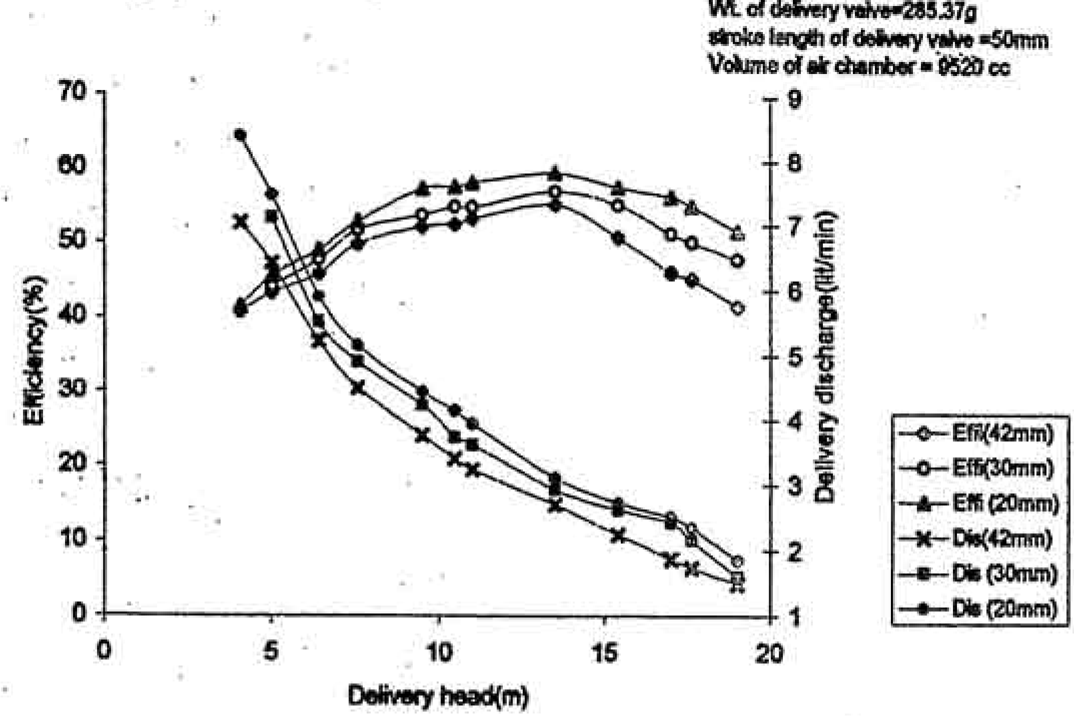
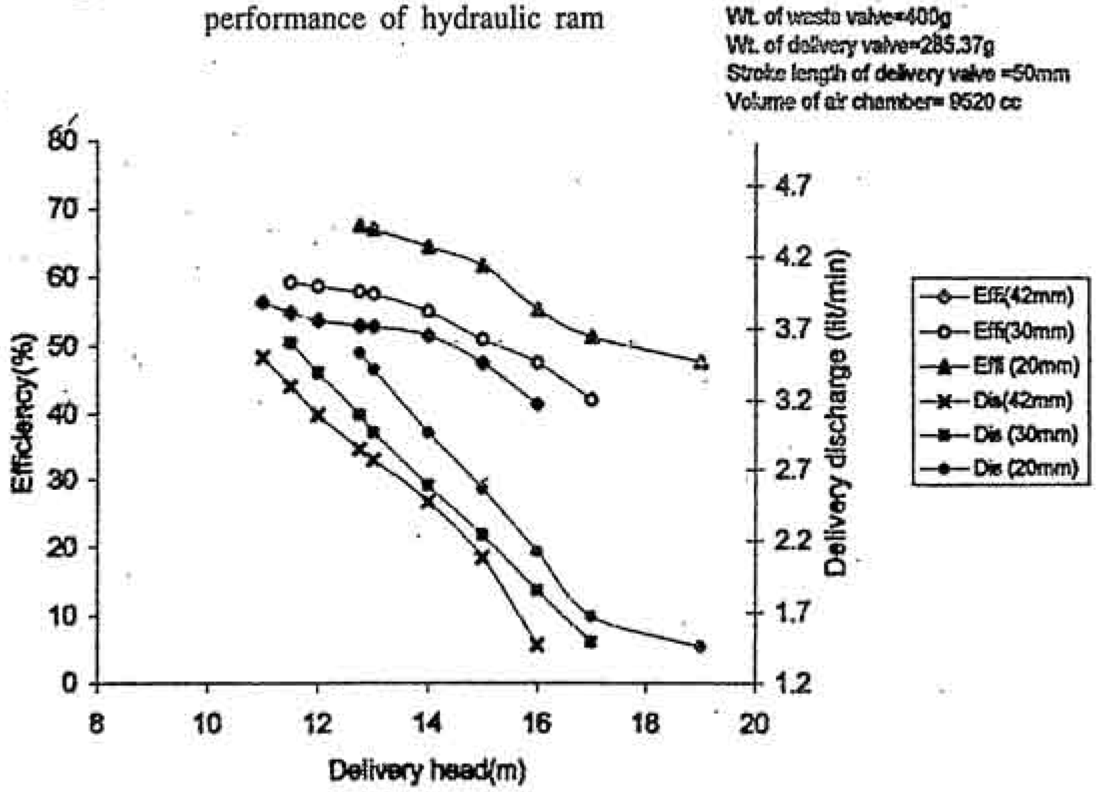


Fig.4 Effect of stroke length of waste valve on the performance of hydraulic ram



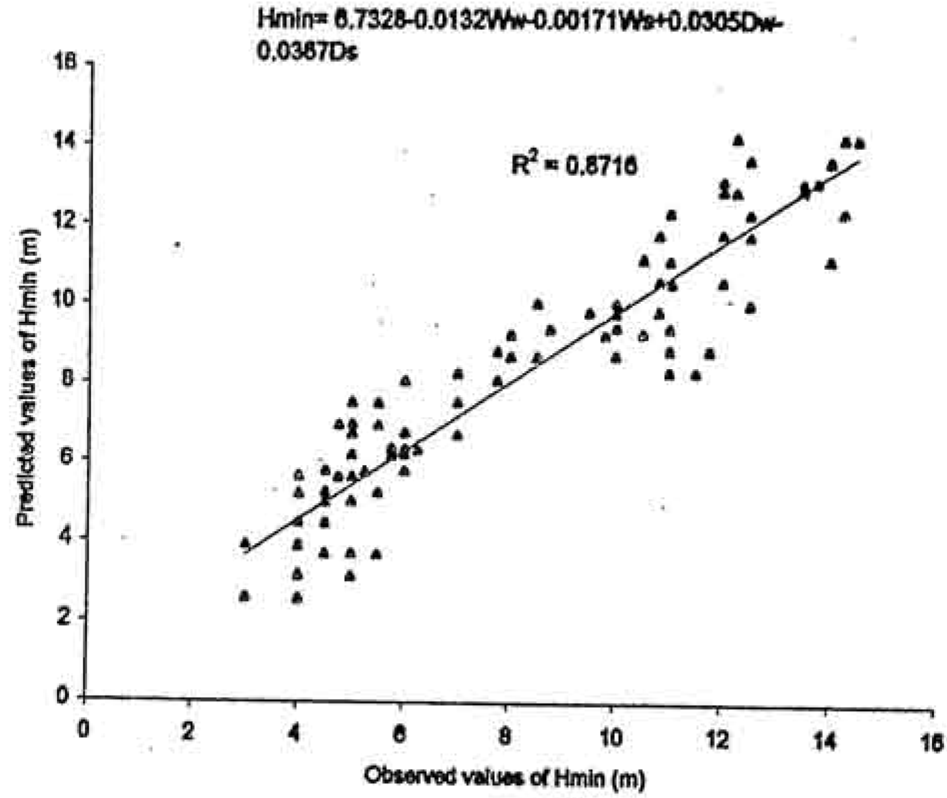


Fig.5 Observed versus predicted values of minimum delivery head

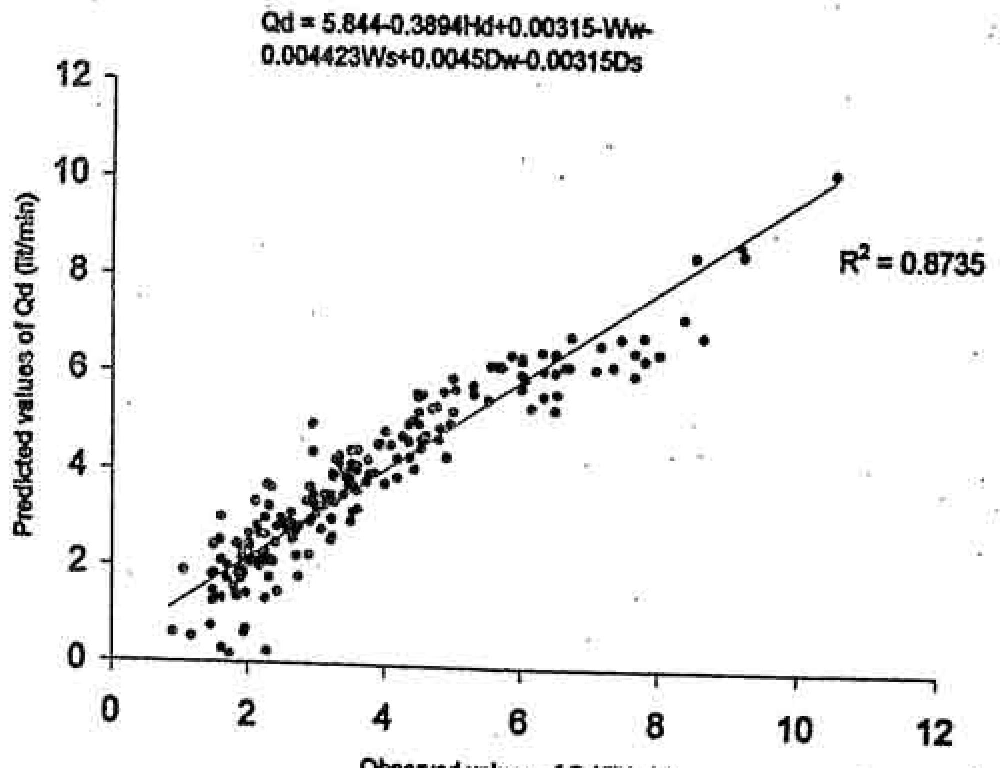


Fig.6 Observed versus predicted values of delivery discharge

moothly even with the heavier delivery valve. he result indicates that corresponding to a ertain weight of delivery valve, there is a inimum weight of waste valve at which hydraulic m functioned satisfactorily.

Multiple regression analysis was done for e data obtained on the minimum delivery ead for the different combinations of weight nd stroke length of both waste valve and elivery valve and an equation was developed hich is given below:

$$H_{min} = 6.7328\text{-}0.0132\ W_w - 0.00171\ W_s\ \ 0.0305\ D_w - 0.0367Ds$$

Where H_{min} = the minimum delivery head which ram operates, W_w = the weight of e waste valve, W_s = the stroke length of aste valve, D_w = the weight of the delivery alve, D_s = the stroke length of delivery valve. he regression analysis showed that the minimum elivery head at which ram operates has a gnificant influence on weight of both waste alve and delivery valve and the stroke length f the delivery valve but not the stroke length f the waste valve.

For the data presented on the delivery ischarge for the different combinations of weight nd stroke length of both waste valve and elivery valve and delivery discharge, a multiple egression analysis was done and an equation vas developed.

$$Q_d = 5.844\text{-}0.3894\ H_d\text{+}0.00315\ W_w\text{-}0.004423\ W_s + 0.00454\ D_w - 0.00315\ D_s$$

Where Q_d = delivery discharge, H_d = lelivery head. From the regression analysis, t was observed that all the independent variables xcept stroke length of both waste valve and lelivery valve were found to have significant influence on delivery discharge. This indicates that weight of waste valve has significant influence both on the delivery discharge and smooth operation of hydraulic ram. It also specifies that even though the delivery discharge corresponding to a given delivery head increases with decrease in stroke length of waste valve, that increase is not significant. The equation indicates that discharge of hydraulic ram increases with increase in weight of both waste valve and delivery valve, whereas it decreases with increase of stroke length of both waste valve and delivery valve. The curves showing the predicted versus observed values for the minimum delivery head and delivery discharge is shown in fig. 5 and fig. 6 respectively.

Conclusions

From the study, it may be concluded that with increase in delivery head there is substantial decrease in delivery discharge. The efficiency of the hydraulic ram was found to increase with decrease in stroke length of waste valve and weight of waste valve has significant effect on delivery discharge, the smooth operation and operating range of hydraulic ram.

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