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Design of Experimentation for Developed Hydraulic Ram pump

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Abstract: In this paper, for new developed Hydraulic Ram pump actual experimental data is recorded and executed as per the approach suggested by Hilbert Schenk Jr.also proper implementation of path of experimentation along with various dependent and independent parameters are identified. Reduction of various variables using dimensional analysis, test planning, design of experimental set-up etc is described in detail.
Keywords: Hydraulic Ram pump, Path of experimentation, dimensional analysis, test planning, independent parameter

I. INTRODUCTION

Design of experimentation is a path for experimentation. Design of experiments (DOE) is a systematic method to determine the relationship between factors affecting a process and the output of that process. In other words, it is used to find cause-and-effect relationships. This information is needed to manage process inputs in order to optimize the output.

A. Development of New Simple Flapper type hydraulic ram pump

After research & brain storming, the new design of hydram is proposed. These new type of ram pump consists of two moving parts, the bronze flapper valve and ball delivery valves. The construction, basically consist of pipe fittings of suitable designed size. The main parameters to be considered in designing these type of hydraulic ram is as follows- Suction head, Diameter of suction pipe, Length of suction pipe, Diameter of flapper waste valve(bronze),Dimensions of non-returning valve(NCL ball type),Diameter of air column, Length of air column ,Delivery head In these type of hydram machine, two different machines of input suction diameters are consider & fabricated which are mention as PVC(plastic)Ram pump, they are as follows-:

B. 25.4mm Flapper PVC (Plastic) ram pump,

Dimensions & Specifications

1) Suction pipe diameter= 25.4mm, Length=3657.6mm
2) Flapper(bronze) Waste valve diameter=25.4
3) Flapper(bronze) Non-returning valve(NRV) diameter= 25.4m
4) Air column of various diameters like 50.8mm, 63.5mm,76.2mm,101.6mm with various lengths
5) Delivery pipe diameter=15mm,

C. 50.8mm Flapper PVC(Plastic) ram pump

Dimensions & Specifications

1) Suction pipe diameter=50.8mm ,
2) Length=4084.3mmFlapper(bronze) Waste valve diameter=50.8mm
3) Ball type Non-returning valve(NRV) diameter=25.4mm
4) Air column of various diameters like 50.8mm, 63.5mm,76.2mm,101.6mm with various lengths.
5) Delivery pipe diameter= 25mm

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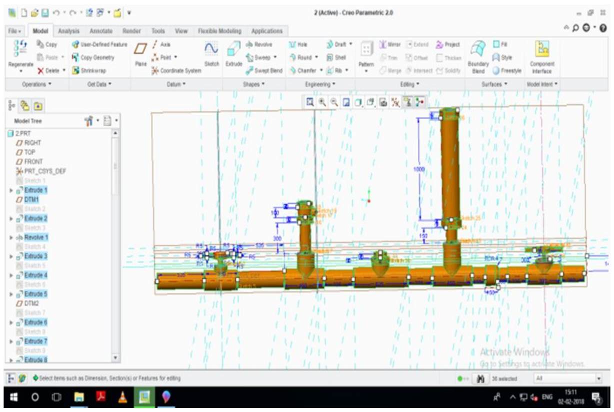

Fig :Cre-o model for hydraulic ram pump

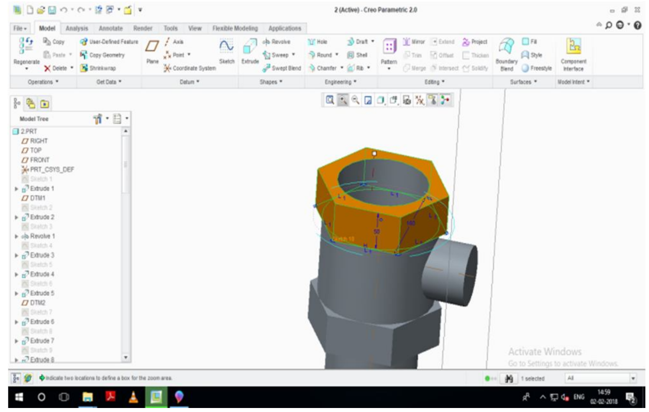

Fig :Cre-o model for waste valve

Fig.:Actual picture of various NRV valves

Hilbert Schenk Jr has discussed two basic theories of experimentations to formulate the experimental data based models or field database models for prediction of behaviour of such complex phenomenon.

II. IDENTIFICATION OF INDEPENDENT AND DEPENDENT PARAMETERS.

Based on experimental set-up & the various input(independent parameter) and output(dependent parameter)are listed in the table below

Table : List of Parameters

SR.NO	Independent parameter	symbol	unit	MLT Term
01	Suction water head(tank)	h	mm	L
02	Diameter of suction pipe	ds	mm	L
03	length of suction pipe	Ls	mm	L
04	Diameter of waste valve	Dw	mm	L
05	Diameter of air column	dA	mm	L
06	Length of air column	LA	mm	L
07	Diameter of delivery pipe	Dd	mm	L
08	Length of delivery pipe	Ld	mm	L
09	Delivery head	Hd	mm	L
10	Density of water	ρw	Kg/mm^3	ML^{-3}
11	Density of pipe material	ρP	Kg/mm^3	ML^{-3}
12	Acceleration due to gravity	g	mm/s^2	LT^{-2}

SR.NO	Dependent parameter	symbol	unit	MLT Term
01	Quantity of water delivered	Qd	mm3/s	$L3T^{-1}$
02	Quantity of water wasted	Qw	mm3/s	$L3T^{-1}$
03	Number of beats of waste valve	N	--	--

III. IDENTIFICATION OF Π TERMS AND DIMENSIONAL ANALYSIS

Dimensional analysis deals with the dimensions of physical quantities. Dimensional analysis reduces the number of variables in a fluid phenomenon by combining the some variables to form non dimensional parameters. Instead of observing the effect of individual parameters the effect of non-dimensional parameters are studied. All physical phenomena is expressed in terms of a set of basic or fundamental dimensions. In fluid mechanics mass (m), length (L), and time (T) or force (F), length (L) and time (T) are considered as fundamental quantities. These two systems are known as MLT system and FLT system. These systems of dimensions are related to Newton's second law of motion

A. Buckingham Pi Theorem

According to this theorem if there are n dimensional variables in a dimensionally homogeneous equation described by m fundamental dimensions they may be grouped in (n-m) dimensionless groups. Buckingham referred to this dimensionless groups as Pi groups. The advantage of this theorem is that one can predict the number of dimensionless groups are to be expected. .

B. Reduction of Variables using Dimensional Analysis and Pi Terms analysis

No. of independent variables = 12

Fundamental variables =3=MLT

Repeating variable =3=g, h, ρ

Π Terms=12-3 = 09

We have $\Pi_1 = (g)^{a_1} (\rho w)^{b_1} (h)^{c_1} ds$

$MLT = (LT^{-2})^{a_1} (ML^{-3})^{b_1} (L)^{c_1} (L)$

For M=0

$MLT = (LT^{-2})^{a_1} (ML^{-3})^{b_1} (L)^{c_1} (L)$

$M = 0 = b_1$, $b_1 = 0$

For L=0

$MLT = (LT^{-2})^{a_1} (ML^{-3})^{b_1} (L)^{c_1} (L)$

$L = 0 = a_1 - 3b_1 + c_1 + 1$

$0 = a_1 + c_1 + 1$----- $(b_1 = 0)$

$c_1 = -1$ ------------- $(a_1 = 0)$

For T=0

$MLT = (LT^{-2})^{a_1} (ML^{-3})^{b_1} (L)^{c_1} (L)$

$L = 0 = -2a_1$

$a_1=0$

so $a_1=0, b_1=0, c_1=-1$

For

$\Pi_1=(g)^{a1}\,(\rho w)^{b1}\,(h)^{c1} ds$

$\Pi_1=(g)^{0}\,(\rho w)^{0}\,(h)^{-1} ds$

$$\boldsymbol{\Pi_1 = ds/h}$$

Similarly

$\Pi_2=Ls/h$ $\Pi_3=dw/h$ $\Pi_4=d_A/h$ $\Pi_5= L_A/h$

$\Pi_6=d_d/h$ $\Pi_7= L_d/h$ $\Pi_8=H_d/h$

For

$\Pi g=(g)^{ag}\,(\rho w)^{bg}\,(h)^{cg}\ \rho_P$

$M^0L^0T^0=(LT^{-2})^{ag}\,(ML^{-3})^{bg}\,(L)^{cg}\,(ML^{-3})$

For

$M=0 \quad = (LT^{-2})^{ag}\,(ML^{-3})^{bg}\,(L)^{cg}\,(ML^{-3})$

$= bg+1$

$bg = -1$

For $L = 0$

$= (LT^{-2})^{ag}\,(ML^{-3})^{bg}\,(L)^{cg}\,(ML^{-3})$

$= ag + cg - 3$ --------------- (as bg=-1,ag=0)

$c_g = 0$

For $T = 0$

$= (LT^{-2})^{ag}\,(ML^{-3})^{bg}\,(L)^{cg}\,(ML^{-3})$

$= -2ag$

$a_g = 0$

So

$\Pi g = (g)^{ag}\,(\rho w)^{bg}\,(h)^{cg}\ \rho_P$

$\Pi g = (g)^{0}(\rho w)^{-1}\,(h)^{0}\ \rho_P$

Reduction of variables

$$\boldsymbol{\Pi g=(\rho_P/\rho_w)}$$

For $\Pi_{1New} = \pi_1\pi_2\pi_3\pi_6\pi_7$

------------------ where $\pi_1\pi_2\pi_3\pi_6\pi_7$ all are Geometric parameters of suction and delivery pipe and waste valve

$\Pi_{1New}= (ds/h)(Ls/h)(dw/h)(d_d/h)(L_d/h)$

$$\Pi_{1New} = \{dsLsdwd_dL_d/h^5\}$$

For $\Pi_{2New} = \pi_4\pi_5$

----------------- where $\pi_{4,}\pi_{5,}$ all are Geometric parameters of Air Column.

$\Pi_{2New}=(d_A/h)\,(L_A/h)$

$$\Pi_{2New}=\{d_AL_A/h^2)$$

For $\Pi_{3New} = \Pi_8$

$$\Pi_{3New} = H_d/h$$

----------------- where π_8 are Geomtic parameters related to water head.

For $\Pi_{4New} = \Pi_g$

$$\Pi_{4New}=(\rho_P/\rho_w)$$

----------------- Density of (machine) material and flowing fluid

so,

$\Pi_{Total} = (\Pi_1\,\Pi_2\,\Pi_3\Pi_4)$ New

therefore

$$\Pi_{01} = f(\Pi_1, \Pi_2, \Pi_3, \Pi_4)$$

$$\Pi_{01} = k_1(\Pi_1)^{a1}(\Pi_2)^{b1}(\Pi_3)^{c1}(\Pi_4)^{d1}$$

$$Qd/\{(\sqrt{g})h^{5/2}\} = k_1\{d_sL_sd_wd_dL_d/h^5\}^{a1}\{d_AL_A/h^2)^{b1}(H_d/h)^{c1}(\rho_P/\rho_w)^{d1}$$

----------------- Qd=Dependent variable and k1,a1,b1,c1,d1=constant, these

values can be find out using "log-Regression" similarly

$$\Pi_{02} = k_2(\Pi_1)^{a2}(\Pi_2)^{b2}(\Pi_3)^{c2}(\Pi_4)^{d2}$$

$$Q_w/\{(\sqrt{g})h^{5/2}\} = k_2\{d_sL_sd_wd_dL_d/h^5\}^{a2}\{d_AL_A/h^2)^{b2}(H_d/h)^{c2}(\rho_P/\rho_w)^{d2}$$

$$N=k3\{d_sL_sd_wd_dL_d/h^5\}^{a3}\{d_AL_A/h^2)^{b3}(H_d/h)^{c3}(\rho_P/\rho_w)^{d3}$$

IV. TEST ENVELOPE & TEST POINTS

Test Envelope are various ranges of measured terms though which various sets of observations are carried out. Test Envelops helps to predefine proper fixed ranges of independent parameters for various dependent parameters for given hydraulic ram pumps are calculated as follows.

Table : Test Envelope

Test Envelope				
Test Envelope	π1=(ds*Ls*dwv*dd*Ld)/h^5	π2=(dA*LA)/ h^2	π3=(Hd/h)	π4=(ρp/ρw)
	π1	π2	π3	π4
	0.000272 to 0.001369	0.0277778 to 0.1388889	1.5 to 2.703325	1.37 to 1.37

Test Points**:** Test points are varied values of test envelops using which various recording of experimentation can be process. test points are various independent parameters differ in fixed range decided by test envelops as follows-

Table: Test Point Parameters

π1=(ds*Ls* dwv*dd*Ld) /h^5	Parameters					
π1	Ds(mm)	Ls(mm)	Dwv (mm)	dd(mm)	Ld(mm)	h(mm)
0.000272	25.4	5303.52	25.4	50.8	2057.4	914.4
0.001369	50.8	4084.32	50.8	63.5	1316.73	

π2=(dA*LA)/h^2	Parameters		
π2	dA(mm)	L_A(mm)	h(mm)
0.0277778	50.8	2057.4	914.4
0.0555556	63.5	1316.73	
0.0622217	76.2	304.8	
0.0833333	76.2	609.6	
0.0999995	76.2	914.4	
0.1111111	76.2	1219.2	
0.125	76.2	304.8	
0.1388889	76.2	609.6	
	76.2	914.4	
	76.2	1219.2	
	76.2	1524	
	76.2	1219.2	
	101.6	512.06	

π3= (Hd/h)	Parameters	
π3	H_d(mm)	h (mm)
1.5	1371.6	914.4
1.666667	1524	
1.833333	1676.4	
2	1828.8	
2.166667	1981.2	
2.333333	2133.6	
2.5	2286	
2.666667	2438.4	
2.703325	2471.92	
π4=(ρp/ρ w)	Parameters	
π4	ρp (Kg/mm^3)	ρw (Kg/mm^3)
1.37	0.000001	0.00000137

Furthermore Sample Size calculation has been done using appropriate formula for experimental database model. Reqired number of observation has been made as per calculation of sampel size which will helps to formulate various statistical models like Exponential model,Log Linear Model.

V. CONCLUSION

In this paper ,for new developed hydraulic ram pumps actual experimental data is recorded and structurized as per the approach of Design of Experimentation. Various Pre-planning for making formulation of standard modeling of parameters of hydraulic ram pump is carried out successfully with proper use of design of experimentation plan

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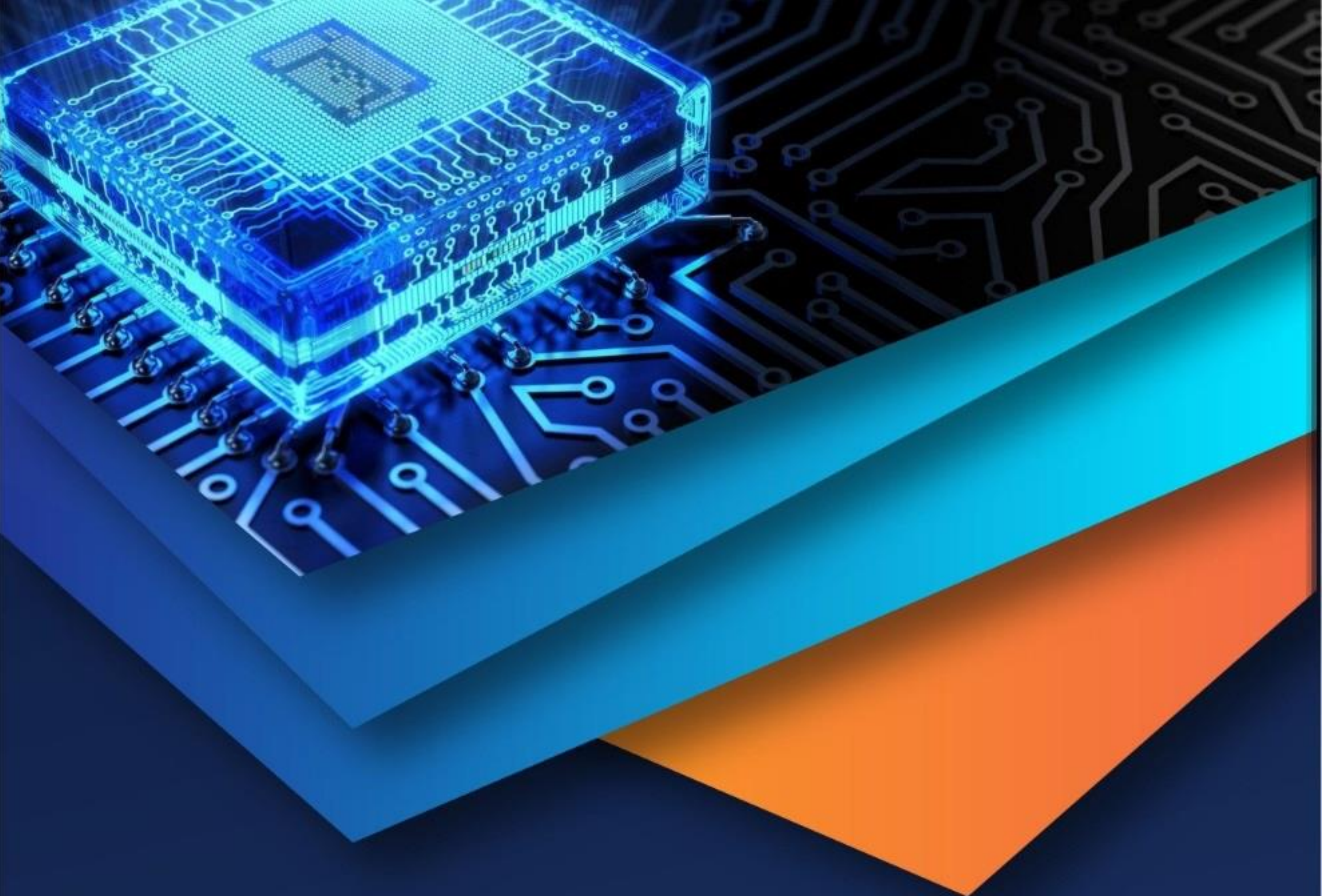

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