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Experimental Validation of Mathematical Model for Vacuum Damped Recoil System

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Abstract: Vacuum damped recoil system is simple and reliable one, to predict the behavior of system the mathematical model is formulated by using the various parameters of vacuum damped recoil system. The parameters identified to formulate the mathematical model are such as recoil time, force, vacuum generated, recoil length and mass of barrel. The mathematical model is formulated for force and recoil time of vacuum damped recoil system. This paper aims at validation of the mathematical model. Experimental setup is developed to validate the mathematical model. Result obtain through the experimental setup is thus used to validate the mathematical mode. The results received validate the mathematical model.
Key Words: Recoil time, Recoil length, Coefficient of correlation, Coefficient of determination, Mathematical model.

I. INTRODUCTION

Recoil system is like a heart of artillery weapons because it plays a decisive role. The firing velocity of artillery weapon is largely depending on the recoil system. Generally the conventional recoil system is consisting of hydraulic and hydropneumatic types, which have more moving parts. In such conventional system the maintenance required is high and time required on the field to reset is large.

Hence here attempt is made to develop simple and reliable recoil system. Vacuum damped recoil system is simple and reliable because it has less moving parts. The behavior of system is predicted by formulating the mathematical model. [3]

The mathematical model developed for recoil time and force of vacuum damped recoil system is as follow –

Recoil time $t = 0.0511 \frac{l}{d}\sqrt{\frac{m_b}{dp}}$ ………… (1)

Force $F = 0.213\ lpd$ …….…………. (2)

Where, l – Recoil length, mm
p – Vacuum pressure, N/mm^2
d – Diameter of cylinder, mm
m_b – Mass of barrel, kg

The validation of these models is done to check whether or not given mathematical models describe a system accurately.

II. EXPERIMENTAL SETUP

An experiment model of vacuum damped recoil system is shown in fig. 1. An experiment model is consist of following main parts –

Pneumatic Cylinder: It is main part of vacuum damped recoil system, in which vacuum is generated.

Vacuum Gauge: it is used to measure vacuum generated in pneumatic cylinder.

Barrel: Is connected to piston rod of cylinder and which is of 2 kg in mass.

Load Cell: Load cell is used to measure force exerted on barrel.

Indicator: Indicator is used to indicate force measured by load cell.

Fig. 1 Experimental Model of vacuum damped recoil system

III. VALIDATION OF MATHEMATICAL MODEL

The validation of mathematical model is done to check correctness of model i.e. to show the value gets from mathematical model is correct and accurate. The validation is carried out to show variation between analytical values which is obtained from mathematical model and experimental values. If the variation between analytical and experimental values is negligible it means that the mathematical model is valid. Here to do validation of model the coefficient of determination is calculated. Coefficient of determination is a statistic that explains the amount of variance accounted for in the relationship between two (or more) variables. Sometime coefficient of determination is called as R-squared (R^2). It is computed as a value between 0 (0 percent) and 1(100 percent). The higher the value, the better the data fit. Coefficient of determination is symbolized by R^2 because it is square of the coefficient of correlation symbolized by R. Correlation studies and measures the direction and intensity of relationship among variables. A high value of R indicates strong linear relationship. The coefficient of correlation for two variables say X and Y is calculated by using following formula-

$$\text{Coefficient of correlation } R = \frac{\Sigma(X-\bar{X})(Y-\bar{Y})}{\sqrt{\Sigma(X-\bar{X})^2}\sqrt{\Sigma(Y-\bar{Y})^2}}$$

Where, $\bar{X} = \frac{\Sigma X}{N}$ and $\bar{Y} = \frac{\Sigma Y}{N}$

N – No. of values of X and Y

∴ Coefficient of determination = R^2

Coefficient of determination is an important tool in determining the degree of linear correlation of variables (‘goodness of fit’).

IV. CALCULATION OF COEFFICIENT OF DETERMINATION

A. *For recoil time*

To calculate the coefficient of determination between experimental and analytical values of recoil time, total fifty readings are taken into consideration. From those readings the following values are calculated.

$\Sigma t = 7.817$, $\Sigma T = 7.663$, No. of total readings N = 50

$$\bar{t} = \frac{\Sigma t}{N} = \frac{7.817}{50} = 0.156$$ and

$$\bar{T} = \frac{\Sigma T}{N} = \frac{7.663}{50} = 0.153$$

Where,

t – Experimental recoil time.

T – Analytical recoil time.

Coefficient of correlation $R = \dfrac{\sum(t-\bar{t})(T-\bar{T})}{\sqrt{\sum(t-\bar{t})^2}\sqrt{\sum(T-\bar{T})^2}}$

$= \dfrac{7.561E-03}{\sqrt{1.004E-02}\sqrt{6.601E-03}}$

Coefficient of correlation R = 0.929

∴ Coefficient of determination $R^2 = 0.863 = 86.3\ \%$

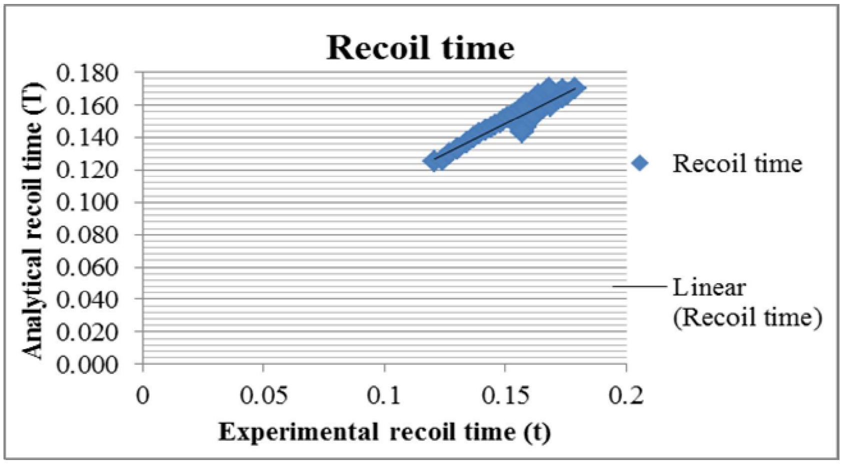

Fig. 2 experimental recoil time vs. analytical recoil time

The coefficient of correlation R = 0.929 is very close to 1 which shows very strong positive relation between experimental and analytical recoil time. From the coefficient of determination $R^2 = 0.863$ (86.3%) it is clear that the experimental and analytical recoil time good fit to each other, hence the mathematical model develop for recoil time is valid.

B. For force

To calculate the coefficient of determination between experimental and analytical values of recoil time, total fifty readings are taken into consideration. From those readings the following values are calculated.

$\Sigma F = 4184.582$, $\Sigma f = 4164.287$, No. of total readings N = 50

$\bar{F} = \dfrac{\sum F}{N} = \dfrac{4184.582}{50} = 83.691$ and

$\bar{f} = \dfrac{\sum f}{N} = \dfrac{4164.287}{50} = 83.285$

Where,

F – Experimental force.

f – Analytical force.

Coefficient of correlation $R = \dfrac{\sum(F-\bar{F})(f-\bar{f})}{\sqrt{\sum(F-\bar{F})^2}\sqrt{\sum(f-\bar{f})^2}}$

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$$= \frac{11781.472}{\sqrt{10404.693}\sqrt{14914.826}}$$

Coefficient of correlation R = 0.946
∴ Coefficient of determination R^2 = 0.895 = 89.5 %

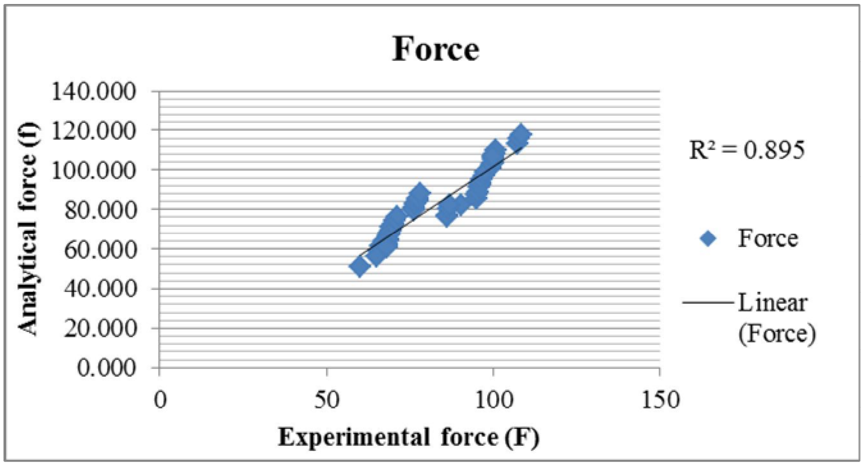

Fig. 3: experimental force vs. analytical force

The coefficient of correlation R = 0.946 is very close to 1 which shows very strong positive relation between experimental and analytical force. From the coefficient of determination R^2 = 0.895 (89.5%) it is clear that the experimental and analytical force good fit to each other, hence the mathematical model develop for force is valid.

V. VACUUM PRESSURE VS. FORCE

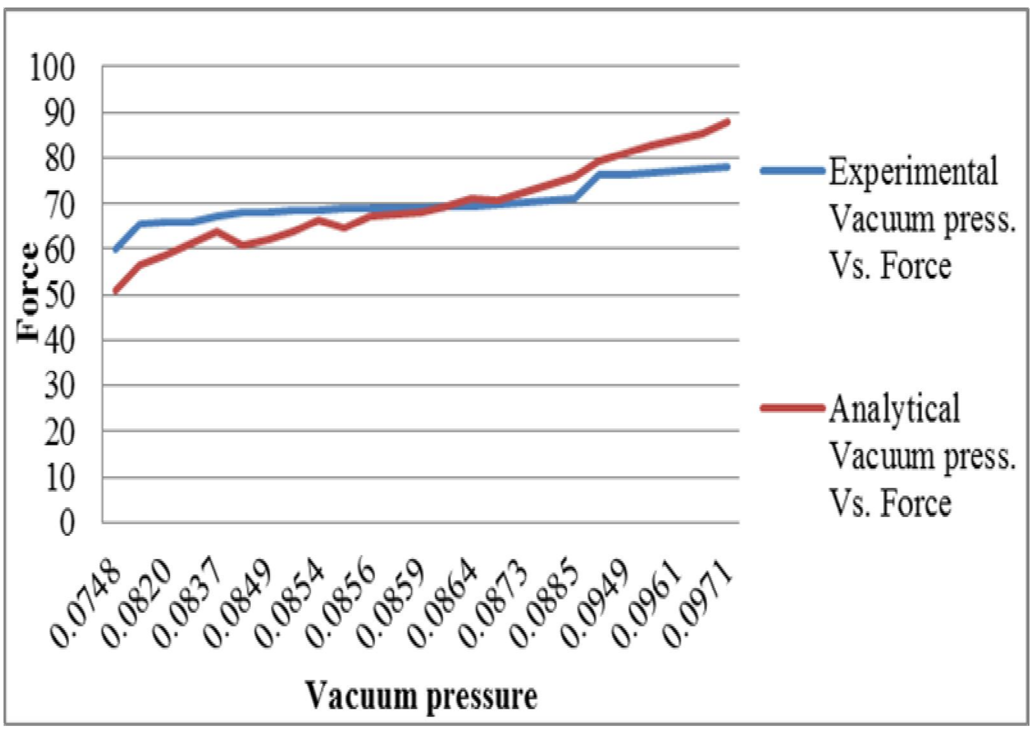

Fig. 4 Vacuum Pressure Vs. Force

From the above chart it is clear that with the increase of vacuum pressure the force required to pull the barrel is goes on increasing. The experimental line and analytical line of vacuum pressure versus force are close to each other which show that deviation between

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experimental and analytical values are negligible. The standard deviation of experimental and analytical force is 4.361 and 9.440 respectively.

VI. VACUUM PRESSURE VS. RECOIL TIME

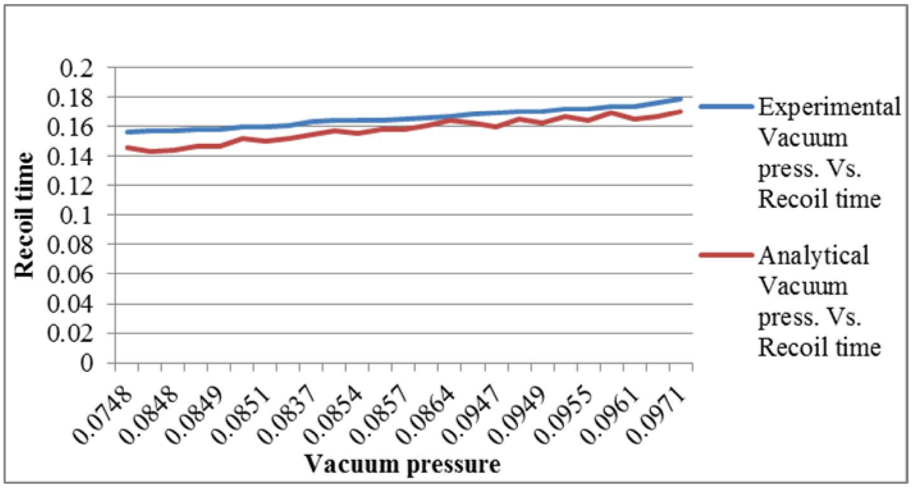

Fig. 5 Vacuum Pressure Vs. Recoil time

From the above chart it is clear that with the increase of vacuum pressure the recoil time is goes on increasing. The experimental line and analytical line of vacuum pressure versus recoil time are close to each other which show that deviation between experimental and analytical values are negligible. The standard deviation of experimental and analytical recoil time is 0.0046 and 0.0081 respectively.

VII.RESULTS

Thus mathematical model is developed for vacuum damped recoil system to calculate recoil time and force.

Recoil time $t = 0.0511 \frac{l}{d}\sqrt{\frac{w}{dp}}$ ………………… (1)

Force $F = 0.213\, lpd$ …………………… (2)

By using equation (1) and (2) recoil time and force can be calculated respectively for vacuum damped recoil system by knowing the other parameters in the equations.

The value of constants k_1 and k_2 in equation (1) and (2) respectively are calculated as 0.0511 and 0.213 respectively.

coefficient of determination R^2 = 0.863 (86.3%) it is clear that the experimental and analytical recoil time good fit to each other, hence the mathematical model develop for recoil time is valid.

coefficient of determination R^2 = 0.895 (89.5%) it is clear that the experimental and analytical force good fit to each other, hence the mathematical model develop for force is valid.

Thus studied the vacuum damped recoil system.

VIII. CONCLUSIONS

Based on analysis of result following conclusion can be draw. Coefficient of determination is an important tool in determining the degree of linear correlation of variables (‘goodness of fit’). The coefficient of determination for experimental and analytical recoil time comes 0.863 and correlation coefficient is 0.929 very close to 1 which interpreted strong positive relation between experimental and analytical recoil time, good fit to each other. In the same way the coefficient of determination for experimental and analytical force comes 0.895 and correlation coefficient is 0.946 very close to 1 which interpreted strong positive relation between experimental and analytical force, good fit to each other. Hence it is concluded that mathematical model formulated for recoil time and force of vacuum damped recoil system is valid, recoil time and force can be calculated using this model very easily by knowing the other parameters in the model. From fig. 4 and 5 is can be seen that profile curve between experimental and mathematical are similar. Hence the mathematical model is validated.

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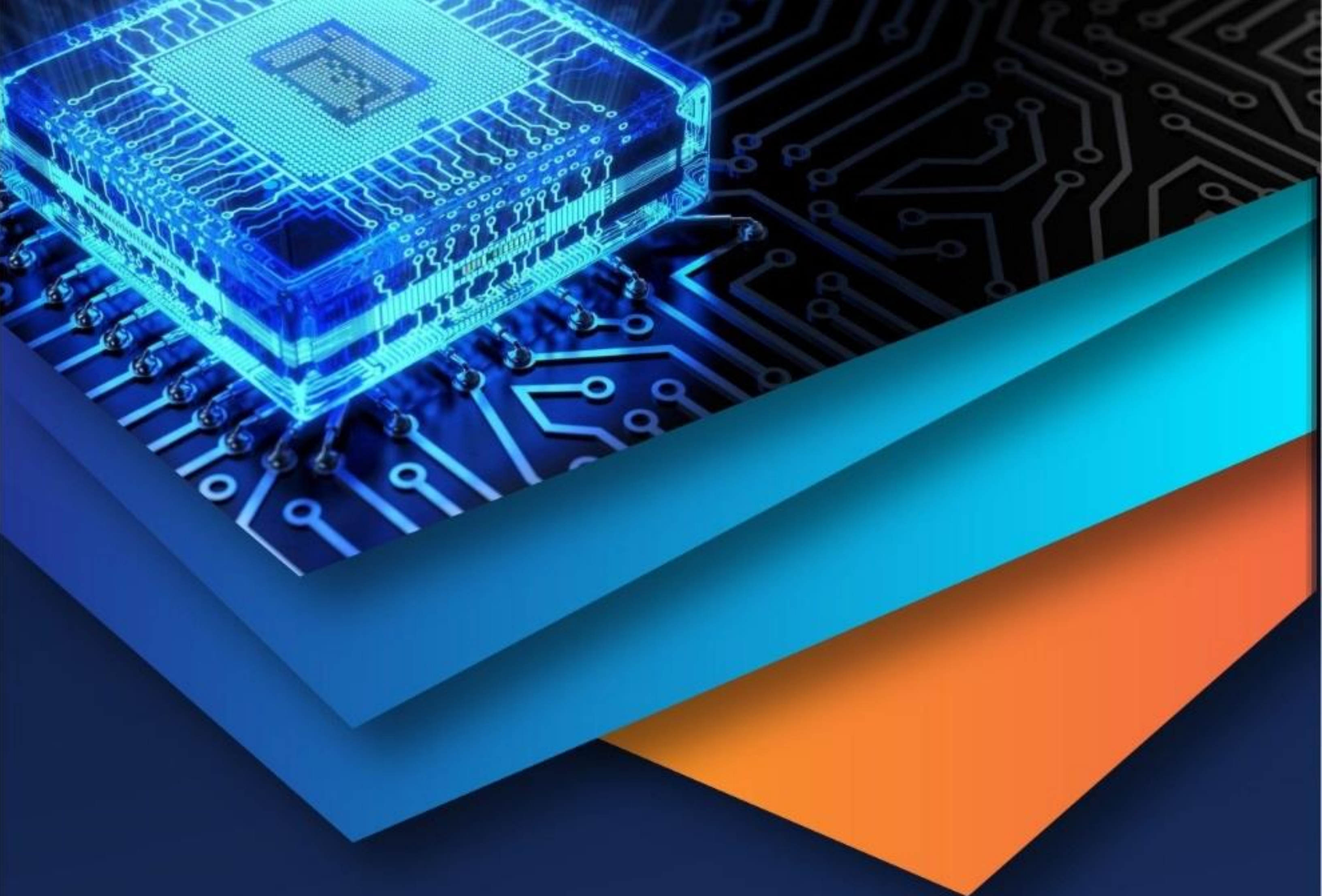

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