Analysis Of Damping Force Of Two Wheeler Front Suspension

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Abstract

The automotive suspension plays a crucial role in vehicle safety and driving comfort. One of the most important components in vehicle suspensions is the damper (or shock absorber). This paper presents a detailed model of a hydraulic shock absorber. The detailed structure includes in the model, are three parameters such as damping hole, suspension velocity, oil viscosity .We analyzed the effect of this three parameters on damping force .The detailed mathematical model is simulated by Minitab14 and simulation results fit experiment data very well this shows that the model can be used to forecast the performance of shock absorber when design

In this investigation, an effective approach based on Taguchi method, analysis of variance (ANOVA), multivariable linear regression (MVLR), has been developed to determine the optimum conditions leading to higher damping force. Experiments were conducted by varying damping hole, suspension velocity, and viscosity using L9 orthogonal array of Taguchi method. The present work aims at optimizing damping force process parameters to achieve high high damping force. Experimental results from the orthogonal array were used as the training data for the MVLR model to map the relationship between process parameters and and damping force the experiment was conducted on two wheeler front suspension. From the investigation

It concludes that suspension velocity is most influencing parameter followed by damping hole and oil viscosity on damping force

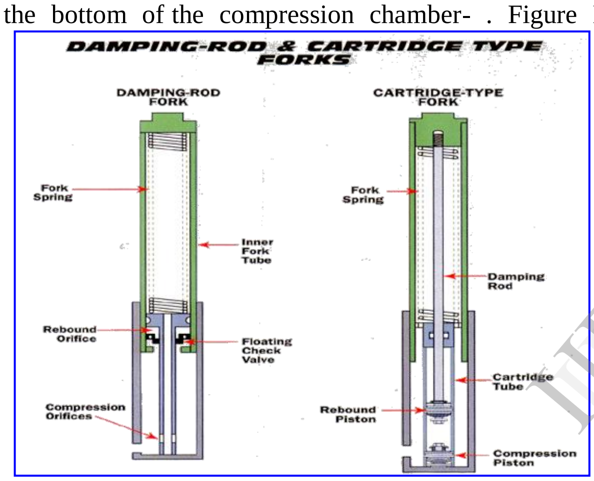
Keywords: ANOVA, Front suspension, MVLR analysis, damping force

1. Introduction

Front suspension of two wheeler, also called as Hydraulic shock absorber (HSA), is one of the most complex components in the automobile suspension system, which plays an important role during the vehicle running [1]. And it can efficiently prevent the relative motion of the sprung and unsprung mass. The front suspension is usually built into the front fork and may consist of telescoping tubes called fork tubes which contain the suspension inside or some multi bar linkage that incorporate the suspension externally A motorcycle fork is the portion of a motorcycle that holds the front wheel and allows one to steer. For handling, the front fork is the most critical part of a motorcycle. The combination of rake and trail determines how stable the motorcycle is. A fork generally consists of two fork tubes (sometimes also referred to as forks), which hold the front wheel axle, and a triple tree, which connects the fork tubes and the handlebars to the frame with a pivot that allows for steering.

There have been several studies are carried out about the shock absorber At first, Lang (1973) proposed a simple mathematical model of the passive shock absorber After that many studies have been carried out to analyze the performance of shock absorber (Stefaan et al, 1997) Cherng et al (1999) reported the noise effects of the shock absorber using acoustic index method Koenraad (1994) proposed a mathematical model of mono- tube type gas charged shock absorber Herr et al (1999) proposed a mathematical model of twin tube type shock absorber Simms et at (2002) investigated the influence of damper properties on luxury vehicle dynamic behavior through the simulation and test Liu et al (2002) reported the characteristics of nonlinear dynamic response for the twin-tube hydraulic shock absorber Nevertheless, there have been few studies carried out about damping force of front suspension of two wheelers

Basically the shock absorber consists of a piston which moves up and down in a fluid-filled cylinder. The cylinder is fastened to the axle or, wheel suspension, and the piston is connected via the piston rod to the frame of' the vehicle. As the piston is forced to move with respect to the cylinder, a pressure differential is developed across the piston, causing the fluid to flow through orifices and valves in the piston. The portion of the cylinder above the piston is known as the rebound chamber, and the portion of the cylinder below the piston is known as the compression chamber. And the volume which surrounds the cylinder is known as the reservoir chamber, The reservoir chamber is partially filled with fluid and partially filled with a gas phase, normally air. The fluid flow between the compression and reservoir chambers passes through the body valve assembly at the bottom of the compression chamber- . Figure I



illustrates the typical configuration of shock absorber

2. Experimental details

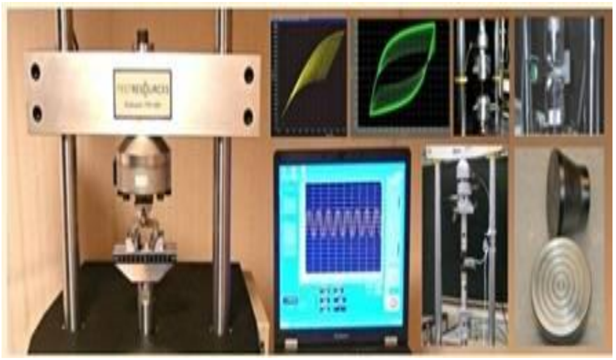
a) Design of experiments: Taguchi and Konishi had developed Taguchi techniques.[8] These techniques have been utilized widely in engineering analysis to optimize the performance characteristics within the combination of design parameters. Taguchi technique is also power tool for the design of high quality systems. It introduces an integrated approach that is simple and efficient to find the best range of designs for quality, performance, and computational cost [9]**.** In this study we have consider 3 factors which affect majorly on quality characteristic such as (A) Damping Dia., (B) Viscosity of oil, (C) Suspension velocity. The design of experiment was carried out by Taguchi methodology using Minitab 14 software. In this technique the main objective is to optimize damping force of front suspension that is influenced by various process parameters

b) Selection of control factors: From the discussion with company peoples strongly felt that front suspension of two wheeler bears a direct relationship with damping force. So that damping forces in N are selected as response parameter for experimentation.

c) Selection of orthogonal array: Since 3 controllable factors and three levels of each factor were considered L9 (3**3) Orthogonal Array was selected for this study

d) Experimental set up: A Series of experiment was conducted to evaluate the influence of front suspension parameters on damping force. The test was carried out on Servo Hydraulic test system Machine for damping force testingThe front suspension is usually built into the front fork and may consist of telescoping tubes called fork tubes which contain the suspension inside or some multi bar linkage that incorporate the suspension externally The experiment was conducted by keeping all other parameter constant. The constant parameters was oil level, clearance between fork pipe and bottom case and other assembly of front suspension

are same



Servo Hydraulic test Machine

e) Work material: Assembly of front suspension of two wheeler selected for experimentation, oil of different viscosity, different damping dia for front suspension and different suspension velocity. Servo Hydraulic test Machine for testing damping force of two wheeler front suspension

f) Weight measurement: Servo Hydraulic applies to systems where the feedback or error correction signals help control mechanical position, speed & other parameters With a servo Hydraulic test system (basically a test system that controls forces & motions) we can do following for suspension components (Shock Absorbers & Front forks):

Sr.No.	Measurement / test	Benefit
1	Damping force Vs velocity characteristics with different velocity ranges from 0.05~2 m/s & waveforms like sine, ramp, sine on sine etc.	Understand the force characteristics & energy damped which decides the riding response/comfort/handling of vehicle
2	Friction forces @ 0.002 m/s velocity	This is imp. parameter which decides life of suspension components.
3	Generate block cycle waveforms for shock absorber/Front fork for actual road data (user defined) from data acquired using data loggers	Validate suspension components for Pave test/bump test/road endurance test on test bench
4	Durability test of suspension components with lateral loads derived from vehicle	To understand life of suspension components in actual vehicle loading conditions

3. Experimental conditions

The experiments were carried out on Servo Hydraulic test system for damping force testing . There are three input controlling factors selected having three levels. Details of parameters and their levels used shown in the table 3.1

Table 3.1: Process parameters and levels

A	Damping Dia.(mm)	1.6	1.8	2
B	Viscosity(c.stoke)	22.93	37	45
C	S-Velocity(m/s)	0.3	0.5	1

Table 3.2: Layout for Experimental Design according to L9 Array

EXP. NO.	A Dia.(mm)	B Viscosity(c.stoke)	C S-Velocity(m/s)
1	1.6	22.93	0.3
2	1.6	37.00	0.5
3	1.6	45.00	1
4	1.8	22.93	0.3
5	1.8	37.00	0.5
6	1.8	45.00	1
7	2.0	22.93	0.3
8	2.0	37.00	0.5
9	2.0	45.00	1

4. Results and Discussion

a) S/N Ratio Analysis- In the Taguchi method, the term 'signal' represents the desirable value (mean) for the output characteristic and the term 'noise' represents the undesirable value for the output characteristic. Taguchi uses the S/N ratio to measure the quality characteristic deviating from the desired value. There are several S/N ratios available depending on type of characteristic: lower is better (LB), nominal is best (NB), or larger is better (LB). Larger is better S/N ratio used here. Larger -the-better quality characteristic was implemented and introduced in this study.

Larger the better characteristic

$$S/N = -10 \log10 (MSD)$$

Where MSD= Mean Squared Division

$$MSD = (1/Y_1^2 + 1/Y_2^2 + 1/Y_3^2 + \cdots\cdots\cdots)/n$$

Where Y1, Y2, Y3 are the responses and n is the number of tests in a trial and m is the target value of the result. The level of a factor with the highest S/N ratio was the optimum level for responses measured. Table 4.1 and Figure 4.1 depict the factor effect on damping force . The higher the signal to noise ratio, the more favorable is the effect of the input variable on the output.

Table 4.1: Summary Report for Different trials conducted during Experimentation

Trial No.	**Damping Force (N)**			**Avg. Damping Force (N)**	**S/N Ratio**
	Trial 1	**Trial 2**	**Trial 3**		
1	2200	2100	2200	2167	61.93
2	2100	2200	2150	2150	61.87
3	2150	2250	2100	2167	61.93
4	2250	2200	2100	2183	62
5	2100	2150	2100	2117	61.74
6	2170	2200	2110	2160	61.99
7	2160	2180	2100	2147	61.86
8	2250	2200	2100	2183	62
9	2190	2230	2100	2173	61.96

Table 4.2Estimated Model Coefficients for SN ratios

Term	Coef	SE Coef	T	P
Constant	52.3483	1.034	50.612	0.000
Dia 1.6	1.9301	1.463	1.320	0.318
Dia 1.8	0.9850	1.463	0.673	0.570
viscosit 22.93	-2.7006	1.463	-1.846	0.206
viscosit 37.00	0.0339	1.463	0.023	0.984
s-veloci 0.3	-9.3672	1.463	-6.404	0.024
s-veloci 0.5	-2.5741	1.463	-1.760	0.221

Summary of Model-

S = 3.103 R-Sq = 97.6% R-Sq(adj) = 90.5%

4.3 Response Table for Signal to Noise Ratios
Larger is better

Level	Dia	Viscosity	s-velocity
1	54.28	49.65	42.98
2	53.33	52.38	49.77
3	49.43	55.01	64.29
Delta	4.85	5.37	21.31
Rank	3	2	1

From the Table 4.1 and Figure 4.1 it is clear that, the optimum value levels for higher damping force are at a damping dia(1.6 mm), viscosity of oil (45 c.stoke), and suspension velocity (1 m/s). Also, for damping force, from it can be seen that, the most significant factor is suspension velocity(C), followed by damping dia (A), and viscosity of oil (B).

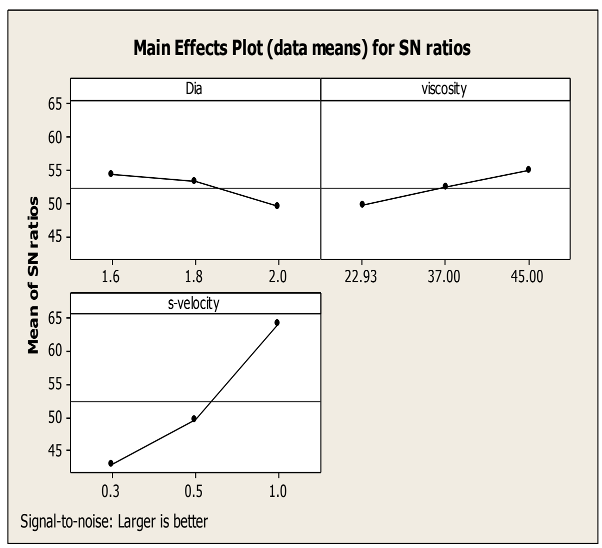


Figure 4.1: Effect of process parameters on S/N Ratio

b) Analysis of Variance (ANOVA): Analysis of variance is a standard statistical technique to interpret experimental results. It is extensively used to detect differences in average performance of groups of items under investigation. It breaks down the variation in the experimental result into accountable sources and thus find the parameters whose contribution to total variation is significant. Thus analysis of variance is used to study the relative influences of multiple variables, and their significance.

The purpose of ANOVA is to investigate which process parameters significantly affect the quality characteristic. The analysis of the experimental data is carried out using the software MINITAB 14 specially used for design of experiment applications. In order to find out statistical Significance of various factors like damping dia (A), viscosity of oil (B), and suspension velocity (C), and their interactions on damping force, analysis of variance (ANOVA) is performed on experimental data. Table 4.2 shows the result of the ANOVA with the damping force . The last column of the table indicates p-value for the individual control factors. It is known that smaller the p-value, greater the significance of the factor. The ANOVA table for S/N ratio (Table 4.4) indicate that, the damping dia (p=0.327), viscosity of oil (p= 0.308) and suspension velocity (p=0.026) in this order, are significant control factors effecting damping force. It means, the suspension velocity is the most significant factor and the damping dia. has less influence on the performance output.

Table 4.4 Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Damping Dia.	2	39.58	39.58	19.791	2.06	0.327
Viscosity	2	43.22	43.22	21.608	2.24	0.308
s-velocity	2	710.90	710.90	355.452	36.92	0.026
Residual Error	2	19.26	19.26	9.628		
Total	8	812.96				

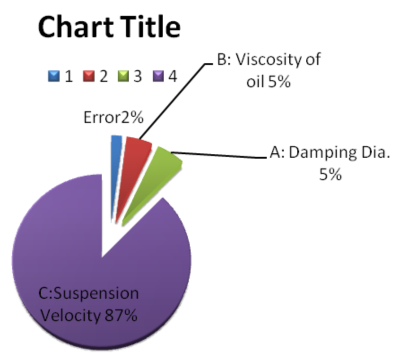
c) Percent contribution-

Percent contribution to the total sum of square can be used to evaluate the importance of a change in the process parameter on these quality characteristics

Percent contribution (P) = (SS'A / SST) *100

Table 4.5: Optimum Condition and Percent Contribution

SR. No.	Factors	Level Description	Level	Contribution (%)
1	A: Damping Dia.	1.6	3	4.87
2	B: Viscosity of oil	45	2	5.32
3	C:Suspension Velocity	1	1	87.44



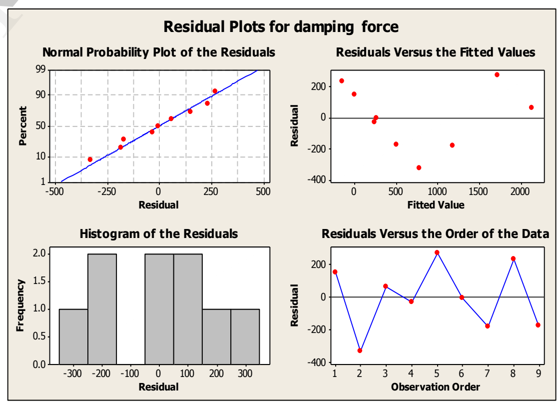


Figure 4.3: Residual Plots for Damping force

d) Regression Analysis- Regression analysis is used for explaining or modeling the relationship between a single variable Y, called the response, output or dependent variable, and one or more predictor, input, independent or explanatory variables Mathematical models for process parameters such as damping dia. , viscosity of oil and suspension velocity were obtained from regression analysis using MINITAB 14 statistical software to predict damping force .

The regression equation is

Y = 615 - 1154*A + 22.4*B + 2361*C

S = 255.616 R-Sq = 93.9% R-Sq(adj) = 90.3%

Where,
Y = Response i.e. Damping Force (N)
A = Damping dia(mm), B = Viscosity of oil (c.stoke),
C = Suspension Velocity (m/s),

If we put optimum parameters which are drawn by ANOVA in equation 1 it will give optimum value of quality characteristic which will maximum Damping force.

Yopt = 615 - 1154*A1 + 22.4*B3 + 2361*C3

Y opt = 615 - 1154* 1.6 + 22.4*45 + 2361*1

Y opt = **2138 N** (Predicted by Regression Equation)

In multiple linear regression analysis, R2 is value of the correlation coefficient and should be between 0.8 and 1. In this study, results obtained from damping force in good agreement with regression models (R2>0.80).

e) Conformation Experiments:

In Order to test the predicted result, confirmation experiment has been conducted by running another four trials at the optimal settings of the process parameters determined from the Analysis i.e. A1B3C3

Observation	Trial 1	Trial 2	Trial 3	Trial 4	Avg. Damping force (N)	S/N Ratio
1	2100	2200	2150	2150	2150	60.62

The results are shown in above table and it is observed that the average Damping force i.e. 66.64 and average S/N Ratio 60.62 which falls within predicted 80% Confidence Interval

5. Conclusions:

The Taguchi method was applied to find an optimal setting of the damping force parameters process. The result from the Taguchi method chooses an optimal solution from combinations of factors if it gives maximized normalized combined S/N ratio of targeted outputs. The L-9 OA was used to accommodate three control factors and each with 3 levels for experimental plan selected process parameters are Damping Dia. (1.6, 1.8, 2 mm), Viscosity of oil (22.93, 37, 45c.stoke), Suspension velocity (0.3, 0.5, 1 m/s). The results are summarized as follows:

- Among three process parameters Suspension Velocity followed by Damping Dia and Viscosity of oil was most influencing parameters on damping force
- The Optimal level of process parameter were found to be **A1B3C3**
- The prediction made by Taguchi parameter design technique is in good agreement with confirmation results
- The result of present investigation are valid within specified range of process parameters
- Also the prediction made by Regression Analysis is in good agreement with
- Confirmation results.
- The optimal levels of Damping force process parameters for optimum Damping force are:

Damping Dia. (mm)	1.6
Viscosity of oil (c.stoke)	45
Suspension Velocity (m/s)	1

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