Effects Of Damping Parameters On Damping Force Of Two Wheeler Front Suspension

Hashmi Ayas Jameel Ahmed
ME Production, Mechanical Engineering Department, Government College of Engineering, Aurangabad

Prof. M. G Rathi
Asst. Professor, Mechanical Engineering Department, Government College of Engineering, Aurangabad

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, OVAT analysis , MVLR analysis, damping force, Servo Hydraulic test Machine

1. Introduction

front wheel suspension assembly for a motorcycle comprising in combination: parallel telescoping forks of the hydraulic type which straddle the front wheel and which are inclined downward in a forward direction, thereby producing a bending moment in said forks with the motorcycle supported in an upright position upon a horizontal surface, each fork comprising an upper tube telescopically mounted within a bottom tube and containing a body of oil, said tubes having continuous cylindrical surfaces in sliding contact and lubricated by said body of oil, a bridge fixed to the upper portions of said upper tubes, means mounting the front wheel for rotation on said bottom tubes, torque receiving means fixed to said bottom tubes, and means including resilient means extending between said bridge and said torque receiving means for applying a counter bending moment to said forks in opposition to the first said bending moment, thereby reducing sliding friction between said telescoping tubes.

Shock absorbers consist of spring which determines posture and cushioning buffer action and a damper which suppresses vibration. On 2-wheeled vehicles, shock absorbers are separated into the categories of the “front fork” and “rear cushion”. The front fork: Front fork serves as rigidity component just like a frame. Vehicle specific rigidity given to present run out while braking and changing the direction of a wheel though handle operations. Maintain balance of vehicle frames stability and secures straight running stability as well as rotationality of the vehicle. The front fork prevents excessive weight on the front wheel during drastic sudden applications the break, softens bumping when driving on rough road surfaces. The front fork maintains proper damping through traction with the road surface

In this investigation we go for maximum Damping force by setting the process parameters at optimum level with the help of Taguchi Design of Experiment. . We are also finding out the contribution of individual factor towards the quality characteristics by using ANOVA analysis. So this study is very much important.

1.1 Suspension system fundamentals

A motorcycle's suspension serves a dual purpose: contributing to the vehicle's handling and braking, and providing safety and comfort by keeping the vehicle's passengers comfortably isolated from road noise, bumps and vibrations

The typical motorcycle has a pair of fork tubes for the front suspension, and a swing arm with one or two shock absorbers for the rear suspension The most common form of front suspension for a modern motorcycle is the telescopic fork. Other fork designs are girder forks, suspended on sprung parallel links (not common since the 1940s) and bottom leading link designs, not common since the 1960s.The suspension has several important functions. They are:

1) Support the weight of the frame, body, engine, transmission, drive train, and passengers. Also called sprung weight.
2) Provide a smooth ride with minimal car body movement.
3) Allow rapid cornering without body roll.
4) Keep the tires firmly planted on the road surface for maximum control at all times.
5) Prevent excessive body squat during acceleration.
6) Prevent excessive body dive during deceleration.
7) Allow the wheels to turn from side to side for steering.
8) Work with the steering system to help keep the wheels in correct alignment.

1.2 Telescopic Front-Suspension Systems

Today's motorcycles, for the most part, use a telescoping, fork-type front suspension. Some early motorcycles used spring-loaded swing arms mounted on stationary tubes to absorb bumps in the road surface. The front fork suspension supports the front wheel and allows it to pivot from side to side for steering by means of a triple clamp, steering head, and stem. Inside the fork tube are one or two springs held in place by a fork cap and fork-slider damping rod. The triple clamp holds the steering damper, if one is included.

Most front forks incorporate telescopic hydraulic shock absorbers to absorb the vertical shock of the front wheel when hitting bumps, thus providing a smooth ride (Figure 1.1. This telescopic motorcycle front-suspension system has been designed to contain a pair of upper-fork tubes containing lower-fork sliders that move into one another. Hydraulic damping is obtained by the transference of oil trapped between the inner- and outer-fork tubes through small holes drilled in the inner fork tube. Some motorcycles use other valve or orifice arrangements to control the transfer of oil, restricting slider movement. The telescopic front suspension system cushions the shock of the front wheel hitting bumps in road surfaces. As the wheel hits a bump, the sliders are pushed upward over the inner-fork tubes and compress the springs. The oil in the outer-fork tube flows through the holes or valves into the inner-fork tube. Since the transfer of oil into the inner fork tube takes up space, trapped air is compressed and the increased air pressure increases oil-flow resistance. This has a damping effect on the shock and limits the upward movement of the outer-fork tubes. As the shock load is relieved, the springs push the slider back to the extended position, and oil is pulled back through the holes (valves) into the vacuum created by the extension of the sliders. The flow of oil is restricted by the size of the holes or valves, and a damping effect is obtained with each movement of the sliders.

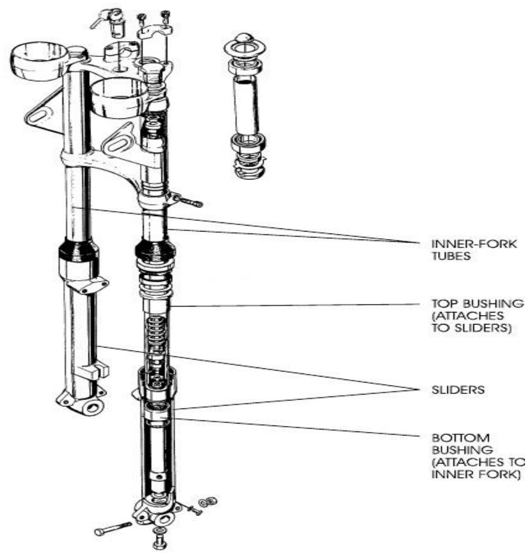


Fig1.1 is a cutaway of a telescopic fork assembly showing the top and bottom-fork bushings

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

c) 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

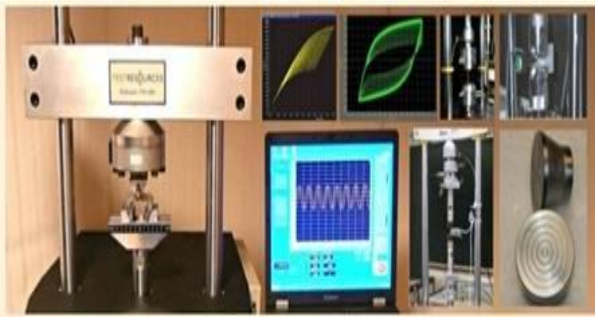


Fig 2.1 Servo Hydraulic test Machine

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

d). 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.

Table 2.1: 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

3. Experimental Analysis

Table 3.1: Layout for Experimental Design with result according to L9 Array

EXP. NO.	A Dia.(mm)	B Viscosity(c.stoke)	C Suspension Velocity(m/s)	Result (damping Force)
1	1.6	22.93	0.3	140
2	1.6	37.00	0.5	450
3	1.6	45.00	1	2200
4	1.8	22.93	0.3	200
5	1.8	37.00	0.5	2000
6	1.8	45.00	1	250
7	2.0	22.93	0.3	1000
8	2.0	37.00	0.5	80
9	2.0	45.00	1	325

a) OVAT analysis of Dia. of damping hole

The level of dia of damping 1.6 mm, 1.8 mm, 2 mm is selected. dia of damping changing and remaining parameter viscosity of oil , suspension velocity putting mean and result damping forces are taken and from table it is clear that as dia of damping increases the damping force decreases .Hence dia of damping is influencing factor on damping force of suspension

Table 3.2 OVAT analysis of dia. of damping hole

Dia of damping hole	Viscosity	Suspension velocity	Result (Damping Force)
1.6	37	0.5	425
1.8	37	0.5	375
2	37	0.5	325

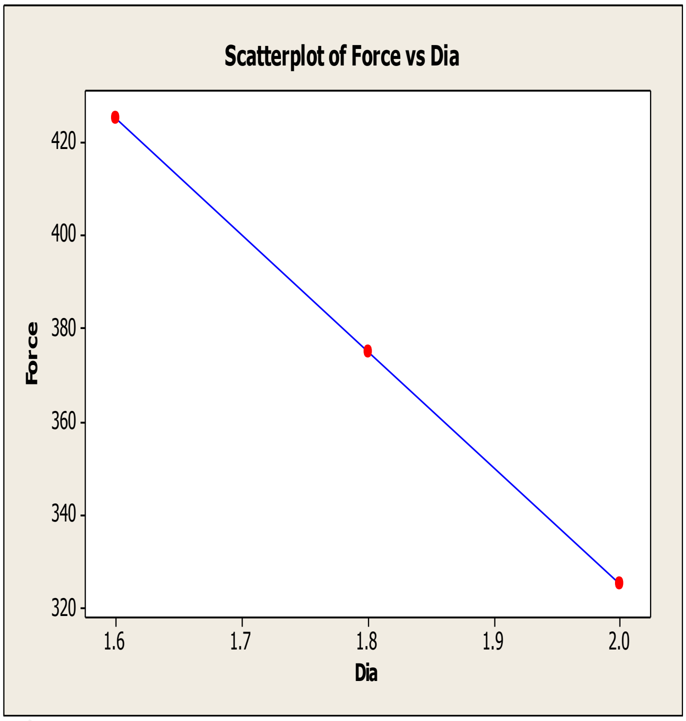


Fig 3.1 Damping force vs. damping dia

b) OVAT analysis of Viscosity of oil

The levels of viscosity of oil 22.93,37,45 (c. stoke) are selected . Viscosity changing and remaining parameter suspension velocity ,dia of damping putting mean and result damping forces are taken and from table it is clear that as viscosity increases the damping force increases .Hence viscosity of oil is influencing factor on damping force of suspension

Table 3.3 OVAT analysis of viscosity of oil

Viscosity (c.stoke)	Suspension velocity(m/s)	Dia of damping hole(mm)	Result(Damping Force)
22.93	0.5	1.8	140
37	0.5	1.8	375
45	0.5	1.8	450

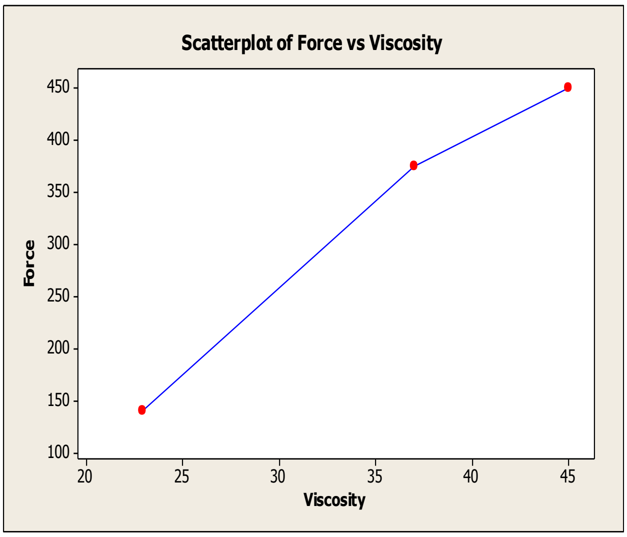


Fig 3.2 Damping force vs. Viscosity

c) OVAT analysis of Suspension Velocity

The level of suspension velocity o.3, o.5, 1 m/s is selected. Suspension velocity changing and remaining parameter viscosity of oil, dia of damping putting mean and result damping forces are taken and from table it is clear that as suspension velocity increases the damping force increases .Hence suspension velocity is influencing factor on damping force of suspension

Table 3.4 OVAT analysis of suspension velocity

Suspension velocity(m/s)	Viscosity(c.stoke)	Dia of damping hole (mm)	Result (Damping Force)
0.3	37	1.8	200
0.5	37	1.8	375
1	37	1.8	1800

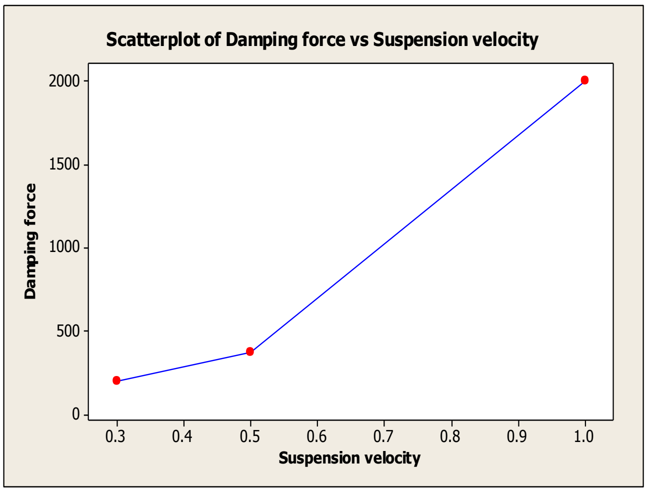


Fig 3.3 Damping force vs. suspension velocity

4. Results and Discussion

The direct influences of damping parameters on damping force have been analyzed in this section. Figures 3.1, 4.3 and 4.4 shows that the process parameter suspension velocity (m/s) has a huge impact on damping force and then comes the damping dia. and oil viscosity . Figure 4.1 depicts that the damping value has shown a continual increase with increase in suspension velocity When suspension velocity is low, the damping force is quite small, which increases with increase in suspension velocity ..

From Figure 4.2 it is clear that the damping force value has shown a continual increase with decrease in damping dia. (mm) When damping dia. is higher than the damping force is quite small, which decreases with increase in damping dia.. When viscosity of oil increases the damping force also increases and damping force decreases with decrease in viscosity of oil

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.

Table 4.1 Estimated 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
viscosity 22.93	-2.7006	1.463	-1.846	0.206
Viscosity 37.00	0.0339	1.463	0.023	0.984
s-veloci 0.3	-9.3672	1.463	-6.404	0.024
s-velocity 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%

Table 4.2 Response 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 4.2 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).

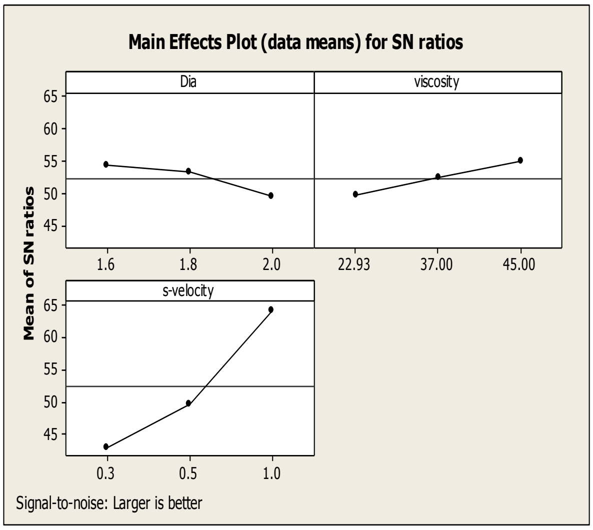


Figure 4.1: Effect of process parameters on S/N Ratio

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
Viscosit y	2	43.22	43.22	21.608	2.24	0.308
s-velocity	2	710.90	710.90	355.45 2	36.92	0.026
Residual Error	2	19.26	19.26	9.628		
Total	8	812.96				

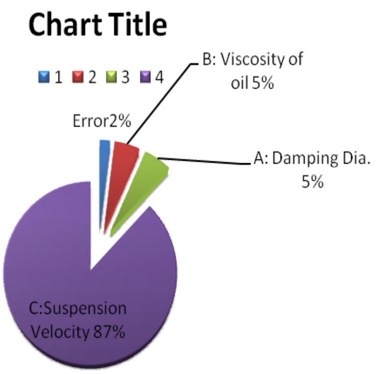
c) Percent contribution-

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 Descriptio n	Leve l	Contributio n (%)
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



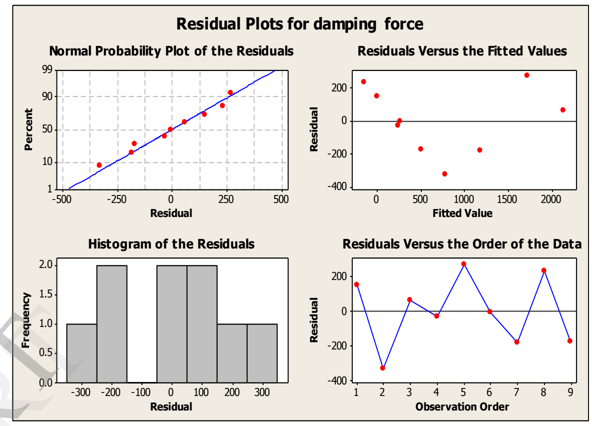


Figure 4.3: Residual Plots for Damping force

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:

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.

In Order to test the predicted result, confirmation experiment has been conducted by running 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. 2150 and average S/N Ratio 60.62 which falls within predicted 80% Confidence Interval

5. Conclusions:

From the whole discussion in suspension system, I observe that suspension system is like a white blood cell . As white blood cell provides energy to our body to fight against diseases or viruses which try to destroy or try to decrease our life ,in the similar way suspension system provides the energy to a vehicle to protect itself from damaging, increasing life of the vehicle ,increases the handing ,increases comfort of passengers and many more. So, according to me if you remove the suspension system, then you feel like in bull- cart in Audi , Mercedes types luxurious cars. The only difference is speed. So, the scope of Suspension System is Too Bright.

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:

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

The optimal levels of Damping force process parameters for optimum Damping force are:

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

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