International Journal of Research in Advent Technology, Vol.6, No.11, November 2018
E-ISSN: 2321-9637
Available online at www.ijrat.org

Quarter model Comparison of Required Force to Deflect Rear Suspension of Various Indian Hatch-Back Cars

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Abstract- Suspension is an essential part of the passenger vehicle, it isolates passengers from road impacts hence provide comfort. Passenger car's rear suspension plays an important role in a comfortable ride of the passengers. Indian hatch-back series car is registered for a capacity of 5 riders in ARAI (Automotive research association of India) This paper represents a rear suspension's reaction of some of the well-known car manufacturers' hatch-back series car performed in ADAMS. An initial data of compression is physically collected with the help of instruments. A calculation of rear suspension spring for its initial deflection, A quarter model analysis of a car and its reaction is included a graphical comparison of different hatch-back series car's rear suspension and its reactions with dynamic loading is also presented. This paper suggests that improvisation in rear suspension is needed attention for better ride comfort. Decrease in active spring length is a major issue to be solved out. This paper concludes that there is not ample amount of active spring length remaining when 5 riders seated in an Indian hatchback car for a comfortable ride.

Index Terms- Indian Hatchback; Car Suspension; Passenger Cars; comparison of existing; suspension; Indian car suspension; hatchback car suspension; deflection limit;

1. INTRODUCTION:

The suspension system of the car plays a crucial role in rider's comfort. Suspension system study is one of the important factors in the field of vehicle design. [1]. The function of a suspension system is to absorb vibration due to irregularities of road conditions. Furthermore, it also designed to maximize the friction between tyre contact patch and the road surfaces to provide vehicle stability under any circumstance associated with accelerating, braking, loaded or unloaded, uneven road, straight line or cornering. It is important to analyze the suspension system properly before implementing it in any passenger or goods carrier. Improper design of suspension system results in poor ride comfort. Some of the researchers have done various studies on the suspension behavior are as under.

Abdel Haleem and Crola defined the design and analysis of a hydropneumatic limited bandwidth of active suspension system. to compare the performance of the proposed suspension with passive and active suspension system, a quarter body of car model is used. [2]. In 2003, Sammier, Sename, and Dugard demonstrated the benefits of semi-active suspension systems over passive suspension. A quarter-body of car model is used to improve the comfort level of the passenger by using an exact nonlinear model of the suspension, via applying H control design strategy [3]. In 2004, Smith and Wang use quarter-body and full-body car models to perform a comparative study of simple passive suspension struts using one damper and inerter[4]. In 2005, Verros, Natsiavas, and Papadimitriou used a nonlinear quarter-body car model which is exposed to random road excitation to present an optimization method for the suspension damping and stiffness parameters [5]. In 2006, the chaos in a quarter- body car model imposed by the road surface was examined by using Melnikov criterion by Litak et. al.[6]. In 2008, A comparative study of a quarter body of car model is presented for the optimal design of vehicle suspension by using three optimization algorithms by Chi, He and Natere. Tire damping was neglected and acceleration of sprung-mass was considered 1m/s2 [7]. In 2010, Gysen et. al. presented A quarter-car model of an electromagnetic active suspension, which provide additional stability and maneuverability in cornering and braking over the application of pitch control and active roll[8]. In 2011, N. Changizi and M. Rouhani study A fuzzy logic method is applied on a quarter - model of car suspension system to control damping of suspension. Results were compared with those uses PID controllers presenting the car dynamics in terms of velocity and displacement. [9]. In 2012, Agharkakli, Chavan, and Phvithran represented a mathematical model for passive suspension and active suspension by using an LQR controller to find out excitation from a road profile via quarter body of the car model. Results were plotted for sprung mass displacement and velocity. [10]. In 2012, Utsav Gadhia and Sumant Patel presented a quarter-body of car model of a passenger car using an ADAMS. They prove the total damping of a wagon-r car is not sufficient to provide comfort for all passengers. Results were plotted for deflections and forces. They neglected the tire damping. [11]. In 2014, Gasemalizadeh et. al. presented a quarter -car model with three -control approaches using MATLAB/Simulink. In comfort-oriented approaches including a power-driven damper, acceleration driven damper and H∞ robust control are used. Tire damping was neglected during the simulation. [12]. In 2014, Tiwari and Mishra presented a quarter -car model to \study active control of a vehicle suspension with PID controls. Tyre damping was neglected during simulation. [13].

2. ANALYSIS OF SUSPENSION SYSTEM:

A quarter body of a car is used in this analysis. Quarter -model of car for a suspension analysis comprises of Spring and damper system. Line diagram of a quarter-body car suspension model is shown in Fig 1 [14]

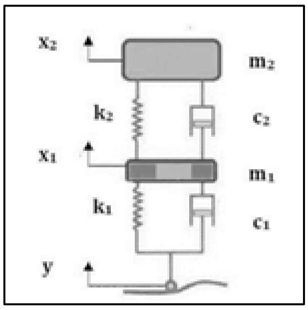

Figure:1 Quarter model of car for analysis.

2.1. Data collection

Based on the physically collected and further calculated data quarter model analysis of various car of car manufacturer Hyundai (India) and Maruti Suzuki (India). Data of 1) Hyundai i-10 (Magna)(P)(2014), 2) Hyundai Santro -GLS(P)(2013), 3) Hyundai i20 Era(D)(2015), 4) Hyundai Grand i10 Sports (P)(2015), 5) Maruti Suzuki Swift Vxi (P)(2016), 6) Maruti Suzuki Alto K-10 Lxi (P)(2016), 7) Maruti Suzuki Wagon-R Lxi (P)(2016), has been collected as shown in table 1.

In Data collection we have first Find out the Kerb weight(w), Total turns(n) and Active turns (n') of spring, Free length of spring (in both suspended condition (L_{fs}) and grounded condition (L_f)). Initial deflection of the rear suspension is gathered by calculation of spring stiffness, damping coefficient of car has been found out by using an equation published

	General Details							Rear suspension data															
Sr. no	Car Maker	Car Name	Kerb Weight (Kg)	KERB Weight acting on rear left spring in (N)	Weght of 4 passanger (considering as per 85 Kg)	Total Force acting on a spring (Kerb +Passenger) (N)	Gross weight (Kg)	Total No of Coil (n')	Total no of Active coil (n)	Free length of coil spring (suspended condition) (in mm) (L_{fs})	Free Length of Coil Spring (Grounded Condition) (in mm) (L_f)	Initial Deflection (δ_i)	Available active length when 2 person seated in car (in mm) (Measured)	Available active length when 4 person seated in car (in mm) (Measured)	Solid length of Spring (Including bush length) (L_s)	Bush Length (in mm) (Measured)	Coil Diameter (in mm) (d)	outer diameter of coil spring (in mm) (Measured)	Mean Diameter of coil spring (in mm) (D)	Spring Index (C)	Distance between Adjacent coil in suspensded condition (in mm) (Measured)	Pitch (in mm) (P)	Spring Stiffness (in N/mm) (K)
1	Hyundai	i-10 Magna	860	1687.3	1668.0	3355.3	1285	7	5	280	200	80	180	158	125.23	49	10.89	133.74	122.85	11.28		49.29	21.09
2		Santro gls	854	1675.5	1668.0	3343.5	1279	7	5	243	175	68	159	137	123.11	55	9.73	97.33	87.6	9.00		40.23	24.64
3		i-20 Era (CRDI)	1058	2075.8	1668.0	3743.8	1483	7	5	304	240	64	225	203	133.4	55	11.2	112	100.8	9.00	47.53	48.45	32.43
5		Grand i-10 Sportz	935	1834.5	1668.0	3502.5	1360	7	5	280	238	42	222	195	127.28	50	11.04	112.2	101.16	9.16	42.7	45.84	43.68
6	Maruti Suzuki	Swift VXI	965	1893.3	1668.0	3561.3	1415	7	5	280	235	45	222	195	127.7	50	11.1	112.5	101.4	9.14	41.92	44.9	42.07
7		Alto K10 Lxi	750	1471.5	1668.0	3139.5	1210	7	5	280	215	65	195	170	132.03	60	10.29	109.6	99.31	9.65	48.73	46.49	22.64
8		Wagon-R Green Lxi	960	1883.5	1668.0	3551.5	1350	6	4	225	170	55	155	140	124.92	60	10.82	133.5	122.68	11.34	47.01	48.02	34.25

Table1: data collection sheet of various cars on the basis of experimental and calculation work

in my previous paper. [15]

Data collection is done for total compression of suspension when two riders seated and later four riders seated in each car for finding out the remaining active length of spring, which proved comfort for fifth passenger. Resulted data will be an input for ADAMS for further calculation and simulation

2.2. Analysis procedure:

A quarter -car body model for all mentioned cars must be analyse with the same input parameter, which makes it easier to compare it for force and deflections. Below mentioned deflections are selected for a particular reason described below

Table 2: bump heights for the analysis car suspension system

Bump height	Description
50	continuous bumps of small height called as rambling strip, Small potholes, unfinished road surface, patchy road surface, etc,
100	Normal bump height, etc,
150	Raised bumps (speed breaker), off-roading, etc.

Table 3: Type of Joints and Degree of Freedom table for quarter -body car model

Links connected with kinematic joints	**Type of joints**	**DOF**
Quarter- body - grounded	Transitional	1
Quarter-body- body support	Fixed	0
Body support- lower support arm	Revolute joint	1
Lower support arm – lower support connects	Fixed	0
Lower support connects- wheel rod	Revolute	1

2.3. Analysis of suspension in ADAMS

Physical parameter of a equation of motion may be calculated, others must only be identified from experiments. [18]. Preparation and analysis of quarter-body car model is performed using a step by step procedure in a my previously published paper [15]. Suspensions are analysed for only quarter part of the body. For stability of quarter- body car model connects with transitional joint for first analysis and ground for further analysis. Connection detail of model is given in table 3 [11]

2.4. Representative model in ADAMS

For the quarter-body car model analysis of each mentioned car's suspension system one demonstrative model has been generated and assembled using joints mentioned in table 2. Assembled model is first verified for the initial deflection and force acting on it and later force and deflection analysis has been performed. Initial deflection and force results verified by comparison with data collected, mentioned in Table1.

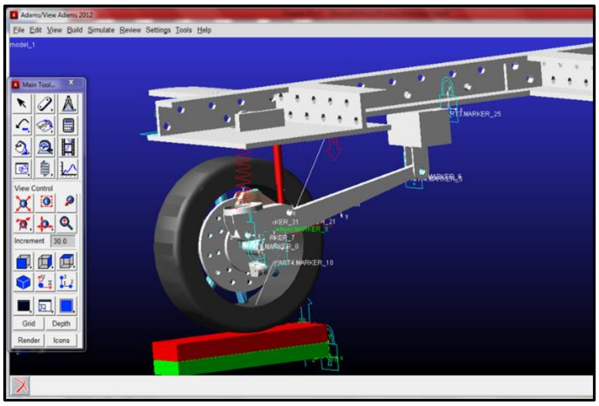

Figure2: Representative model in ADAMS

3. ANALYSIS RESULTS OF QUARTER MODELS:

Results of quarter body of car model is generated for all eight different (mentioned) car according to the collected and calculated data. All mentioned car suspension quarter model is analyzed for 50 mm, 100 mm and 150 mm of deflection for a reason mentioned in Table 1. The resultant graphs of ADAMS simulation software are shown here, which indicates a clear result of force and deflections.

3.1. Force comparison of each car for 50, 100 and 150 mm deflection

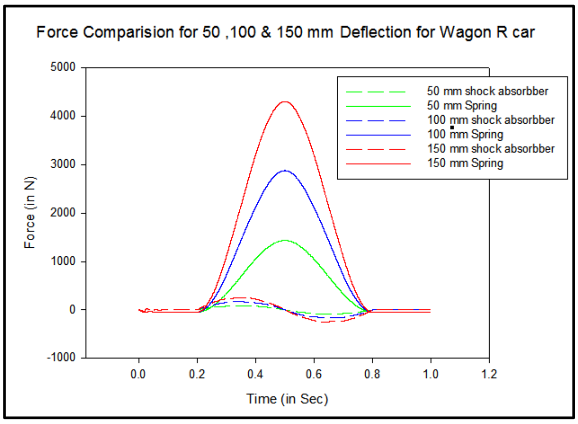

Figure 3: Force comparison of Hyundai i10 Magna (P) 50, 100 and 150 mm of deflection

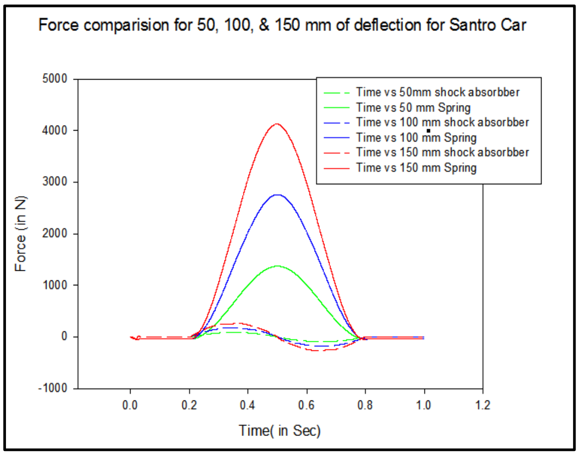

Figure 4: Force comparison of Hyundai Santro for 50,100 and 150 mm of deflection

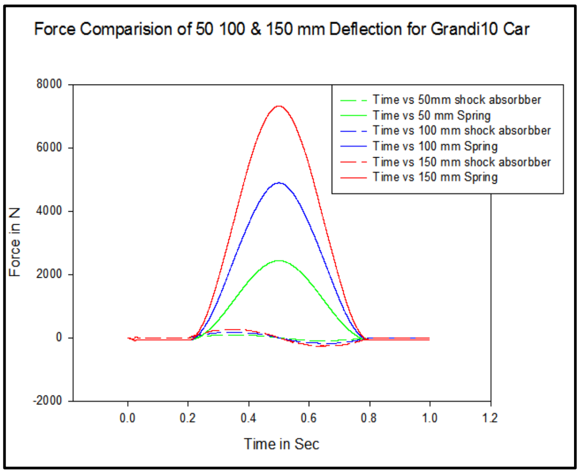

Figure 7: Force comparison of Hyundai Grand i-10 Sports (P) for 50, 100 and 150 mm of deflection

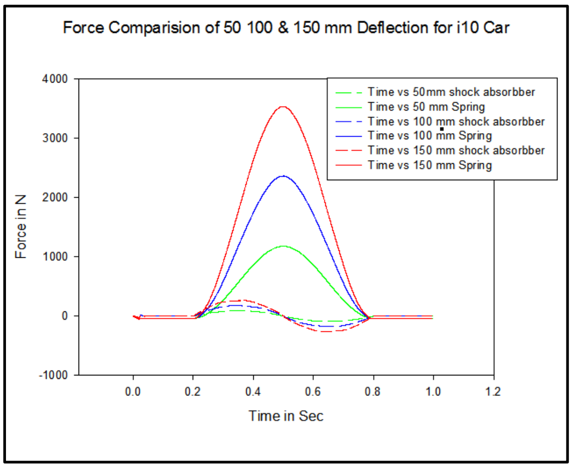

Figure 5: Force comparison of Hyundai i20 Era 50, 100 and 150 mm of deflection

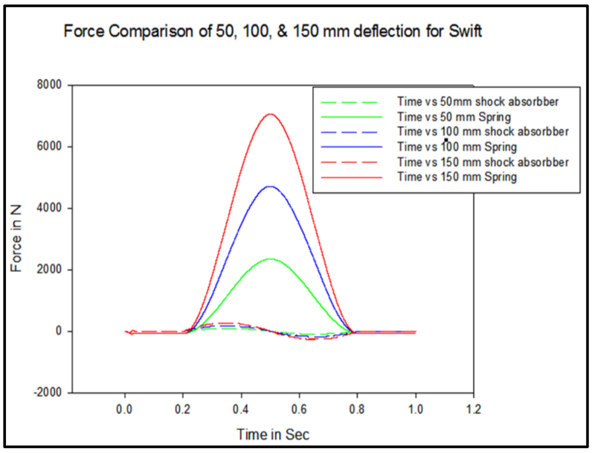

Figure 8: Force comparison of Maruti Swift (P) for 50, 100 and 150 mm of deflection

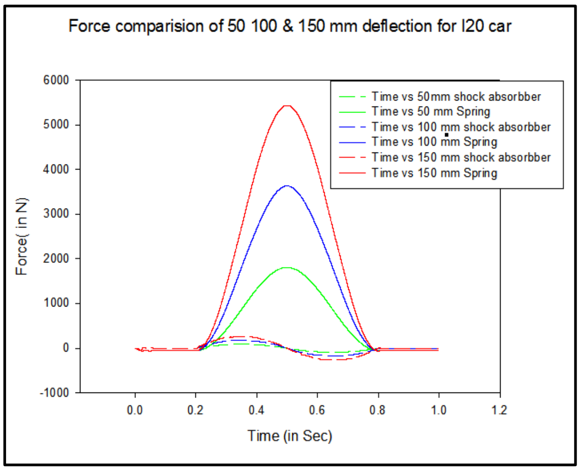

Figure 6: Force comparison of Maruti Wagon-R Lxi (P) for 50, 100 and 150 mm of deflection

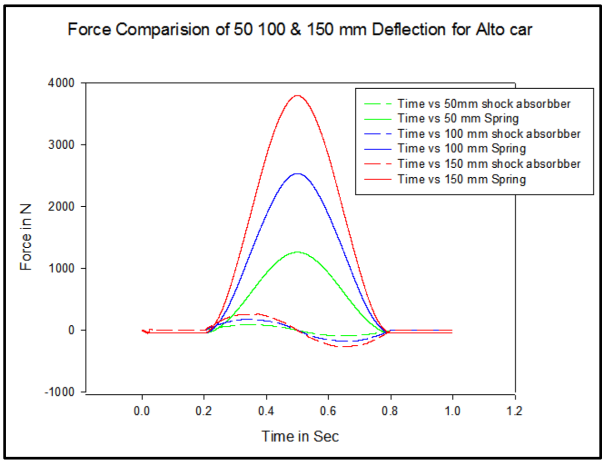

Figure 9: Force comparison of Maruti Suzuki Alto K-10 Lxi (P) 50, 100 and 150 mm of deflection

3.2. Force Comparison of all mentioned cars for various deflections 50, 100 & 150mm

The comparison of all mentioned (in Table 1) cars' rear suspension with different deflection bar of 50 mm, 100 mm, and 150mm will leads us towards graphical results, that can be compared for the further analysis and can also be used for optimization.

Table 4: Force Required to Deflect Rear Suspension of Various Indian Hatch-Back Cars for 50, 100 and 150 mm of deflection.

Name of Car	Wagon-R	Swift	Santro	I20 Era	i10	Grand i10	Alto
Force required for 50 mm deflection in (N)	1430	2346	1375	1809	1177	2435	1263
Force required for 100 mm deflection in (N)	2877	4712	2762	3634	2364	4892	2538
Force required for 150 mm deflection in (N)	4305	7052	4132	5437	3537	7321	3797

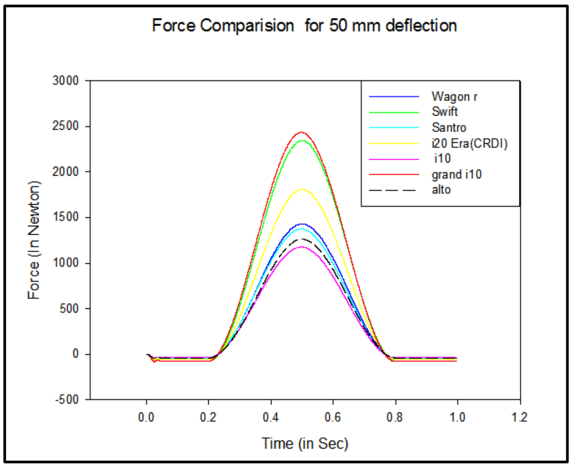

Figure 9: Force comparison of all mentioned cars for 50 mm of deflection

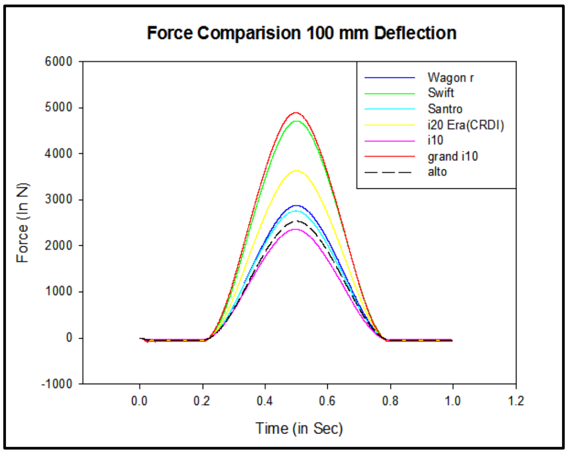

Figure 10: Force comparison of all mentioned cars for 100 mm of deflection

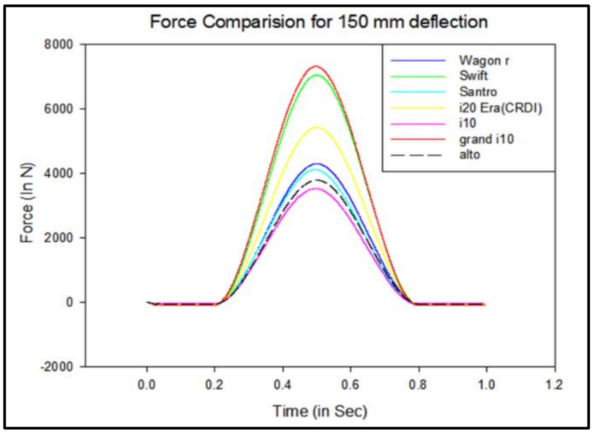

Figure 11: Force comparison of all mentioned cars for 150 mm of deflection

As per the comparative analysis is shown in figure 9, 10 and 11 that i10 requires minimum whereas Grandi10 requires a maximum force (amongst mentioned cars) to deflect the rear suspension. As per the data generated after analysis, we come to know that the force value exerts on suspension for 150 mm of deflection, exceeds the total capability of individuals' suspension and hence no mentioned car can withstand 150 mm of deflection. Hence considering a force comparison of 100 mm deflection graph, the value lies between 2364N to 4892N

4. CONCLUSION

As per the force value we obtain by analysis shown in table 4 and the data collected by measuring the initial values shown in table 1, we can conclude that in mentioned Indian hatch back cars there is no ample comfort for 5^{th} passenger. Most of the active spring length is utilized for four passengers. Hence the modification or optimization of the existing suspension system is required in future

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