Experimental Investigation on the Dynamic Behaviour of the All-Terrain Vehicle (ATV) Suspension System

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ABSTRACT

An All-Terrain Vehicle (ATV) is defined by the American National Standards Institute (ANSI) as a vehicle that travels on low pressure tires, with a seat that is straddled by the operator, along with handlebars for steering control. In some vehicles steering wheel similar to passenger cars is also used. As the name suggests it is designed to suspension system. negotiate a wider variety of terrain than most other vehicles. Although it is a street-legal vehicle in some countries, it is not legal within most states and provinces of Australia, the United States and Canada and definitely not in India. By the current ANSI definition, it is intended for use by a single operator, although a change to include 2-seaters is under consideration.

The term "ATV" was originally coined to refer to non-straddle ridden, typically six-wheeled, amphibious ATVs, such as the Jiger produced by the Jiger Corporation, the Amphicat produced by Mobility Unlimited Inc, and the Terra Tiger produced by the Allis-Chalmers Manufacturing Company in the mid-1960s and early 1970s. With the introduction of straddle ridden ATVs, the term AATV was introduced to define the original amphibious ATV category.

1. INTRODUCTION

The All-Terrain Vehicle (ATV) was initially developed in the 1960‟s as a farm town vehicle in isolated, mountainous areas. During spring thaws and rainy seasons, steep mountainous roads were often impassable with conventional vehicles. It soon became a recreational vehicle however, providing transportation to areas inaccessible by other motorized transport. Royal Enfield CO built and put on sale a powered Quadra cycle in 1893 that worked in the same way as, and resembles, a modern quad-bike. ATVs were made in the United States a decade before 3- and 4-wheeled vehicles were introduced by Honda and other Japanese companies. During the 1960s, numerous manufacturers offered similar small off-road vehicles that were designed to float and were capable of traversing swamps, ponds and streams, disciplines as motocross, woods racing, desert racing, hill climbing, ice racing, speedway, tourist trophy, flat track, drag racing and others. The early ATV‟s was mainly used for agricultural purpose only. But now the definition of ATV is changing. Many countries are allowing ATVs as commercial vehicle, though with the regulations on its use and safety. Now days, ATVs are generally used in defence and sports application redefining the ATV. Now the ATVs are also coming with durable roll cages, added safety of seat and shoulder belts and higher ground clearance making it more rugged vehicle. The rear cargo deck is more useful for hauling camping gear, bales of hay, tools and supplies making it suitable for exploring back country, riding sand dunes, hunting, fishing and camping.

Fig1.1: 6x6 Military used ATV

Fig1.2: Three-wheeler ATV

Fig1.3: Four-wheel bike ATV

Fig1.4 seat four-wheel ATV

ATVs Sport models are built with performance, rather than utility, in mind. To be successful at fast trail riding, an ATV must have light weight, high power, good suspension and a low centre of gravity. These machines can be modified for such racing terrain.

The first three-wheeled ATV was the Sperry-Rand Tricart. It was designed in 1967 as a graduate project of John Plessinger at the Cranbrook Academy of Arts near Detroit. The Tricart was straddle-ridden with a sit-in rather than sit-on style (similar to the contemporaneous Big Wheel toy). In 1968 Plessinger sold the Tricart patents and design rights to Sperry-Rand New Holland who manufactured them commercially. Numerous small American manufacturers of 3-wheelers followed. These small manufacturers were unable to compete when larger motorcycle companies like Honda entered the market in 1969.

Suzuki was a leader in the development of mass production four-wheeled ATVs. It sold the first model, the 1982 Quad Runner LT125, which was a recreational machine for beginners. Adventure Vehicles of Monroe, Louisiana made the first quad ATV in 1980. They called it the Avenger 400. Prior to that, Adventure Vehicles made 3-wheel ATVs and a dump body utility 3-wheeler using Kohler 8 hp engines and Comet drive systems (Comet centrifugal belt-driven clutch, and a Comet forward, neutral, reverse transaxle, with a rigid rear axle or rear differential option.) The Avenger 400 was a rigid suspension vehicle with a fiberglass body and welded tube construction. It was a rudimentary vehicle reminiscent of the Tote Gote of the 1960s. Suzuki sold the first four-wheeled mini-ATV, the LT50, from 1984 to 1987. After the LT50, Suzuki sold the first ATV with a CVT transmission, the LT80, from 1987 to 2006.

Suspension system of an “All-Terrain Vehicle” include durability, light in weight, optimum efficiency and cost effective. The vehicle should also be able to handle different road conditions which also in turn signify that the suspension system should be able to tackle all the on-road conditions. Suspension system includes the shock absorbers, coil springs and linkages that connects the vehicle body to its wheel and helps in relative motion between the two. It also keeps the operator isolated from bumps and other road vibrations.

2. LITERATURE REVIEW

Mr. Prashanthasamy R.M.T and et all [2016] concluded that stresses and deformation is maximum in the existing design with AISI 1040 of 218 MPa and 2.062 mm respectively. The stresses and deformation for the existing design with aluminium alloy is almost maximum compare to AISI 1040. In the existing design of wishbone suspension arm is completely hallow and it is welded joint, due to which there is a chance of fracture at the welded joints. [1]. M. Sridharan et al. [2016] in his paper deals with the reduction of unsprung mass of vehicle by topology optimization of lower control arm. For analysis existing lower control arm of Mac-Pherson suspension system is selected. On the basis of stress developed, topology optimization is carried out by removing excess material from CAD model. Lower control arm is redesigned and is analysed for stress distribution and deformation. It is observed that total reduction of weight in existing model is found to be 13.46 %. [2]

John C. Dixon [2009] explained that the need for suspension arises because of the roll and pitch associated with vehicle manoeuvring, and from the roughness of roads. [3]

Jornsen Reimpell et. al. [2002] said that the suspension of modern vehicles needs to satisfy a number of requirements whose aims partly conflict because of different operating conditions (loaded/unloaded, acceleration/braking, level/uneven road, straight running/ cornering). [4]

William F. Milliken, Douglas L. Milliken [1995] said that suspension linkages are expected to position the knuckle very accurately in all directions while allowing it to move up and down against the spring shock. [5]

Khan Noor Mohammad and et. al (2018) said in his research paper that the suspension geometry of double wishbone suspension system restricted with two degree of freedom one is tie rod which controlling one degree of freedom. He goes with H-arm shape for rear suspension system, H-arm nothing but link of shape H where two mountings are on chassis and two on knuckle. He refers us suspension geometry for good methodology, design and tensile strength. They used AISI 4130 for making the front and rear suspension system. In his paper they said suspension system deals with three C’s comfort, contact, and control. By using lotus software with help of Catia and the analysis carried out by the Ansys software. [6]

Raj D. Pal and et. at. (2019) describe in his paper the rear suspension of all-terrain vehicle not get enough highlight as it required. Dual unequal A-arm are selected for better camber curve of dynamic condition which provides maximum contact with camber link is selected as it offers best straight-line stability and resist lateral forces. [7]

Shivanand R. Patil and et. al. (2018). they described the true consideration of double wishbone suspension system and the Mc-pherson strut and damper is best modification for double wishbone suspension system they also present their self-modified design for the rear suspension system. Several iterations were carried out to optimize the proposed design.in calculations where the forces acting were calculated and considered as the loading conditions. In their terminology the upper arm or double wishbone was designed so as to help accommodating a coil spring shock absorber in all-terrain vehicle without altering the motion ratio and providing more flexibility in choosing and angle correction factor. [8]

Upendra S. Gupta and et. al. (2015) said in his paper to design and develop the roll cage for all-terrain vehicle material selection based on strength, cost and availability. A software model prepared in solidworks software based on the results obtained from these tests the design is modified accordingly. Since the chassis is the main part of an automobile it should be strong and light weight. The Adams steering system used in his design for pinion steering over the other system due to low cost. However, they didn't show much focus on suspension system design and analysis unless for clamping and brakes. [9]

Nayan Deshmukh and et. al. (2017). The suspension system of BAJA vehicle has to withstand major shocks over uneven terrain. This calls for high stiffness springing and rigid body. However, higher the stiffness, lesser will be the comfort. Hence driver will be the premature fatigue and thereby the performance will be affected on the way of other in extreme use of springing.

The suspension system which is widely used in off-road vehicle like BAJA and Quad and many commercial vehicles is independent suspension. That gives from to wheel to oscillate about certain point without disturbing each other motion. [10]

Mahmoud Omar and et. al. were represented the active performance compared against the passive is performed experimentally and numerically utilizing SIMULINK's Simscape library. Both systems are modelled as single degree-of-freedom to simplify the validation process. Economic considerations were considered during the rig's implementation.

2.1 Problem Definition

The suspension system in conventional buggies, does not provide enough gain over track in terrain conditions like off-roading and mountings, this makes one of the wheel leave the ground contact unnecessarily. When the buggy bounces on the rough terrain condition, wheels should be on ground to gain control over the vehicle. A solid design methodology that uses the time, resources, talent and research available to produce a competitive vehicle has not been established. Many hours have been spent acquiring resources and research for the betterment of the organization.

2.2 Objective

The objective was to study the dynamic parameter of the suspension system of an ATV by determining and analysing the dynamics of the vehicle when driving on an off-road racetrack. Though, there are many parameters which affect the performance of the ATV, the scope of this work is limited to determination, design and analysis of suspension systems and to integrate them into whole vehicle systems for best results.

The goals were to identify and optimize the parameters affecting the dynamic performance suspension systems within limitations of time, equipment and data from manufacturer.

The objective includes:

- To study the dynamic parameters of the suspension system.
- To determine design parameters for front suspension system.
- To work out the parameters by analysis, design and optimization of suspension system.

2.3 Methodology

- Steps in optimization:
  1. After getting correct parameters design the suspension parts in Solid works software.
  2. After checking its 3d views go for analysis in Ansys.
- Finite Element Analysis of Suspension System:
  Ansys workbench offers variety of efficient way of CAD interaction, handling and documenting all data involved in the analysis. For the suspension analysis need to go for transient analysis option (Implicit). Transient analysis having capability to solve the problem with dynamic way.
  1. Import model from CAD and disfeature in using design modeller.
  2. Applied material property to arms and knuckle.
  3. Do the proper connections between knuckle and arm.
  4. Constrain knuckle and arm's proper location.
  5. After solving problem, we will get results of analysis.

3. DESIGN

3.1 Formulation

We first determine the chassis dimensions from this step, we decide the track width and finally the turning radius. From these steps, we get the total available space to accommodate the suspension arms. Hence, we consider the fixed points (hard points) and set up the theoretical values into LOTUS software. LOTUS suspension software is mainly used for designing the hard points such that the required kinematic behaviour is achieved. Any number of results can be displayed graphically against bump motion, braking motion and steering motion. These results are updated in real time as the suspension hard points are moved. This software uses different templates to identify specific 3D suspension types. The lengths of the both upper and lower control arms are fixed according to the iteration done in the LOTUS software. At first sample length are taken and designed, different graphs of camber, caster over steer, under steer and kingpin inclination are obtained from LOTUS software and according to the results from the graphs the shapes and lengths of the control arm are fixed. The lengths are then modelled in the CAD software and then analysis is performed for forces and torques for verifying if they will sustain the loads.

Step 1 - The design process starts by first taking approximate dimensions of the arms and other components on paper.

These dimensions are derived from

- Wheelbase
- Track width
- Approximate roll centre
- Approximate pitch centre

Step 2 - Based on these approximate values, the design is formulated in the LOTUS software and the draft design is analysed using the available graphs of

- Camber
- Castor
- King pin inclination
- Toe

Step 3 - These parameters are tested with respect to

- Bump
- Steer
- Brake

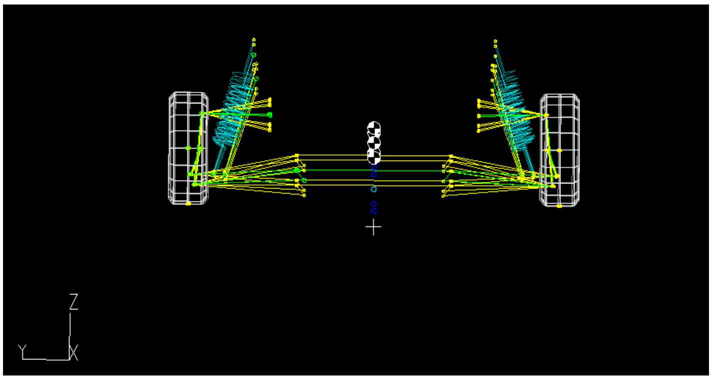

Fig4.1: Front view of geometry

This is the table which shows the positions of all the hard points in the suspension geometry. These points are adjustable and these changes vary the suspension geometry. This variation gives different results on analysis.

Steer is a phenomenon in which the vehicle takes a turn. While taking the turn, the hard points also change its position thus causing a change in the suspension parameters such as toe, camber, castor and king pin inclination. These changes can be viewed and visualized with the help of these graphs. The goal is to minimize these variations in the suspension parameters and through an iterative procedure, the hard points are reset to get the desired toe (0-degree change), camber (camber should reduce when the wheel rises from the ground), caster (always positive, max 10 degrees) and king pin inclination.

Brake is a condition in which the suspension system is analysed for the vehicle's braking nature when sudden brake applied. The aim is to observe the variation in the suspension parameters during the braking condition of the vehicle. These graphs depict the variation of suspension parameters like toe, camber, castor and king pin inclination. The goal is to minimize these variations in the suspension parameters and through an iterative procedure, the hard points are reset to get the desired toe (0-degree change), camber (camber should reduce when the wheel rises from the ground), caster (always positive, max 10 degrees) and king pin inclination.

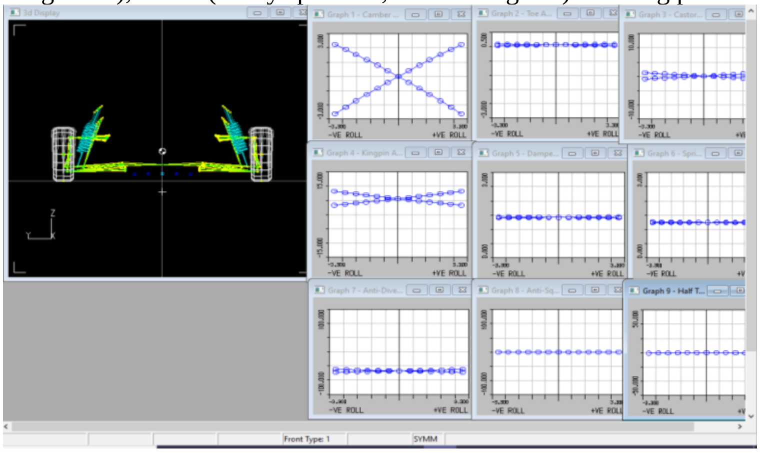

Fig4.2: Analysis of graph on brake

Bump is the final test condition where the suspension parameters are observed and corrected for the required values. These graphs show the variation of the parameters when the vehicle passes over a bump (an obstacle). Here too, the aim like in the previous two cases, is to set the hard points in such a way so as to ensure that all the parameters are as desired.

4. RESULT AND DISCUSSION

Figure 5.2-5.10 represents the analysis of suspension with requisite boundary conditions for AISI1018 and brake, steer and bump are the parameters of load. The results of total deformation, directional deformation and von-mises criteria of maximum stress are presented in table 6.1. Similarly, figure 5.11-5.19 shows the analysis of suspension with requisite boundary conditions for AISI1040 and brake, steer and bump are the parameters of load. The results of total deformation, directional deformation and von-mises criteria of maximum stress are presented in table 6.1. Also, figure 5.20-5.28 represents the analysis of suspension with requisite boundary conditions for AISI1080 and brake, steer and bump are the parameters of load. The results of total deformation, directional deformation and von-mises criteria of maximum stress are presented in table 4.1. All above mentioned parameters are taken as experimental setup and analyzed to obtain optimized results for concluding the final material to be selected for fabrication of double wishbone suspension.

Table 4.1: Result comparing table

	Total deformation (mm)	Directional deformation (mm)	Von-mises stress (MPa)
AISI1018			
Brake	78.583	2.79	68.409
Steer	12.704	0.946	13.88
Bump	92.379	91.924	90.44
AISI1040			
Brake	71.439	2.627	56.437
Steer	11.714	0.869	12.774
Bump	87.152	86.813	81.012
AISI1080			
Brake	68.219	2.446	52.191
Steer	10.789	0.796	11.69
Bump	81.778	81.537	78.224

5. CONCLUSION

- After studying about different types of All-Terrain Vehicles, it is crucial to design suspension system which is vary in different road conditions.
- Double wishbone suspension is designed in Solid works software and tested in different parameters with different materials.
- The model was built in finite element. By performing analysis in Ansys software, we get different values with each material.
- It has been found that AISI1080 is best suited material for arms and knuckle. The deformation and von-mises stress are less in all parameters i.e, brake, steer and bump comparatively AISI1018 and AISI 1040.

6. REFERENCES

[1] Prashanthasamy. "Design and Modal Analysis of Lower Wishbone Suspension Arm Using FE Approach" Imperial Journal of Interdisciplinary Research (IJIR) Vol-2, Issue-9, 2016.

[2] M. Sridharan et al. "Design and Analysis of Lower Control ARM" International Journal of Innovative Research in Science, 5, Issue 4 April 2016

[3] John C. Dixon; Suspension analysis and computation geometry; ISBN: 978-0-470-51021-6; October 2009. Publications, ISBN: 9780470-51021-6.

[4] Reimpell, H., Stoll, H. and Betzler, J. W. (2002). The Automotive Chassis: Engineering Principles. Butterworth Heinemann, Oxford. ISBN 0-7506-5054-0.

[5] William F. Milliken, Douglas L. Milliken, (1995). Race Car Vehicle Dynamics. Published by sae International.

[6] Khan noor mohammad. "Dynamic analysis of front and rear suspension system of All-terrain vehicle" International Research Journal of Engineering and Technology. (IRJET) Vol-5, Issue-3, 2018. e-ISSN:2295-0056, p-ISSN:2395-0072.

[7] Raj d. pal." Design and analysis of suspension system for All-terrain vehicle" Journal of Applied Science and Computations. (JASC) Vol-6, Issue-6, June 2019 ISSN-1076-5131.

[8] Shivanand r. patil. "Design modification and analysis of upper A-arm of an all-terrain vehicle suspension system" NAFEMS India Regional Conference of Engineering, Modelling, Analysis, Simulation and 3D Printing. (NIRC-2018). July-2018.

[9] Upendra s. gupta. "Design and manufacturing of all-terrain vehicle- selection, modification, static and

dynamic analysis of ATV" International journal of Engineering Trends and Technology. (IJETT) Vol-21 Number-3 Feb-2015. ISSN-2231-5381.

[10] Naryan Deshmukh. "Design of double wishbone suspension system of BAJA vehicle" International Journal of Advance Engineering and Research. (IJAERD) Vol-4 Issue-12 Dec-2017.

[11] Mahmoud Omar, M.M. El-kassaby, Walid Abdelghaffar, " A universal suspension test rig for electrohydraulic active and passive automotive suspension system", Alexandria Engineering Journal (2017) xxx, xxx–xxx.

[12] Tian Mi, Gabor Stepan, Denes Takacs, Nan Chena, Ning Zhanga," Model Establishment and Parameter Analysis on Shimmy of Electric Vehicle with Independent Suspensions", Procedia IUTAM 22 (2017) 259 – 266.

[13] Carlos Arana, Simos A. Evangelou, Daniele Dini," Series Active Variable Geometry Suspension application to comfort enhancement", Control Engineering Practice 59 (2017) 111–126.

[14] Jan Dizo, Stasys Steisunas, Miroslav Blatnicky, "Vibration analysis of a coach with the wheel-flat due to suspension parameters changes", Procedia Engineering 192 (2017) 107-112.

[15] Anirban. C. Mitra, Gourav. J. Desai, Saaish. R. Patwardhan, Parag H. Shirke, Waseem M. H. Kurne, Nilotpal Banerjee," Optimization Of Passive Vehicle Suspension System By Genetic Algorithm", Procedia Engineering 144 (2016) 1158 – 1166.

[16] A.A. Koshurina, M.S. Krasheninnikov, R.A. Dorofeev,"Strength Calculation and Analysis of Equalizer Beam Embodiments for the Operated Equalizing Beam Suspension of the Universal Rotor-Screw Rescue Vehicle for the Arctic", Procedia Engineering 150 (2016) 1263 – 1269.

[17] PanosBrezas, Malcolm C. Smith, Will Hoult," A clipped-optimal control algorithm for semi-active vehicle suspensions: Theory and experimental evaluation", Automatica 53 (2015) 188–194.

[18] Werner Scheele, Igor Iroz," Uncertainties in road vehicle suspensions", Procedia IUTAM 13 (2015) 151 – 159.