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RESEARCH ARTICLE

ESTIMATION OF VERTICAL AND TIRE FORCE OF A VEHICLE

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ABSTRACT

The estimation of tire force from the ground is the most peculiar forces which act on the suspension parts and it is transferred to other parts. In general, the forces are assumed as 2g or 3g forces which act on the suspension parts and it leads to increase in material cost and increase in material dimensions due to the reason of factor of safety. The tire force generated from the ground due to the road surface can be estimated by using a displacement sensor, which measures the displacement continuously and it is controlled by microcontroller which gives the value of the load acting on the suspension and the tyre force is estimated by means of motion ratio of the particular suspension system. To do this, a microcontroller and a displacement sensor is used for the current test in a vehicle. So, the vehicle manufacturer, instead of assuming the forces, they can actually estimate the maximum tire force generated from the ground of that particular prototype vehicle and the material used for the suspension can be optimized leading to cost reduction and material reduction for the further optimization of the vehicle. This finding will clearly estimate the forces generated from the tire and it can be used for the optimization of the material used in the suspension system, which leads to a compact vehicle, with low weight and increased performance with lower fuel consumption.

INTRODUCTION

This chapter deals with the background of the study, general objectives, and justification.

Background to the study

As optimization has become a major role in the automotive industry for increased performance in vehicle, the need for optimization has become an important part. The tire force estimation is one of the most important criteria to design the parts of the suspension system. Estimation of tire forces is generally taken as assuming the forces as 2g or 3g times the quarter car weight of the car of that particular suspension system. They are also calculated by fixing an accelerometer at the tire patch. The vertical tire force estimation helps in designing the suspension components which are subjected to high amount of forces, due to unexpected forces generated from the ground, due to unevenness of the road.

General objective

The objective is to estimate the vertical tire force generated from the ground, due to unevenness of the road by means of a displacement sensor, and a microcontroller, which estimates the maximum displacement upto which the suspension compresses. So, from this, the tire force is estimated by motion ratio. This method can be used, by producing a prototype of the entire vehicle and then fixing this setup inside it, and then the tire force is calculated, and the optimization can be done for the suspension parts and then the vehicle with optimized suspension parts can be used for mass production which will have a factor of safety due to the optimization.

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MATERIALS AND METHODS

Introduction: This study was done in Sri Venkateswara College of Engineering which is located in Sriperumbudur, Tamilnadu on 01-July 2017 at Automobile department. Its objective was to assess the tire force generated for that particular quarter car so that optimization can be made for the suspension system parts of that particular car

Research design: In this research, suspension deflection is used as a parameter to estimate the tire force from the ground. The designs of automobile suspension system are a compromise between softness in riding and handling ability, depending upon the manufacturers objective. A properly designed suspension also produces minimum wear on the tyres and other parts of the suspension system [2].

The wheels of a vehicle are either mounted conventionally on a spring suspended axle or suspended independentally on a spring. In conventional suspension system, two pairs of wheels are each mounted on a rigid axle. The chassis is then supported on axles through springs. But in independent suspension , the movement of the two wheels are not interdependent , because the chassis is supported on the road wheels without using rigid axles[1]. In this estimation, electronics has been used which could determine the values with better accuracy. A displacement sensor is fixed in the bottom of aindependent suspension and a plate on the end side of the stroke. This displacement sensor is fixed with a microcontroller which actually estimates the varying displacement of the suspension with respect to time. This value is taken for estimating the load acting on the suspension by keeping the stiffness constant. Then the load from the tire is calculated by means of motion ratio, which is a fixed parameter while designing a suspension system.

RESULTS AND DISCUSSIONS

The suspension used is a pneumatic suspension system in which the stiffness can be varied accordingly. For testing purpose, the suspension is fixed at a certain pressure and the test was carried out. The following values were obtained for different pressures.

Table 1. Stiffness of the suspension at different pressures

Pressure in PSI	Stiffness In N/Mm
150	108.41
140	88.42
130	77.92
120	65.62
110	56.67
100	49.87
90	45.33
80	35.12
70	29.33
60	23.52
50	19.33
40	16.8

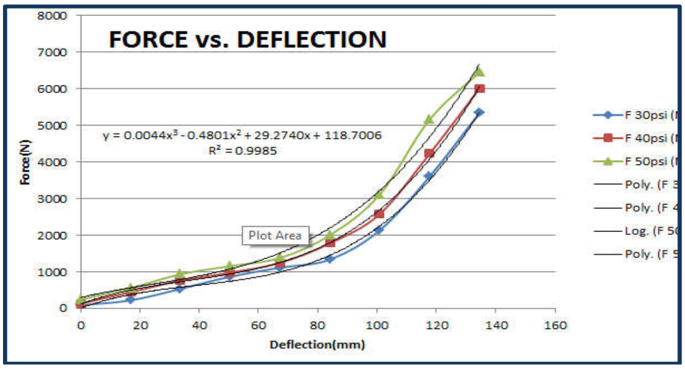

Fig. 1. Force vs deflection of the suspension

Design parameters of A-arm suspension system:

Reaction on one wheel – 60 kg
Motion ratio – 0.85
Suspension stiffness – 23.5 N/mm.
Initial compression – 14.4 mm
Rebound value – 152.4 mm

These values are obtained from the vehicle which was used for testing. Several tests has been carried out which gave the stiffness of the pneumatic suspension at various pressures. The suspension has been kept in the test rig and the values has been obtained.

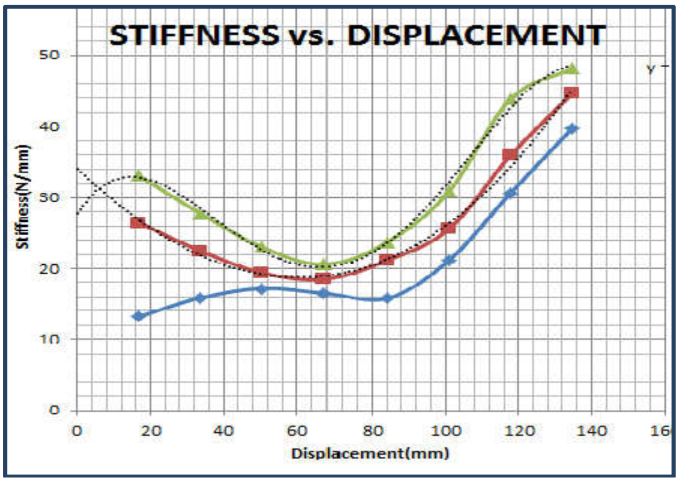

Fig. 2. Stiffness vs displacement of the suspension

Determination of roll centre

The roll centre at dynamic conditions for different wheel travel has been carried out in ADAMS software and the results are obtained.

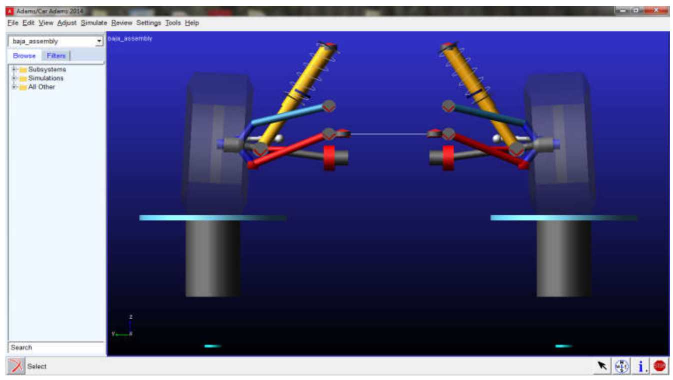

Fig. 3. Setup of vehicle suspension system in ADAMS CAR

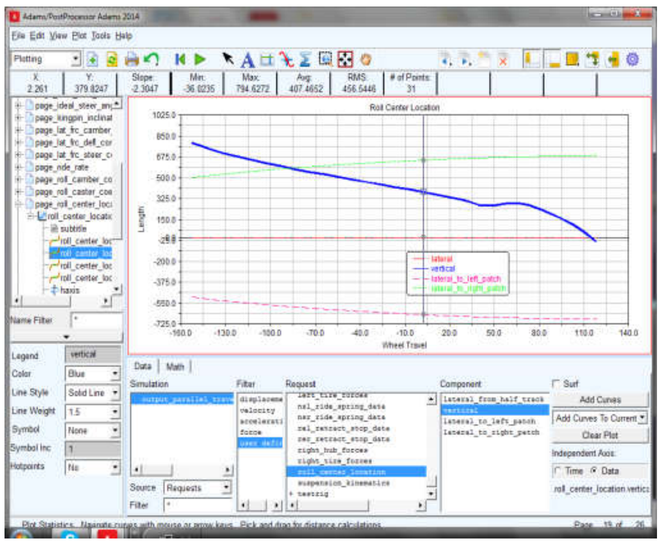

Fig. 4. Estimation of roll centre in ADAMS preprocessor

Calculation of tire-force

A displacement sensor was which senses the displacement and microcontroller tells the displacement of the suspension which varies with time. In this experiment, the maximum bump which a vehicle can experience is chosen and the displacement of the suspension for that bump is sensed using displacement sensor, and the tire force is obtained.

The layout of the wishbone suspension with displacement sensor is shown:

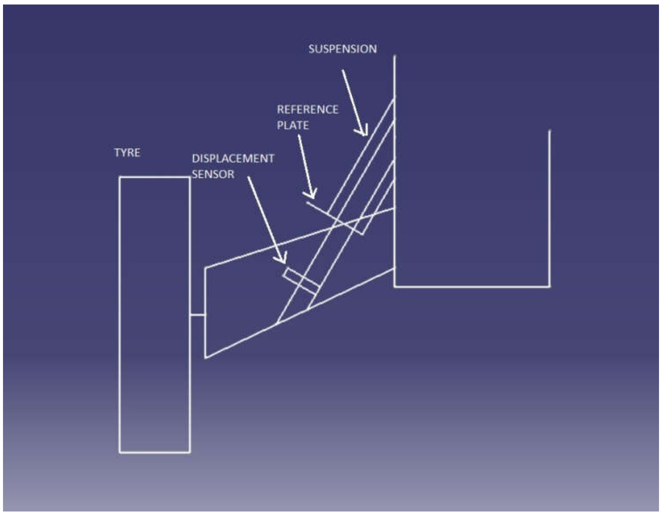

Fig. 5. 2-D layout of the experimental setup

The original setup is shown in the image below

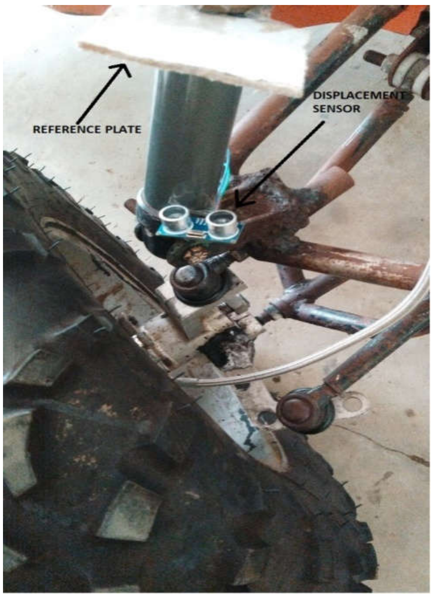

Fig. 6. Experimental setup in an ATV

Motion ratio:
Motion ratio is defined as the ratio of the total force acting on the suspension to the total force generated from the tyre[3]

Motion ratio = $\frac{\Delta S}{\Delta T}$

Where,
ΔS = Load in suspension,
ΔT = Load from tyre

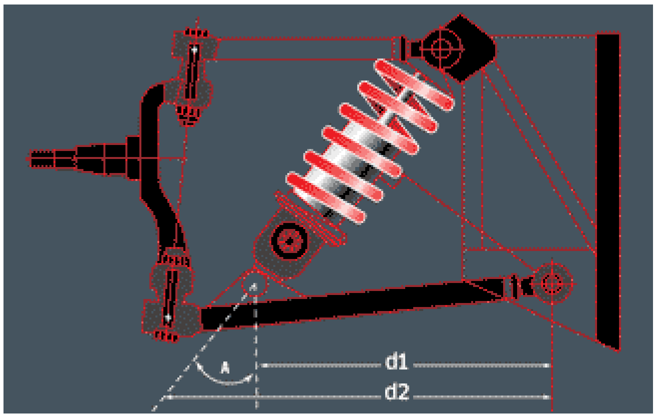

Fig. 7. Motion ratio

The experiment is done for a 20 cm pot hole.

The stiffness of the suspension is defined as the load per displacement.

So, Stiffness = $\frac{LOAD}{DISPLACEMENT}$

For 60 PSI, the stiffness was found to be 23.5 N/mm.

The vehicle suspension was fixed at 60 PSI and the vehicle was allowed to go into a 20 cm pot hole at its maximum speed and the displacement of the suspension was found to be 40 mm.
So, the load acting on the suspension is calculated and found as 940 N. Now, to calculate the tire force, the motion ratio is used. The motion ratio was set at 0.85. So the load which generated from the tyre was found to be

Motion ratio = 0.85 = $\frac{940}{\Delta T}$

So, the force at tyre is found to be,

ΔT = $\frac{940}{0.85}$

ΔT = 1105.8 N.

So, the g force which is acting on the tyre and to the suspension components is given as,

G-force = $\frac{1105.8}{(50 \, x \, 9.81)}$

= 1.87 g.

Therefore, the maximum longitudinal g force is obtained as 1.87 g. So, the suspension components are designed on the basis of this force and the assumption of the values are neglected and thereby optimization of this component is made and its factor of safety is also increased , since the optimization leads to reduce in weight of the vertical reaction thereby, its g-force is reduced leading to increase in factor of safety.

Design of microcontroller and displacement sensor

The displacement sensor was programmed using a microcontroller. It was programmed to determine the various displacement of the suspension with respect to time. This program included in the microcontroller senses the displacement of the sensor with respect to suspension travel and displays the displacement in the LCD screen which will be located in the steering wheel of the driver[4] The microcontroller used in ARDUINO UNO and a displacement sensor with a response time of 0.5 seconds is used [4].

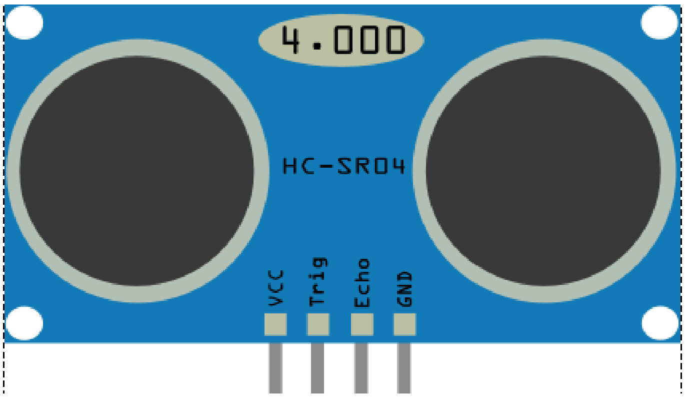

Fig. 8. Ultrasonic sensor

The values will be displayed in the steering wheel of the driver and it is shown

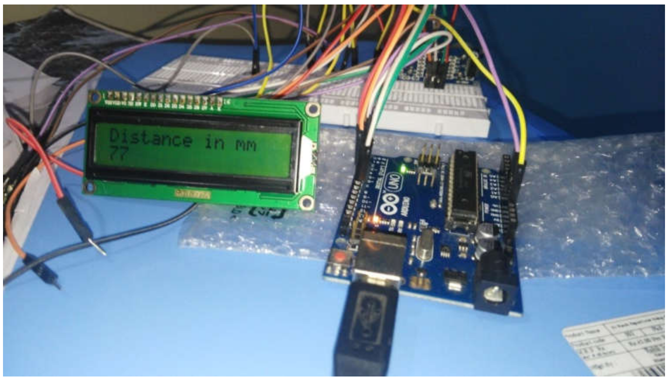

Fig. 9. Experimental setup of electronic system of the research

Conclusion

Thus, instead of finding the tire force by using a accelerometer sensor in the tyre, the longitudinal force generated can be found out by this method, which is cost effective and accurate values can be obtained which can be further used to optimize and design an effective suspension system having higher factor of safety. The only method to be followed is that, first the values of the forces should be assumed and a suspension system should be designed. Then, the system is optimized by experimenting the vehicle. The calculation of this force is important, since the part of the suspension system is an unsprung mass. So, optimizing the weight of the suspension reduces the unsprung mass, thereby, the vibrations transmitted are also significantly reduced, leading to comfortable ride. In this research, the value of the force generated from the tyre is obtained by measuring the displacement of the suspension with the help of a microcontroller and a displacement sensor.

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