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Dynamic Behavior of Three Wheeler Vehicle - A Review

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ABSTRACT
The study of vibration in vehicles was almost exclusively based on test results until a few years ago. Then came the practice of using rigid body model with two parameters namely viz., the sprung mass and un-sprung mass. Recently, the vehicle modelsbased on finite element method have become a practical alternative to rigid body models. This approach enables the analyst togenerate a model based on structural blue print dimensions and continuously varying displacements impose at the tyre contactpoints of the vehicle traversing on a road may be considered to be an input excitation of a dynamic system of masses, stiffnessand dampers. A wobble instability is one of the major problems of a three wheeled vehicle commonly used in India, and theseInstabilities are of great interest to industry and academia. In this paper, we have studied this instability using a multi-bodydynamic (MBD) model and with experiments conducted on a prototype three wheeled vehicle (TWV) on a test track. The MBDmodel of a three wheeled vehicle is developed using the commercial software ANSYS. In an initial model, all componentsincluding main structures like frame, steering column and rear forks are assumed to be rigid bodies. A linear eigenvalueanalysis, carried out at different speeds,reveals a mode that has a predominantly steering oscillation, also called a Wobblemode, with frequency around 5 to 6 Hz.

Keywords: three wheeled vehicle (TWV), multi-body dynamic, Wobble mode, ANSYS

I. INTRODUCTION

The power driven three-wheeled road vehicles, typically used in India on a large scale, are important part of transportation system in major cities and also becoming increasingly popular in smaller towns. This vehicle, commonly known as an Auto-rickshaw. The next two decades are likely to witness a sharp rise in the use of threewheeler. The main compelling reasons for this are scarcity of energy resources and space. Three wheelers also have the advantage of being a compromise between two wheeled and four wheeled vehicles in various aspects like cost, load carrying capacity, fuel consumption, space occupied, weight etc. Any efforts in solving the above problems will directly and/or vehicle dynamics is of great significance and increasing importance. The three-wheeled vehicles operating in India have their front steering with one wheel similar to those of motor cycles and motor scooters, the two rear wheel sare the driving wheels with a differential and a suspension, which are similar to those of automobiles. The three wheeled vehicle is a very common public transport vehicle in India, with a maximum speed of about 14 m/s. similar vehicles are used throughout the world, especially in Asian countries, for public transport as well as to carry freight. The total weight of the vehicle is around 650 kg including the driver and three passengers. It has one front wheel with linkage (trailing or leading) suspension attached to the steering column and two rear wheels attached to corresponding winging arms that are pivoted to the frame.

II. LITERATURE

The study of wobble instability problem of a three wheeled vehicle. The main focus is to model the vehicle close toreality to predict the frequency and damping of the wobble mode more accurately. The implication of this study is thatthe flexibility of the main structures shall be Included in the dynamic model of a three wheeled vehicle; suchconsiderations will predict the stability issues more precisely in design stage. To predict the wobble instability andstudy it in detail, we have used finite element based flexible model. Although flexible models based on finite elementmeshes is common in multi body simulation, its use in study of stability for two and three-wheeled vehicles has notbeen published more often.

The development of a dynamic model of a three wheeled vehicle (TWV), using ANSYS. A schematic of themodel is shown in Figure 1. The rigid model has 25 degree of freedom. These are: 6 degree of freedom for the frameplus rigidly attached rider, 6 degree of freedom for the powertrain, 3 rotations of each trailing arm (total 6), 1 rotationof each rear suspension (total 2), 1 rotation at the steering pivot, 1 front trailing link rotation and 3 wheel rotations.
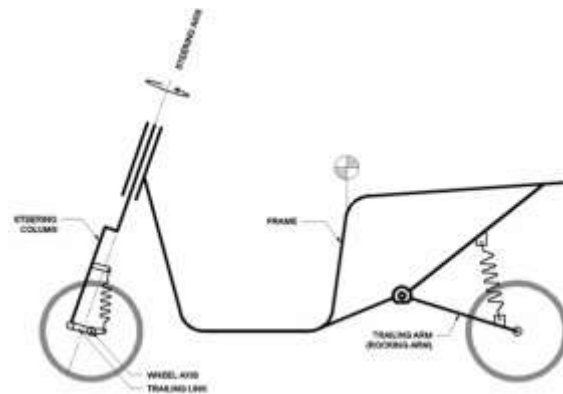
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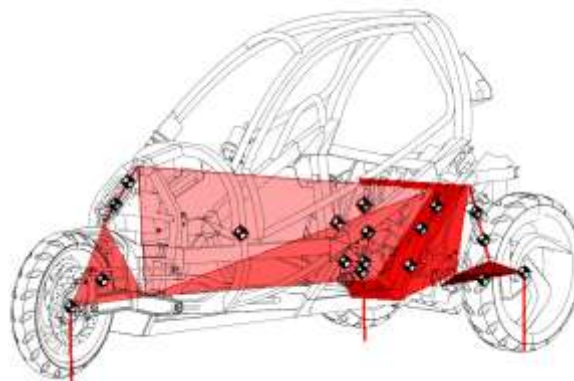**Figure 1:** A schematic of a three wheeled vehicle. [1]

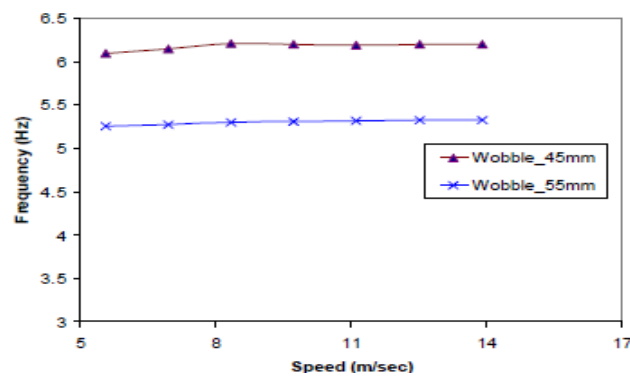**Figure 2:** Multi-body dynamic model of a three wheeler.
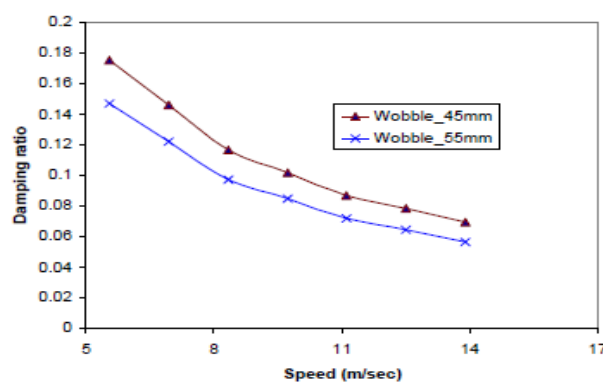

Figure 3: Variation of Wobble mode frequency

Figure 4: Variation of Wobble mode damping ratio (for 45 mm and 55 mm steering offset) with speed.

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The simulation results show that there are 50 eigenvalues including 6 rigid body modes. Each mode shape wasexamined visually and only the steering oscillation mode is selected for presentation here. This mode predominantlyinvolves steering oscillation, small body movements, and has low damping. The mode seems similar to the Wobblemode of a two-wheeler and hence we have called it a Wobble mode. Figure 2 shows the imaginary parts of theseWobble mode Eigenvalues each divided by 2π to give frequencies in Hz. The variation of frequency with the vehiclespeed is plotted for Wobble mode. The results show that the frequency of oscillation is nearly constant, around 5.5 Hzfor 55 mm steering offset and around 6.1 Hz for 45 mm steering offset. Similarly, Figure 3 shows the variation ofdamping ratio with vehicle speed. The results show that the damping of the mode is positive at all speeds below 13.89m/sec (50 Kmph) and the damping decreases as the speed increases. Overall, the results show that the mode is stable.The model analysis different mode shapes like bounce; roll, front hop, and yaw were found and observed the obtaineddisplacement using the model analysis. In the harmonic analysis the change in displacement with frequency over theentire range (0 – 80 Hz) was obtained. For transient analysis a semicircular bump was taken as excitation force andnoticed the variations in displacement.
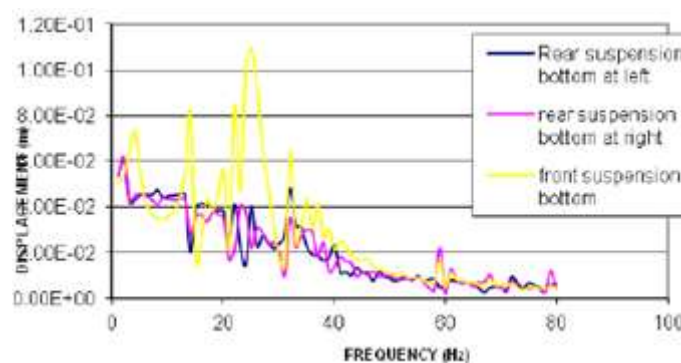
Figure 5: Variation in displacement at the left and right end of the rear chassis
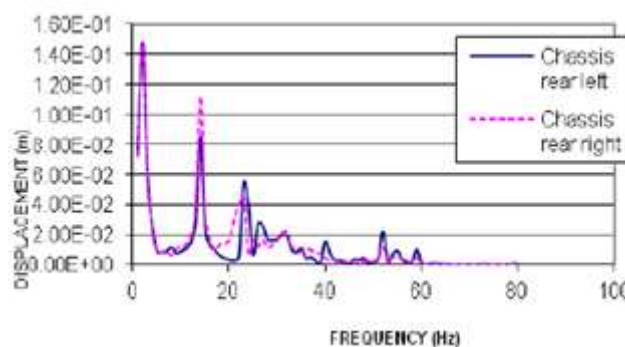
Figure 6: Variation in the displacement values at the suspension bottoms the displacements of various nodes and stresses for different elements over the entire frequency range 0 – 80Hz with amplitude of 0.05m were obtained. The displacements at various nodes were plotted against frequency and are shown infigures 5 and 6.

III. CONCLUSION

A detailed simulation of a three wheeled vehicle using a multi body dynamic model is very useful in industry, especially in the design stage. One important aspect of this vehicle is instabilities of steering oscillations especially at lower speeds. Also the steering column flexibility may be one of the main reasons for these instabilities.

The maximum displacement 0.1474m was observed in rear right chassis in harmonic analysis. Also in the SVM method maximum displacement is observed in rear right chassis. The displacement is 0.153m, when compared with finite element model the error is 3.6% The dynamic model, results and findings of this study can be used not only in future industrial design oriented studies, but also will lead to improved understanding of three wheeler dynamics as well, especially the wobble instability.

Future work will include experimental study of wobble with steering column flexibility and study of modal interactionsof various modes that may lead to instabilities at particular vehicle speeds.

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