VIBRATION ANALYSIS IN A MOTOR CYCLE USING FINITE ELEMENT MODELLING

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Abstract

This paper deals with Vibration, which occurs in most machines, structures, and mechanical components. In this paper you have explained the Systems of The Vehicle Modelling Motorcycle, Periodic Vibration, Modal Analysis and Frame Flexibility Model. The Lanczo's method has been successfully used in performing modal analysis to extract the eigenpairs of the two-wheeler.

I. INTRODUCTION

All mechanical systems have natural frequencies. When analyzing these systems engineers sometimes apply rigid body dynamics. Rigid body dynamics has been used in many industries such as automotive, agricultural & aerospace. In industry, multi-degree of freedom (DOF) systems is used to obtain measurements & simulate movement under certain conditions. The purpose of a multi-DOF system is to represent the subsystems of the body. When simplifying a mechanical system in terms of a rigid body, it is necessary to determine the best method to do that. Take for instance many researchers were interested in vehicle parameters required for vehicle dynamics simulation & determined that there are three categories used to develop the vehicle dynamics simulation. The three categories are low DOF linear models, nonlinear lumped parameter models, & multi-body dynamic models.

The usage of the 2-DOF models is only a technique to extract meaningful parameters from measured data. Evaluation methods using an unreasonable number of parameters have no purpose for the development of new motorbikes or for comparison of similar vehicles since drivers' reference vary widely in various handling characteristics.

II. SYSTEMS OF THE VEHICLE

Road vehicles include motorcycles, passenger cars, trucks, buses, & articulated road vehicle systems, such as, truck/tractor-trailer combinations. Major systems of these vehicles are:

1. Passenger-seat system
2. Body
3. Chassis or the Frame
4. Suspension System &
5. Wheels with pneumatic tyre.

A. MODELLING MOTORCYCLE

The motorcycle's model is composed by several rigid bodies: front & rear wheel, rear swinging arm, front unsprung components, front frame, & rear frame with motor & rider rigidly attached. The geometry depicted here is that for the nominal configuration in static equilibrium & the key points of the model are labeled. The motorcycle model as shown in Fig.1 and body structure diagram as shown in Fig.2. The compliance of the rear frame is important, because it controls the location of the steering head bearings & consequently the boundary conditions for the vibrations of the front steering frame. Other sources of compliance in the frame are known to be less important & are consequently ignored here.

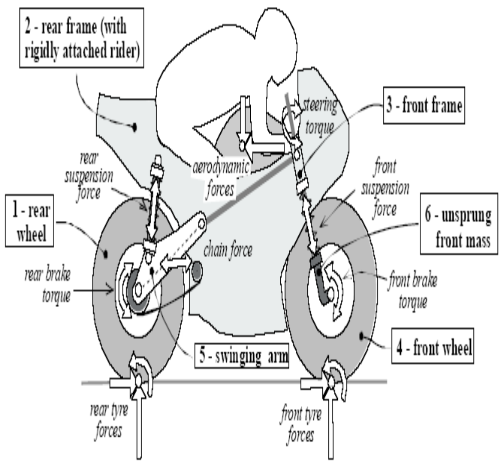


Fig.1.The Motorcycle Model

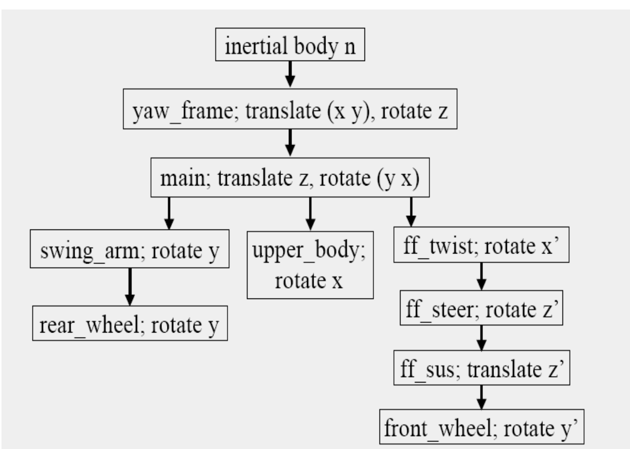


Fig.2. Body Structure diagram, showing the parent/child relationships & relative freedoms allowed.

III. METHODOLOGY

Technical details are obtained form the catalogue supplied by the manufacturer. Suitable measurements are made & skeleton model is prepared before the analysis. The centers of gravity of the vehicle under various conditions like driver alone or with the pillion rider are ascertained by taking into account the mass & the posture of the riders. The inertia properties of the sprung & the unsprung mass of the two-wheeler were calculated based on the specification & the skeleton of the two wheeler. The model was created & simulated in the commercial software ANSYS®.

A. SPECIFICATION

The various parameters of the motorbike obtained from the manufacturer.

IV. FINITE ELEMENT MODELING- PERIODIC VIBRATION

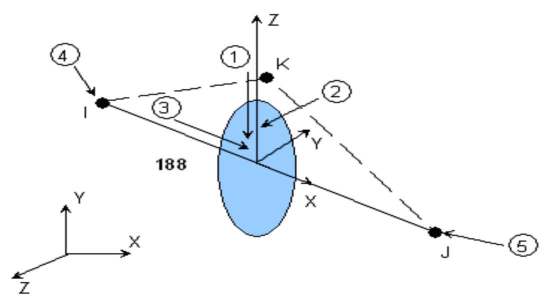


Fig.3.Element BEAM188 Geometry

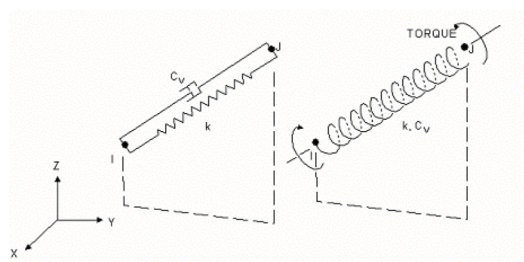


Fig.4. ElementCOMBIN14 geometry

The parameters of the spring & the tyre are taken from table.2 & the two-wheeler was modeled as shown in Fig.5. The mass of the whole body including engine, petrol tank, seat, tyres was lumped to the C.G of the frame & was transmitted to the frame by LINK elements. The bottom points of the tyre springs have been fully arrested. The discretization was performed using manual meshing in ANSYS.The number of nodes & elements in the finite element model generated are 1781 & 493 respectively.

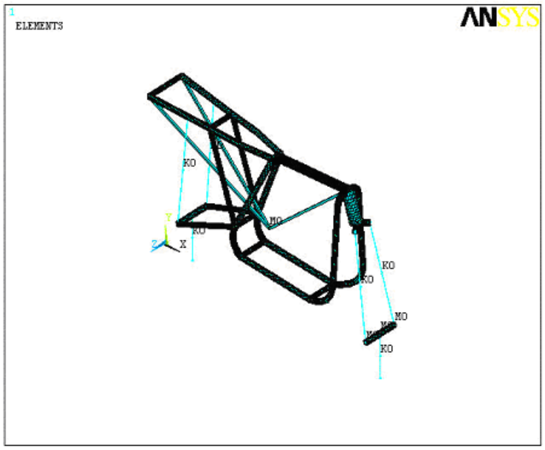


Fig.5..Finite Element model of frame

A. MODAL ANALYSIS

The equations of motion for free vibration of an n degree of freedom system with viscous damping can be written as.

$$[M]\{\ddot{q}\}+[C]\{\dot{q}\}+[K]\{q\}=\{0\} \text{---} \quad (1)$$

Where $\{q\}$ in general is a vector representing the generalized co-ordinates of the system. The two-wheeler was constrained at the axle, which are in the front & in the back of the vehicle. Since the tyre being a point contact it was properly arrested with suitable constraints. The constrained model of the two-wheeler is shown in Fig.6.

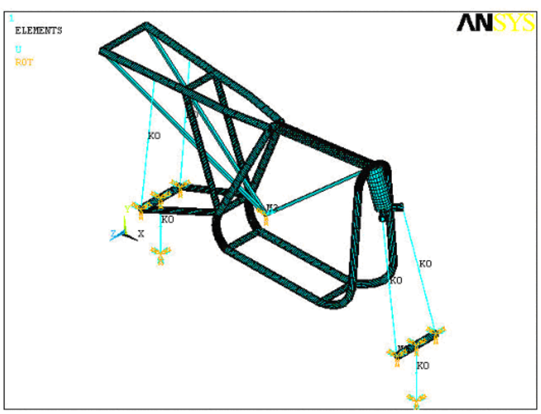


Fig.6.Frame discretization

B. EVALUATION OF EIGEN PAIRS (LANCZOS' SCHEME)

There are two types of harmonic responses arising in the vehicle. They are due to

1. System under harmonic force
2. System due to harmonic base excitation

System under harmonic force The equation of a system when it is excited harmonically is given by $[M]\{\ddot{x}\}+[C]\{\dot{x}\}+[K]\{x\}=\{F\cos(\omega t)\}$ ---(2)

System due to harmonic base excitation A vehicle moving on a road, a locomotive running on a railroad track with gaps between adjacent rails, an instrument panel with the support excited by neighboring machine unbalance force is some practical examples of this type of motion. $[M]\{\ddot{x}\}+[C]\{\dot{x}-\dot{y}\}+[K]\{x-y\}=0$ -- (3)

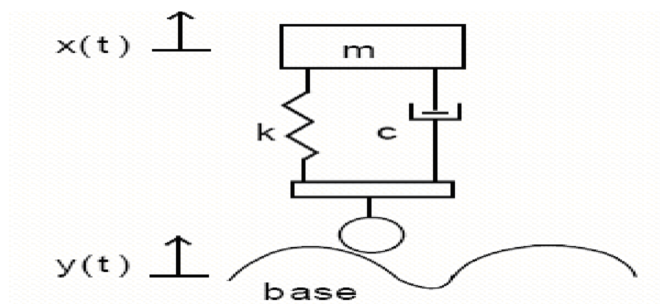


Fig.7. Base Excitation Problem

C. FRAME FLEXIBILITY MODEL

A simplified three-dimensional model of the frame of a two-wheeler is used to illustrate the influence of different frame flexibility representations. This model is not a complete representation of a physical vehicle; engine, batteries, fuel tank & many other components are missing.

The longitudinal member of the frame was discretised using SOLID55 element as shown in Fig.4.6, which was, ascertained a property of Cast iron in case of the normal mode extraction.

The normal mode shapes of the frame were obtained by performing modal analysis by extracting the natural frequencies from 0-20Hz using Block Lanczo's scheme.

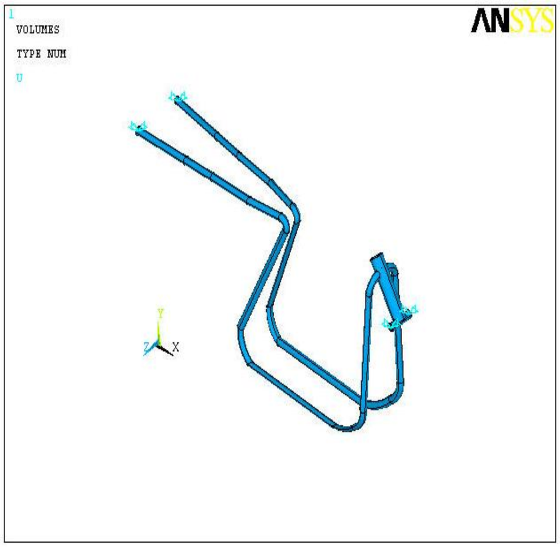


Fig.8. Finite Element Model of the Frame

V. WHEEL & TYRE SYSTEM

A. RIGID RING MODEL

A real tyre is a very complex structure, with distributed stiffness & diffused road contact. Actually one of the most common approaches to tyre representation by the use of a Mathematical function in the model developed by H.B. Pacejka in the SAE papers 870421 (1987) & 890087 (1989)

The two-dimensional model utilises a rigid ring model by Zegelaar in (1996) & (1997) shown in Fig 4.7. The tyre belt is modeled as a rigid body with single-point road contact, the slip model using ANSYS.

The finite element model of the tyre-wheel assembly was modeled based on the material & geometric properties given in Table.2.These parameters were taken into account for tyre modeling & was modeled in ANSYS software shown in Fig.9.

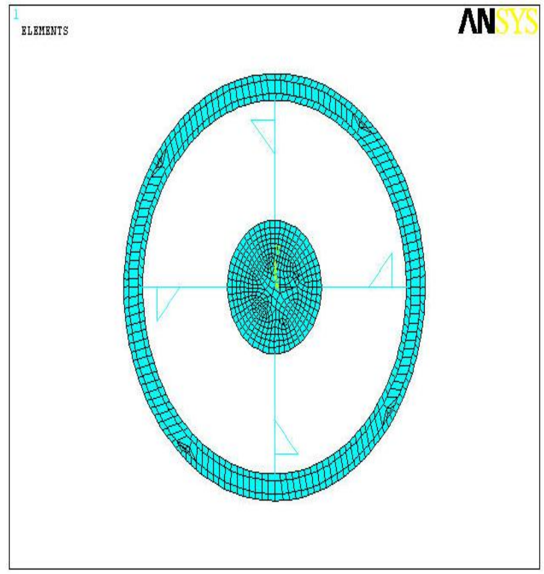


Fig.9. FE Model of the tyre-wheel Random vibration Stochastic models of guide ways

B. ROADS/RUNWAYS

A road consists of a prepared two-dimensional surface of finite width, a nominal camber & grade. Since road/runway pavements are considerably more rigid than vehicle tyre,

$$R(\delta 1, \delta 2) = E[Z(s1, s2)\, Z(s1+\delta 1, s2+\delta 2)] \text{--(5.1)}$$

i. RANDOM ANALYSIS USING ANSYS

The road input acceleration power spectral density was sampled in the range of 0-100 Hz using Spectrum analysis procedure in ANSYS, which is a technique to compute a structure's response to transient excitations that contain many frequencies. A spectrum is a representation of a load's time history in the frequency domain. The random road undulations that were applied for the studies are of two types of excitation, which were obtained from Donald (2002). The two Standard profiles used for automotive environment are:

1) Mil-Std-810E Section 514 and 516 (For Composite wheeled)
2) SAE J1211

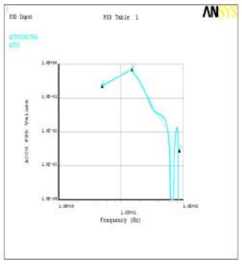
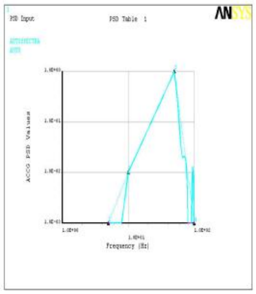
 (a)Mil-Std-810E Composite Wheeled	 (b)SAE J1211

Fig.10.Different type of Random Road Excitations

C. *RESPONSE TO RANDOM LOADING*

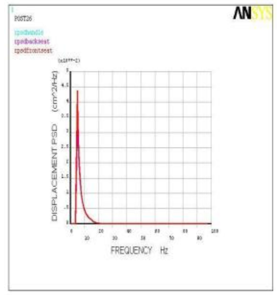
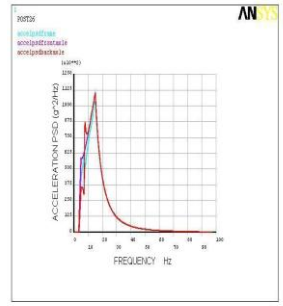
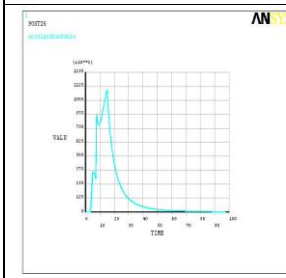
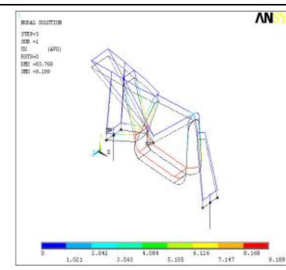
It is well known from Robson (1964) that the power spectral density of the response of a system at any frequency is equal to the power spectral density (p.s.d) of the exciting force at that frequency multiplied by square of the modulus of the receptance at that frequency.

Table.1.Standard Road Profiles

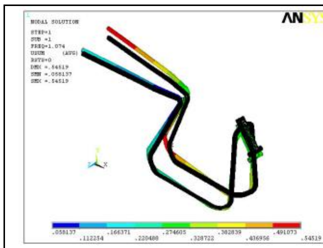
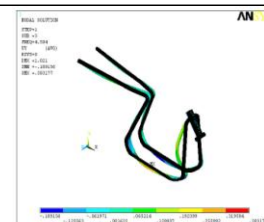
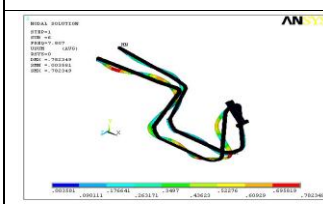
Frequency (Hz)	Mil-Std-810E Composite Wheeled PSD (g^2/Hz)	Frequency (Hz)	SAE J1211 PSD (g^2/Hz)
5	.2308	5	1×10^{-5}
15	.7041	10	1×10^{-4}
87	.0028	50	1
247	.015	100	1×10^{-4}
500	.011	500	1×10^{-4}

VI. RESULTS AND DISCUSSION

Table 2. Response due to random loading

 Fig.a.Displacement PSD	 Fig.b.Acceleration PSD
 Fig.c.Acceleration PSD at the rear axle	 Fig.d.1-σ Displacement values in UX direction.

Random response for MIL-STD810E input.

 Fig.a.Pitch mode at 1.074Hz.	 Fig.b.Bending mode at 4.594Hz.
 Fig.c.2nd Bending mode at 7.807Hz.	Fig.d.Torsion mode at 6.637Hz.

VII. CONCLUSION

An attempt has been successfully made to compare the results of the mathematical models and the finite element models for modal and vibration analysis of the motorcycle. The Lanczo's method has been successfully used in performing modal analysis to extract the eigenpairs of the two-wheeler which was modeled as a simplified model of the axles, suspension and tyres with concentrated masses at appropriate locations. The spectrum analysis was performed to calculate the PSD of acceleration of the two test tracks which have been as input to the tyres the dynamic response of the vehicle in terms of acceleration has been computed .The frequencies that were obtained from suspension theory models by applying double conjugate points method was compared with the results of the modal analysis that were obtained from Finite element model .The periodic response of the motorcycle to periodic and aperiodic excitation were computed to identify the peak points of the acceleration and displacement of the vehicle which need a further study to isolate the vibration occurrences at these specified points.

The sensitivity of the vertical response characteristics to some vehicle system parameters is studied within the context of ride quality. Further improvements in ride behavior are possible by minimizing sprung mass displacement/ acceleration, suspension travel and dynamic tyre deflection using optimization techniques.

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