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ACOUSTIC ANALYSIS OF ROLLING TIRE FINITE ELEMENT METHOD

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ABSTRACT- In the automotive sector, tire noise has a significant impact on Driving comfort and noise pollution. During the movement of a vehicle, tire noise mainly arises due to interaction between tire tread and road surface. Tire pattern, tire type, road surface condition and driving are few of the elements affecting tyre noise.Tyre noise tends to grow with increasing vehicle spee d and is also related to uneven or rough road surfaces.The acoustic analysis of rolling tyres using the finite element method (FEM) is the main component of this research.It comprises of several simulation sound radiation processes, starting with the development of a half-model of a two-dimensional axisymmetric tyre and the application of section material properties and boundary conditions. Next, this model was rotated around any reference axis to create a dimensional tyre. Any reference plane is reflected by this 3D tyre in order to create a full 3D tyre, and boundary conditions such as axel load tyre inflation pressure are applied. Foot print analysis of tire. After completion of foot print analysis Tire under steady state dynamic analysis in this step tire rolling different speed and applying harmonic excitation and extract the frequency response and modal analysis of rolling tire. Acoustic simulation is a last step of analysis create air cavity surrounding of tire and analyze sound pressure level (SPL) at different speed.

I. INTRODUCTION

Tyre Acoustic Cavity Resonance Wheels' Energy Transmission CharacteristicsThe structure inten sity distribution and energy transmission efficiency can be characterised and analysed with clarity using the Power Flow Method.Additionally, the effects of material structure dampening and the quantity of spokes on the transfer of energy are also covered [12].A simplified finite element mod el of an automobile tyre with an acoustic cavity that introduces rotation was used in the simulatio n and experimental validation of the sound field in a rotating tyre cavity. of automobile tire is established, is proposed to gain the sound field in the cavity of a rotating automobile tire. And the test of sound pressure in a rotating tire is also performed to validate the proposed simulation method. [3] Research on Sound Radiation Analysis of Tyre by LS-DYNA. In this paper information about radiation of noise by effect of road tyre interaction produce vibration. There are two phases in analysis of tyre noise first is dynamic analysis of tyre by harmonic excitation and other is determine pass by pass noise by boundary element method by using LS-DYNA Acoustic solver [9]. A Simulation Methodology for Tire/Road Vibration Noise analysis. A new methodology for simulating tire/road vibration noise is presented, which is is based on the Mixed Lagrange–Euler Method and Pseudo Excitation Method [8]. Automotive wheel and tyre design for suppression of acoustic cavity noise through the incorporation of passive resonators [20]. Vehicle noise and tire noise were briefly reviewed in the background introduction. Then the motivation of and approaches to reducing tire noise was reviewed from open literature [7]. Finite Element Method (FEM) analysis is done on a standard tyre, steel rim and tyre-rim assembly to find out the resonance frequencies and modes of vibration of tyre rim and cavity which is used to find out the modal coupling which will cause the amplification of noise and vibration transmission [13].Tire Cavity Induced Structure-Borne Noise Study with Experimental Verification High frequency interior noise is mostly airborne and usually is not associated with structural vibration from road excitation [22].

II. METHODOLOGY

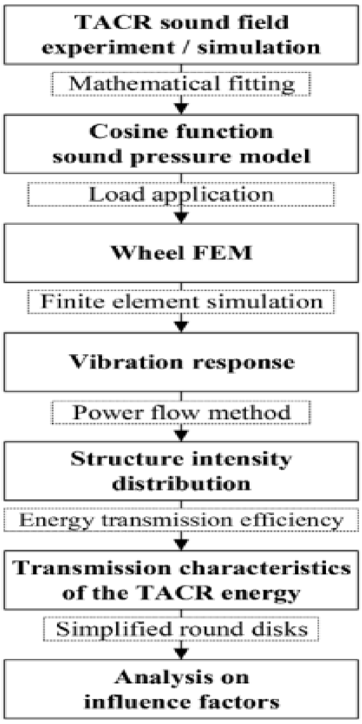

Figure 2.1- Methodology

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III. TIRE MODELLING & SIMULATION METHOD

3.1 Finite element method for analysis

The material qualities of an 185/60R15 tyre are investigated, with information from the tyre manufacturer.The vehicle wheel is treated as a rigid body throughout the simulation process since its stiffness is significantly higher than that of a tyre.While the crosssectional aspects of the tread pattern are disregarded characteristics of the tire are retained. Besides, a tire is very complex structure and it is formed by layers of parallel string reinforcements and rubber parts. In modeling of the tire, a two-dimensional (2D) FEM of automobile tire is built first, and then revolved into a three-dimensional (3D) FEM of automobile tire. The 2D FEM of tire with the size of 185/60R15 is built in Abaqus software [3].

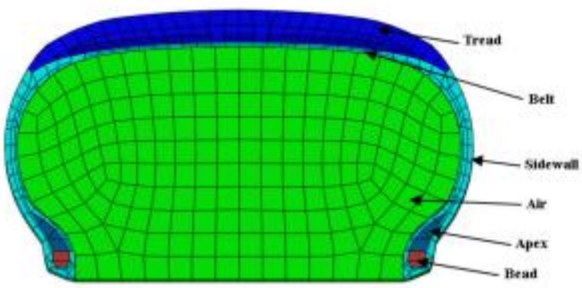

Figure 3.1.1. 2D FEM of tire

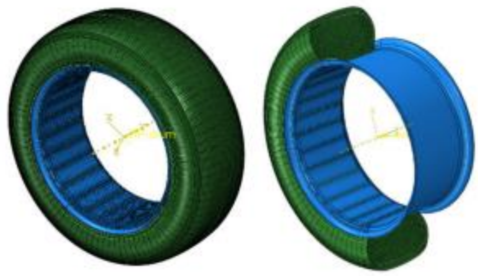

Figure 3.1.2- 3D tire Model

3.2 Tyre rolling structural dynamics simulation

An Arbirary Lagrangian Eulerian (ALE) formulation is used to describe the dynamics of rolling tyres.In this method, the motion is divided into pure rigid body motion and deformatio ns inside a broad deformation framework.A spatially fixed mesh is used to describe the motio n of the rigid body, or in an Eulerian fashion. the deformation is measured with respect to this intermediate reference in Lagrangeian coordinates. The advantage of such a procedure is that steady state rolling is computed time and that the transient dynamics are described spatially, as needed for the noise radiation simulation. The ALE-method is well accepted for the computation of steady state rolling, for the general theory and computational aspects an Eigen analysis is performed for the rotating system [6].

3.3 Mixed Lagrange–Euler method for rolling analysis to analyze rolling noise, we want a precise acceleration field. Because the ALE method is not suitable, the explicit Lagrange method is generally used to obtain the changes of the velocity and the acceleration of the material with time. On the other hand, the noise analysis requires the acceleration field on the same stationary mesh as the input signal, which is given by $a = a(\chi,t)$ where χ is the reference configuration. is used to achieve this goal. First, the explicit FE method is used to analyze the vibration of the rotational structure. The information is then mapped from the Lagrange mesh to the reference Euler mesh by dynamic mapping. Only the information from the skin of the

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model is required for the vibration simulation. The mapping is performed using Finite Element Interpolation, which ensures the precision and the reliability of the data during the mapping. The Lagrange and Euler meshes are shown in Figure. [8].

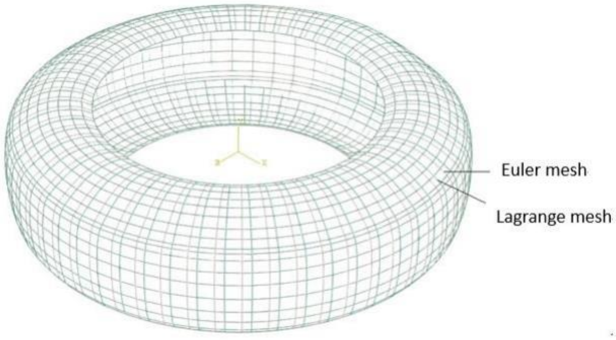
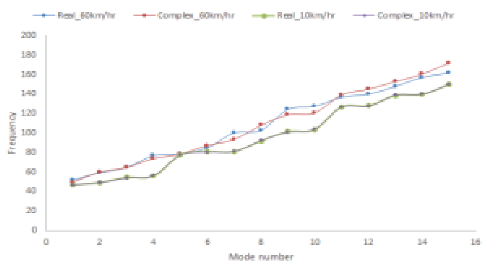


Figure 3.3 The relationship between the Lagrange mesh and the Euler mesh

3.4 The axisymmetric model was discretized with bilinear elements. A partial three-dimensional model was generated by revolving the axisymmetric model about the rotational axis. The generated partial model. This partial three-dimensional model is also composed of bilinear elements except for footprint region where more linear elements have been utilized to increase resolution near contact patch. The full three-dimensional model was generated by reflecting the partial three-dimensional model. One thing should be noted that all the elements used for the analysis is hybrid in nature [1].

IV. FREQUENCY ANALYSIS

4.1 Subspace-based steady
state dynamic investigation involves immediately projecting the solution into a reduced-dimensional subspace of an undamped system in order to ascertain the dynamic response of a system that has undergone harmonic stimulation.In the frequency domain of interest, Eigen frequency has been extracted before analysis.The Eigen value and frequency of the FE tyre



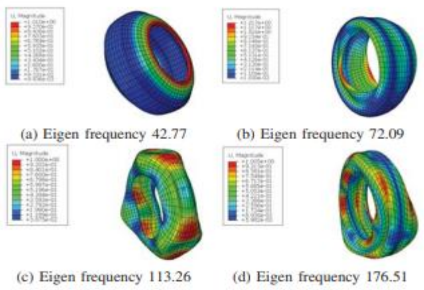
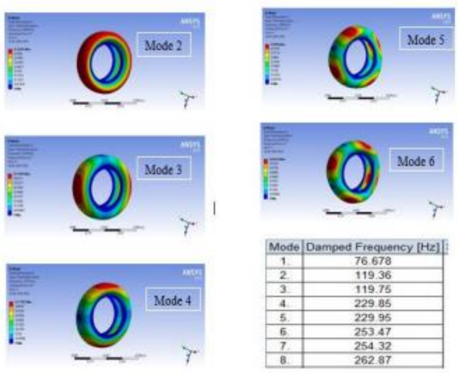


Figure 4.1.1- Frequency V/S Mode Graph

Figure 4.1.2- Mode shapes

4.2 The tire model used for analysis is Bridgestone (P205/65/R15).. Fixed support is applied at the bead region of the tire and air pressure is given at inner surface of tire as 220 KPa and FEA analysis is done. Results are obtained as shown in the figure. The natural frequency of

5th mode shape is around 229 Hz shows the different mode shapes and corresponding frequencies obtained for tire structure [13].



Mode	Damped Frequency [Hz]
1.	76.678
2.	119.36
3.	119.75
4.	229.85
5.	229.95
6.	253.47
7.	254.32
8.	262.87

Figure 4.2.1- Mode shapes

V. METHOD OF TIRE ACOUSTIC ANALYSIS

5.1 A Ffowcs Williams Hawkings computation that employs the pressure and velocity field at the interface of the perfectly matched layer as inputs is used to evaluate the pressure in the fa r field. The sound pressure maps are shown on a half sphere with a set radius of one metre. Such a half sphere has been already used in the articles which has been used to validate the simulation model. It allows to observe the radiated power pattern of the tire. Figure 1 gives a representation of the tire, the surrounding fluid and the half sphere for the two test cases [18].

Figure 5.1.1- Acoustic cavity

5.2 Sound pressure amplitude distribution in tire cavity under the road load. Sound pressure amplitude distribution in the FEM. Sound pressure amplitude distribution in the polar coordinate system [3].

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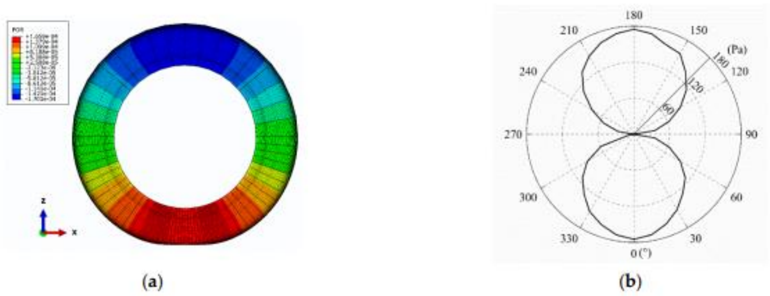

Figure 5.2.1- Mode shapes

5.3 boundary element method by using LS-DYNA Acoustic solver are used to create acoustic cavity surrounding to tyre model [9].

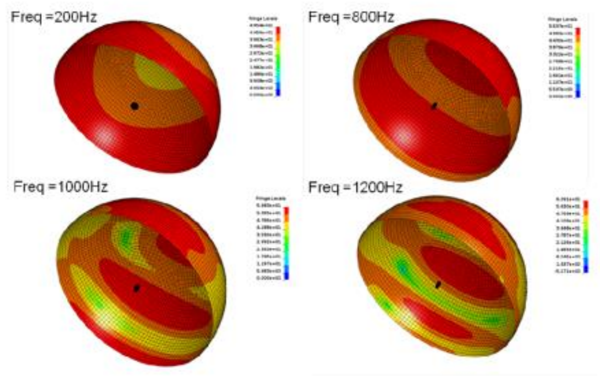

Figure 5.3.1- Acoustic cavity by BEM

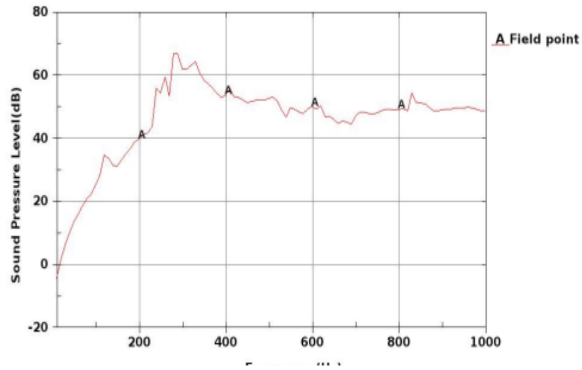

Figure 5.3.2- SPL Chart

VI. EXPERIMENTAL ANALYSIS

6.1A hybrid experimental scheme is established to explore the TBR (Truck and Bus Radial Tyre) noise source, the frequency characteristics, and their pass by noise characteristics.The whole test system, as shown in Figure, consists of a semianechoic chamber, a drum, a test veh icle, tyres, a far field test setup, and a holography matrix.

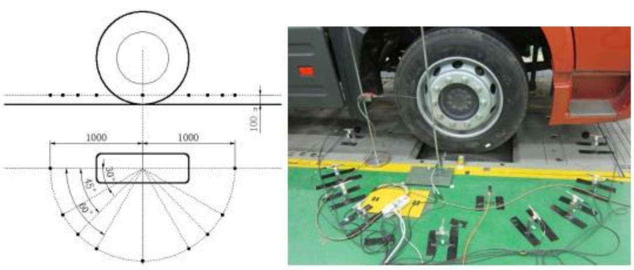

Figure 6.1.1 Near Field TBR noise test setup microphone position, test drum/tire assembly

6.2 CPX set-up The CPX set-up used is developed within the ‘CCAR’ project with TNO and the University of Twente and is shown in Figure 1. The self-induced wind noise plays a role

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only below 350 Hz for driving speeds up to 80 km/h and structural vibrations have no effect on the microphone signals [15].

Figure 6.2.1 – CPX measurement set-up

6.3 Measurement of the car interior sound pressure level using a cleat operation test: Three types of tires were installed to measure the car interior sound pressure level at the operating chassis dynamo attached to the cleat test car. The chassis dynamo using test can operate the front left tire of a car. The car interior sound pressure level was measured at the driver's ear position at 60 km/h when the power train was stopped [19].

Figure 6.3.1 rolling cleat test to measure the sound pressure in a vehicle

VII. CONCLUSION

To examine all research on tyre acoustics, it is important to recognise that road irregularities a nd the air cavity in the tyre are also responsible for producing noise. Tyre noise is produced by structural vibration of the thread.Researchers used the boundary element method and finite element method to create this noise simulation.One of the key factors in tyre noise is tyre speed.I've done research on using the finite element method to calculate the sound pressure level of a passenger car tyre at various speeds.

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