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Noise Generation Mechanism of Tires

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Abstract:- In the automotive industry noise generation by tire has become an important area for the researchers because of the strict noise norms. According to norms, the noise limit for the passenger car is 80 dB. In an automotive vehicle there are three basic noise generation mechanisms which are wind turbulent noise, power unit noise and tire noise. The part of this component in the total noise generation depends upon vehicle speed i.e., whether the vehicle is accelerating, decelerating or turning. Among the different noise generation sources tire noise contributes 10-15% of the overall noise generation. When the vehicle starts to accelerate, the wind turbulence noise comes into picture. The noise from the engine, fan and exhaust comes under the category of power unit noise. Whenever the tire is rolling over the road, as a result of the interaction of the tire with the road, noise generation takes place which is known as tire noise or tire-road noise.In this project, our main aim is to find out how tire noise is generated and to discuss the various mechanisms causing the tire noise. We will also find the preventive methods to reduce the tire noise to meet the strict noise norms.

Keywords:- Noise generation, acoustic, turbulence, tire-road interaction, mechanisms

I. INTRODUCTION

Our environment is not only affected by pollution of exhaust gases from vehicles, but also by external voice radiated from vehicles. Tire noise from vehicles, especially from commercial heavy vehicles adds to the exterior noise created by vehicles, such as exhaust, powertrain. There are different sources for the tire noise generation. One of the sources is the sound of the tread contacting the road. Another source is the sound of air being compressed inside the tread grooves. Road surface state also plays an important role in the generation of noise. Reducing all exterior noises from vehicles to improve rider comfort is becoming a tough challenge for automotive designers. This also includes the reduction of tire noise due to the rolling. The type of road surface also determines the level of noise generated at the tire road interface.

The mechanism of tire noise is complex. It is an additive effect of tire, vehicle and tire road interaction. The tire noise accounts about 10-15% of the overall vehicle noise. There are two mechanisms discussed in detail i.e. Impact and adhesion mechanism[1]. Another research has maintained that the tire noise is due to the air activity inside the tire. The frequency of the waves are qualified by the circumference of the air cavity and the sound speed[2]. Another research suggests that the tire air cavity geometry is affected by the dynamic and static loads. Equations for cavity noise under static loads have been developed. Based on this model the vertical forces acting on the cavity due to the tire road interface are obtained[3]. The predicted results and the experimental results of peak frequency are compared and its relation with vehicle speed and vertical tire load is defined[4].

II. CAD MODELLING OF TIRE

Modeling of the tire is done using Creo 2.2 parametric software. Dimensions which are necessary for modeling are taken from the code available on the Ford Eco-sport model. The Tire specifications for this model are 205/60R16 92H. As per the designation system, the important information available from the code is Section height = 205mm and Section width = 60mm. These are the two important dimensions required to model the tire. Thread dimensions are assumed for the sake of simplicity in modelling. There are two methods which can be used to model the tire. One method is the simple extrusion method and the other one is the toroidal bend method. Toroidal bend is a relatively more complex method but it reduces the modeling time to a large extent, therefore this method is preferred over the simple extrusion method which takes more time for modeling. The main stages of modelling are a follows:

A. Basic Sketch

The basic sketch is formed using the section height and section width which will form a rectangle. The various thread patterns are made on the upper surface of the rectangle as shown in Fig. 1.

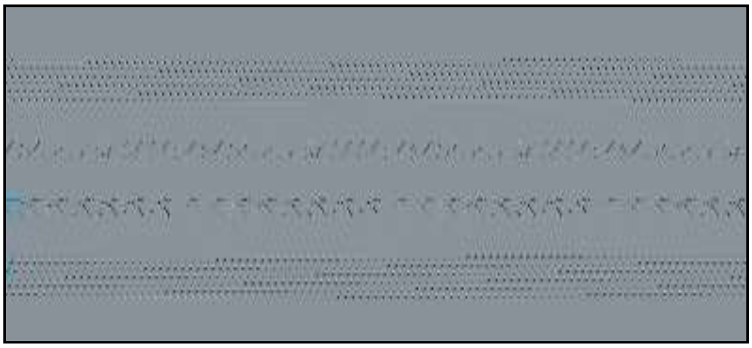

Fig 1. Thread Pattern

B. Wrap Tool

Wrap tool is used to form the hollow curved structure of Tire. For the hollow curved part the basic sketch is wrapped by -180^{O} about the appropriate coordinate axis as shown in Fig. 2.

Fig 2. Wrapped tire structure

Fig 3. Complete tire structure

C. Toroidal Bend Tool

This step is the most important step in the modelling of the complete tire. A 360 degree bend is used to obtain the final tire structure as shown in Fig. 3.

III. FLOW ANALYSIS OF TYRE MODEL

The flow analysis to obtain the relevant parameters is conducted in Ansys Workbench 15 (Fluent). The modeled tyre as described above is used for the analysis purpose. The flow of air around the tyre is simulated under the assumption that the vehicle is moving at a velocity of 120 km/hr.

A. Domain generation and meshing

The domain for the geometry is created as a rectangular cuboid shaped volume surrounding the tyre in order to define the flow around the tyre. In order to simplify the computation and reduce the computation time, the domain is split into three sections; one section containing the tyre where the accuracy of data measurement will be higher and the other two sections where the main purpose is to obtain the data for the flow field.
The domain is shown in Fig 4 below and the dimensions of the domain are as given in Table 1 below.

Table I: Domain dimensions

Sr. No.	Parameter	Dimension (mm)
1	Length	3000
2	Width	400
3	Height	800

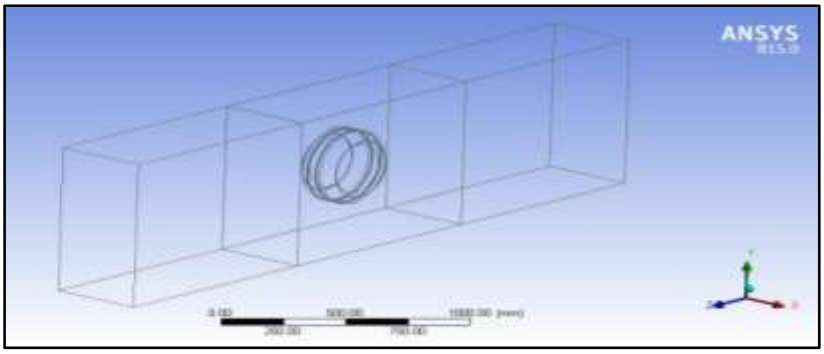

Fig 4. Domain of flow field

The meshing for the domain is shown in Fig 5 below. A rectangular mesh is used for the sections without the tyre and a triangular mesh is used for the section containing the tyre. The cell size for the mesh is 100 mm for the flow field domain and 50 mm for the tyre. A smaller mesh cell size can be used; the larger cell size is used in this case to reduce the computational time required. A longitudinal cut section of the domain is represented in Fig 5 as shown below. In this figure, the difference in the cell size is apparent and can be observed.

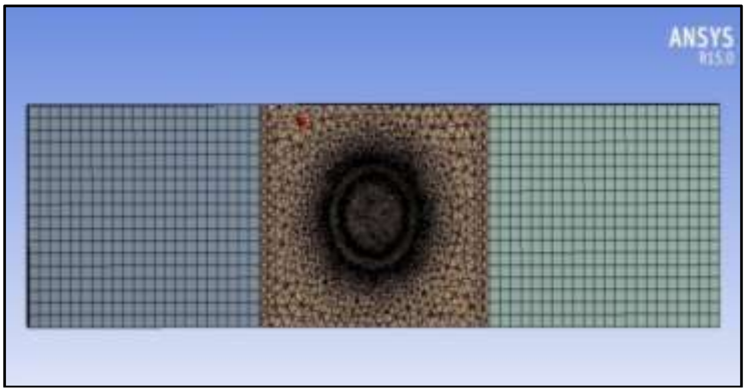

Fig 5. Meshed domain

B. Velocity and pressure contours

In order to obtain the acoustic data, the pressure acting on the tyre is one of the most important factors that cause the sound variations. In order to determine the areas where significant variations in pressure occur, the velocity contours must be observed so that important regions such as stagnation pressure zone and wake areas can be identified. The velocity magnitude contours as describe above are shown in Fig 6 below. The small circular area to the left of the tyre is the stagnation pressure zone where the minimum velocity of flow is almost 0 m/s. This stagnation pressure zone causes a large pressure difference with the surrounding area of flow having a velocity of 41 m/s approximately. This area is mostly responsible for the production of sound waves with maximum magnitude. Also, the area to the right of the tyre shows the wake region of flow due to boundary layer separation. This region is also partially responsible for the sound created near the tyre.

The static pressure contours for the flow field are shown in Fig 7 below. As can be observed from the same, the pressure in the stagnation pressure zone is approximately 874 Pa while the pressure in the region surrounding the stagnation zone is approximately 283 Pa. This pressure difference causes generation of pressure waves which are responsible for the sound generation. Also, in the wake area, the pressure is approximately -426 Pa i.e., the pressure is below atmospheric pressure. The surrounding region has a pressure of 165 Pa; causing a further generation of pressure waves and hence; the generation of sound waves.

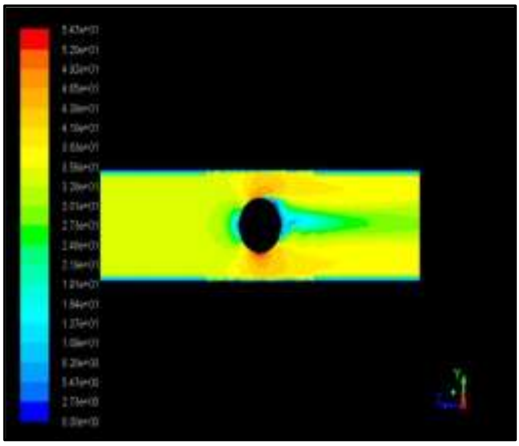

Fig 6. Velocity magnitude contours

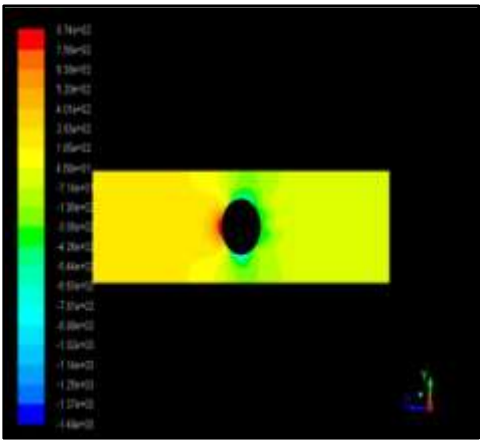

Fig 7. Static pressure contours

C. Sensors for acoustic analysis

To obtain the acoustic data in the region surrounding the tyre, sensors are placed near the tyre in pre-decided positions so as to observe the sound levels generated near the tyre. The locations of the sensors are shown in Table 2 below. The locations shown are for the condition that the center of the tyre is at the point (0, 0, 0) in the three dimensional co-ordinate system.

Table II: Locations of acoustic sensors

Sensor	**Co-ordinates**		
	X (mm)	**Y (mm)**	**Z (mm)**
Sensor 1	0	0	-300
Sensor 2	0	0	300
Sensor 3	0	300	0
Sensor 4	0	-300	0
Sensor 5	150	0	0
Sensor 6	-150	0	0

D. Results from acoustic analysis

Two major parameters need to be measured from the sensors and the flow field; these are sound pressure levels and sound amplitude. These are obtained in the form of graphs versus the frequency of sound waves. To obtain the graphs required, monitors are set-up during the flow field set-up in Fluent and data is recorded from the same. The data recorded from these sensors are shown in Table 3 and 4 below. The graph of sound amplitude versus frequency of waves as obtained for Sensor 1 is shown in Fig 8 below. Similarly, the graph of sound pressure levels versus frequency for Sensor 1 is shown in Fig 9 below.

Table III: Sound amplitude data

Sr. No.	**Sensor**	**Sound amplitude (dB)**	**Frequency (Hz)**
1	Sensor 1	12.5	50
2	Sensor 2	12.5	50
3	Sensor 3	22.5	50
4	Sensor 4	25	50
5	Sensor 5	9.8	50
6	Sensor 6	9	50

Table IV: Sound pressure levels

Sr. No.	**Sensor**	**Sound pressure levels (dB)**	**Frequency (Hz)**
1	Sensor 1	27.5	50
2	Sensor 2	28	50
3	Sensor 3	47.5	50
4	Sensor 4	54	50
5	Sensor 5	24	50
6	Sensor 6	18	50

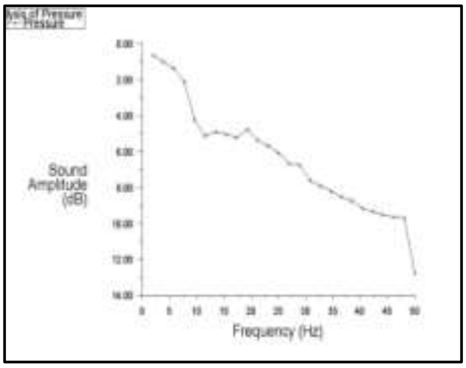

Fig 8. Sound amplitude data for Sensor 1

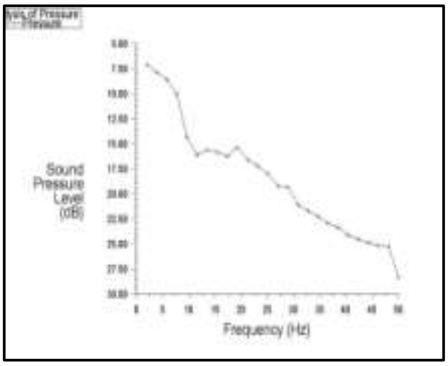

Fig 9. Sound pressure levels data for Sensor 1

IV. CONCLUSION

- The acoustic analysis of the tire was carried out at a vehicle speed of 120 km/hr.
- The three main areas of noise generation were focused upon and acoustic data regarding the same was obtained.
- The pressure and velocity data for the flow field was obtained.
- The region at the tire-road interface was found to generate the maximum noise.
- The sound amplitude at this region was 25 dB and the sound pressure level was found to be 54 dB.

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