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Tire Modal Analysis Using ANSYS

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Abstract

The paper is aimed to analyze and get a further understanding of the dynamic characteristics of the tire by means of computing modal analysis. We attempt to study how the amplitude of exciting force and loading changes affect the tire modal analysis which lays a foundation for applying the tire modal test into practical use. And it takes advantage of ANSYS to set up the finite element model of the tire and to analyze the tire structural dynamics, and it also studies the law of tire's dynamic characteristics and its reason.

Keywords*: ANSYS, Modal analysis*

1. INTRODUCTION

Automobile tire is an important component of the car, whose structural parameters and mechanical properties of the tire determine the car's main drive performance. In a hundred years of automotive development, the studies on tire mechanics have greatly attracted researchers' attention who works in automobile field. Hence in order to improve the drive performances of car a new tire which completely eliminates the use of air but instead uses it structure to balance weight known as airless tire was created.

Vertical force longitudinal force, lateral force and moment are the result of the tire deformation, tire pressing strongly ground. Uneven pavement, the unevenness of the movement axle and tire in homogeneity will cause the tire vibration. This vibration is transmitted to the axle and further to the vehicle body. It will lead to changes in vertical force response, which will bring

important and often adversely affected to longitudinal force on the axle, lateral force and thus movement of the vehicle.

With the development of mechanics, computers and other related technologies, people have been able to create complex and accurate vehicle dynamics model, and make a simulation study of specific issues. However, in the vehicle dynamics model, practicality and accuracy of the tire model is still an important and key issue to be set. In the study of the tire model, using model methods have been noticed by domestic and foreign researchers. We can make use of modal parameters to estimate the parameters of the tire modal, and we can get the modal parameters by analyzing it.

The thesis is divided into three steps: First it summarizes the present situation of research on the dynamic tire characteristics. Then the author use ANSYS to set up the finite element model of the tire and analyze the tire structural dynamics, which aims to understand the dynamic characteristics of the tire and establish the modal test system for tires. Finally it studies the dynamic characteristics of the tire rule and analyzes its causes.

2. THE PRINCIPLE OF MODAL ANALYSIS

Modal analysis can be defined as analytical analysis of structural dynamic characteristic and experimental analysis. And dynamic characteristics of the structure are characterized with the modal parameters. In mathematics, the modal parameters are Eigen values and vectors of mechanical system differential equations of motion, that is, if you want to know the geometry boundary conditions and material properties of the structure, it's necessary to show the distribution of mass, stiffness and damping distributions of the structure with the use of mass matrix, stiffness matrix and damping matrix. So that there is enough information to determine the modal parameters of the system (natural frequency, damping and mode shapes). It proves in theory, modal parameters can fully describe the dynamics of the system [4]. With the studying development of modal analysis, modal analysis technique has been broadly interpreted to include determining the dynamic characteristics of the mechanical system and its application in most areas related from recognition of the system to the Structure sensitivity analysis and dynamic modification, etc.

3. FEM MODAL ANALYSIS THEORY

Finite element calculation mode, in fact, is structural dynamics of the eigenvalue. Eigenvalues and eigenvectors is natural frequencies and mode shapes modal analysis.

Vibration system equations of motion:

$$[M]\{\ddot{x}(t)\}+[C]\{\dot{X}\}+[K]\{x(t)\}=\{f(t)\} \quad (1)$$

[M], [C], [K], {f(t)}, {x(t)} are the mass matrix, damping matrix, stiffness matrix, force vectors and response vector respectively.

Assuming free vibration and ignoring damping:

$$[M]\{\ddot{x}\}+[K]\{x\}=0 \quad (2)$$

This is an Order Linear Homogeneous differential equations, in the form of its solution are:

$$\{x\}=\{\phi\}\sin\omega t \quad (3)$$

Then put (3) into (2), and get:

$$([K]-\omega^2[M])\{\phi\}=0 \quad (4)$$

Generalized eigenvalue problem, Solving this equation and that the solution can be determined features

$$(\omega_1^2,\{\omega\}_1),(\omega_2^2,\{\omega\}_2),\cdots(\omega_n^2,\{\omega\}_n)$$

Their amplitude can be normalized in the following formula for quality planning

$$\{\phi\}_i^T M\{\phi\}_i = I(i=1,2\cdots n) \quad (5)$$

Then what obtained is vector regular modes.

4. EXTRACT TIRE NATURAL FREQUENCY

Density must be defined in modeling; only use linear units and linear materials; non-linear nature is ignored. The specific progress of tire finite element model in ANSYS can be found in literature. This article extracts natural frequency based on the existing finite element model of tire. In order to simplify calculation process, it's necessary to simplify properly 3D CAD model based on the computer's performance

5. TIRE CALCULATE MODAL ANALYSIS RESULTS

Modal Characteristics of tires directly reflects the structure of the mechanical characteristics of the tire. The modal analysis of the tire enables us not only to understand the dynamics of the tire, but also provide a reference for the next tire modal experiments, such as in Modal experiment, According to modes (finite element results), we can determine whether it's the main mode, and avoid exciting at the nodes on the basis of the following three-dimensional finite element model of the tire.

6. MESHING THE TIRE IN ANSYS

Figure: 1 Mesh in Ansys

1. Frequency

Mode	Frequency(Hz)	Load Step	Sub Step	Cumulative
1	22.61	1	1	1
2	43.699	1	2	2
3	43.709	1	3	3
4	47.212	1	4	4
5	52.133	1	5	5

6	66.132	1	6	6
7	76.424	1	7	7
8	76.539	1	8	8
9	96.543	1	9	9
10	96.5672	1	10	10

2. Vibration pattern

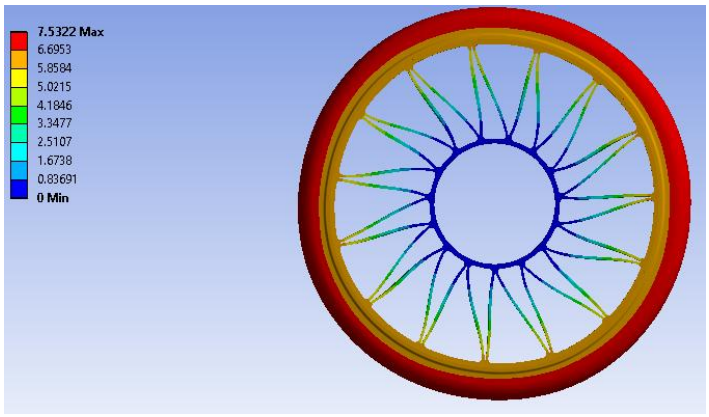

Figure 2: First and second order

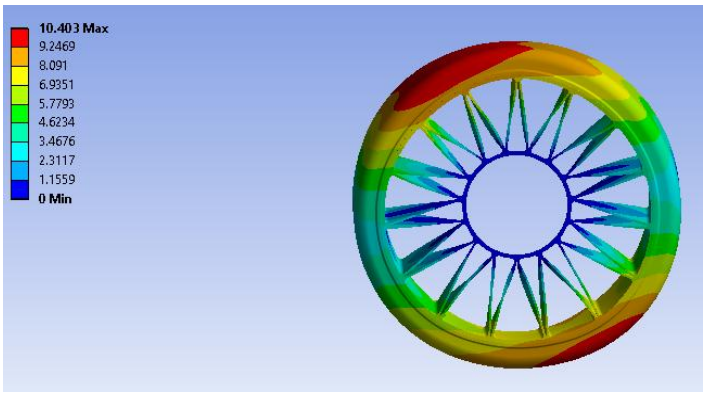

Figure: 3 Third and fourth order

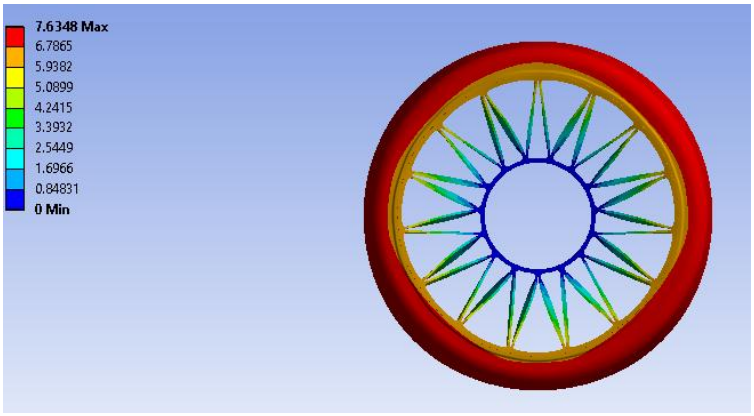

Figure: 4 fifth order

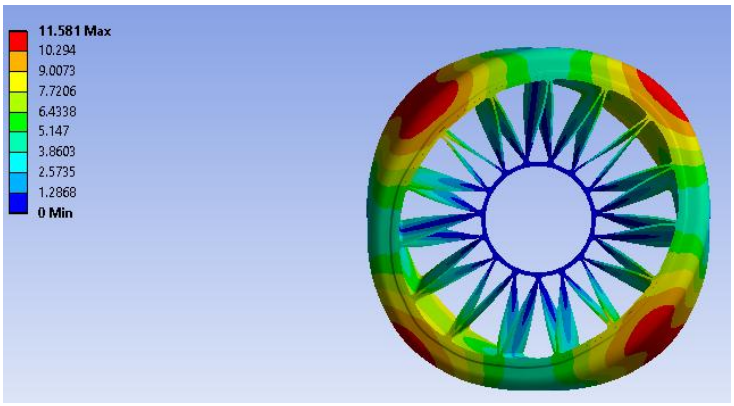

Figure: 5 sixth order

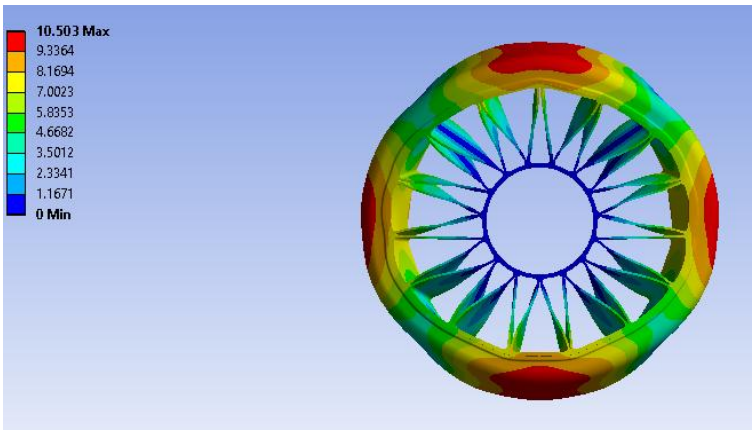

Figure: 6 Seventh and eighth order

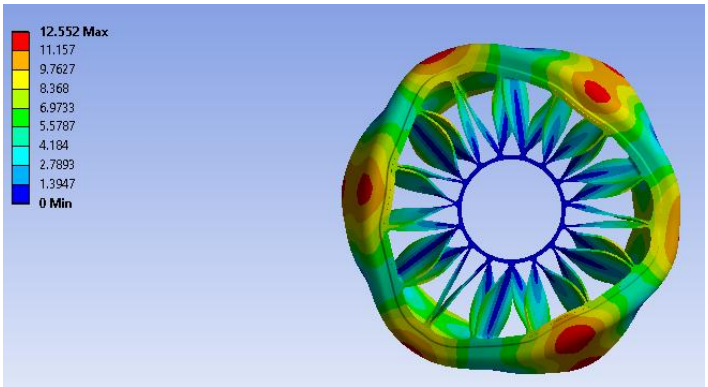

Figure: 7 Ninth and tenth order

These results show that tires from the eighth stage began to show increasing twist, which explained that, the design and the use of tire need to avoid these natural frequencies. However, the modal (displacement) vector is a relative value; therefore it does not represent the actual physical displacement, merely reflecting the ratio between different parts of the deformation that is a kind of modal vector normalization.

CONCLUSION

- The inherent characteristics of the tire consists of the natural frequency, mode shape modal parameters etc. It is determined by the tire itself (mass and stiffness distribution), which has nothing to do with the external load, but determine the influence of the structure on the dynamic load.
- The tire vibration model case can be seen by modal analysis: tire surrounding has a large deformation. From the eighth to tenth modal, the center has maximum deformation.
- So when designing a tire, we should depend on the data from modal analysis. Let the wheel natural frequency stagger relative external frequency, so it can increase comfort.

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