A comprehensive review on the finite element analysis of mechanical components

[1]B.Udaya lakshmi, [2]K.N.D.Malleswara Rao, [3]V.Sankararao

[1,2,3]Assistant Professor, Department of Mechanical Engineering, Lakireddy Bali Reddy College of Engineering(Autonomous), LB Reddy Nagar, Mylavaram, India

Abstract : Finite element analysis (FEA) has been extensively used as an active numerical analysis method in the design of automobile components and other fields. This paper mainly focused on the finite element analysis development in mechanical parts and the difficulties faced during analysis are summarized in detail. Moreover, the applications of FEA in automobile components such as wheel/rim, leaf springs, drive shaft, steel plate spring, clutch plates, gears and so on are summarized and compared with associated research studies.

Keywords - **FEA, design, analysis, mechanical components.**

I. INTRODUCTION

With the social economy rapid development and science and technology constant progress automobiles are have become most important in daily life for transportation. However, with the car ownership continuous growth the automobile safety and energy saving problems become famous around the world. Whereas the safety performance of vehicles depends on the design and manufacture of automotive parts. Moreover the safety performance of the vehicle greatly varies from design methods, right material, strength and stability, which is main problem that vehicle manufacturers should solve now. Regular methods cannot efficiently improve the structure safety but also cause a large amount of work which contains more calculation errors.

Finite element method [1] extensively used in the parts design of automobile components, such as design of lightweight automotive frame and the analysis of body and frame vibration characteristics, which can efficiently solve the problem of the deformation and stress whole distribution of complex parts. Moreover it also contributes a strong support for the stiffness and strength analysis of wheels/rims, leaf springs, clutch plates, gears, drive shafts and other vehicle parts. FEA is used to analyze stress condition under different working conditions, which effectively improves the design efficiency and reduces the calculation error. Automobiles are composed of three parts: body, chassis and engine. The body is involved in the material, manufacturing process, modeling and so on. It is the most important and the most complicated part, and its strength and stiffness are closely related to safety performance. FEA can introduce the virtual simulation into traditional design methods, greatly reduces the test cost and shortens the manufacturing period.

II. BSAIC STEPS OF FEA

2.1 Grid quantities

The number of grids directly affects the computational accuracy and the size of the computational workload. Increasing the number of grids can improve the accuracy, but also increasing the computation load. When the grid number is small, increasing the number of grids will greatly improve the accuracy without significantly increasing the amount of computation. However, when the number of grids increases to a certain extent, increasing the number of grids will not get a great sense of the upgrade for the final calculation accuracy, but will make a substantial increase in computing volume. Therefore, accuracy and computation amount should be both taken into account when determining the number of grids.

2.2 Unit type.

How to choose the correct unit type is closely related to the results accuracy. Rod unit can only bear the pulling force or pressure in the direction of the rod, but cannot bear bending moment. Beam unit can withstand both tensile and bending moment. The shell element is the most suitable for thin-walled structures, which can reduce the computational complexity to a certain extent. The solid elements have more calculation, including the common hexahedral elements, which are often used for simple structural analysis. For complex structures, using a tetrahedral unit with an intermediate node is a good choice.

2.3 Meshing.

The solution domain is approximated as a discrete domain consisting of finite units of different sizes, also known as meshing. How to disperse the model into the appropriate number of cells in this process is a critical and difficult problem. Smaller grids correspond to higher accuracy, but calculation amount will increase. In the case of stress concentration, that is, when the data change ladder is larger, we should use denser grid to simulate the data change law. On the other hand, if the gradient of change is small, we should use more evacuation network to reduce the workload.

2.4 Unit order.

The units are divided into linear, quadratic, and cubic forms, where the quadratic and cubic units are called higher order units. High-order form of the unit has a better precision advantage. When analyzing a more complex or non-uniform stress distribution structure, we usually use high-order unit, because its surface or surface boundary can fit the analyzed structure's surface or surface boundary. However, the corresponding use of high-order unit will cause the incensement of the number of grids and nodes dramatically. So the unit order should be balanced to consider the accuracy and time consumption. Because increase the number of grids or increase the unit order can effectively improve the accuracy of the calculation, so in order to optimize the program, we will use different unit order in the unified structure. If structure is complex or stress is concentrated, we will choose high order unit, if the low precision of results is required, we will choose low order unit.

2.2.5 Unit shape.

The element shape of the grid plays a very important role in the calculation results, and unreasonable shapes can lead to poor accuracy or even termination [3].

III. APPLICATIONS OF FEA IN THE DESIGN OF MECHANICAL COMPONENTS

3.1 Wheels

In the transportation industry wheels/rims plays vital role, whereas its strength is critical to safety. Fatigue failure is the main failure of the wheels/rims. In general the wheels are designed by considering force of the wheels using FEA and at extreme positions (force division situation and dynamic response) the failure position and dangerous point can be determined [2, 5].

3.2 Leaf spring

In the heavy transport vehicles leaf springs are the most important part for suspension and load carrying, they are used for minimize the vibrations and impacts due to road irregularities and also create a comfortable ride. Rigidity is the most important parameter in springs [7, 8].

3.3 Analysis of drive shaft

Drive shaft is the most critical component in the vehicles which is used to transfer the power to the rear wheels. Static and dynamic analysis of the drive shaft can be carried out by FEM to simulate the deformation and stress in the working conditions, and also the defects are found and corrected at the design stage [6].

3.4 Gears

Gears are mainly used in the power or torque transmitting places. Other devices also there for transmitting the torque such as belt drive, chains drives because those have more disadvantages like slip. Gears are mainly used in lathes machines, automobiles and all torque transmitting units. It mainly deals with design, modeling and analysis of spur gear and Optimization of spur gear. For that we had considered a design problem and solved the problem with two different materials namely cast-iron, Steel for the same application. Then that designed Spur gear is modeled using Pro-E. Then we have done analyses on each gear namely, static analysis. Finally we have compared the results of cast iron spur gear with that of Steel gear and also compared the all spur gear with those optimized form of spur gear [4].

3.5 Clutch plates

Clutch is one of the essential components in automobiles. It is located between the engine and the gear box. The main function of the clutch is to initiate the motion or increase the velocity of the vehicle by transferring kinetic energy from the flywheel. Multiplate clutch is one of the important parts in the power transmission systems. Good design of clutch provides better system performance. Multiplate clutch is widely used in racing cars and heavy duty vehicles, which have space limitations and require high torque transmission. The structural analysis of clutch plate is done over different materials. The analysis is carried out on FEA package to get the foremost appropriate material for pressure plate of clutch [9].

CONCLUSION

The design of automobile components and other fields finite element analysis has been extensively used as an active numerical analysis method. This paper integrates domestic engineering technicians and scholars about FEM of automotive parts.

Fatigue damage is the main failure mode of automobile parts (wheels/rims), so it is critical to take the radial load fatigue test and bending fatigue test. In the bending fatigue test conditions, the bolt preload and rotational centrifugal force should be considered for the part structure. By comparing the traditional method, the common curvature method and the concentrated load method with FEM, FEM can not only analyze the strength and stiffness characteristics, but also can take into account the actual use of friction in the process of analysis, further improving the accuracy. The results show that the maximum stress and the maximum displacement are within the allowable range of the actual situation.

REFERENCES

[1] Zhu Yijing. Review of applications of finite element method in automobile design[C]. Automotive Engineering Technology Seminar of Henan Province, the Proceedings of the 9th Henan Automobile Engineering Technology Seminar, 2012:3.

[2] K.N.D.Malleswara Rao, Rao KNDM, Babu MNVS, Narayana VS, et al. Model optimization and structural analysis of car rim. J. Technological Advances and Scientific Res. 2016; 2(2):105-114, DOI: 10.14260/jtasr/2016/17

[3] Du Ping'an. Basic principles of finite element meshing [J]. Machinery Design & Manufacture, 2000(1):34-36.

[4] K.N.D.Malleswara Rao, Tippa Bhimasankar Rao, "Modeling and Optimization of Spur Gear Using Finite Element Analysis" International Journal of Engineering Research and Development, Volume 5, Issue 12 (February 2013), PP. 42-47.

[5] Zhong Cuixia. Design and structural analysis of aluminum alloy wheel [D]. Hangzhou: Zhejiang University, 2006.

[6] Raffi Mohamme, K.N.D.Malleswara Rao and Mohammed Khadeeruddin, "Modeling and Analysis of Drive Shaft Assembly Using FEA" International Journal of Engineering Research and Development, Volume 8, Issue 2 (August 2013), PP. 62-66.

[7] Shokrieh M M, Rezaei D. Analysis and optimization of a composite leaf spring [J]. Composite Structures, 2003, 60(3):317-325.

[8] Meghavath. Peerunaik, Tippa Bhimasankara Rao, K.N.D.Malleswara Rao, "Static and Modal Analysis of Leaf Spring using FEA" International Journal of Computational Engineering Research, Volume 3, Issue 4 (April 2013), PP. 107-110.

[9] Pulavarthi Krishram Raju, P.Siva Subramanyam, K.N.D.Malleswara Rao. "Optimal design and analysis of multi friction plates using creo and fea package" Journal of Technological Advances and Scientific Research; Volume 1, Issue 04, October-December 2015; Page: 366-372, DOI: 10.14260/jtasr/2015/51.