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Stress Analysis of Front Axle of JD 955 Combine Harvester Under Static Loading

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ABSTRACT

JD 955 combines manufactured by Iran Combine Manufacturing Company was modified. Resulting from the applied modifications, total weight and the loads applied on front axle of modified combine were increased. Stress analysis of front axle of JD 955 combine under static loading conditions resulted from the applied modifications was performed by using finite element method. The commercial finite element package ANSYS version 9.0 was used for the solution of the problem. Numerical results showed that the calculated value of factor of safety is very low and the front axle of JD 955 combine isn't strong enough to be installed on the modified combine.

Key Words: Axle; Stress analysis; Combine; Finite element method

INTRODUCTION

Iran Combine Manufacturing Company (ICMCO) is the greatest Iranian company that produces combines and that is committed to excellence and competitiveness in the national market. The following objectives are pursued in ICMCO's product development process:

- Highest product quality and reliability
- Customer satisfaction
- Reduction of development time and costs.

The urgent issues for industrial companies today are how to reduce the time and cost required for developing a new product (Beckert, 1996; Kojima, 2002). Accordingly, they have tried to use the computer's huge memory capacity, fast processing speed and user-friendly interactive graphics capability to automate and tie together other-wise cumbersome and separate engineering or production tasks, thus reducing the time and cost of product development and production. Computer-aided design (CAD), computer-aided manufacturing (CAM), computer-aided engineering (CAE) are the technologies used for this purpose during the product cycle (Lee, 1999).

ICMCO has manufactured JD 955 combines since many years in Iran. ICMCO modified the existing product in order to improve its product quality and efficiency, while reducing development time. During product modification the variations occurred in existing combine for example: increasing grain tank capacity, using longer discharge tube, increasing engine power, adding driver chamber, using internal volume of front axle as compressed air tank etc (Ayyazi, 2004). Therefore the loads applied on the front axle of combine were increased due to the variations occurred in the modified combine. Front axle of combine is one of the major and very important component and needs very good design as this part experiences the worst load condition of the whole combine. Front axle of JD 955 combines has no field failure reports.

The main objective in this research was to analyze the front axle of JD 955 combine under static loading conditions resulted from the applied modifications and investigate the mechanical strength of front axle of combine under new loading condition and arrive at a conclusion whether existing front axle can do the job or total redesign of the component is required.

Leon *et al.* (2000) used experimental and numerical methods, for the stress analysis of a frontal truck axle beam. The results obtained by finite element method were verified experimentally using photo stress. Mahanty *et al.* (2001) performed an experimental and numerical analysis of a tractor's front axle. Based on finite element analysis results redesign was carried out for the front axle for weight optimization and easy manufacturability. Five different models were proposed based on ease of manufacture and weight reduction. The results obtained by finite element method were analyzed by thirteen different certification test load conditions. Maly and Bazzaz (2003) used experimental and numerical methods, for design change from casting to welding for an axle casing.

MATERIALS AND METHODS

Material data. The front axle of JD 955 combine was made from St 37-2 with following material properties:

E = 200000 MPa	Young's modulus
ν = 0.3	Poisson's ratio
ρ = 8000 kg/m^3	Density
σ_y = 235 MPa	Yield stress

σ_u = 340 MPa Limit stress.

Loads on front axle beam. All vehicles are subjected to both static and dynamic loads. In this study, only static loads that applied on the front axle of combine is considered. Front axle of combine is considered as a support for front wheels, hydraulic cylinders of combine's head, gear-box, bodywork or super-structure etc.

Static loads that applied on front axle are as follows: vertical right and left bodywork loads, vertical loads on the gear-box supports, head lifting loads from hydraulic cylinders. These forces were determined by experimental and theoretical methods.

Analysis. The commercial finite element package ANSYS version 9.0 was used for the solution of the problem (2005). The geometric model for the front axle was created based on the drawings provided. Several simplifications of the model structure have been made with the purpose of reducing the analysis time and size model (In order to increase accuracy of the analyses). These simplifications are as follows: omitting the side bodywork bases, omitting holes in the side connection plates and omitting gear-box supports. The front axle is modeled with two dimensional elements, SOLID 82 and hexahedral three dimensional elements, SOLID 95. At first the cross-section areas of the lower box, upper box, hydraulic cylinders supports and connection plates were meshed using the SOLID 82 elements and then these cross section areas were extruded using the SOLID 95 elements. The individual components have been coupled together so that there is no free motion between components. The upper box has been coupled to the lower box and the hydraulic cylinder supports have been coupled with the lower box and the connection plates have been coupled with the lower and upper box assemblies.

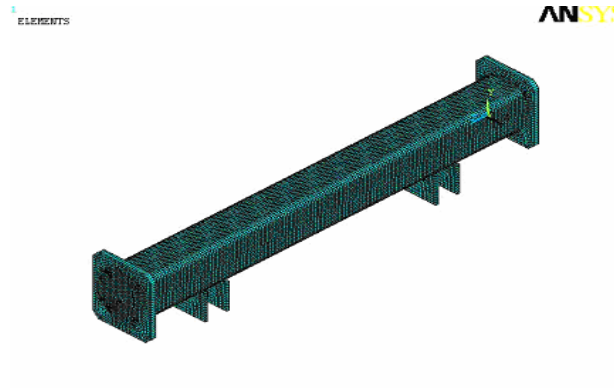
The next step was the definition of the boundary conditions. All degrees of freedom are constrained at the connection plates of the model. The next step was the definition of the loads that has to be previously described and defined.

The static analysis of front axle was carried out after several sensitivity analyses; elements with average size of 10 mm were used. The size of the finite model is approximately 19000 elements and 123000 nodes. Meshed model of front axle of JD 955 combine is shown in Fig. 1. After obtaining the solution the results of analysis can be reviewed using post processing to determine maximum induced stress and its location.

Calculating factor of safety. In designing parts to resist failure, it is assured that the internal stresses do not exceed the strength of the material. If the material to be used is ductile, then it is the yield strength that designer is usually interested in, because a permanent deformation would constitute failure. The distortion-energy theory is also called the Von-Mises theory, which is the most suitable theory to be used in ductile materials (Shigley & Mischke, 1989).

Von-Mises stress is calculated by using the formula:

Fig. 1. Meshed model of front axle of JD 955 combine



$$\text{Von-Mises stress } (\sigma') = \left[\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_1-\sigma_3)^2}{2}\right]^{1/2}$$

Where σ_1, σ_2, σ_3 = Principal stresses associated with the three principal directions.

According to distortion-energy theory, allowable stress in order to avoid fracture is equal to yield stress strength. Factor of safety can be calculated by dividing yield stress to maximum Von-Mises stress.

RESULTS AND DISCUSSION

The results of the analysis of the model that was meshed with elements with average size of 10 mm are given in Fig. 2. As seen from the figure the maximum Von-Mises stress appear on the upper box and near to the left connection plate as shown by the arrow in Fig. 2.

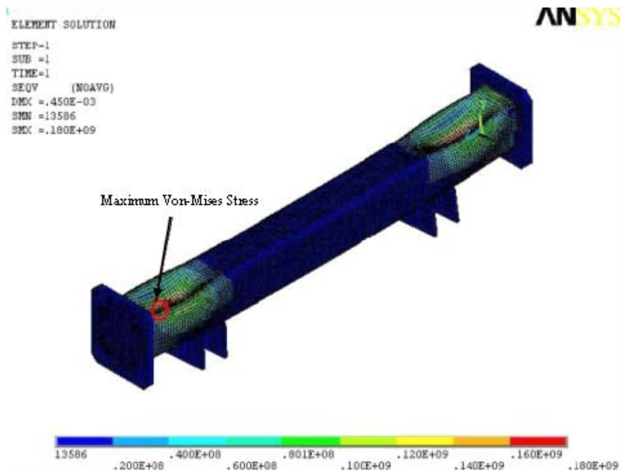
From the value of maximum induced stress and allowable stress a factor of safety value is calculated 1.3 and found to be less than required value. Calculated value of factor of safety is very low and obviously this value decreases under cyclic loading conditions of field operation. The present study clearly indicates that the front axle of JD 955 combine isn't strong enough to be installed on the modified combine. There is a need to optimize the existing design of the front axle of JD 955 combine in order to install on modified combine. Suggested modifications to increase strength and reliability are:

1. Increase the thickness of upper box and lower box,
2. Use horizontal bodywork supports instead of vertical bodywork supports,
3. Reduce welding in order to reduce stress relief and cost.

CONCLUSION

In this study, the finite element analysis of front axle of JD 955 combine under static loading conditions resulted from the applied modifications was carried out. Calculated value of factor of safety is very low and obviously this value

Fig. 2. Von-Mises stress distribution on front axle



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