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Static Structural Analysis of Rotary Weeding Blades using CAD Software

Manjunatha, K.*[1], M. Anantachar[2], Vijayakumar Palled[3], Sushilendra[4], K.V. Prakash[5], Sunil Shirwal[6]

[*1,2,3,4,5,6] Department of Farm Machinery and Power Engineering, College of Agricultural Engineering, University of Agricultural Sciences, Raichur – 584 104, Karnataka, India

vs.palled@gmail.com

Abstract

Rotary weeding blade is one of the important component for a tractor operated rotary weeder and need to be designed in such a way that they have enough strength in order to avoid the unbalancing force on the rotary weeder. The application of computer aided design (CAD) for structural analysis of rotary weeding blades on the basis of finite element method was carried out using ANSYS-software for three types of weeding blades viz., L, C and J-type. The different types of weeding blades are geometrically constrained with preparation of solid model and the simulation is done with actual field performance rating parameters along with boundary conditions. Prediction of stress distributions among the blades is important for the designers and manufacturers in order to minimize the errors and breakdowns. The analysis showed that, the maximum and minimum principal stresses were found to be 439.35 and 9.09 MPa respectively with a total deformation of 3.05 mm for L-type blade. Whereas for C-type blade, these values were 729.9 and 38.84 MPa respectively with a 4.65 mm total deformation. While the maximum and minimum principal stresses for J-type blade were found to be 362.68 and 17.7 MPa respectively with a total deformation of 1.65 mm. It was observed that, the stress values were within the limits of the yield stress of the material (758 MPa). Hence, the blades designed and selected for the study could be adopted for the development of the rotary weeder.

Keywords: CAD, Deformation, Stress, Structural analysis and Weeding blades.

Introduction

Structural analysis probably the most common application of the finite element method. A static analysis calculates the effects of steady loadings on a structure, while ignoring inertia and damping effects, such as those caused by time varying loads. A static analysis can, however, include study inertia load, and time-varying loads that can be approximated as static equivalent loads. Static analysis determines the displacements, stresses, strain and forces in structures or components caused by loads that do not induce significant inertia and damping effects.

Computer-aided design (CAD) is becoming one of the most important software tools in the design industry. Quite simply, CAD programs allow the designer to draw the object on his or her computer screen, instead of with pencil and paper. It uses the computer systems to assist in the creation, modification, analysis and optimization of a design. In today's world, everything from small nut-bolt to large machines are being visualized and designed using Computer-aided design (CAD) software. By using CAD, engineers, manufacturers and drafters can imagine, invent and revise detailed drawings used to give physical form to their ideas. This field often appeals to individuals with a construction background who prefer designing projects over physically building them.

Helping with developed technologies and design software which integrated in new generation of computers, designs are getting easier and reliable. Designers can design own products in virtual screen and they can evaluate the product for their work performance by simulating techniques using the computers. In agricultural machinery industry, especially in small and middle scales, insufficient technical knowledge, usage of new technology and incautious design features can cause problems such as breakdowns, failures etc., during the manufacturing or field operations. Failure of machinery devices is one of the major problems in engineering (Javad Tarighi, *et al*., 2011).

Design of machine is not an easy task. Over a period of time, design of different machines was done by using the paper and drafting tools, but now most of the designing work is done by using CAD (Computer Aided Design) tools. A numerous software's are available in the market like Auto CAD, PRO-E, Solid Edge, Solid Works etc., which have different functionality that are used by specific fields for specific purposes. Some CAD software not only generate sketches and 3D models of the machines, but also includes simulation and structural analysis of the model. Solid Edge, CATIA and SolidWorks provide all features desired to develop and analyse the machine stresses and forces even before actual making of the physical model. CAD technology is very helpful for the design engineers as it provides extendibility that makes design easy. CAD softwares help in future expansion of model by providing facilities to modify the designed work later (Parminder Kamboj, *et al*., 2012).

Some of the researchers have used the ANSYS simulation software to carry out the structural stability of the implements in order to determine the energy requirement and cutting force required for the operation. ANSYS software can be adopted to choose best subsoiler shape with maximum working life (Kaveh Mollazade, *et al*., 2010). The prediction of deformation and structural stress distributions on the machine elements during tillage operations is very important for the designers and agricultural machinery manufacturers, which will allow them to manufacture optimised machinery by using predicted knowledge (Mehmet Topakci, *et al*., 2010). Gopal, *et al*. (2011) carried out computer aided engineering analysis and design optimization of rotary tillage tool on the basis of finite element method and simulation method is done by using CAD-software for the structural analysis. A opener set of no-till planter was simulated with CATIA software in order to determine the dynamic analysis of its components and imported in ADAMS software and the behaviour of them were investigated in four different conditions (Ebrahimi, *et al*., 2012). The process of soil cutting is modeled using finite element method considering the effect of forward speed, rotary speed and soil moisture content on rate of stress applied to the soil (Mohammad Shekofteh, *et al*., 2012). Wang Hongli (2012) used the 3D parametric modeling software Pro/Engineer for 3D solid modeling of the stubble breaking device’s parts and the parts were assembled into the assembly with pro/E. Then finite element analysis of the strain and stress on the key part (the ripple disc sickle) has been carried out.

Finite Element (FE) is one of the methods used for evaluation of a structure under static and dynamic loads before making the main model which improve the design strength. ANSYS is a general purpose software package based on the finite element analysis. Finite element method was used by many researchers in order to design the tillage tools or investigate the interaction between soil and tillage implement. An optimum design is one that is as effective as possible. Virtually any aspect of the design can be optimized: dimensions (such as thickness), shape (such as fillet radii), placement of supports, cost of fabrication, natural frequency, material property and so on. Any ANSYS item that can be expressed in terms of parameters is a candidate for design optimization (Anonymous 2005). The ANSYS program can determine an optimum design that meets all specified requirements yet demands a minimum in terms of expanses such as weight, surface area, volume, stress, cost and other factors.

Rotary weeder is a machine which is used for weed control in wide row spacing crops. Rotary weeding blades are used to achieve advantages of better weed control and more efficient inversion and trash mixing. Blades are the main critical parts of rotary weeder, engaged with the soil for weeding operation. These blades interact with soil in different ways than normal ploughs which are subjected to impact and high friction that ultimately creates the unbalancing force on the rotary weeder resulting in wearing of the blades. The design optimization and manufacturing errors can be minimized by the proper design analysis of the components. Especially, the blades have to be reliable in the field performance against the operating forces. Prediction of stress distributions among the blades is important for the designers and manufacturers to optimize the power requirement. Under these circumstances, an engineering analysis of blades used in a rotary weeder was carried out using CAD software and structural stability of blades were analysed using ANSYS software in order to determine the energy requirement and cutting force.

Material and Methods

Model design and analysis

A solid geometry of the three sets of rotary blades (L, C and J type) were created based on bottom-up modeling method. The rotary blades consists of three portions *viz*., shank portion, hold on portion and cutting portion. For modeling and stress analysis of the blades, the commercial 3D modeling and finite element package Solidworks-2011 and ANSYS 12.1 package were used. The three important steps in ANSYS programming used for CAD-modeling and analysis are, Preprocessing, Solution and Post-processing.

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In the preprocessing section, the data and structures that define the particular problem statement are defined. These include the finite element discretization, material properties, solution parameters etc. During the solution phase, finite element software assembles the governing algebraic equations in matrix form and computes the unknown values of the primary field variable(s). The computed values are then used by back substitution to compute additional, derived variables, such as reaction forces, element stresses and heat flow. Analysis and evaluation of the solution results is referred to as post-processing. Post-processor software contains sophisticated routines used for sorting, printing and plotting selected results from a finite element solution. A typical post-processor display overlays coloured contours representing stress levels on the model.

Material properties

Considered material for the structure of blade was high carbon steel whose properties are shown in the Table 1.

After preparing a solid geometry of blades the important steps are meshing and applying loading and boundary conditions in the pre-processor so that simulation can be run to get a solution and generate results in the post-processor.

2.3 After validation of the model, next step is generation of Finite Element Mesh. For the rotary blades, CFX mesh is used for meshing. A very fine mesh of freedom of the model increases. Hence a designer has to model it optimally i.e. placing fine mesh only at critical area and coarse mesh at other, so that the run time is less and also the accuracy is not much affected. The static structural analysis of three sets of rotary blades were carried out and elements with course size were used. After obtaining the solution, the results of analysis can be reviewed using post processing to determine maximum induced stress and its location. Finite element analysis was used to predict the exact location of the regions where compressive stress concentrations were seen. Stress analysis was carried out using ANSYS 12.1 package. The size of finite models were approximately 1852 elements and 634 nodes, 4370 elements and 1423 nodes, and 1478 elements and 500 nodes for L-type, C-type, and J-type blade, respectively.

Boundary and Loading Conditions

Boundary conditions were in the holes of the shank portion of the blade which provide the facility to connect the shank to the flange of rotary weeder. All of these conditions were constrained in the all degree of freedom. This makes the shanks unable to move or rotate in any directions. The basic requirements for the blade like material property, depth of penetration, specific resistance of soil (*i.e.*- force developed by the soil to the blade), were applied during the analysis. The CAD - analysis cycle of different types of blade is shown in Fig. 1.

Results and Discussion

A solid geometry of rotary blades were developed in Solid-Works software and exported as IGES file to the ANSYS 12.1 package. The next important steps are meshing and applying loading and boundary conditions in the pre-processor

so that simulation can be run to get a solution and generate results in the post-processor. The minimum and maximum developed stress in the fastened area of the blade was indicated in the colour chart from blue to red respectively. The colour indicated from blue to red is the minimum and maximum value for all the deflection and stresses on the blade respectively: the load acting in the fastening area of the different types of blades were shown in Fig. 2, 3 and 4 respectively for L, C and J type blades.

The stress intensity at each points of the blade was assessed and the results obtained from the colour chart are presented in Table 2. It was observed that, the maximum and minimum principal stresses were found to be 439.35 and 9.09 MPa respectively with a total deformation of 3.05 mm for L-type blade. Whereas for C-type blade, these values were 729.9 MPa and 38.84 MPa respectively with a 4.65 mm total deformation. While the maximum and minimum principal stresses for J-type blade were found to be 362.68 and 17.7 MPa respectively with a total deformation of 1.65 mm. The stress values were within the limits of the yield stress of the material (758 MPa). Hence, the blades designed and selected for the study could be adopted for the development of a rotary weeder.

Conclusions

The application of computer aided design (CAD) for structural analysis of rotary weeding blades on the basis of finite element method was carried out using ANSYS-software in order to facilitate the designers for to make design of weeding blades easy. The present study focuses on the stress distribution on different types of blades viz., L, C and J-type which are important for the designers and manufacturers in order to minimize the errors and breakdowns. The results of static structural analysis carried out for three sets of blades revealed that, the stress values developed in the blades were within the limits of the yield stress of the material (758 MPa). Hence, the blades designed and selected for the study could be adopted for the development of a rotary weeder.

Table 1: Material properties of selected blades

Sl. No.	Material name	Material properties		
		Elastic Modulus (Pa)	**Poisson Ratio**	**Density (1000 kg/m^3)**
1.	High carbon steel	1.9e + 11 to 2.1e + 11	0.27 to 0.3	7.85

Table 2. Deformation and stress distribution of different types of blades.

Types of blades	Deformation (mm)		Stresses (MPa)		
			Equivalent (von-Mises) Stress	Minimum principal stress	Maximum principal stress
L-type	Along X - direction	0.12	496.97	9.09	439.35
	Along Y - direction	0.18			
	Along Z- direction	3.04			
	Total deformation	3.05			
C-type	Along X - direction	1.26	751.5	38.84	729.9
	Along Y - direction	4.58			
	Along Z- direction	0.12			
	Total deformation	4.65			
J-type	Along X - direction	0.99	362.68	17.7	362.68
	Along Y - direction	0.01			
	Along Z- direction	0.16			
	Total deformation	1.65			

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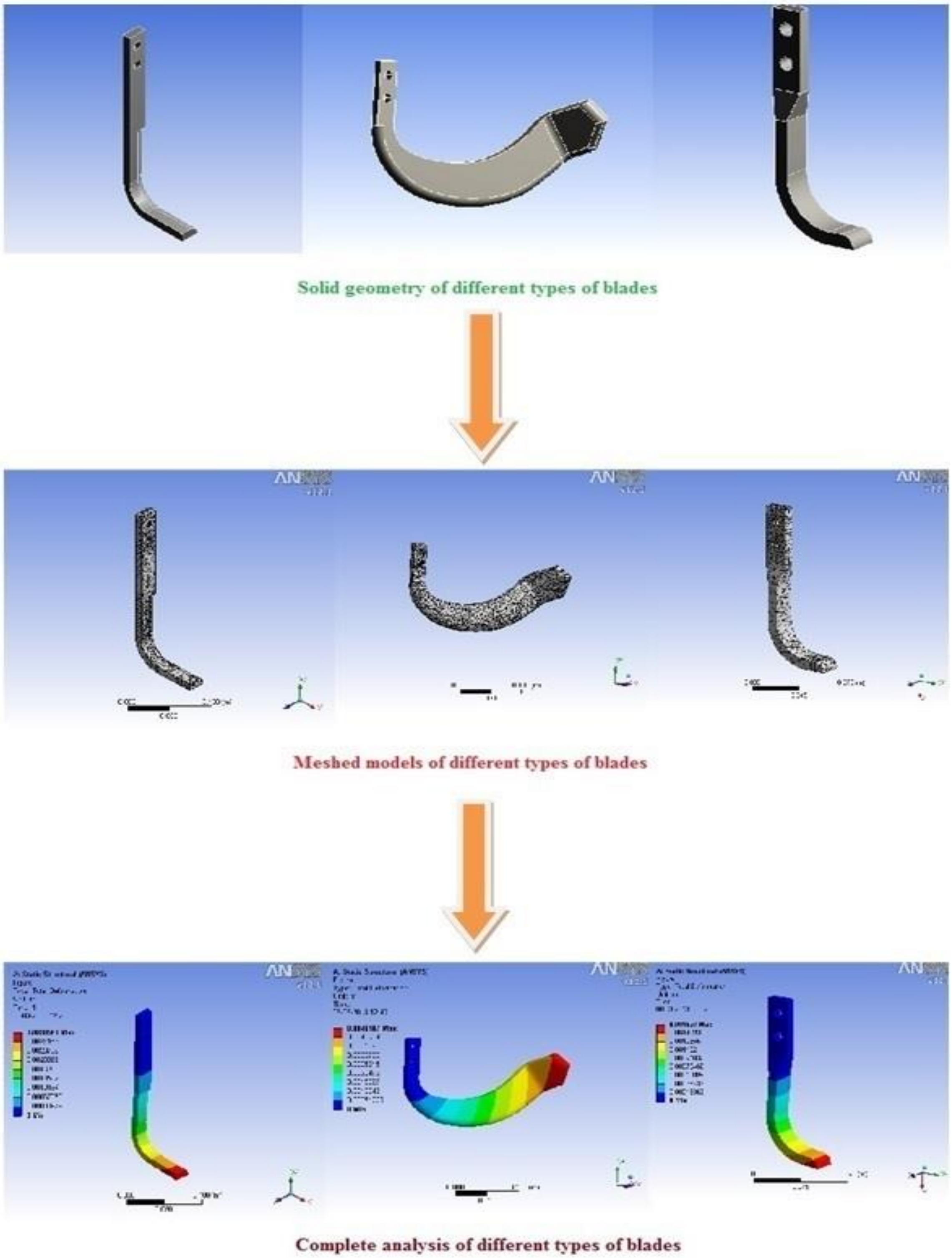

Figure 1. **CAD-Analysis Cycle**

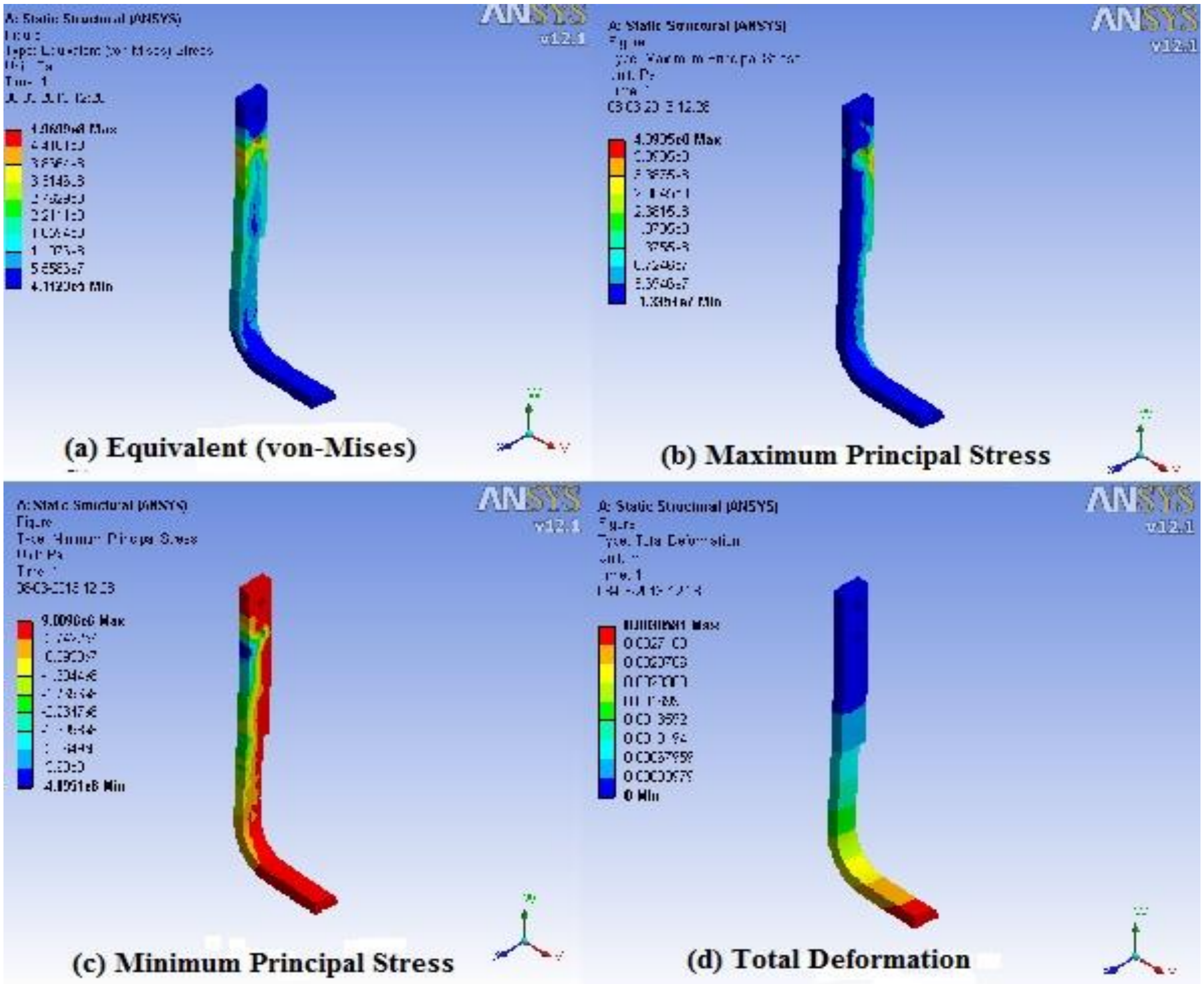

Fig. 2 Principal stresses and deformation plots in L-type blade

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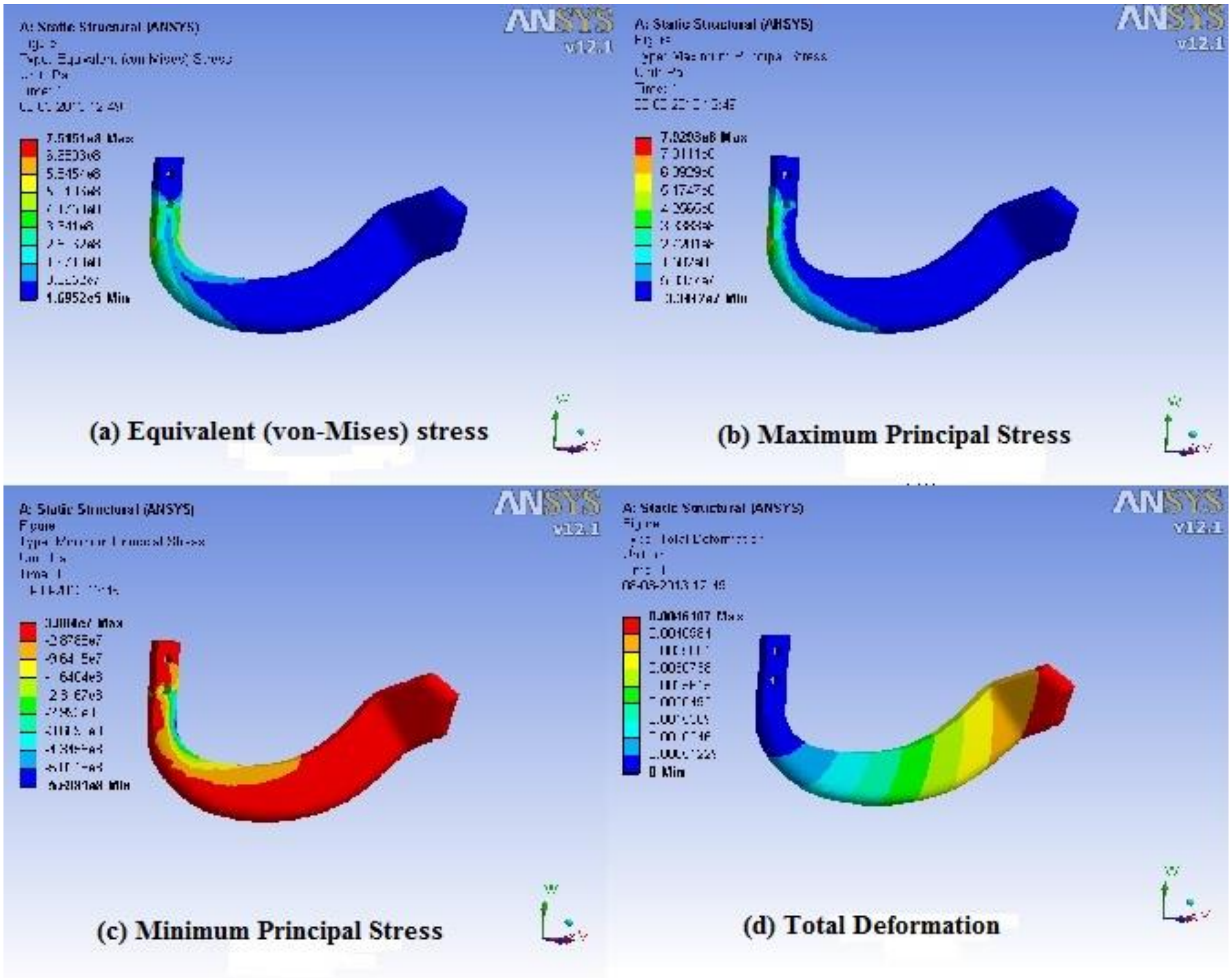

Fig. 3 Principal stresses and deformation plots in C-type blade

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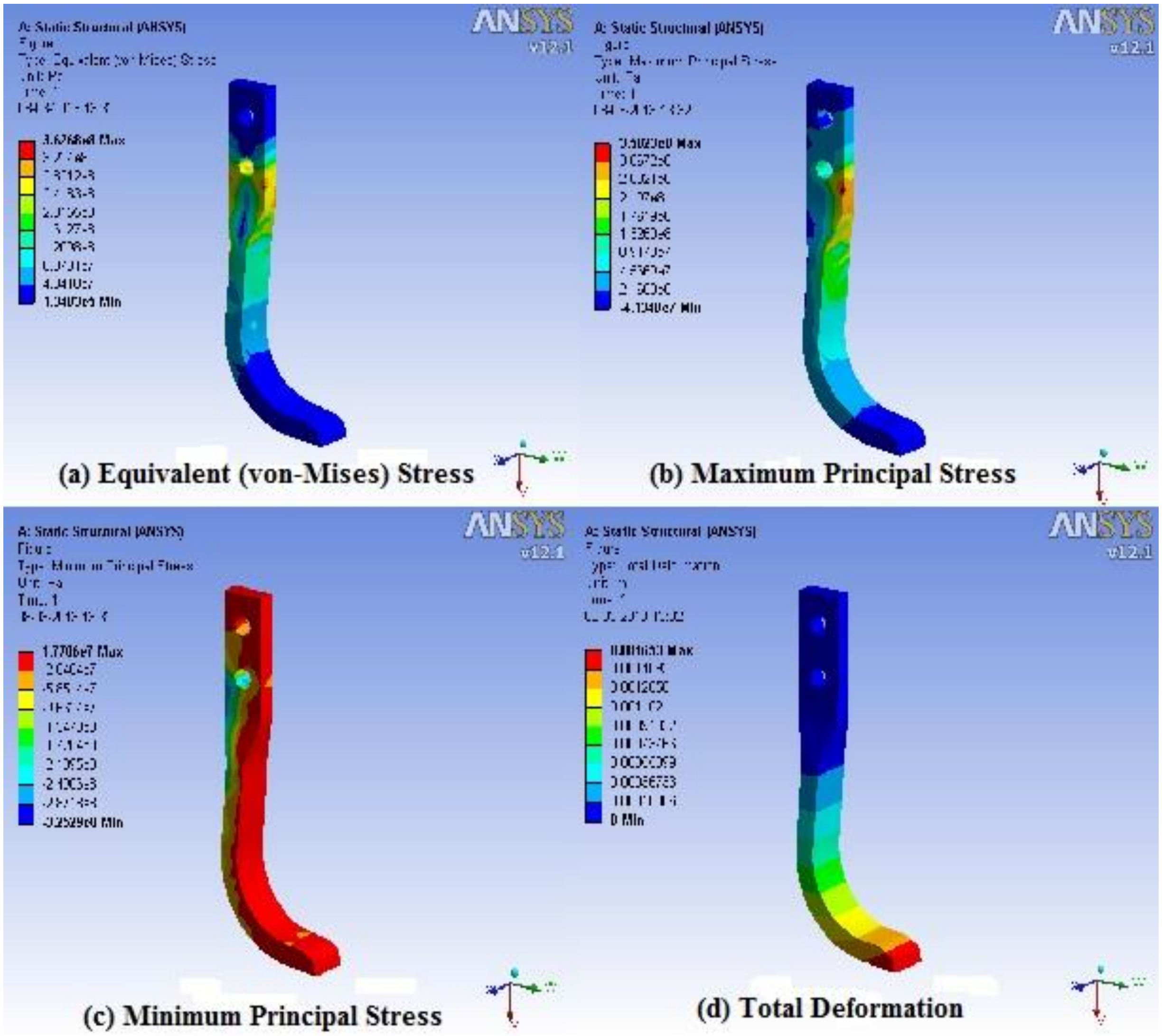

Fig. 4 Principal stresses and deformation plots in J-type blade

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