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STRUCTURAL ANALYSIS OF PARABOLIC TYPE SUBSOILER USING CAD SOFTWARE

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Abstract: The goal of modern farming system is to economize energy consumption and to reduce farming cost. Optimal design of agricultural machines proportionate to the present tractor power must be considered in order to achieve this goal. In this study finite element analysis of parabolic type subsoiler was carried out using Creo and ANSYS software. 3D model of parabolic type subsoiler was made using Creosoftware and static structural analysis of subsoiler was carried out using ANSYS software. The dimensions of parabolic type subsoiler was selected as per local manufacturing database of subsoiler whereas loading condition defined by maximum draft force which was exerted on parabolic type subsoiler in field. Results of simulation showed that maximum deformation was observed as 2.69 mm at the end of the share while maximum equivalent (von-mises) stress was 220.43 MPa at the clamp. Maximum principal stress and maximum shear stress was found as 245.49 MPa and 77.25 MPa respectively in subsoiler. The value of factor of safety was 1.59 and it was observed that, the stress values were within the limits of the yield stress of the material. Hence, the design of parabolic type subsoiler adopted for the development of the subsoiler.
Keywords: Agricultural machinery design, CAD, Deformation, FEA, Stress, Subsoiler.

Introduction

Nowadays, there are many implement which done primary and secondary tillage operations. But traffic of heavy agricultural machinery or the action of tillage tools, particularly where the same tool is used at the same cultivating depth in successive operations, lead to soil compaction (Srivastava *et al.,* 2006). This soil compaction layer is called the hard pan or plough pan. This hard layer must be cut into parts because it restricts vertical growth of roots, which reduces extraction of water and nutrients from deeper layers. Hard pans also accelerate soil erosion by decreasing infiltration and increasing runoff. (Stafford and Hendrick, 1988).

This has been particularly true, where soils have been proven to be highly compactable by natural forces and vehicle traffic. Numerous techniques have been used to minimize soil compaction. Controlled traffic (Dumas *et al*., 1973), reduced tire inflation pressure, reduced vehicle size (Cooper *et al.,* 1969), and cover crops (Reeves *et al.,* 1992) have been all used to

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reduce the negative effects of soil compaction. One technique commonly used to alleviate the effects of soil compaction is subsoiling (Campbell *et al.,* 1974).

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. CAD technology is very helpful for the design engineers as it provides Extendibility that makes design easy. CAD software help in future expansion of model by providing facilities to modify the designed work later (Shind *et al.,* 2011).

When working with the subsoiler, its construction is subjected to reaction forces from the soil due to the deep tillage. If the construction does not compensate the soil reaction forces, elements of the subsoiler could be subjected to forces that cause deformation. This deformation could cause machinery failure during operation. Therefore, proper design of subsoiler is necessary in order to increase their working life time and reduce the farming costs. So the objective of this study was analysis of parabolic type subsoiler using computer aided design (CAD) applications. A field experiment was conducted to determine draft force of the subsoiler.

Material and Methods

Field experiment

A two-tractor method with load cell sensor connected dynamometer was used to measure draft force of the subsoiler. The tractor speed and maximum depth of subsoiling were 2.5 km/h and 45 cm, respectively during the subsoiling. The study was carried out in the field of College of Agricultural Engineering and Technology, JAU, Junagadh. Type of soil, cone index and moisture content were Medium black soil, 3.45 Mpa and 18.13%, respectively. Field experiment results were created according to data from data logger, where a maximum draft force of 38,320 N was measured.

Finite element analysis of the subsoiler

To achieve the objectives of the present study, dimensions of parabolic typesubsoiler was taken from the local manufacturing database of subsoiler. The three important steps in ANSYS programming used for CAD-modelling and analysis are Pre-processing, Solution & Post processing [8]. The same steps were followed in the current research work.

A. Model design

A solid model of parabolic type subsoiler was created using Creo software. The 3D solid model of the parabolic type subsoiler is given in *Fig. 1*. The commercial FEM software package, ANSYS Workbench, was utilized for the stress analysis process.

B. Material properties

The materials used for the subsoiler is Hot rolled structural steel. The material property for this material was shown in table 1.

Table 1. Material properties of the parabolic, inclined and straight type subsoiler

Material Name	Hot rolled structural steel
Elastic Modulus (MPa)	205000
Poisson Ratio	0.29
Density (g/cc)	7.87
Tensile Strength ultimate (MPa)	420
Yield Strength (MPa)	350
Hardness (BHN)	135

C. Mesh generation

After assign material, model was meshed by three dimensional elements, SOLID 45. Fig. 1 shows the created model in the meshing condition. The size of finite models was approximately 4565 elements and 9475 nodes for parabolic type subsoiler.

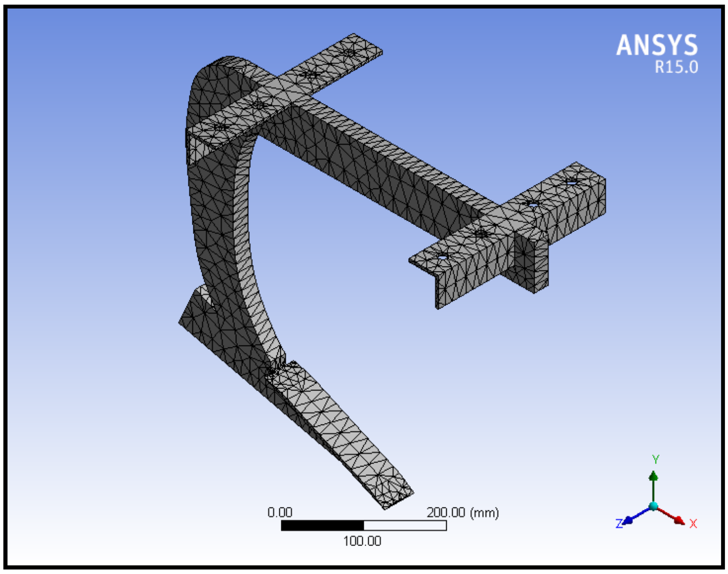

Fig. 1. Mesh structure of parabolic type subsoiler

D. Boundary and Loading Conditions

The boundary conditions are the critical factors for the correctness of calculation. Boundary conditions were in the holes of the shank which provide the facility to connect the shank to the frame of machine. All of these conditions were constrained in the all degree of freedom. This makes the shanks to not able to move or rotate in any directions.

Maximum draft force, which was obtain from the experimental study, applied on surface of narrow share of tine as 6994 N on solid model of parabolic type subsoiler. Boundary conditions were applied on solid model of parabolic type subsoiler is shown in Fig. 2.

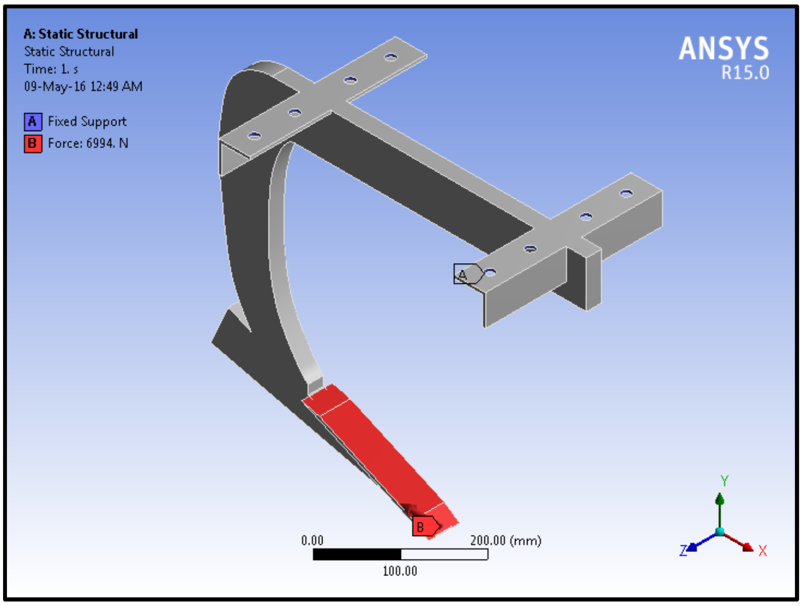

Fig. 2. Boundary conditions of parabolic type subsoiler

The simulation was carried out after defining boundary conditions. The parameters selected for static analysis of the subsoiler was total deformation, equivalent stress, principal stress, shear stress and factor of safety.

Result and discussion

A solid geometry of parabolic type subsoiler was developed in Creo software and exported to the ANSYS 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 subsoiler 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.

Volume and mass of the parabolic type subsoiler was discovered as 2296900 mm^3 and 18.077 kg respectively. Hot rolled structural steelhaving yield stress of 350 MPa was selected as a material of the parabolic type subsoiler.

During simulation, the maximum deformation was observed as 2.69 mm at the given boundary conditions which appeared at the end of the share which is shown in Fig.3.

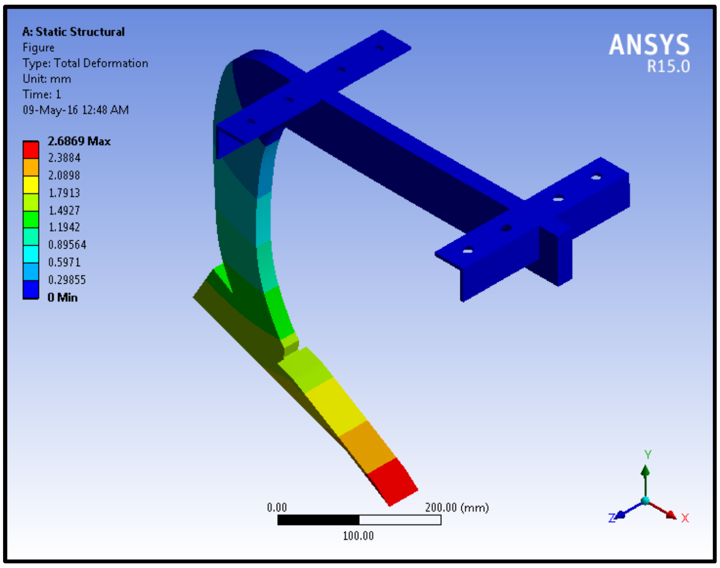

Fig. 3. Total deformation of parabolic type subsoiler

The maximum equivalent stress was analysed as 220.43 MPa shown in Fig.4whereas maximum and minimum principal stress was observed as 245.49 MPa and -79.87 MPa respectively in Fig.5.In designing of subsoiler, it is desirable to keep the stress lower than the maximum or ultimate stress at which failure of the material take place.

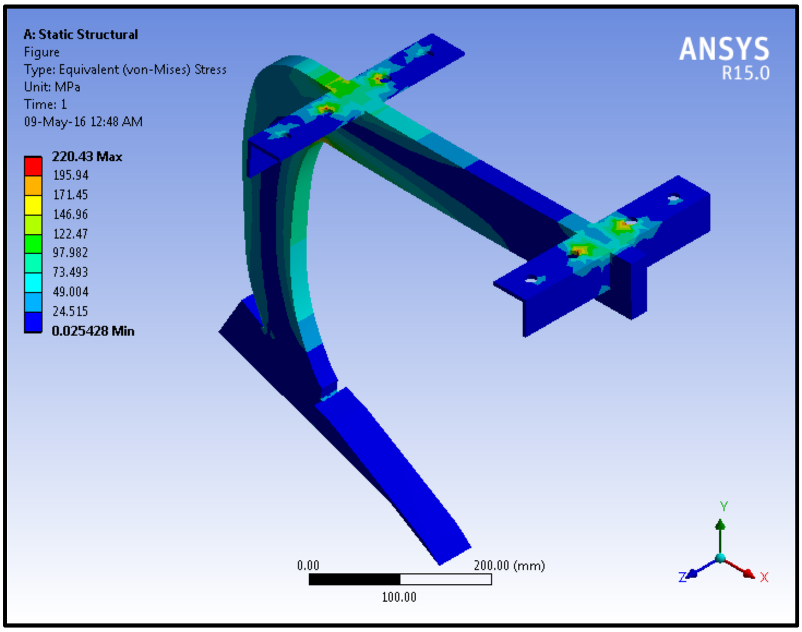

Fig. 4. Equivalent (Von-Mises) stress of parabolic type subsoiler

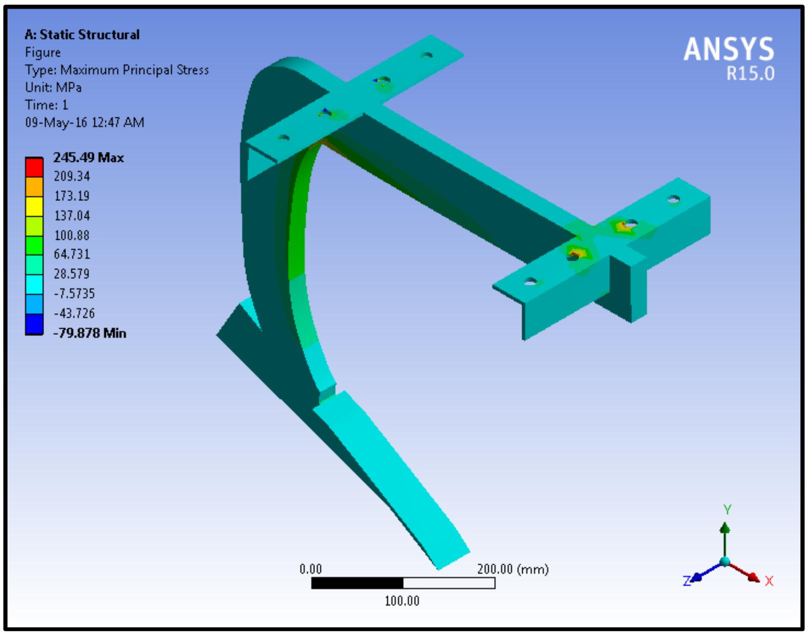

Fig. 5. Maximum principal stress of parabolic type subsoiler

The maximum shear stress was found as 77.25 MPa in Fig.6. While minimum factor of safety was discovered as 1.59 which is shown in Fig.7.The selection of a proper factor of safety in designing of any machine component increases reliability of the properties of the material under applied load.

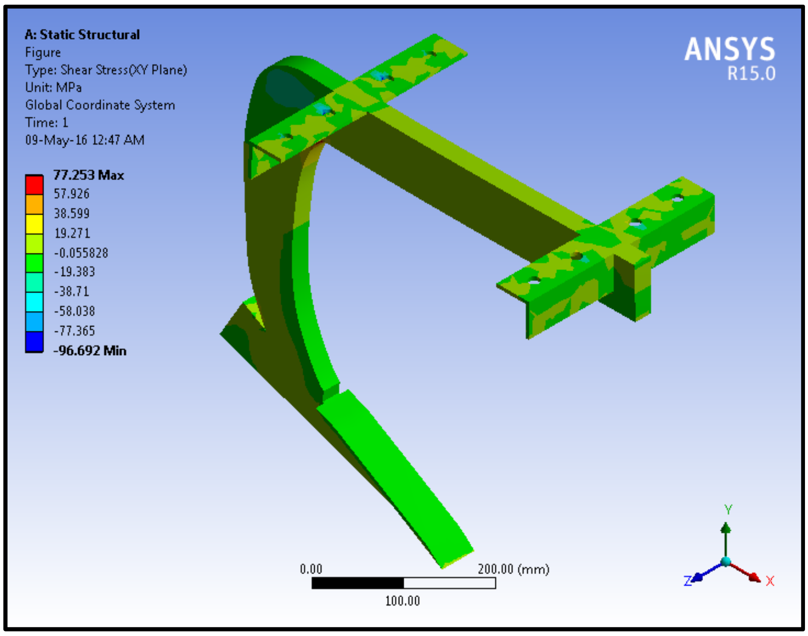

Fig. 6. Maximum shear stress of parabolic type subsoiler

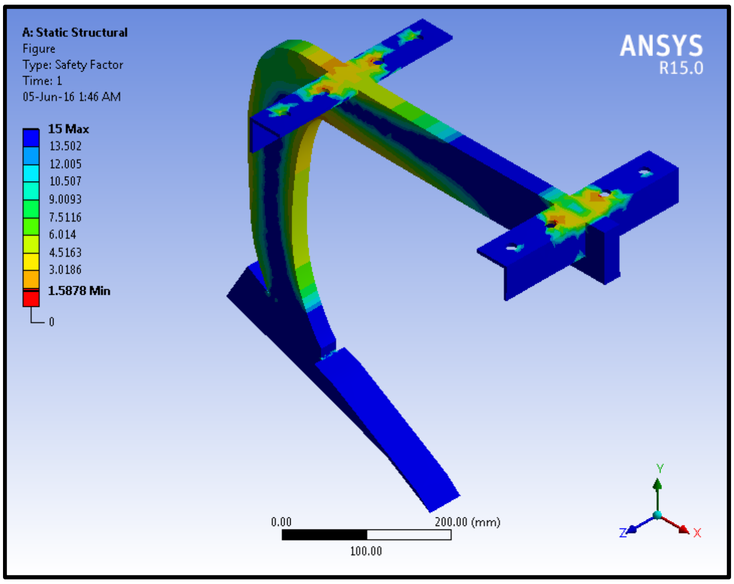

Fig. 7. Safety factor of parabolic type subsoiler

Conclusion

The application of computer aided design (CAD) for structural analysis of parabolic type subsoiler on the basis of finite element method was carried out using ANSYSsoftware in order to facilitate the designers for to make design of subsoiler easy. The present study focuses on the stress distribution on parabolic type subsoiler which is important for the designers and manufacturers in order to minimize the errors and breakdowns. Maximum deformation appeared at the end of the share and maximum equivalent (von-mises) stress was observed at hole of clamp. The results of static structural analysis carried out for subsoilerdiscovered that, the stress values developed in the subsoiler were within the limits of the yield stress of the material. Hence, the subsoiler designed and selected for the study could be adopted for the development of a subsoiler.

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