RESEARCH PAPER International Journal of Agricultural Engineering | Volume 10 | Issue 1 | April, 2017 | 78-81
e ISSN–0976–7223 ■ Visit us : *www.researchjournal.co.in* ■ **DOI: 10.15740/HAS/IJAE/10.1/78-81**

Structural analysis of inclined type subsoiler using CAD software

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Received : 24.01.2017; **Revised :** 25.02.2017; **Accepted :** 10.03.2017

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■ **ABSTRACT :** Proper design of agriculture implements is necessary in order to increase their working life time and reduce the farming costs. In this study Creo and ANSYS software were used to carry out finite element analysis of inclined type subsoiler. 3D model of inclined type subsoiler was made using Creo software and static structural analysis of subsoiler was carried out using ANSYS software. The dimensions of inclined type subsoiler was selected as per local manufacturing database of subsoiler whereas loading condition defined by maximum draft force which was exerted on inclined type subsoiler in field. Results of simulation showed that maximum deformation was observed as 2.74 mm at the end of the share while maximum equivalent (von-mises) stress was 280.71MPa at the clamp. Maximum principal stress and maximum shear stress were found as 283.30MPa and 46.24MPa, respectively in subsoiler. The value of factor of safety was 1.25 and it was observed that factor of safety was very low so optimized design is required.

■ **KEY WORDS :** CAD, Deformation, FEA, Stress, Subsoiler

■ **HOW TO CITE THIS PAPER :** Jakasania, R.G., Vadher, A.L. and Yadav, R. (2017). Structural analysis of inclined type subsoiler using CAD software. *Internat. J. Agric. Engg.,* **10**(1) : 78-81, **DOI: 10.15740/HAS/IJAE/10.1/78-81.**

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

Now-a-days, there are many implements to do 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).

Subsoiling usually is done to break up impervious soil layers below the normal tillage depth to improve the water infiltration, drainage and root penetration. A number of different types of subsoiler designs can be seen in agricultural fields, which are used for a number of varied applications. When working with the subsoiler, its construction is subjected to reaction forces from the soil due to the deep tillage. Therefore, it is very important for the designers and agricultural machinery manufacturers to predict deformation and structural stress distributions on the machine elements during subsoiling operations, which will allow them to manufacture optimised machinery by using predicted knowledge. 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 the analysis of inclined type subsoiler using computer aided design (CAD) applications.

METHODOLOGY

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, J.A.U., Junagadh. Type of soil, cone index and moisture content were medium black soil, 3.45 Mpa and 18.13 per cent, respectively. Field experiment results were created according to data from data logger, where a maximum draft force of 7,288 N was measured.

Finite element analysis of the subsoiler:

To achieve the objectives of the present study, dimensions of inclined type subsoiler 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 and Post processing (Kamboj *et al.*, 2012). The same steps were followed in the current research work.

Model design :

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

Material properties :

The materials used for the subsoiler is Hot rolled structural steel. The material property for this material is shown in Table A.

Table A : Material properties of the inclined 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

Mesh generation :

After assign material, model was meshed by three dimensional elements, SOLID 45. Fig. A shows the created model in the meshing condition. The size of finite models was approximately 4593 elements and 9720 nodes for inclined type subsoiler.

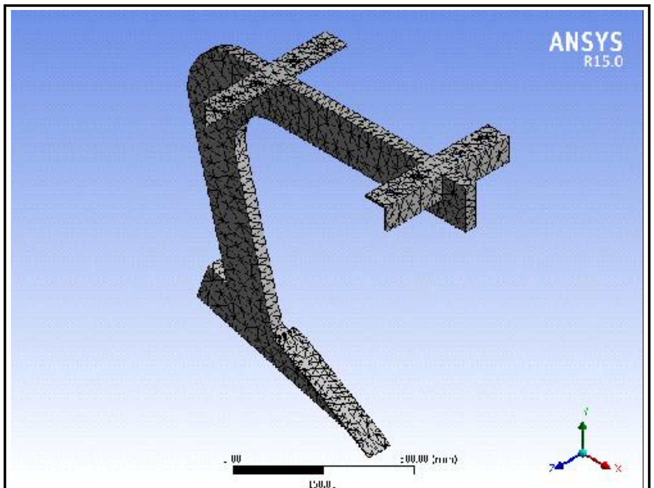

Fig. A : Mesh structure of inclined type subsoiler

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 provided 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 direction (Jakasania *et al*., 2016).

Maximum draft force, which was obtained from the experimental study, applied on surface of narrow share of tine as 7,288 N on solid model of inclined type subsoiler. Boundary condition was applied on solid model of inclined type subsoiler as shown in Fig. B.

The simulation was carried out after defining boundary conditions. The parameters selected for static

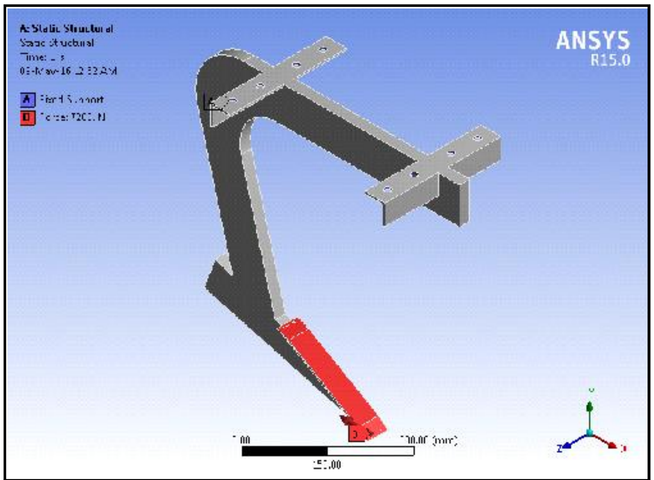

Fig. B : Boundary conditions of inclined type subsoiler

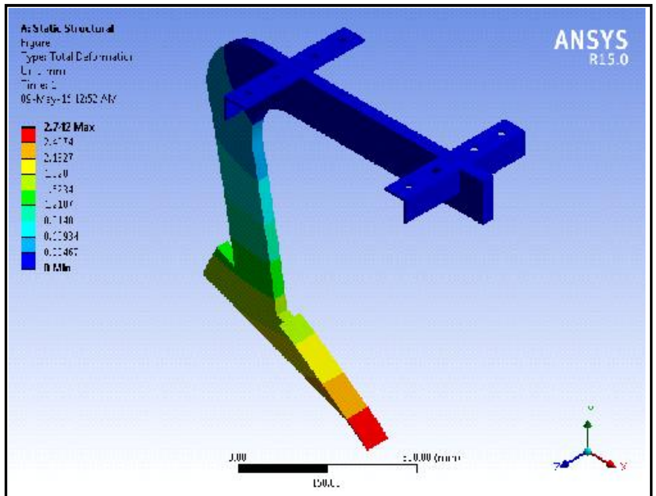

Fig. 1 : Total deformation of inclined type subsoiler

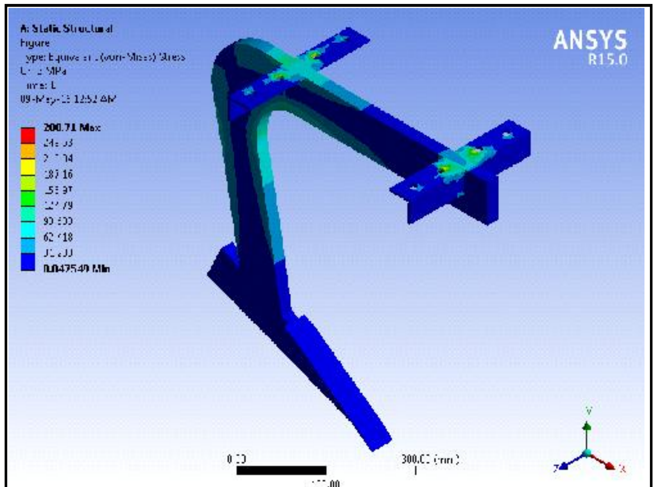

Fig. 2 : Equivalent (Von-Mises) stress of inclined type subsoiler

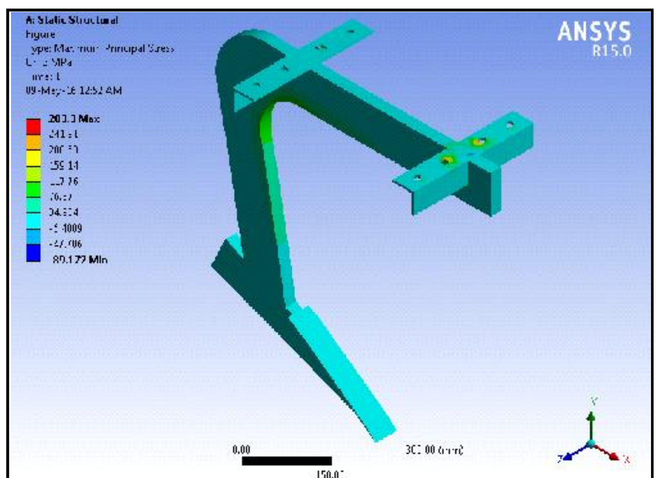

Fig. 3 : Maximum principal stress of inclined type subsoiler

analysis of the subsoiler was total deformation, equivalent stress, principal stress, shear stress and factor of safety.

RESULTS AND DISCUSSION

A solid geometry of inclined 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 subsoiler, respectively.

Volume and mass of the inclined type subsoiler was discovered as 3212200 mm^3 and 25.280 kg, respectively. Hot rolled structural steel having yield stress of 350 MPa was selected as a material of the inclined type subsoiler.

During simulation, the maximum deformation was observed as 2.74 mm at the given boundary conditions which appeared at the end of the share which is shown in Fig. 1.

The maximum equivalent stress was analysed as 280.71MPa as shown in Fig. 2 whereas maximum and minimum principal stress was observed as 283.30 MPa and -89.17 MPa, respectively (Fig. 3). In designing of subsoiler, it is desirable to keep the stress lower than the maximum or ultimate stress at which failure of the material takes place.

The maximum shear stress was found as 46.24MPa

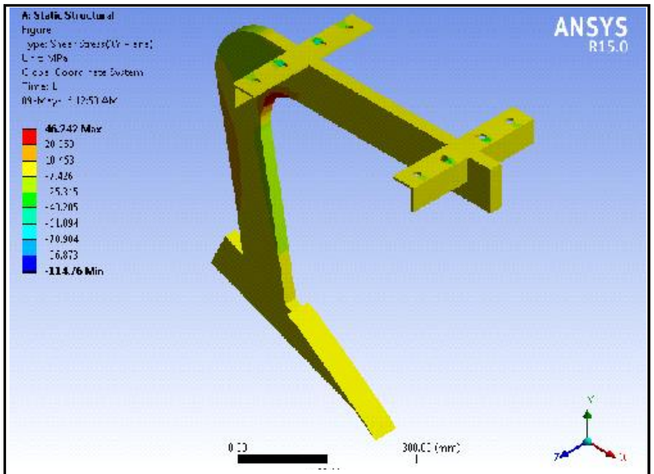

Fig. 4 : Maximum shear stress of inclined type subsoiler

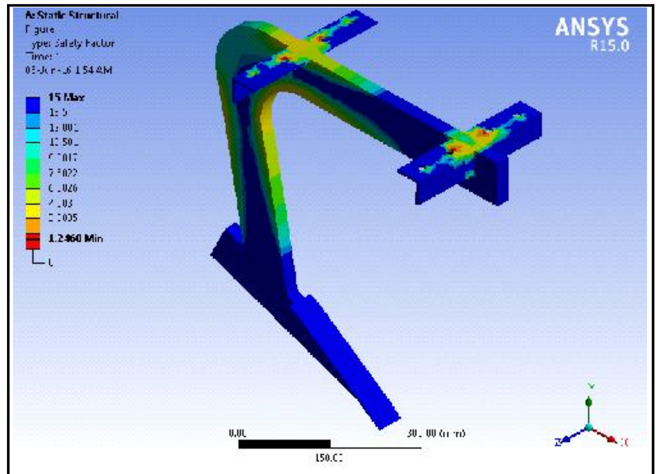

Fig. 5 : Safety factor of inclined type subsoiler

(Fig. 4). While minimum factor of safety was discovered as 1.25 which is shown in Fig. 5. 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.

Conclusion :

Computer Aided Design (CAD) is an effective tool for the development of any critical product. Here in this study, CAD method has been explored the design of inclined type subsoiler. Results of simulation showed that maximum deformation was observed as 2.74 mm for inclined type subsoiler at the given boundary conditions while maximum equivalent (von-mises) stress were 280.71MPa. Maximum principal stress and maximum shear stress were found as 283.30MPa and 46.24MPa, respectively in inclined type subsoiler. The value of factor of safety was 1.25 and found to be very low and obviously this value decreases under unwanted loading conditions of field operation so subsoiler doesn't satisfy the safety condition. Due to low factor of safety modified design is required for inclined type subsoiler.

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