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COMPUTER AIDED DESIGN AND ANALYSIS OF ROTARY TILLAGE TOOL COMPONENT FOR FAILURE

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ABSTRACT

This paper presents stress analysis of rotavator blade for different thickness and different materials. We have selected L-shaped blade for the study because L shape is usually superior to others in heavy trash. They are better for killing weeds. Rotavators work in the very difficult conditions, so they bear heavy dynamic loads. Therefore, proper design of these equipment is necessary to increase their working life time and reduce the farming costs. For the study we have selected A 15 HP Mahindra Yuvraj 215 tractor and Shaktiman SRT 2.5 mini rotavator. We calculated Forces acting on each blade for different thickness as well as different materials. After modeling of blade, we applied boundary and loading conditions on the models. Finally, models were analysed with analysis software. Results of this research can help the designers of rotavator blade to make similar works in their designs and increase the working life of blade

I. INTRODUCTION

Tillage, a process of applying energy to the soil to change its soil physical condition or to disturb soil for some other purpose, is one component in any system of soil management for crop production. Tillage processes are used in crop production for several purposes, such as loosening soil to create a seedbed or a root bed, moving soil to change the micro topography, or mixing soil to incorporate amendments. Soil tillage has always been a major research area in agriculture. As a tillage operation is a procedure for breaking up soil, soil failure depends mainly upon the soil properties, tool geometry, and cutting speed[1].

A rotary tiller is a type of motorized cultivating equipment that breaks or works the soil with the aid of rotating blades. Rotary tillers are available with advanced technologies and innovative designs which provide great performance. The rotary tiller can be self-propelled and driven forward on wheels. Featuring a gearbox, the rotary tiller enables one to increase the rotation speed of the blades more than the forward speed of the equipment. Rotary tillers have become world famous for preparation of seedbed in fields. This equipment's are often used for breaking or working the soil in lawns, gardens, etc. Garden rotary tillers are used for the plantation of seeds in your garden or backyard. Electric rotary tillers are commonly used in gardens and fields. Nowadays, utilization of rotary tillers has been increased in agricultural applications because of simple structure and high efficiency for this type of tillage implements[2].

By taking advantage of rotary tillers, the primary and secondary tillage applications could be conjugated in one stage. Therefore, the agricultural soil could be prepared with only one cross of this type of tillage implements from the land. This results in a decrease in the number of machinery passes on the land and subsequently, causes a decrease in the soil compaction which could be obtained due to the excessive equipment's crosses from the land. Despite of their high energy consumption, since rotary tillers have the ability of making several types of tillage applications in one stage, the total power needed for these equipment is low. Because rotary tillers power is directly transmitted to the tillage blades, the power transmission efficiency in rotary tillers is high. Moreover, the negative traction existence in rotary tillers causes the required

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1.1 Tillagetool parameters

1.1.1 Blade configuration:

Many types and shapes of blades have been developed forrotavators. Currently, some of the commercially available blade configurations include the L-shaped the C-shaped, the C-L hybrid, the hook-shaped or pick-type blades, and the hoe type. Because these blades havedifferent soil-tool interaction systems, they affect both the power performance and the quality of work of rotavator. The development of rotavator blades is an ongoing process and new blades, particularly in the Asian subcontinent and Japan, where the rotavator is widely used in the preparation of paddy rice fields, has been reported in the recent past.

1.1.2 Direction of rotation

There are different opinions in the literature concerning the effects of rotor rotationdirection on tillage quality and energy consumption. Ponjican (2011) imply that in the case of reverse rotor rotation direction more energy is consumed in tillage because of the higher speed and cutting length. That was concluded based on the observation of soil as a homogenous material. Salokhe and Ramalingam (2003) have discovered that, in the case of reverse rotor rotation direction, the cutting principle is completely changed, thus affecting the soil resistance and quality of soil breaking [3]. In the laboratory conditions, Lee et al. (2003) measured 20 to 30% lower values of torque for reverse rotor rotation direction [4].

1.1.3 Depth of tillage

Tillage depth has an important effect on physical properties of the soil layer and power requirements of the tillage tool. Tillage depth is an important parameter in the design of tillage implements. For pull-type tillage implements, the ratios of tillage depth to tillage width, and for rotary tillers, the ratio of rotor diameter to tillage depth are considered in evaluating tillage performance. For practical working conditions, the set tillage depth of rotary tillers is less than the rotor radius. The tillage depth of a pull-type tillage implement that has straight-cutting edges in a single horizontal plane is relatively constant. Rotary tillage implements that have tools rotating about a horizontal axis, however, cause irregularities in tillage depth even though a fixed depth setting is used. During the rotary soil-cutting process, some untilled ridges occur at the bottom of the tillage layer of soil. When these ridges are small, the depth of tillage is nearly uniform, and this typically is a desired condition (Celik et al, 2008) [5].

1.1.4 The rotavator kinematic parameter, λ

The kinematic parameter, λ is the ratio of the blade peripheral velocity to the forward travel velocity of the tractor. It is perhaps the most important rotavator operational parameter for quantifying this tool's tillage performance because it influences both the energy requirements and the resultant tilth quality of a rotavator. Being a ratio of the blade peripheral velocity to the forward travel velocity, λ can be varied in the following ways: (1) changing the rotor radius, (2) changing the rotor velocity, and (3) changing the machine travel velocity. In practice the rotor radius for a rotavator of given configurations remains unchanged and the manufacturer only provides means of varying the ratio between the tractor PTO and the rotor velocity as a means of changing the λ. This provision is usually by means of suitable gearing mechanism. Changing of λ has a significant influence on the performance of a rotavator since this changes the bite length or tilling pitch, which affects the volume of the soil cut per revolution by the rotavator blades.

From the findings of Beeny and Greig (1965), larger values of λ mean more cutting by the blade per unit volume, which increases the specific work of the rotavator.

Blade experiences less stress when tilling the nonrocky soil comparing to tilling in rocky soil. It implies that different blades must be used for different soil quality. The combination of minimum speed (v) and minimum value of λ is obtained at first gear (heavy) so the tractor should be operated on first gear (heavy) [11].

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II. METHODOLOGY

The values of the maximum tangential force acting on the shaft (Ks), soil force acting on the each blade (Ke), bending stress, shear stress and equivalent stress were obtained by using input parameters as per the selected tractor and rotary tiller by using empirical formula for different thickness.

2.1 Technical characteristics of the tractor and rotary tiller

For designing and analysis of the rotary tiller blade, the tractor model of MahindraYuvraj 215 was considered as the rotary tiller power supply and Shaktiman SRT-M 2.5 miniseries rotary tiller was considered. The technical characteristics of the tractor model ofMahindra Yuvraj 215 are presented in Table 3.1 and technical characteristics of rotary tiller are presented in table 3.2.

2.2 Equivalent stress calculation for different thicknesses

The maximum tangential force acting on the shaft was calculated by the following formula [9]:

$$Ks = Cs\frac{75N c\eta c\eta z}{\mu min}kg$$

Where, Ks is the maximum tangent forces at the rotor axle in kg; uminis the minimum linear velocity of rotor in m/s;Cs is the reliability factor that is equal to 1.5 for non-rocky soils and2 for rocky soils.
The soil force acting on each of the blades (Ke) was calculated by the following equation [9]:

$$Ke=\frac{Ks \times Cp}{iZene}kg$$

Where: Ks is the maximum tangential force (kg), Cp is the coefficient of tangential force, i is the number of flanges, Ze is the number of blades on each side of the flanges, and ne is obtained through division the number of blades which action jointly on the soil into the total number of blades.
Considering the shape of the blades, the bending stress
(σzg), the shear stress (τskt), and the equivalent stress (σzt) can be calculated by the following equations [9].
Bending stress,

$$\sigma zg= 6\frac{K_e\, S}{b_e h_e^2}kg/cm^2$$

Shear stress,

$$\tau skt= \frac{3Ke\ S1}{\left(\frac{h_e}{b_e}-0.63\right)b_e^3}kg/cm^2$$

Equivalent stress,

$$\sigma zt=\sqrt{(\sigma zg^2+ 4\tau skt^2)}kg/cm^2$$

The dimensions of the blades are defined as the form presented in Figure 3. The values of be, he, Ss, S and S1 are considered equal to 0.8, 7, 11.3, 14.5 and 8 cm, respectively.

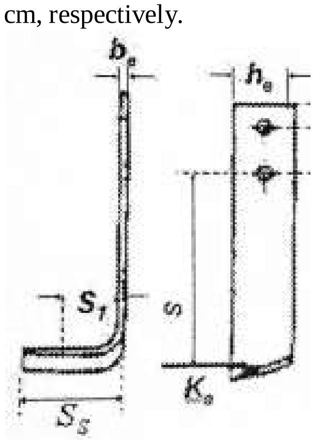

Fig. 2.2 Dimensions of the blade [11]

We have obtained the values of the maximum tangential force acting on the shaft (Ks), soil force acting on the each blade (Ke), bending stress, shear stress and equivalent stress for rocky soil by using respective equations. Cs is the

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reliability factor that is equal to 2 for thicknesses 7 mm, 8mm and 9 mm for non-rocky soil and material is high carbon steel. Values of equivalent stress are mentioned in table 2.2

2.3 Modeling and Meshing

Modeling of rotavator blade is carried out in CAD softwareCATIA V5. We drafted the design in sketcher module with the available dimensions of blade. Modeling was finalized in part design workbench. For analysis we used analysis software.After preparing a solid geometry model we import geometry file in analysis software. The important steps in analysis software are meshing and applying loading and boundary conditions in the preprocessor in order to get a solution. Then results will be generated in the post-processor. The element type was SOLID187 (3D, 10-Node Structural Solid). For meshing we used free mesh. The size of finite model was approximately 34786 elements and 54856 nodes for blade.Meshed model is shown in the figure 2.3.

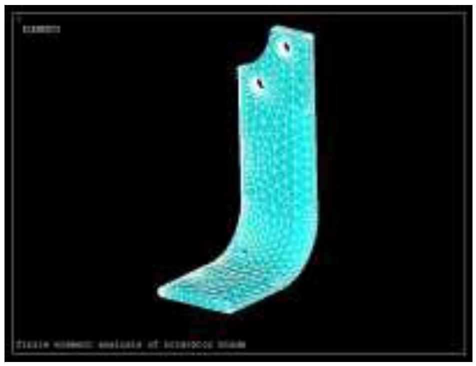

Fig 2.3 Boundary and Loading Conditions

We have fixed the holes of the blade which provide the facility to connect the blade to the rotor. This makes the blade to not able to move or rotate in any directions.

III. RESULT AND DISCUSSION

The analytical results of the maximum tangential force acting on the shaft (Ks), soil force acting on the each blade (Ke), bending stress, shear stress and equivalent stress were calculated for L shaped blade. By using software we obtained Von Mises stresses for 7mm, 8mm and 9mm thickness (shown in Fig.3.1, 3.2 &3.3) as well as for different materials like high carbon steel, mild steel and St 37-29. All the results are mentioned in below table.

Table 3.1 Stress induced in blade

Thickness	Equivalent stress (N/mm^2)	Von mises Stress (From Ansys) (N/mm^2)
7 mm	256.752	301.329
8 mm	201	191.155
9 mm	158.369	184.031

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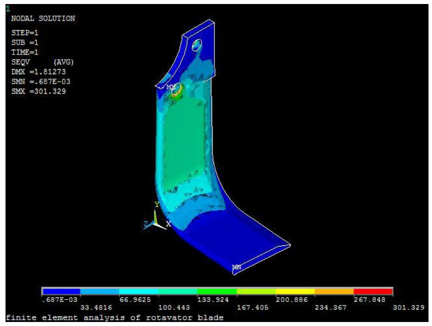

Fig. 3.1 Von mises stress for High carbon steel (7 mm thickness)

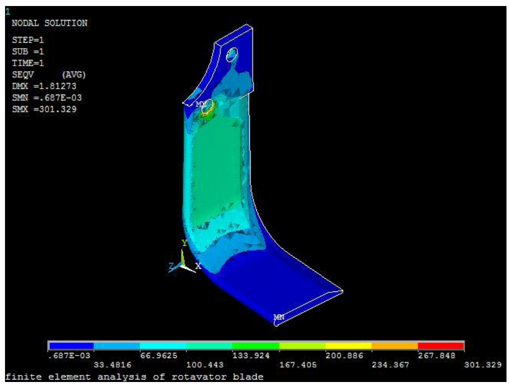

Fig. 3.2 Von mises stress for High carbon steel (8 mm thickness)

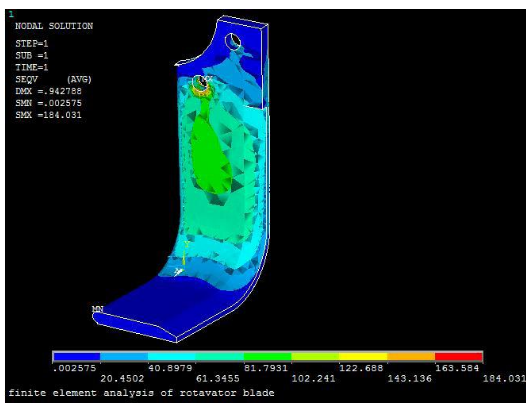

Fig. 3.3 Von mises stress for High carbon steel (9 mm thickness)

IV. CONCLUSIONS

In this study CAD method has been explored to design and analysis of an L-type blade,which happens to be the main parts of a tractor mounted rotary tiller. It is observed that, Computer Aided Design (CAD) is an effective tool for the development of any critical product and Finite element Method is an effective tool for investigation of fatigue analysis in components. Hence for this study we used Finite Element Analysis for investigation of stresses experienced by the blade.

Shape of the blade is an important factor for the tillage. It is observed that, L-shaped blades are better than C or J type blades in trashy conditions as they are more effective in killing and they do not pulverize the soil as much.

The kinematic parameter, λ is the most important rotavator operational parameter for quantifying this tool's tillage performance because it influences both the energy requirements and the resultant tilth quality of a rotavator. The kinematic parameter, λ is the ratio of the bladeperipheral velocity to the forward travel velocity of the tractor. It observed from the present study that as forward speed of prime mover and value of λ affect the forces acting on the blade.

So by calculation we choose the combination of minimum speed (v) and minimum value of λand it is conclude that the tractor should be operated on first gear (heavy).

Tillage quality and power requirement of tiller also depend on the direction of the rotation of the rotary tiller blades. At the forward rotation of the rotary tiller shaft, the tillage power consumption is decreased 10-15 %, in comparison with the shaft reverse rotation and it is observed that the reverse rotor rotation direction provided better tillage quality. With the rotor blades cutting upwards, the tilled soil was scattered out of the seeding furrow and a seedbed was not formed. A down-cut process is therefore necessary for effective seedbed preparation.

It is also observed that stress on the blade is also depending on the type of soil. Acomparison was made between the stresses acting on the blade for non-rocky soil and rocky soil.

The results showed that, blade experiences less stress when tilling the non-rocky soil comparing to tilling in rocky soil. This ultimately enhances the shelf life of the blade. Material of the blade plays vital role in the life of the blade. In present study, it isobserved that maximum deformation and stresses for the blade of material St 37-2 are less ascompared to mild steel and high carbon steel. The results of this study should be verified by further field trials on rotary tillers.

Design parameters like thickness of blade, degree of clearance angle decide the amount of stress acting on the blade. For the three different thicknesses for the same material it is found that more the thickness reduces in the value of Von mises stress.

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