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Minimizing Soil and Water Pollution by Improving Rotavator Blade Design Towards Enhancing Agricultural Soil Productivity

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Tillage is an operation performed on the field to obtain a desirable soil structure for perfect seedbed preparation for sowing seeds. Rotavator or rotary tiller is a tillage machine manufactured for preparing land by breaking the soil with the help of rotating blades. The rotary tiller's blade is geometrically constrained with the preparation of solid model in CAD-Software and the analysis is done with actual field performance rating parameters by using CAD-Analysis software for the structural analysis. The energy constrained for the tillage tool operations with 37 HP and 45 HP power tractor and estimated forces acting at the soil-tool interface. The resultant effect on rotary tiller's blade is obtained from deformations and von-misses stress distribution plots. The present working model with tillage blade is analysed to new design constraints with a change of its geometry for the maximum weed removal efficiency is suggested for the lab and field testing. This paper describes the design analysis of blade through computational method. The rotary tiller's blade is geometrically constrained with the preparation of solid model in CAD-software and the analysis is done with actual field performance rating parameters by using CAD-analysis software for the structural analysis.

KEYWORD

Deformation, Rotary tiller's blade, Rotavator, Structural analysis, Von Mises stress.

INTRODUCTION

In recent years, fertilizer consumption increased exponentially throughout the world, causes serious environmental problems. Plants absorb the fertilizers through the soil; they can enter the food chain. Continuous use of chemical fertilizers leads to infertility of land and water pollution. Also, farmers are more interested to improve cost to benefit ratio by reducing the land preparation cost and increase the yield. But the increase in diesel fuel prices and fertilizer prices leads to higher level of agricultural land preparation cost which directly leads to increase in the cost of food. Combination of rotavator for seedbed preparation and organic fertilizers will be highly appreciable to gain higher cost to benefit ratio. Also, it will help to maintain fertility in the permanent agricultural land and helps to minimise soil and water pollution (Mandal *et al.,* 2013). Rotavator can play an important role in double or multiple cropping systems where the time for land preparation is very less or limited. It is used for mixing manure or fertilizers into the soil and for seedbed preparation. It offers an advantage of superior soil mixing, better pulverisation, rapid seedbed preparation and reduced draft compared to conventional tillage. Results show that rotavator saved 30-35 % of the time and 20-25 % of the cost of operation as compared to tillage by cultivator. It gave a higher quality of work (25-30 %) than tillage

Table 1. *Blade parameter*

Parameter	Value
Rotary tiller work depth, mm	220
Rotary tiller work width, mm	1500
Rotor, rpm	210
Blade peripheral velocity, m/s	5
Total number of blade	36
Number of blades on each side of the flanges	6
Prime mover forward speed, m/s	1.2
Number of blades which action jointly on the soil	6
Prime mover power, HP	37-45
Traction efficiency, ηc	0.9

by cultivator (Firouzil and Alizadeh, 2012).

It is clear that rotavator can play an important role in double or multiple cropping systems where the time for land preparation is very less or limited. Rotavator is a tillage implement comprising of various types of blades, like L-shaped, C-shaped and J-shaped mounted on flanges, L-shaped blades are preferred over C-shaped and J-shaped blades. This implement affixed to a shaft, that is driven by tractor Power-Take-Off (PTO). It is used for mixing manure or fertilizers into the soil and for seedbed preparation. It offers an advantage of superior soil mixing, better pulverisation, rapid seedbed preparation and reduced draft compared to conventional tillage. More or less rotavator can be alternative for the excessive use of chemical fertilizers to improve benefit to cost ratio for farmers (Asoodar and Yousefi 2009).

Blade detail

L-shaped blades are mostly used in rotary tillers manufactured in India because of its effectiveness over 'C' type and 'J' type blades. These blades are normally mounted with three right handed and three left handed blades per flange (Mandal *et al.,* 2014) (Table 1).

METHOD AND METHODOLOGY

From the available present literature, it is clear that an 'L' type blade is most suitable for Indian farming conditions compared to 'C' and 'J' type blade, a blade was designed in 3D CAD software on the basis of geometrical parameters of actual 'L' type blade, followed by analysis in ANSYS. The steps performed in ANSYS for analysis are imported design, meshing, input parameters and solution. The structural analysis was done based on field trial data available from the manufacturer and farmers (Shinde *et al.*, 2011).

Input parameter for the analysis

$$Ks = Cs\frac{75Nc.\eta c.\eta z}{u} \quad ...(1)$$

Where Ks is maximum tangential force (kg), Nc is Prime mover tractor power (HP), ηc is traction efficiency, ηz is coefficient of reservation of tractor power, Cs is is the reliability factor, that is equal to 1.5 for non-rocky soils and 2 for rocky soils and u is prime mover forward speed (m/s).

$$Ke = \frac{Ks.Cp}{i.Ze.Ne} \quad ...(2)$$

Where Ke is soil force acting perpendicularly on the cutting edges of each of the blades, Cp is coefficient of tangential force, i is number of flanges, Ze is number of blades on each side of the flanges, Ne is number of blades which action jointly on the soil.

RESULT AND DISCUSSION

The analysis results of the left hand and right-hand blade in graphical mode have shown in the figures 1 to 14. As in case of tillage tools, deformation is related to tool wear, but stress plays a major role which results in wear of the tool. In this analysis, because of variations in tool shape, the stress variation is obtained. The resultant deformation and Van-Misses stress are shown in the figure for LH rotavator blade (Tables 2 and 3). The analysis results of rotary tiller's blade in graphical mode have shown in figures 1 to 14. As in case of tillage tools, deformation is related to tool wear but stress plays a major role which results in wear

Result for rotary tiller's blade of 7 mm thickness

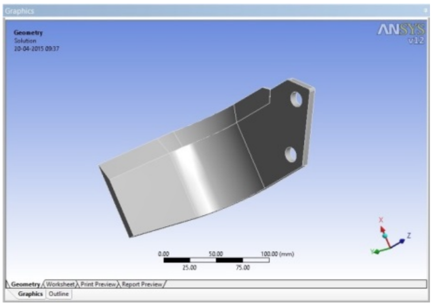

Figure 1. *3D-Model*

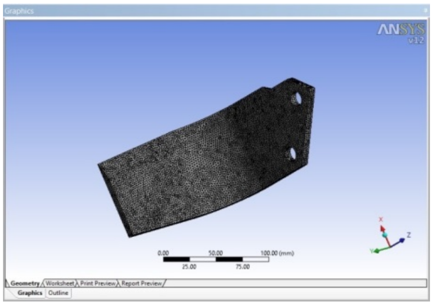

Figure 2. *Meshing*

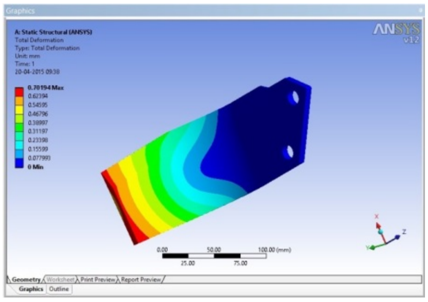

Figure 3. *Deformation*

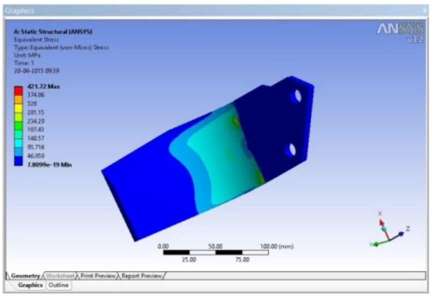

Figure 4. *Von-Misses stress*

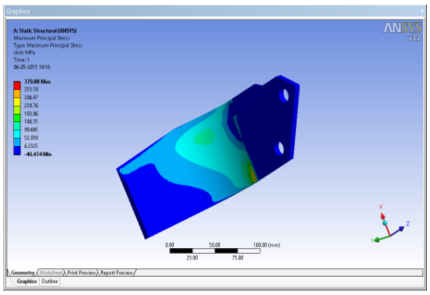

Figure 5. *Max principal stress*

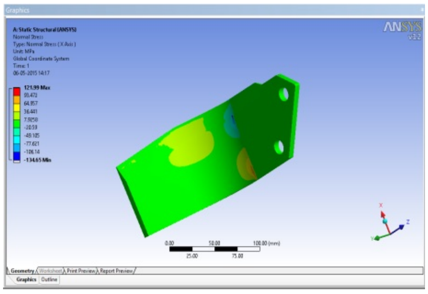

Figure 6. *Tensile stress*

Result for rotary tiller's blade of 9 mm thickness

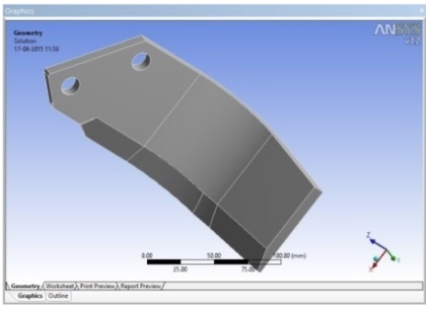

Figure 7. *3D-Model*

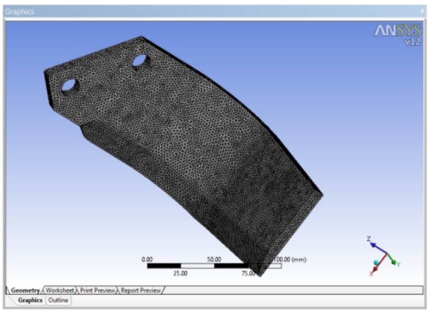

Figure 8. *Meshing*

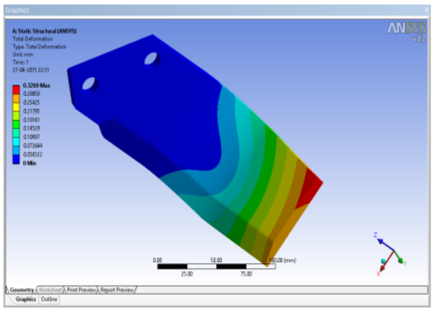

Figure 9. *Deformation*

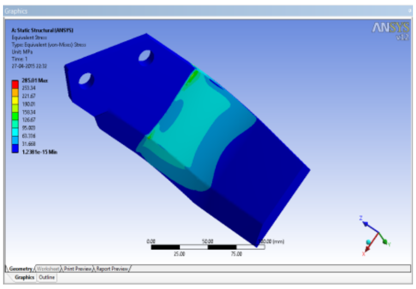

Figure 10. *Von-Misses stress*

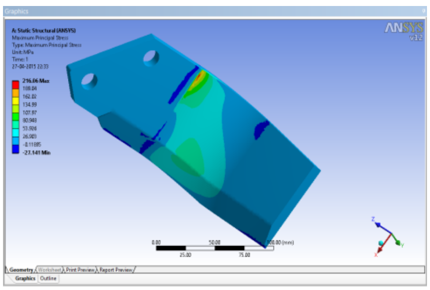

Figure11. *Max principal stress*

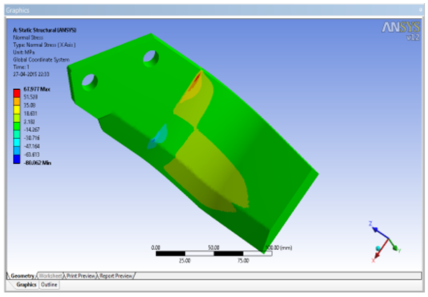

Figure 12. *Tensile stress*

of the tool. In this analysis, because of variations in tool shape, the stress variation is obtained. The resultant for deformations, Von-Misses stress, maximum principal stress, tensile stress and shear stress is shown in figures are for existing rotavator blade of 7 mm thickness and 9 mm thickness (Matani and Doifode, 2015).

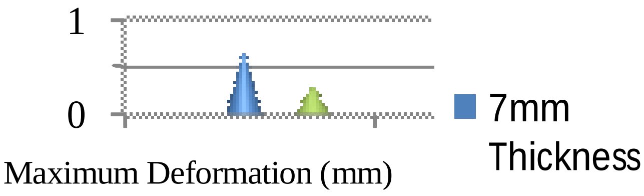

Figure 13. *Deformation in 7 mm and 9 mm blade*

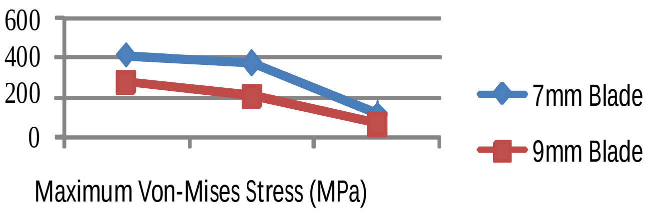

Figure 14. *Comparison of stresses in 7 mm and 9 mm blade*

Table 2. *Stresses in blade*

Factor	Value
Maximum deformations	0.7 mm
Maximum Von-Misses stress	421.72 MPa
Maximum principal stress	379.88 MPa
Maximum tensile stress	121.99 MPa

Table 3. *Input parameter for the analysis*

Factor	Result	
	7 mm blade	9 mm blade
Maximum deformations	0.7 mm	0.33 mm
Maximum Von-Misses stress	421.72 MPa	285 MPa
Maximum principal stress	379.88 M	216 MPa
Maximum tensile stress	121.99 MPa	68 MPa

CONCLUSION

3D CAD model of rotary tiller's blade has been analyzed for both 7 mm as well as 9 mm blade thickness. These models are analyzed for deformations, Von-Misses stress, maximum principal stress and tensile stress. The results of the structural analysis are evaluated for 45 HP tractor and found that all the result parameters of analysis become almost half for the blade of 9 mm thickness compared to the blade of 7 mm thickness. The analysis results of right-hand blade in graphical mode have been analyzed. As in case of tillage tools, deformation is related to tool wear but stress plays a major role which results in wear of the tool. In this analysis, because of variations in tool shape, the stress variation is obtained. The resultant deformation and Van-Misses stress are analyzed for LH and RH rotavator blade. The energy constrained for the tillage tool operations with 37 HP and 45 HP power tractor and estimated forces acting at the soil-tool interface and the resultant effect on rotary tiller's blade is obtained from deformations and various stress distribution plots. The present working model with tillage blade is analysed to new design constraints with the change of its geometry for the maximum weed removal efficiency is recommended for the laboratory and field testing.

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