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Use of Cad Tool for Design and Development of Rotavator Blade

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Abstract: Agricultural land preparation cost has increased to a new high label due to increase in fossil fuel prices. This directly increases the cost of food. Demand of food also increases due to high rise of population and at the same time land sizes becoming small (< 2-4 ha) due to fragmentation of land. So farmers are more interested to reduce the land preparation cost and increase the yield. Due to these facts, preparation of seedbeds for deep tillage in conventional tillage system, particularly in Indian farming, the situation is becoming worsened day by day. This system of tillage escalates land preparation costs because it requires a series of operations using passive tillage tools to realize an acceptable tilth quality. It also ties down capital in the form of additional machinery and tillage tools; thus increasing significantly the cost of land preparation. Rotary tiller or rotavator is a tillage machine most suitable for seedbed preparation. In a Rotary tiller, Blades are the main critical parts which are engaged with soil to prepare the land. These blades interact with soil in a different way than normal plows which are subjected to impact and high friction that creates unbalancing and non uniform forces which results wearing of the blades as a whole. This actually decreases the service life of a blade. Therefore, it is necessary to design and develop suitable blade so that service life also enhanced. This paper presents design and development of rotavator blade through the use of computer aided design (CAD) tools/method.

Key words: Rotavator · CAD/CAM · 3D Model · FEA · Blade wear

INTRODUCTION

Rotary tilling is a widely used tillage operation in Indian farming because of its superior ability to mix, flatten and pulverize soil. However, the use of rotary tiller is strongly restricted to "shallow" tillage because of its high energy requirements. Deep rotary tillage using less energy has recently become a subject of wide interest to combat soil fatigue caused by excessive use of chemicals among other reasons and to convert paddy fields into dry fields such as kale fields. Rotary Tiller or rotavator is a highly effective machine for intensive tillage. It is one of the most efficient tillage systems when looking for solutions to specific soil tillage problems. No matter the soil type, soil conditions or the amount of residue, Rotavating will always produce the best result. The Rotavator can be easily adjusted for various working depths and soil finishes. The rotating blades chop and mix the residues evenly throughout the working depth, outperforming any other implement.

A rotary tiller is a specialized mechanical tool used to plough the land by a series of blades which are used to swirl up the earth. It can be adjusted according to the specific requirements of the soil [1]. Nowadays, utilization of rotary tillers has been increased in agricultural applications because of simple structure and high efficiency for this type of tillage implements. By taking advantage of rotary tillers, the primary and secondary tillage applications could be conjugated in one stage [2]. 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 equipments is low [3]. 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 tractive force to be decreased and consequently, smaller tractors could be used with this type of tillage implements for land preparation. Power to operate the rotary tiller is restricted by available tractor power [4].

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Rotavator perform well in suitable soil conditions but consume high amounts of energy. In the past, a number of studies were conducted to design suitable blades of rotavator in order to reduce the energy and power consumption [5].

The continuous fluctuating impact of soil develops high stress on blade tip or blade critical edges. Due to these stresses blade wear takes place after certain period of usage which is depends on the soil type/variety. This period vary from 80-200 h for local blade and 300-350 h for imported blade in normal soil condition [6]. Considering this, some work on material characterization has been done to improve the service life of a rotavator blade but these works did not address to reduce the overall costs of blade. Another way to improve the service life of blade is the improvement in blade geometry. The geometry of tiller blades is considered to be the most important factor in their design since both the shape of the blade tip and the length of the tiller blade facilitate cutting [7]. Hence there is a need to improve the design through geometrical modifications so that will reduce the blade cost as well as land preparation cost. This paper describes the design improvement and development of blade through computational methods.

Computer Aided Design (CAD) Method

Cad Technology: Computer aided design refers to the design process using sophisticated computer graphics techniques backed up with computer software packages to aid in analytical problems associated with design work The 3-D models created on a CAD system with the help of curves and surfaces. Those curves and surfaces are generally NURBS [8]. Wire frame models are used as input geometry for simple analysis work such as kinematics studies, surface models are used for visualization automatic hidden line removal and animations, solid models are used for engineering knowledge and visualization and are mathematically accurate description of the products and structures. The solid model can be shaded to improve visualization of the product, structure and physical models are automatically generated from the geometric models through rapid prototyping technology.

Computer Aided Design-CAD is defined the use of information technology (IT) in the Design process. Its use does not change the nature of the design process but as the name states it aids the product designer. The designer is the main actor in the process, in all phases from problem identification to the implementation phase. The following advantages generally achieved form CAD [9]:

- Accurately generated and easily modifiable graphical representation of the product
- Perform complex design analysis in short time. Implementing Finite Elements including Static, Dynamic and Natural Frequency analysis, Heat transfer analysis, Plastic analysis, Fluid flow analysis, Motion analysis, Tolerance analysis, Design optimization
- Record and recall information with consistency and speed

CAD systems can shorten the design time of a product. Therefore the product can be introduced earlier in the market, providing many advantages to the company. CAD systems enable the application of concurrent engineering and can have significant influence on final product cost, functionality and quality [9].

Finite Element Method (FEM): The following are the three basic features of the finite element method [10].

- Discretization of the given domain into a collection of preselected finite elements.
- Derivation of element equations for all typical elements in the mesh
- Assembly of element equations to obtain the equations of the whole problem
- Imposition of the boundary conditions of the problems
- Solution of the assembled equations
- Post processing of the results

Finite Element (FE) is one of those methods which used for evaluation of a structure under static and dynamic loads before making the main model. This leads to improve the strength of design. ANSYS is a general purpose software package based on the finite element analysis. This allows full three-dimensional simulation without compromising the geometrical details [11, 12]. Finite element method was used by many researchers in order to design the tillage tools or investigate the interaction between soil and tillage implement. Most investigation used a blade as the object studying the interaction between soil and tool, because its geometric simplicity made the corresponding FEM analysis relatively easier [13, 14].

Computer Aided Engineering Tools (CAE): Engineering analysis is concerned with analysis and evaluation of engineering product designs. For this purpose, a number

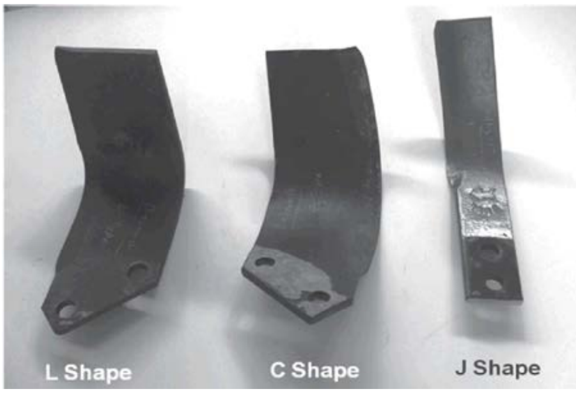

Fig. 1: Different types of rotavator blade [19]

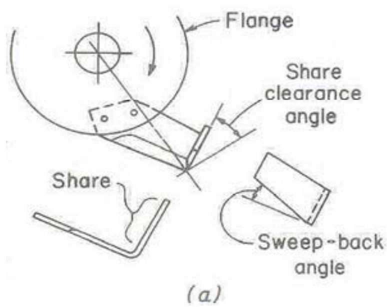

Fig. 2: Three views of an L-shaped blade for rotary tiller [20]

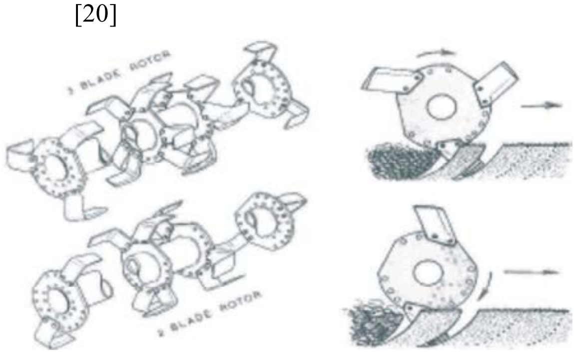

Fig. 3: Rotary tiller rotors with L-type blades showing methods of mounting and cutting action [3]

of computer-based techniques are used to calculate the product's operational, functional and manufacturing parameters. Finite element analysis (FEA) is one of the most frequently used engineering analysis techniques.

Besides FEA, tolerance analysis, design optimization, mechanism analysis and mass property analysis are some of the computer aided techniques available to engineers for the purposes of analysis and evaluation of the engineering product designs.

Blade Details: Based on the market survey and available literature, it was found that generally three types of blades are used in a rotary tiller or rotavator. These are L' shape, 'C' shape, & 'J' shape, to suit various operating conditions as shown in Fig. 1. 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 [15]. The detail of an L-shaped blade is shown in Fig. 2. Again in India, L-shaped blades are mostly used in Indian rotavator which are normally mounted with three right handed and three left handed blades per flange as shown in Fig. 3.

MATERIALS AND METHODS

As discussed in the preceding section that a 'L" type blade is most suitable for Indian farming conditions, a blade was designed following CAD-CAE-FEM route. Initially, 3D Modelling was done on the basis of geometrical parameters normally used in commercially available blades using 3D CAD software. This model was analyzed through ANSYS for Finite Element Analysis. Based on the analysis results, final blade has been designed. Table 1 and Fig. 4 show the specifications and important parameters of the blade, respectively. This blade was designed by considering: (1) cutting width which should be more than 40mm for cutting and breaking paddy residues into pieces and making a seedbed of sufficient width for direct seeding; (2) maximum radius of rotation should be more than 150mm to achieve a cutting depth of 60mm without the rotary shaft touching the surface. Fig. 5 shows the 3D Model and original photograph of the developed blade.

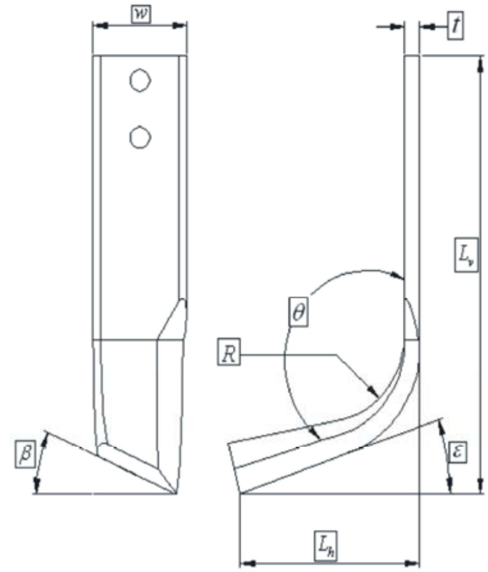

Fig. 4: Important parameters of a rotary blade

Table 1: Parameters of different blades designed for the study

Parameters	Notations	Values
w	Blade span, mm	40
L_v	Effective vertical length, mm	212
L_h	Blade cutting width, mm	88.7
R	Curvature between L_v and L_h mm	40
θ	Blade angle, degree	108
β	Clearance angle, degree	20
t	Blade thickness, mm	8.0
ε	Bending angle, degree	22

Table 2: Input parameters for the analysis

Parameter	Values /range
Rotary tiller work depth	100 mm – 150 mm
Rotary tiller work width	1600 mm
Rotor rpm	200- 220
Blade peripheral velocity	5-6 m/s
Total number of blade	66
Number of blades on each side of the flanges	11
Prime mover forward speed	0.7- 1.7 m/s
n_e, number of blades which action jointly on the soil into the total number of blades	11/66
Prime mover Power (N_c)	30-40 hp
Traction efficiency (η_c)	0.8-0.9
Coefficient of reservation of tractor power (η_z)	0.7-0.8

Table 2: Materials properties

Young's Modulus, Pa	Poisson's Ratio	Bulk Modulus, Pa	Shear Modulus, Pa	Compressive Yield Strength, Pa	Ultimate Tensile Strength, Pa
2e+11	0.3	1.6667e+011	7.6923e+010	2.5e+008	4.6e+008

Fig. 5: Geometry (3D Model) the developed Blade

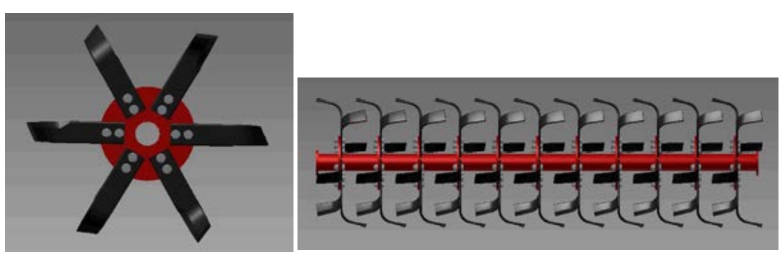

Fig. 6: CAD Model for arrangement of blades on the rotor shaft

Cad-Modeling And Analysis In The Present Work: The assembly or rotor shaft was done with 66 nos. of blade. There were six blades in a single flange as shown in Fig. 6. The three important steps in ANSYS programming used for CAD-modelling and analysis are Pre-processing, Solution and Post processing [16]. The same steps are followed here and analysis was done based on field trial data available from the manufacturer and farmers for the developed blade in ANSYS 14.0 software.

Material Properties: Material properties used in the analysis are presented in Table 2.

RESULT AND DISCUSSION

The analysis results of left hand and right hand blade in graphical mode have shown in Fig. 6. The results have been computed and presented in Table 3. Similar analysis also done for standard used “C” type and “J” type rotavator blade. The results are compared and it was found that developed “L” type blade experienced least stress while deformation is almost similar. Ass in case of tillage tools, deformation is related to tool wear but stress plays a major role which results in wear of the tool. Here in this analysis, this stress variation is obtained because of variations in tool shape. The shape of the cutting edge can materially affect draft as well as vertical and lateral components of soil forces. These components of soil forces are important which results in stresses of the cutting edges. In the “L” shape blades these stresses are minimum as the shape is better than the other types. Fig. 7 and 8 shows the comparison of results for deformations and stress respectively for all the blades. From the figures it appears that the developed blade shows somewhat good characteristics of load sharing capacity over standard available blades.

Table 3: comparison of results

Sl No.	Blade variants	Soil force acting on the blade surface, N	Maximum Deformation, mm	Von mises stress, Pa
1	L type Blade (Left)	3800	0.5310	$1.152x10^9$
2	L type Blade (Right)	3800	0.5974	$1.152x10^9$
3	J type Blade (Left)	3800	0.6124	$1.657x10^9$
4	J type Blade (Right)	3800	0.5998	$1.710x10^9$
5	C type Blade (Left)	3800	0.5517	$2.157x10^9$
6	C type Blade (Left)	3800	0.5468	$2.089x10^9$

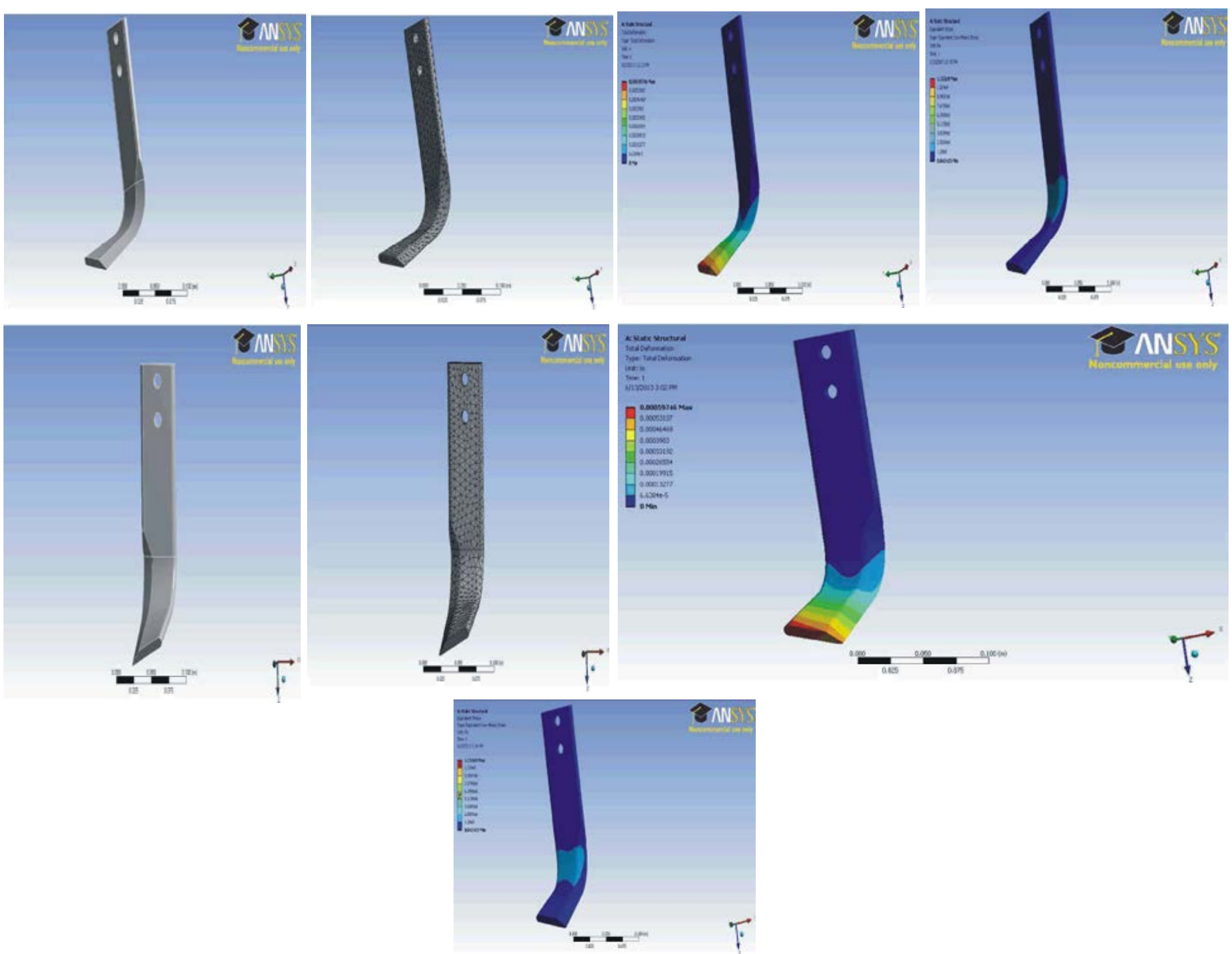

Fig. 6: Analysis results [For both Left & Right] (3D Model, Meshing, Deformation and Von mises stress respectively)

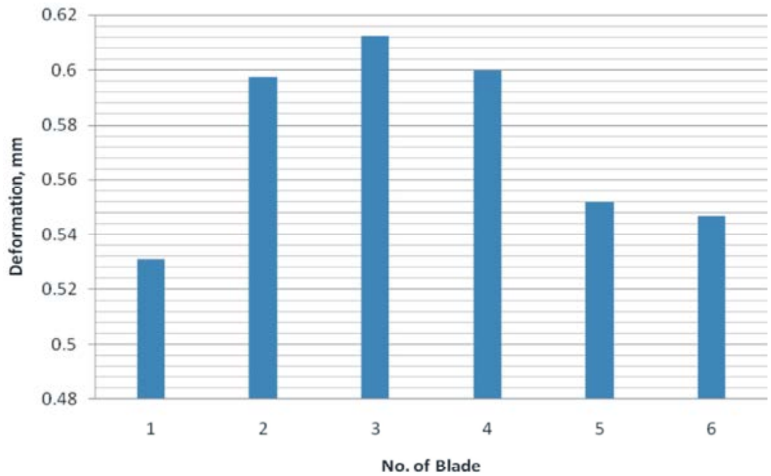

Fig. 7: Comparison of results for deformation

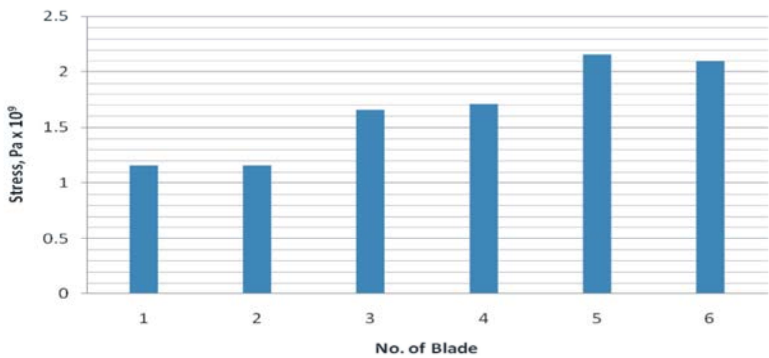

Fig. 8: Comparison of results for stress

CONCLUSION

CAD method is an effective tool for the development of blade as this is the main critical parts of a rotavator. CAD model is also very much useful for investigation of stresses experienced by the blades. Rotary tillers are primary tillage tools which used for solving the hardpan problems in the agricultural lands. This research focuses on the design and development of rotary tillers blade through CAD method which results better design in terms of less stress on the cutting edges that results less wear which ultimately enhances the service life. However further study of field observation is required so that a better comparison can be made.

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