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Design and Analysis of Rotavator Blades for its Enhanced Performance in Tractors

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ABSTRACT

The design and optimization of rotary tillage tool on the basis of simulation and finite element method is done by using ANSYS software. The different rotary tillage tool parts are geometrically constrained with preparation of solid model of blades and simulation has been done with actual field performance rating parameters along with boundary conditions. The proposed work results are identifying sufficient tolerance in changing the material such as EN 8 steel and EN 24 steel. The dimensions of rotavator blade sections and to rise the life cycle of the blades for a reliable strength. The present geometry working model with tillage blade is analysed to new design change constraints of its geometry for the maximum weed removal efficiency by presenting its analysis results from the field performance.

Keywords: Structural Analysis, Deformation Analysis and Modal Analysis.

1. INTRODUCTION

The rotary tillage machine has been used in soil-bed preparation and weed control in the field of fruit gardening agriculture. It has a large capacity for cutting, mixing to topsoil preparing the seedbed directly. It has a more mixing capacity seven times than a plough.

Its components works under miscellaneous forces due to power, vibration, pointless, impact effect of soil parts as after reaching to higher side. The manufacturing and design optimization errors can be minimized by its components design analysis and optimization.

The design optimization of tillage tool has obtained by reducing its weight, cost and improving a field performance to high weed removal efficiency. The analysis has been prepared a three dimensional solid modeling and applications of finite element method are getting so widespread in the industry.

The undesired stress distribution components, it cannot compensate to the operating forces in the field of environment and results in breakdown and failure due to higher stresses and deformation.

The proposed work has developed a computer aided experimental system for design testing and valuation of agricultural tools and equipments. The selected physical model of rotavator has been measured with accurate dimensions and 3D solid model is prepared in CAD-software such as ANSYS, CATIA, Pro/E, SOLID WORKS etc.

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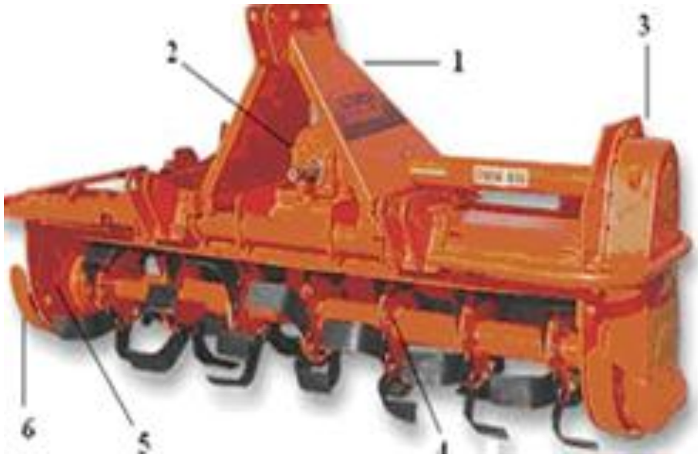

Rotavator with Six Components

1. Independent Top Mast
2. Single / Multi Speed Gear Box
3. Chain / Gear drive
4. Six Blades per flange
5. Adjustable depth skids
6. Central with offset positions

Fig.1. 3D View of Rotavator

1.1 Blade configurations: The rotavator is a tillage tool primarily comprising of L-shape blades mounted on flanges that are fixed to a shaft and it is driven by the tractor power-take-off (PTO) shaft. In comparison to passive tools, the rotavator has a superior soil mixing and pulverization capability. During rotavator tillage operations various factors affect its energy requirements. These factors can include soil conditions, operational conditions and rotavator configuration.

There are two types of blade configuration used in rotavator. The following blade configuration shows high grade of cultivation,

- Three blade configuration
- Two blade configuration

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1.1.1 Three Blade Configuration: This is the standard blades configuration and has a three pair of blades per flange except the end flanges which are fitted with one hand only.

1.1.2 Two Blade Configuration: The rotor may be converted into two blade configuration. Two blades per flange used in the rotavator except the end flanges. In this blade configuration, less tendency to the rotor to clog in sticky soil conditions. A cloddy finish can be obtained and rotor can be driven at faster rpm.

1.2 Types of Blade: Rotavator are usually supplied with 'power' or L blades for general work. When working in heavy and puggy clay soils, the 'speed' or 'C' blades should be used.

- 'L' blade
- 'C' blade

1.2.1 'L' blade: The long shank blade as the name implies, has longer shank than the standard power blade. This allows the greater clearance between the blade and rotor. With this, a greater depth of cultivation is obtainable if tractor power and conditions are allowed.

1.2.2 'C' blade: This blade has more efficient self-cleaning action, uses less power and produces a coarser finish than the other blades. Other blades like trash, renovating to fit the special rotors for specific applications.

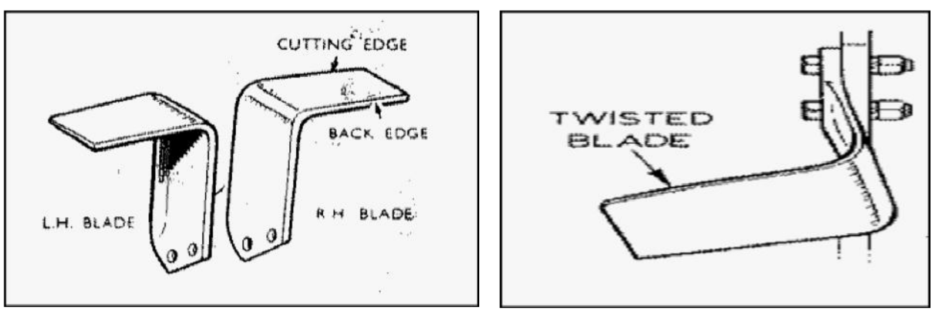

Fig.2. Types of Blade

1.3 Blade Fixing: On all flanges, except the stub axle flange (RH end flange), Blades are bolted to the left of the each flange, with left hand blade leading.

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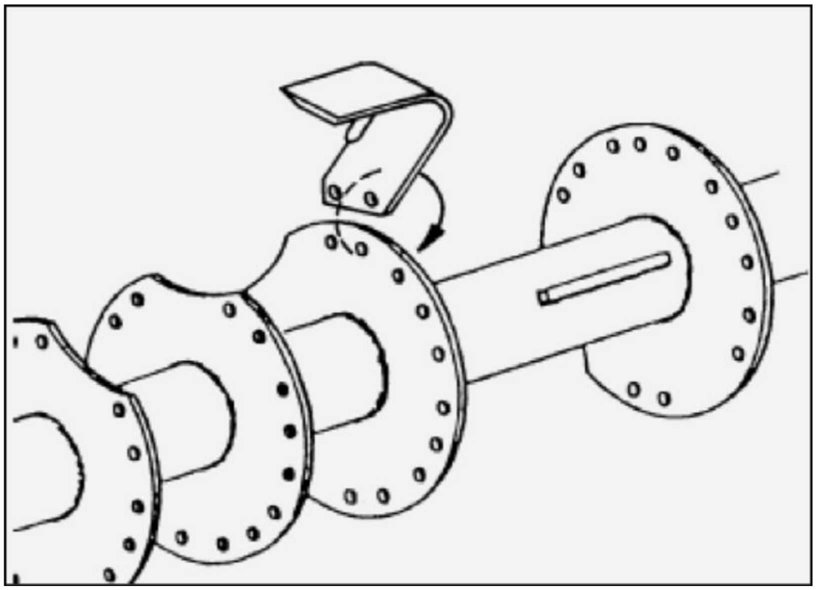

Fig.3. Fixing of Blades

On the stub axle flange, blades are on the right side of the flange. This ensures blades cross over the flange and protect it from wear.

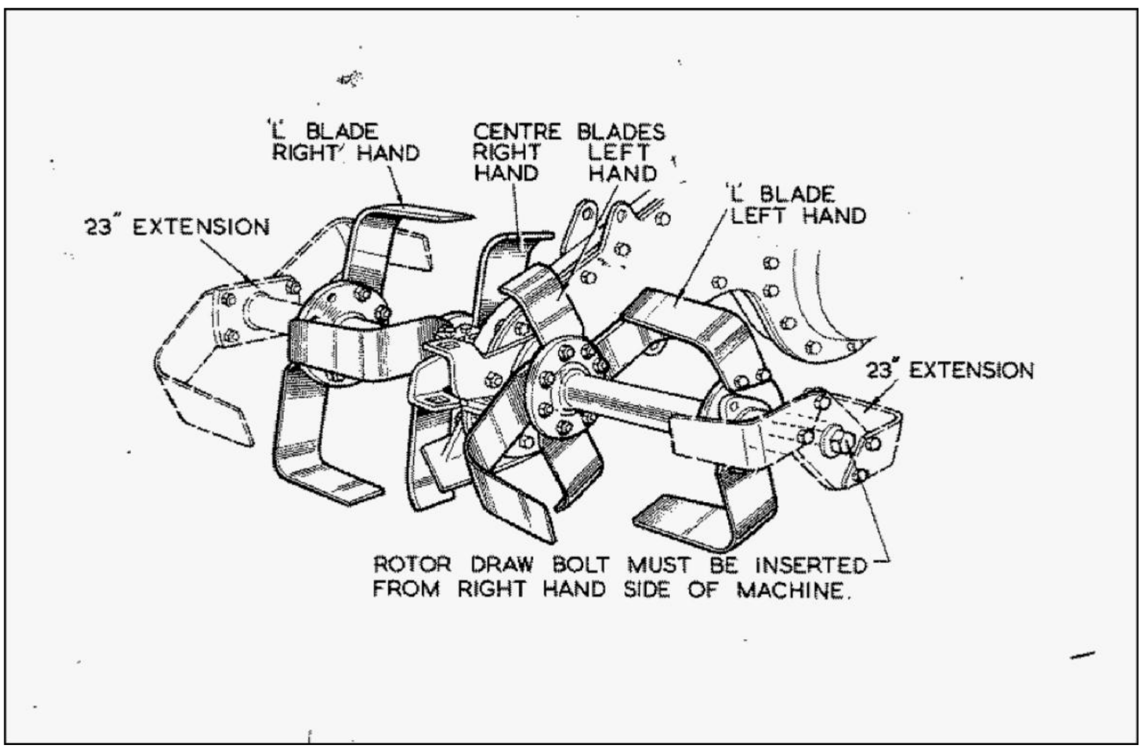

Fig.4. Assembly of Blade Section in Rotavator Blades

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1.4 Fitting of blades: If it is necessary to fit the blades, the following reasons has to be done,

- Identify the left and right hand blades,
- Viewed from the rear end of the machine (behind the handle bars), the left hand flange carries two right hand blades and the right hand blade carries two left hand blades.
- The outer blades are fitted to outer sides of end flange and the center blades on the inner sides of center flange.
- It should be equally spaced, because only one blade at a time can enter the ground for cultivation.

1.5 Maintenance of blades: Only the cutting edges of the blades should rub in the soil. The back of the blades should be clear. The blades are so designed that use in average soil keeps them sharp. The efficiency of the blades should be determined largely by the condition of blades. If they are left bend or distorted the striking the solid obstacles in the ground and are not straightened, they will require double the power to drive, the quality of work is poor and the blade will wear much more quickly. Trouble will also arise with clogging under the shield. Blades must be examined daily and any bent ones straightened quickly.

2. LITERATURE REVIEW

Godwin R.J, O'Dogherty M.J "Integrated soil tillage force prediction models" 2006. This paper describes the integration of a series of models to predict the forces acting on a range of tillage tools from simple plane tines to mouldboard ploughs. The models adequately reflect the changes in soil strength and implement geometry[1].

Gopal U. Shinde and Shyam R. Kajale "Design optimization in rotary tillage tool system components by CAEA" 2012. The design optimization of rotary tillage tool by the application of Computer Aided Engineering (CAE)-Techniques on the basis of finite element method and simulation method is done by using CAD-Analysis software for the structural analysis. The different tillage tool parts of rotary tillage tools are geometrically constrained by the preparation of solid model, Meshing and Simulation is done with actual field performance rating parameters along with boundary conditions[2].

Khalid Usman, Ejaz Ahmad Khan, Niamatullah Khan "Effect of Tillage and Nitrogen on Wheat Production, Economics, and Soil Fertility in Rice-Wheat Cropping System" 2013. Conservation tillage and nitrogen may improve soil fertility, yield and income on sustainable

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basis. The aim of this study was to evaluate the impact of three tillage systems viz. zero (ZT), reduced (RT), and conventional tillage (CT) and five N rates (0, 80, 120, 160, and 200 kg·N·ha−1) on yield and yield components, soil organic matter (SOM), total soil N (TSN), and income of wheat grown after rice[3].

Mahesh M. Sonekar, Dr. Santosh B. Jaju "Fracture analysis of exhaust Manifold stud of Mahindra Tractor through finite Element method (FEM) – a past Review" 2011. Failures were observed even after designing the components with maximum stress value well below yield / ultimate stress. Tests were then carried out for time varying loads. Results proved that the component fails at values below yield stress when subjected to time varying load. It was also observed that below a specific stress value components were not failing at all.

This stress value was termed as endurance limit. For example yield stress for general steel is around 250 N/mm^2 and endurance limit 160 N/mm^2.In general while using FEM technique for failure analysis, a finite element routine would be first used to calculate the static and dynamic displacement and stresses under the maximum compression and tension loading, which were then used for critical points evaluation[4].

Rahul Davis "Optimization of surface roughness in wet turning operation of EN24 steel" 2012. The present experimental study is concerned with the optimization of cutting parameters (depth of cut, feed rate, spindle speed) in wet turning EN24 steel (0.4% C) with hardness 40+2 HRC. In the present work, turning operations were carried out on EN24 steel by carbide P-30 cutting tool in wet condition and the combination of the optimal levels of the parameters was obtained.

The Analysis of Variance (ANOVA) and Signal-to-Noise ratio were used to study the performance characteristics in turning operation. The results of the analysis show that none of the factors was found to be significant. Taguchi method showed that spindle speed followed by feed and depth of cut was the combination of the optimal levels of factors while turning EN24 steel by carbide cutting tool in dry cutting condition[5].

Rahul Davis, Jitendra Singh Madhukar "A parameteric analysis and optimization of tool life in dry turning of EN24 steel using taguchi method" 2012. To obtain an optimal setting of these turning process parameters –spindle speed, feed rate and depth of cut, which may result in optimization of tool life of Carbide P-30 cutting tool in turning En24 steel (0.4 % C). Turning operations were performed by Carbide P-30 cutting tool under various dry cutting conditions by using sample specimens of EN-24 steel.

The effects of the selected process parameters on the tool life and the subsequent optimal settings of the parameters have been accomplished using Taguchi method. The Analysis of

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Variance (ANOVA) and Signal-to-Noise (SN) ratio and were used to analyze the performance characteristics in turning operation The results depict that Spindle speed followed by feed rate and depth of cut was the combination of the optimal levels of factors that significantly affects the mean and variance of the tool life of the carbide cutting tool and gives the optimum tool life[6].

Sirisak Chertkiattipol, Tanya Niyamapa "Variations of torque and specific tilling energy for different rotary blades" 2010. The torque characteristics and the specific tilling energies of three commonly used rotary blades, i.e. the Japanese C-shaped blade, the European C-shaped blade and the European L-shaped blade, were studied to develop a suitable rotary blade for seedbed preparation. The experiments were carried out in a laboratory soil bin at forward speeds of 0.034, and 0.069 m/s, and rotational speeds of 150, 218, 278 and 348 r/min (or 3.30, 4.79, 6.11 and 7.65 m/s) in sandy loam and clay soils.

Subrata Kr. Mandal and Basudeb Bhattacharyya "Design&Development of rotavator blade: Interrogation of CAD method" 2013. 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 result in blade wear. Therefore, it is necessary to design and develop a suitable blade so that self-life is enhanced. This paper presents design and development of rotavator blade through the interrogation of computer aided design (CAD) method[7].

Venkata siva S.B, Srinivasarao G, Mahesh kumar M "Study of phase transformations in EN8 steel material using acoustic emission technique" 2012. Experiments are carried out to distinguish different phases using online monitoring technique - Acoustic Emission (AE).

The objective of this work is to have a better understanding of the growth mechanism and solid-state phase transformations that can occur in carbon steel (EN8). It is found from the experiments that the basic parameters by which the phase transformation can be found out are energy, counts, RMS and amplitude[8].

Zarroug.N.M, Padmanabhan.R, MacDonald.B.J, Young.P, Hashmi.M.S.J "Mild steel (EN8) rod tests under combined tension–torsion loading" 2003. The results obtained from combined tension–torsion loading tests carried out on Mild steel (En8) specimen.

The loading of the specimen was carried out in different modes: (i) maintaining tensile force or axial displacement constant and increasing torque or angle of twist; (ii) maintaining torque or angle of twist constant and increasing load or axial displacement. A finite element solution of the problem was obtained to gain further insight into the effects of the loading modes[9].

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3. METHODOLOGY

The proposed work results in identifying sufficient tolerance in changing the material (EN 8 steel & EN 24 steel). It is expressed in methodology as,

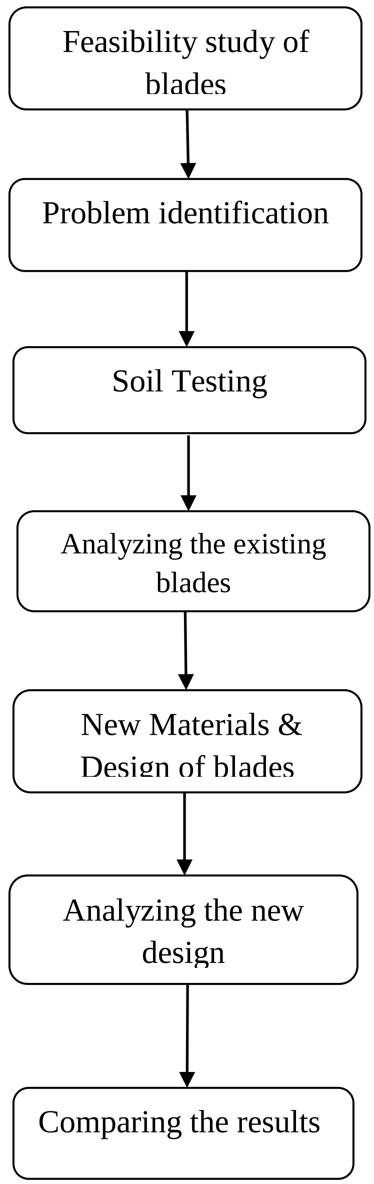

Fig.5. Methodology

4. RESEARCH OBJECTIVES

1. To evaluate Structural Analysis

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2. To find out Deformation Analysis

3. To evaluate Modal Analysis

4. To evaluate soil test

5. EXPERIMENTAL WORK DISCUSSION

5.1 Problem identification

Based on the problem, we had identified that the rotavator blade bends and breaks while cultivation. This is because the existing design cannot withstand the given load conditions and also it is identified that the maximum working hours for the blades is 20-200hrs, but the cultivation time is more and hence it is not convenient for the farmers to use it. Hence, we need to design a blade which withstands higher load conditions and longer working hours.

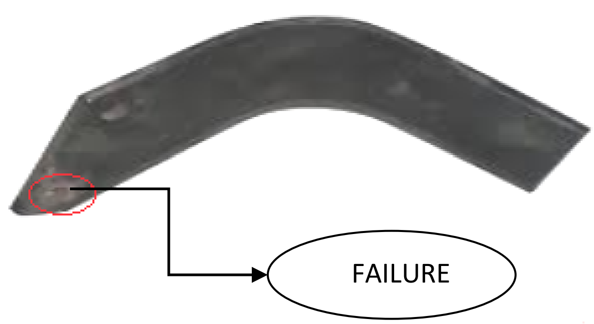

Fig. 6. Failure in Blade (Mild Steel)

5.2 Dimensions and Materials of Blades

The design for existing blade is given below,

5.2.1 Dimensions of Existing Blade

Generally, rotavator blades dimensions are taken from industry's manufacturer's catalogue. In that different types of blades are used in their process.

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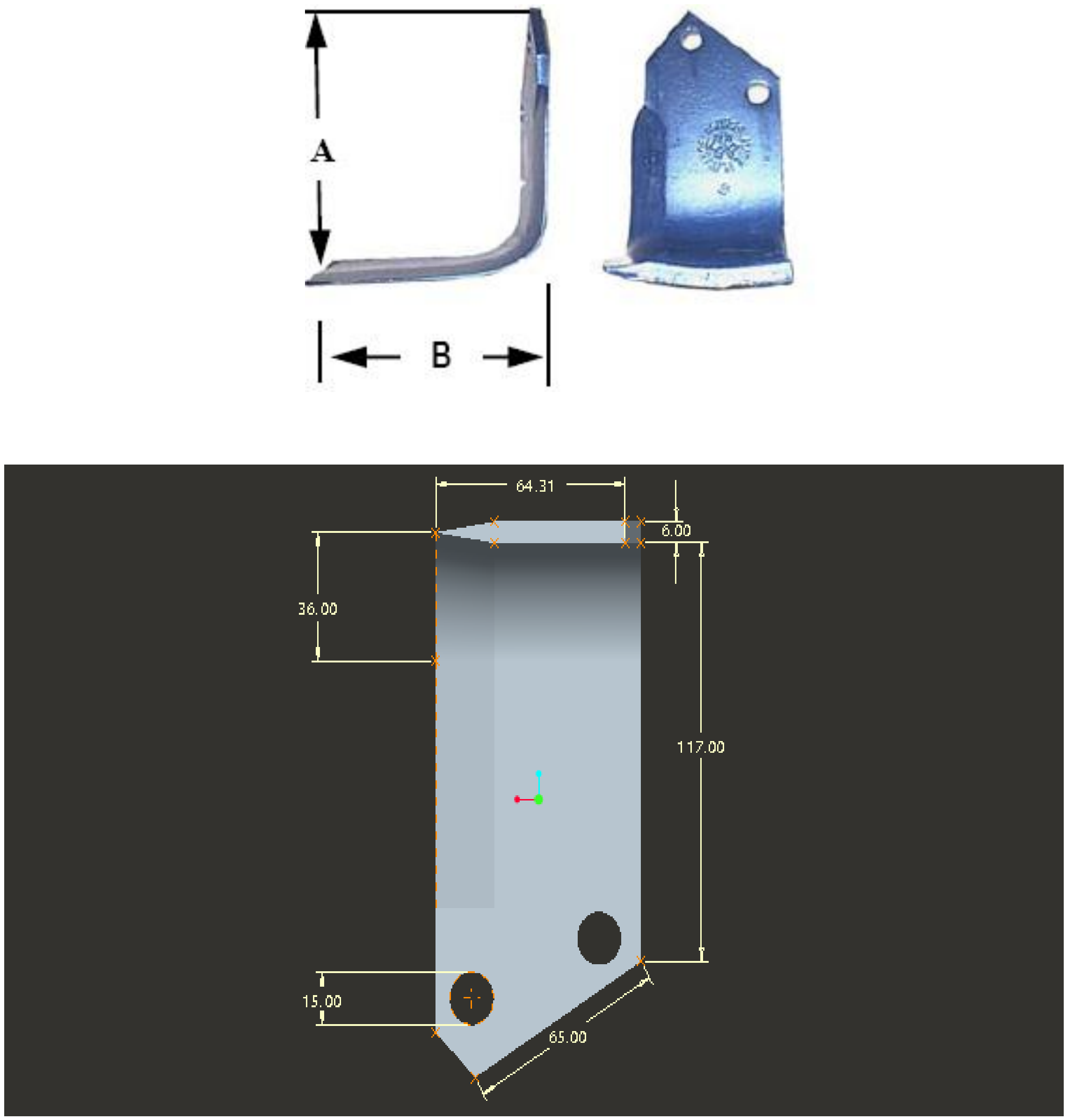

Fig.7. Dimensions of Blade

5.2.2 Materials of Blade

Generally blade materials are classified into three types as given below,

- High carbon steel,
- Cast iron and
- Mild steel.

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5.3 Modeling and Analysis

It is very difficult to find the best design for rotavator blades, in which there are still researches, are being carried to find out behavior of blades during agricultural applications. There is always a need of some assumptions to model any complex geometry. These assumptions are made, keeping in mind the difficulties involved in the theoretical calculation and the importance of the parameters that are taken and those which are ignored. In modeling we always ignore the things that are of less importance and have little impact on the analysis. The assumptions are always made depending upon the details and accuracy required in modeling.

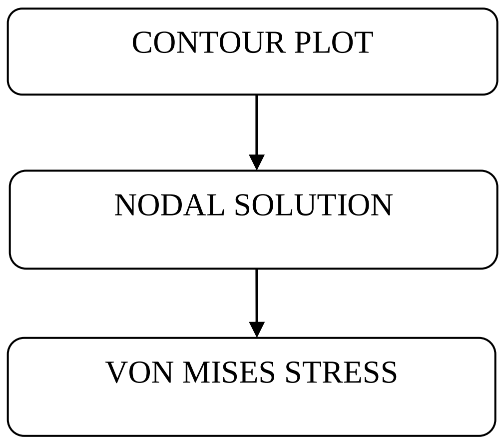

Fig.8. General Steps

The assumptions which are made while modeling the process are given below,

- The blade material is considered as homogeneous and isotropic.
- The domain is considered as axis-symmetric.
- Inertia and body force effects are negligible during the analysis.
- The blade is stress free before its application in rotavator applications.
- The analysis is based on pure force loading and displacement and thus only stress level due to the above said is done. The analysis will determine the life of the blades.

5.4 Soil Test

Soil test is carried out by using core cutter, in various agricultural soils have been tested.

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5.4.1 Core cutter

Core cutter is a device used to test the impact loads on the soil by using core box and is able to find the density of the soils.

$$\text{Density} = \text{one kilogram/meter}^3 \text{ for unit area of material}$$

Fig.9. Core Cutter

5.4.2 Core cutter dimension

- Core cutter weight= 1.950kg.
- Core diameter= 8.100cm.
- Height of the core = 28.200cm.

5.4.3 Procedure for using core cutter

Expose approximately 300 mm square of the soil layer to be tested. Place the steel dolly on top of the cutter and hammer the latter into the soil layer until the top edge of the cutter is a few millimeters below the soil surface. Take care not to rock the core cutter. Repeat with other cores in close proximity so as to obtain sufficient replicates. Dig out the core samples, taking care not to damage them. Trim the ends of the core level with the ends of the cutter and steel straight edge. Reject those that are not completely filled with soil. If the cores are satisfactory, pack them in loose soil in plastic bags or other containers.

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Two or three cores may be placed in one plastic bag but, in this case, wrap each core in aluminum foil. Transfer back to the laboratory in an insulated box packed with foam or vermiculite. For subsurface samples, dig a pit of the necessary size and depth, and sample as above. If desired, samples may be taken from the wall of the pitch Weight the cutter containing the wet core to the nearest gram. If the soil moves freely in the cutter, extrude the core into an aluminum tray and dry to constant weight at 105 °C. Then the soil is dried in place for an extended period. Weigh the dry soil with the cutter and then the cutter separately. Calculate internal volume of the core cutter, in cubic centimeters from its dimensions measured to the nearest 0.5 mm.

5.4.4 Types of soil used for testing

- Red soil with clay mix,
- Red soil.

Based among the two soils and density values has been taken for maximum tolerance limit.

5.4.5 Red Soil with Clay Mix

The load values obtained for red soil with clay mix are,

Density = mass of the soil /volume of core cutter

= 2.190/0.001453

= 1507.23 kg/m^3

= 1507.23 * 9.81*1.5

= 22178.89 N/m^3

Load acting on the blade area = **600 N**

Fig.10. Red Soil with Clay

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5.4.6 Red Soil

The load value obtained for red soil are,

Density = mass of the soil /volume of core cutter

= 2.060/0.001453
= 1417.76 kg/m^3
= 1417.76 * 9.81*1.5
= 20862.34 N/m^3

Load acting on the blade area = **563 N**

Fig.11. Red Soil

6. RESULTS AND DISCUSSIONS

From the analysis of rotavator blades, it is observed that the stress value of a material has been reduced by applying the design change and changing the materials as,

- EN24,
- E8 steel.

The comparison table as shown below,

6.1 Dimensions of new blade

Modelling is created by means of a Pro/E Creo Software, Dimensions of new blade is given below,

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6.1.1 For Blade Radius 34

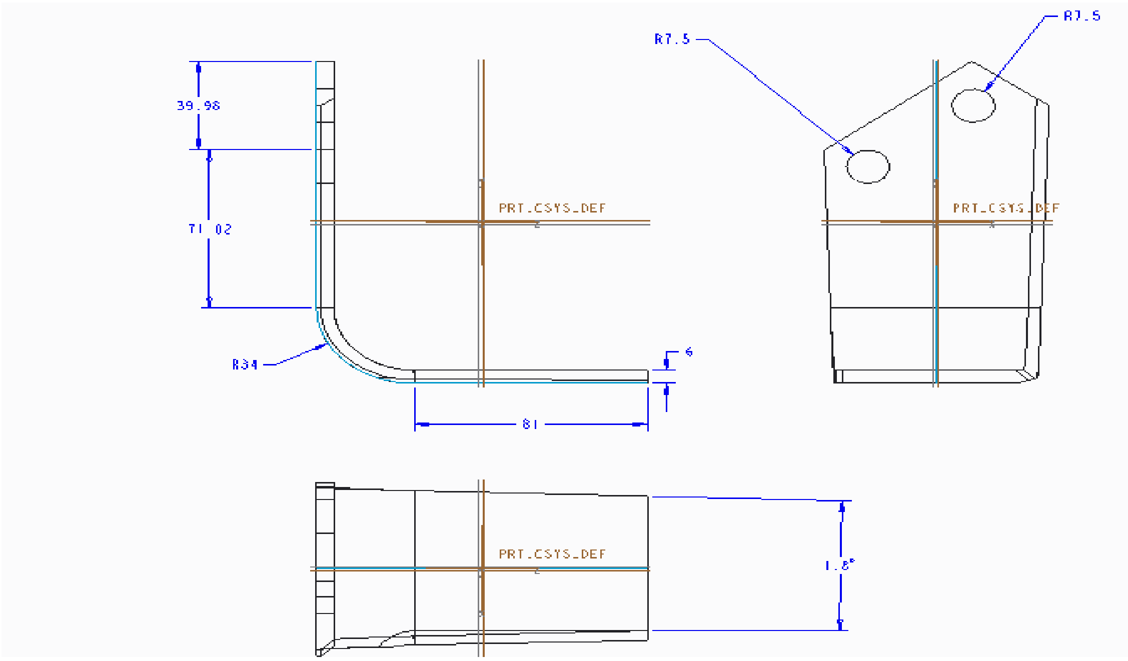

Fig.12. Radius 34

6.1.2 For Blade Radius 38

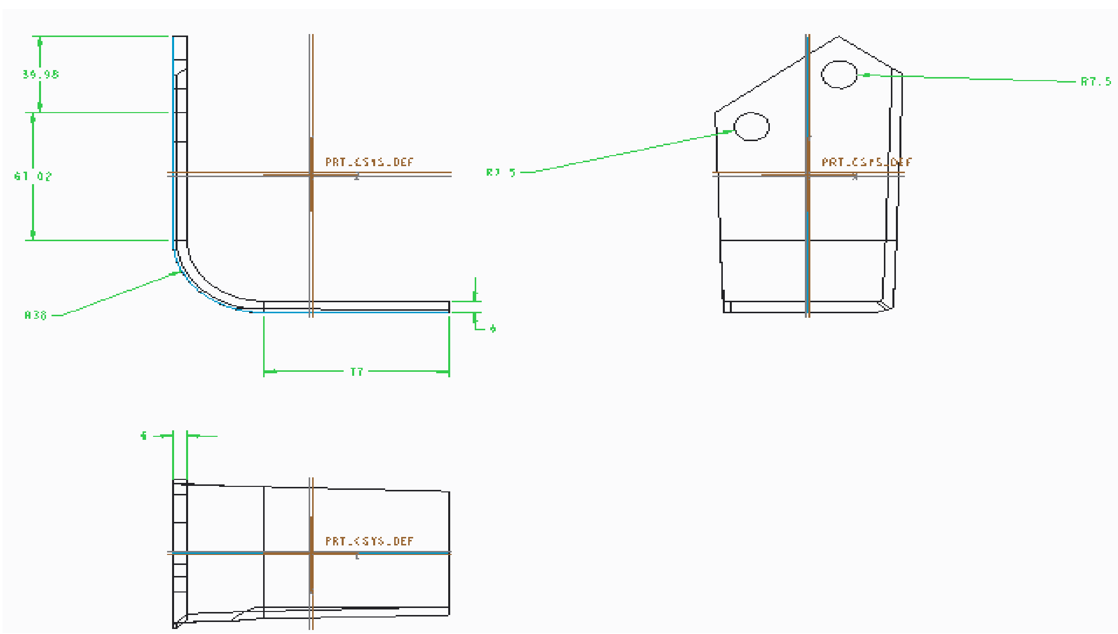

Fig.13. Radius 38

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6.2 Analysing the Blade

Existing and new materials are analysed in the ANSYS workbench and the results are compared and graph is plotted.

6.3 For Blade Radius 34

6.3.1 Deformation

The obtained result for deformation is tabulated below,

Table1. Deformation

	Red soil	**Red soil with clay**
MILD STEEL	461.28	491.59
EN8 STEEL	479.55	511.06
EN24 STEEL	473.01	504.10

The obtained result for deformation is plotted as shown,

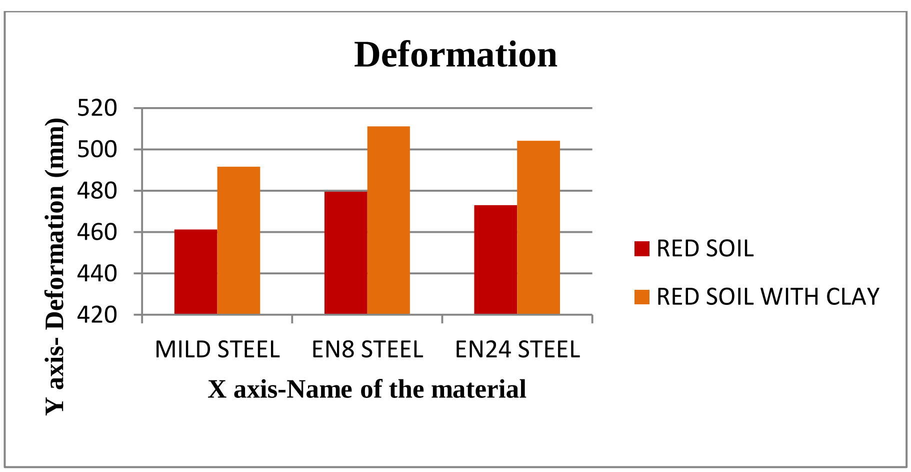

Fig.14. Deformation

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The Deformation is analysed in ANSYS as shown below,

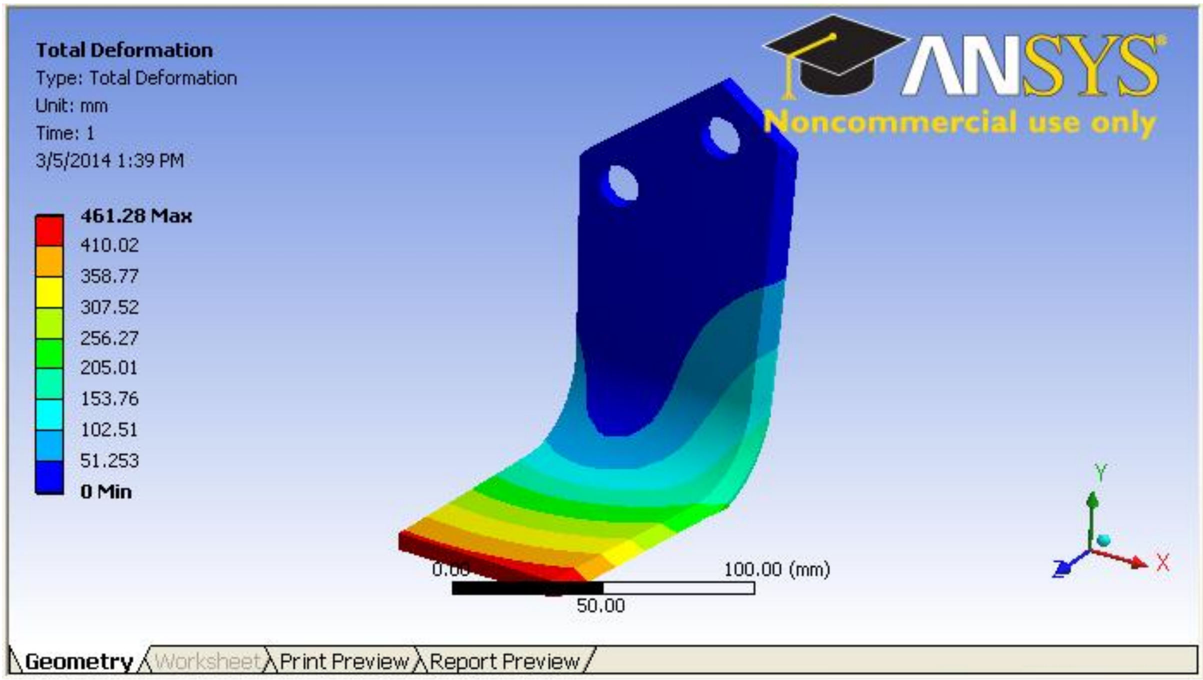

Fig.15. Deformation Diagram

6.3.2 Strain

The obtained result for strain is tabulated below,

Table 2. Strain

	RED SOIL	RED SOIL WITH CLAY
MILD STEEL	0.24037	0.25617
EN8 STEEL	0.24989	0. 26632
EN24 STEEL	0.23696	0.25253

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The obtained result for strain is plotted as shown,

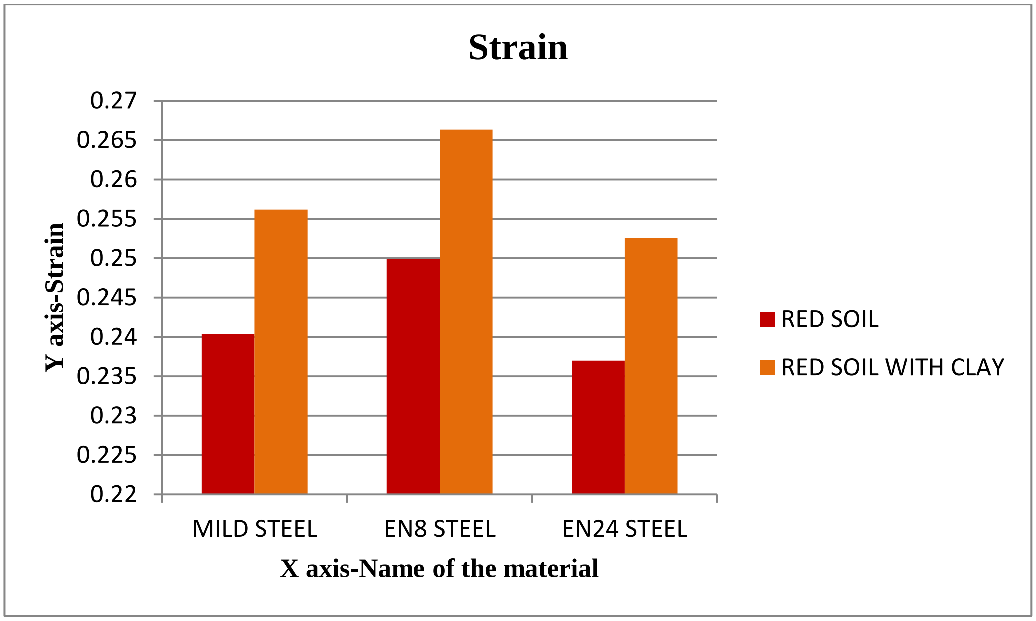

Fig.16. Strain

The Strain is analysed in ANSYS as shown below,

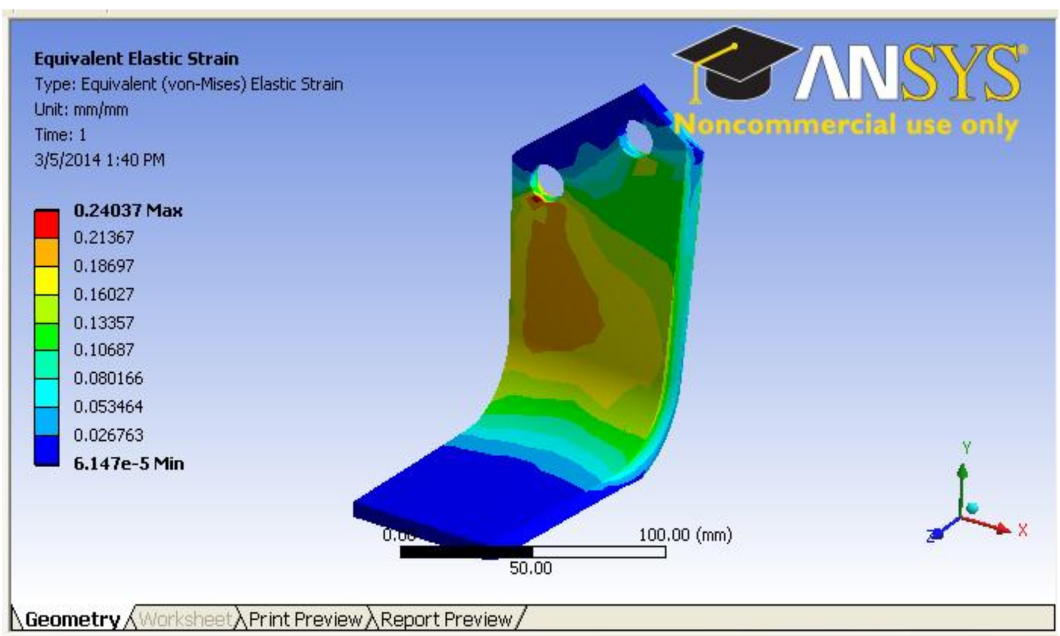

Fig.17. Strain Diagram

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6.3.3 Stress

The obtained result for stress is tabulated below,

Table 3. Stress

	RED SOIL	RED SOIL WITH CLAY
MILD STEEL	50479	53796
EN8 STEEL	50479	53796
EN24 STEEL	49050	52273

The obtained result for stress is plotted as shown,

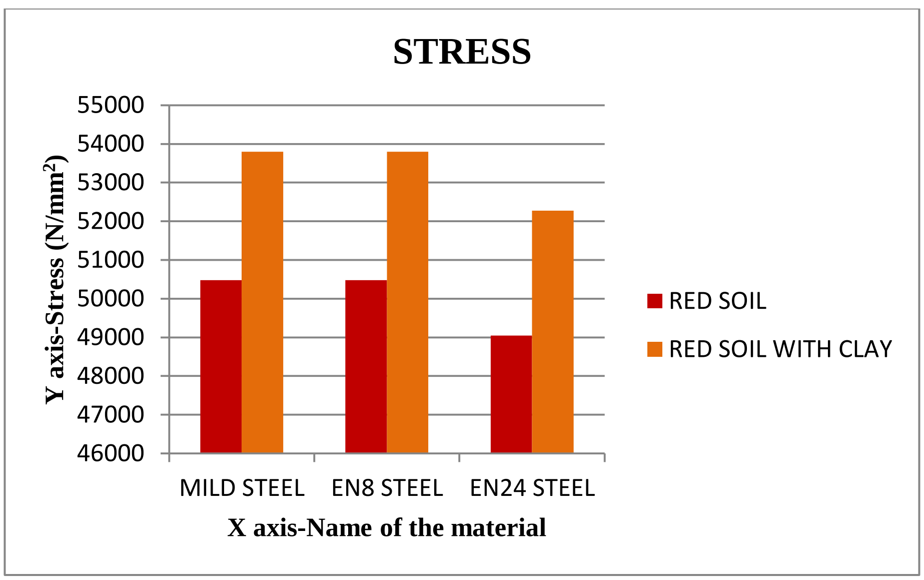

Fig.18. Stress

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The Stress is analysed in ANSYS as shown below,

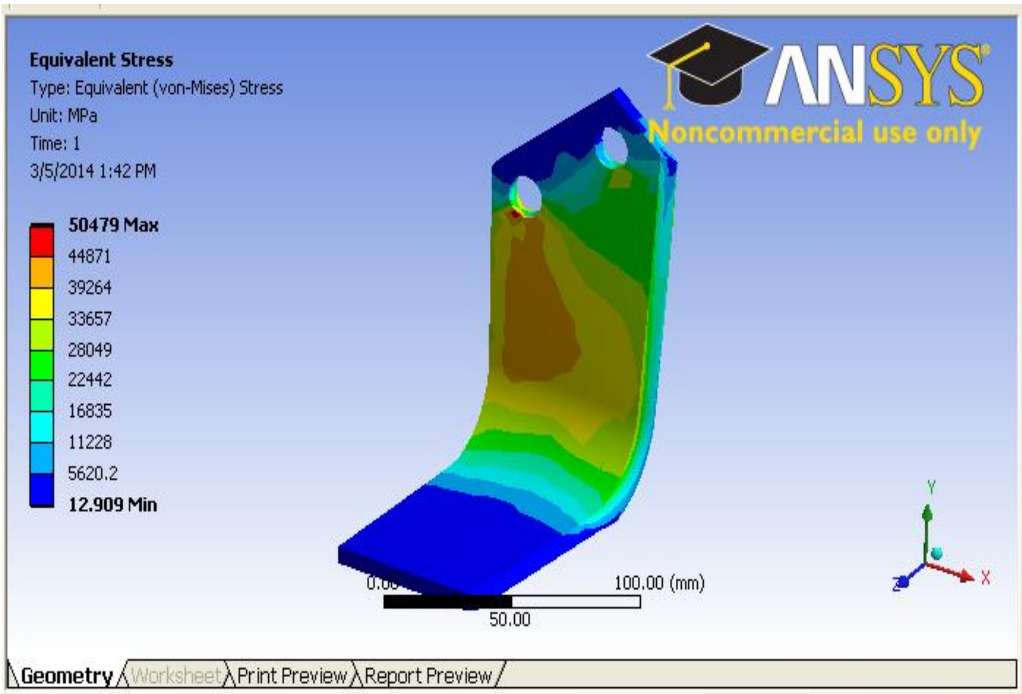

Fig.19. Stress Diagram

6.4 For Blade Radius 38

6.4.1 Deformation

The obtained result for deformation is tabulated below,

Table 4. Deformation

	RED SOIL	RED SOIL WITH CLAY
MILD STEEL	449.85	479.41
EN8 STEEL	467.66	498.40
EN24 STEEL	461.27	491.59

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The obtained result for deformation is plotted as shown,

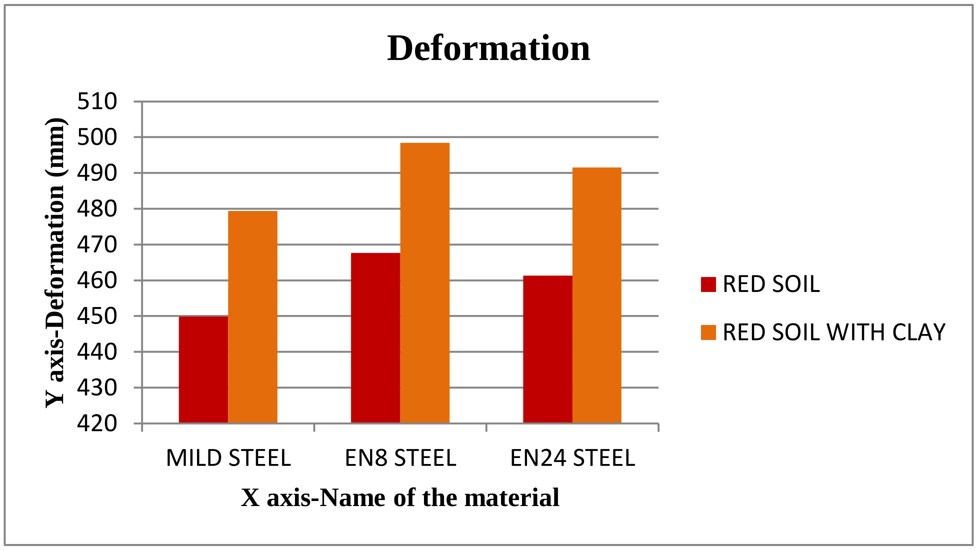

Fig.20. Deformation

The Deformation is analysed in ANSYS as shown below,

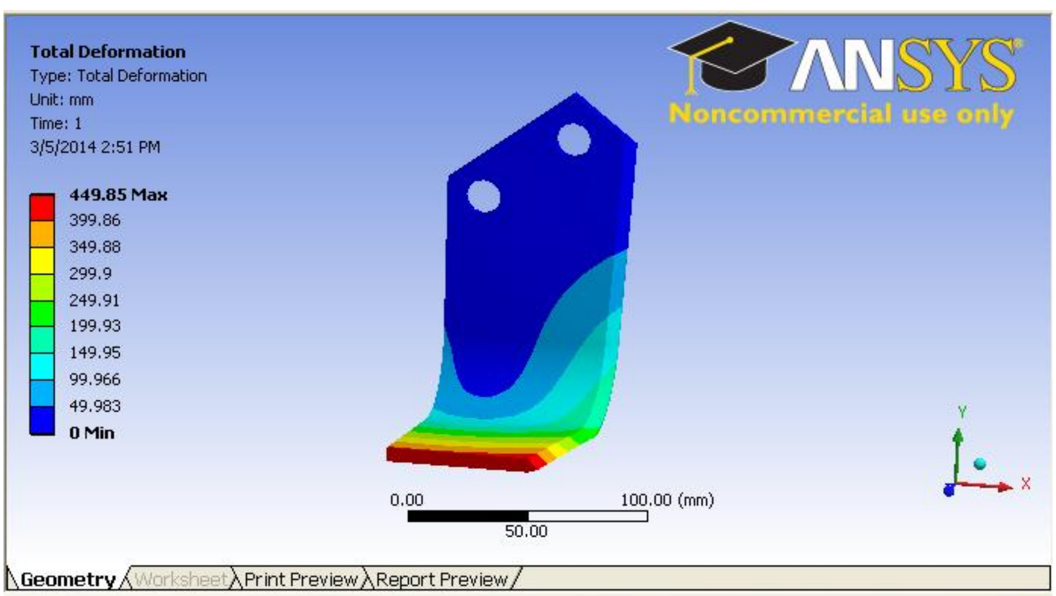

Fig.21. Deformation Diagram

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6.4.2 Strain

The obtained result for strain is tabulated below,

Table 5. Strain

	RED SOIL	RED SOIL WITH CLAY
MILD STEEL	0.26712	0.28467
EN8 STEEL	0.27769	0.29594
EN24 STEEL	0.26259	0.27985

The obtained result for strain is plotted as shown,

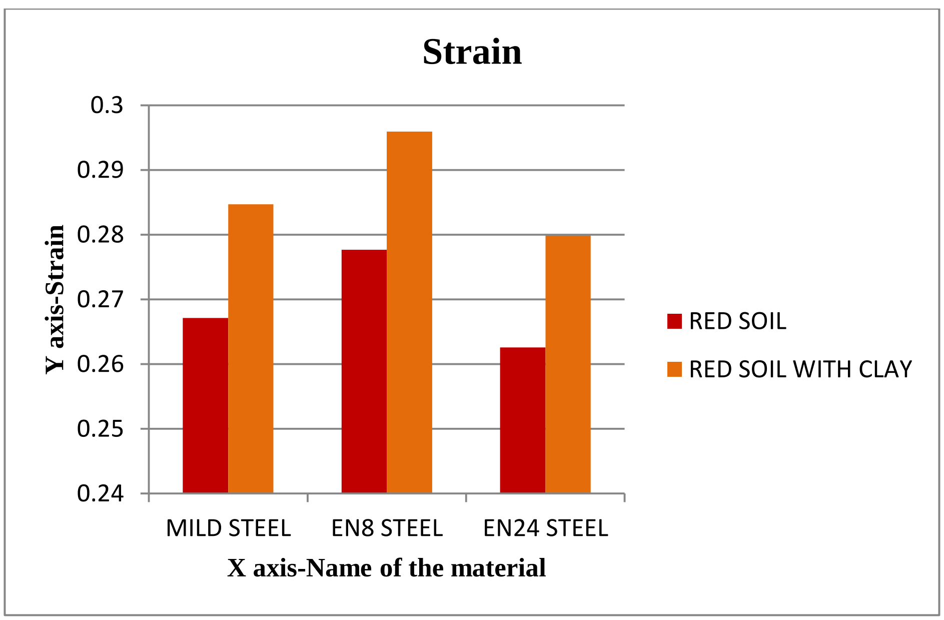

Fig.22. Strain

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The Strain is analysed in ANSYS as shown below,

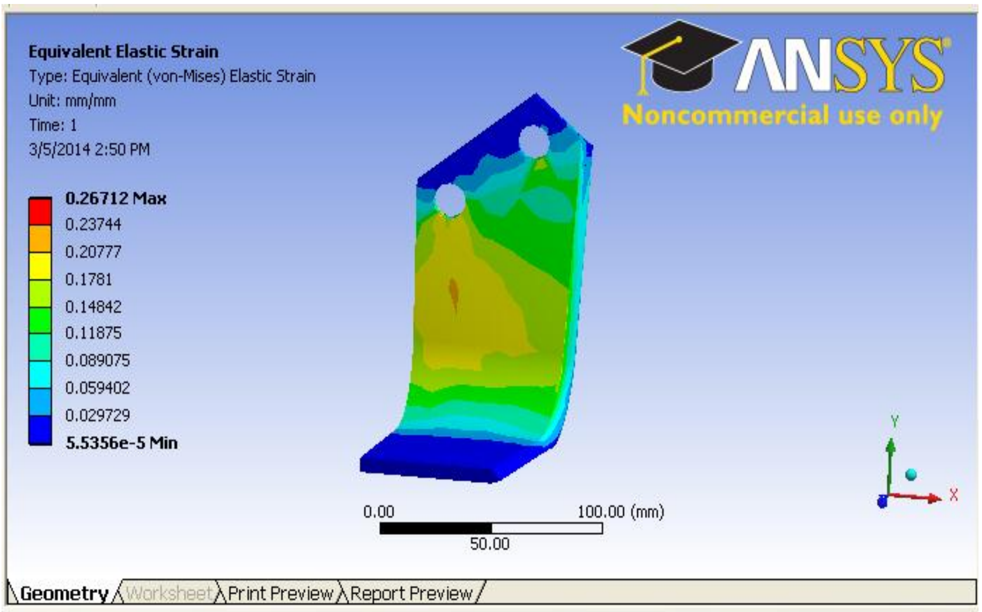

Fig.23. Strain Diagram

6.4.3 Stress

The obtained result for stress is tabulated below,

Table 6. Stress

	RED SOIL	RED SOIL WITH CLAY
MILD STEEL	56094	59781
EN8 STEEL	56094	59781
EN24 STEEL	54356	57985

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The obtained result for stress is plotted as shown,

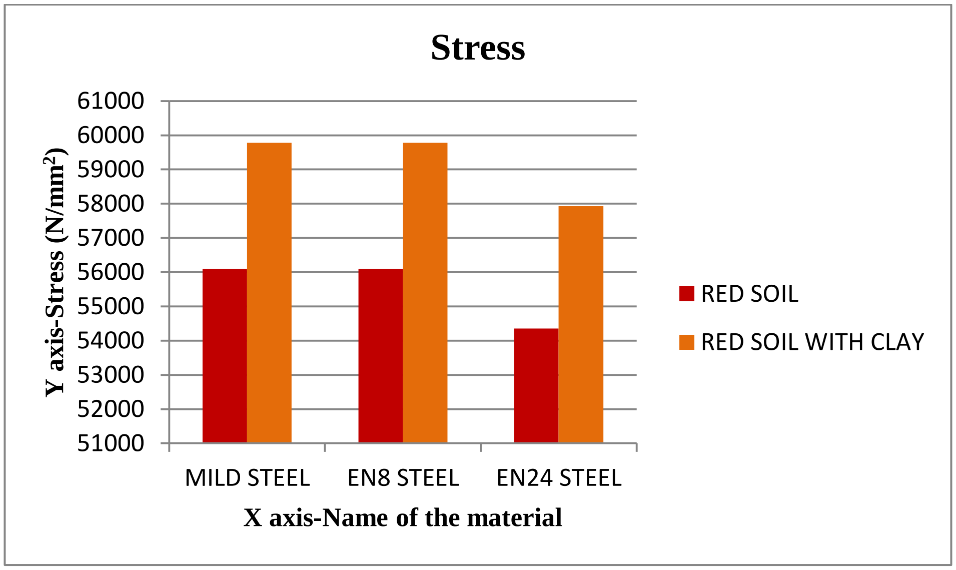

Fig.24. Stress

The Stress is analysed in ANSYS as shown below,

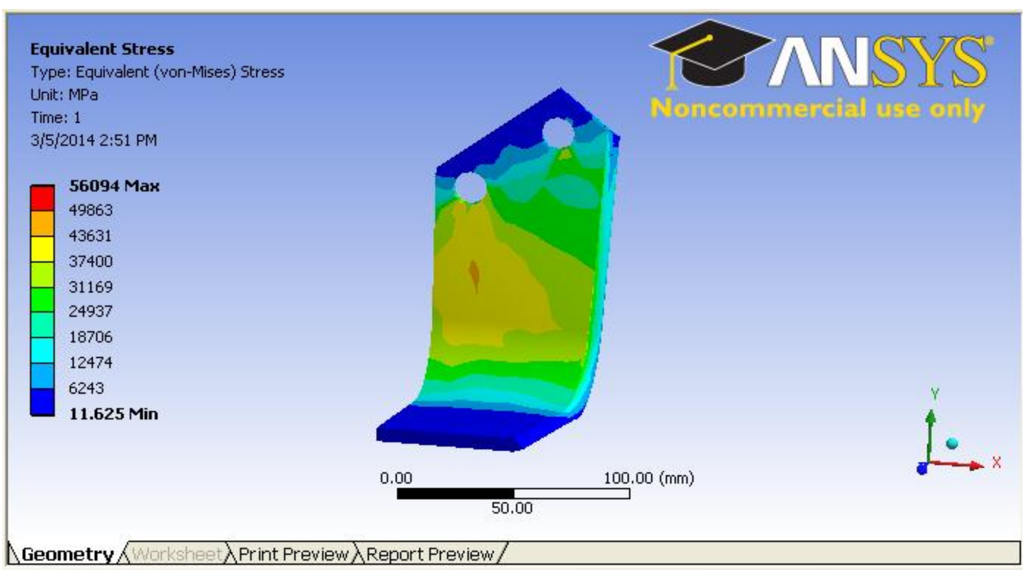

Fig.25. Stress Diagram

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7. CONCLUSIONS

- The problems on the blade were identified and solved. The standard material used for blade is mild steel and it is producing high stress.
- In this project, EN8 & EN24 Steel materials and different blade dimensions are taken for analysis.
- The load condition is applied for existing and modified design blades.
- EN8 and EN24 steel materials are producing less stress compared to Mild steel.
- Deformation and strain characteristics are also accepted and provide accurate result compared to existing design.
- By this, we can increase the working hours of the blades and by using different materials we can increase the wear resistance of the blades.

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