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Design and Analysis of Rotavator Blades for Enhancing the Performance

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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 AUTODESK FUSION 360 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 performances.

1.INTRODUCTION

A cultivator is any of several types of farm implement used for secondary tillage. One sense of the name refers to frames with the teeth (shanks) that pierce the soil as they are dragged through it linearly. Another sense refers to machines that use rotary motion of disks or teeth to accomplish a similar result. The rotary tiller is a principle example.

Cultivators stir and pulverize the soil, either before planting (to aerate the soil and prepare a smooth, loose seedbed) or after the crop has begun growing (to kill weeds—controlled disturbance of the topsoil close to the crop plants kills the surrounding weeds by uprooting them, burying their leaves to disrupt their photosynthesis, or a combination of both). Unlike a harrow, which disturbs the entire surface of the soil, cultivators are designed to disturb the soil in careful patterns, sparing the crop plants but disrupting the weeds Cultivators of the toothed type are often similar in form to chisel plows, but their goals are different. Cultivator teeth work near the surface, usually for weed control, whereas chisel plow shanks work deep beneath the surface, breaking up hardpan. Consequently, cultivating also takes much less power per shank than does chisel plowing.

Small toothed cultivators pushed or pulled by a single person are used as garden tools for small-scale gardening, such as for the household's own use or for small market gardens. Similarly sized rotary tillers combine the function of harrow and cultivator into one multipurpose machine.

Cultivators are usually either self-propelled or drawn as an attachment behind either a two-wheeltractor or four-wheel tractor. For two-wheel tractors they are usually rigidly fixed and powered via couplings to the tractors' transmission. For four-wheel tractors they are usually attached by means of a three-pointhitch and driven by a power take-off (PTO). Drawbar hookup is also still commonly used worldwide. Draft-animal power is sometimes still used today, being somewhat common in developing nations although rare in more industrialized economies.

In the experiment the soil was cultivated using a Kongskilde Germinator Pro, which utilizes a front leveling board consisting of a series of flat tines (Kongskilde, 2015). These leveling tines are the first soil treatment (not counting the tines that loosen the soil in the tractor tracks) and eliminate unevenness in the topsoil. The tips of the tines are flat with a width of 4.5 cm and with a 6 cm gap between each tine. In the experiment we analyzed the effect of the leveling tines at two cultivation depths using 3D scans of the soil surface. The experiment was a split-plot design with the intensity of the leveling tines as the whole plot factor and the depth as a sub plot factor. The cultivator leveling tines were adjusted to 5 different settings ranging from no interaction with the soil to maximum possible extension of the tines. The cultivator had two working sections, which were used to process the soil at 2 different cultivation depths in one pull. The cultivator was pulled at 10 km/h and the working sections were set to a depth of 5 and 8 cm. The experiment had 4 blocks/replications, within which the leveling tine settings were randomized. Each plot in the experiment was 3 by 20 m and the plots were laid out in a grid 4 plots wide and 5 long. The experiment was done in an area of the field with a homogeneous soil texture. Along the cultivation direction the plots were separated by enough space to ensure that the tractor could accelerate to the required speed.

2. RESEARCH OBJECTIVES

- To evaluate Structural Analysis
- To find out Deformation Analysis
- To evaluate Modal Analysis
- To evaluate soil test

3. Design for Manufacturing and Assembly (DFMA)

Design procedure

Before we proceed to the process of manufacturing, it's necessary to have some knowledge about the project design essential to design the project before starting the manufacturing. Maximum cost of producing a part of product is established originally by the designer.

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Design procedure:

When a new product or their elements are to be designed, a designer may proceed as follows:

- Make a detailed statement of the problems completely; it should be as clear as possible & also of the purpose
- for which the machine is to be designed.
- Make selection of the possible mechanism which will give the desire motion.
- Determine the forces acting on it and energy transmitted by each element of the machine
- Select the material best suited for each element of the machine.
- Determine the allowable or design stress considering all the factors that affect the strength of the machine part
- Identify the importance and necessary and application of the machine
- Problems with existing requirement of the machine productivity and demand.

Failures in blade

Dimensions of Existing Blade

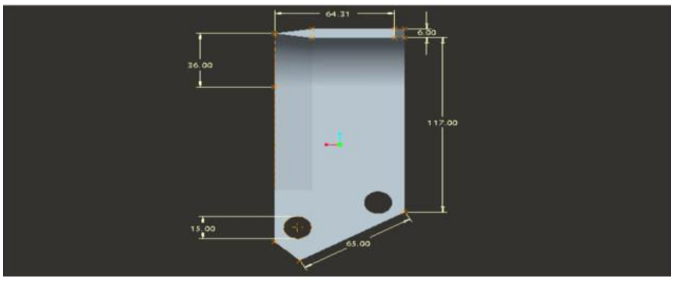
Generally blade materials are classified into three types as given below,

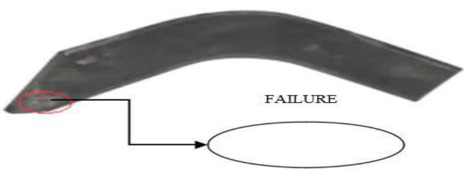
- High carbon steel,
- Cast iron and
- Mild steel

Types of soil used for testing

Black soil with clay mix

Black soil





Black 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
= 600 N

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

Black 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
= 563 N

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

6. DESIGN PROCEDURE, MATERIAL SELECTION & MANUFACTURING

The basic question is how do we go about selecting a material for a given part? This may seem like a very complicated process until we realize than we are often restrained by choices we have already made. For example, if different parts have to interact then material choice becomes limited. When we talk about choosing materials for a component, we take into account many different factors. These factors can be broken down into the following areas. Material Properties. The expected level of performance from the material Cost and Availability Material must be priced appropriately (not cheap but right) Material must be available (better to have multiple sources) Processing Must consider how to make the part, for example: Casting Machining Welding Environment The effect that the service environment has on the part.
The effect the part has on the environment. The effect that processing has on the environment. Now clearly these issues are inter-linked in some fashion. For example, cost is a direct result of how difficult a material is to obtain and to machine. And the effect of the environment on the material is clearly related to the material properties. So if we really want to use a novel or unusual material, the choice must be made early in the design process. Then we can do the detailed design work using the correct material properties.

Material Properties As mechanical engineers we are most concerned with characteristics such as:

- **Brittleness:**

Ability of a material to break or shatter without significant deformation when under stress; opposite of plasticity

- **Bulk modulus:**

Ratio of pressure to volumetric compression (GPa)

- **Compressive strength:**

Maximum stress a material can withstand before compressive failure (MPa)

- **Creep:**

The slow and gradual deformation of an object with respect to time

- **Ductility:**

Ability of a material to deform under tensile load (% elongation)

- **Durability:**

Ability to withstand wear, pressure, or damage; hard-wearing.

- **Elasticity:**

Ability of a body to resist a distorting influence or stress and to return to its original size and shape when the stress is removed

- **Fatigue limit:**

Maximum stress a material can withstand under repeated loading (MPa)

- **Flexibility:**

Ability of an object to bend or deform in response to an applied force; pliability;complementary to stiffness

- **Fracture toughness:**

Ability of a material containing a crack to resist fracture (J/m^2)

- **Hardness:**

Ability to withstand surface indentation and scratching (e.g. Brinnell hardness number)

- **Plasticity:**

Ability of a material to undergo irreversible or permanent deformations without breaking or rupturing; opposite of brittleness

- **Poisson's ratio:**

Ratio of lateral strain to axial strain (no units)

- **Resilience:**

Ability of a material to absorb energy when it is deformed elastically (MPa); combination of strength and elasticity

- **Shear modulus:**

Ratio of shear stress to shear strain (MPa)

- **Shear strength:**

Maximum shear stress a material can withstand

- **Specific modulus:**

Modulus per unit volume (MPa/m^3)

- **Specific strength:**

Strength per unit density (Nm/kg)

- **Specific weight:**

Weight per unit volume (N/m^3)

- **Stiffness:**

Ability of an object to resist deformation in response to an applied force; rigidity; complementary to flexibility

- **Tensile strength:**

Maximum tensile stress of a material can withstand before failure (MPa)

- **Toughness:**

Ability of a material to absorb energy (or withstand shock) and plastically deform without fracturing (or rupturing); a material's resistance to fracture when stressed; combination of strength and plasticity

- **Viscosity:**

A fluid's resistance to gradual deformation by tensile or shear stress; thickness

- **Yield strength**:

The stress at which a material starts to yield plastically (MPa)

- **Young's modulus:**

Ratio of linear stress to linear strain (MPa)

Dimensions of new blade

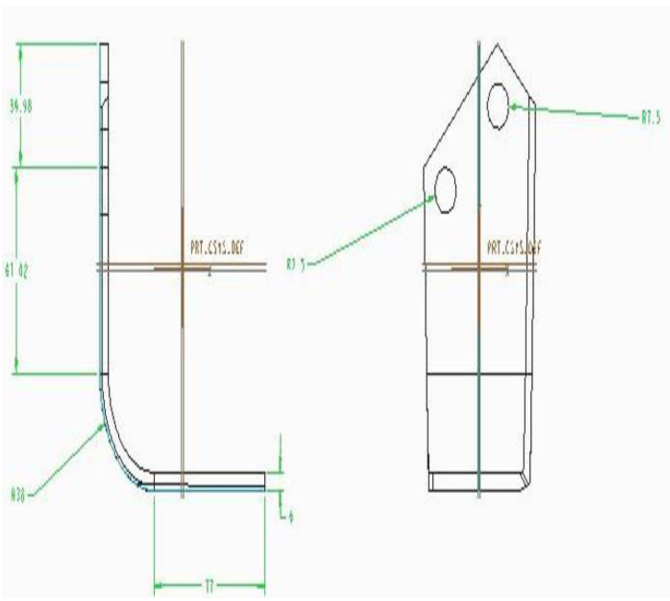


Fig. Rotavator blade of Radius 38

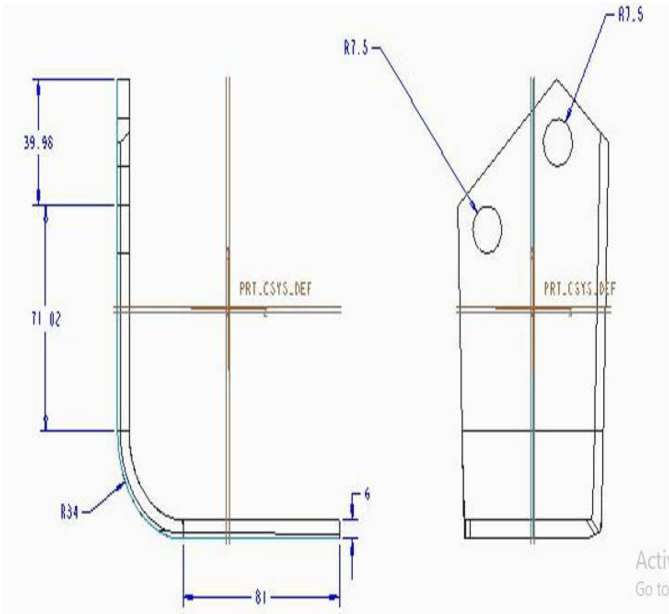


Fig. Rotavator blade of Radius 34

3 D Model

Manufacturing

Bending

In applied mechanics, bending (also known as flexure) characterizes the behavior of a slender structural element subjected to an external load applied perpendicularly to a longitudinal axis of the element.

The structural element is assumed to be such that at least one of its dimensions is a small fraction, typically 1/10 or less, of the other two. When the length is considerably longer than the width and the thickness, the element is called a beam. For example, a closet rod sagging under the weight of clothes on clothes hangers is an example of a beam experiencing bending. On the other hand, a shell is a structure of any geometric form where the length and the width are of the same order of magnitude but the thickness of the structure (known as the 'wall') is considerably smaller. A large diameter, but thin-walled, short tube supported at its ends and loaded laterally is an example of a shell experiencing bending.

In the absence of a qualifier, the term bending is ambiguous because bending can occur locally in all objects. Therefore, to make the usage of the term more precise, engineers refer to a specific object such as; the bending of rods, the bending of beams, the bending of plates, the bending of shells and soon.

Euler–Bernoulli bending theory

In the Euler–Bernoulli theory of slender beams, a major assumption is that 'plane sections remain plane'. In other words, any deformation due to shear across the section is not accounted for (no shear deformation). Also, this linear distribution is only applicable if the maximum stress is less than the yield stress of the material. For stresses that exceed yield, refer to article plastic bending. At yield, the maximum stress experienced in the section (at the furthest points from the neutral axis of the beam) is defined as the flexural strength.

Sharpening of rotavators blades

A grinding machine, often shortened to grinder, is any of various power tools or machine tools used for grinding, which is a type of machining using an abrasive wheel as the cutting tool. Each grain of abrasive on the wheel's surface cuts a small chip from the work piece via shear deformation.

Grinding is used to finish work pieces that must show high surface quality (e.g., low surface roughness) and high accuracy of shape and dimension. As the accuracy in dimensions in grinding is of the order of 0.000025 mm, in most applications it tends to be a finishing operation and removes comparatively little metal, about 0.25 to 0.50 mm depth. However, there are some roughing applications in which grinding removes high volumes of metal quite rapidly. Thus, grinding is a diverse field Surface grinder, which has a head that is lowered to a work piece, which is moved back and forth under the grinding wheel on a table that typically has a controllable permanent magnet (magnetic chuck) for use with magnetic stock (especially ferrous stock) but can have a vacuum chuck or other fixturing means. The most common surface grinders have a grinding wheel rotating on a horizontal axis cutting around the circumference of the grinding wheel. Rotary surface grinders, commonly known as "underneath. This type of machine removes large amounts of material and grinds flat surfaces with noted spiral grind marks. It can also be used to make and sharpen metal stamping die sets, flat shear Blanchard" style grinders, have a grinding head which rotates the grinding wheel on a vertical axis cutting on the end face of the grinding wheel, while a table rotates the work piece in the opposite direction blades, fixture bases or any flat and parallel surfaces. Surface grinders can be manually operated or have CNC controls.

FINITE ELEMENT ANALYSIS

Introduction to finite element method

The finite element method is a powerful tool for the numerical procedure to obtain solutions to many of the problems encountered in engineering analysis. Structural, thermal and heat transfer, fluid dynamics, fatigue related problems, electric and magnetic fields, the concepts of finite element methods can be utilized to solve these engineering problems. In this method of analysis, a complex region defining a continuum is discretized into simple geometric shapes called finite elements the domain over which the analysis is studied is divided into a number of finite elements. The material properties and the governing relationship are considered over these elements and expressed in terms of unknown values at element corner .An assembly process, duly considering the loading and constraint, results in set of equation. Solution of these equations gives the approximate behavior of the continuum.

Steps involved in FEM

The different steps involved in the Finite element method are as follows:

Step1: Discretization of continuum

The first step in any FEM is to divide the given continuum in to smaller region called element. The type of elements has to be taken depending on type of analysis carried out like one dimensional, two dimensional, and three dimensional.

Step 2: Selection of displacement model

For the continuum discretized in to number of element, displacement variation over each of these element is unknown .Hence a displacement function is assumed for each of the element ,this function is called displacement model.

Step 3: Derivation of elemental stiffness matrix

The equilibrium equation for an element is determined by using the principal of minimum potential energy.

Step 4: Assembly of the element stiffness matrix

This step involves determining of global stiffness matrix. This is done by using the compatibility conditions at the nodes. The displacement of a particular node must be the same for every element connected to it. The externally applied loads must also be balanced by the forces on the elements at these nodes.

Step 5: Apply the boundary conditions

To obtain a unique solution of the problem, some displacement constraints (i.e. boundary conditions) and loading conditions must be prescribed at some of the nodes. This may be of the following forms

1) Elimination method
2) Penalty method
3) Multi constraint method

These boundary conditions are incorporated into the system of linear algebraic equations, which can then be solved to obtain a unique solution for the displacements at each node.

Step 6: To find unknown displacement, strain and stress

After solving the global equations, displacements at all the nodal points are determined. From the displacement values, the element strains can be obtained from the stress-strains relations. In FE formulation only the displacements are the independent variables, that is, forces, strains and stresses are obtained from the displacements.

Convergence study

Convergence is a process of refining mesh, as the mesh is refined, the finite element solution approach the analytical solution of the mathematical model. This attribute is obviously necessary to increase the confidence in FEM results from the standpoint of mathematics.

The fundamental premise of FEM is that as number of elements (mesh density) is increased, the solution gets closer and closure, however solution time and compute resources required also increases dramatically as we increases the number of elements to the true solution. The objective of analysis decides how to mesh the given geometry, if we are interested in getting accurate stress; a fine mesh is needed, omitting geometric details at the location we needed. If we are interested in deflection results, relatively course mesh is sufficient.

There are two convergence studies

- h-convergence study
- p-convergence study

h- Convergence study is done by increasing number of elements which can be done by making mesh size finer, and it is important to maintain continuity in meshing and element check should be done for aspect ratio, warping angle, skew ratio and others The elements must have enough approximation power to capture the analytical solution in the limit of a mesh refinement process.

p- Convergence study is done by increasing number of nodes. Meshing of a given model will be done depending on geometry of the model, it is better to have more degrees of freedom hence more number of elements so that results obtained will be closure to analytical results. In two bay panel analyses, crack region is meshed with more number of elements when compared with other parts of fuselage, for obtaining a converged solution which in turn a better solution.

Structural analysis

Structural analysis is probably the most common application of the finite element method. The term structural implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

Static Analysis:
Static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time-varying loads. A static analysis can, however, include steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads (such as the static equivalent wind and seismic loads commonly defined in many building codes). Static analysis involves both linear and nonlinear analyses. Nonlinearities can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep. The FE analysis used for the major part of this work is static analysis which involves both linear and nonlinear structural analysis. Hence more prominence is imparted on Linear and nonlinear analysis in further sections.

The procedure for a model analysis consists of four main steps:

1. Build the model.
2. Apply loads and obtain the solution.
3. Expand the modes.

Review the results

The Guidelines of DFA
The general guidelines of DFA that attempt to consolidate manufacturing knowledge and present them to the designer in the form of simple rules to be followed when creating a design. The process of assembly can be divided naturally into two separate areas, handling assembly which means acquiring, orienting and moving the part. The secondly area is insertion and fastening assembly which means mating a part to another part group or group of part.

A DFA guideline
A DFA guideline is given below.

a) Aim for simplicity
Minimize part numbers, part variety, assembly surfaces; simplify assembly sequences, component handling and insertion, for faster and more reliable assembly

b) Standardize

Standardize on material usage, components, and aim for as much off-the-shelf component as possible to allow improved inventory management, reduced tooling, and the benefits of mass production even at low volumes

c) Rationalize product design

Standardize on materials, components, and subassemblies throughout product families to increase economies of scale and reduce equipment and tooling costs. Employ modularity to allow variety to be introduced late in the assembly sequence and simplify JIT production

.

Design Guidelines for Part Handling

a) Design parts that have end-to-end symmetry and rotational symmetry about the axis of insertion. If not try to design parts having the maximum possible symmetry.

b) Design parts that, in those instances where the part cannot be made symmetric, are obviously asymmetric

c) Provide features that will prevent jamming of parts that tend to nest or stack when stored in bulk

d) Avoid features that will allow tangling of parts when stored in bulk

e) Avoid parts that stick together or are slippery, delicate, flexible, very small or very large or that are hazardous to the handler.

5.DFA Process

Once parts are manufactured, they need to be assembled into subassemblies and products. The assembly process consists of two operations, handling followed by insertion. The DFA is a two steps process (Shih-Wen Hsiao, 2001): -

a) Evaluate the assimilability of the individual parts whether they are easy to be assembled or not.

b) Evaluate the theoretical minimum number pf parts that should be in the product.

In step 1 the designer uses some established rating system to evaluate each individual part with respect to its:

Grasp ability: To check that the part is easy to be graspedor not during the period

Orient ability: To check if the part is easy to be oriented or not when it is being assembled

Transfer ability: To check whether the part is easy to be transferred to the work position or not.

Insert ability: To check if the part is easy to be inserted into the correct position or not when it is being assembled.

Secure ability: To check whether the part or the product is secure or not after the part has been assembled.

6. Design for Manufacture Guidelines

Design for manufacture or 'Manufacturability' concerns the cost and difficulty of making the product. At a simple level manufacturability, design for manufacture (DFM) at a part level, involves detail such as ensuring that where a pin is to be assembled into a hole that is only slightly larger in diameter, then it is much easier if the end of the pin or the entry to the hole (or both) are chamfered or finished with a radius. This applies whether the assembly is carried out manually or automatically. This is a fine-tuning process carried out once the product form has been decided. Indeed, automatic assembly would be very difficult / expensive if neither component of a close-fitting pair was chamfered. At a more complex level, product DFM tackles the more fundamental problem of deciding on the product structure and form. Design for assembly (DFA) is an important part of this. Some 'manufacturability' software is available, relating both to manufacture and to assembly. This section starts with some simple but important principles of manufacturability (David Grieve, 2003).

General Principles of manufacturability

a) Reducing the number of parts frequently reduces the weight of the product which is advantageous. Eliminating the need for a separate housing or enclosure can be beneficial. One method that has been successful in many cases is to replace a fabricated sub - assembly, which may utilize many fasteners, with a single casting. In some cases, this has given weight savings as well as cost savings.

b) A robust design is one that has been optimized so that variations from the nominal specification cause a minimum loss of quality. To determine these optimal values will normally necessitate experimental work on a prototype.

c)The assembly of products made up from 4 to 8 modules with 4 to 12 parts per module can usually be automated most readily. It is also helpful to maintain a generic configuration as far as possible into the assembly process and install specialist modules as late as possible.

d)Assembly from 1 direction is beneficial whether manual or automated assembly is to be used. Generally assembling top down, along the z axis, like making a sandwich, is the best solution.

e)Designing so only correct assembly is possible is useful where semi - skilled labor is used and it is also an electric desirable if there are safety considerations if the product were to be incorrectly assembled. Manufacturers of mains powered consumer electrical appliances frequently supply them with a flex having a moulded on supply plug. This minimizes the danger of the consumer incorrectly wiring a plug and suffering shock.

f) Using standard sizes will reduce costs directly and reduced delivery times will indirectly give savings. This will also reduce the cost of repairs and maintenance.

g)Fasteners can add significantly to costs, frequently the cost of installation will greatly exceed purchase cost. If fasteners must be used then minimize the sizes and types. Small fasteners and parts should be avoided.

h) Mechanical adjustments add to the cost of fabrication and cause assembly, test and reliability problems. The need for adjustments can often be negated by using dowel pins, detents, notches or spring mounted components. If a designer understands why an adjustment has been recommended, a way of eliminating or reducing the need can often be found.

i) Wiring and other flexible components are difficult to handle during assembly. The use of rigid or process applied gaskets, circuit boards rather than electric wiring helps to minimize this problem.

j) Dimensioning from 1 datum simplifies gauging and minimizes errors in tolerances. Dimensions should also be measured from points or surfaces on a component, not points in space.

k) Using large radii is generally good practice for most processes, casting, forming etc. as material flow is facilitated - and stress concentration is reduced. However sharp corners are inevitable with some processes, e.g. 2 intersecting machined surfaces and punch face - wall edge in a powdered metal component. There is no cost advantage in preventing these sharp corners.

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Linear Static Analysis

In linear analysis, the behavior of the structure is assumed to be completely reversible; that is, the body returns to its original undeformed state upon the removal of applied loads and solutions for various load cases can be superimposed.

The assumptions in linear analysis are:

1) Displacements are assumed to be linearly dependent on the applied load.
2) A linear relationship is assumed between stress and strain.
3) Changes in geometry due to displacement are assumed to be small and hence ignored.
4) Loading sequence is not important and the final state is not affected by the load history. The load is applied in one go with no iterations.

Non Linear static analysis

In many engineering problems, the behavior of the structure may depend on the load history or may result in large deformations beyond the elastic limit. The assumptions/ features in nonlinear analysis are:

1) The load-displacement relationships are usually nonlinear.
2) In problems involving material non-linearity, the stress-strain relationship is a nonlinear function of stress, strain, and/or time.
3) Displacements may not be small; hence an updated reference state may be needed.
4) The behavior of the structure may depend on the load history; hence the load may have to be applied in small increments with iterations performed to ensure that equilibrium is satisfied at every load increment.

From the above assumptions, the finite element equilibrium equation for static analysis is:

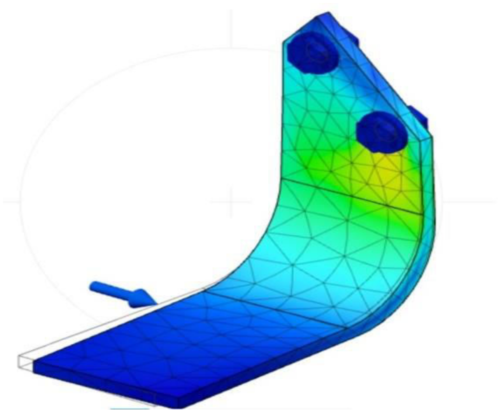
$$[K]\{U\} = [F]$$

Where $[K]$ is the linear elastic stiffness. When the above assumptions are not valid, one performs nonlinear analysis.

10.FEA RESULTS

Analysing the Blade

Existing and new materials are analysed in the AUTODESK FUSION 360 and the results are compared and graph is plotted.



A. Deflection (mm)

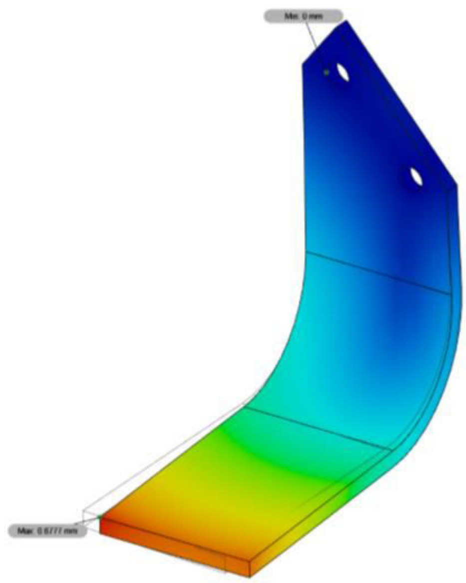
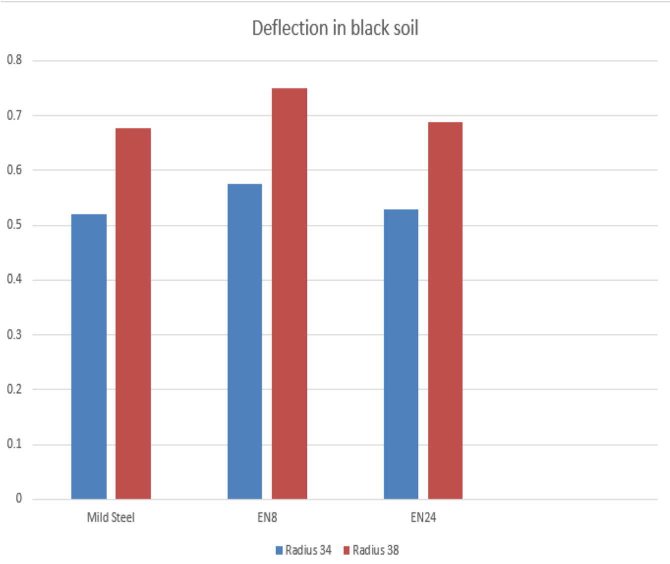


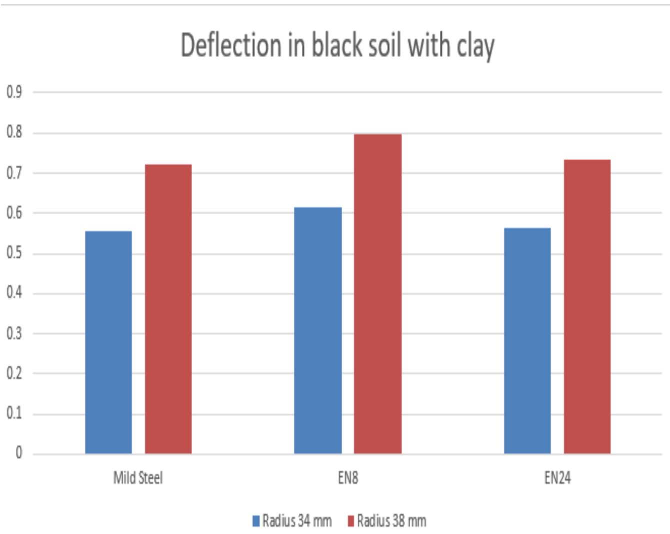
Fig. Deflection

	Radius 34		Radius 38	
Material	Black Soil	Black soil with clay	Black Soil	Black soil with clay
Mild Steel	0.5209	0.5552	0.6777	0.7223
EN8	0.5758	0.6136	0.7491	0.7983
EN24	0.5285	0.5632	0.6876	0.7328

Table : deflectiom table



Graph: Deflection in black soil



Graph: Deflection in black with clay

B. Stress (MPa)

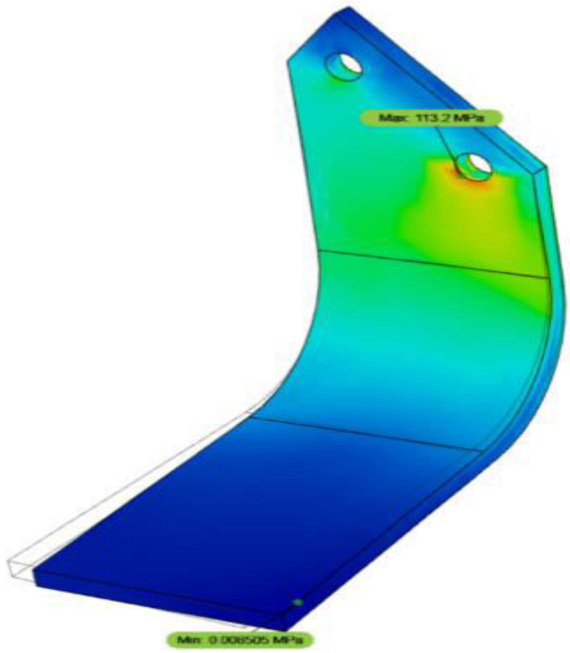
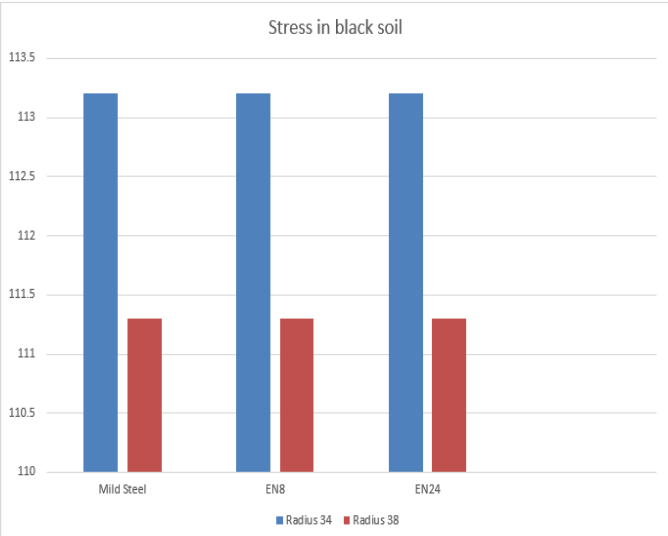


Table Stress(Mpa)

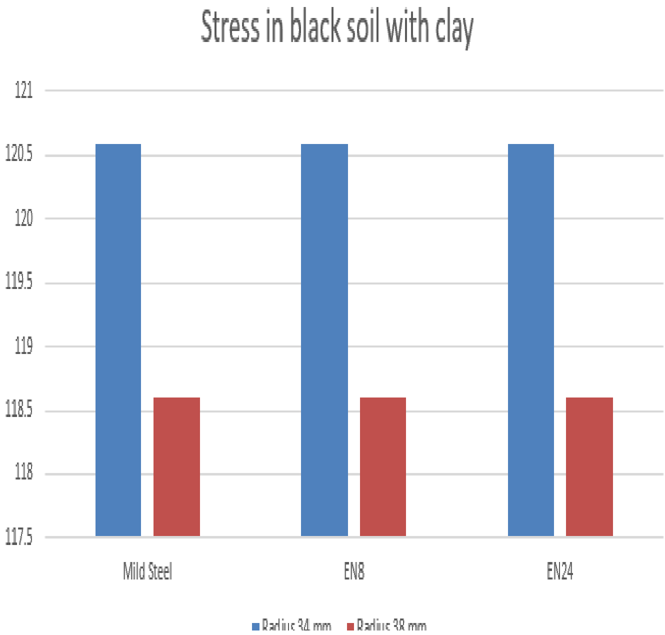
	Radius 34		Radius 38	
Material	Black Soil	Black soil with clay	Black Soil	Black soil with clay
Mild Steel	113.2	120.6	111.3	118.6
EN8	113.2	120.6	111.3	118.6
EN24	113.2	120.6	111.3	118.6

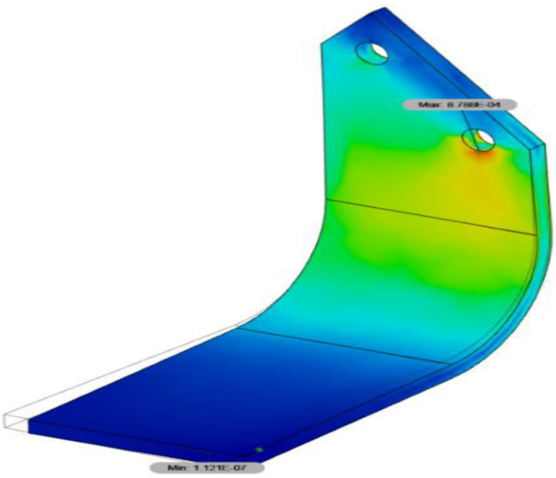
Table . Stress (MPa)

Graph Stress in Black Soil



Graph Stress in Black Soil



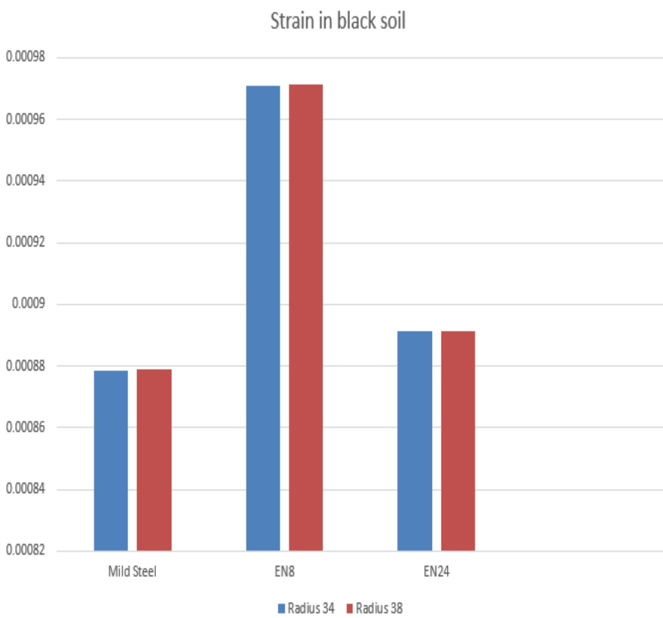


C. Strain

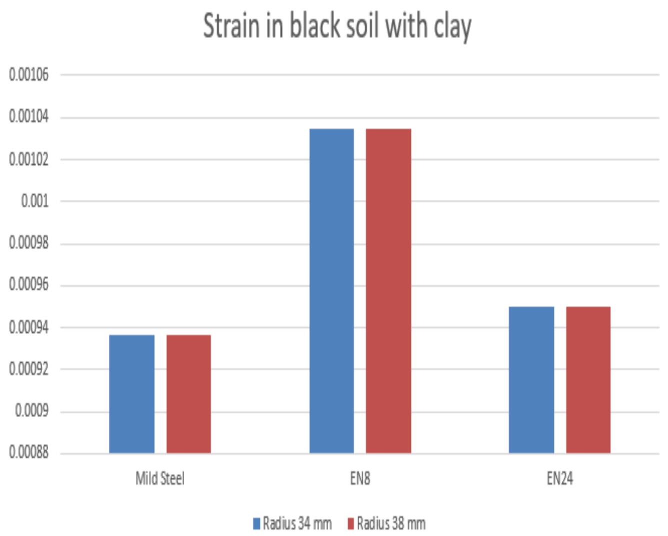
Table Strain

	Radius 34		Radius 38	
Material	Black Soil	Black soil with clay	Black Soil	Black soil with clay
Mild Steel	0.0008784	0.0009362	0.0008788	0.0009366
EN8	0.0009709	0.0010350	0.0009713	0.0010350
EN24	0.0008912	0.0009497	0.0008915	0.0009501

Graph Strain in black soil



Graph Strain in black soil with clay



11.CONCLUSION

- 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.
- Deflection 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. Also we can increase the wear resistance of the blades.

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