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Modeling and FEM Analysis of Shovel of 5-Tyne Duck Foot Cultivator

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Abstract: *For soil preparation Cultivator is important agricultural equipment. As an important agriculture equipment for soil preparation cultivator is used in which stress are form due to contact with soil where tyne and shovel works as actual member of cultivator which is direct contact with soil. We can reduce the stress from changing the design of tine or shovel of cultivator. The main objective of this analysis is to analyze the forces developed on shovel during operation. To analyze this Shovel using FEM, firstly a proper CAD model has been developed using CATIA cad software. Then by using ANSYs software FEM analysis have been done to determine the stresses.*

Keywords: Duck Foot, Cultivator, Tyne, Shovel

I. Introduction

In last few decades we all witnessed the development in each and every field. Also in the field of agricultural also we had seen remarkable development, big farmers are now a day's using cultivator, harvester, tractor, advance machine tools and advance farm equipments, but in the country like India where more than 80% of farmers are small and marginal and they are still doing farming by traditional method only they are also in need of improved agricultural tools that may be hand driven or bullock driven.

Tractor operated 5 tyne duck foot cultivator is one of recently popularized implement being used by the farmers for primary tillage operation to plough the field. Cultivators are used to break up, stir and pulverized the soil. They are pulled behind tractors using either a three-point linkage or a tractor drawbar. Cultivators are generally used before plough to till the soil and prepare it for the dispersing of seeds and after the crops are sowed. They can provide other functions, such as removing and destroying weeds, as well as fertilizing the soil and covering seeds with soil.

In market various companies are available that manufacture different type of cultivators according to their suitability to application and wide range of power to drive it.

To execute this study, Raj 5 Tyne Duck Foot cultivator is taken into consideration to check its maximum cutting depth and calculate the stresses on tyne during on field operation.

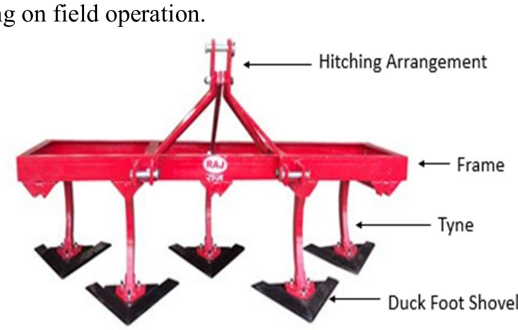

Figure: 5-Tyne Duck Foot Cultivator

The duck foot cultivator consists of a box type steel rectangular frame, rigid tynes and sweeps. The sweeps are triangular in shape similar to foot of duck, hence called duck foot cultivator. The sweeps are made from En45 material and joined to tynes with fasteners, which makes them replaceable after being worn out or becoming dull. The tynes are made of mild steel flat and forged to shape. The equipment is mounted to the tractor with three point hitch and operation in the field is controlled through hydraulic system of the tractor. The implement is mostly used for shallow ploughing and in hard soils. The equipment is generally available in two sizes depending on the number of sweeps as five or seven.

1.1 Types of Cultivator

Cultivators groups such as small, farm, field and row types can be described as

1. **Small Cultivators:** It is used for gardening, powered by small motors, and controlled by an operator walking behind. Garden cultivators can be used to mix soils with manures and fertilizers in preparation for planting.
2. **Farm Cultivators:** A tractor-mounted tiller Cultivators are pulled by tractors and can vary greatly in size and shape, from 6 feet (2 m) to 80 feet (24 m) wide. Many are equipped with hydraulic wings that fold up to make road travel easier and safer.
3. **Field Cultivator:** Field cultivators are used to complete tillage operations in many types of arable crops fields. The main function of the field cultivator is to prepare a proper seedbed for the crop to be planted into, to bury crop residue in the soil (helping to warm the soil before planting), to control weeds, and to mix and incorporate the soil to ensure the growing crop has enough water and nutrients to grow well during the growing season.
4. **Row Crop Cultivator:** The main function of the row crop cultivator is weed control between the rows of an established crop.

II. Literature Review

The study of various researchers has been carried in detail under the literature review. By conducting literature review it has been observed that different researchers had analyzed different implements like subsoiler, rotary tiller (rotavator), mould board plough, sweep cultivator (duck foot cultivator) etc. It is presented as under

[1] Manikandan, G. et al. (2021), had studied the draft requirement of five tyne duck foot plough in clay soil for different soil moisture content, depth of operation and forward speed of tractor using a specially designed three-point hitch dynamometer. The designed dynamometer was matched with the tractors having category II or III hitch systems. The investigation was carried out at that three levels soil moisture content (10-13%, 14-16% and 17-20%), at three different depth of operation (15, 20 and 25 cm) and three levels of the forward speed of tractor (3, 5 and 7 km h-1). The designed dynamometer performed well in all the levels of the experiment. The results showed that draft force required for five tyne duck foot plough was increased (408 kg) with an increase in soil moisture content (17-20%), depth of operation (25 cm) and forward speed of tractor (7 km/h). The suitable sweep, the forward speed of operation, depth of operation and soil moisture content that influenced the draft force and energy consumption for tillage operation of duck foot type plough were identified and developed duck foot plough was better coverage with better soil operation.

[2] Mr. R.L. Raper (2005), administered a study on force requirements and soil disruption of straight and bent leg subsoilers for conservation tillage systems. to help in choosing the simplest shank for strip-tillage systems, comparisons among several shanks commonly used to provide in-row subsoiling before planting in conservation systems were made. it's observed that the bent leg shanks had low draft requirements as compared to the straight shanks for both soil types

[3] Mehmet Topakci. et al. (2010), focused on obtaining optimum geometry parameters of a subsoiler tine by using computer aided engineering (CAE) applications. A field experiment was conducted to determine draft force of the subsoiler. The results from the experimental study were used in the finite element analysis (FEA) to simulate stress distributions on the subsoiler tine.

[4] U. R. Badegaonkar et al. (2010), had investigate the effect of shank geometry on draft requirement under simulated conditions. Experiments were conducted in a soil bin sizing L:W: H as 16.0 : 2.5 : 1.0 m. The shank geometry was varied with respect to bend angle and bend length. Bend angles of 0^0, 15^0, 30^0 and 40^0 and bend lengths of 150, 200 and 250 mm were used in experimentation in the soil bin under uniform conditions, at 50, 100, 150 and 200 mm depth levels. Using the experimental results, the bend angle and bend length were parametrically optimized for the shank of duck foot cultivator. A significant increase in draft was observed for all the shanks with increase in tillage depth. Shank with 300 bend angle and 200 mm bend length gave minimum force at all depth of operation, as compared to other shanks.

[5] According to R. L. Raper and A. K. Sharma (2004), a decent seedbed is usually considered to imply finer particles and greater firmness within the vicinity of seeds. In arid and semi arid areas with high average soil temperature and dry spells, there is a need to break the soil, which becomes very hard. A pointed tool like chisel or bar point are used on country plough

to break soil without inverting or disturbing crop residue, in order to collect and store rain water and reduce wind erosion and evaporation losses. Under such conditions list plough, rigid tine cultivator, duck foot sweeps and other similar equipment are useful and may be operated for one or two passes. One of the important parameters for performance evaluation of these tools is soil disruption. This depends on type of soil, depth, speed of operation and design of tyne on which they are mounted. *[6] Prof. Srinivasan. K and Prof. Viswanath R. P*, researched rotavator blades. The purpose of their research is to design and make the Rotavator Blade have a better life and be more efficient on the field. Therefore, any improvement in the performance of the same field can also increase productivity in the agricultural sector. Within the study they had various kinematic and static analysis statistics on rotavator blades and various soil areas were also analyzed by the appropriate failure model and finally described the effect of flexible analysis of rotavator blades during planting using soil. FEA Abaqus tool.

III. Problem Identification

3.1 Research Gap

After conducting a detailed literature review it is observed that so many authors had carried out FME analysis on tynes and shovels of cultivator. In particular there is very less research done on modification of shovel design especially in case of duck foot cultivator. Shovel design play a vital role in performance of cultivator. It needs to be modified so as to get maximum work done within reasonable time.

3.2 Formulation of Problem

It has been observed that there are frequent complaints from customer performance of 5-tyne duck foot cultivator. Customer experienced that the tillage depth is less as compared to other brand cultivators. They get only 6 to 7 inches depth with the cultivator. Also if they lower the draft position to get more depth sometimes the cultivator gets stuck in soil which leads to tyre slippage and to free the cultivator they have to raise the draft up and again restart the work.

IV. Design Calculations

To calculate the force acting on cultivator a on field demonstration is carried out in which a 45 HP tractor (Mahindra 575 DI) is used. The depth control lever of tractor is set to 2.5 mark position. Also the engine RPM is set at 1000 RPM and gear is engaged at High 1^{st} so as to move tractor with uniform speed. The demo was carried on land measuring 2.4 m x 55 m (132 Sq.m). It took 1 min 5 sec (65 Sec) to cultivate 132 Sq.m land.

Hence, Velocity = Distance/Time
= 55/65
= 0.846 m/s

We know the horse power of tractor For 45hp
Force = Power/Velocity
Power = Force x Velocity
Power = 45hp = 45 x 746 = 33570 W

Pulling Force

Now, Force = Power / Velocity
= 33570 / 0.846
= 39680.85 N (for five tyne)

For one tyne,
Force = 39680.85 / 5
= **7936.17 N** (**Pulling Force**)

Soil Resistive Force

Considering the value of soil resistance pressure **= 0.56 kg/cm²** and also the formula of force exerted by soil on blade directly from the paper Ms. Pooja Raut. et al. (2014)

Soil Resistive Pressure = 0.56 kg/cm^2
Pressure = Force /Area
Area of Duck Foot = 1067.3 cm^2
Soil Resistive Force = 0.56 x 9.81 x 1067.3 = **5863.31 N**

Total Force = Pulling Force + Soil Resistive Force = 7936.17 + 5863.31 = **13941.62 N**
Hence a total force of 13941.62 N is acting on single shovel in contact with soil when cultivator is used on 45 HP tractor.

V. CAD Modeling

Modeling is the important step, this is done by using CAD software. There are a number of software available today for modeling purposes like Auto-CAD, CATIA, ProE, Creo, Solid Edge, Solid Works, etc. Here in this project, CATIA is used to design the parts of the Cultivator.

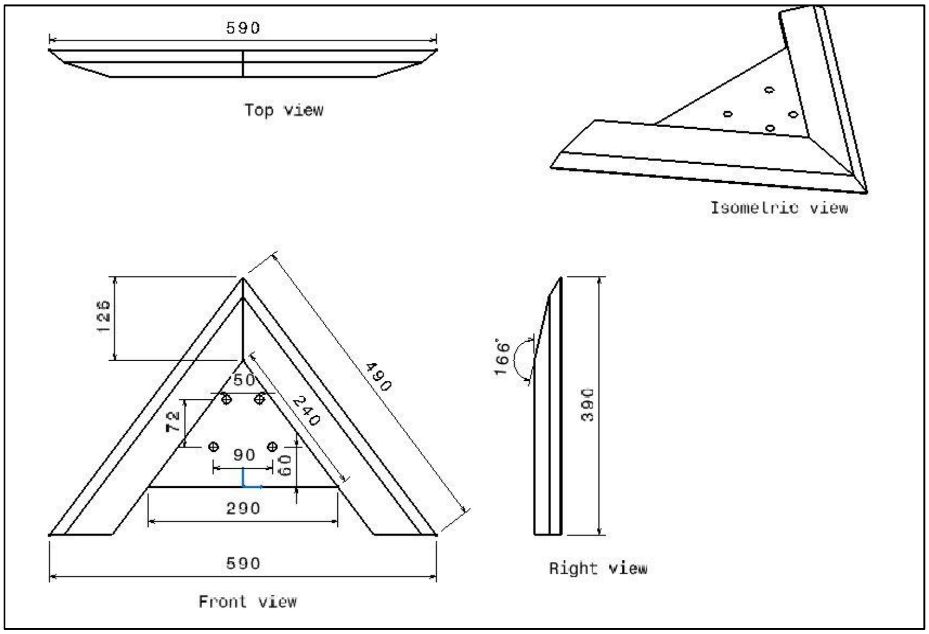

Figure: Modeling of Duck Foot Shovel

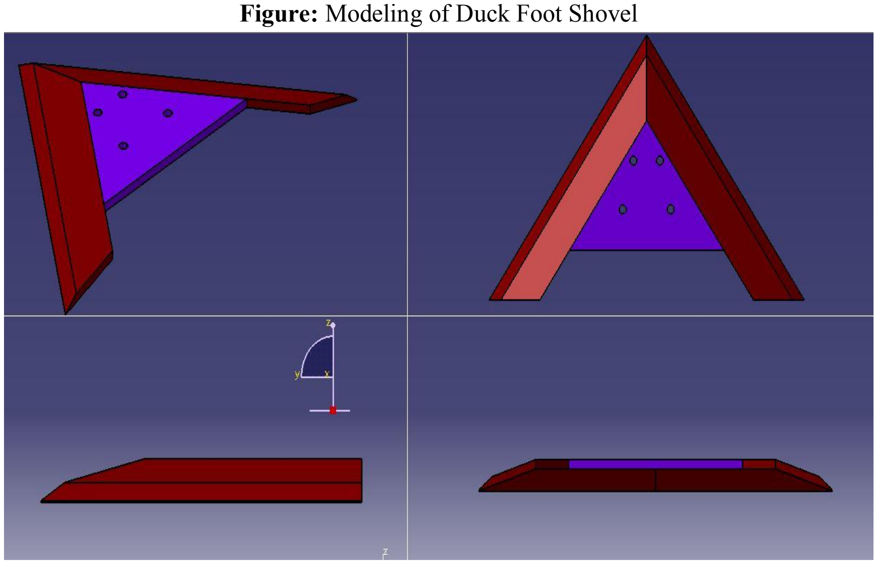

Figure: Solid Modeling Duck Foot Shovel

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VI. FEM Analysis

After finding out the values of forces acting on the shovel in Catia software by assigning the material to the shovel blade of shovel material as EN45, Ansys and Catia model is merged and then performed the FEM analysis.

The first step is to import the geometry in .igs format. Then go in the outline window and specify the proper material in a tab of geometry. Then select mesh and define require parameters such as sizing.

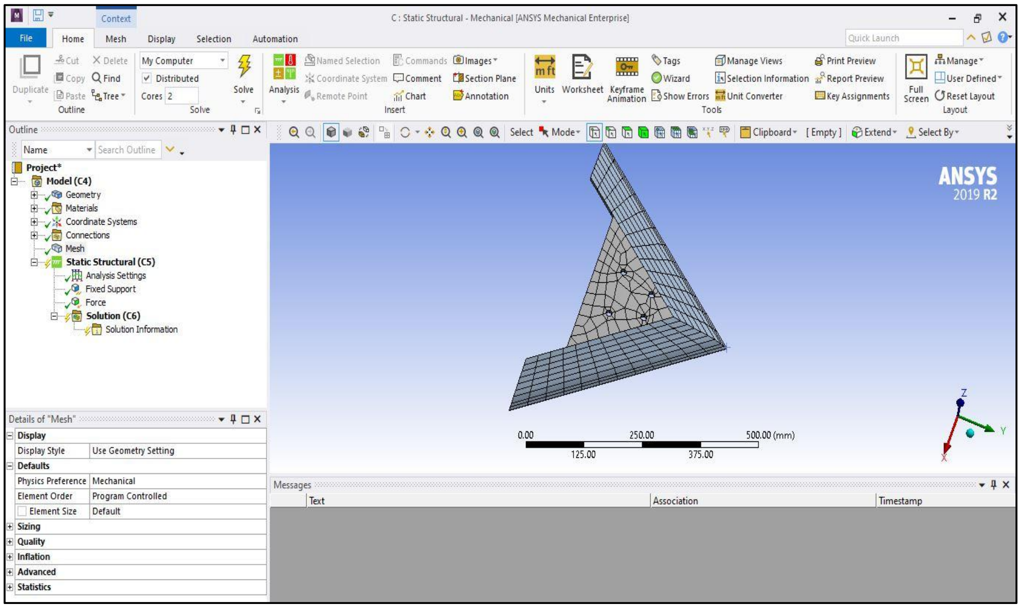

Figure: Meshing of Shovel

After the mesh generation, apply the boundary conditions like fix supports and forces. These conditions defines the parameters within which the geometry will work. The final results depends on this conditions so it necessary to input the boundary conditions correctly.

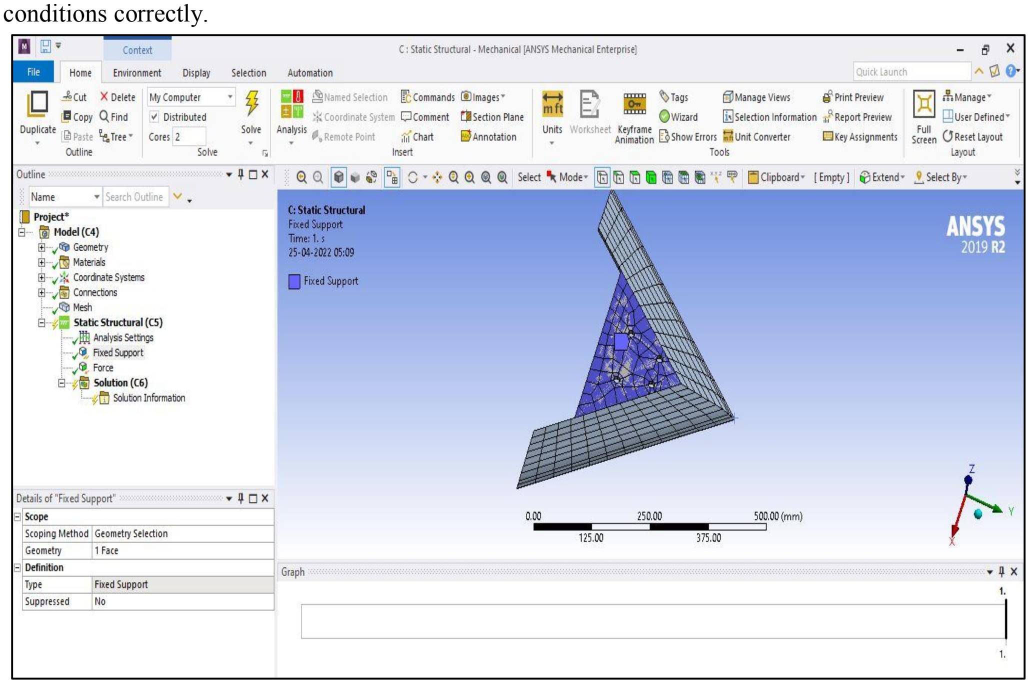

Figure: Applying Fix Support to Shovel

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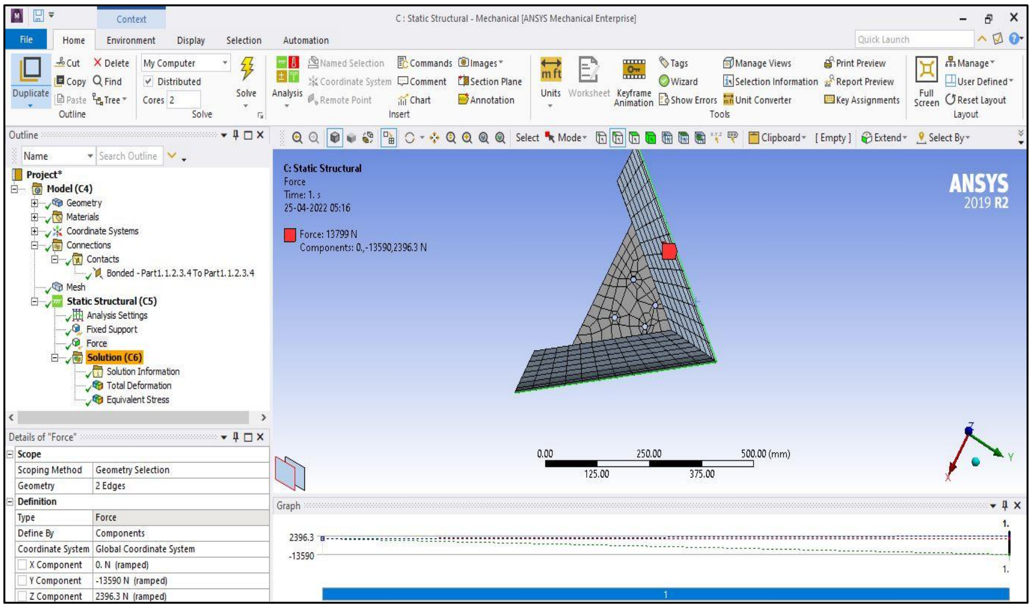

Figure: Applying the Force along the edges of Existing Shovel Blade

After applying boundary conditions, click on solve button. Solver has performed in interaction has provided desired results which are asked.

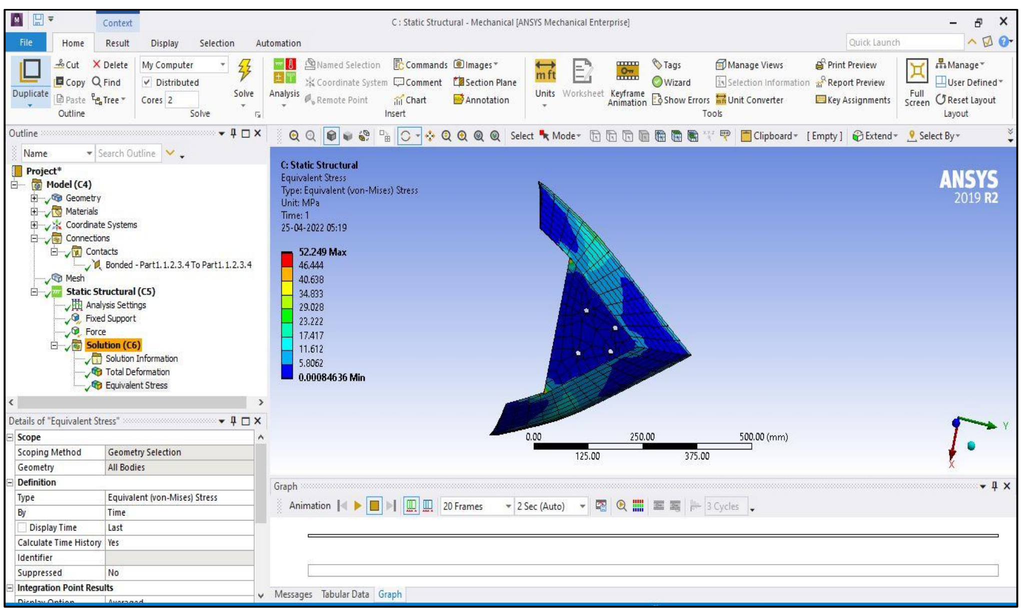

Figure: Maximum Equivalent stress on Shovel Design (52.249 MPa)

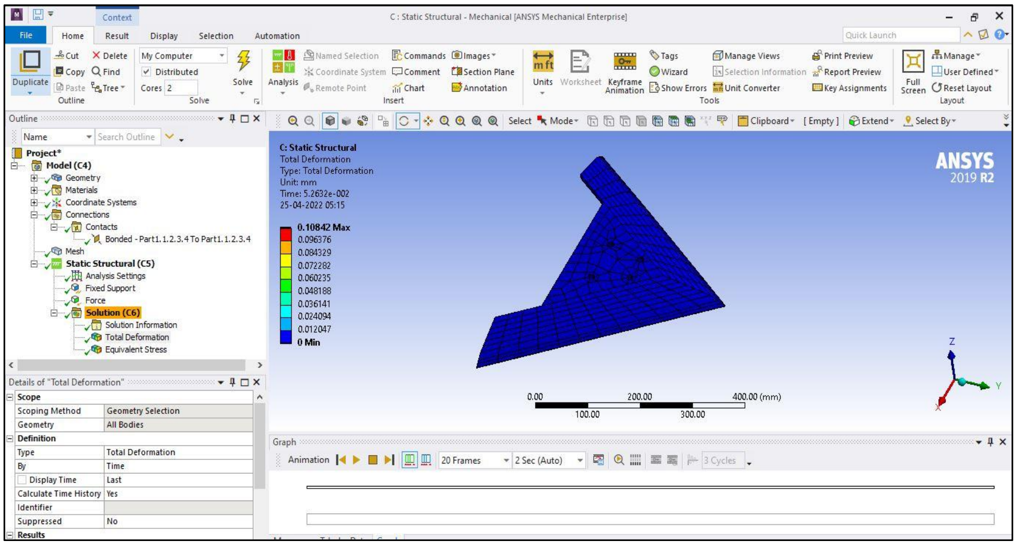

Figure: Maximum Total Deformation of Shovel Design (0.10842 mm)

After the FEM analysis of existing shovel design it is observed that maximum Equivalent stress is 52.249 MPa and maximum Total Deformation is 0.10842 mm.

VIII. Results

From the above analysis, it is found that the total force acting on the shovel is 13941.62 N due to which maximum Equivalent stress of 52.249 MPa and maximum total Deformation is 0.10842 mm is generated in shovel. The stress generated on shovel is far less as compared to tensile stress on EN45 which is 551 MPa hence there is no chance of failure of shovel.

IX. Conclusion

Modern engineering tools like CAD, CAM, FEM, QFD and RP etc are the powerful tools for the manufacturing of improved agricultural tools. By using CAD/CAM technology visualization, coluor selection, checking interference between mating parts of an assembly, modifying and improvement in the models of the components become easy. Also, this technology helpful in preparing detailed component drawings and assembly drawings. By using FEM technology, it is possible to analyze correctly different type of stress which is going too developed on the product with the different loading condition. The Shovel design of duck foot cultivator can be further optimized by making design modifications and reducing its surface area.

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