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Analysis of Chisel Plough Shovel Designs Using Finite Element Methods

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Abstract

The chisel plow is the most common plow due to its ease of operation. It goes deep into the soil to a relatively large depth. It also does not leave large clumps on the soil surface after plowing, as it breaks and loosens the soil without turning it. In this paper, three types of chisel plow tine designs (shovel, reversible, and pointed) were used for simulation to show which design is better. The plow was made in a state company of the automotive industry and equipment /mechanical factory. The input data of the simulation is based on real data field performance parameters which are moisture and soil resistance. CATIA Software was used to design the frame and tine that was used in this research, the simulation method (Finite Element Method) is done using ANSYS 2020. The material added to the tine plow has been unity for the three types. Also, the boundary conditions for the three models were fixed, namely fixing the tine plow stand and applying the load. In this study, three kinds of agricultural chisel plow tine are used in the analysis for designing stress, strain, and deformation. The simulation results showed the shovel tine is safer than the other two types.

1. Introduction

Agriculture and the plough were very important for the civilization for thousands of years [1-3]. The plough is a tool used in farming for initial cultivation of soil in preparation for sowing seed or planting. It has been a basic instrument for most of recorded history, and represents one of the major advances in agriculture [4]. Numerical models can assist shorten and improve the design processes for tillage machines and their components [5, 6]. Pawan Sharma and, Manish Bhargava [7] studied two different kinds of Chisel Plows old and new generation for agricultural use by using FEM and compared the results of the old working model of the Chisel Plow with new design parameters for the maximum weed exclusion efficiency by showing its realistic results from the actual field performance. Mwangi Simon Thuku [8] studied the effect of chisel ploughing tillage implements on physical and mechanical soil properties on maize cropped field. From the study, there is a significant difference in the effects of tillage implements on mechanical and physical soil properties as well as the variation of these properties with depth of tillage. Therefore, proper implement selection and depth optimization are pertinent for optimum energy consumption and favorable for plant growth. Rostislav Chotěborský [9] used high boron steel applicable for agriculture tools such as chisels, rings and other. The experimental process included two dissimilar chemical compositions of high boron cast iron with and without chromium content. The best wear resistant properties are received if the heat treatment and forging was applied. Adam Kesner and et.al [10] determined a model for calculate stress on the segment of frame and chisel of soil tillage machine. The model was based on a DEM (Discrete element method) and FEM (Finite element method) stress analysis. Stress was analyzed where is chisel was mounted (holding plates) and on the chisel shank itself. The biggest benefit of this work was the combined use of DEM and FEM produced data, which allowed for the detection of stresses in the entire frame of the agricultural machine. In this study, three different types of design chisel plow tine were used for simulation in the Ansys program to show which ones have optimum properties in terms of deformation and stresses accompanied by these types.

2. Materials and Methods

2.1. Chisel Plow Components

Figure (1) below shows the main components of the chisel plow with three proposed tines (shares). The modelled chisel tine shapes and dimensions corresponded to real values and full scale.

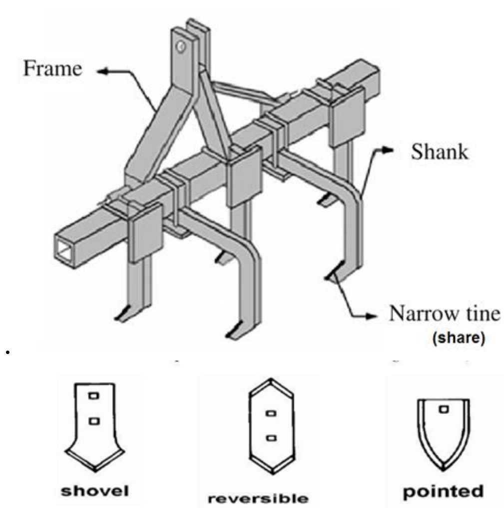


Figure (1): Three types of tine used with chisel plough.

2.2. Materials

The material that used in frame is structural or medium carbon steel, while the tine was made from manganese spring alloy structural steel (65 ┌) according to Gost standard. Table (1) illustrates mechanical, physical and chemical properties of (65 ┌) steel [11.12].

Table (1): Specification of 65 ┌ steel [11].

<table>
<tr><td>Steel name</td><td colspan="5">65 ┌</td></tr>
<tr><td rowspan="6">Steel properties</td><td colspan="3">Tensile Yield Strength</td><td colspan="2">780 MPa</td></tr>
<tr><td colspan="3">Tensile Ultimate Strength</td><td colspan="2">980 MPa</td></tr>
<tr><td colspan="3">Density</td><td colspan="2">7830 Kg/m³</td></tr>
<tr><td colspan="3">Elastic modulus</td><td colspan="2">215 GPa</td></tr>
<tr><td colspan="3">Torsional shear elastic modulus</td><td colspan="2">84 GPa</td></tr>
<tr><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td rowspan="2">Chemical properties</td><td>C%</td><td>Mn%</td><td>Si%</td><td>P%</td><td>S%</td></tr>
<tr><td>0.6-0.7</td><td>0.9-1.2</td><td>0.15-0.4</td><td><0,04</td><td><0,04</td></tr>
</table>

2.3. Soil Parameters

In this research work, the analysis of a chisel plow that was locally made (Alexandria Factory / Babylon). Many variables are taken into consideration to determine the soil resistance which means the force that the plow makes to dig the soil, such as humidity, density, type of soil, and so on. Soil properties were approved, and it is from the Telkef region of Ninawah Governorate and its type is alluvial clay. It was also used at the source [13] shown in Table (2), to find the strength of soil resistance. The soil moisture content, blade depth and width, and various blade angles are the parameters that influence the tillage tool performance [14].

Table (2): Soil specification according to reference [13].

Type of Soil	Moisture Content (%)	Drag force KN	Soil Resistance (KN/m^2)
alluvial clay	11	8.29	923

2.4. Simulation of Chisel Plow

The model construction to simulate a chisel plow using the finite element method needs many methods and parameters. Boundary conditions were utilized to one shank's plow that contain one of the three shares. Also, the amount of compound force taken from soil resistance is applied to the center of the share as in Figure (2).

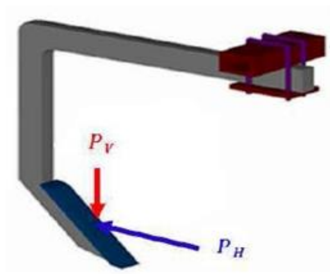


Figure (2): Location of applied force.

The plow model will be discretized into small elements with different shapes such as triangles or circles or rectangular. Every element of the model has controlling differential equations. Different kinds of meshing are used in model of chisel Plow elements. Fine mesh with a good number of relevance is important in the simulation. The chisel plow was drawn by CATIA v 18 as in Figure (3), and then imported to simulate by ANSYS 20 program. The comparison is made after analysis in terms of vonmises, total deformation, and stiffness for each type of blade.

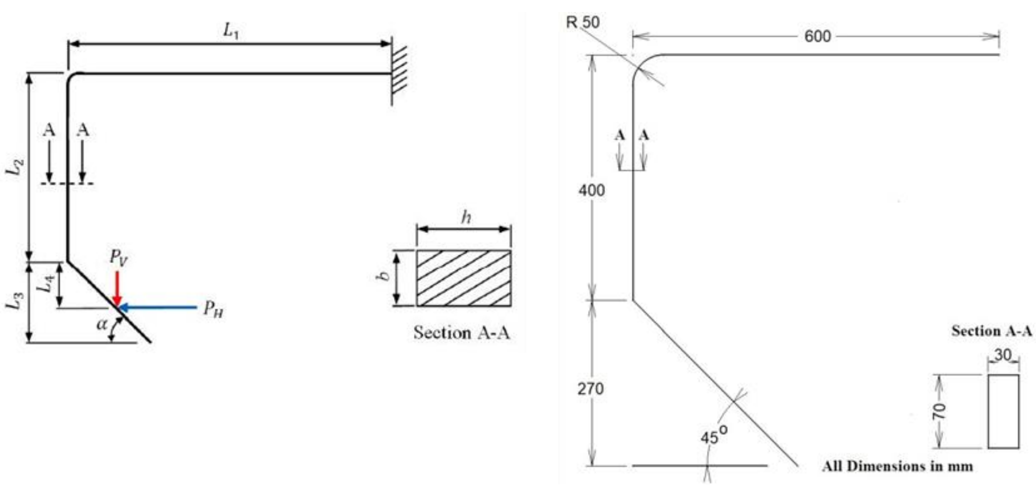
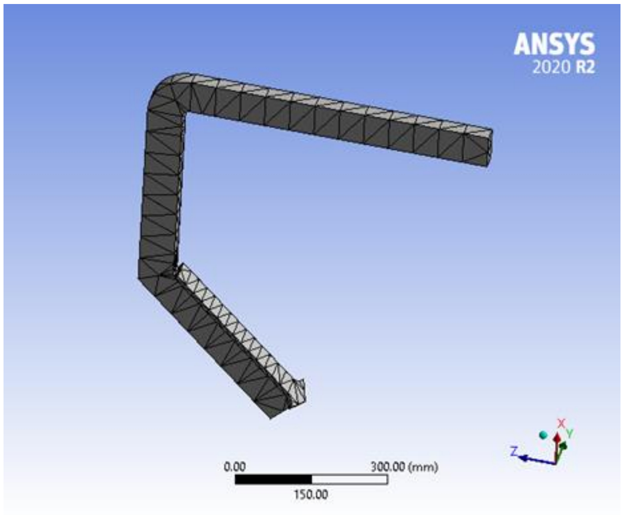
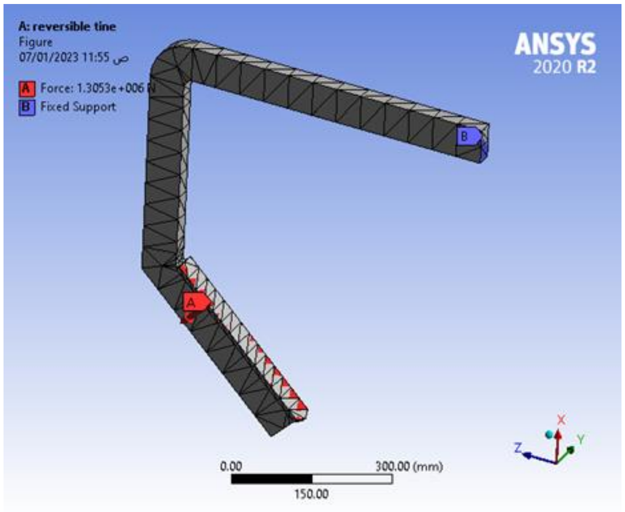


Figure (3): The sketch of chisel plow.

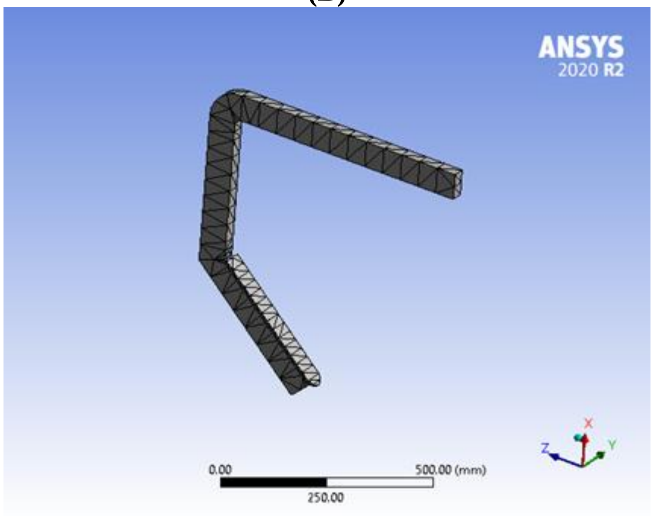
Figure (4) elucidates the meshed model of the three chisel plows using finite element analysis that governs differential equations for each element of the model. A triangular mesh element was used for the solid mesh



(A)



(B)



(C)

Figure (4): Shows the meshed model for three plows: A shovel, B reversable and C pointed.

Table (3) shows the number of elements and nodes for present chisel plows, the relevance number can be used to increase element numbers. Thus, after meshing the chisel plow, load and boundary conditions are applied.

Table (3): The number of elements and nodes for three models.

Shovel tine	Reversible tine	pointed tine
No. of elements 492	No. of elements 478	No. of elements 480
No. of nodes 1231	No. of nodes 1189	No. of nodes 1195

2.5. Simulation Boundary Conditions

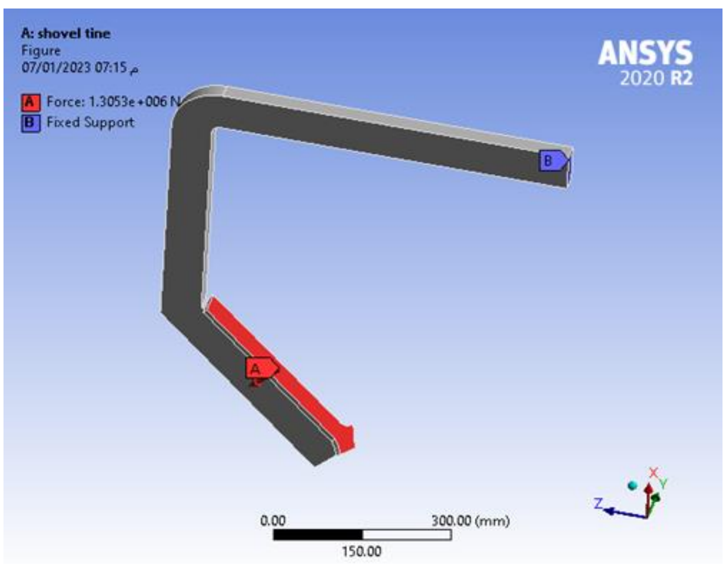
The type of supports and forces that are used on the geometry of the plow which is essential for defining and analysis of the model.

2.6. Type of Support

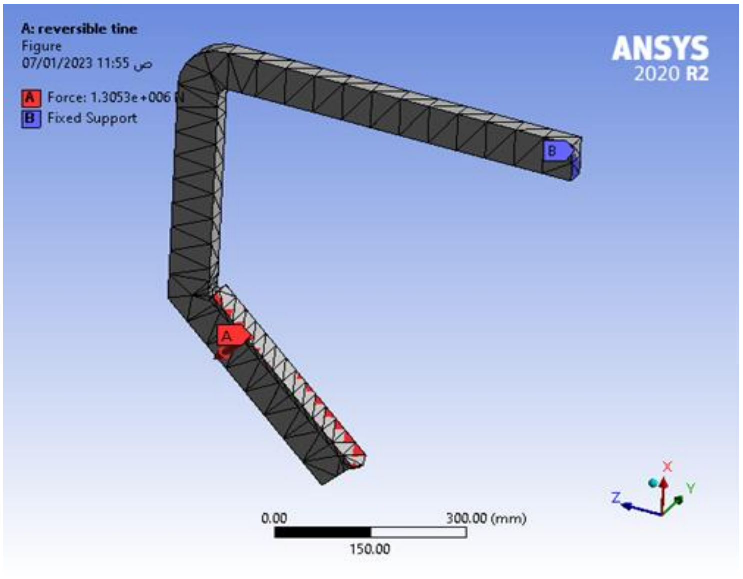
In this problem fixed support was used in the simulation of three chisel plows on the face that resist displacement movement due to applied load.

2.7. Applied Force

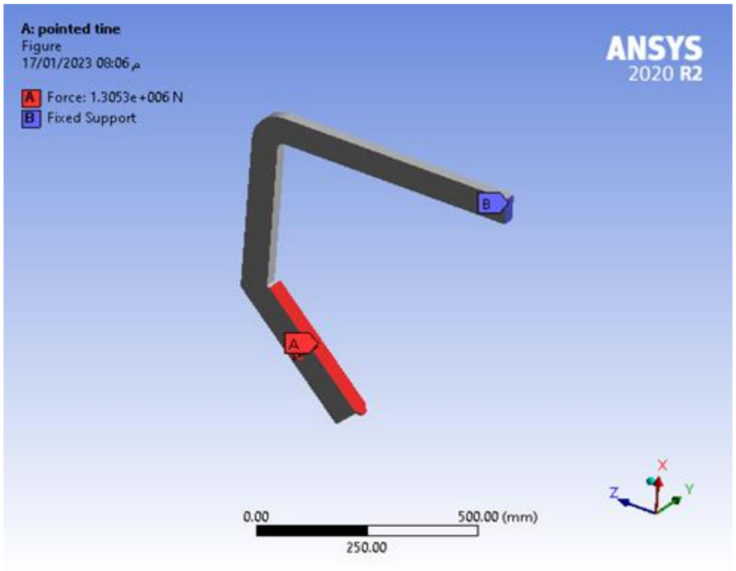
The force was applied on each plow by the soil that resist the motion of the chisel in the reverse direction. The force component will be applied on the center of the inclined tine face as: x= 923KN, Y= 0, Z= 923KN. as in Figure (5).



(A)



(B)



(C)

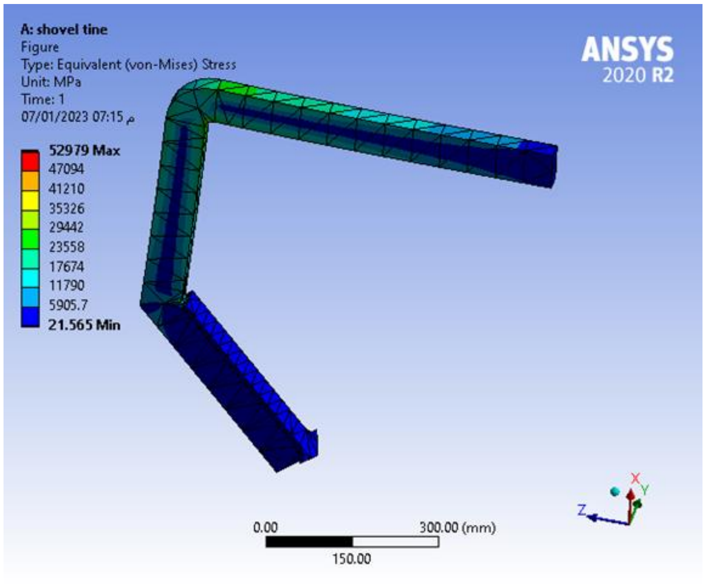
Figure (5): (A, B, C) Boundary conditions for three chisel tine.

2.9. Simulation Analysis

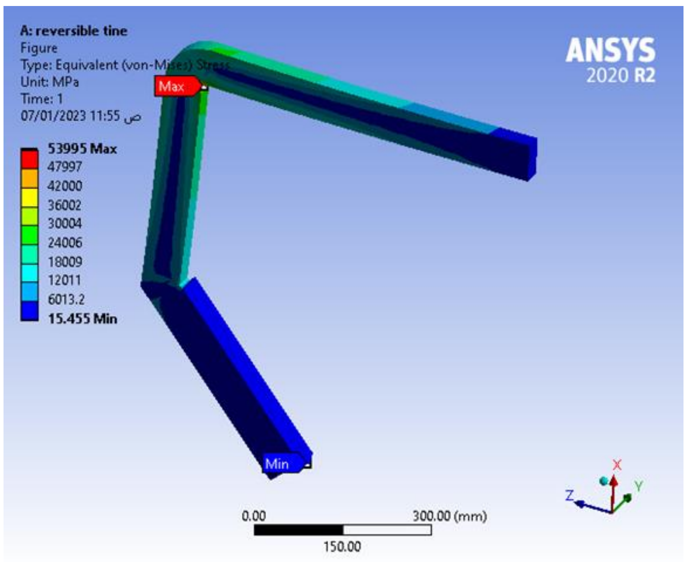
In this research three kinds of analysis were used stress analysis, strain analysis, and deformation analysis.

2.10 Stress Analysis

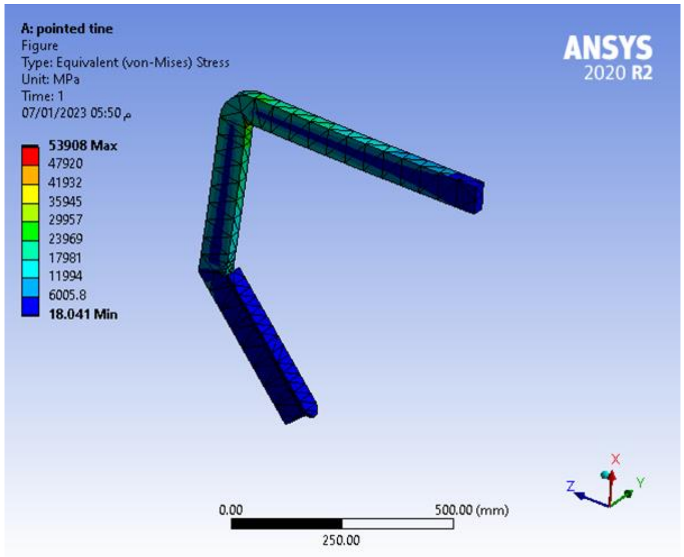
Figure (6) displays stress analysis for three chisel plows with the same fixed support and applied force.


A: shovel tine
Figure
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
07/01/2023 07:15 م
52979 Max
47094
41210
35326
29442
23558
17674
11790
5905.7
21.565 Min
ANSYS
2020 R2
0.00
300.00 (mm)
150.00

(A)


A: reversible tine
Figure
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
07/01/2023 11:55 ص
53995 Max
47997
42000
36002
30004
24006
18009
12011
6013.2
15.455 Min
Max
Min
ANSYS
2020 R2
0.00
300.00 (mm)
150.00

(B)



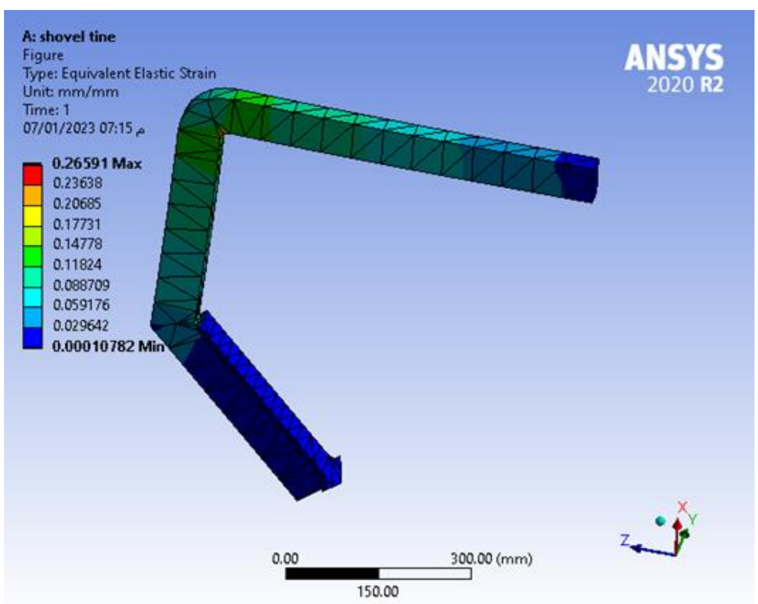
(C)

Figure (6): (A, B, C) shows stress analysis for three chisel tines.

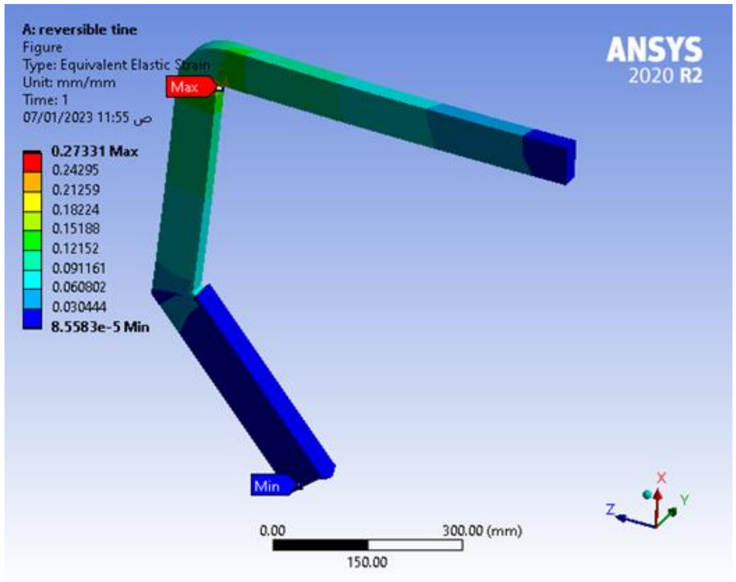
At the same magnitude of applied force, the maximum stress is 52979 MPa for shovel tine, and Figure 6(b) shows the reversible tine Model of Chisel in which the maximum stress is 53995 MPa, and Figure 6(c) shows pointed tine in which the maximum stress is 53908 MPa. The lower stress developed in shovel tine compared with the other two types at the same force magnitude which is safer than the other types. The shape of the soil tillage tool affects the traction force of the plow, this is agreed with ref. [14].

2.11. Strain Analysis

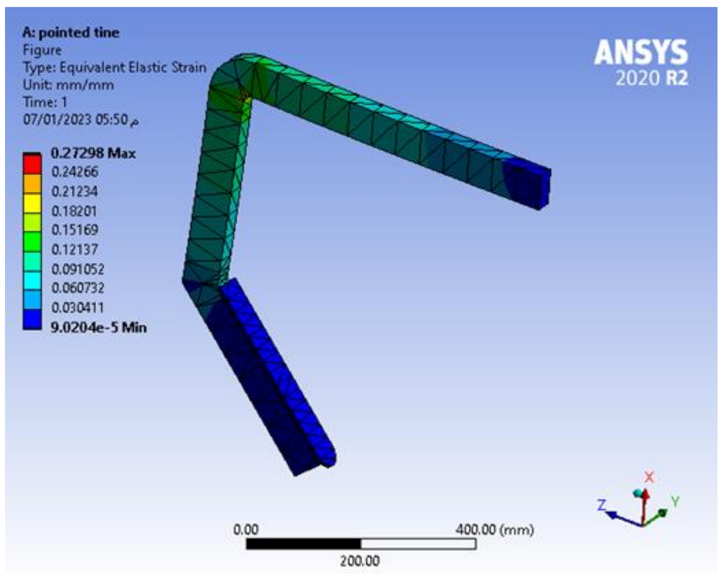
Figure (7) shows strain analysis for three chisel plows with the same fixed support and applied force.



(A)



(B)



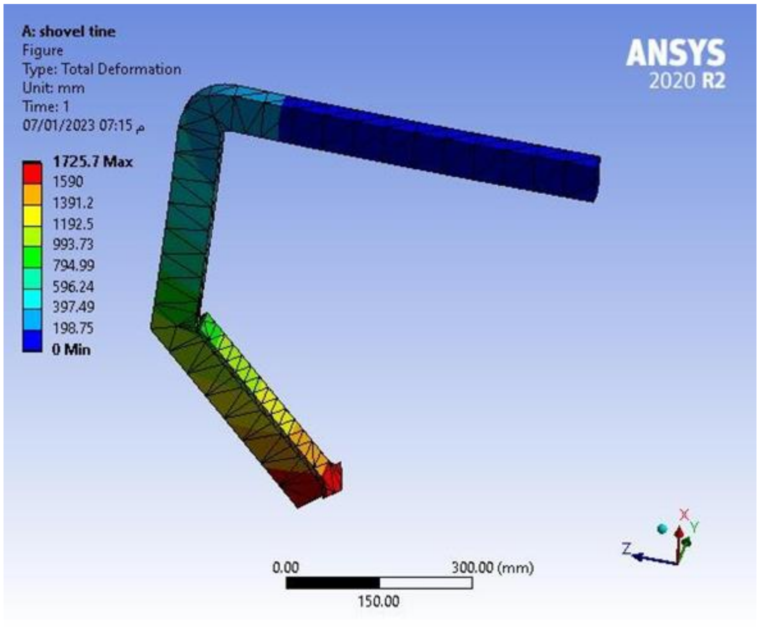
(C)

Figure (7): Illustrates strain analysis for three chisel tines.

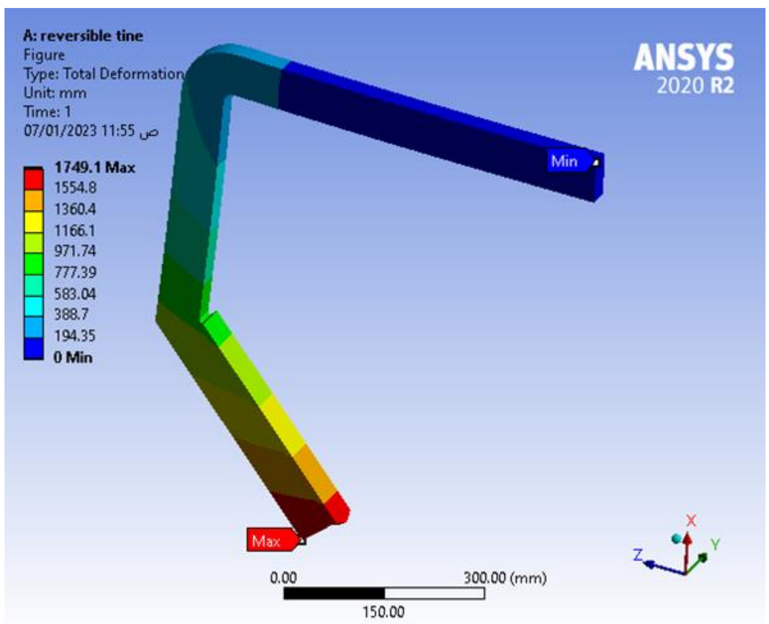
Figure (7) shows the effect of equivalent elastic strain for three chisel tines that resulted from the applied component force in the same value on each. The maximum strain in shovel tine is 0.26591 as shown in Figure 7(a). In figure 7(b) the reversible tine model of the chisel had a maximum strain is 0.27331. And Figure 6(c) shows pointed tine in which the maximum strain is 0.27298. Thus, at the same magnitude of force, the minimum strain developed in shovel tine which is safer.

2.12. Deformation Analysis

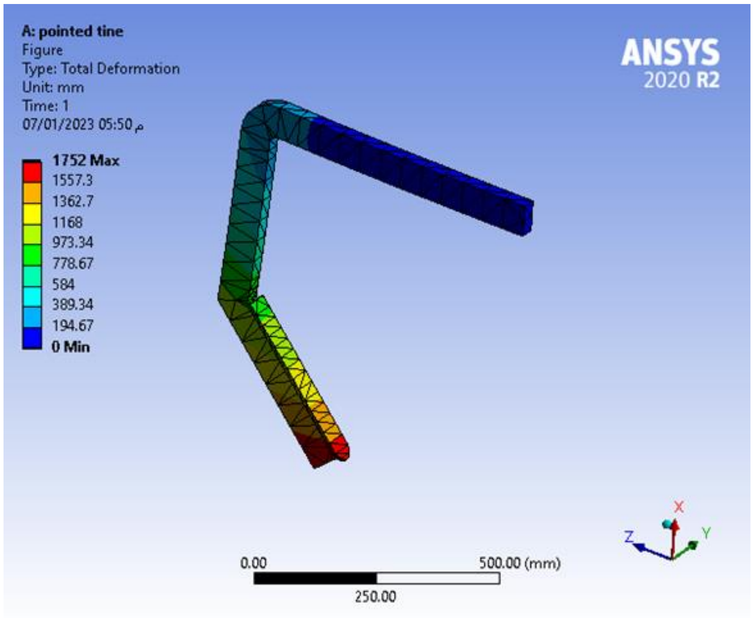
Figure (8) shows deformation analysis for three chisel plows with the same fixed support and applied force.


A: shovel tine
Figure
Type: Total Deformation
Unit: mm
Time: 1
07/01/2023 07:15 م
1725.7 Max
1590
1391.2
1192.5
993.73
794.99
596.24
397.49
198.75
0 Min
ANSYS
2020 R2
0.00
300.00 (mm)
150.00

(A)


A: reversible tine
Figure
Type: Total Deformation
Unit: mm
Time: 1
07/01/2023 11:55 ص
1749.1 Max
1554.8
1360.4
1166.1
971.74
777.39
583.04
388.7
194.35
0 Min
ANSYS
2020 R2
Min
Max
0.00
300.00 (mm)
150.00

(B)



(C)

Figure (8): Presents the deformation analysis of chisel plow tines.

Figure (8) shows the effect of total deformation for three chisel tines that resulted from the applied component force in the same value on each. The maximum deformation in shovel tine is 1725.7 mm as shown in Figure 8(a). While the maximum deformation in reverse tine was 1749.1 mm as shown in Figure 8(b). Figure 8(c) shows the maximum deformation in pointed tine was 1752 mm. Therefore, the minimum deformation was obtained in the shovel tine as compared with the other two types of tine at the same applied component force.

3. Conclusion

Three chisel plow tines (shovel, reversible, and pointed) were designed in CATIA software and used in program simulation to show which design is better than others. The analysis was done for stress, strain, and total deformation for three tines. The shovel tine showed a lower in stress and deformation developed which is 52979 MPa and 1725.7 mm respectively, which is a stiff design than others tine.

Conflict of Interest: The authors declare that there are no conflicts of interest associated with this research project. We have no financial or personal relationships that could potentially bias our work or influence the interpretation of the results.

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