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Determination of Equivalent Stress and Total Deformation in Different Types of Harrows

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Abstract: Using classical design methods for a tillage machine does not completely show a safety results. The 3D finite element analysis method (FEM) is one of the technique that generally used for total deformation and equivalent stress analysis in farm machinery and tools under different condition. In this study, the total deformation and equivalent stress were investigated in two different types of harrows and three different types of tines. Commercial FEM analysis software Ansys and SolidWorks were used in this study. SolidWorks software was used for design stage and Ansys Workbench was used in the analysis of the generated models. The proposed models was taken into account both the variability in tillage system parameters and operational conditions. The FEM analysis was set up in 3D, linear, general material model assumptions. Stainless steel material were assigned for the models. Ansys Workbench meshing functions were utilized to create a mesh structure of the models. According to the simulation results, maximum equivalent stress value 34.374 MPa and maximum total deformation value 9,9982 mm were obtained. According to results, all models can be use in tillage operations.
Key words: Finite element method, equivalent stress analysis, total deformation analysis, agricultural machinery design, harrow

INTRODUCTION

Secondary tillage, to improve the seedbed by increased soil pulverization, to conserve moisture through destruction of weeds and to cut up crop residues is accomplished by use of various types of harrows, rollers, or pulverizers and tools for mulching and fallowing. Used for stirring the soil at comparatively shallow depths, secondary-tillage equipment is generally employed after the deeper primary-tillage operations; some primary tillage tools, however, are usable for secondary tillage. There are five principal types of harrows: the disk, the spike-tooth, the spring-tooth, the rotary cross-harrow, and the soil surgeon. Rollers, or pulverizers, with V-shaped wheels make a firm and continuous seedbed while crushing clods. These tools often are combined with each other. (http://www.britannica.com/, 2014)

Tine harrows are used to refine seed-bed condition before planting, to remove small weeds in growing crops and to loosen the inter-row soils to allow for water to soak into the subsoil.

Tine harrows are manufactured using steel for the construction. Usually, tine harrow has a main framework, tines, and connecting points for tractor. Tine harrows work under low level soil reaction forces because of the shallow tillage.

Structural analysis is a very important method nowadays that determines the deformation in material and subjected forces so several usage recommendations are given.

The main purpose of this study was to obtain the optimum geometry parameters of tine harrow without any plastic deformation under defined condition. For this reason, Finite Element Method software package, Ansys 14.0, was utilized for the stress and deformation analysis but 3D solid model and assembly process were created using SolidWorks 3D design software.

MATERIALS and METHOD

3D design stage of the models

A tine harrows used as a material in our study and was created using SolidWorks 2012 and then stress analysis was performed by ANSYS 14.0. After 3D modelling by SolidWorks, boundary conditions were defined.

3D Models of different main frameworks and tines are shown in figure 7, 8, 9, and 10.

Complete 3D models are shown in figure 1, 2, 3, 4, 5, and 6 respectively.
And all of the 3D models design parameters are shown in Table 1.

The finite element analysis was set in assumption of 3D, static, and linear material properties. Material parameters of stainless steel is shown in table 2.

Bounding Box properties of the all 3D Model of Tines are shown in Table 3.

Table 1. 3D Models Design Parameters

3D Model	Bounding Box Lenght x-y-z (mm)	Properties Volume (mm^3) / Mass (kg)	Statistics Nodes / Elements
Light Harrow Straight Tines	978,14-1212,1-641,53	1.5381×10^7 / 119,2	84838 / 41891
Light Harrow Curved Tines	978,14-1212,1-712,14	1.5919×10^7 / 123,38	98230 / 49523
Light Harrow Ripper Teeth	978,14-1223,9-701,03	1.5811×10^7 / 122,53	88486 / 43715
Heavy Harrow Straight Tines	1364,9-1446-765	3.0895×10^7 / 239,44	60881 / 29834
Heavy Harrow Curved Tines	1364,9-1446-856,93	3.1964×10^7 / 247,72	65186 / 31654
Heavy Harrow Ripper Teeth	1364,9-1446,1-819,49	3.1552×10^7 / 244,53	62281 / 30394

Table 2. Properties of Stainless Steel

Density (kg/mm^3)	Compressive Yield Strength (MPa)	Tensile Yield Strength (MPa)	Tensile Ultimate Strength (MPa)
$7,75 \times 10^6$	207	207	586

Table 3. Bounding Box properties of the all 3D Model of Tines

3D Model of Tines	Bounding Box Lenght x-y-z (mm)
Straight Tines of the Light Harrow	10-185-12
Curved Tines of the Light Harrow	15,308-255,61-51,185
Ripper Teeth of the Light Harow	14,134-244,5-63,632
Straight Tines of the Heavy Harrow	15-242,5-18
Curved Tines of the Heavy Harrow	22,813-334,43-69,707
Ripper Teeth of the Heavy Harrow	21,202-296,99-70,692

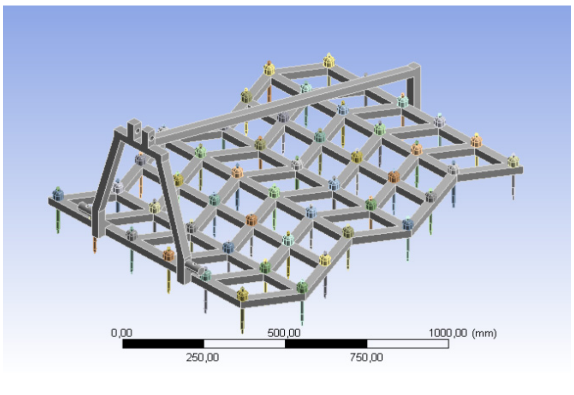

Figure 1. Light Harrow Straight Tines

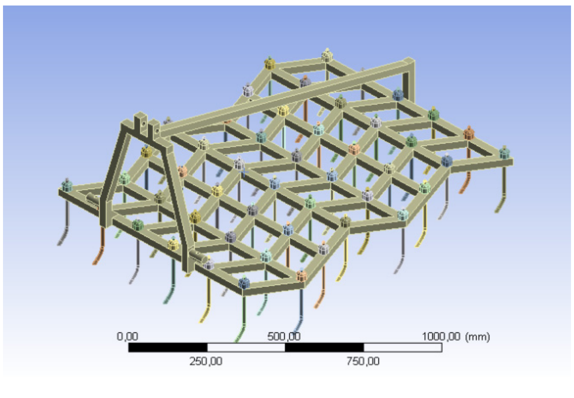

Figure 2. Light Harrow Curved Tines

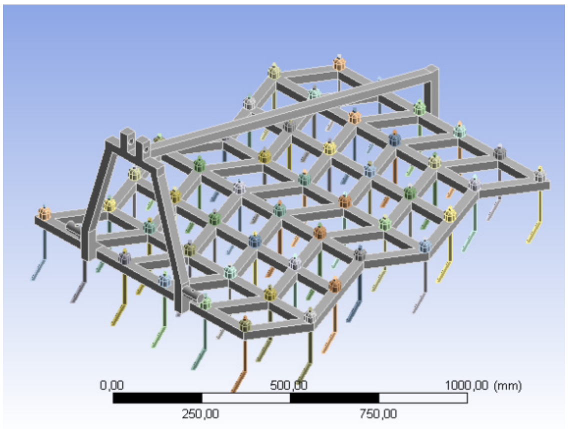

Figure 3. Light Harrow Ripper Teeth

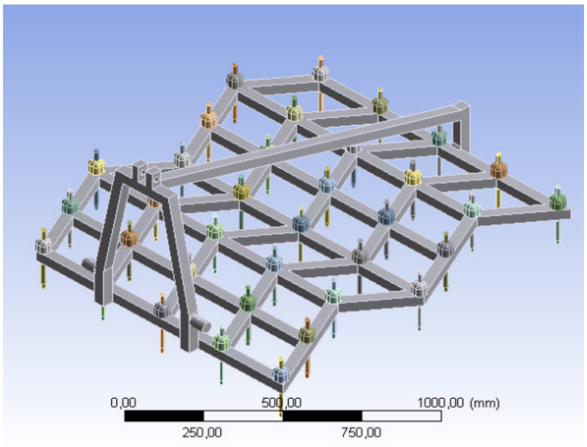

Figure 4. Heavy Harrow Straight Tines

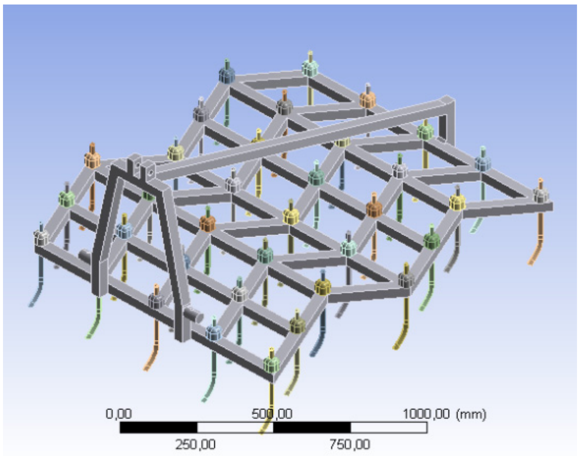

Figure 5. Heavy Harrow Curved Tines

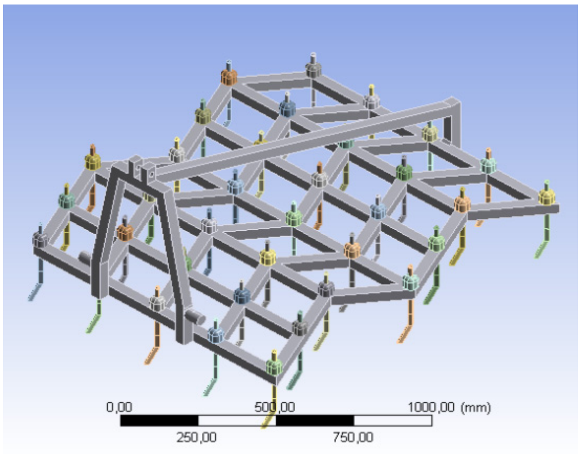

Figure 6. Heavy Harrow Ripper Teeth

All of the models designed with respect to the construction parameters. (Dilmaç, 1984)

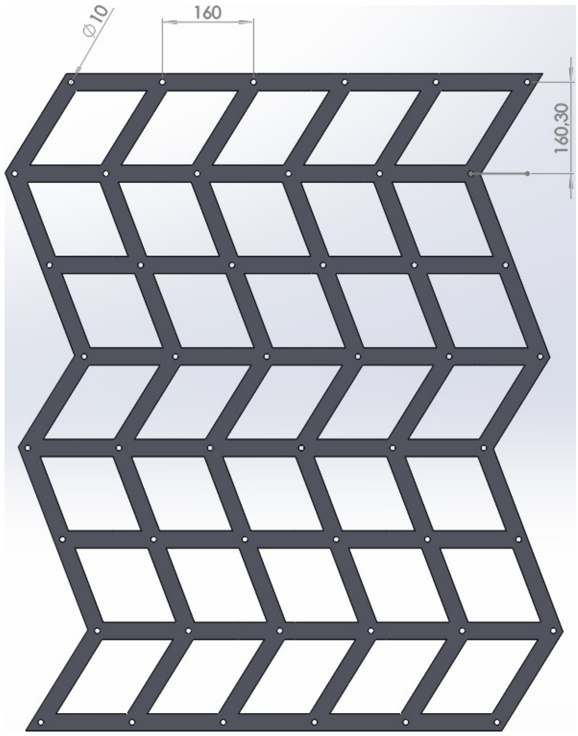

Figure 7. Main Framework of Light Harrow

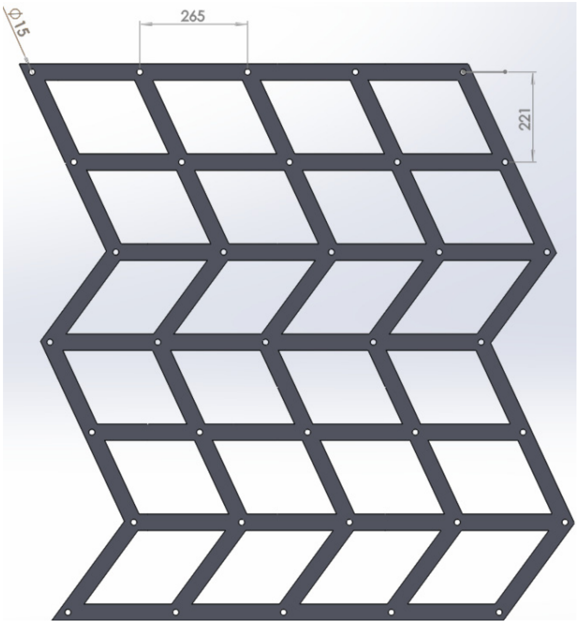

Figure 8. Main Framework of Heavy Harrow

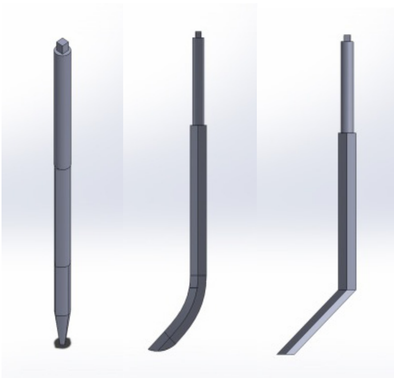

Figure 9. Tines of Light Harrow (Straight Tines, Curved Tines, and Ripper Teeth, Respectively.)

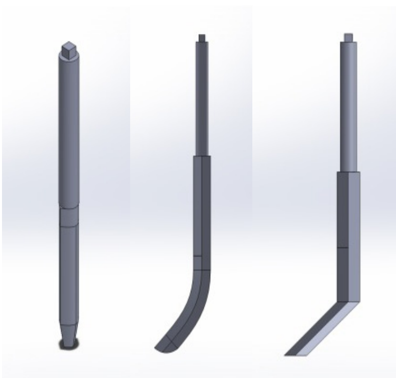

Figure 10. Tines of Heavy Harrow (Straight Tines, Curved Tines, and Ripper Teeth, Respectively.)

Finite element analysis and optimization of the Models

The 3D models were created by SolidWorks 2012. After that, models were meshed by Ansys 14.0.

We suppose that all the models use the same material, the density is 7,75 x 10^6 kg/mm3, and the Young's Modulus of elasticity and the Poisson's ratio are 1,93 x 10^5 MPa, and 0,31 respectively.

Loading force is along the deployment axis in a front-back direction, and is uniformity distributed at the all tines. The magnitude of the force at each tine is 20 N for light harrow and 50 N heavy harrow, respectively.

And we supposed that zero displacements are assumed at the three point linkage and harrows.

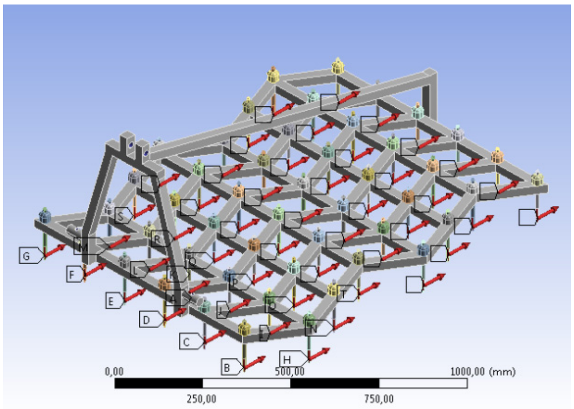

Figure 11. Loading Forces of the Light Harrow Straight Tines

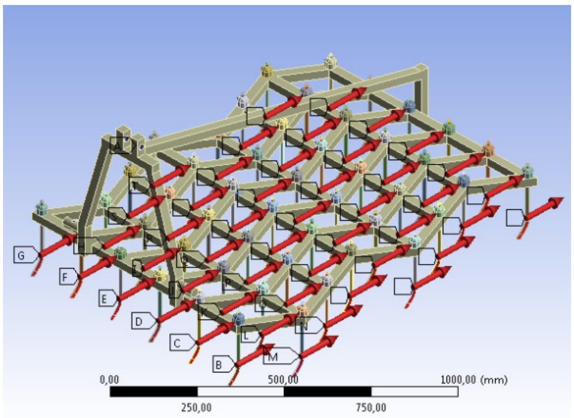

Figure 12. Loading Forces of the Light Harrow Curved Tines

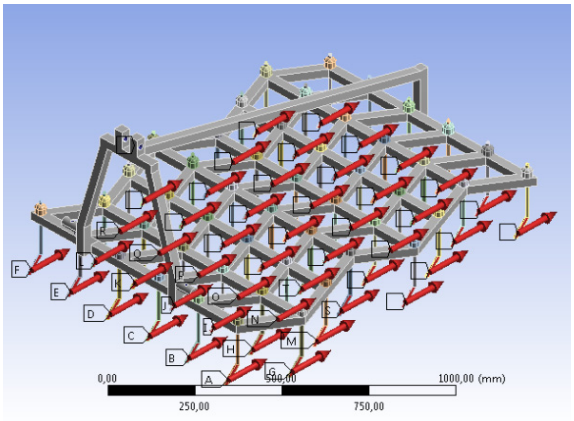

Figure 13. Loading Forces of the Light Harrow Ripper Tines

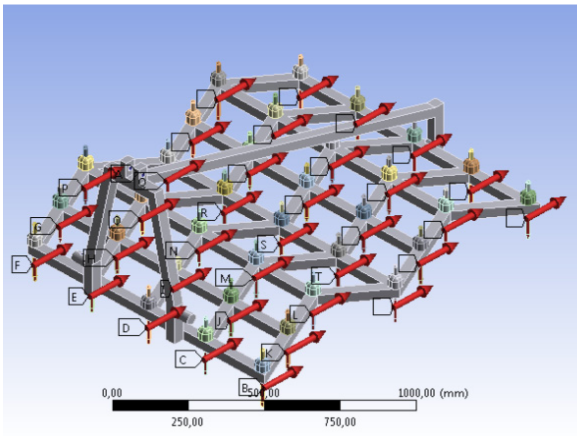

Figure 14. Loading Forces of the Heavy Harrow Straight Tines

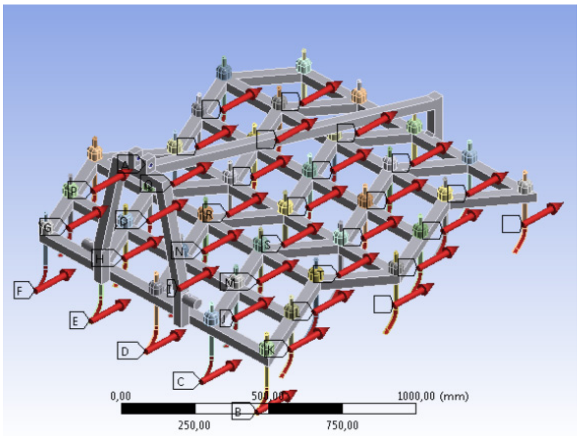

Figure 15. Loading Forces Heavy Harrow Curved Tines

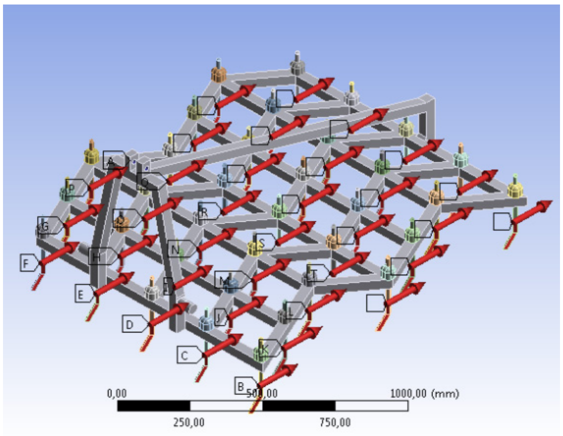

Figure 16. Loading Forces of the Heavy Harrow Ripper Tines

RESULTS and DISCUSSION

Topakci (2010) made studies on this issue and the results from the experimental study were used in the finite element analysis (FEA) to simulate stress distributions on the subsoiler tine. The maximum equivalent stress of 432,49 MPa was obtained in the FEA. Visual investigations and FEA results showed that according to the tine's material yield stress point of 355 MPa, plastic deformation was evident.

Yılmaz (2011) in his work found that, the result of the FEA showed that the maximum stress occurred on 40000 N forced as 1584,9 MPa for chassis of the turbomatic sprayer and maximum displacement was obtained as 133.045 mm on contact point of the tractor with machine. The simulation results showed that safety factor was found greater than 1 for 10000 N, but safety factor of the 20000 and 40000 N was found less than 1. If the machine will be work by 20000 and 40000 N, higher yield stress material should be chosen and the chassis should be manufactured by this material.

According to Mollazade found that (2010), the biggest value of stress in meshed models of subsoilers were occurred in the shank's holes as 129 MPa in the node 621 for C shape subsoiler, 566 MPa in the node 38 for sloping shape subsoiler, and 801 MPa in the node 1103 for L shape subsoiler. Results showed that fracture probability of subsoiler in the points near to the shank's holes is higher than the other points and this is due to exist of a bending moment which is produced by the soil resistance force acting on the blades and lower section of shanks.

Shinde (2011) in his work found that The displacement and Von Misses Stress is maximum at rotovator blade section such as 6.757 mm and 417.03 Mpa respectively for 35 hp tractor and the displacement and Von Misses Stress is maximum at blade section such as 7.893 mm and 503.21 Mpa respectively for 45 hp tractor.

At the end of the analysis process, equivalent stress, displacement, and strain results were obtained and showed that tables 4.

The stress distribution and the deflection of the all models are found. A maximum stress of 34.374 Mpa was occurred that light harrow curved tines and maximum displacement was measured as 0.37788 mm that heavy harrow curved tines.

The Von Misses Stress distributions, displacement, and safety factors of six different models are presented in figure 17, 18, 19, 20, 21, and 22, respectively.

Table 4. Equivalent Stress, Displacement, and Strain Results

3D Model	Total Deformation (mm) (max)	Equivalent Stress (MPa)	Safety Factor (min)
Light Harrow Straight Tines	0,20624	20,704	9,9982
Light Harrow Curved Tines	0,33667	34,374	6,022
Light Harrow Ripper Teeth	0,30190	27,816	7,4417
Heavy Harrow Straight Tines	0,24144	26,613	7,781
Heavy Harrow Curved Tines	0,37788	31,194	6,636
Heavy Harrow Ripper Tines	0,31755	29,443	7,0306

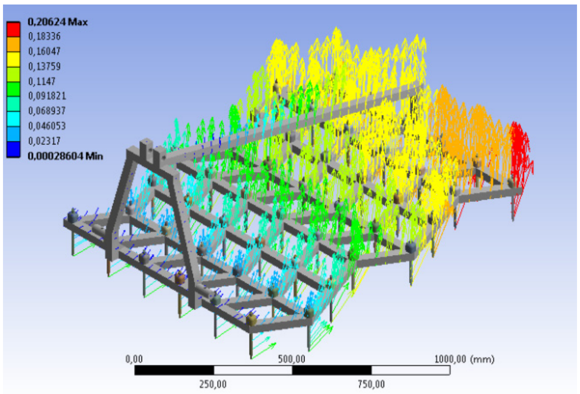

Figure 17. Total Deformation of the Light Harrow Straight Tines

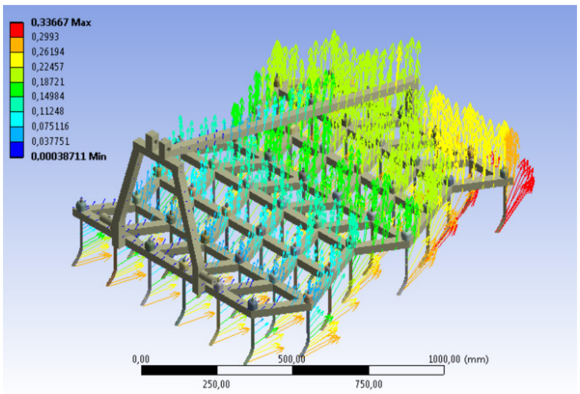

Figure 18. Total Deformation of the Light Harrow Curved Tines

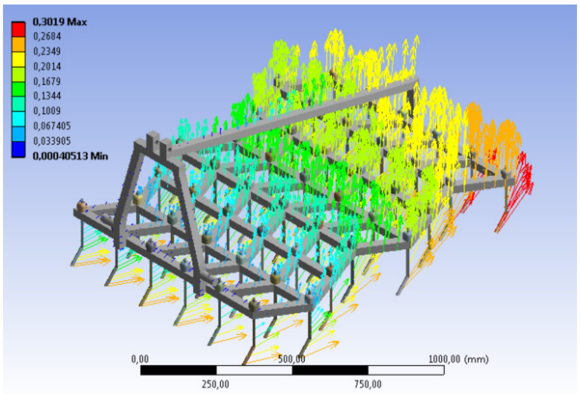

Figure 19. Total Deformation of the Light Harrow Ripper Tines

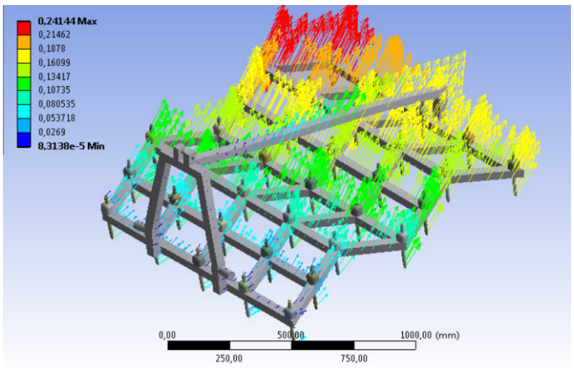

Figure 20. Total Deformation of the Heavy Harrow Straight Tines

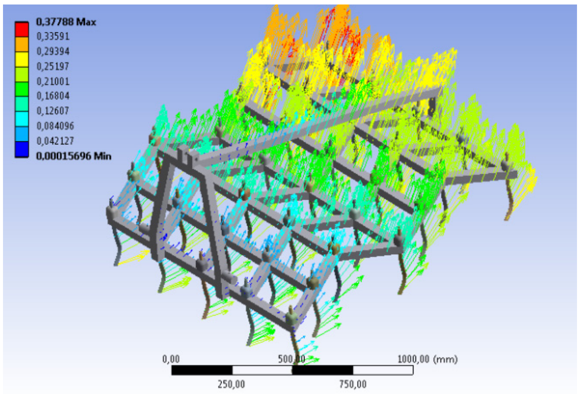

Figure 21. Total Deformation of the Heavy Harrow Curved Tines

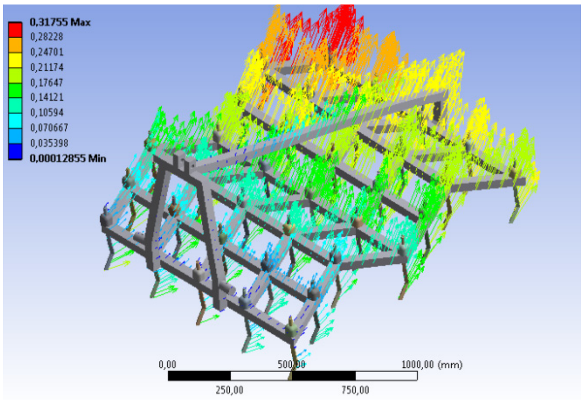

Figure 22. Total Deformation of the Heavy Harrow Ripper Tines

CONCLUSIONS

Based on the data obtained from the analysis, it has been found that the deformation and displacement on the tines which near the three point linkage of the harrows. But it found that evidence was not reach to critical state for tillage operation.

The highest value of the Total deformation and Equivalent Stress and the lowest value of the safety factors are found in curved tine models.

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