PARAMETRIC DESIGN ANALYSIS AND FEA SIMULATION OF A CHISEL PLOW FOR AN AGRICULTURE USE

Pawan Sharma[1] and Prof. (Dr.) Manish Bhargava[2]

[1,2]Department of Mechanical Engineering
[1,2]Maharishi Arvind Institute of Engineering and Technology, Jaipur, India

ABSTRACT

CAD Software for the structural analysis is basically used for the application of CAD/CAM in design optimization of tillage tools, which is based on the simulation method and Finite Element Method. The various components of the tillage tools are simulated with help of actual field performance rating parameters which are prepared by solid models along with actual boundary conditions. The planned work outcomes of sufficient tolerance in varying the working parameters of Chisel Plow sections for ejecting the extra weight in a solid section and also to increase the weight of plow for a consistent potency.

In this paper parametric study of two different kinds of Chisel Plow for an agriculture use in designing from stress, strain, deformation and fatigue analysis has done. One is Old Chisel Plow & another is New Generation Chisel Plow. The old working model of Chisel Plow is compared with new design parameters with change of its geometry for the maximum weed exclusion efficiency by showing its realistic results from the actual field performance.

KEYWORDS

Stress, Strain, Deformation, Fatigue, Modeling, Analysis & Shape Optimization.

1. INTRODUCTION

The development of field is very costliest process in farming. It includes forest cleaning, soil aperture using bottomless tillage tools, movements of soil from high to low places, farm road construction, land leveling etc. These all operations can be performed by using self propelled and heavy equipments such as crawler tractors, high horsepower tractors, scrapers, ditchers, chisel ploughs, levelers etc. To gain the required seedbed to provide optimal atmosphere for start germination and plant development, mechanical exploitation of soil is required, known as tillage operations and for minimize the design optimization and manufacturing errors of the components, design analysis and optimization is necessary.

Particularly blades and spread parts must be consistent in field the concert against to working conditions. Forecasting of Stress Analysis must be required for manufacturers, designers and researchers. The optimization in design of a chisel plow can be obtained by decreasing its weight, cost and by improving the weed exclusion rate. In industries, CAD software's are used for the designing the desired model and FEA software's are used for the solid analysis of the model. Thus after the analysis of stress, strain, safety factor, displacement, fatigue etc. on FEA software, the simulation results shown in terms of safe results or in terms of breakdown and failure due to high stresses and deformation.

The planned work shows an experimental way for model testing and validation of agriculture tools and equipments. The selected model of a chisel plow is measured with actual dimensions and its solid model is prepared on Autodesk Inventor 2014 and the simulation is done on ANSYS v14.5. [1]

1.1 Types of Chisel Plows

- Animal Drawn Mouldboard
- Melur
- Improved Iron
- Animal Drawn Bose
- Khargaon
- Dabra
- Rau
- Chisel
- MP Iron Wedge
- Birsa Animal Drawn Ridger
- Kapas Ridger
- Bullock Drawn Ridger
- Bullock Drawn Disc Harrow
- Disc Harrow
- Blade Harrow
- Bullock Drawn Puddler
- Animal Drawn Puddler
- Animal Drawn Helical Blade Puddler
- Bullock Drawn Land Leveler
- Bullock Drawn Cultivator
- Tractor Mounted Mouldboard
- Tractor Drawn Disc

These are the various types of Chisel Plows used in agriculture field for different types of soils.

2. MATERIALS

The materials are taken from the engineering database of Chisel Plow production system specification drawn by Industry. The properties of Material and Soil are taken as per the following data:

Table 1. Material Properties

Material Name	Stainless Steel	
Material Properties	Density	7750 Kg/m^3
	Young's Modulus	1.93 X 10^{11}
	Poisson Ratio	0.31
	Bulk Modulus	1.693 X 10^{11}
	Shear Modulus	7.3664 X 10^{10}
	Tensile Yield Strength	207 MPa
	Compressive Yield Strength	207 MPa
	Tensile Ultimate Strength	586 Mpa

Table 2. Soil Properties

S. No.	Type of Soil	Soil Resistance (Kg/m^2)	Optimum Moisture Content (%)
1	Sandy Soil	2000	3.5
2	Sandy Loam	3000	5.8
3	Silt Loam	3500-5000	5.8
4	Clay	4000-5600	7.18
5	Heavy Loam	5000-7000	13.30

2.1 Soil Parameters

The properties of the soil related to the desired chisel plow were recognized as types of soil, wetness, mass concentration and cone index. The measurement and categorization methodologies are discussed in the subsequent section. Black type of soil is used in this research work for the chisel plow analysis. The humidity substance of soil performs a significant task for the development of the crops therefore subsequent Soil resistance and humidity substance of soil are taken as per the table 2. [6]

3. MODELING AND DESIGNING METHODS

The modeling and designing methods include the number of various parameters, methods and steps for model construction. The input boundary conditions will be required for the pre processing stage of the desired chisel plow.

3.1 Finite Element Method for Chisel Plow

The useful features of finite element methods are as follows [7]:

- Discretization of the whole model into small elements, which may be square, rectangle, and triangle or in polygon shapes.
- Derive the governing differential equations for each element of the model.
- Assembly of all elements, based on stability of the solution.

3.2 Mesh Generation

The conversion of whole model into number of small elements is known as Mesh generation. The meshing is a very important step for the accurate solution. Various kinds of meshing are used in the pre-processing. We are using the mesh generation with a good number of relevance with fine mesh. For the Chisel Plow elements are used for meshing.
The elements may be rectangular or triangular. We are using triangular mesh for a high accuracy. The number of elements represents the solution accuracy of the model. The elements can be increased by increasing the relevance number. So that the run time is less and also the accuracy is not much affected.

The mesh view of both the Chisel Plows is given below:

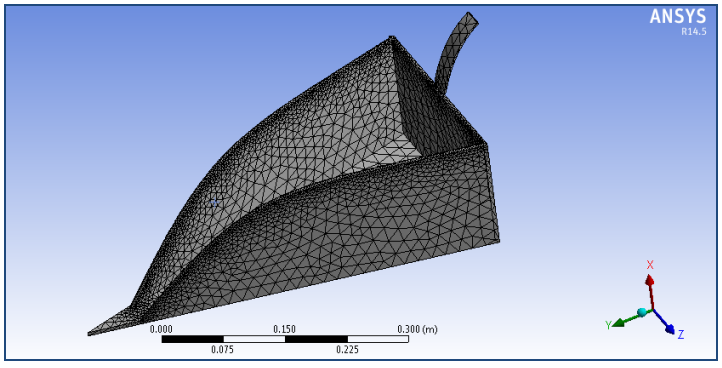

Figure 1. Mesh Pictures of the Old Model of Chisel Plow

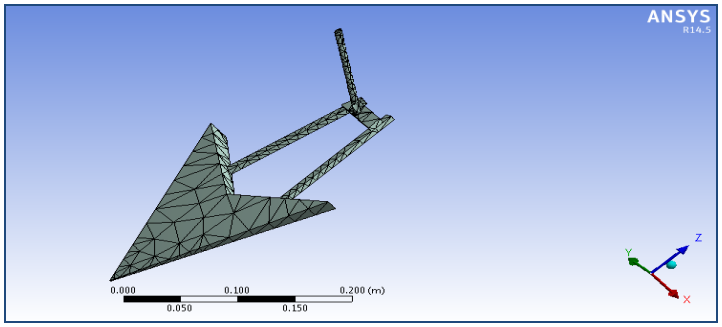

Figure 2. Mesh Pictures of the New Generation Model of Chisel Plow

The fine triangular mesh is showing with scale in the above figures shows the accuracy of mesh at small and large surface areas.

3.3 Model Description

The Model Description for the Chisel Plow is given below:

Table 3. Model Description

Old Model of Chisel Plow		New Generation Model of Chisel Plow	
Length X	0.24281 m	Length X	0.10152 m
Length Y	0.55658 m	Length Y	0.23556 m
Length Z	0.25 m	Length Z	0.33916 m
Volume	1.0423e-003 m^3	Volume	2.1013e-004 m^3
Mass	8.1817 kg	Mass	1.6495 kg
Scale Factor Value	1	Scale Factor Value	1
No. of Nodes	32105	No. of Nodes	1751
No. of Elements	16472	No. of Elements	693

The model description shows in the above table number 3. The model description shows the exact location and orientation of the model with respect to the global coordinate system. The model description includes the model length in X, Y & Z direction, Volume & Mass of model, No. of Nodes & Elements in the model of Chisel Plow after meshing.

4. ANALYSIS OF CHISEL PLOW BY USING ANSYS

The Analysis of the model can be done by using boundary conditions. After applying the boundary conditions, we can get the required results. Analysis can be done by using the analysis tool. The Modeling tool is Autodesk Inventor 14 and Analysis tool is ANSYS Workbench 14.5. There are three steps in ANSYS working procedure used for the analysis are:

- Preprocessing
- Solution
- Post processing

After preparing a solid geometry of Chisel Plow in Autodesk Inventor 14 the important steps are meshing (that we have already done) and applying load on inclined face of the Chisel Plow by the soil and boundary conditions in the preprocessor, so that simulation can be run to get a solution and generate results in the post-processor.

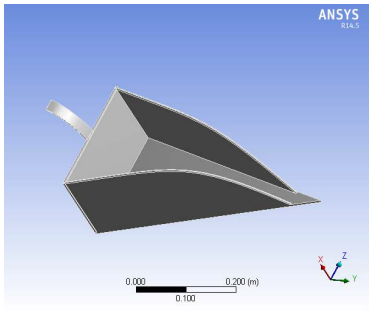

Figure 3(a). Old Model of Chisel Plow

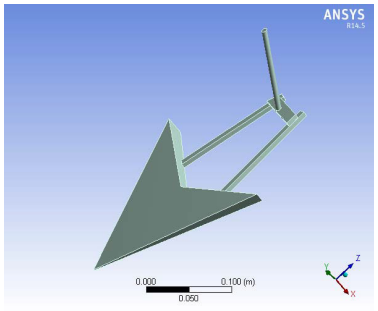

Figure 3(b). New Model of Chisel Plow

The above figure shows the modeled view of Chisel Plow on the modeling tool Autodesk Inventor 14. Figure 3(a) showing the Old Model of Chisel Plow and Figure 3(b) showing New Generation Model of Chisel Plow.

4.1 Boundary Conditions and Input Parameters

The boundary conditions are type of supports and forces on various faces, also various supports & forces are the input parameters for the Chisel Plow.

4.1.1 Type of Support

Fixed Support will be applied on the face on which the body experiences the resisting force. Thus, Fixed Support will be applied at the handle of ploughs of both Old Plough & New Generation Plough.

4.1.2 Force

The Force will be applied by the soil in the opposite direction of motion. Thus, the force will be applied on the inclined face of both Old Plough & New Generation Plough.

Table 4. Force Description

X Component	500 N
Y Component	0 N
Z Component	500 N

The above boundary conditions are used for modeling and analysis of the Chisel Plow.

4.2 Types of Analysis

We will use total three types of Analysis for both the Chisel Plows under the fix ranges:

4.2.1 Stress Analysis

At the same magnitude of force and fixed support, the stress analysis is:

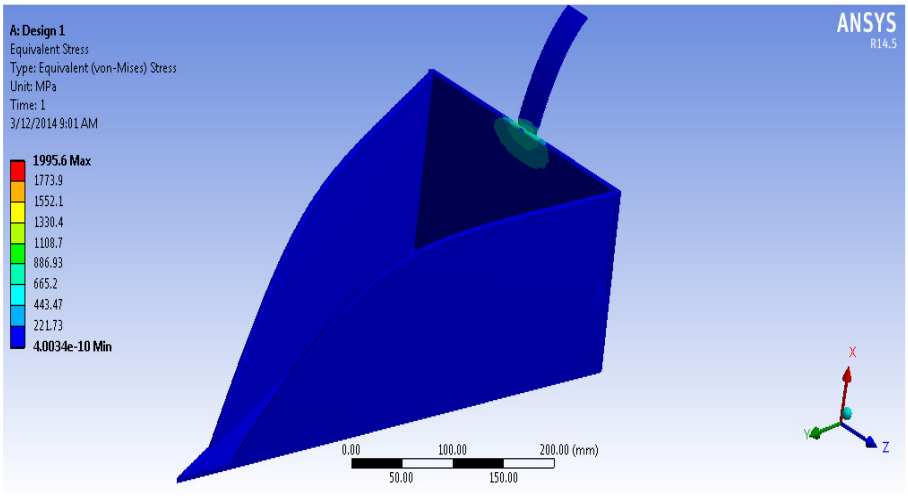

Figure 4(a). Old Model of Chisel Plow

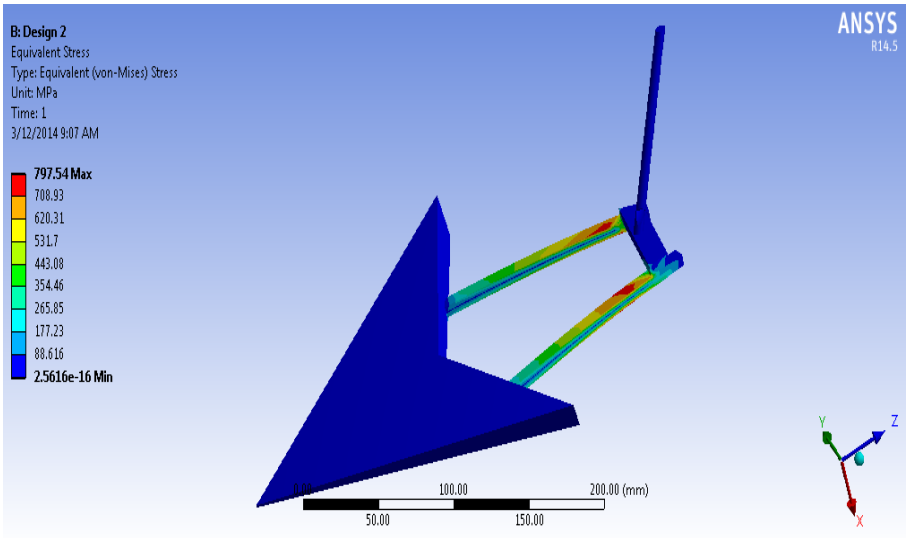

Figure 4(b). New Generation Model of Chisel Plow

Above Figure 4(a) shows Old Model of Chisel Plow, in which under the action of the force of 500 N, the maximum stress is **1995.6 MPa** and Figure 4(b) shows New Generation Model of Chisel Plow in which the maximum stress is **797.54 MPa**. Thus at the same magnitude of force the lower stress developed in the New Generation Model of Chisel Plow, hence it is safe then the Old Model of Chisel Plow.

4.2.2 Strain Analysis

At the same *magnitude* of force and fixed support, the strain analysis is:

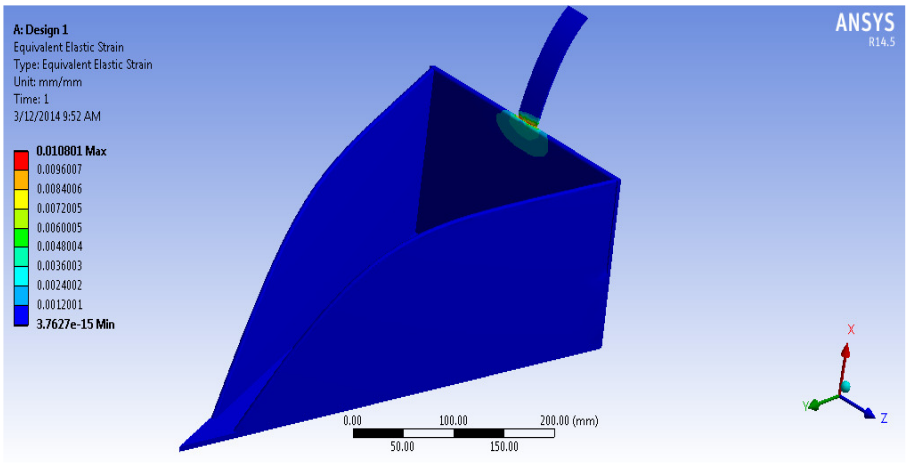

Figure 5(a). Old Model of Chisel Plow

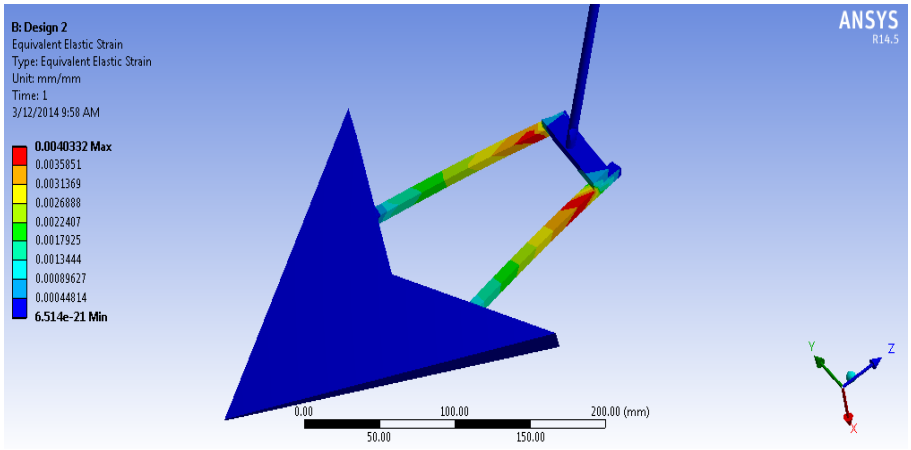

Figure 5(b). New Generation Model of Chisel Plow

Above Figure 5(a) shows Old Model of Chisel Plow, in which under the action of the force of 500 N, the maximum strain is **0.010801** and Figure 5(b) shows New Generation Model of Chisel Plow in which the maximum strain is **0.0040332**. Thus at the same magnitude of force the lower strain developed in the New Generation Model of Chisel Plow, hence it is safe then the Old Model of Chisel Plow.

4.2.3 Deformational Analysis

At the same magnitude of force and fixed support, the deformation analysis is:

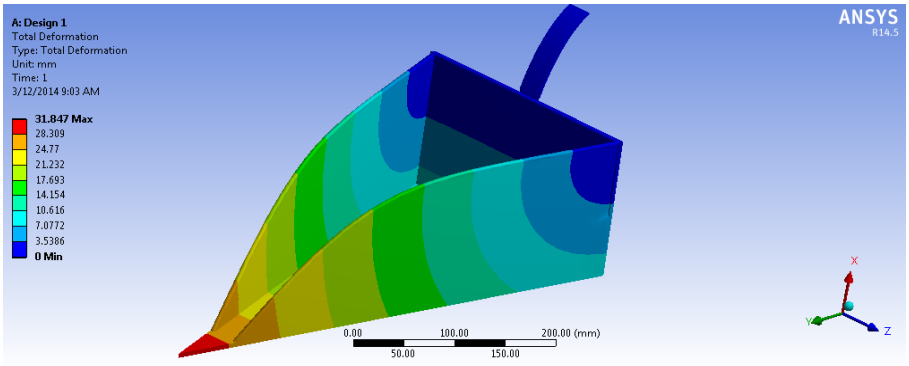

Figure 6(a). Old Model of Chisel Plow

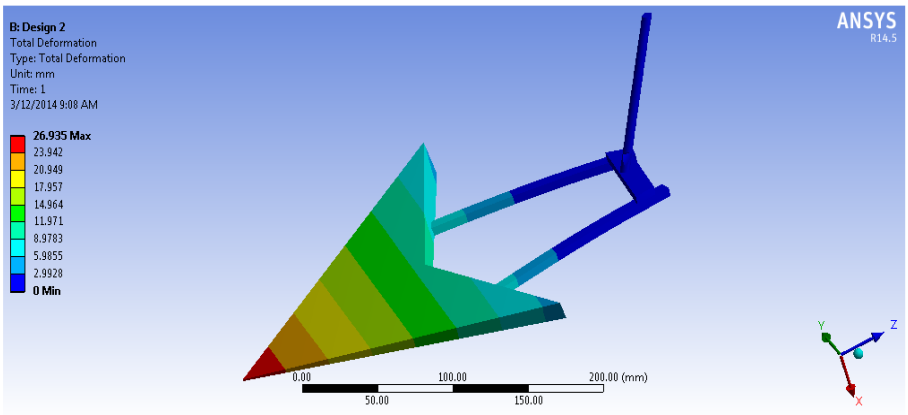

Figure 6(b). New Generation Model of Chisel Plow

Above Figure 6(a) shows Old Model of Chisel Plow, in which under the action of the force of 500 N, the maximum deformation is **31.847 mm** and Figure 6(b) shows New Generation Model of Chisel Plow in which the maximum deformation is **26.935 mm**. Thus at the same magnitude of force the lower deformation developed in the New Generation Model of Chisel Plow, hence it is safe then the Old Model of Chisel Plow.

4.2.4 Fatigue Analysis

At the same magnitude of force and fixed support, the life analysis is:

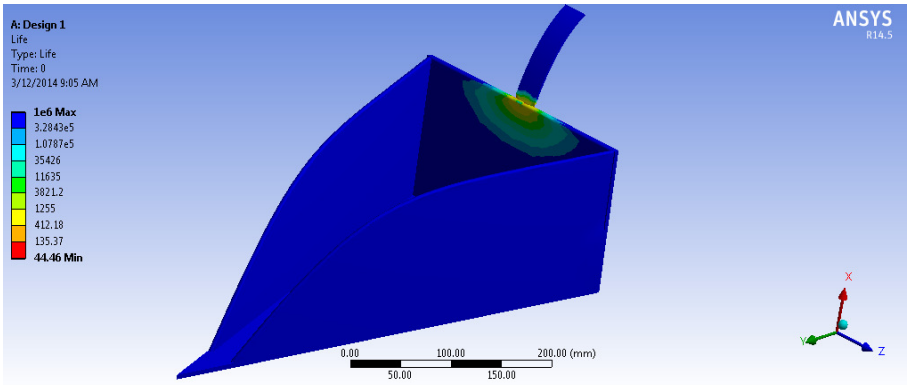

Figure 7(a). Old Model of Chisel Plow

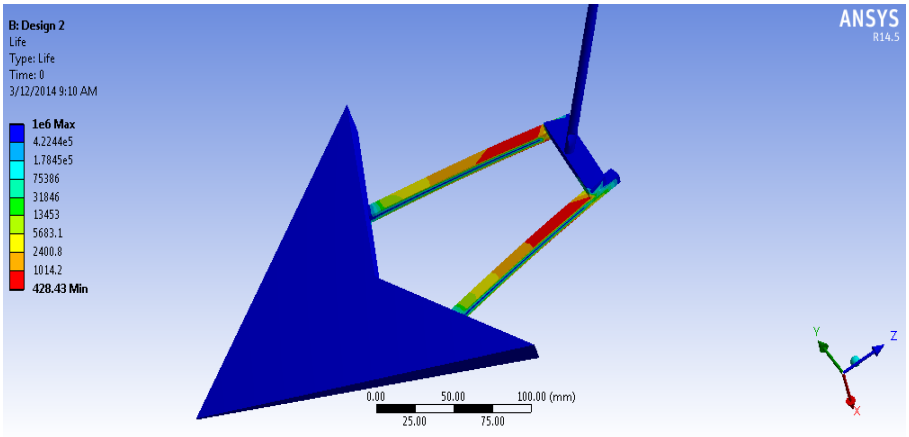

Figure 7(b). New Generation Model of Chisel Plow

Above Figure 7(a) shows Old Model of Chisel Plow, in which under the action of the force of 500 N, the maximum life cycles are **35,426 Cycles** and Figure 7(b) shows New Generation Model of Chisel Plow in which the maximum life cycles are **4,22,440 Cycles**. Thus at the same magnitude of force the maximum life cycles are in the New Generation Model of Chisel Plow, hence it is safe then the Old Model of Chisel Plow. Thus the above Stress, Strain, Deformation and fatigue analysis of Chisel Plow shows that under the same magnitude of force and fixed constraint the Design of Old Model of Chisel Plow get failed and the Design of New Generation Model of Chisel Plow will safe.

5. PARAMETRIC RESULTS

The parametric results shows the stress, strain, deformation & fatigue results for old model & new generation model of Chisel Plow.

5.1 Stress Results on Chisel Plows

The Stress result shows in the comparison of Old Model of Chisel Plow and New Generation Model of Chisel Plow.

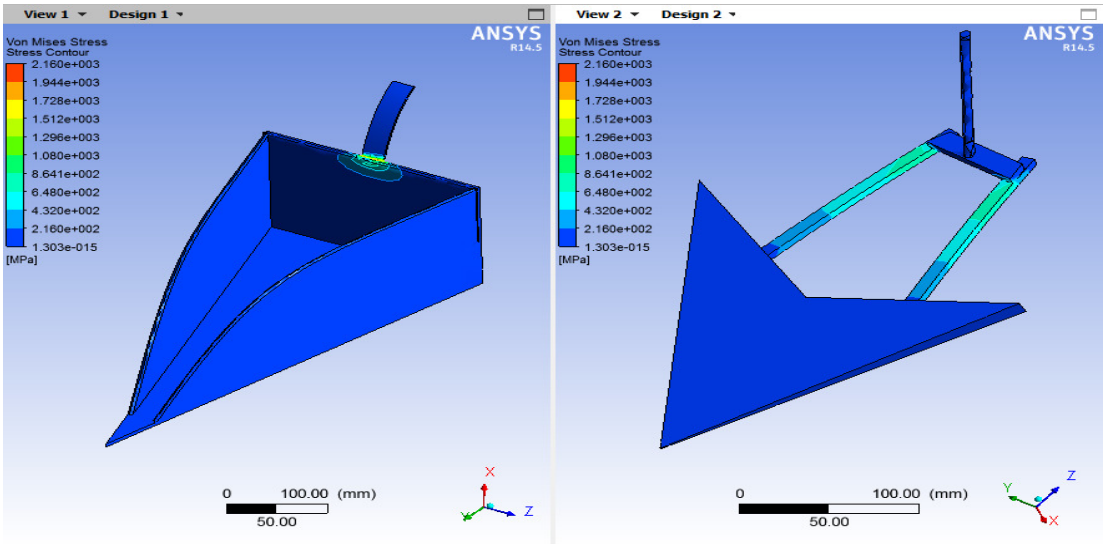

Figure 8. Comparative Stress Results of Both Chisel Plows

Table 5. Stress Results on Chisel Plows

Von Mises Stresses Results		
	Old Model of Chisel Plow	New Generation Model of Chisel Plow
Maximum Stress (MPa)	1995.6	797.54
Minimum Stress (MPa)	4.0034×10^{-10}	5.5616×10^{-16}

Thus, the stress result shows that at the same magnitude of force, the maximum von mises stress developed in Old Model of Chisel Plow is **1995.6 MPa** and in New Generation Model of Chisel Plow is **797.54 MPa.**

Thus, the Old Model of Chisel Plow get failure and New Generation Model of Chisel Plow get safe at the same magnitude of force & fixed support.

5.2 Strain Results on Chisel Plows

The Strain result shows in the comparison of Old Model of Chisel Plow and New Generation Model of Chisel Plow.

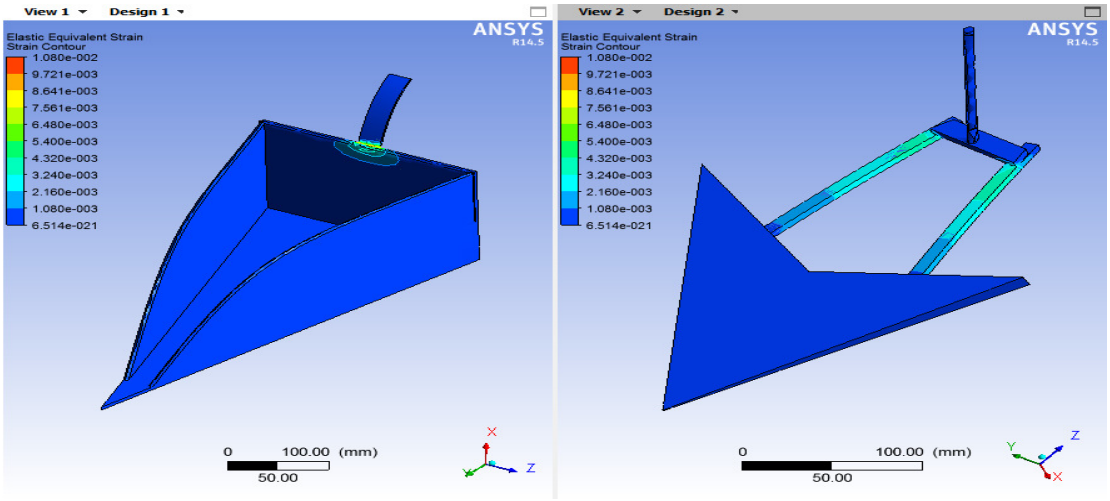

Figure 9. Comparative Strain Results of Both Chisel Plows

Table 6. Strain Results on Chisel Plows

Elastic Equivalent Strain Results		
	Old Model of Chisel Plow	New Generation Model of Chisel Plow
Maximum Strain (mm)	0.0108	0.0040
Minimum Strain (mm)	3.7627×10^{-15}	6.514×10^{-21}

Thus, the strain result shows that at the same magnitude of force, the maximum strain developed in Old Model of Chisel Plow is **0.0108 mm** and in New Generation Model of Chisel Plow is **0.0040 mm.**

Thus, the Old Model of Chisel Plow gets more deformation then New Generation Model of Chisel Plow at the same magnitude of force & fixed support.

5.3 Deformation Results on Chisel Plows

The Deformation result shows in the comparison of Old Model of Chisel Plow and New Generation Model of Chisel Plow.

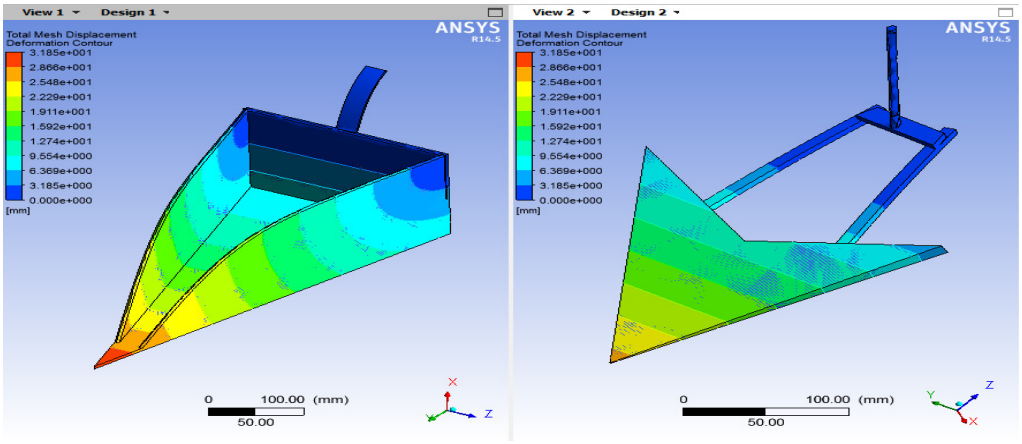

Figure 10. Comparative Deformation Results of Both Chisel Plows

Table 7. Deformation Results on Chisel Plows

Deformation Results		
	Old Model of Chisel Plow	New Generation Model of Chisel Plow
Maximum Deformation	31.847 mm	26.935 mm
Minimum Deformation	0	0

Thus, the Deformation result shows that at the same magnitude of force, the maximum strain developed in Old Model of Chisel Plow is **31.847 mm** and in New Generation Model of Chisel Plow is **26.935 mm.**

Thus, the Old Model of Chisel Plow gets more deformation then New Generation Model of Chisel Plow at the same magnitude of force & fixed support.

5.4 Fatigue Results on Chisel Plows

The Fatigue result shows in the comparison of Old Model of Chisel Plow and New Generation Model of Chisel Plow.

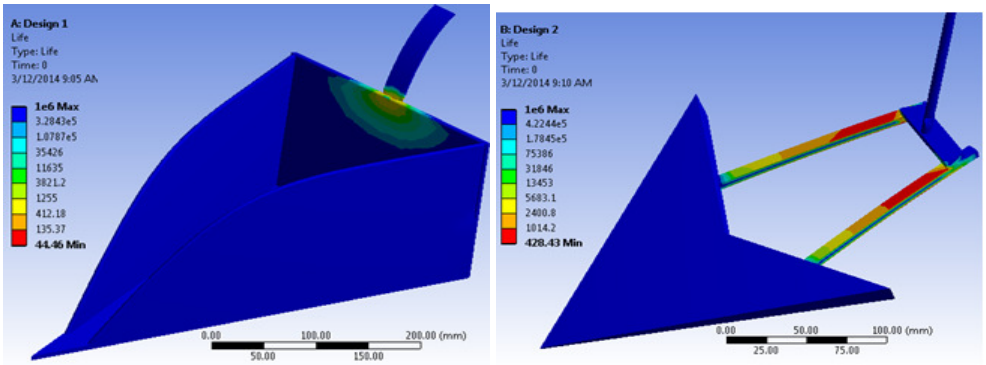

Figure 11. Comparative Fatigue Results of Both Chisel Plows

Table 8. Fatigue Results on Chisel Plows

Fatigue Results		
	Old Model of Chisel Plow	New Generation Model of Chisel Plow
Failure Occurs at	35,426 Cycles	4,22,440 Cycles

Thus, the Fatigue result shows that at the same magnitude of force, the Failure Occurs in Old Model of Chisel Plow is **at 35,426 Cycles** and in New Generation Model of Chisel Plow is **at 4,22,440 Cycles.**

Thus, the Old Model of Chisel Plow gets failure then New Generation Model of Chisel Plow at the same magnitude of force & fixed support.

Thus, the Parametric Results on the basis of Stress, Strain, Deformation and Fatigue Results, the New Generation Model of Chisel Plow is much Safe than the Old Model of Chisel Plow. The design of New Generation Model of Chisel Plow is much safe design for an agriculture use. Also the life of New Generation Model of Chisel Plow is greater than Old Model of Chisel Plow.

CONCLUSION

A tillage tool such as Chisel Plow is designed in computer aided design software. The motion of Chisel Plow and soil surface interaction is considered. The tillage operations introduces a quality parameters and development scope in obtaining a width of cut , depth of cut, Speed of operation, field efficiency, field capacity, theoretical draft the rate of work, quality of work, draft measurement etc. The analysis of stress, strain, deformation and life cycle shows the safe designs at the same range of input parameters between old model of Chisel Plow and New Generation Model of Chisel Plow.

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AUTHORS:

Pawan Sharma has completed his B.Tech in Mechanical Engineering, M.Tech in Machine Design from RTU (Kota), Rajasthan, INDIA. He has published more than 25 research papers in the refereed International journals and conferences. He has published three Engineering Books in the field of FEA/FEM. His area of research includes CAD/CAM, FEA/FEM, Composite Materials, CFD and Vibration Analysis.

Prof. (Dr.) Manish Bhargava holds M.Tech. in Manufacturing System Engineering, Ph.D. in Mechanical Engineering from MNIT, Jaipur. He has published more than 30 research papers in the refereed International journals and conferences. He has a teaching and research experience of more than 14 years. Currently, He is working as a Professor in Mechanical Engineering & Principal with Maharishi Arvind Institute of Engineering and Technology, Jaipur, Rajasthan, India. His area of research includes CIMS, CAD/CAM, Reliability & Maintenance, Manufacturing Systems and Material Science.