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Dynamic Analysis on Tillage Equipment Used in Agriculture Using Ansys Software

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ABSTRACT

Tillage is the agricultural preparation of soil by mechanical agitation of various types, such as digging, stirring, and overturning. Primary tillage process tillage equipment loosens the soil and mixes in fertilizer and plant material, resulting in soil with a rough texture. Secondly, the tillage process, tillage equipment produces finer soil and in few cases shapes the rows, preparing and arranging the seed bed as per the requirement. It also provides weed control from beginning to the end the growing season during the total maturation of the farms, unless such weed control is instead achieved with low-till or no-till methods involving herbicides. In the process of cultivation tillage equipment under goes worst loading condition which reduces the life of the equipment. In this project, a detailed structural Analysis of the tillage equipment under the worst loading condition was carried out. During the part of a project, a dynamic analysis of tillage equipment was performed using finite element analysis package. The three dimensional model of the tillage equipment shall be designed using NX-CAD. Then the 3-D model shall be imported into ANSYS using the Para solid format. The analysis can be evaluated in a dynamic condition. From the analysis results, Mode shapes and frequencies are documented by using FEA software. Harmonic analysis is performed by providing the force i/p to determine amplitude v/s frequency, and the graphs are marked. Transient analysis is done by providing Impulse or Shock loads for determining Amplitude w.r.to Time and the graphs are plotted. In this project, we shall also find out the safety factor of tillage equipment. Finally, design optimization of the tillage equipment shall be done to increase the life of the tillage equipment component. NX-CAD software shall be used for 3D modeling of the tillage equipment and ANSYS software shall be used to do the structural analysis of the tillage equipment.

Keywords : Tillage, Soil, Harmonic & Transient Analysis, NX-CAD

I. INTRODUCTION

Tillage is the agricultural (farming) development of soil by mechanical agitation of many types, such as digging, overturning, and stirring. Examples for human-powered tilling techniques using hand tools such as shoveling, picking, raking, hoeing, and mattock work. Examples of animal-powered or completely mechanized working include ploughing (overturning with moldboards or chiseling with chisel shanks), rot tilling, rolling, spanning with cult packers or other rollers, cultivating, and harrowing with cultivator spines (teeth). Small-scale grassing and farming, for household food cultivation or small business production, tend to use the small-scale procedures above, whereas medium- to completely large-scale farming tends to use the larger-scale methods. There is a fluid continuum, however. Any grassing or farming, but particularly larger-scale commercial categories, may also use low-till techniques as well.

Tillage is categorized into two types, primary and secondary. Between these no strict boundary between them so much as a weak distinction tillage that is way harder and more through (primary) and tillage that is narrow and a few times more particular of location (secondary). Primary tillage like ploughing tends to cultivate a rough surface finish, where about secondary tillage tends to develop a much smoother surface finish, as required to furnish a good seedbed for a wide variety of crops. Rot tilling and harrowing often combine primary and secondary tillage and work as the single operation.

II. LITERATURE REVIEW

Design Optimisation in Rotary Tillage Tool System Components by Computer Aided Engineering Analysis by Gopal U. Shinde and Shyam R. Kajale. The design optimisation of rotary tillage tool by the application of Computer Aided Engineering (CAE)-Techniques by finite element and simulation methods are done in CAD-Analysis software for the results in structural analysis. The various tillage tool parts of rotary tillage tools are geometrically constrained by the preparation of robust model, Meshing and Simulation are done with actual field performance rating parameters along with boundary conditions. The energy limited for the tillage tool applications with 35Hp and 45Hp power tractor and estimated forces acting at the soil-tool interface. The subsequent effect on tillage blade and whole rotor assembly is procured from deformations plots and stress distribution. The suggested work results in identifying sufficient tolerance in the change of the dimensions of rotavator frame sections and side gear box for eliminating the surplus weight in a solid section and also to increase the weight of blade for a reliable strength. The present working model with tillage blade is analysed to new design constraints with a change of its geometry for the most of the weed removal efficiency by showing its practical results from the field performance.

Design and Development of rotor blade by Prof.Mr Yendhe N.L, Mr Shinde V.B, Mr Sangle H.S, Mr Malve R.N, Mr Bari G.E. The soil tilling is an older technique applied in farm and rotavator is a tilling machine used on a farm for soil tilling. Since the blade is a crucial part in rotavator and it can manufacture or fabricated in different shapes like L, J and C. In L-shape type two more subtype is a) right hand L-shape blade b) Left-hand L-shaped blade, These shapes are manufactured as per local manufacturer. This study is aimed at design and development of L-shape rotavator blade of alloy steel and plain carbon steel. The life of the blade is a crucial factor, and it depends on forces coming on blade and force and geometry of blade has a direct relationship with each other. For the increase in life span of blade forces coming on it should be reduced. For the above reason, a mathematical model is developed, and analysis of new model and previous model is carried out using Solid Works software applying Finite element analysis method by stresses and deflection induced in blade after application of force. This result is compared with each other, and it is found that new model has less deflection and fewer stresses induce in a blade.

III. PROBLEM DEFINITION AND METHODOLOGY

Problem Definition

Now a day new Technologies are developing by human's knowledge. Agriculture technology is one of them. Development of farming field is very costliest. Simple structures and excellent efficiency of components increase the utilization and life growth rate of elements. These are all performed in design optimization. Tillage operations such as the creation of seedbed movements of soil from high to low places, farm road construction, land leveling etc. have depended on the design of tillage. To good seedbed preparation, design optimization of tillage component is necessary. The current document presented about a 3D model of tillage component by using NX CAD software. Developed 3-D model of tillage component imported into ANSYS using the Para solid format. The analysis shall be performed in a dynamic condition. Modal analysis and Harmonic analysis and Transient analysis are carried out by providing inputs as force impulse or shock loads in FEA software.

Methodology:

Develop the 2D sketch and 3D model of tillage components by NX CAD software.

Assembly of tillage components is performed in NX CAD software.

Modal analysis executed in ANSYS 15.0 software to determine the natural frequencies and their mode shapes. Harmonic analysis of tillage is done in ANSYS 15.0 software.

Documentation of frequencies and amplitudes are done. Transient analysis of tillage is performed in ANSYS15.0 software. Documentation of time and amplitudes are plotted. Modifications are done to model for better results.

IV. 3D MODELING OF TILLAGE EQUIPMENT ASSEMBLY

3d modeling of tillage equipment assembly consists of several parts. All the parts of the tillage equipment assembly are modeled in NX-CAD software.

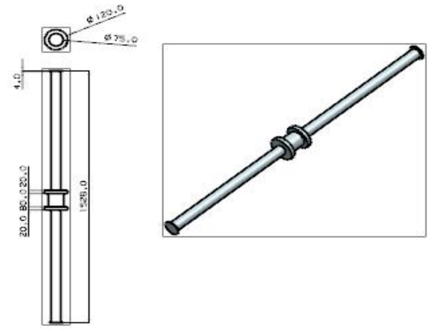


Fig.1: shows drafting and 3d model of flange

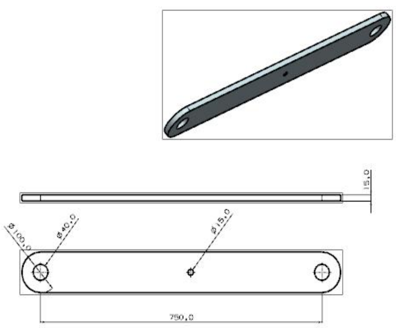


Fig.2: shows drafting and 3d model of collar support

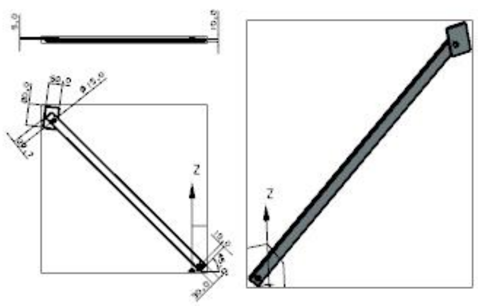


Fig.3: shows drafting and 3d model of independent top mast

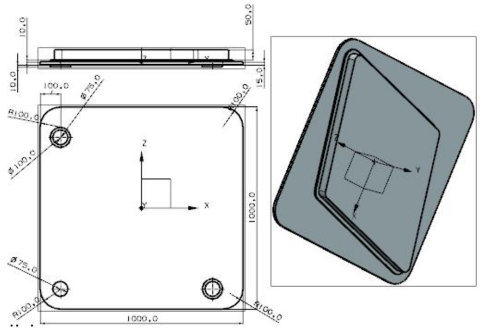


Fig.4: shows drafting and 3d model of gear drive

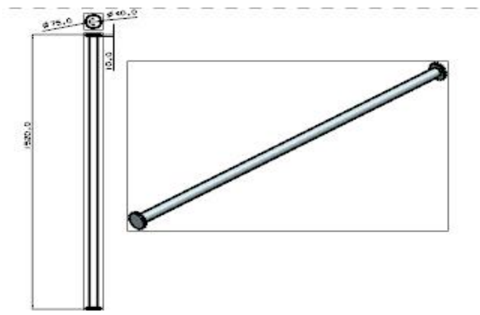


Fig.5: shows drafting and 3d model of plane flange

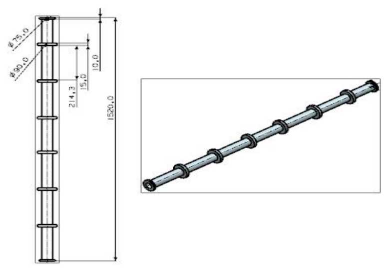


Fig.6: shows drafting and 3d model of spine with circular segments

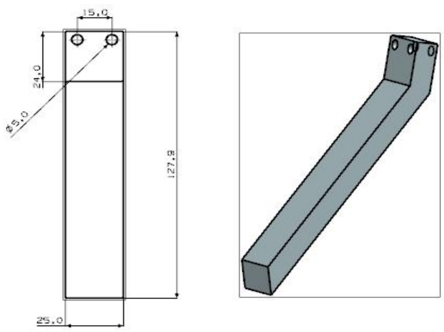


Fig.7: shows drafting and 3d model of blade

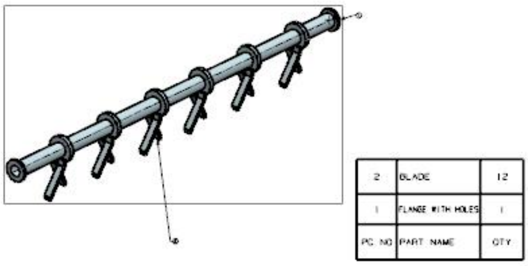


Fig.8: shows drafting and 3d model of flange and blade assembly

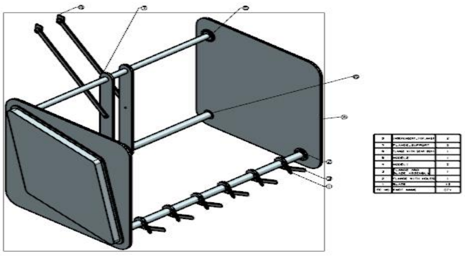


Fig.9: shows 3d modeling of tillage equipment assembly

V. FINITE ELEMENT ANALYSIS OF TILLAGE EQUIPMENT ASSEMBLY

FEM (Finite Element Modeling) and FEA (Finite Element Analysis) are two most leading mechanical engineering applications offered by existing CAE systems. This is attributed to the reality that the FEM is perhaps the most popular numerical technique for solving engineering problems. The method is common enough to handle any complex shape of geometry, any material properties, any loading conditions and any boundary conditions. The generality of the FEM suits the analysis requirements of today's critical engineering systems, and designs, where closed form solutions are governing equilibrium equations, are not available. Also, it is an efficient design tool by which designers can perform parametric design studying various cases (material loads, different shapes, etc.) analyzing them and choosing the optimum layout.

MODAL ANALISYS OF TILLAGE EQUIPMENT ASSEMBLY

Material properties of Hadfield manganese steel:

Young modulus(E) = **206GPa**

Density (ρ) = **7880 kg/m3**

Yield strength = **380MPa**

Poison's ratio = **0.3**

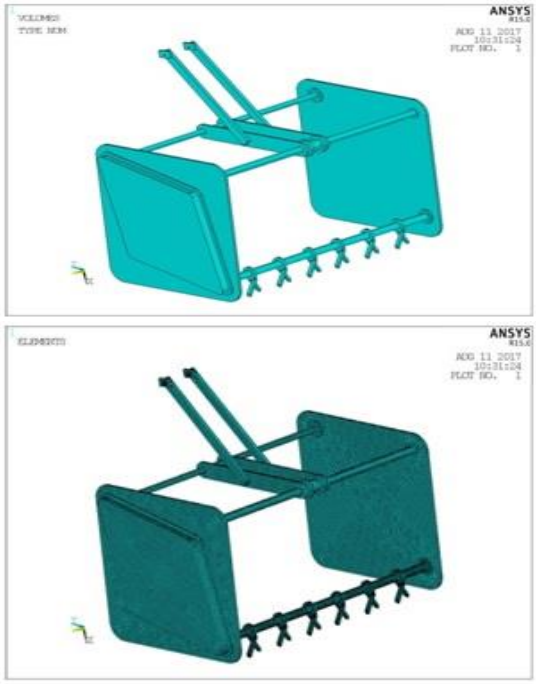


Fig.10: Shows the Geometric and FE Model of the Tillage equipment Assembly

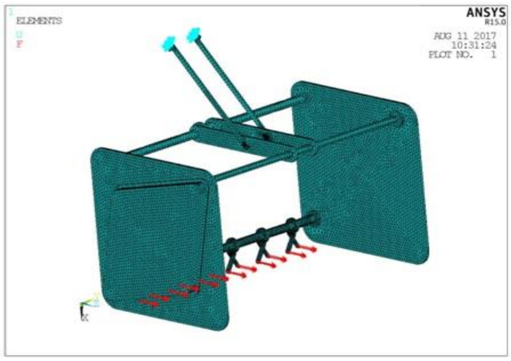


Fig.11: shows boundary and loading conditions used on the tillage equipment assembly

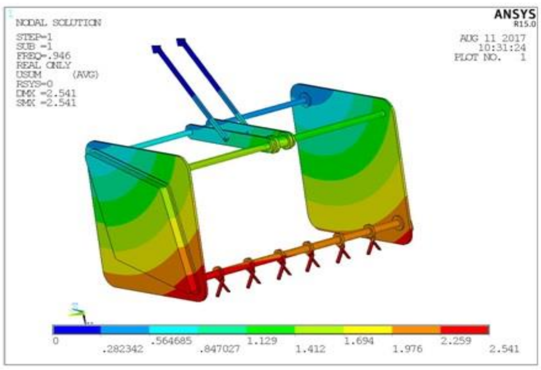
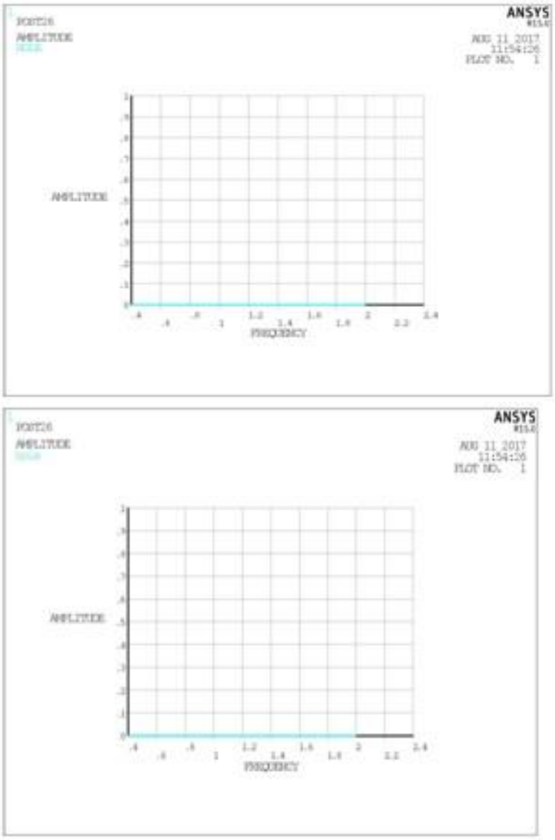


Fig.12: shows Displacements and stresses of tillage equipment assembly @0.94 Hz

Below graph shows comparison of graph between stepped and ramped frequencies of the hole on the top mast in harmonic analysis



Graph.1: shows comparison of graph between stepped and ramped rates of the hole on the top pole in harmonic analysis

VI. 3D MODELING OF MODIFIED TILLAGE EQUIPMENT ASSEMBLY

Tillage equipment assembly is amended by increasing the thickness of the independent top mast, Diameter of a hole on top pole changed, and the thickness of the blade is increased for a better factor of safety for forced vibrations.

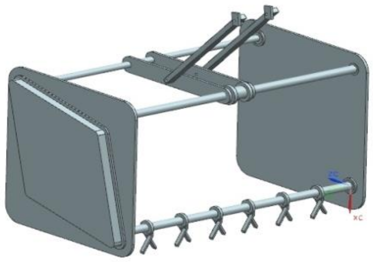


Fig.13: shows 3d modeling of modified tillage equipment assembly

VII. MODAL ANALYSIS OF MODIFIED TILLAGE EQUIPMENT ASSEMBLY

Modal analysis was carried out on modified tillage equipment assembly to determine the natural frequencies and mode shapes of a structure in a range of 0 to 3.5 Hz. From the modal analysis, a total of 2 natural frequencies are observed in a range of 0 to 3.5 Hz. The total weight of the modified tillage equipment assembly considered for the analysis is 0.79 Tones.

Boundary conditions: The boundary conditions applied for the modal analysis are shown below

The positions where are modified tillage equipment attached to the vehicle are constrained in all DOF.

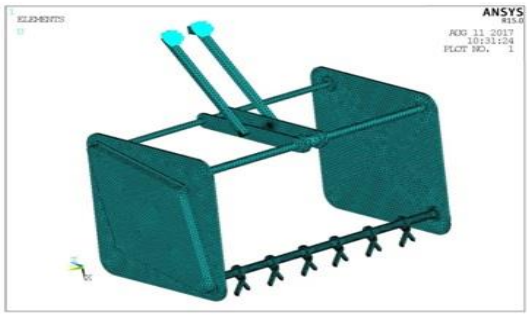


Fig.14: Shows the boundary conditions on modified tillage equipment assembly

TRANSIENT ANALYSIS OF TILLAGE EQUIPMENTASSEMBLY

Transient analysis is a technique commonly used to determine the response of a structure to arbitrary time-varying loads such as an explosion. The transient dynamic analysis is used in the design of Structures subjected to shock loads, such as automobile doors and bumpers, building frames and suspension systems. Structures subjected to a time-varying load such as bridges, earth moving equipment, and other machine components. Household and office equipment subjected to "bumps and bruises," such as laptop, computers, cellular phones, and vacuum cleaners.

- The equation of motion for a transient dynamic analysis is the same as the general equation of motion.

$Mu+C\{u\}+K\{u\}=\{Ft\}$

- This is the most general form of dynamic analysis. Loading may be any arbitrary function of time.

Depending on the method of solution, ANSYS allows all types of nonlinearities to be included in a transient dynamic analysis - large deformation, contact, plasticity, etc.

RESULTS

Displacements and Stresses at sub step-1 of load step-2:

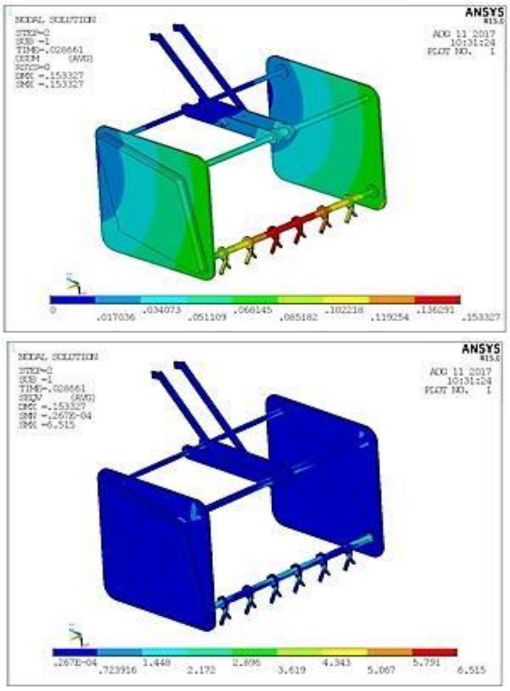
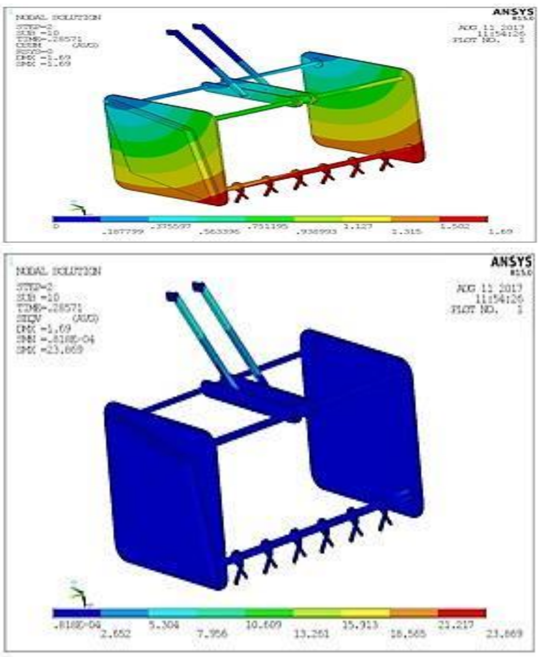


Fig.15: shows total displacement, and Von Mises observed on modified tillage equipment assembly

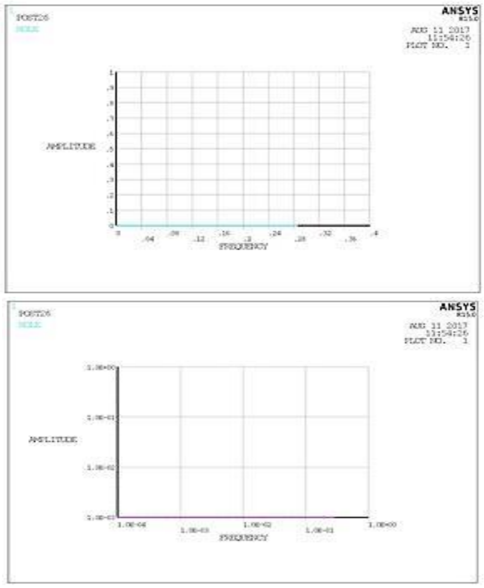
Displacements and Stresses at sub step-10 of load step-2:



GRAPHS:

Graph-2:

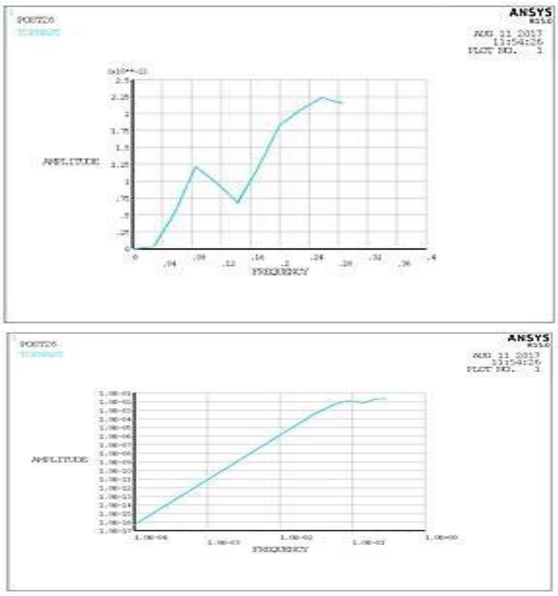
Fig shows graph between amplitude vs frequency of the hole on the Top Mast for transient analysis



Graph.2: shows graph between amplitude vs frequency of the hole on the Top Mast for transient analysis

Graph-3:

Graph shows graph between amplitude vs frequency on the Top Mast for transient analysis



Graph 3: shows graph between amplitude vs frequency on the Top Mast for transient analysis

VIII. RESULTS AND CONCLUSION

Tillage equipment assembly was modeled in NX-CAD software. Tillage equipment assembly is studied for different analysis. They are

1) Modal Analysis
2) Harmonic Analysis

Modal analysis of tillage equipment assembly:

The following observations are made from the modal analysis:

- The total weight of the tillage equipment convention is 0.78 Tons.
- The mass participation of 0.12 tons is observed at frequency 0.94 Hz in X-direction which is 15.3% of the total mass of the tillage equipment.
- The mass participation of 0.68 tons is observed at frequency 1.96 Hz in Y-direction which is 87.1 % of the total mass of the tillage equipment.
- The mass participation of 0.51 tons is noticed at frequency rate 0.94 Hz in Z-direction which is 65.3 % of the total mass of the tillage equipment.

To check the magnitude values of deflections and stresses at the frequencies as mentioned earlier due to the operating loads, harmonic analysis is carried out on the tillage equipment assembly.

Harmonic analysis of tillage equipment assembly:

From harmonic analysis results, the yield strength of the material, i.e. 380MPa. In case of 1.21Hz frequency, the Von Mises stress is less than the yield strength, but considering the factor of safety, it is deficient. So, there is a chance of failure for sudden loads. Hence, modifications are to be done on the model of tillage material assembly to get the better factor of safety.
3D Model of tillage equipment is modified and following analysis was done on the tillage equipment assembly. They are:

1. Modal analysis
2. Harmonic analysis
3. Transient analysis

Modal analysis of modified tillage equipment assembly:

The following observations are made from the modal analysis:

- The total weight of the modified tillage equipment assembly is 0.79 Tons.
- The mass participation of 0.11 tons is observed at frequency 1.45 Hz in X-direction which is 13.9 % of the total mass of the modified tillage equipment.
- The mass participation of 0.086 tons is observed at frequency 1.31 Hz in Y-direction which is 10.8 % of the total mass of the modified tillage equipment.
- The mass participation of 0.51 tons is observed at frequency 1.45 Hz in Z-direction which is 64.5 % of the total mass of the modified tillage equipment.

To check the magnitude values of stresses and deflections at the frequencies mentioned above due to the operating loads, a Harmonic analysis is carried out on the modified tillage equipment assembly.

Harmonic analysis of modified tillage equipment assembly:
From harmonic analysis results, the Von Mises stress at all frequency is lower than a yield strength of the material, i.e. 380 MPa and factor of safety is also high. So, modified tillage equipment assembly further studied for transient loads.

Transient analysis of modified tillage equipment assembly:

Table-7: Shows the step wise results on displacement, Von Mises stress and Factor of safety

Load sub step	Displacement	Von misses stress	Factor of safety
STEP 1	**0.15**	**6.5**	**58.4**
STEP 2	**0.21**	**6.05**	**63.3**
STEP 3	**0.35**	**14.04**	**26.3**
STEP 4	**0.55**	**10.92**	**34.5**

STEP 5	**0.81**	**6.94**	**54.7**
STEP 6	**0.99**	**13.03**	**29.2**
STEP 7	**1.17**	**19.81**	**19**
STEP 8	**1.38**	**22.20**	**17.2**
STEP 9	**1.54**	**24.72**	**15.2**
STEP 10	**1.69**	**23.86**	**15.8**

From above results, modified tillage equipment convention at every intermediate step of load step-2 has von misses stresses less than the yield strength of the material. The yield strength of the material (i.e. steel) is 380 MPa. The factor of safety of tillage equipment at every individual step of load step-2 is good. Hence, the modified tillage equipment is also secure for transient weights.

IX. CONCLUSION

The tillage equipment assembly is modeled in NX-CAD software, and ANSYS software was used to perform the finite element analysis for Hadfield manganese steel. First natural frequencies are marked by performing modal analysis on, tillage equipment assembly. Later on, the Harmonic analysis is carried on tillage material assembly. The stress at all frequencies is less than the yield strength of the material, but the factor of safety is very low at a 0.66Hz frequency. So, to get the better factor of safety 3D model of tillage equipment assembly is modified. The amended tillage assembly is subjected to modal analysis, preceded by harmonic analysis, Transient analysis. All the analyses the results are better than original tillage equipment assembly. Hence it was concluded that modified tillage equipment assembly is better than that of original tillage equipment assembly.

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