DESIGN AND DEVELOPMENT OF A CHASSIS FRAME FOR MINI-HARVESTING MACHINERY

Darwish Jahangir[1], Adithyan Pradeep[2], Anal Raj[3], Adwaith Prasannan[4]

[1,2,3,4] *B.Tech Student, Department of Mechanical Engineering, Rajadhani Institute of Engineering and Technology, Trivandrum, Kerala 695102*

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***Abstract** - The purpose of this thesis is to design and create a chassis frame for a harvesting automobile's harvesting mechanism. The focus of this research is on the viability of simple manufacturing at the lowest possible cost. The present industries have identified many types of chassis for forming equipment, particularly harvesting equipment. Those chassis are being investigated. Different harvesting equipment load scenarios are also investigated. A new chassis design is created based on the findings of the investigation using Solidworks 2020. The harvesting part assemblies that were previously designed are assembled on the chassis using various bolts and plate connections to connect the various assembly parts. As previously stated, the Chassis is designed, developed, and verified for a variety of load scenarios using Ansys Workbench.*

Key Words: **Chassis frame, Harvesting Automobile, Harvesting Mechanism, Solidworks, Assembly, Ansys, Load Scenarios.**

1. INTRODUCTION

Farming is one of the most important occupations for generating food and food products all over the world. India is one of the world's largest producers of rice, wheat, and vegetables. Farmers cultivate crops in a systematic manner at various times throughout the year. Every crop production requires a great deal of manual labor and physical effort. Engineers are working on a variety of semi-automated and mechanical machinery to aid in the growing of formals. We are developing a chassis frame for a tiny harvesting machine in this thesis.

Every automobile's chassis frame is a critical component. It's the foundation on which the vehicle's components are mounted. The vehicle's body is constructed on top of the chassis frame. When compared to a standard automobile chassis, the chassis frame of a harvesting machine carries a variety of loads.

A vehicle chassis is designed and engineered to withstand loads resulting from various flat road conditions. However, harvesting machines work in fields with extremely uneven topography, putting extraordinary pressures on their chassis.

A chassis in common bears all of the mechanical parts and the vehicle body, ensuring that the vehicle is balanced on the road or terrain. A chassis structure for the aforementioned micro harvester is designed in this bachelor thesis. The loads and load cases for the chassis to function is analyzed and verified for its durability.

1.1 CHASSIS

Chassis is a French word that refers to the vehicle's frame components or primary structure. It is often referred to as a carrying unit. A chassis is the framework upon which a vehicle is constructed. It also supports numerous components that are installed on it while carrying the weight as well as permits smooth run over varying road surface. It is comprised of steel and serves as the vehicle's backbone. All major units required to drive the vehicle, give it motion, and stop it is equipped on the chassis itself.

1.2 FUNCTIONS OF CHASSIS

The following are the functions of the Chassis. It:

- Supports or bears the vehicle's body load.
- Provide space and a mounting position for various vehicle components.
- Supports the weight of the vehicle's different systems, such as the engine and transmission.
- Supports the weight of passenger and such varying loads.
- Withstands the strains caused by poor road conditions.
- Sustains vehicle stresses during braking and acceleration.

1.3 TYPE OF LOADS ACTING UPON CHASSIS FRAMES

The loads operating on the chassis frame are as follows:

- Stationary loads refer to loads that are permanently attached to the vehicle, such as the chassis and body.
- Loads caused by unexpected events, such as head-on collisions.
- Loads resulting from vehicle irregularities and overloading.
- Short-duration loads: the vehicle load when turning or braking.
- Momentary loads, which are applied to the vehicle during rapid acceleration, sharp braking, and so on.

- The weights applied when crossing terrains with irregular or uneven surfaces.

1.4 CLASSIFICATION OF CHASSIS FRAMES

Chassis frames are classified into:

- Conventional Chassis or frame-full chassis
  This type of chassis comprises of two long members and suitable number of cross members to make a ladder form. It is usually seen in commercial vehicles such as trucks and busses and some SUVs. Some passenger vehicles still use this frame due to its high load capacity and strength and its practical feasibility of easy manufacturing. The major disadvantage is that the body tends to vibrate easily and the vehicle dynamics are drastically compromised when compared to the other types.

- Non-Conventional or Frameless Chassis
  It's also known as a uni-body chassis or a frameless chassis. This chassis does not have a ladder frame; instead, the body serves as a frame. It also supports all of the vehicle's elements and components. These are commonly utilized on most modern vehicles in the same way that traditional chassis are.

2. METHODOLOGY

Following the research, extensive expertise of concept design with presumptive parameters, hand calculations, 3D modelling, material selections, and harvester operation systems with consideration of the target and objectives is gained. The design's outcomes were assessed and debated. A thorough conclusion is then reached in light of all the findings.

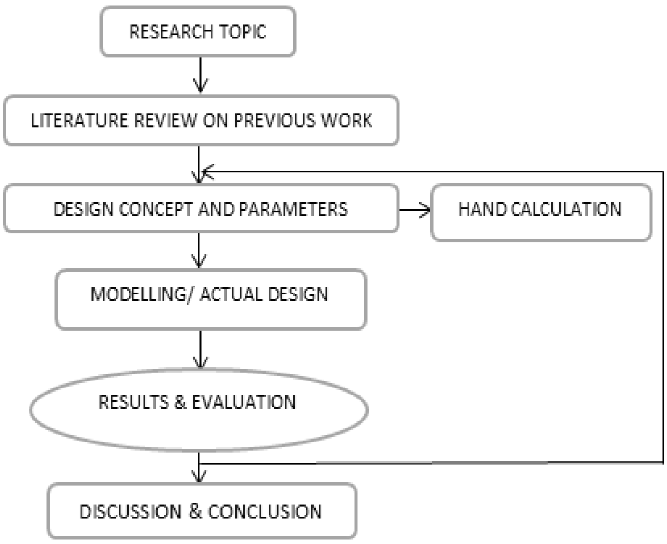


Fig -1: Methodology

3. MODEL DESCRIPTION

As illustrated in the diagram, the chassis geometry is put together with the following parts. The long-members, cross-members, and C-clamp are all part of the chassis frame geometry. Because these parts are identical, they can be mounted together appropriately to form a whole chassis assembly. Two of these long-members, three of these cross-members, and six of these C-clamps were utilized for the chassis sub-assembly alone.

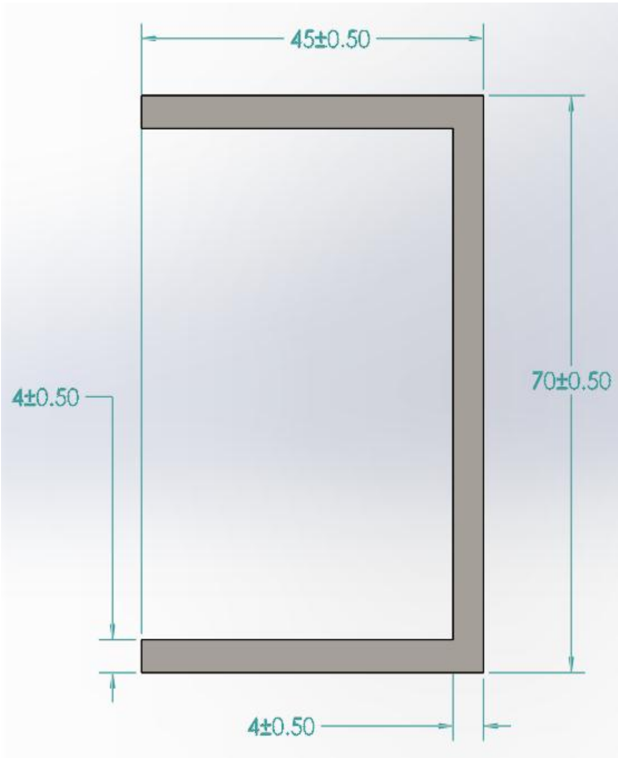


Fig -2: Cross-section dimension of the long member

The chassis dimensional parameters were compared to information in reference journals and validated with Indian Standards (ISO) for practicality. Because this thesis is primarily concerned with cost reduction, all of the parts designed and used here will be manufactured of sheet metal, which is easily available and inexpensive. All of the planned pieces were tested for production viability using conventional sheet metal forming techniques like curling, punching, and blanking. The chassis structure was made out of AISI 1045 Mild Steel, which is ideal for our application.

AISI 1045 is a medium tensile low hardenability carbon steel generally with a typical tensile strength range 570 - 700 Mpa and Brinell hardness range 170 - 210. This type of steel exhibits medium tensile strength, good weldability and machinability, and high strength. Typically used in machinery parts, die forging, hot upsetting, gears, crankshafts, shafts, axles, bolts, studs, pinions, casters, and support plates. It approximately constitutes of 98.5% of Iron, 0.45% of Carbon, 0.74% of Manganese and less than 0.04% of Phosphorous.

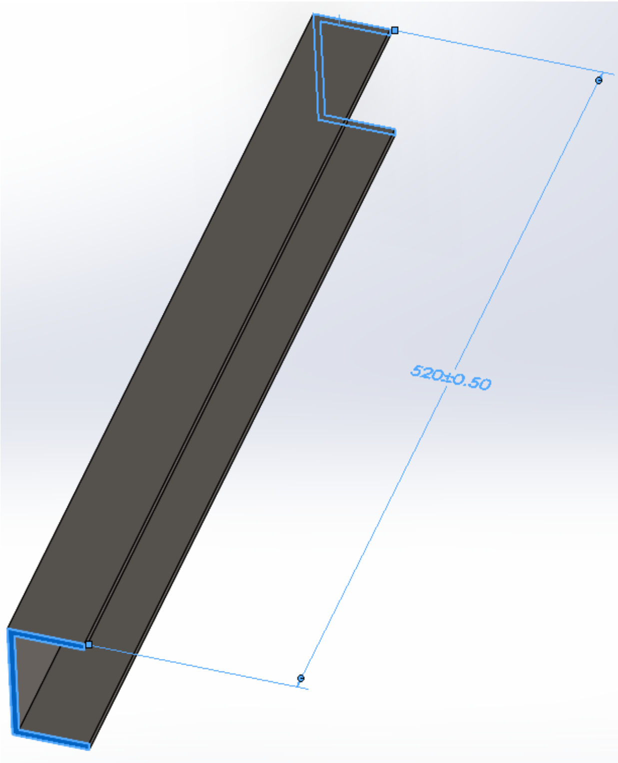


Fig -3: Lateral dimension of the long member

Similar to that illustrated in the figures 2 and 3, for the cross-members, the cross-sectional dimensions were given 26mm, 54mm and a thickness of 4mm respectively whereas the lateral dimensions were given the value of 790mm all with a tolerance of 0.5mm.

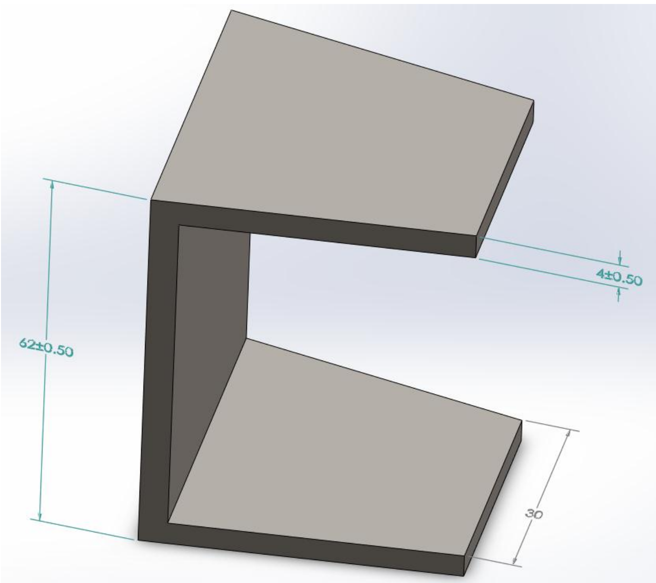


Fig -4: Dimensions of the C-Clamp

3.2 HARVESTING EQUIPMENT

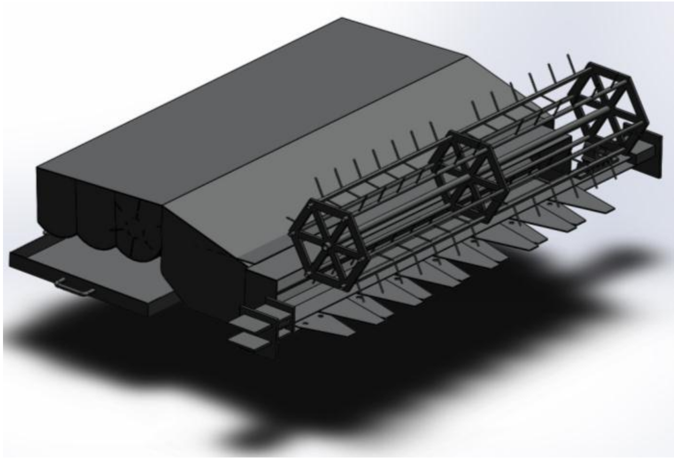


Fig -5: Pre-designed outlook of the harvesting machinery

Figure 5 depicts the pre-designed assembly of harvesting machinery components. For preliminary load estimates, this equipment is considered to be made of alloy steel. Each portion of this apparatus is built in such a way that it may be made entirely of sheet metal, dramatically lowering the manufacturing costs. It was made a point throughout the design process to avoid using fillet or curves that would be incompatible with sheet metal forming methods.

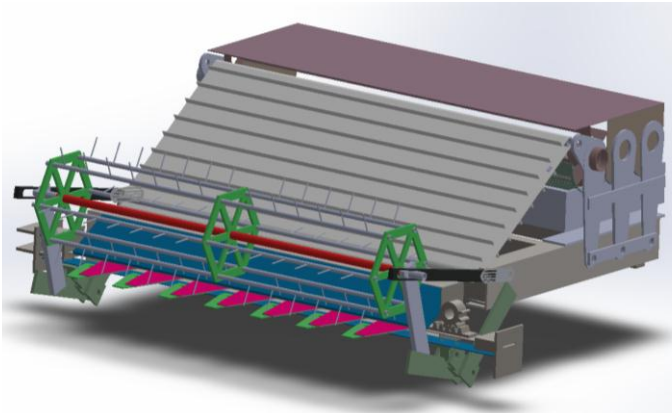


Fig -6: The internal parts and connections of the harvesting equipment on the chassis frame

All of these parts were designed and developed in consideration with the present days existing outlook of the mini and conventional harvesting equipment.

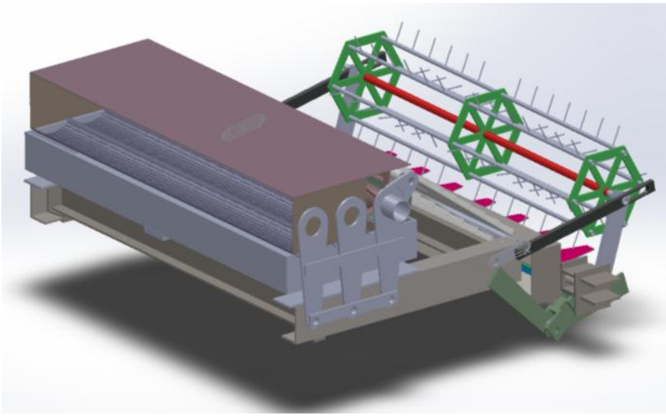


Fig-7: Rear isometric view of the internal parts and connections of the harvesting equipment on the chassis frame

3.3 MATERIAL PROPERTIES

Table -1: CHEMICAL COMPOSITION

Element	Content
Carbon, C	0.420 - 0.50 %
Iron, Fe	98.51 - 98.98 %
Manganese, Mn	0.60 - 0.90 %
Phosphorous, P	≤ 0.040 %
Sulfur, S	≤ 0.050 %

Table -2: MECHANICAL PROPERTIES

Mechanical Properties	Metric	Imperial
Hardness, Brinell	163	163
Hardness, Knoop (Converted from Brinell hardness)	184	184
Hardness, Rockwell B (Converted from Brinell hardness)	84	84
Hardness, Vickers (Converted from Brinell hardness)	170	170
Tensile Strength, Ultimate	565 MPa	81900 psi
Tensile Strength, Yield	310 MPa	45000 psi
Elongation at Break (in 50 mm)	16.0 %	16.0 %
Reduction of Area	40.0 %	40.0 %
Modulus of Elasticity (Typical for steel)	200 GPa	29000 ksi
Bulk Modulus (Typical for steel)	140 GPa	20300 ksi
Poissons Ratio (Typical For Steel)	0.290	0.290
Shear Modulus (Typical for steel)	80 GPa	11600 ksi

Table -3: PHYSICAL PROPERTIES

Physical Properties	Metric	Imperial
Density	7.87 g/cc	0.284 lb/in^3

4. ANALYSIS OVERVIEW

The analysis is done using Ansys Workbench 2022 R1. For the most ease and simplicity for an efficient analysis, from various reference journals and practical inferences, the total load consideration along by including a factor of safety of 3 which is the usual amount for factor of safety considered for steel, we came into the conclusion that 6000N is being applied on the chassis frame totally. From relevant journals which focuses on the load cases acting upon the chassis frames shows us that the cross-members of the structures are the weakest part of the chassis were most amount of deformation due to the applications of load occurs. Also from engineering theories, we know that if the critical point on the structure withstands the total amount of load, then it is definite that the entire structure as a whole also withstands the load. Critical point is defined as the virtual point on any structure where when a load is applied is concentrated at maximum deformation is found. For our chassis frame, due to the above-mentioned highlights we can assume that the critical points is in the middle span of the cross- members.

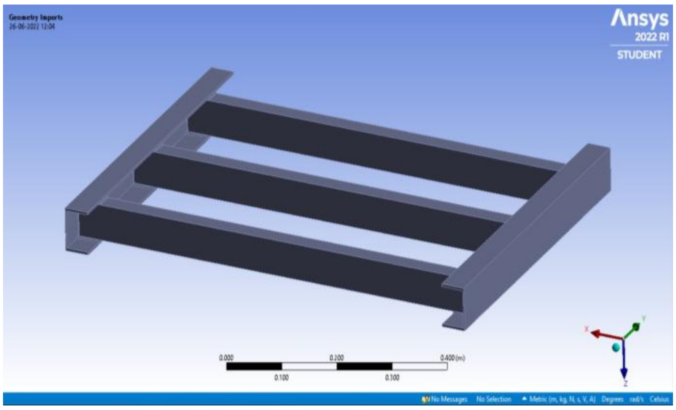


Fig -8: The chassis assembly for analysis

4.1 SUPPORTS FOR LONG MEMBERS

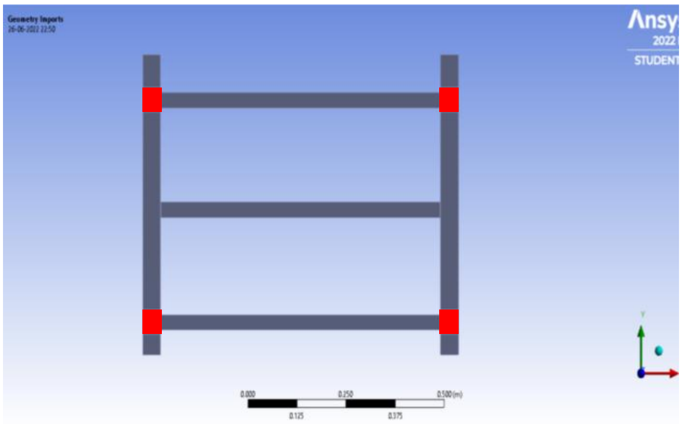


Fig –9: Red marking shows where the support reactions are applied at the bottom of the chassis frame

On the observation that as that of every common vehicle, this would also take the use of four-wheels mechanism for the purpose of motion. These four wheels provide supports from 4 corner regions. On assuming the supports by the four-wheel mechanism as four support reactions, we have applied four-point loads at the places marked in red in the above given figure. This assumption was also made into consideration from various reference journals and practical observations.

4.2 SUPPORTS FOR CROSS-MEMBERS

From the design we can see that the cross-members are attached to the long-members in a way that both the ends of the cross-members are fixed on the long-member with a C-clamp. On relating this to the engineering theories, we can significantly consider it as a beam with two ends fixed. For any beam with both ends fixed with have both horizontal and vertical reaction forces at both ends. Since we consider only vertical forces being applied for now, which also the major force here, the horizontal forces are neglected for the analysis, hence the horizontal support reactions are also neglected.

4.3 COORDINATE SYSTEMS

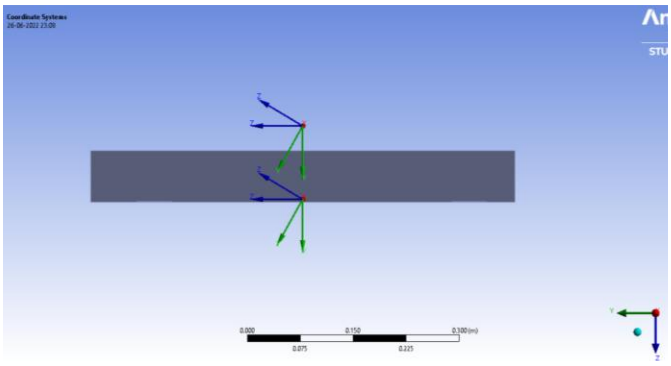


Fig -10: Side view of the coordinates in the geometry

As we can see in the diagram there are two coordinates for the geometry, in which one of them corresponds with the coordinate system for the chassis frame assembly and the other coordinate system with its origin happening to be from the centre of gravity of the entire machinery which includes both the harvesting equipment, the chassis and the parts connecting them.

On detailed studies, for a particular load condition for our analysis when the machinery is moving along a 30-degree inclined path, the same load is to be applied with 30-degree inclination with respect to the vertical axis (y axis). For the same reason one more axis is created with 30 degrees of inclination with the vertical axis as like the above given figure demonstrates.

4.4 CONNECTIONS

On defining the connections for the analysis of the imported geometry, the input was given that all the components are connected to each other as per the given constraints and the coincident faces.

4.5 MESHING ATTRIBUTES

The above shown mesh in the diagram is generated with an element size of 1.e-002 m (1.094x10^{-2}m) which was given by the adaptive sizing function available. The elements of mesh for the long members were considered triangle and for the Cross-members were considered rectangle. That is also taken into consideration for generating meshes from reference journals of such analysis. For the C-clamps also the elements were considered triangles. From the detailed mesh report available in the software, we can see that the total number of nodes are 78776 and the total number of elements present in this geometry is 21852.

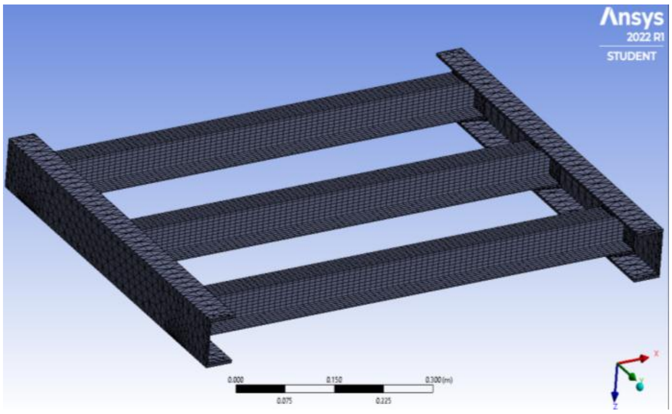


Fig -10: View of mesh for the analysis

5. RESULT FOR DIFFERENT LOAD CASSES APPLIED

5.1 0^0 STATIC LOAD

As per the analysis considerations previously mentioned in this thesis, for the practical case where only the dead load of the harvesting machinery is acting upon it when the machinery is static or kept stationery, the deformation for this scenario is obtained.

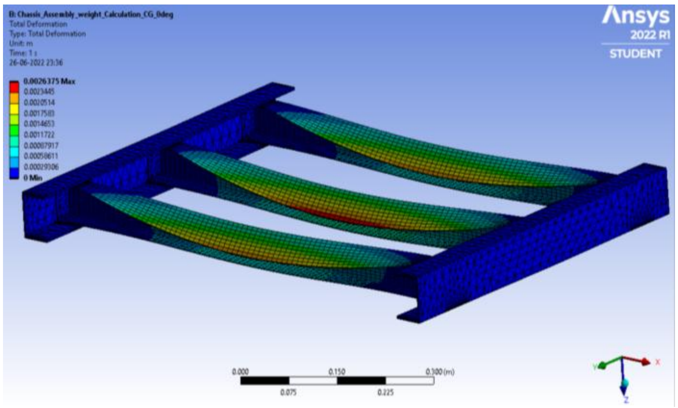


Fig -11: Deformation for 0-degree load

From the image we can see that the maximum deformation happening here is 0.0026375m which is visible to be happening at the previously assumed critical point region on the cross-member.

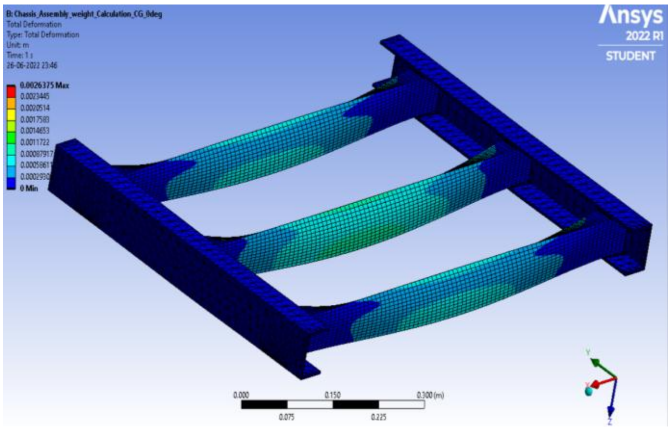


Fig -12: Isometric view of the deformation due to 0-degree static load

5.2 STATIC LOAD AT 30^0 INCLINATION

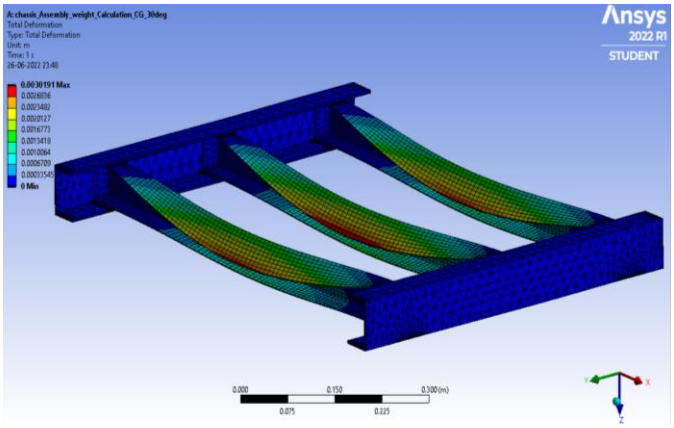


Fig -13: Deformation for 30-degree static load

On considering the practical application where the harvesting machinery taking its path of motion along a 30-degree inclined terrain, the static load due to the gravitational force would act in a way that it is acting inclined as much with respect to the inclination of the terrain. For that case study, we have inclined the load applied at an angle of 30 degrees with respect to the vertical axis (y axis) of the coordinate system employed for analysis. The deformation for such a case is thus obtained.

From the analysis, we can see that the total magnitude of deformation occurred is 0.0030191m which also located near the critical point region of the cross-member as studied earlier.

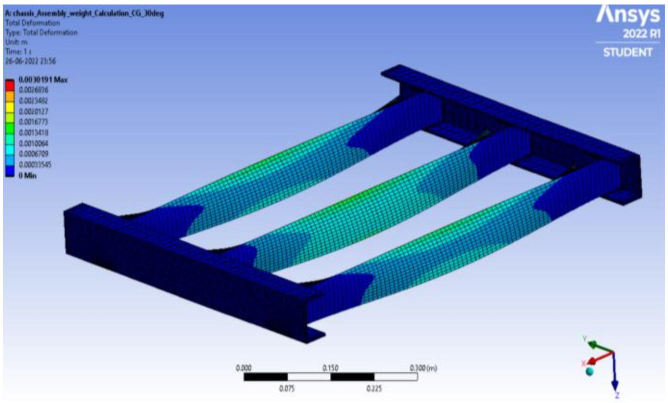


Fig -14: Isometric view of deformation due to 30-degree static load

5.3 WHEN ONE OF THE SUPPORT REACTIONS FAIL

This load condition came into consideration when in a practical scenario when one of its tyres falls into a pitch or breaks so that it fails to provide the support the machinery to rest normally. For this load condition study, we have removed one of its support reactions on the long member and the dead load is applied vertically in order to act like the above-mentioned practical case and for this the total deformation is obtained.

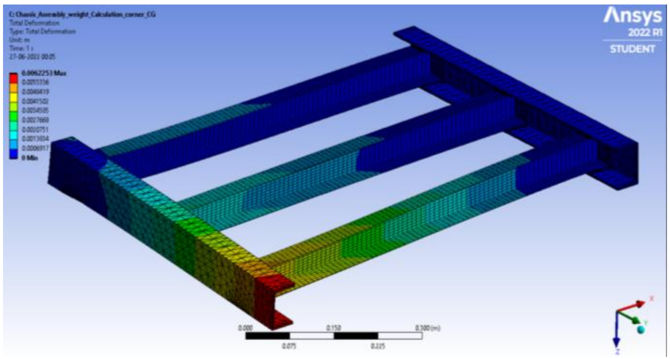


Fig -15: Deformation when one of the support reactions fail

Here it is observed that the total deformation happening here is 0.0062253m for the described case.

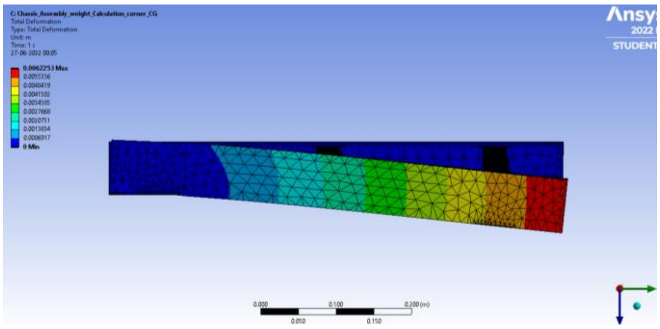


Fig -16: Side view of the deformation when one of the support reactions fail

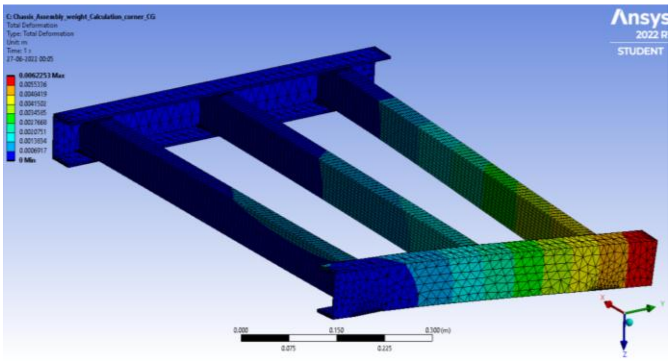


Fig -16: Isometric view of the deformation when one of the support reaction fails

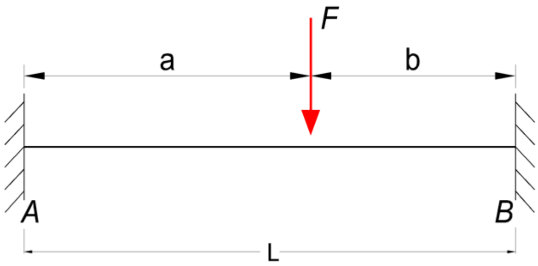
6. VERIFICATION OF THE RESULTS

6.1 VERIFYING THE DEFORMATION OBTAINED FOR 0-DEGREE LOAD CASE

Considering the cross-member as a beam with both ends fixed, but the horizontal support reactions are neglected because only vertical loads are applied, therefore there is no necessity of horizontal support reactions being formed.

The total load of 6000N is applied all along the three cross-member, therefore for the calculation of deformation for a single beam, we need to consider only one-third of the total load which is 2000N.

For a simply supported beam carrying a point load of 2000N eccentrically,



From data hand book of K Mahadevan we know, maximum deflection y_{max},

$$y_{max} = \frac{2}{3} \times \frac{Wa^2b^2}{EI(3a+b)^2}$$

Where,

W = load applied

b = distance from point of load applied to the right support

a = distance from point of load to the left support

E = Young's Modulus

I = Moment of Inertia for a C Section beam

Here,

W = 2000N

a = 395mm

b = 395mm

E = 205 GPa (AISI 1045 Steel)

a and b are equal as the load is considered as a point load here acting upon the centre of cross-member, but in real life practice the point of load applied may differ, thus the equation for eccentric loading is employed.

Moment of Inertia 'I' for C section (from K. Mahadevan Data hand book),

$I = [bd^3 – h^3(b-t)] / 12$

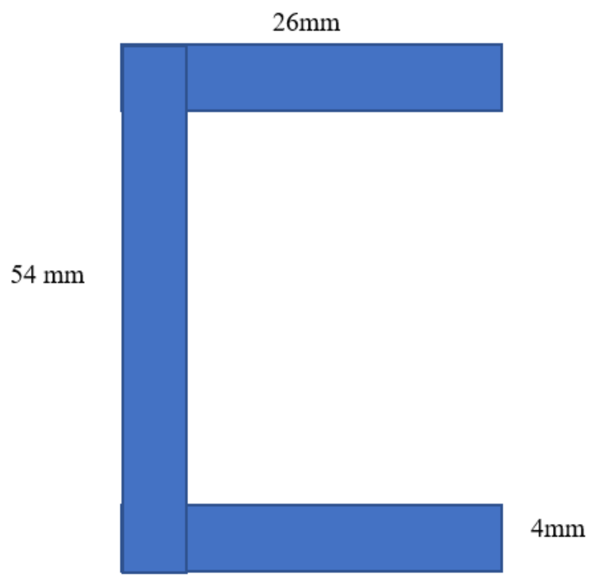


Fig -17: Cross sectional dimension of the cross member is illustrated in this diagram

Here,

b=26mm

d=54mm

t=4mm

h=50mm

For the given values,

Moment of Inertia I = 112005.33 $kgmm^2$

Thus, on substituting all the obtained values in the equation for maximum deflection,

y_{max} =2.598mm which is equal to 0.002598m of deflection

The obtained result on numerical calculation for deformation is almost similar to the deformation obtained on the computational analysis for the respective load condition. Hence the obtained results are successfully verified.

7. CONCLUSION

The difference between the value of the deformation obtained from the numerical calculation and the simulation calculation has a negligible difference of 0.032mm. This implies that the load cases calculations through simulation are sufficiently accurate and can be considered as the result of the study.

For both the 0 degree and 30-degree inclined load application it is observed that the maximum deformation is happening at the maximum allowable limit on the application of 6000N. The load of 6000N was considered including a factor of safety of 3 for steel as usual, which also makes it evident that practically this load is safe for the chassis to with stand.

Since the aim of this thesis was to study the practical feasibility of manufacturing a chassis frame with sheet metal, from the above static load conditions it is visible that it is visible that for this application as the chassis for harvesting machinery it is reliable.

The primary objective of the design is to reduce the cost of the final product by involving sheet metal to manufacture all of the necessary components for this harvesting machinery and hence found successful in that aspect too.

It is found that the chassis fails to withstand the load on the third load case study where one of the support reactions fail. In that particular point of view, this thesis can be further studied to overcome the failure happening in that instance which makes this concept of using sheet metal for chassis a total success.

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REFERENCES

[1] D. Kornack and P. Rakic, "Cell Proliferation without Neurogenesis in Adult Primate Neocortex," Science, vol. 294, Dec. 2001, pp. 2127-2130, doi:10.1126/science.1065467. Apata, T. G., Linkages between Crude-oil Exploration and Agricultural Development in Nigeria: Implications for relevant qualitative data collection and analysis to improve rural economy., 2010.

[2] Olajide, O. T., Akinlabi, B. H., and Tijani, A. A. Agriculture Resource and Economic Growth in Nigeria. 2012.

[3] Engineering Export Promotion Council (EEPC), Agricultural Machinery, Parts and Tractors Market in Nigeria., 2013.

[4] Talabi, S. O. and Onasanya, O. Agricultural Introduction. 2013 22/09/2014]

[5] Faborode, M. O. Strategies for sustainable National Agricultural Infrastructures Development. in Sustainable Engineering Infrastructures development. Port Harcourt: The Nigerian Society of Engineers,2001.

[6] Akande, L. O., Empowerment of the Rural People through Agricultural Mechanization, Osun State College of Education, 2006.

[7] Lamidi, W. A. and Akande, L. O., A Study of Status, Challenges and Prospects of Agricultural Mechanization in Osun State, Nigeria. 1(1): p. 001 -008, 2013.

[8] Takeshima, H. and Salau, S., Agricultural Mechanization and the Smallholder Farmers in Nigeria; Nigeria strategy support program, 2010.

[9] Abdulkareem, Y. A., Indigenous Technology, Past, Present and Futures, in Workshop for the Processing of Raw Materials: Raw Materials Research and Development Council, 1992.

[10] Adamade, C. A. and Jackson, B. A., Agricultural mechanization: a strategy for food sufficiency. Scholarly Journal of Agricultural Science. 4(3): p. 152-156, 2014.

[11] Asoegwu, S., Agricultural Field Implements and Mechanization., 1998.

[12] André-Michel, E. Despite recovery, Africa needs more jobs, says ECA. 2016.

[13] Quick, G. R. and Buchele, W. F., The Grain Harvesters. American society of agricultural engineers., 1978.

[14] Olukunle, O. T., Developments in Grain Harvesting Mechanisation. Journal of Agricultural Engineering and Technology (JAET). 18(1), 2010.

[15] AMRI, Test Report Indian Combine Harvester SWARAJ-8100, Agricultural Mechanization Research Institute (AMRI), Multan Government of the Punjab, Lahore, 2014.

[16] Ademosun, O. C., Adewumi, B. A., Olukunle, O. J., and Adesina, A. A., Development of Indigenous Machines for Weeding and Grain Harvesting: FUTA Experience. FUTAJEET 3(2): p. 77-84, 2003.

[17] BioSat Agricultural Biomass Sources. 2016.

[18] Karande, O., Gauri, S. K., and Chakraborty, Applications of Utility Concept and Desirability Function for Materials Selection. Material and Design Journal 45: p. 349-358, 2012.

[19] Shackelford, J. F., Introduction to Materials Science for Engineers. Fifth ed.: Prentice Hall, 2000.

[20] Granta, Cambridge Engineering Selector (CES), Granta Design Limited, UK, 2014.

[21] Childs, P. R. N., Mechanical Design. Second ed.: Oxford: Butterworth-Heinemann, 2003.

[22] Khurmi, R. S. and Gupta, J. K., A Textbook of Machine Design. Ram Nagar, New Delhi: Eurasia Publishing house, 2005.

[23] Pahl, G., Beitz, W., Feldhusen, J., and Grote, K.- H., Engineering Design: A system Approach. Thirded., London: Springer-Verlag 2007.

[24] Sapuan, S. M., A knowledge-based system for materials selection in mechanical engineering design. Materials & Design. 22(8): p. 687-695, 2001.