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Design Analysis of Chassis used in Self-Propelled Onion Harvester using FEA Tool

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Abstract: Onion farming is more commonly practiced for an irrigated crop, resulting in a high yield with large sized bulbs. Manual harvesting of an onion being meticulous requires a large amount of manpower as well as time. Thus, we have constructed and evaluated a self-propelled onion harvester which will have good performance in terms of productivity, fuel economy, less damage to crop and operator comfort. This paper is intended to discuss the results of the design and analysis of the chassis under the guidelines of the SAE TIFAN rulebook [1]. The chassis is designed using tool CATIA V5 followed by Finite element analysis (FEA) using ANSYS and the consequent results have been plotted and comparative results of old and modified chassis has proposed. During chassis designing and analysis, several factors are taken into account like material selection, strength, durability, boundary conditions, force distribution, induced stresses, optimum factor of safety, ergonomics and aesthetics. All the decisions for design are based on all pros and cons from testing and results of previous competitions.
Keywords: Space Chassis, Safety, FEA, Design, Stresses.

I. INTRODUCTION

A vehicle without body is known as chassis. The automotive chassis serves as a frame work for supporting the body and different parts of the automobile. It is the backbone of vehicle on which total load of vehicle is applied. It bears all the stresses on the vehicle in both static and dynamic conditions. Also, it has to withstand the shock, twist, vibration and other stresses caused due to sudden breaking, acceleration, bad road condition, centrifugal force by cornering. The issues related with chassis are the mounting of the components in proper place so that the vehicle is properly balanced.

Normally main chassis structure is divided into several segments, which are, the main hoop, front hoop, side impact protection and crush zone. For this, several options are available such as Uni-body frame, X-frame, Perimeter frame, Platform frame, Space frame, Sub frame. All systems of self-propelled harvester machines such as digging system, transmission system, conveying system, withdrawing systems are mounted on the chassis. In present design of chassis and manufacturing following factors are considered i.e., safety, easy manufacturing, durability and maintenance of the frame targeting for a compact, lightweight, ergonomic and aesthetic design. For this, space frame structure is preferred as it is easy to manufacture.

II. LITERATURE REVIEW

[2] Grzegorz Szczęśniak et al (2014), had explained important stage of the vehicle production, which is design of chassis and frames. Many of vehicle’s properties are strictly connected with the chassis or frame. Dynamic properties and static or geometric parameters of the vehicle depends on chassis or frames. Also, vibration phenomena in heavy vehicles are an important issue. As far as dynamic responses isolation in cabs is well recognized for the isolation of loads there are many investigations needed. These issues are very important for vehicle designers and engineers and has to be take into focused consideration in all productions processes, especially during assumptions and constructions of chassis or frames.

[3] Amol Raut, Ankit Patil (2017), The paper introduces several of the key concepts of frame design experimental. The different loading conditions and requirements of the vehicle frame are first discussed focusing on road inputs and load paths within the structure. Next a simple spring model is developed to determine targets for frame and overall chassis stiffness. This model examines the frame and overall chassis torsional stiffness relative to the suspension spring and anti-roll bar rates. Further a finite element model is developed to enable the analysis of different frame concepts. Some modelling guidelines are presented for both frames in isolation as well as the assembled vehicle. Finally, different experimental techniques are presented to determine what stiffness is actually achieved from a constructed vehicle. A comparison of frames tested in isolation versus whole vehicle testing is made, and a simple whole-car chassis torsion test method is discussed.

[4] Prof. Prashant B. Shelar et al (2018), give us the information regarding various calculations for stress analysis, load values & deflections. They are concerned towards the factory of safety and according to that they made their design. Stress distributions, lateral displacements during static and mode shape were analysed. Found considerably high factor of safety.

III. DESIGN DESCRIPTION

This paper is focused on the design, analysis, fabrication of chassis. The inspiration behind the design was to build sturdy, cost effective, light weight and enduring chassis. Design of any component is depending on the requirement. We have to design self-propelled onion harvester with considering safety, optimum design, comfort and durability. The chassis type is of front engine front wheel drive. The chassis of 2019 TIFAN is the first prototype that will serve as the test bench for chassis produce. In order to provide suitable mounting points, initially we assumed certain mounting points for each component which are resting on chassis considering stability of vehicle. Then analysis is carried out for this prototype. The process is repeated till we get optimum mounting points. Structure of individual members of the chassis are designed to contribute maximum strength with minimum increase in weight. Machine ergonomics is considered to provide safety of operator and easily accessible of each parameter such as knee angle, pedal angle, back rest seat pan angle and steering angle. Chassis is designed so that operator can easily access the direct arc of visibility and should be able to turn around freely to see operation and obstacle in field. Thus, three-dimensional space chassis is designed to meet all requirement.

IV. TECHNICAL SPECIFICATION

The chassis design must ensure for ease of access and servicing of drivetrain components as well as to reduce weight of the chassis. Considering all guidelines provided by rulebook the specifications of the present chassis are as follows,

TABLE I. Overall Technical Specification

Sr.No.	Parameters	Specifications
1	Overall Dimensions (mm)	2470*1400*1500
2	Static Ground clearance (mm)	300
3	Machine total weight (Kg)	310
4	Wheel base (mm)	1500
5	Maximum track width (mm)	1360
6	Maximum speed (kmph)	13.23
7	Working width (mm)	1000
8	Working Depth (mm)	100
9	CG Location (X, Y & Z) from machine mid and wheel Centre. (mm)	731

V. MATERIAL SELECTION

Material selection is important step in design and fabrication. The criteria of selecting the material must include technical inspection which satisfied sufficient bending stiffness, bending strength and it should be available with optimum cost. As per guideline circular issued by SAE, steel tubing should be used in construction of chassis and it must have a carbon content of at least 0.18%. Based on market survey and information provided by manufacturer, we select low carbon steel grade AISI 1018. This material offers a good balance of toughness, strength and ductility. It is easy to form an AISI 1080 in the anneal condition. It can be welded using most of the conventional methods. For chassis structure following material section are used.

TABLE II. Material Section Dimension

Type of members	Dimensions	Material
Cylindrical pipe	OD 25mm, Thickness 3mn	AISI 1018
Square pipe	Side 25mm, Thickness 2mm	MS

TABLE II. Properties of AISI 101

Property	Value
Density (kg/cubic meter)	7870
Young's modulus (MPa)	2.1×10^5
Tensile strength, Ultimate (MPa)	440
Tensile strength, yield (MPa)	370
Poisson's ratio	0.29
Hardness (HB)	126

TABLE III. Chemical Composition of AISI 1018

Elements	Content
Carbon (C)	0.14 - 0.20 %
Iron (Fe)	98.81 - 99.26 % (as remainder)
Manganese (Mn)	0.60 - 0.90 %
Phosphorous (P)	≤ 0.040 %
Sulphur (S)	≤ 0.050 %

VI. DESIGN ANALYSIS

Model of the chassis is made by Generative Shape Design (GSD) to create wire frame of chassis. Present design of onion harvester chassis Fig. 1 is based on roll cage chassis design model. In analysis design stresses such as Von Misses stress, shear stress and maximum principal stress must be within permissible limit. The FEA analysis of the model is carried out to optimize the roll cage pipe sizing to withstand the various loads coming on frame. The various Static loads includes weights of engine, Gear box, Conveyor, withdrawing system, Steering, blade, Driver and mounting element. These forces are applied on the machine CG and are transferred to tyre. The boundary condition is applied to lower side of chassis noted as N shown in Fig. 2. The mesh size is 60 division per line for getting best ANSYS result.

During FEA analysis, number of iteration of chassis members position were carried out to obtain a safe chassis with proper triangulation mesh. From analysis, it is observed that it is excellent in bending and good in torsional strength. This leads to have a higher factor of safety for the field. with further analysing the present design it necessitates to increase torsional strength. The modified model of chassis is designed with crossmember at middle where engine is seating and appropriate bending applied in front member Fig. 4. With proper triangulation, the FEA model is analysed. The result shows increased torsional strength & reduces stresses in great number.

VII. STATIC ANALYSIS

A. Calculation

$$\text{Bending Strength} = \frac{\text{Moment} \times \text{Vertical distance from neutral axis}}{\text{Moment of inertia}} = \frac{129782.44 \times 12.5}{\pi/64 \times 25^{\wedge}4} = 84.605 \text{ MPa}$$

$$\text{G Force} = \frac{\text{Mass} \times \text{Velosity}}{\text{Time}} = \frac{410 \times 3.51}{0.2} = 7195.5 \text{ N}$$

No. G Force (for 0.2 sec Impact time) = 1.66 G

B. First CATIA Model

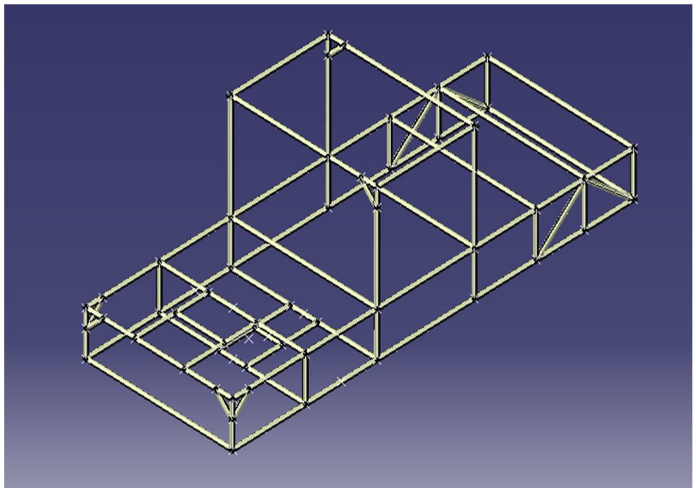

Fig. 1 First CATIA Model

C. Applied Forces

TABLE III. APPLIED FORCES

Member	Element	Applied Force(N)
A & G	Gear Box	196.2
B & D	Engine	235.44
E	Conveyor	147.15
C & F	Driver and miscellaneous element	4905
H & I	Windrowing System	73.575
J	Rear axel	24.525

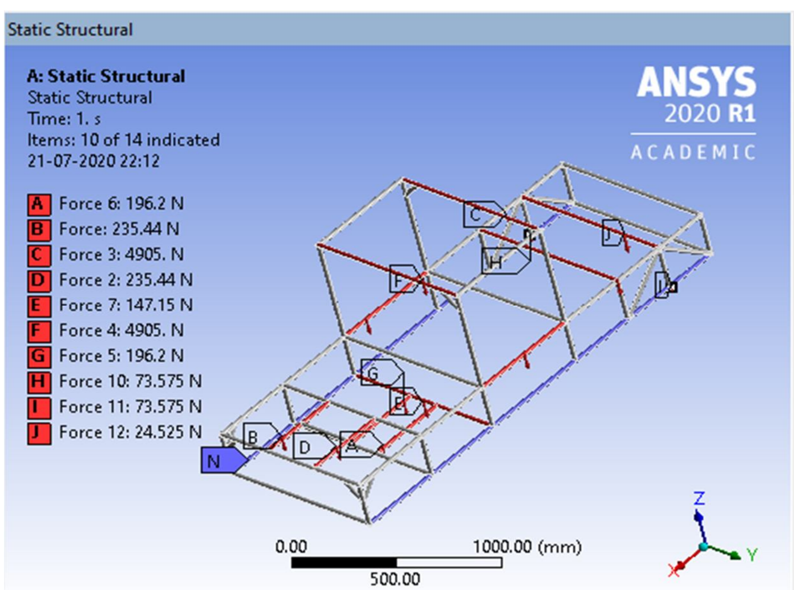

Fig. 2 Applied force

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D. FEA Analysis

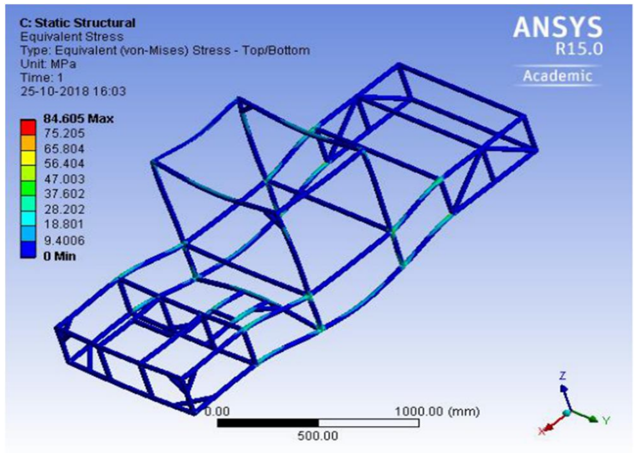

Fig. 3 FEA Analysis

E. Modified CAD Model

Referring to first ANSYS result it is required to improve the strength of the front member therefor, we introduced cross member that improved the strength and reduced the deflection under similar loading condition.

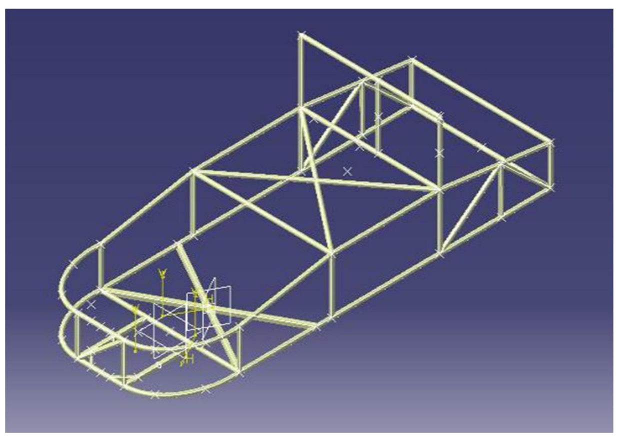

Fig. 4 Modified CATIA Model

F. FEA Analysis

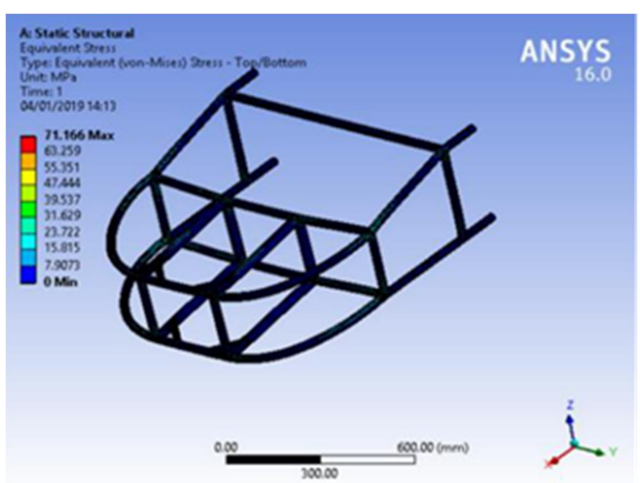

Fig. 5 Equivalent Von Misses stress

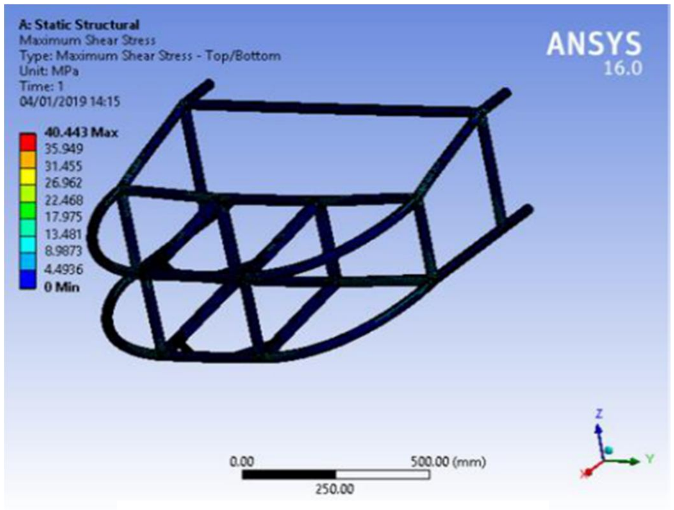

Fig. 6 Maximum Shear Stress

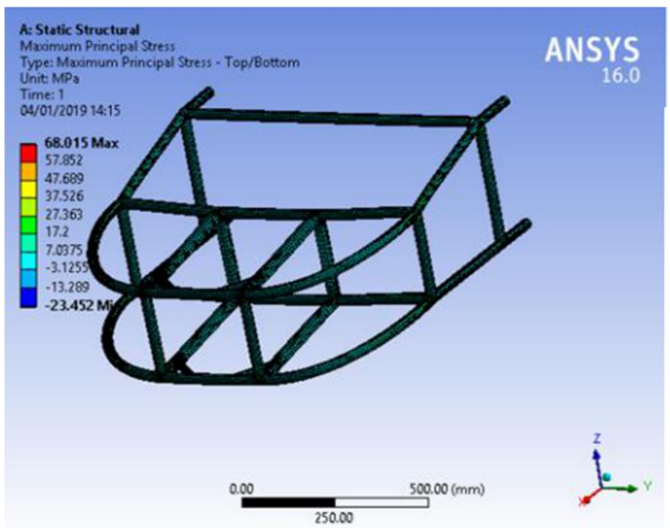

Fig. 7 Maximum Principal Stress

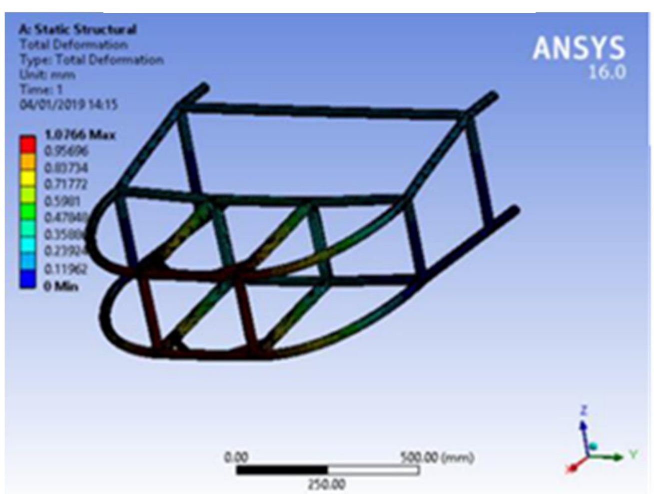

Fig. 8 Total Deformation Subject

G. Comparison With First Result

TABLE IV. Comparative Results

Stresses	Result (MPa)	First Result (MPa)
Equivalent Von Misses Stress	71.166	84.605
Maximum Principal Stress	68.085	50.153
Maximum Shear Stress	40.443	48.432
Total Deformation Subject	1.0766	1.86

VIII. RESULTS AND DISCUSSION

In this paper, static analysis of the three-dimensional space frame is performed to achieve more strength and durability of the chassis with the application of static loads. Several modifications have been carried out to minimize the stresses as well as deformation. From the analysis, it is clear that, for chassis material AISI 1018, Equivalent Von Misses Stress is less than the yield strength. After the modification, the values of the Equivalent Von Misses Stress can be observed as 71.166 MPa and that of shear stress as 40.443 MPa, which are lesser than the first model. Along with the stresses, value of the deformation resulted into 1.0766mm, reducing deformation in the first model by 0.7834mm (approximately 42%).

IX. CONCLUSION

This paper presents comparative study and optimization of space frame chassis & static analysis is generated in ANSYS. The stresses and the deformation significantly optimized by modification using proper triangulation & cross members in frame. High Torsional bending strength observed in drive end by introducing cross member near engine mounting. we used rounds & curves in design for aesthetics.

The design can be considered very safe with high factory of safety and thus can be manufactured for an actual SAE-TIFAN competition.

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