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Chassis Design of Self- Propelled Onion Harvester

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Abstract: SAE TIFAN is an intercollegiate competition organized by Society of Automotive Engineers (SAE) to design, build and Agriculture harvesting vehicles. Chassis is an important part of the vehicle that supports the body and other different parts of the vehicle. It also surrounds and protects the occupant in case ofimpact and roll over incidents and also gives the aesthetics of the vehicle. The paper deals with selection of material and cross section for the chassis and analysing the frame design for different loading conditions to predict whether it will survive various impact scenarios using ANSYS workbench. The chassis design will be based on SAE TIFAN India 2021 rule book taking safety and other aspects into account. The results from these simulations indicate that the frame is safe enough for the variety ofworst-case scenarios tested.

I. INTRODUCTION

The SAE TIFAN is an event for the undergraduate students of engineering, organized by the Society of Automotive Engineers. It serves as a platform for young engineering students to showcase their skills by designing, fabricating and validating a single seater onion harvester and acquiring real-life experience while overcoming obstacles and challenges. The main function of a chassis is to support the vehicle's mechanical components and deal with static and dynamic loads, without deflection or distortion. It should be designed in an ergonomic and strong effective manner at optimum cost and weight for agricultural purposes. In the current scenario available are over designed i.e., their structuralrigidity and sturdiness are more than requirement. This leads to an increase in weight and cost of manufacturing. Dnyaneshwar Mule's analysis allowed theaddition of three important and key structural components to help the vehicle withstand front and side impacts as well as the forces dueto the loading of the shock mounts. Om Patil analysed four interactions of the frame design. A simple loading case was applied to the different frame versions, and the frame design with the highest factor of safety was chosen for Torsional bending, Vertical bending. Yash Chikhalkar thoroughly dealt with various load analysis on chassis and considerable Factor of Safety (FOS) applied to the roll cage design to minimize the risk of failure and possibleresulting injury. This clearly reaffirms thevehicle's ability to withstand extremeconditions. While Nishant Rahangdale and other team members discuss the finite element analysis of chassis in detail using ANSYS software. The paper deals with one such design model of SAE TIFAN chassis as per the guidelines of SAE TIFAN India 2021. The work discussed in the following sections include theMaterial selection, Cross-section selection, Design of a Chassis and Analysis of the Chassis.

II. DEFINITION

The chassis of an automobile is defined as a frame supported on springs and attached to the axle that holds the body and engine of the vehicle. Chassis is a French word and was initially used to denote the frame parts or basic structure of an automobile. It is the backbone of the vehicle.

It is the main mounting for all the components. So, it is also called a Carrying unit. The chassis of an automobile consists of following components suitably mounted:

1) Engine
2) Transmission system
3) Suspension system
4) Wheel Assembly
5) Steering System
6) Brakes System
7) Fuel Tank
8) Other Miscellaneous Components

All the components listed above are mounted in either of the two ways, viz., the conventionalconstruction, in which a separate frame is used and the frameless or unitary construction in which no separate frame is employed. Out of these, the conventional type of construction isbeing used presently only for the heavyvehicles. While for the vehicle the same has been replaced by the frameless type or the monocoque chassis.

The purpose is to design and manufacture tubular space frame chassis that should be strong enough to absorb the energy when front, back, side, torsional loads are applied. For the purpose of the applicationon a high-performance vehicle, it has to meet the following criteria:

a) Minimize the weight to stiffness ratio
b) Maintain Low Center of Gravity
c) Reasonable material and manufacturingcosts
d) Create a solid base chassis to evolve on foryears to come
e) Aesthetically pleasing design Chassis

A. The Chassis

The chassis is possibly the most important partof any vehicle. Its main role is to provide the vehicle with a main structure which all other components can be fixed to. The chassis must be rigid in both torsion and bending. The chassis must be able to accommodate and support all the components of the vehicle and any occupants and must absorb all loads without excessive deflection.

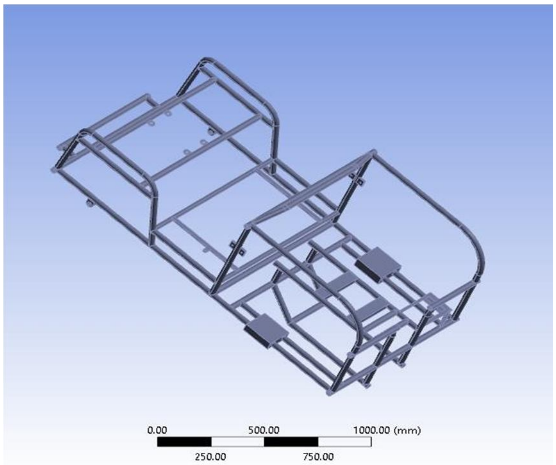

Figure 1: Isometric View of Chassis Frame

B Types of Chassis Design

1) Ladder Frame Chassis

The ladder frame chassis was the earliest type of chassis used. It was widely used for theearliest cars until the early 60s. The design is, as the name suggests, similar to a ladder. Thereare two longitudinal rails running the length ofthe vehicle which are connected together by several lateral and cross braces.

2) Tubular Frame Chassis

The tubular frame was the next logical step upfrom the ladder frame. A tubular frame has a number of features that distinguish it from a ladder frame and add massive advantages. A perfectly designed space frame would have thetubular sections arranged so that the only forces on them are either tension orcompression.

3) Monocoque Chassis

The Monocoque style of chassis is used byalmost all car manufacturers today. A Monocoque is a one-piece structure thatdefines the overall shape of the vehicle. This type of chassis is very attractive to mass production as the process can be automated very easily. The structure also has very good crash protection as crumple zones can be builtinto the structure itself.

4) Backbone Chassis

A backbone chassis is a simple style of frame that uses a central backbone running the length of the chassis that connects to the front and rear suspension attachment areas. The backbone usually has a rectangular crosssection. The body of the vehicle is then placed onto the structure. This type of chassis is usedsometimes for small sports cars however itprovides little or no protection against a side impact and so requires the body to be designedto accommodate this.

III. DESIGN CONSIDERATION

The layout manner of the chassis includes many steps, from the preliminary project to the mission of chassis layout to the beginning of production. These steps are; to become aware of the restriction, decide the specified overall performance standards, study layout techniques and technique, use of CATIA software program to layout chassis and ultimately begin creation. Throughout thosesteps, picks should be made based on the objectives which might be to be executed to meet the performance requirement.

The designer of the chassis needs to have an idea as to how all additives of the vehicle are going to feature when it comes to every different.

As a result, the designer has to understand how all parts ought to interact andtake this interplay into account while designingthe body. The design of a vehicle chassis for that to be counted, is going to be primarily based on suspension points, powertrain format, driving force function controls, protection, and many others. These vital pointsmust come collectively to form a powerful bundle for the car to perform as meant.

A. Various Loads Acting on Chassis

1) Weight of the vehicle and passengers, whichcauses vertical bending of the side members.
2) Vertical loads when the vehicle comes across a bump, which results in longitudinal torsion due to the wheel being lifted (or lowered) withother wheels at the usual road level.
3) Loads due to road camber, side wind, cornering force while taking a turn, which result in lateral bending of side members.
4) Load due to wheel impact with the road obstacles may cause that particular wheel to remain obstructed while the other wheel tendsto move forward, distorting the frame to parallelogram shape.
5) Engine torque and braking torque tend to bend the side members in the vertical plane.
6) Sudden impact loads during collision, whichmay result in a general collapse.

B. There are several factors that must beconsidered when designing the frame

1) Safety

Fortunately, the SAE TIFAN rules committee has set up a group of rules requiring certain tubing sizes in areas of the frame critical to driver safety in the event of an accident. Theserules define outer diameters and wall thicknesses for the front bulkhead, front roll hoop, main roll hoop, side impact tubing, roll hoop bracing, and front impact zones. The stated rules are adhered to without deviation so that the driver may be safe and the car can pass technical inspection at competition.

2) Stiffness

Normally, a vehicle chassis should be as stiff aspossible to withstand torsion. This is to facilitate easier suspension tuning. When determining the handling qualities of a vehicle,one of the most effective methods of adjustingthe amount of oversteer and under-steer is theadjustment of roll stiffness, front-to-rear.

3) Torsional Stiffness

Torsional order to design a car of maximum torsional stiffness the basis or generalized equation for torsion must be examined. Stiffness is the resistance of the frame to torsional loads.

$$T = G\theta J/ L$$

The above equation is a simple formula that relates the angle of twist to the applied torque, with J representing the shafts polar moment ofinertia, with θ denoting the resultant twist of the shaft, G representing the shear modulus ofthe material and L being the length of the shaft.

Now a chassis can be made extremely stiff by adding significant amounts of material to the frame. However, this additional material mightdegrade the performance of the car because ofthe added mass. Therefore, while designing a race car chassis it is important to get a balancebetween the weight and stiffness of thechassis.

4) Weight

As discussed earlier, wherever possible, weight should be minimized. Just as important as weight, is mass moment of inertia. A vehicle with a lower mass moment of inertia will be able to turn more quickly. In order to reduce mass moment of inertia, all weight on the chassis is pushed as far as possible towards thecenter of the vehicle.

5) Ergonomics

Ergonomics, or the study of human-machine interfacing, is important to vehicle design because the ultimate control of the vehicle belongs to the driver. When designing this 'interface' between person and machine, several aspects should be taken into account so that the best system of control is produced.

6) Seating Position/Field of View

A key input to the interface is the driver's vision. The field of view should include visibilityahead and to the sides of the vehicle (Approximately 180-degree arc– more is even better) and visibility of the road surface. The driver needs a sufficient level of information about the nature of the oncoming road surface and what is occurring beside them through peripheral vision to drive confidently. If the driver must strain their neck to see enough to feel confident.

7) Control Positions

Vehicle controls should be within a comfortable reach of the driver and be comfortable to operate. Controls that are awkward to reach or difficult to operate will distract the driver and potentially result in more driving mistakes.

IV. STRUCTURAL DESIGN

No. of Joints	77

Mass

Estimated Load of the Vehicle The various loads which are acting on the vehicle are estimated according to the centre of gravity of the vehicle. As the various loads acting on the vehicle are distributed are shown in the belowtable.

By considering miscellaneous masses such as the wheels, fuel tank etc. The weight of the caris considered to be approximately 410 Kg.

Table 1: Mass Distribution of Harvester

Sr.No.	Components	Mass (Kg)
1.	Driver	80
2.	Engine	47
3.	Gear Box	28
4.	Chassis	74.4

V. MATERIAL SELECTION

Material selection for SAE TIFAN vehicles is oneof the key design decisions that has great influence on the safety, reliability and performance of the vehicle. It also decides theweight of the vehicle, fabrication processesand cost. The qualities that were given due importance are yield strength, the strength to weight ratio and good weldability property. Asper the guidelines of the SAE TIFAN rule book the minimum carbon content should be 0.18%.The materials selected for the study include AISI 1018. Table 1 gives the details of the chemical composition and Mechanical Properties of the material.

Table 2: Chemical Composition of AISI 1018

Element (%)	AISI 1018
Carbon, C	0.15 – 0.20
Iron, Fe	98.81 – 99.26
Manganese, Mn	0.60 – 0.90
Phosphorous, P	≤ 0.04
Sulphur, S	≤ 0.05

The aforementioned materials have low carbon content, hence can be welded easily. However, AISI 1018 alloy steel is selected as it has higher yield strength and strength to weight ratio than other materials.

Table 3: Comparison of Different Material

Properties	AISI 1018	AISI 4130	AISI 4140
Tensile Strength (MPa)	440	560	655
Yield Strength (MPa)	370	460	415
Elastic Modulus (GPa)	210	190-210	190-210
Poisson's Ratio	0.29	0.27-0.3	0.27-0.3
Brinell Hardness	126	217	197
Density (g/cm^3)	7.87	7.85	7.85
Elongation (%)	15	22	26
Thermal Conductivity(W/mK)	51.9	42.7	42.6

Availability is one of the main factors which dominate the material selection process. Working on this single list of different desirable and available material was prepared. Steel and aluminum alloys are always the choice most of the time. After reviewing mechanical properties, availability, cost and other significant factors, Steel AISI 1018 was selected. AISI 1018 grade is a versatile alloy with good atmospheric corrosion resistance, reasonable strength and thermal conductivity.It shows good overall combinations ofstrength, toughness and fatigue strength. The above table provides a comparison of availablematerial.

Bending Stiffness

The bending stiffness of the chassis refers to the amount of force required to deflect the chassis from the side of the vehicle. The bending stiffness affects the amount of energylost through the structure when accelerating. Thus, having a stiffer chassis will result in moreenergy being transferred to the wheels and theforward motion of the car. A chassis that has agood torsional stiffness also has adequate bending stiffness.

The bending stiffness and bending strength must be calculated about a neutral axis that gives the minimum values.

Bending stiffness is considered to be proportional to the product E*I

where,

E→ Modulus of elasticity,

I→ Second moment of area for the structural cross section

The Bending strength is given by equation:$(\boldsymbol{Sy}*\boldsymbol{x}*\boldsymbol{I})/\boldsymbol{C}$

Where,

Sy → Yield strength, C→ Distance from neutral axis to extreme fiber

VI. DESIGN AND ANALYSIS SOFTWARESELECTION

CATIA V5R21 was the CAD software used for designing, ANSYS 21 was used to analyze the impact test and LOTUS for steering design. All specifications laid down by the rulebook are taken as the foremost concern while designingand selection of parts.

VII. FINITE ELEMENT ANALYSIS (FEA)

After completion of the design, the CAD model of chassis was analysed by using the Ansysstudent version. The five analyses for chassis are given below.

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A. Longitudinal Torsion

For longitudinal torsion test first, we fixed the supports at the end of the chassis where the tires are connected to the chassis. Then, for the front side of the chassis where the tires areconnected, we applied load on one side and weapplied the same amount of load on the otherside but in the opposite direction.

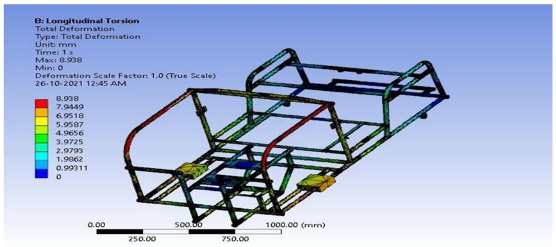

Figure 2: Longitudinal Torsion

The result after analysis is as follows:Max Deformation: 8.93mm
Max Von Mises Stress:142.58MPaTotal Deformation: 1.67mm
Fos: 1.57

B. Vertical Bending

Vertical bending strength is a strength thatshows chassis endurance towards other carcomponents' weight such as engine, body, wing, drivetrain, and driver under gravitation effect.

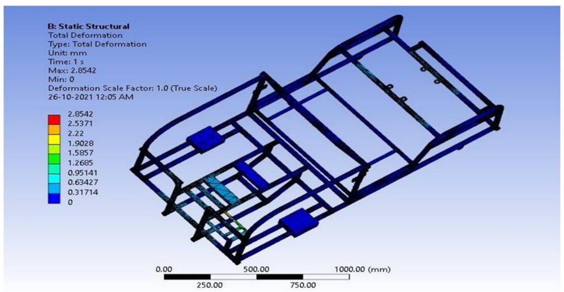

Figure 3: Vertical Bending

For analysis of vertical bending first we fixed the support at the joints where wheels areconnected to chassis, then one side of chassis (wheel and chassis joint) is subjected to a loadin upward direction and the other side is subjected to same load but in opposite direction to mimic the condition in real life.
The result after analysis are as follows:Force of Application: 0.88 G
Total Deformation: 0.347mm Max Von Mises Stress: 164.2MPaMax Deformation: 2.85mm
Fos: 2.58

C. Transverse Bending

For transverse bending, as name implies the forces are applied in transverse directionmeans one side of the front axle and diagonally opposite side on the rear axle is marked as fixed and other two remaining axles wheresubjected to a vertically upward force in the same direction and of the same magnitude.

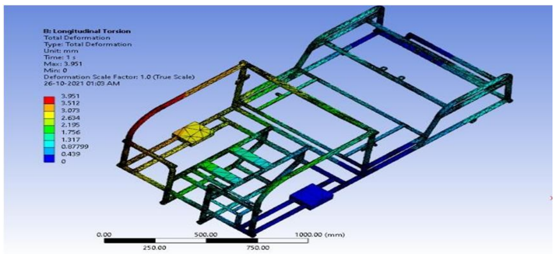

Figure 4: Transverse Bending

The result after analysis are as follows:Force of Application: 1 G
Max Von Mises Stress: 116.47MPa
Max Deformation: 3.95mm Total Deformation: 2.35mmFos: 2.58

D. Draft Force

Draft force is force applied on a digger while digging or coming up from ground. The force acting on diggers takes on the point where

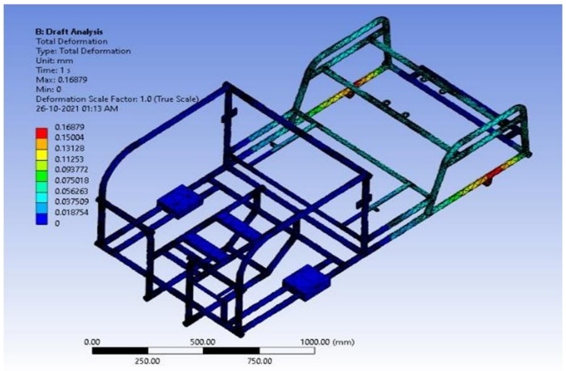

Figure 5: Draft Force

Conveyor is connected to the chassis. Draftforce is not perpendicular but at a certain angleso first it was divided in two components and then applied on the point of application.
The result after analysis are as follows:Force of Application:0.646 G
Max Von Mises Stress: 38.475 MPa
Max Deformation: 1.687mmTotal Deformation:1.47mm Fos: 2.58

E. Modal Analysis

In modal analysis the points of fixing are the axle points where wheels are attached to the chassis and a natural frequency of 36.617 Hz isapplied on the chassis for modal analysis.

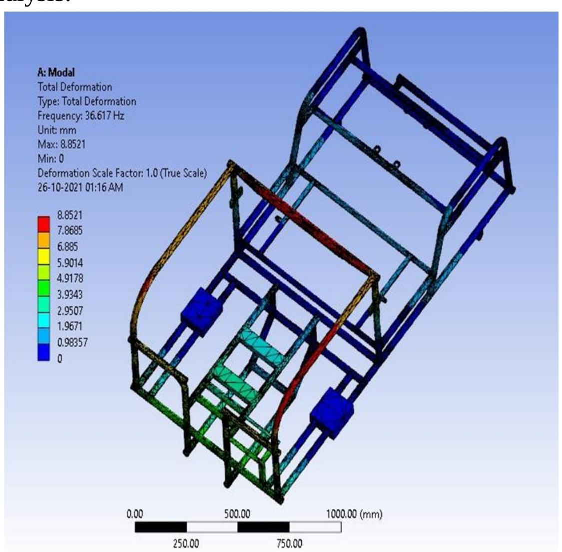

Figure 6: Modal Analysis

The result after analysis are as follows:
Frequency: 36.617 Hz
max deformation: 8.8521 mm

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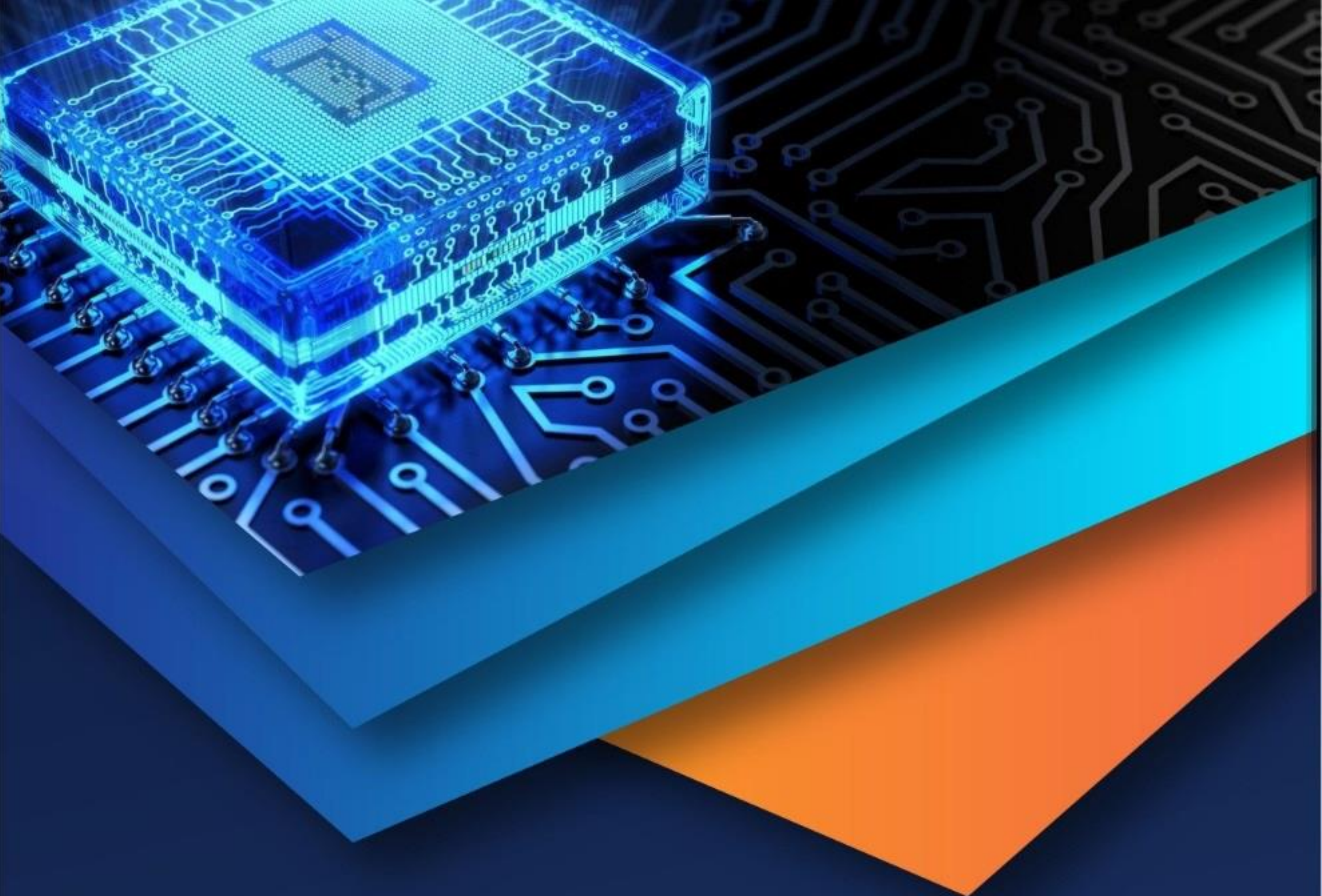
Table 4: Total Deformation and FOS

Type	Total Deformation	Factor of Safety
Longitudinal Bending	1.67mm	1.57
Vertical Bending	0.347mm	2.58
Transverse Bending	2.35mm	3.17
Draft Force	1.47mm	4.2
Modal Analysis	8.85mm (Natural frequency)	-

G-force calculation:
For G-force calculation we have to considerthe following formula:
G= F/Mgwhere,
F= Force acting
M = Mass of harvester
g= acceleration due to gravity

Table 5: G- Force Calculation

Bending	Magnitude of acting force (N)	G-Force
Draft Force	2849.54	0.646 G
Vertical Bending	3535.84	0.88 G
Longitudinal Torsion	518.85	0.129 G
Transverse Bending	4022.1	1 G



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