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Static and Modal Analysis of Formula Racing Car Frame

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ABSTRACT: Chassis Frame is major Load Carrying Structure of the Formula Racing Car, the main function of Chassis Frame is to provide Mounting Points Location to assemble different sub-assemblies like engine, fuel tank, fuel filter, Suspension system and bear the self-weight of vehicle and passenger. Vibrational Characteristics of chassis frame is very important for providing proper stiffness to chassis frame to meet the Vehicle noise and durability requirements. It is designed to Support all major sub-assemblies of vehicle. Chassis is major Component and backbone of Vehicle it serves the purpose of carrying the full vehicle load under its operating conditions along with occupant weight . The main objectives of this work is to design a new model chassis for two materials and to find the deformation and modal values of the structure. CAD modeling is done by using CATIA and Finite Element analysis is done by using HYPERMESH V19 which includes all the prepossessing activities like applying material properties and boundary conditions and static loads for structural analysis using Optistruct. In the present work two materials are considered for the analysis and from these two materials result obtained best materials is selected for chassis frame . Analysis results are validated with analytical result .

Key Words: Chassis, Catia Tool ,Optistruct, Modeling, Boundary Conditions, Hypermesh.

INTRODUCTION

This Research Paper focuses on chassis analysis. It is designed to support all major sub-assemblies of the vehicle, and the chassis is the major component and backbone of any vehicle. All of the other parts are attached to the chassis structure. Because the chassis frame serves as the vehicle's skeleton, it must be capable of withstanding a variety of loads. Analyzed with FEA Prior to manufacture, the ability to assess the forces and safety of the design is met.Chassis should have enough strength to sustain the self-weight of vehicle and Occupant along the various operating Loading Conditions.Modal Analysis is carried out to check the static behavior of Chassis Frame and Static Equivalent of Frontal Analysis will be carried out to check the strength of Chassis under operating Loading Conditions.FEA Approach is used for solving this Engineering Problem, which involves mainly Three Stages, Pre-Processing, Solving and Post-Processing.Catia Tool is used for Geometric Modeling of chassis Frame and Hypermesh, Optisruct FEA Tools will be used for Pre-processing and Solving Activities, and Hyperview is used for Post-Processing (Analysis Result Visualization)

The ASTM913 steel is recommended for chassis because of its has the high carbon content among them high strength and corrosion resistance. The goal of this study paper is to build and analyse the chassis of a Formula . A vehicle's chassis is its foundation. The frame provides slots for the vehicle's components to be attached. However, car Frame Chassis is simple to construct and obtain The complete design process for a Formula race car will be examined in this article, as well as the numerous problems that must be solved. Several elements will be considered, including modelling and analysis, as well as overall chassis production and performance.

OBJECTIVES

Main objective this analysis is to check stress deformation in both materials and to check the behaviour of chassis under frontal impact able to sustain or not in take up load and selecting the suited materials for race car frame

LITERATURE REVIEW

Amogh rahut, aniketh patil has did work on design and analysis of formula racing car using FEA tool by using 4130 alloy steel and state that the material give the maximum stress under the tension strength and minimum FOS in front torsion stress. And also change in engine is also reduce the engine space and here they reduce they weight (51kg to 31kg).

Shobith agrwal, prashat awashti, tarun saatyki , worked on the design and analysis on the chassis os FSAE vehicle by using AISI4130 steel they did study on the torsion rigidity and bending stiffness for both back and front . the AISI4130 steel have the low carbon content and it is easy to welding.

Patil vijayakumar v and R.I patil they worked on the design and analysis on chassis race car frame and they gives the information on various calculation of stress analysis, reducing load, deflection. And reducing the maximum stress.

Rupesh patil, vinayak chikalli worked on the FEA analysis on FSAE. Here they used the AISI4130 steel and molybdenum they conclude that the increasing the torsion rigidity and decreasing the weight and deformation and chassis will experienced that the minimum deflection under the race condition.

Parsoon gupta, ashok b , alok joshi worked in the design optimization on the suspension on the race car frame the frontal and rear stable suspension were constructed on the bases of designing the frame here the validating the frame was done by performing the torsional rigidity stimulation and computing the average over the three cases by the varying with the force applied on hard points.

M L Mohamad, M T A Rahman worked on design and analysis on static structural analysis of race car frame by using the steel and here they conclude that after an analysis has been made , all results are in von mises stress and displacement are compared in order to find which material is best sutied for the chassis.

S f khan, M H bhash has worked on the design and the structural race car frame using the HSS steel here they conclude that the basic foundation of the chassis is supporting chassis to which the engine and other mechanical prats are fastened and the new design under gone sever before develop.

Rakesh kumar sahu, suman kumar sahu has worked on design and analysis on race car frame here they conclude that the determine the linear stress distribution on the critical area which highest stress chassis and predict to failure.

Ravindar pal singh worked on structural formula analysis on SAE racing car here they concluded that dominant characteristic of structural behaviour viz.torsional rigidity increased by 2.46 times with an average value of615.98 kg/deg without compromising weight.

Antim gupta worked on design and finite element analysis of formula student chassis and here they choosed the AISI1020 material here the stress data generated . all the values were below yield strength of material that is 310Mpa. And it is plastic deformation and they conclude that the material is safe for chassis.

MATERIAL SELECTED

Material selected for chassis is ASTM913. steel this is characterized by good corrosion resistance high strength, hardness and wear resistance are produced using special chemical composition and manufacturing processes. Both aspects affect their mechanical properties at elevated temperatures and after cooling down, and particularly the residual strength and the ductility of the structural members.

AL 7075 : AL 7075 is extremely hard and good ductility and therefore good form ability. Aluminium is known for work hardening rapidly and is readily weldable. It also possesses high corrosion resistance and it is applicable for many product to attractive appearance and it is easy to fabricate aluminium is desirable in many application because of there high strength to weight ratio and corrosion resistance.

MATERIAL PROPERTIES

properties	ASTM913	Al7075
Young's modulus	21e05	22e05
Density	0.3	0.2
Poisson's ratio	7.85e	6.78e

Table 1 material properties of ASTM913 and AL7075

Catia Tool/Software will be used for Geometric Modeling of chassis Frame and Hypermesh, Optisruct FEA Tools will be used for Pre-processing , post-processing and Solving Activities, and Hypermesh is used for Post-Processing (Analysis Result Visualization)

MATERIAL USED AND ANALYSIS

When the material is selecting for car frame the most common things considered as it should be strength , displacement and stress of the vehicle. But in order to design the vehicle frame it would be light and strong and here chassis are made by using ASTM 913 steel , which is relatively low cost steel compare to others such as stainless steel and aluminium, and what is more importance than other factors is the ability of the material to handle certain load and impact if sudden load is applied to the material .

OPERATIONAL LOAD CASES:

Loads Acting on System under consideration during working condition/Vehicle running condition.

Frontal Impact is an dynamic Event we need to convert Dynamic case into static case by considering dynamic load factor of 1G load .

Chassis Frame should be strong enough to take up this load without harming much to the Driver.

DESIGN ANALYSIS

Model of chassis is first made in catia .

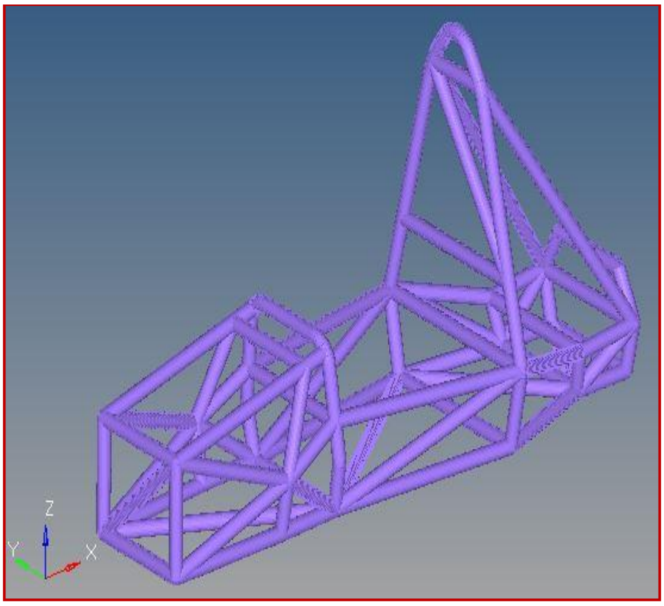

Fig1 Initial design with mass =49.54 Kg

The figure 1 represent the initial design of chassis car frame with the mass 49.54 kg and it is done in catia .and this design satisfy the maximum load of safety rider. And it have the 2mm thickness and 50mm diameter.

Above figure2 represent boundry condition for the chassis frame and here impact force is applied for frontal corner of chassis frame. And also the end portion represent the the rear suspension portion in constrained in all degree of freedom.

After this we will importing in hyper mesh , and in this we will conduct main functions as preprocessor, optistruct and solution result.

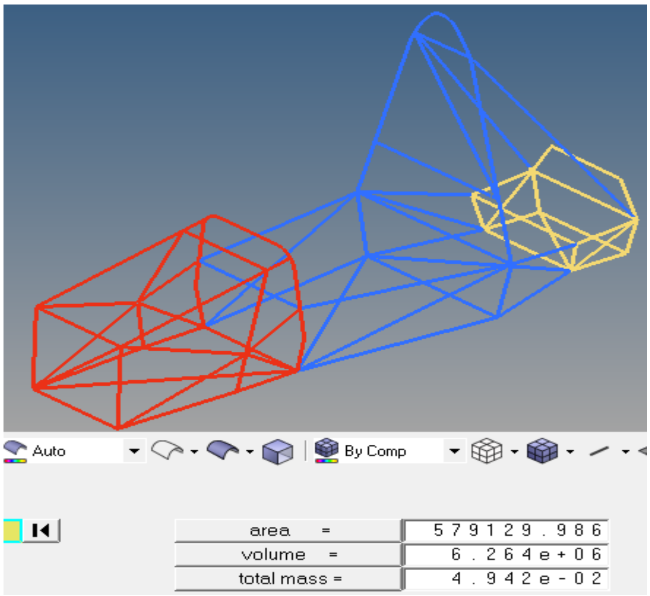

Fig3 Initial model of ASTM 913

Above figure3 represent the initial model of ASTM913 which done in hypermesh by importing from the CATIA model.here the mass of the chassis is 49.42 Kg.

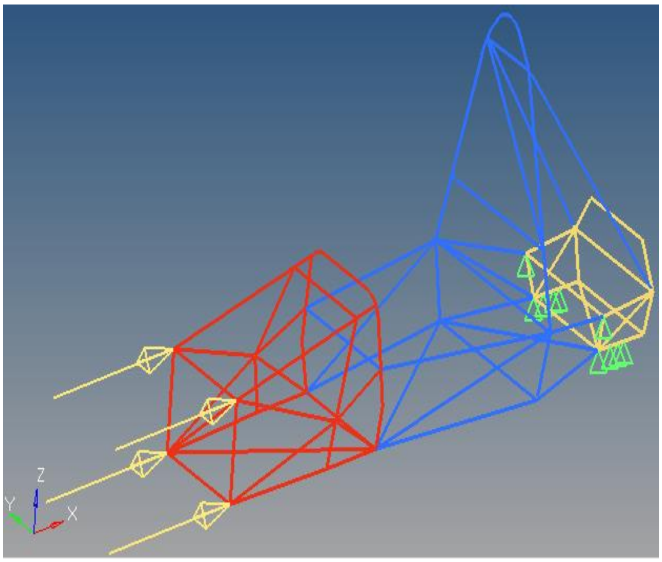

Fig2 Boundry condition

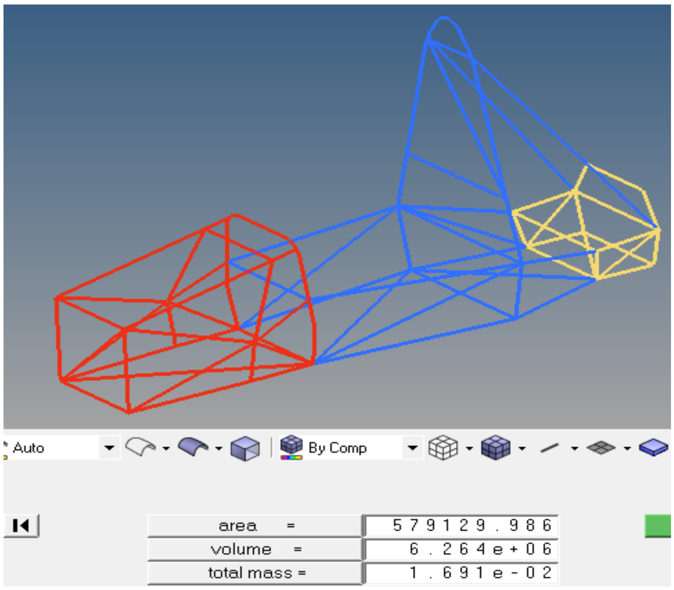

Fig4 Initial model of AL7075

Above figure 4 represent the initial model for mass is 16.91Kg of AL 7075 material model for chassis car frame and this is done in hyper mesh by assinging the properties like, young's modulus, possion's ratio density and outer ratio and inner ratio to the material .

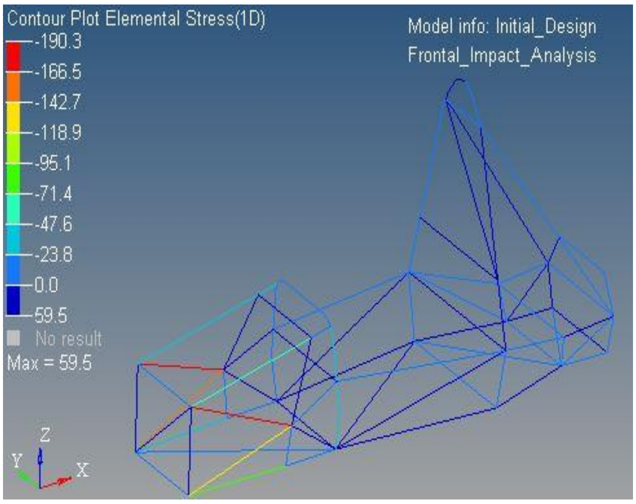

Fig5 maximum stress observed in ASTM913

SI NO	Design model	material	mass	stress	displacement
1	Initial design	ASTM 913	49.42	190.3	0.7
2	Initial design	AL 7075	16.92	190.3	3.8

The figure5 represents that the maximum stress observed in ASTM 913 material in hyper mesh by appling the material properties like youngs modulus and poissons ratio and density.after the assigning these properties we got the above the maximum result for ASTM913 material.

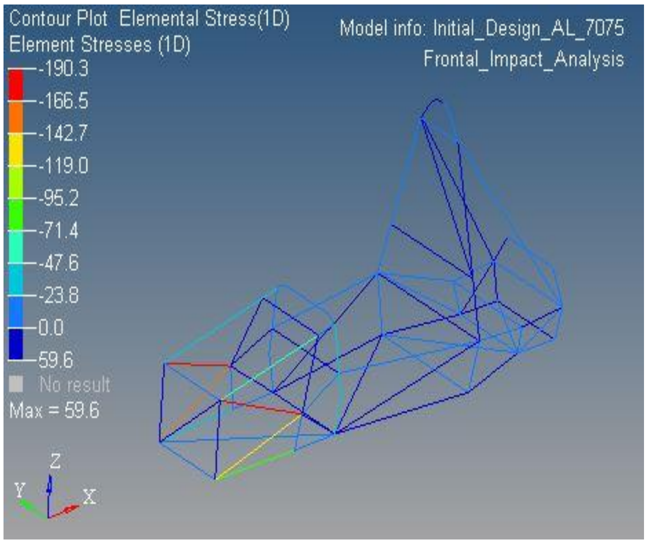

Fig6 maximum stress observed in AL 7075 material

The figure 6 state the maximum stress observed in AL 7075 material and here we are importing the model from the CATIA to hyper mesh .and also we are appling the material properties like young's modulus ,poisson's ratio and density for the AL7075 material.

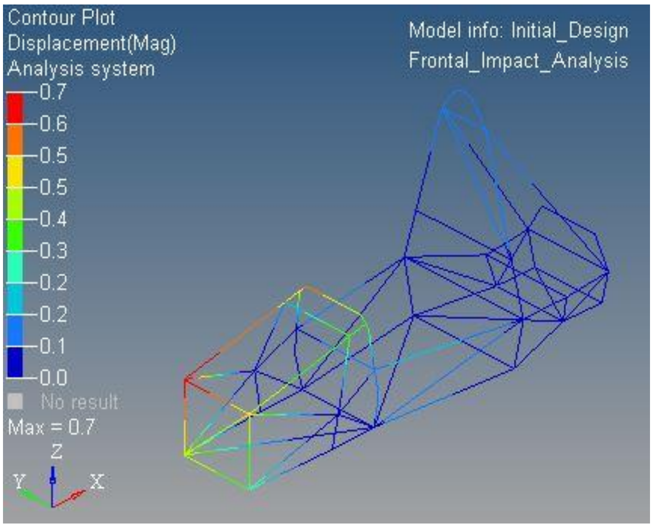

Fig7 displacement initial design for ASTM 913

The above figure represent the displacement for initial design for ASTM913 and the displacement value for the material is 0.7mm for the ASTM913 material in hyper mash and this value we got by assigning the material properties for material.

FEA Result Comaparision for ASTM 913 AND AL 7075

Table 2 results comparision for ASTM913 AL7075

From the above result we can conclude that , the displacement of ASTM913 is 0.7 under impact load and for the AL7075 the displacement is about 3.8 because of less stiffness leads poor handling and riding performance which is not acceptable.and here the result table represent that change material does not have any on stress but it have significant effect on deformation

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and stiffness parameters as per the above result ASTM 913 best suit for chassis model and for optimization.

So here we are continue with the ASTM913 material for optimization by using FEA method in hyper mesh .after performing the optimization we came to conclusion that we can reduce this much of mass with safest design which will have stress lesser the yield strength of the material. Optimized design is fullest usage of given material capacity.and we got some results for the ASTM913 material

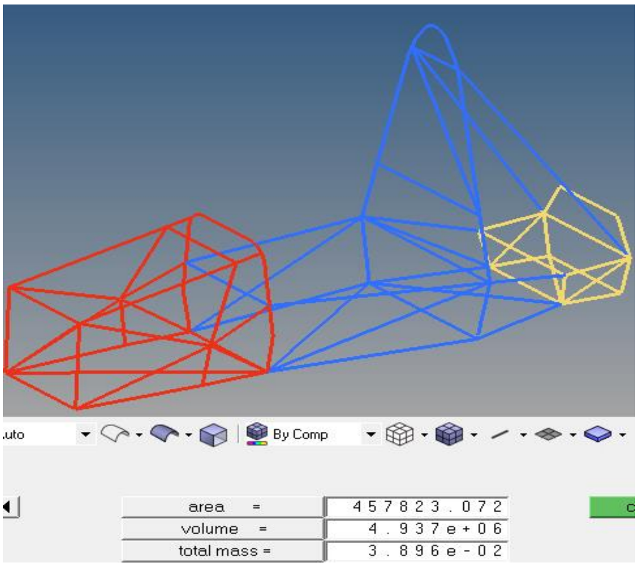

Fig7 optimized mass for the ASTM 913 material

The above figure7 represent that the optimized mass=38.96kg for ASTM913 material at hyper mesh . by assign the material properties like density , poissons ratio and youngs modulus to the ASTM 913 material.

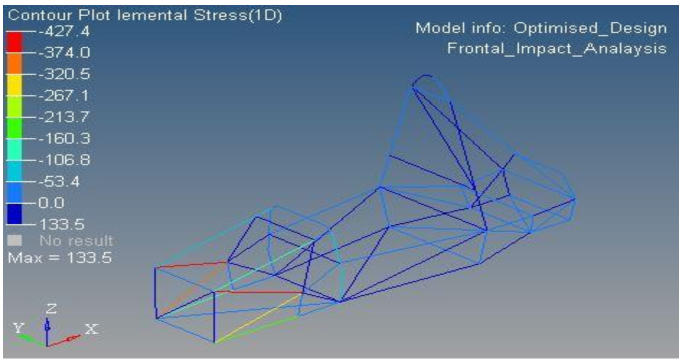

Fig 8 optimized maximum stress for ASTM913 material

The above figure 8 represent the maximum stress is 427.4 MPa for ASTM913 material .here we are optimizing the mass and this is lesser initial value and is the safest stress for the chassis frame for frontal impact .

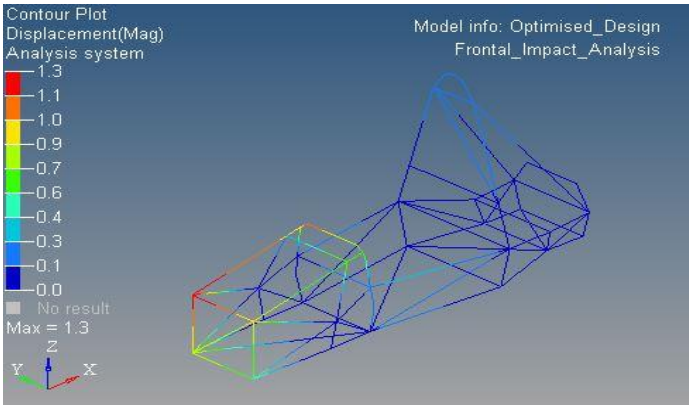

Fig9 optimized displacement for ASTM913 material

The above figure represent that the displacement value as 1.3mm to the ASTM913material. Here we are getting the optimizing displacement for chassis for frontal impact and the optimized displacement value is lesser than the initial displacement value and this most suited for chassis frame.

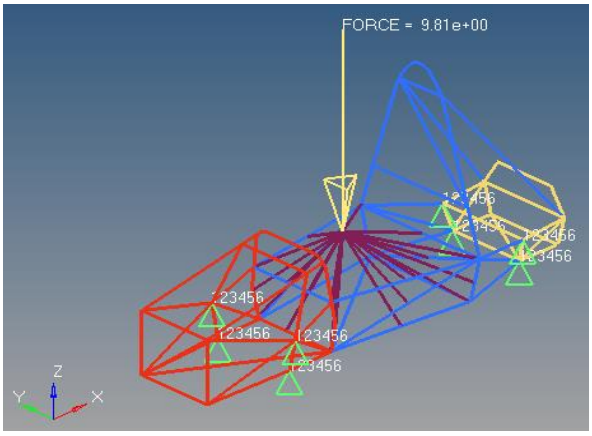

Fig 10 frequency calculation for ASTM 913 material

The above figure represent that the frequency for ASTM913 material and her we get the frequency has 26.95HZ for frontal impact and this value we got after optimization .

Analytical Calculation for frequency to ASTM913 material.

Frequency calculation:

Frequency , $\omega = \sqrt{g/\delta}$

$\omega = \sqrt{9.81/1.35e{-}02}$

$\omega = \sqrt{726.6667}$

ω= 26.95 HZ

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Si no	Design model	Mass(Kg)	Stress(Mpa)	displacement	fos
1	Initial design	49.42	190.3	0.7	2.5
2	Optimized design	38.96	427.3	1.3	1.4

Results	Mass	Analytical	% difference
Stress	427.3	394.2	7.75
Displacement	1.3	1.18	9.23
Frequency	28.21	26.95	4.47

ANALYTICAL HAND CALCULATION FOR THE OPTIMISED VALUE :

Analytical calculation is done by considering the following assumption:

1) This problem is treated as a cantilever beam of Hollow Circular Section (cross section) subjected to Axial load .

2) Stress values Calculations are assumed to be within elastic limit (Linear case).

3) Principal of superposition is applied for getting effective deformation and stress values of the Chassis Tubes for Applied Load.

4) Welded connections are not taken into the consideration for calculations.

5) Material Behaviour Assumed to be Linear Elastic and Isotropic .

6) Localized portions (Tubes) are considered for Hand Calculations where Max Stress Observed from Loading point to SPC

Optimized stress calculation:

The effective stress of the frame tuber under the load of F=5576.75 N acting consider the Bending Equation along the section A to B, $0 \le X \le 725$ & Section B to C $725 \le X \le 1849$.

$\mathcal{E}$ = strain = dx/L

$\sigma = E*\mathcal{E}$

$\sigma_{eff}=(E/L)*\int_A^B[(p*x)/(A*E)]dx+\int_C^B[\{P*(L-X)\}/(A*E)]\,dx$

$\Sigma_{eff} = \sigma_a+\sigma_b$

We get σ_{eff} = 8.234 e 7/(2.0887e05)

σ_{eff} = 394.2 Mpa

Optimized displacement calculation:

The effective deformation of Frame Tubes under G load of 5575.75 N Acting at Point A

consider the section A to B, $0 \le X \le 725$ Section B to C $725 \le X \le 1849$.

$\delta_{eff}=(E/L)*\int_A^B[(p*x)/(A*E)]dx+\int_C^B[\{P*(L-X)\}/(A*E)]\,dx$

$\delta_{eff} = \delta_a+ \delta_b \rightarrow 1$

$\delta_{eff} =\int \{5576.75/\sin(20)\}*x) /(E*A)+\int 5576.75 * (1849 -X) /(E*A) \rightarrow 2$

Where E=210000Mpa, young's modulus of the material

After solving the above integral equation

we get δ_{eff} =8.6564 e9/ E*A. = 3.1346 e07 /(2.1 e05*1.265 e02)=1.18mm

FEA Analytical results comparison:

Table 3 FEA analytical results comparison

Table 4 FEA analytical results comparison

Here we can save the mass up to 10.47 Kg with optimization the design we can achieve industry standard design.

CONCLUSION:

We conclude that the ASTM913 has the low stress and this material have the less (0.7mm) under impact load .as per the result we can conclude that ASTM913 is the best suite for chassis model and there is scope of optimization.

Here we achieved that with optimization result of the ASTM913 is practice of industry standard FOS is 1.4. and here we saved the mass up to 10.47Kg.

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Identify applicable funding agency here. If none, d