Increase Factor of Safety of Go-Kart Chassis during Front Impact Analysis

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Abstract

This paper aims to increase the factor of safety of the Go-Kart chassis which is designed keeping in mind the rules imposed by Go – Kart Design Challenge 2015. Theoretical calculations are carried out which have been realized through several analyses. These result, coupled with appropriate research has been used to create a new chassis that possesses improved performance and safety. During front impact analysis, the chassis should meet the required factor of safety. In order to enhance factor of safety the computer aided design model was altered marginally such that it meets the safety requirements. An innovative method of design optimization has been discussed, without significant increase in the overall kerb weight of the chassis.
Keywords: Chassis, Factor of Safety, Front Impact Analysis, Go-Kart

I. INTRODUCTION

Chassis is a French term and was initially used to denote the frame or main structure of a vehicle [1]. Chassis is sub-divided into the running gear and the power plant. The running gear includes the frame, steering system, brakes, wheels and the tyres. The power plant includes the engine assembly and power transmission assembly [1] and hence chassis should have adequate strength to protect the driver in the event of an impact. The chassis must have the capacity to resist all the lateral and longitudinal forces exerted on it. The design and fabrication of the go - kart is accomplished keeping in mind the requirements and guidelines imposed by Go-Kart Design Challenge (GKDC) [2] which include restrictions on the vehicle's weight, shape, size and dimensions. The chassis had to be modelled considering the dynamic events in GKDC which include acceleration test, brake test, autocross, skid pad and endurance test which would test the ultimate performance of the chassis on the track. Keeping these events and the constrains of the rule book in mind, five chassis were modelled using CATIA V5 R20 and structural analysis was performed on these chassis using ANSYS 14. The chassis that produced a satisfactory result was chosen for design optimisation in order to increase the factor of safety.

The uncertainties associated with the machinery concerning stress and strength includes:

- Composition of material and the effect of variation on properties.
- Variations in properties from place to place within a bar of stock.
- Effect of nearby assemblies such as weldments and shrink fits on stress conditions

We must accommodate uncertainty [3]. There are mathematical methods to address uncertainty, the primary technique being the deterministic method. The deterministic method established is the design factor based on the absolute uncertainties of a loss of function parameter and a maximum allowable parameter can be load, stress, deflection, etc. [3]. Therefore, factor of safety can be defined as the ratio of the yield stress to the working stress for a ductile material.

II. MATERIAL

The Material chosen for modelling the chassis is AISI 1018. AISI 1018 is a mild/low carbon steel offering a good balance of toughness, strength and ductility [4]. Along with the above mentioned properties, the material also possesses good weldability aspects. Therefore, AISI 1018 was chosen for analysis and fabrication.

Circular seamless tubes having an outer diameter (OD) of 0.02921m (1.15 inches), with a wall thickness of 0.002 m (0.078 inches) was selected. The mechanical properties of the material are shown in table 1.

Table – 1
Mechanical Properties of AISI 1018

Property	*Value*
Density	*7.87 g/cc*

Tensile Strength (Yield)	*370 MPa*
Tensile Strength (Ultimate)	*440 MPa*
Modulus of Elasticity	*205 GPa*
Bulk Modulus	*140 GPa*
Poisson's Ratio	*0.29*
Shear Modulus	*80 GPa*

Chemical compositions of the material are shown in table 2.

Table – 2
Chemical Composition of AISI 1018

Composition	*Percentage (%)*
Carbon (C)	*0.14 – 0.20*
Iron (Fe)	*98.81 – 99.26*
Manganese (Mn)	*0.60 – 0.90*
Phosphorus (P)	*<= 0.04*
Sulphur (S)	*<= 0.05*

III. Chassis Design

Our primary focus was to increase load-bearing capabilities, depreciate the cost, to reduce weight of chassis and intensify driver's safety. The chassis which produced results meeting the safety and load bearing requirements was chosen for further analysis, which is shown in Fig 1(a)

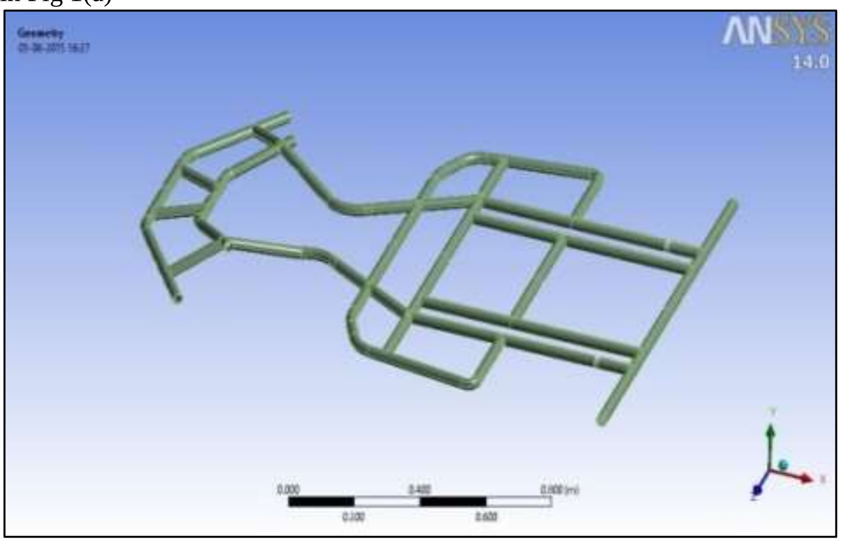

Fig. 1(a): Modelled chassis that is used for further analysis.

The modelled Chassis weighs 16.64 kg.

Entire chassis was meshed as regular tetrahedron cells with sides of length 0.005 m. Theoretical calculated loads were applied at different components of the chassis. Fig (b) shows the meshing of chassis.

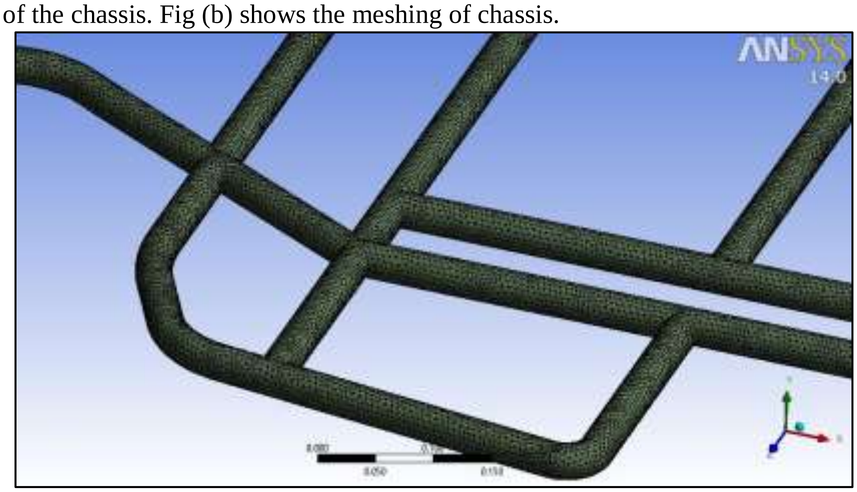

Fig. 1(b): Regular tetrahedron meshed chassis.

IV. FRONT IMPACT ANALYSIS

In order to perform Front Impact Analysis, the rear bumper of the Chassis was constrained.
The force is applied at the front bumper which is calculated using Newton's mass moment equation,

$$F = m \times \delta v / t. \quad (1)$$

Where,
m- mass of the vehicle with the driver.
δv- change in velocity.
t- time taken to decelerate.

The total mass of the vehicle is 165 kg (includes weight of the engine, drive system, brake unit, body kits and weight of the driver) and total time taken for the Go-Kart to decelerate from 60-0km/hr and come to rest is 0.85seconds. Therefore, the force was calculated using (1)

$F = 165 \times 16.67/.85$
$F = 3235.94$ N

A. Results

Table 3 depicts the Stress, Strain and Total Deformation.

Table – 3
Analysis Results

Type	*Maximum*	*Minimum*
Stress	*1.309e8 Pa*	*3.725e-10 Pa*
Strain	*0.000696*	*3.055e-15*
Total Deformation	*0.015714 m*	*0 m*

The factor of safety (FOS) obtained during front impact analysis is 1.99. Mechanical properties available for us are due to uniaxial testing, the chassis could fail due to other lateral loads acting on it during its performance on the track and hence FOS for the chassis should be greater than 2 for the design to be safe. It is clear from Fig 2(a) that the chassis is subjected to failure at the lateral bends, because chassis is highly stressed.

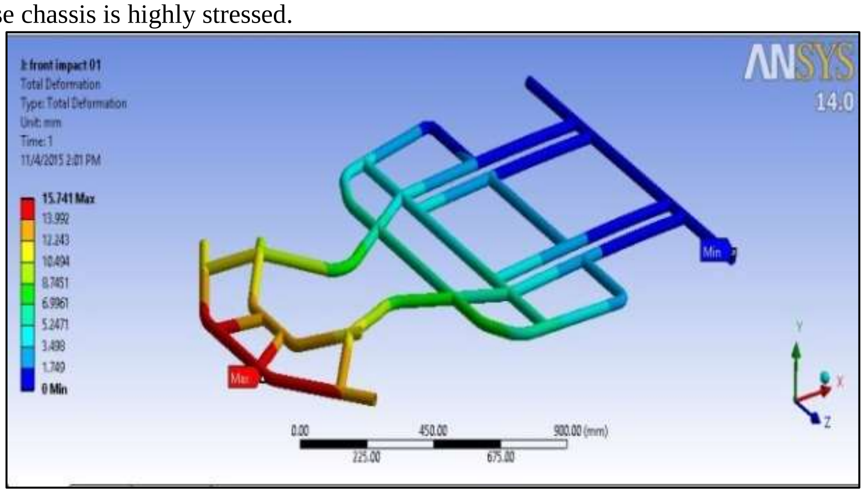

Fig. 2(a):

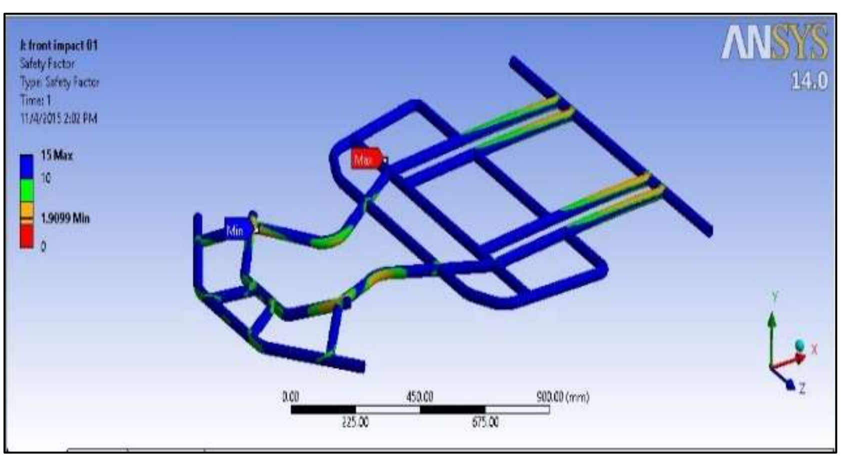

Fig. 2(b):
Fig. 2: Results obtained after analysis (a) Total deformation (b) Factor of Safety.

V. DESIGN OPTIMIZATION

In order to increase the FOS of the chassis and produce a stable design during front impact, an AISI 1018 bush having the following dimensions was used:

- Outer diameter of 0.0385m,
- Inner diameter of 0.0305m, and
- 0.050m long.

The modelled mild steel bushes shown in Fig 3(a) are so designed such that they can be inserted into the front bumper of the chassis and thereby possessing a clearance fit. The other supporting structures of the bumper and the chassis are welded on the bush which is shown in Fig 3(b).

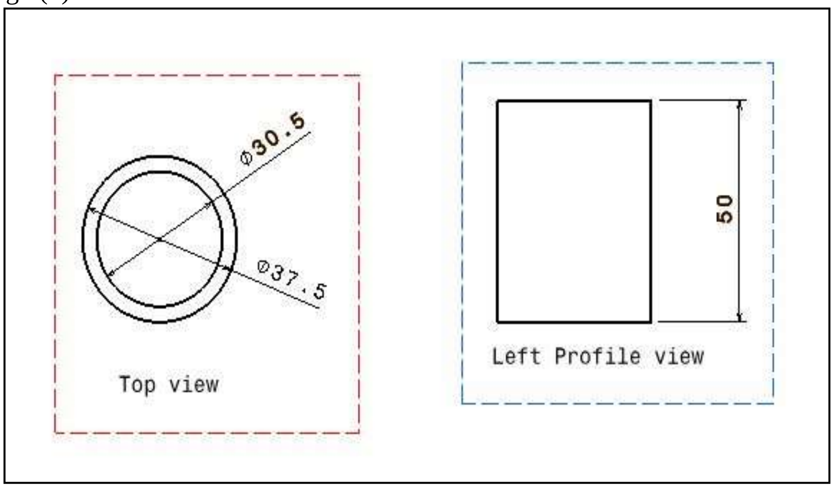

Fig. 3(a):

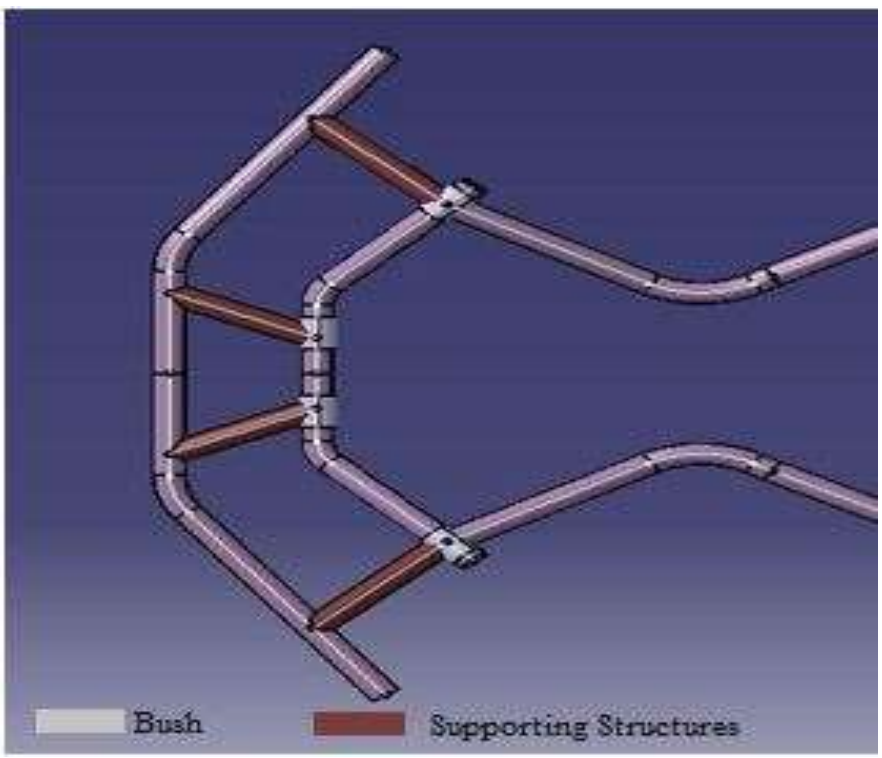

Fig. 3(b):
Fig. 3: (a) Designed bush dimensions in mm. (b) Application of bush on the chassis.

A. *During Impact*

During time of collision the force is applied on to the front bumper where energy is transferred from the bumper to the chassis through the supporting structure and the bush. At the time of collision, the bumper absorbs 20% of the total impact energy and the remaining 80% of the energy is transferred onto the bush. As the bush possess a clearance fit with the front bumper, the impact force is converted into rotational force about the axis of the bush, and thereby decreasing the load transfer on the chassis. Analysis was performed on the bush were a force of 2588.752 N was applied.

B. Results

Table 4 depicts the Stress, Strain and Total Deformation on the analysis performed on the bush.

Table – 4
Analysis Results of the bush

Type	*Maximum*	*Minimum*
Stress	*1.69e7 Pa*	*0.00089 e6Pa*
Strain	*9.2196e-5*	*5.0134e-9*
Total Deformation	*0.00153mm*	*0.mm*

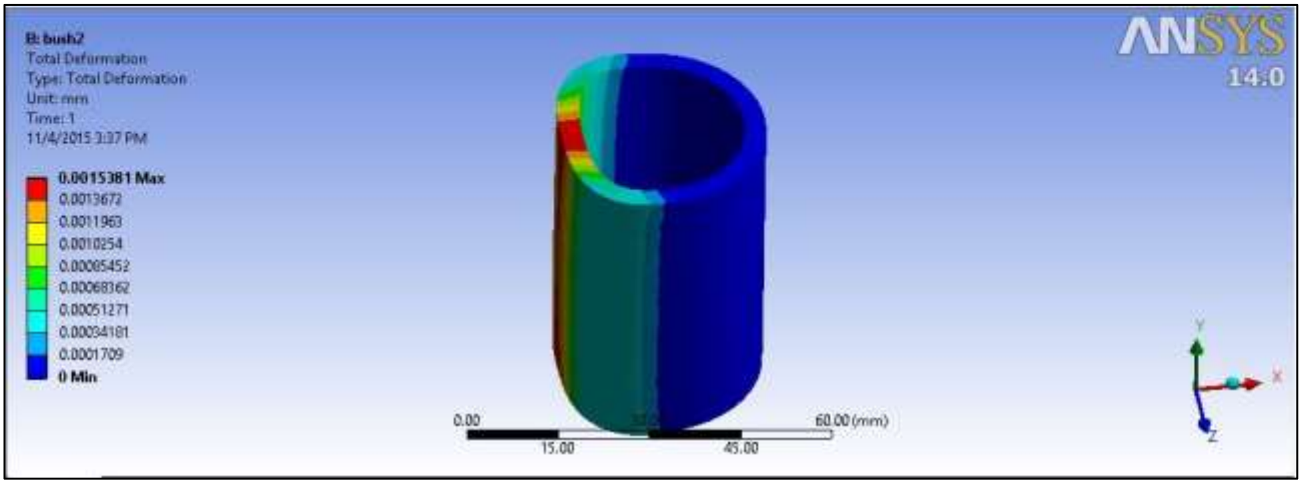

Fig. 4(a):

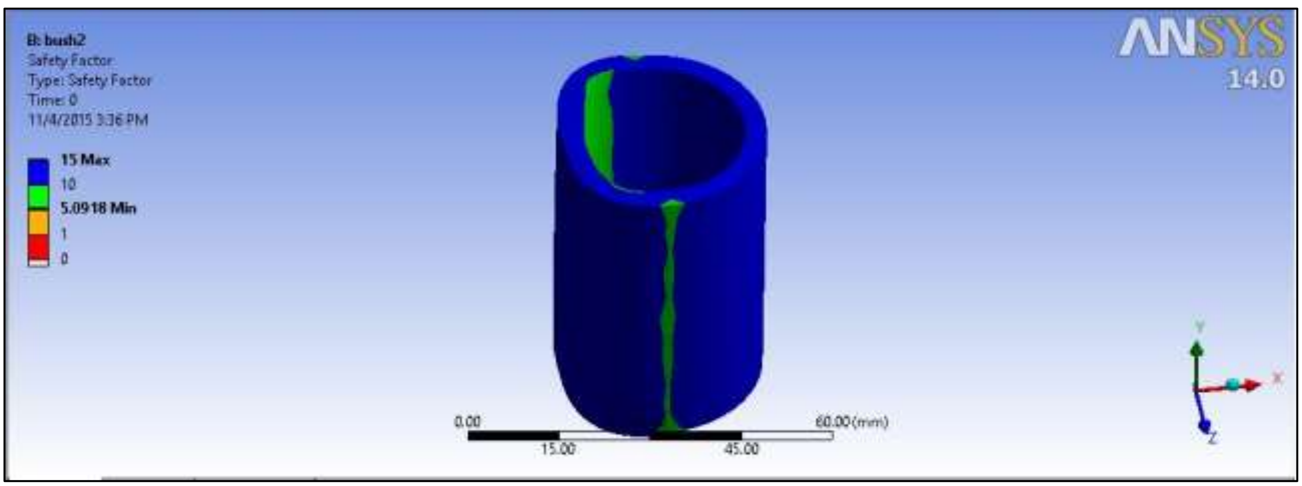

Fig. 4(b):

Fig. 4: (a) Total Deformation of the bush (b) FOS obtained after analysis on the bush Factor of safety for the bush after analysis was 5.0918.

VI. CONCLUSION

Go-Karts compatibility has been investigated in many studies using different approaches such as real world crash statistics and crash testing, but due to insufficient resources, the above mentioned techniques cannot be adapted. With the theoretical approach of analyses after inserting the bush it is seen that the FOS of the bush alone is 5.0918 which is shown in Fig 4(b).

Coupling both the FOS of chassis as well as the bush the overall FOS increases more than 2 thereby proving that the chassis is safe during front impact and the uncertainties during the design phase are taken care. During the impact it is also seen that the geometry of the chassis remains unchanged without affecting the Karts performance on the track.

Theoretical results obtained can vary in accordance with actual scenario.

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