INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

RESEARCH ARTICLE

Impact behaviour analysis of a newly designed go-kart chassis

Prateek Mahapatra[1]*, **Gourav Arora**[1], **Manan Aggarwal**[1], **Shivam Singh**[1], **Ritvik Manocha**[1]

1 Department of Mechanical Engineering, Manav Rachna University, Faridabad, India

Abstract

Background/Objectives: The main objective of this study is to propose a new design of go-kart chassis and to assess the ability to bear the front, rear and side impacts on this proposed design. Another goal of this study is to make this design with different materials and also to test them in different loading conditions. To determine the safest material for the proposed Go-Kart chassis design based on the results obtained. **Methods/Statistical analysis:** A new and lighter go-kart chassis model is proposed in this study. A 3D go-kart chassis was modelled and its Finite Element Analysis was carried out on Autodesk fusion 360 software. Global test standards were used to simulate the impact behavior on go-kart chassis. In addition, this Go-kart chassis design was also made from three different materials i.e., AISI-4130, Al-6061 and CFRP composite. These Go-kart chassis were tested under different loading conditions. A comparative study of the obtained results was also carried out. **Findings:** The results of simulations performed under different conditions, showed this design has demonstrated adequate resistance against deformation in front, back and side impact tests. In every situation, factor of safety was more than one. Therefore, it can be inferred that the proposed design was completely safe under testing conditions. Under different loading conditions, the design made up of CFRP composite was safest among all the materials used. However, detailed modelling and simulation studies are needed before testing it in real-life conditions. **Novelty/Applications:** Go-kart type of small vehicles are primarily used for recreational and racing purposes which are mainly powered by batteries as well as low capacity engines. The lower weight and better design of the chassis have the ability to improve their performance to a great extent.

Keywords: Gokart; Autodesk fusion 360; finite element analysis; chassis; impact behaviour

1 Introduction

A Go-Kart is a simple four-wheel single-seat racing vehicle typically designed on the open-wheel car concept. An engine or electric motor is used to drive the vehicle, which can be powered by fossil fuel or battery power, respectively. Typically, the use of an engine or electric motor is based on the specific applications of this vehicle.

In recreational go-karts, engines or electric motors could be employed as per convenience, whereas two-stroke or four-stroke engines are used in racing go-karts. Go-karts are usually single-seater; however, some recreational models may accommodate an additional seat for a passenger. In addition to suitable driving capability, it is essential to use a strong chassis in go-kart, capable of providing complete protection to the driver and co-driver. The average weight of professional racing go-karts used on outdoor and indoor tracks is 70-75 kg. To increase the efficiency of this vehicle, research is being conducted on the lightweight chassis design, which is also capable of providing excellent safety to the occupants. However, a vehicle with a lightweight chassis may face enhanced vibration or damping problem owing to various factors such as road irregularities, engine vibrations etc. In this situation, problems can be felt in terms of ride, safety and stability[1,2]. In the current scenario, computer-based analysis techniques like solid modeling, finite element analysis etc. is proving to be a reliable technique in terms of product design and development. These methods not only save time but also limit the need for physical testing. It is becoming prevalent as an appropriate method for analyses and predict the dynamic performance of various structures accurately[3,4]. The impact and vibrational behaviour of the Go-Kart chassis using finite element analysis was studied by Saini et al.[5,6] in two different publications. They designed a Go-Kart chassis with four different materials and studied their vibrational modes as well as their front, rear and side impact behaviors. They observed that AISI-4130 exhibited the best vibration and impact resistance among all the studied materials.

In this investigation, a new design for the go-kart is proposed. The ability to withstand the direct impact on go-kart chassis from various directions has been studied in detail. A suitable Finite Element Analysis method has been used to perform this study. Another goal of this study is to make this design with different materials and also to test them in different loading conditions. Additionally, to determine the safest material for the proposed go-kart design based on the results obtained.

2 Experimental Procedure

The go-kart is designed in Autodesk FUSION 360 software. This design attempts to optimize in terms of durability, weight and performance. In this proposed structure, rigid cylindrical sections of steel (AISI 1020) tubular sections have been used in the chassis design. Chemical composition and mechanical properties of AISI 1020 steel is shown in Tables 1 and 2, respectively. This material is used to withstand extreme stress during driving conditions. All components of this go-kart chassis were enclosed efficiently to ensure driver safety at the time of impact. The chassis frame is the fundamental and supporting part of the entire vehicle. The go-kart chassis must be sufficiently stable so that it can efficiently absorb the vibrations generated when the cart is moving. The use of steel tubular constructions in design may be able to meet these requirements. Also, the stability of the chassis is ensured when all its ain parts are solidly interconnected. This is not an articulation but a significant need for solid construction. However, articulated connections are only permitted for the support of the steering knuckle and steering column.

Table 1. Chemical composition of AISI-1020 mild steel

Elements	Fe	Mn	C	P	S
Wt%	99.08–99.53	0.3–0.6	0.18–0.23	0.04 max	0.05 max

Table 2. Mechanical properties of AISI-1020 mild steel for FEA

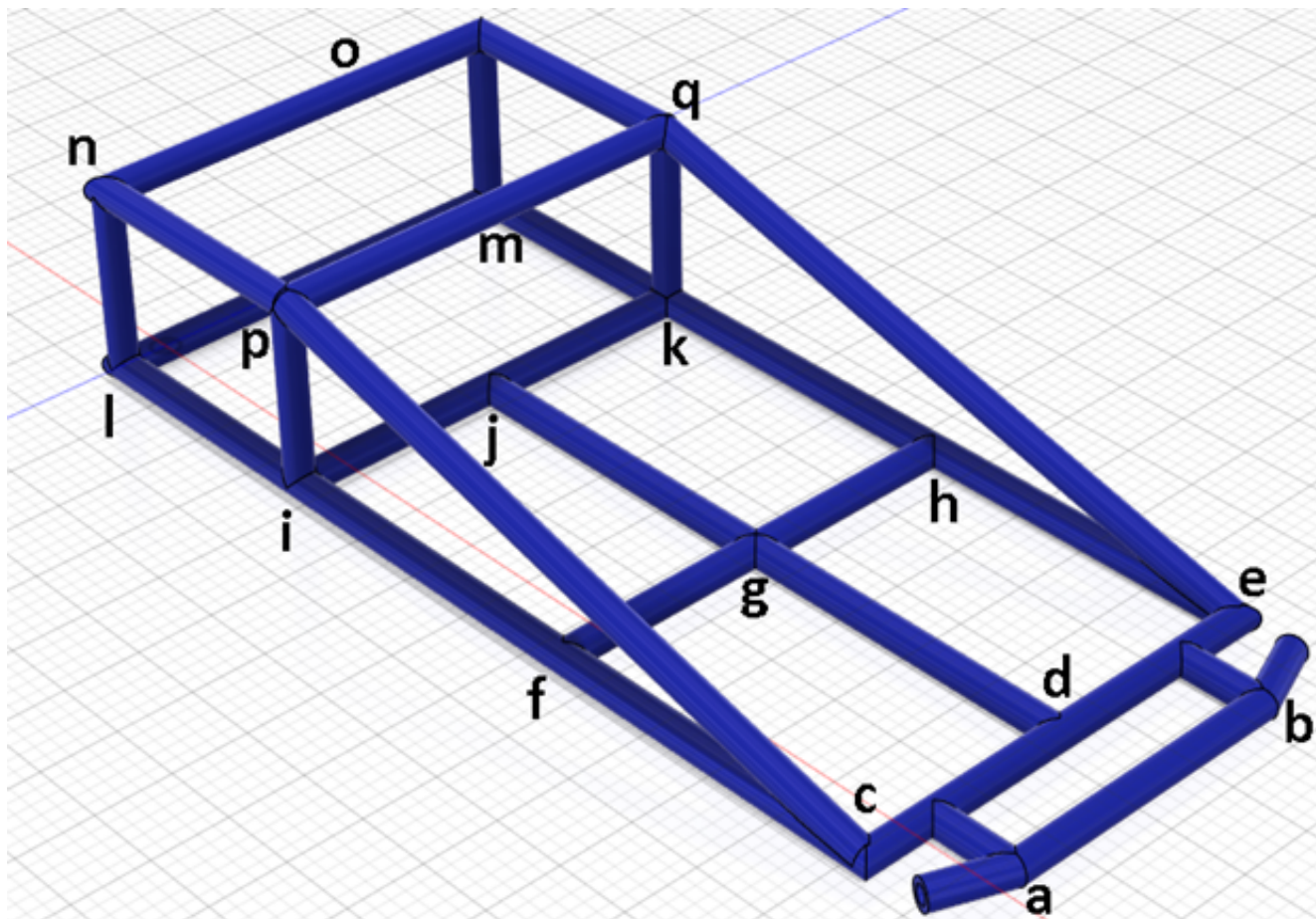| S. No.	Property	Value
1.	Density	7.879 g/cm^3
2.	Young Modulus	205 GPa
3.	Poissons Ratio	0.29
4.	Ultimate Tensile Strength	420 MPa
5.	Yield Tensile Strength	350 MPa

Fig 1. Basic structure design of go-kart chassis designed on Auto desk fusion 360

2.1 Design Considerations and Testing

The center of gravity of the chassis was determined by AUTODESK FUSION 360. The top priority of this design was to keep the frame of the chassis as light as possible. The weight of the vehicle is a major factor in vehicle performance when the power of the vehicle is limited. The chassis frame is one of the heaviest components of the car. Owing to that factor, special attention is being paid to reduce the weight of the vehicle frame. To reduce the overall weight, it is very important to determine the proper design of the chassis and to employ the right materials at the appropriate locations. The use of Finite Element Analysis (FEA) can provide overall support to meet baseline safety design requirements for the car chassis. The use of FEA can make the chassis design process efficient and effective, and helps detect high or low-stress situations in different members at testing conditions. In this study, AISI-1020 steel pipes with a wall thickness of 10.16 mm and an outer diameter of 50.48 mm have been used to make the chassis frame. This material has been chosen due to its weight reduction capability and beneficial properties. The overall weight of the chassis can be reduced considerably by taking into account certain facts such as the selection of suitable material, simpler design, the use of fewer members etc. The weight of the chassis designed for this study was 147 kg and the gross weight of the vehicle with the driver is estimated to be 222 kg.

In this investigation, structural analysis such as static and impact analysis was performed using FEA. Also, the behavior of the designed chassis was reviewed under various situations. Thus, the severity of any undesirable outcome was estimated and an attempt was made to examine the need for any necessary modifications on the design.

3 Results and Discussion

3.1 Front Impact Test

The front impact testing was simulated at a velocity of 64 km/h.

Using equation

$$Force = \frac{\triangle P}{\triangle t} = \frac{m \times v}{t} \tag{1}$$

Where, m = total weight of go-kart = 222 kg

v = impact velocity = 64 km/h

t = impact time = 1 s

The calculated force was 14.2 kN. This calculated force was applied to the front part of the chassis while the rear part was restricted for motion. The simulated behaviour of the designed chassis in front impact conditions in terms of stress, displacement and safety factor is shown in Figure 4.
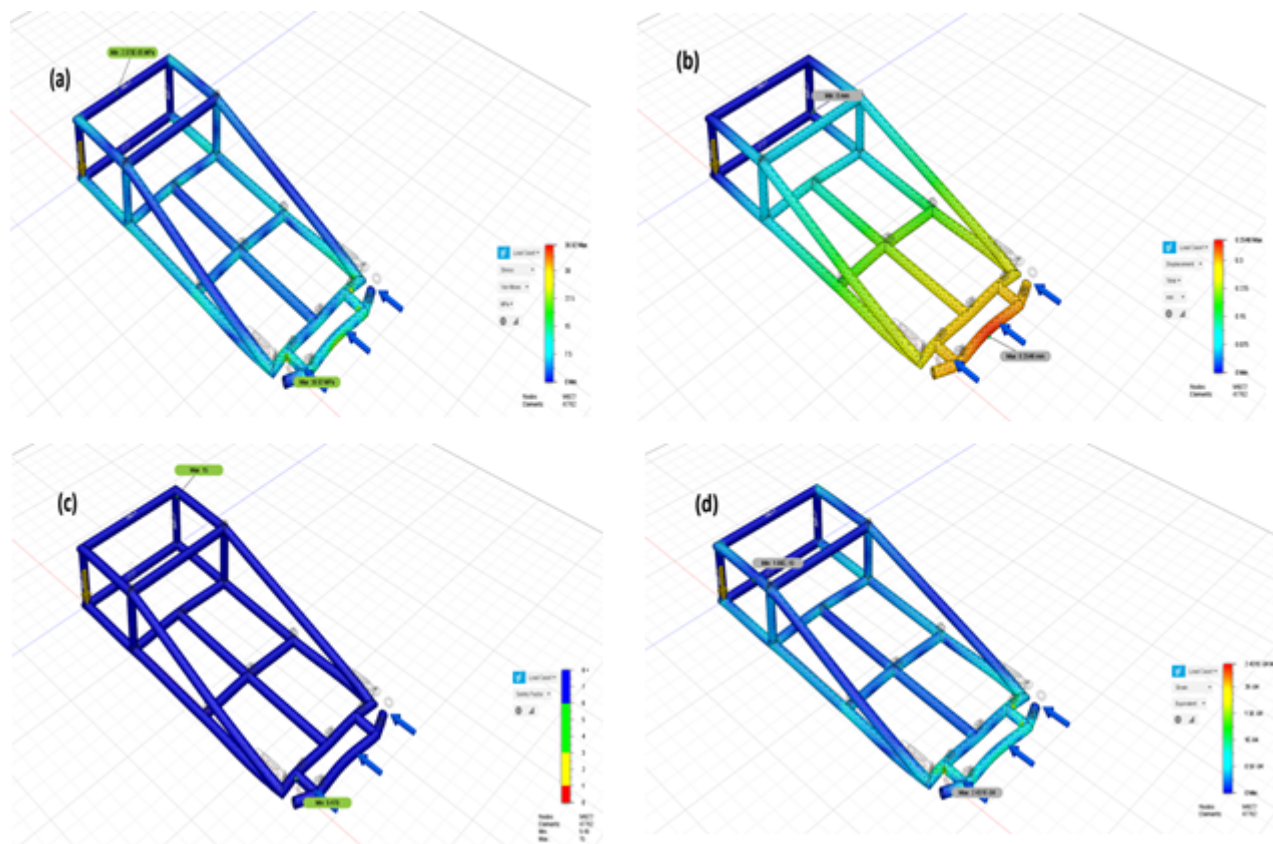

Fig 2. Front impact test (a) stress (b) displacement (c) safety factor (d) strain

Figure 2 (a) revealed the von-Mises stress profile of go-kart at front-loading conditions when the rear end was restricted against the movement. The von-Mises stress is utilized to predict the appropriateness of the material for a particular set of loading conditions. If the von-Mises stress is higher than the yield strength, the material is said to be crumpled[7]. It is generally used to study the failure behaviour of the ductile components. The von-Mises theory considers all types of stresses responsible for failure. On the other hand, Tresca theory omits the intermediate principal stress during analysis[8]. From Figure 2(a), it would be conferred that the maximum stress was observed at the front panel of the go-kart and nearby region of driver seating position. The maximum stress on the go-kart cage is well below the yield strength of the steel; therefore, the susceptibility of cage deformation is low at the maximum stress points. At maximum loading conditions, the go-kart cage may bear high localized pressure. Owing to this localized pressure or stresses the go-kart cage may face slight structure deformation during

front impact. The maximum equivalent stress was observed at the joints of the rod 'ab' and 'ce' on the frame (shown in the Figure 1). It is clear from the observation of the Figure 2(a) that stress is being distributed almost evenly at the bottom section of the frame. The maximum strain is also being generated on these points especially at the joints, which is also exhibited in the Figure 2(d). In frontal-impact condition, the sturdiness of the go-kart frame may compromise due to localized stress point formation. The deformation behaviour on the go-kart cage can be observed on the deformation profile during the front impact test on Figure 2(b). The maximum deformation can be observed at the frontal part of the frame, more specifically the middle of the rod 'ab' and at the vicinity of that area. This is obvious because the applied force is directly impacted on this section. Figure 2(c) exhibits the factor of safety profile of the structure during the previously mentioned test conditions. The safety factor indicates that the applied stress is always lower than the maximum permissible stress on the go-kart cage in these test conditions. Therefore, the structure is safe and durable in the applied test conditions.

3.2 Side impact test

Similarly, the side impact test was also simulated at 50 km/h speed. The impact duration was considered as one second. Here the impact velocity was 50 km/h and the calculated force was 11.1 kN. One side face of the go-kart was restricted for movement and the calculated force was applied to the other face. The simulated behaviour of the designed chassis in side impact conditions in terms of stress, displacement, safety factor and equivalent strain is shown in Figure 3.
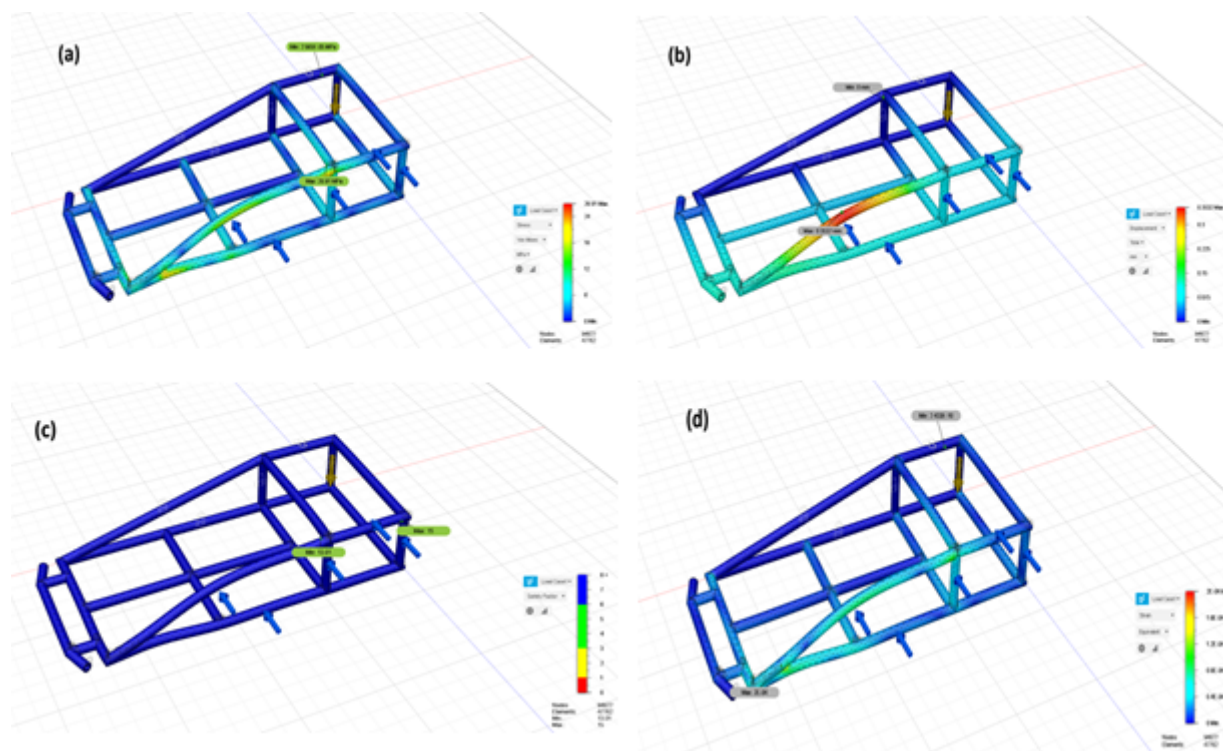

Fig 3. Side impact test (a) stress (b) displacement (c) safety factor (d) strain

The von-Mises stress profile of the go-kart chassis in side impact test conditions are shown in Figure 3(a). In this condition, the maximum stress on the go-kart cage is lower than the yield strength of the material used. Which indicates that the damage occurred during side impact is not catastrophic. Localized pressure points are located on the structure. The maximum von-Mises stress was observed at the joint designated as 'q' in Figure 1. Also, sections 'qe' and 'eh' bear the maximum stress which is evident from Figure 3(a). If Figure 3(d) is examined, then it becomes clear that maximum strain is also being generated in these parts of the frame. Due to that, the go-kart cage has minor susceptibility to localized structural damage in these sections. From Figure 3(c), it can be observed that the factor of safety is higher in this situation as well. Therefore, this structure is safer against side impact than the front or rear impact. The deformation profile for this condition can be observed in Figure 3(b). The structure section named 'qe' exhibits maximum deformation and this deformation is progressing from impacted face to the other face. Due to the direct collision on this part, the effect is more visible on the above-mentioned section. However, close

observation of Figure 3(b) exhibits that the other parts of the side frame have the ability to absorb collision energy uniformly.

3.3 Rear Impact Test

The rear impact test was carried out at 64 km/h. The calculated force was 14.2 kN. The front face of the model was kept immovable. However, 14.2 kN force was applied to the rear end of the chassis. The simulated behaviour of the designed chassis in rear impact condition in terms of stress, displacement, safety factor and equivalent strain as shown in Figure 3.
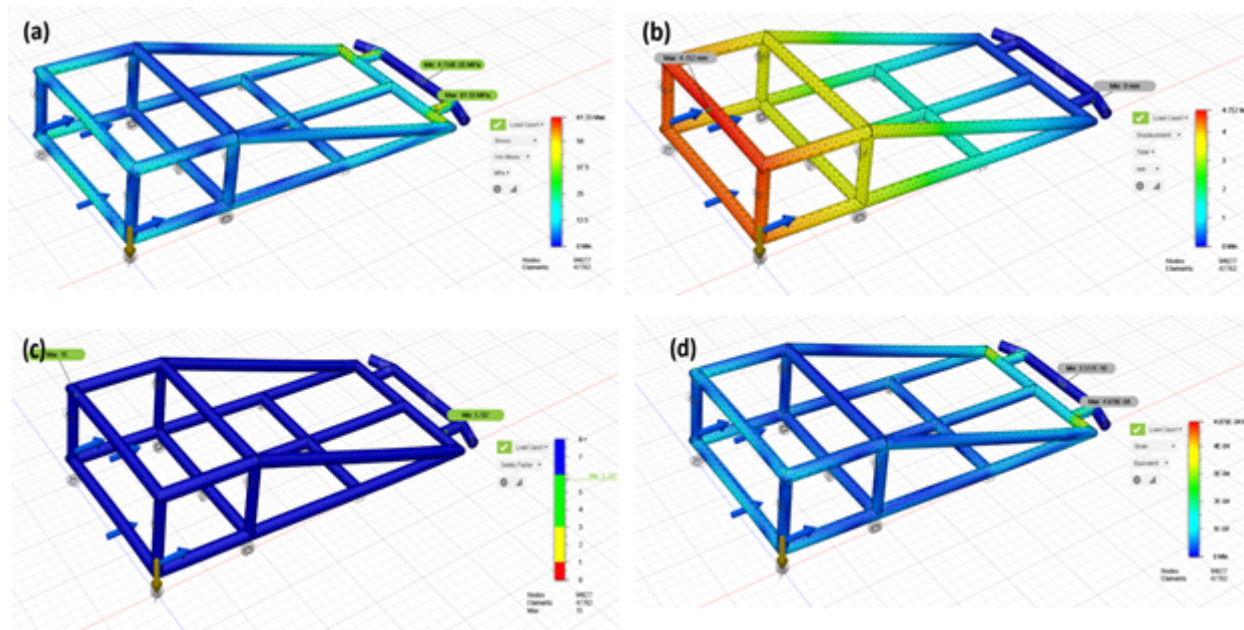

Fig 4. Rear impact test (a) stress (b) displacement (c)safety factor (d) strain

Table 3. Maximum stress, deformation and safety factor for different impact conditions

	Stress (MPa)	Deformation (mm)	Strain
Front Impact	36.92	0.3546	2.431E-04
Side Impact	26.91	0.3532	2E-04
Rear Impact	61.33	4.752	4.878E-04

The von-Mises stress profile of the go-kart chassis in back impact test conditions are shown in Figure 4 (a). The maximum stress on the go-kart cage is lower than the yield strength of AISI 1020. Again, the susceptibility of chassis deformation in this test condition is not very high at the maximum stress points. At maximum loading conditions, the go-kart structure may bear high localized pressure at the rear profile section. Due to the high localized pressure or stresses the go-kart cage can face high structure deformation in the rear section. Here also, the maximum stress intensity was observed on the frame at the joints of 'ab' and 'ce' pipes and their immediate vicinity (shown in the figure 1). However, as per the Figure 4(a), the load distribution is almost uniform throughout the cage or frame. These sections are equally susceptible to deformation due to high-stress distribution. Figure 4(d) provides the description of the equivalent strain profile of rear impact testing. It can be observed from this figure that the maximum strain is being produced eventually at the places where the frame is experiencing maximum von-Mises stress. In rear-impact condition, the sturdiness of the go-kart frame might compromise due to more number of localized stress point distribution in the rear section.

The deformation profile in rear impact conditions can be observed in Figure 4(b). The deformation can be observed at the rear section of the frame (more specifically on 'lmno' section) and at the immediate vicinity of these points. Figure 4(c) exhibits the factor of safety profile of the structure. Here also, the factor of safety is high which indicates that the probability of failure of the frame is minimal even in a rear impact situation. This indicates that the applied stress is lower than the maximum permissible stress and the structure is safe in the rear impact test conditions as well. As per the front and rear impact results, it can be said

that the structure is safer for front impact than the rear one. Maximum stress, maximum strain and maximum deformation in front, side and rear impact conditions are reported in Table 3.

4 Comparative Study of Chassis Materials at Different Loading Conditions

In this section, this design of Go-Kart was made from different materials and was tested at different load conditions. AISI-4130, Al-6061 and CFRP composite are the three materials that have been tested for this Go-kart design. The density of these three materials are 7.85 g/cc, 2.7 g/cc, 1.55 g/cc respectively. Therefore, among these three materials, the lightest is CFRP composite and the heaviest is AISI-4130 steel. The results obtained from these experiments are compiled into the following tables i.e., Tables 4, 5 and 6 . The Table 4 shows the outcomes of the front impact test of the Go-Kart design made up of these three materials under different loading conditions. Similarly, Table 5 and Table 6 are showing the rear and side impact test data, respectively.

Table 4. Front Impact Test for AISI 4130, Al-6061, CFRP Chassis Materials

Material	Load Consideration	Applied Force (kN)	Equivalent Strain	Von-misses Stress (M Pa)	Deformation (mm)	Safety Fector	Design Consideration
	4g	8.713	1.471E-04	22.63	0.2541	20.32	SAFE
	6g	13.070	2.209E-04	33.95	0.3307	13.54	SAFE
AISI-4130	8g	17.426	2.947E-04	45.27	0.4081	10.16	SAFE
	10g	21.783	3.685E-04	56.59	0.486	8.12	SAFE
	16g	34.853	5.9E-04	90.55	0.721	5.08	SAFE
	4g	4.927	2.51E-04	12.77	0.3646	21.53	SAFE
	6g	7.391	3.781E-04	19.17	0.4966	14.34	SAFE
Al-6061	8g	9.855	5.052E-04	25.56	0.6294	10.75	SAFE
	10g	12.318	6.322E-04	31.95	0.7627	8.60	SAFE
	16g	19.709	0.001013	51.12	1.163	5.37	SAFE
	4g	1.051	2.871E-05	2.707	0.0575	110.8	SAFE
	6g	1.577	4.286E-05	4.061	0.0716	73.87	SAFE
CFRP	8g	2.102	5.719E-05	5.416	0.0859	55.39	SAFE
	10g	2.627	7.171E-05	6.771	0.1004	44.3	SAFE
	16g	4.203	1.153E-04	10.84	0.1441	27.67	SAFE

Table 5. Rear Impact Test for AISI 4130, Al-6061, CFRP Chassis Materials

Material	Load Consideration	Applied Force(kN)	Equivalent Strain	Von-misses Stress(MPa)	Deformation (mm)	Safety Factor	Design Consideration
	4g	8.713	1.685E-04	23.54	0.3263	19.54	SAFE
	6g	13.070	4.187E-04	52.76	3.809	8.71	SAFE
AISI-4130	8g	17.427	6.807E-04	88.79	7.339	5.18	SAFE
	10g	21.783	9.443E-04	125.8	10.87	3.65	SAFE
	16g	34.853	0.001775	236.8	21.46	1.94	SAFE
	4g	4.927	5.196E-04	21.51	5.009	12.78	SAFE
	6g	7.391	9.745E-05	42.47	11.03	6.47	SAFE
Al-6061	8g	9.855	0.001457	63.44	17.06	4.33	SAFE
	10g	12.318	0.001941	84.41	23.08	3.25	SAFE
	16g	19.709	0.003391	147.3	41.15	1.86	SAFE
CFRP	4g	1.051	6.298E-05	5.294	0.6101	56.66	SAFE
	6g	1.576	4.857E-05	4.261	0.0825	70.40	SAFE

Table 5 continued

Material	Load Consideration	Applied Force(kN)	Equivalent Strain	Von-misses Stress(MPa)	Deformation (mm)	Safety Factor	Design Consideration
	8g	2.102	9.819E-05	7.642	0.7376	39.25	SAFE
	10g	2.627	1.497E-04	11.59	1.407	25.88	SAFE
	16g	4.203	3.103E-04	25.08	3.417	11.96	SAFE

Table 6. Side Impact Test for AISI 4130, Al-6061, CFRP Chassis Materials

Material	Load Consideration	Applied Force(kN)	Equivalent Strain	Von-misses Stress(M Pa)	Deformation (mm)	Safety Factor	Design Consideration
AISI-4130	4g	8.713	1.597E-04	20.85	0.2837	22.06	SAFE
	6g	13.070	2.321E-04	31.95	0.4072	14.39	SAFE
Al-6061	4g	4.927	2.378E-04	11.37	0.4599	24.18	SAFE
	6g	7.391	3.558E-04	17.28	0.687	15.91	SAFE
CFRP	4g	1.051	2.713E-05	2.347	0.06079	127.8	SAFE
	6g	1.576	4.038E-05	3.596	0.08024	83.42	SAFE

These results indicate that all three materials used in the current investigation meet all loading criteria and are suitable for this design of the Go-Kart. Present investigation exhibits that all three materials are not only suitable for this Go-Kart design but also showed sufficient resistance against front, rear and side impact tests. In-depth observation of the above mentioned tables i.e., Tables 4 and 6 suggests that CFRP composite material seems to be showing the best properties among all the materials used here.

5 Conclusion

The basic requirement of a small go-cart vehicle is a high strength to weight ratio. In this study, attempts have been made to simplify the go-kart design in terms of construction and to optimize its strength and durability. The three-dimensional model of go-kart was analyzed by the Finite Element Analysis method in AutoDesk Fusion 360 software. The results of simulations performed under different conditions showed that this design has demonstrated adequate resistance against deformation in front, back and side collision tests. The material used in this experiment not only reduces the specific weight of the go-kart but also exhibits suitable resistivity against deformation during the collision. In every condition, the Factor of Safety was found to be more than one. On that basis, it can be said that the proposed model of Go-Kart may be able to meet the safety criteria. In addition to this experiment, this Go-Kart was also made by three more materials i.e., AISI-4130, Al-6061 and CFRP composite and tested in different loading conditions. Under different loading conditions, a comparative study of Go-Kart design was carried out. It was observed that among all the materials, the design made up of CFRP composite are the safest. The strong and weak points of the design can be recognized by the Finite Element Analysis method of a three-dimensional model. All the necessary improvements in the design can also be made to the model after identifying its shortcomings. It is not only economical and convenient but the analysis also takes lesser time. Later on, the optimal design can be fabricated and tested in real-life conditions. This proposed model needs to be further analyzed before being tested in real-life circumstances.

References

1) Cardoso C, Ferreira J, Alves V and Araujo RE. The design and implementation of an electric go-kart for education in motor control. In: and others, editor. International Symposium on Power Electronics, Electrical Drives, Automation and Motion . 2006,. p. 1489–1494. Available from: https://doi.org/10.1109/SPEEDAM.2006.1650003.

2) Joeri VM, Jean-Marc T, Philippe L and Peter VB. Project oriented education: Build your own electric go-kart. In: and others, editor. European Conference on Power Electronics and Applications. IEEE . 2005,. .

3) Abdullah NAZ, Sani MSM, Husain NA, Rahman MM and Zaman I. Dynamics properties of a Go-kart chassis structure and its prediction improvement using model updating approach. *International Journal of Automotive and Mechanical Engineering*. 2017;14:3887–3897. Available from: https://doi.org/10.15282/ijame.14.1.2017.6.0316.

4) Sani MSM, Ming GL, Rahman MM, Sulaiman AS, Mon TT and Kadirgama K. Dynamic Correlation Technique and Model Updating on Go Kart Chassis Structure. In: and others, editor. Proceedings of EnCon2008, 2nd Engineering Conference on Sustainable Engineering Infrastructures Development &

Management . 2008,. .

5) Saini NK, R R, Hassan MN and Goswami K. Design and Impact Analysis of Go-kart Chassis. *International Journal of Applied Engineering Research*. 2019;14(9):46–52.

6) Saini NK, Panwar MS, Maurya A and Singh PA. Design and Vibration Analysis of Go-kart Chassis. *International Journal of Applied Engineering Research*. 2019;14(9):53–60.

7) Suherman WB, Praptijanto A, Santoso WB, Nur A and IEEE. Modeling and static analysis of a connecting rod in range extender engine. In: and others, editor. In: 2016 International Conference on Sustainable Energy Engineering and Application (ICSEEA). IEEE . 2016,. p. 17–21. Available from: https://doi.org/10.1109/ICSEEA.2016.7873561.

8) Ali HMM and Haneef M. Analysis of fatigue stresses on connecting rod subjected to concentrated loads at the big end. In: and others, editor. Materials Today: Proceedings. vol. 2. Elsevier BV . 2015,. p. 2094–2103. Available from: https://dx.doi.org/10.1016/j.matpr.2015.07.205.