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A study on structural behaviour and vibrational characteristics of a go-kart chassis

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Abstract. A go-kart is a four-wheel drive that lacks a suspension system and differential unit due to the very low ground clearance usually employed for Formula E or Formula 1 racing. Due to the absence of a suspension system, the chassis of the go-kart should be rigid and strong enough to withstand the impact loads, as well as other support equipment. The present research focused on the design, material selection, and structural and vibrational analysis on the go-kart chassis. For this, the chassis is designed with suitable dimensions and materials. In this, the chassis is modelled by using CATIA V5 software and performed static structural and vibrational analysis by using Finite Element Analysis (FEA) ANSYS software. The chassis was designed with Circular pipes with a diameter of about 26.4 mm with a 4 mm pipe thickness made of AISI 1018, AISI 1026, AISI 4130, and structural steel were chosen due to their superior mechanical properties to perform the finite element analysis to find the total deflection, equivalent stress, factor of safety and first six mode shapes of the chassis configuration.

keywords: Go-kart chassis, Suspension, Impact load, Vibration, AISI.

1 Introduction

A go-kart is a four-wheel, single-seated vehicle with no suspension system and differential typically employed for Formula 1 or Formula E racing. The ground clearance should not be more than 70 mm, so it is known as a very low ground clearance vehicle. Art Ingels invented the first go-kart in America in the year 1956. Due to its high speed, aesthetic look, and simplicity in construction, it is very popular all around the world. The chassis, engine, steering, brakes, and tyres were the go-kart's essential components. The chassis is a skeleton frame made from a steel structure which acts as a base and supports all the required equipment for the vehicle and withstands the driving torque as well as impact loads. The chassis should possess adequate strength, stiffness, and high twisting resistance due to the lack of suspension. There are three types of chassis they are frame chassis, unit-body chassis, and space frame chassis. The frame-type chassis is a normal chassis different from ordinary car chassis especially used for go-karts.

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The go-kart chassis should be made with lightweight material at the same time it should be able to withstand impact loads when applied.

A foldable go-kart chassis was developed by Raghuvanshi et al. [1] in two parts, the front and rear chassis, with circular pipes made of AS-202 stainless steel that was 30 mm in diameter and 5 mm thick. These pipes are joined together with the aid of a self-locking joint made of mild steel and can be folded in the middle to save space. They performed the strength analysis on the self-locking joint of this foldable chassis. Finally, they conclude that a foldable chassis with a joint makes any vehicle compatible. Hajare et al. [2] used SOLIDWORKS software to design the go-kart chassis and ANSYS & HYPERMESH software to do structural analysis on the go-kart chassis. They suggested that for a chassis, a minimum of 3.125 mm thick tubing either square or round cross-section is required for better performance of the vehicle. To find the deflection by performing the structural analysis on the chassis, they selected low/mild carbon steel materials like AISI 1018, AISI 1026, and AISI 4130. It is found that AISI 4130 is a suitable material to construct the chassis because it has less deflection. Further, Nagendra et al. [3] designed and analyzed the chassis with different materials by using CATIA and ANSYS software. In order to perform the static analysis, they used structural steel, AISI 1010, and AISI 4340 materials. They retrieved the outcome in the form of deflection and equivalent stress. The total deflection for structural steel, AISI 1010, and AISI 4340 materials in the front-impact test was found to be 66.3 mm, 639 mm, and 494 mm, respectively. They concluded that structural steel material is recommended to construct the chassis because it has less deflection compared to AISI 1010, and AISI 4340.

Sannake et al. [4] designed and performed dynamic analysis on the go-kart chassis by using CERO PARAMETRIC 3.0 and ANSYS software. They constructed the chassis with hollow cross-section pipes made of AISI 1018 material whose diameter is 26.4 mm with a pipe thickness of 5 mm because of its high tensile strength, toughness, and ductility. The length and width of their chassis are 42 inches and 38 inches respectively. In dynamic analysis, they performed front and rear impacts at 50 Kmph and side impacts at 30 Kmph, with a time of impact as 0.2 sec to find the total deflection and von-misses stress. Later, using the FEA ANSYS software, Srivastava et al. [5] carried out a numerical analysis to examine the structural and vibration properties of three different go-kart chassis layouts. The vibrational analysis is performed to extract the first twelve mode shapes at each natural frequency and also performed impact testing to find the total deflection, and equivalent stress for the front, rear, and side collision tests. Saini et al. [6] designed and performed an impact analysis on the go-kart chassis. They modelled the chassis in the CAD software and performed the static analysis in the ANSYS software. In order to find the total deformation, equivalent stress, and safety factor for the front, rear, and side collisions at a load criterion of 4g, 6g, 8g, and 16g, they chose AISI 1018, AISI 1026, AISI 1020, & AISI 4130 materials for the chassis. They considered the mass of the chassis along with the driver as 200kg. it is found that the safety factor is high for AISI 4130 material when compared to the remaining materials. Finally, they conclude that AISI 4130 material has a safety factor more than 1 up to 6g loading conditions compared to remaining materials.

An electric go-kart was fabricated by Krishnamoorthi et al. [7] by designing and performing the static analysis in SOLIDWORKS and ANSYS software respectively, to find the total deflection, von-misses stress, and safety factor for the front, rear, and side impacts. They chose AISI 1018 material for the chassis to perform the impact tests. The front and rear impact tests are performed by applying a load of 7652 N and the side impact test is performed by applying a load of 5102 N. It is found that the highest safety factor is having for the side impact test i.e., 5.88, and the least safety factor is having for the front impact test i.e., 3.07. However, the limited studies are carried out to understand the structural and vibrational characteristics of go-kart chassis. So, this work is focused on design and model the go-kart chassis with suitable dimensions and materials, and to perform the static structural and vibrational analysis in order to find the total deflection, equivalent stress, factor of safety & mode shapes of the chassis configuration at each natural frequency.

2 Methodology

In this work, the go-kart chassis was designed with a dia. of 26.4 mm and a 4 mm pipe thickness with four different materials such as AISI 1018, AISI 1026, AISI 4130, and structural steel individually in order to study the structural and vibrational characteristics of the chassis configuration.

2.1 Design of chassis

Go-kart chassis generally differ from normal car chassis. There are three types of chassis they are frame chassis, unibody, and space frame chassis. Usually, go-kart chassis should have less weight to attain high speeds. Frame-type chassis are commonly used for go-karts because it has very less weight which results in the high speed of the vehicle when compared to unibody chassis and space frame chassis.

The CATIA V5 software is used here to model the frame-type chassis. The chassis was designed in a hollow-cross section where the diameter is 26.4 mm with a 4 mm pipe thickness. The overall length and width of the chassis are 1520 mm and 720 mm, respectively. The wheelbase and wheel track are kept at 1210 mm and 940 mm, respectively. Tools like profile, constrain, rib, and trim are used to model the chassis. To convert the model of the chassis from 2D to 3D pad feature is used.

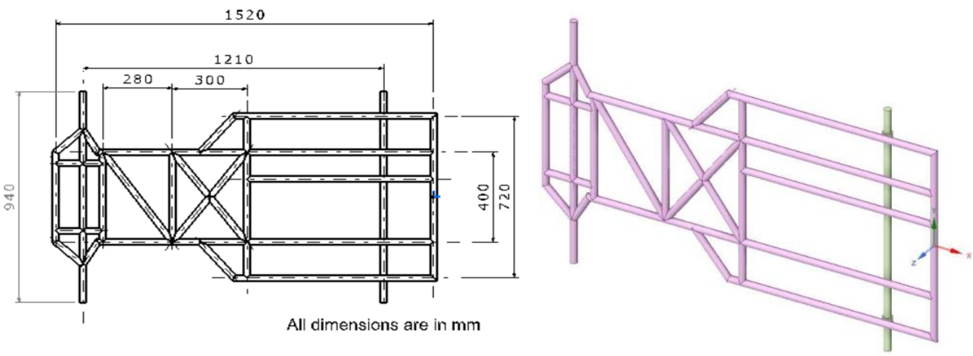

Fig. 1. Drawing views of 3D model frame chassis.

2.2 Material Selection

The material selection for the go-kart chassis plays a vital role in the design process. To withstand impact loads, the chassis should have high tensile strength, torsional rigidity, toughness and ductility to bear the vibrations and minimize the deformation. Generally, for a go-kart chassis low or mild-carbon steel materials are well suited. Here in this present work, AISI 1018, AISI 1026, AISI 4130, and structural steel materials were chosen to perform the structural and vibrational analysis on the chassis due to its superior mechanical properties. The mechanical properties of these materials were shown in Table 1.

Table 1. Mechanical properties of the materials

Material	Density (kg/m³)	Modulus of elasticity (GPa)	Passions' Ratio	Tensile yield strength (MPa)
AISI 1018	7850	200	0.29	370
AISI 1026	7850	200	0.3	415
AISI 4130	7858	210	0.3	435
Structural steel	7750	203	0.29	250

2.3 Static Structural and Modal Analysis

FEA analysis is a numerical method, in which an unknown function of the problem domain is calculated in a piecewise-defined function. To perform the structural and modal analysis on the chassis configuration, we are using Finite Element Analysis (FEA) ANSYS 2022 R1 software. We assigned AISI 1018, AISI 1026, AISI 4130, and structural steel materials for the chassis. The chassis has meshed with a triangular shape for the entire geometry and it is discretized into 243,977 nodes and 150,584 elements. In static structural analysis, the front, rear, and side collision tests were performed by applying a force of 15000 N by considering the vehicle's mass as 180 kg along with the driver, optimum speed, and time of the collision as 60 Kmph, and 0.2 sec, respectively to find the total deflection, equivalent stress and safety factor. In modal analysis, the vibrational test is performed to extract the first six mode shapes of the chassis configuration at each natural frequency. The formula used for calculating the safety factor is

F.O.S = Tensile yield strength/Von-misses stress

2.3.1 Front Collision Test

To perform the front collision test, the boundary conditions are applying the impact force on the front portion by fixing the rear portion of the chassis which is shown in Fig. 2a

2.3.2 Rear Collision Test

To perform the rear collision test, the boundary conditions are applying the impact force on the rear portion by fixing the front portion of the chassis which is shown in Fig. 2b

2.3.3 Side Collision Test

To perform the side collision test, the boundary conditions are applying the impact force on either the left or right side of the chassis by fixing the remaining other side which is shown in Fig. 2c

2.3.4 Vibrational Test

To perform the vibration test, the boundary conditions are fixed supports at the front and rear wheels on the front and rear axle which is shown in Fig. 2d

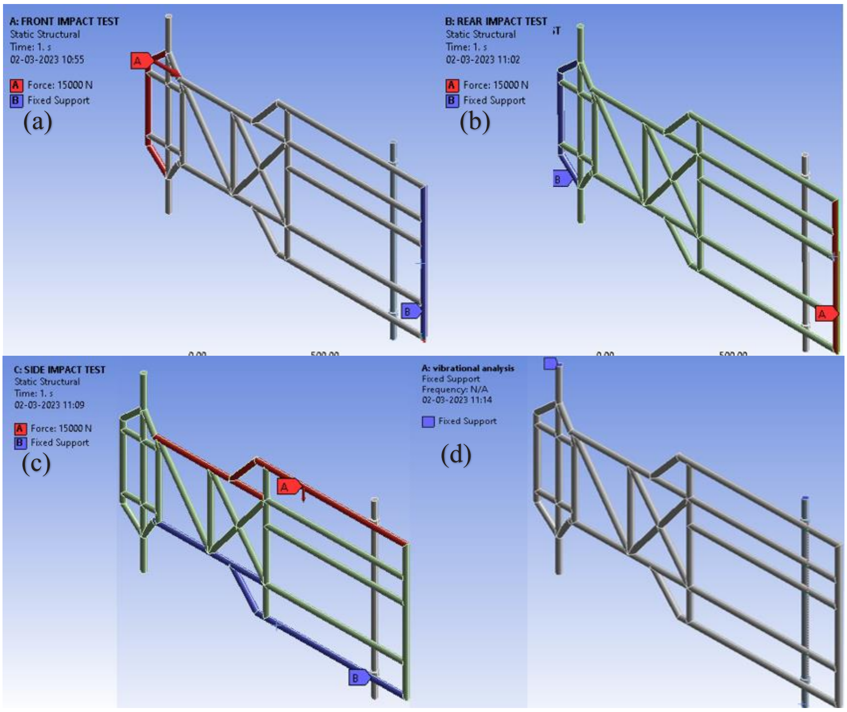

Fig. 2 Static structural and Modal analysis boundary conditions (a) Front collision test (b) Rear collision test (c) Side collision test (d) Vibrational test.

3 Results and Discussions

3.1 Static Structural Analysis

From the static structural analysis of chassis made of four different materials such as AISI 1018, AISI 1026, AISI 4130, and structural steel individually with 4 mm pipe thickness are presented in Table 2,3,4 and Fig. 3 to 4. From the results presented in Tables 2,3, and 4, it is observed that the least deformation and high factor of safety are had for chassis with AISI 4130 material during all three impact tests and also observed that the safety factor is above 1 in all cases except during the side impact test with structural steel material. During the front, rear, and side collision tests, the least deflection i.e., 0.35423mm, 0.43852 mm, and 1.8413 mm are having for the chassis designed with AISI 4130 material and similarly, during the front, and rear collision tests, the max. deflection i.e., 0.37208 mm and 0.46060 mm are having for the chassis designed with AISI 1018 material and during the side collision test, the max. deflection i.e., 1.9334 is having for the chassis designed AISI 1018.

During the front collision tests, the least equivalent stress i.e., 137.09 MPa is having for the chassis designed with AISI 1018, and structural steel materials and during the rear, and side collision tests, the least equivalent stress i.e., 133.9 MPa, and 285.18 MPa are having for the chassis designed with AISI 4130 and AISI 1026 materials. Similarly, during the front collision test, the max. equivalent stress i.e., 137.96 MPa is having for the chassis designed with AISI 4130 and AISI 1026 materials and during the rear, and side collision tests, the max equivalent stress i.e., 134.2 MPa, and 285.36 MPa are having for the chassis designed with AISI 1018 and structural steel materials.

Table 2. Front Collision test results

Material	Total Deflection (mm)	Equivalent stress (MPa)	Safety factor
AISI 1018	0.37208	137.09	2.69
AISI 1026	0.37195	137.96	3.00
AISI 4130	0.35423	137.96	3.15
Structural steel	0.36658	137.09	1.82

Table 3. Rear collision test results

Material	Total Deflection (mm)	Equivalent stress (MPa)	Safety factor
AISI 1018	0.46060	134.2	2.75
AISI 1026	0.46044	133.9	3.09
AISI 4130	0.43852	133.9	3.24
Structural steel	0.45379	134.2	1.86

Table 4. Side collision test results

Material	Total Deflection (mm)	Equivalent stress (MPa)	Safety factor
AISI 1018	1.9319	285.36	1.29
AISI 1026	1.9334	285.18	1.45
AISI 4130	1.8413	285.18	1.52
Structural steel	1.9033	285.36	0.87

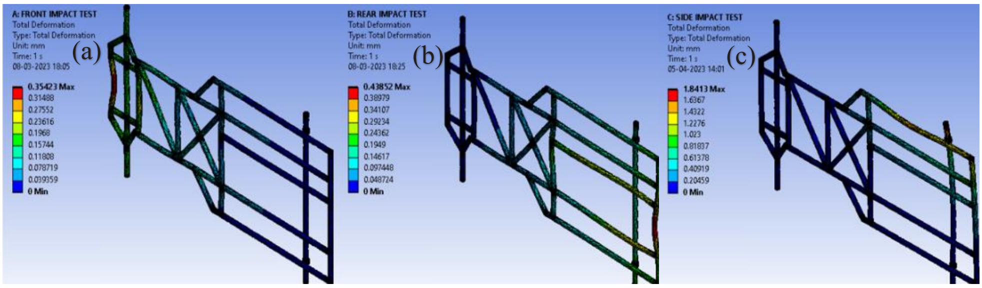

Fig. 3 Total deflection for (a) Front collision test (b) Rear collision test (c) Side collision test.

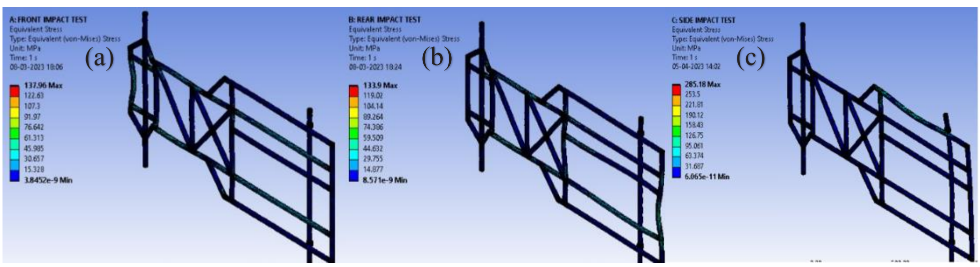

Fig. 4 Equivalent stress for (a) Front collision test (b) Rear collision test (c) Side collision test.

3.2 Modal Analysis

From the modal analysis of chassis made of four different materials i.e., AISI 1018, AISI 1026, AISI 4130, and structural steel individually with 4 mm pipe thickness is presented in Table 5 & Fig 5. From the results presented in Table 5, it is observed that for the AISI 1018, AISI 1026, AISI 4130, and structural steel materials, the highest frequencies are 142.83 Hz, 142.68 Hz, 146.32 Hz, and 143.93 Hz and their corresponding total deformations are 11.889 mm, 11.854 mm, 11.921 mm, and 11. 858 mm respectively. From this, it is clear that AISI 4130 material is the better material for the chassis among the four materials.

Table 5. Vibration test results

Mode shapes	Natural frequency applied (Hz)			
	AISI 1018	AISI 1026	AISI 4130	Structural steel
Mode shape 1	38.817	38.749	39.723	39.085
Mode shape 2	76.932	76.817	78.773	77.523
Mode shape 3	79.603	79.411	81.452	80.182
Mode shape 4	104.39	104.31	106.95	105.16
Mode shape 5	139.98	139.91	143.47	141.08
Mode shape 6	142.83	142.68	146.32	143.93

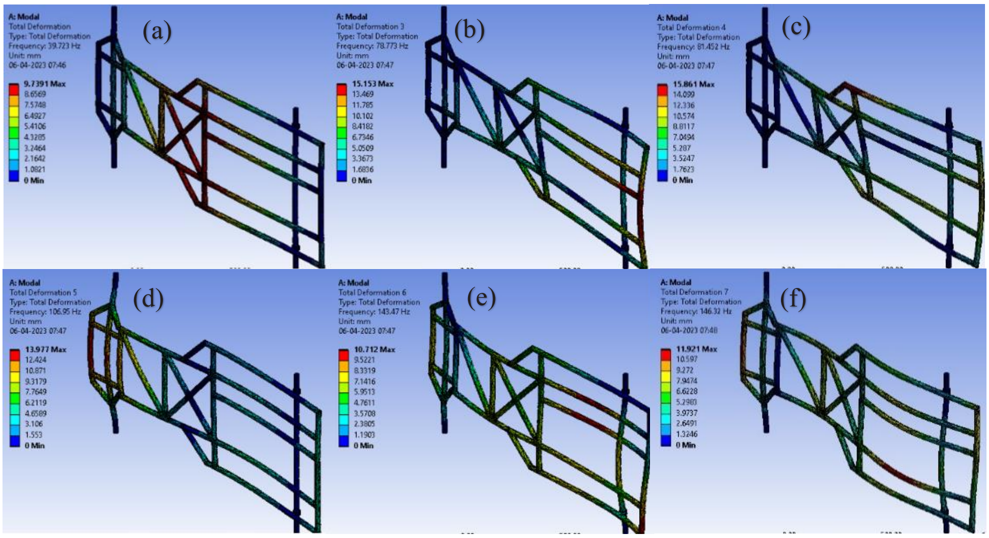

Fig. 5(a-f) First six modes shapes for chassis with AISI 4130 material

4 Conclusion

The modeling and FEM analysis on the chassis was carried out in this work using the CATIA V5 and ANSYS 2022 R1 software. To study the structural behavior and vibrational characteristics to determine the total deflection, equivalent stress, safety factor, and first six mode shapes for the chassis configuration, four widely used materials such as AISI 1018, AISI 1026, AISI 4130, and structural steel with 4 mm pipe thickness were selected. It is observed that the safety factor for the chassis is above 1 when an impact force of 15000 N is applied in all the front, rear, and side collision tests with all four materials except during the side impact test with structural steel material. The design of the chassis with all the materials are safe designs except structural steel material. It is clear that AISI 4130 material is the perfect suitable material for the chassis because it has better simulation results compared to AISI 1018, AISI 1026, and structural steel materials.

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