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Design Optimization and Analysis of Chassis and Power Transmission Sub-System of Go-Kart

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Abstract - The Go-Kart is a four wheeled racing vehicle with no suspension or differential. Go-karts come in all shapes and forms, from non-motorized models to high-performance racing karts. There are only four sub systems in Go-Kart they are Chassis, Steering, Power Transmission and Braking. The main objective of this paper is to find out the loop holes particularly in chassis and power transmission sub-system and also to optimize the design and analysis of chassis by considering the front, rear and side impact loads by using CATIA V5 and ANSYS 19.1. The suitable material for the chassis as well as various parts of power transmission is designed and analyzed. The frame is the most significant aspect of the go-kart's chassis sub-system; frame optimization is done by comparing 2D and 3D frames in various viewpoints, and structural analysis is done by considering the minimum and maximum impact loads. The optimization of the Power Transmission sub-system is done by addressing heat transmission from the vehicle by adding exterior fins, which boosts the engine's as well as vehicle's efficiency. The go-kart is modified to incorporate the new design in the relevant sub-systems.

1. INTRODUCTION

A go-kart is a small-footprint, four-wheeled racing vehicle. These are single-seat racing car without a differential or suspension. Although there are many different sizes and designs of go-karts. There are also different varieties of it, from motorless models to incredibly strong racing vehicles. The go-kart can only be utilized on flat racing tracks because of its limited ground clearance. Using 3D CAD software, we will create a model, and analytical tools will be used to test the design against all potential failure modes, loads, and deformations. By definition, a go-kart lacks both a suspension and a differential. Usually, they race on smaller tracks. Most people think of carting as a stepping stone to the more elite and expensive levels in motorsports. Most people agree that kart racing is the most affordable type of motor sport. Almost anyone can participate in it as a free-time pastime, and it allows for open racing. Kart racing is frequently utilised as a low-cost and largely safe introduction to motor racing for new drivers.

There are different sub-system in Go-Kart, they are:

- Chassis sub-system
- Power Transmission sub-system
- Steering sub-system
- Braking sub-system

We have thought about optimizing the design and analysis of the chassis subsystem as well as the power transmission subsystem out of these subsystems. As the chassis serves as the primary support structure for all automobiles, including go-karts, and power transmission aids in the transmission of the power which is generated near the engine to the wheels of the Go-kart and helps to move the vehicle.

2. PROBLEM IDENTIFICATION

In Chassis sub-system, Using of a 2D frame and longer wheelbase

- Gives less clearance,
- Increases the turning ratio,
- Difficulty in performing tasks such as Autocross and Skid pad.

In Power-Transmission sub-system, As the engines are manufactured by the companies itself, so there is no defect in the engine, but the vehicle must use complete performance of the engine and also increase its efficiency.

- Increase in height of the RRH will not allow the air to pass through the engine due to which the engine cooling is not possible which in turn decreases the efficiency of the engine.

3. LITERATURE REVIEW

The previous research work description as follows, The explanation behind using the materials used in the fabrication of the chassis and axle is included in the process for the virtual design and testing that has been explained in depth. Additionally, the justification for creating a novel go-kart chassis design that differs from the traditional go-kart chassis design has been provided and demonstrated. Even though the entire design and testing procedure that has been described has produced intriguing results, the methodology still has to be confirmed through dynamic experimental tests. This will enable the development of a fully specified and validated mathematical model, providing the foundation for subsequent advancements regarding the process of go-kart performance optimization. The virtual design process for the go-kart transmission system has been explained in detail. Also specified are the assumptions that must be taken into account and the defined path for the calculations. Dynamic experimental tests have been conducted to evaluate and validate the transmission system designs for go-karts. This will make it possible to change the methodology. The foundation for the transmission system's developments and improvements is provided by this study. Carry out a dynamic analysis of the circular beam-constructed go-kart chassis. CATIA and ANSYS are used, respectively, for modelling and analysis.The go-kart chassis is different from ordinary car chassis. The chassis is designed in such a way that it requires less materials and ability to withstand loads applied on it. Forces which are responsible for causing crack initiation and deformation in the vehicle results in Stress Generation in the Roll Cage.

4. DESIGN, ANALYSIS AND FABRICATION OF CHASSIS SUB-SYSTEM

Chassis is the main base of the vehicle which supports all the components of the vehicle. In Go-Kart we have used free type 3D frame chassis, which helps to increase the clearance as well the suspension of the vehicle.

Steps for the fabrication of chassis:

a) Design of chassis
b) Mock chassis for ergonomics
c) Selection of appropriate material
d) Calculation of impact forces
e) Analysis of chassis
f) Fabrication of chassis

a) Design of old chassis

CATIA V5 software is used for chassis modeling. The wheelbase and track width of the go-kart are taken into account while designing the chassis, and the primary and secondary members are positioned by taking into account the locations of the kart's various parts, such as the engine, rear axle, C clamps, seat, etc.

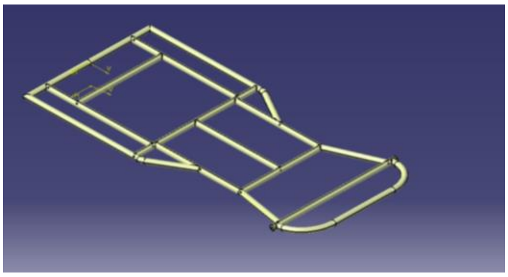

Fig-1: Design of old chassis

The design of old chassis had longer wheelbase and 2D frame due to which the turning radius of the vehicle increased, because of the longer length of the wheelbase skid pad and Autocross tasks are very difficult to qualify and suspension of the vehicle decreased, as chassis itself act as suspension in Go-Kart

b) Design of optimized chassis

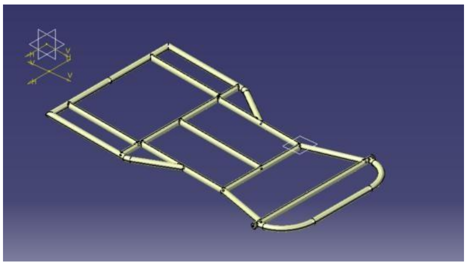

Fig-2: Isometric view of optimized chassis

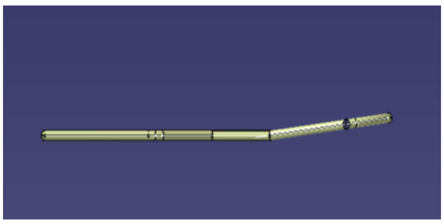

Fig-3: Side view of optimized chassis

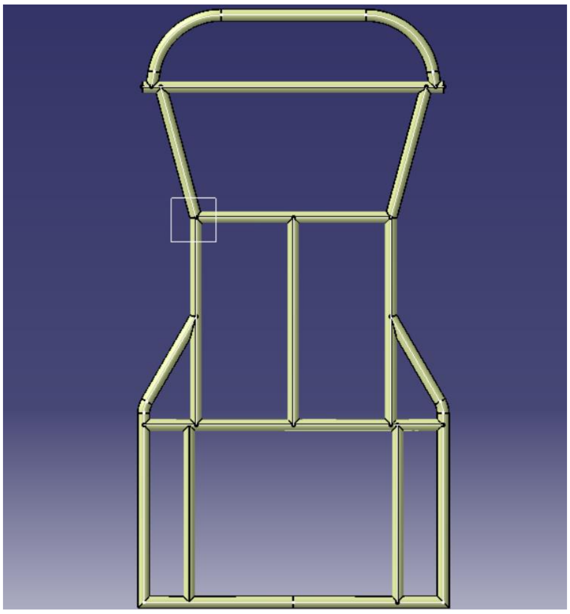

Fig-4: Top view of chassis

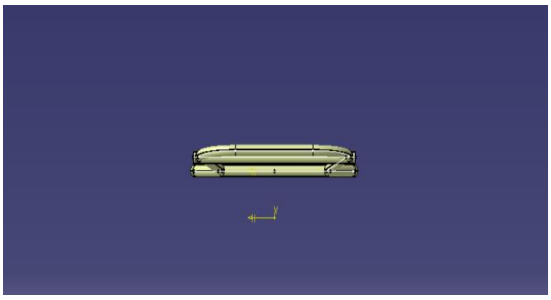

Fig-5: Front view of chassis

Result

The optimized chassis wheelbase is decreased and also it is an 3D frame due to which the clearance of the vehicle increased, suspension of the vehicle increased and turning radius decreased, as a result Autocross, Skid pad tasks are easy to qualify.

c) Material selection for chassis

The material for the chassis of the Go-Kart should have high strength, yield strength and ultimate strength. The material should be seamless pipe so that, after collision the chassis should be able to deform easily. As a result the driver will not be effected by impact forces.

There are different dimensions of seamless pipes available, using 1inch diameter pipe with 1.5thickness will be suitable for the chassis fabrication, as chassis weight should also be taken into consideration.

There are different type of materials that can be chosen for the fabrication of the chassis which can be seen in the following table:

Material	Yield Strength	%Elongation	Cost per material
AISI 1026	260-240MPa	17-27%	445
AISI 4140	445-750MPa	18-26%	745
AISI 1020	240-270MPa	18-28%	415
AISI 1018	270-400MPa	18-29%	400

Table-4.1: Types of materials

It has been noted from the table 4.1 that AISI 1018 is a material with great machinability and a low cost. Although the material AISI 4140 is a suitable choice in terms of yield strength, AISI 4140 has a stronger strength to weight ratio.

Due to its high carbon content and poor machinability, AISI 4140 was rejected; yet, this steel is widely used in the race car business but is difficult to get in India. As a result, 1018 is the best material for the fabrication of Go-Kart. Also AISI 1018 material does not affect the weight or stiffness in member with same geometry and has excellent weld ability and produces a uniform and harder case and it is considered as the best steel for carburized parts.

AISI 1018 PHYSICAL PROPERTIES	
Density	8.05kg/m3
Youngs modulus	205GPa
Yield strength	370Mpa
Ultimate strength	470Mpa

Table-4.2: Physical properties of AISI 1018

AISI 1018 CHEMICAL COMPOSITION	
Carbon	0.14-0.2%
Manganese	0.6-0.9%
Phosphorous	<0.04%
Iron	98.81-99.26%

Table-4.3: Chemical properties of AISI 1018

d) Calculation of impact forces

Three impact forces should be calculated which acts on chassis, they are:

- Front impact force
- Rear impact force
- Side impact force

For the analysis of chassis we have considered the maximum velocity of the kart.

V= u + at

final velocity v= 50 kmph

u=initial velocity = 0kmph

a= acceleration=?

t= impact time >0.5 sec for front and rear impact

0.6sec for Side impact

Now by substituting these values in above equation

V=u + at

50=a + a(0.5)(for front & rear impact]

a= 50 kmph/0.5

a=50x 5/18/ 0.5

a= 27.7m/s² > for front & rear impact

Similarly for side impact

v=u + at

50 = 0 +a (0.6)

a=50*5/18/0.6

a= 24.148 m/s² "for side impact

f=ma

where F=dynamic force

m=cart weight=180kgs

a=derived acceleration of front, rear &side impact

So, the dynamic force for the front & rear impact is

$F=110*27.7m/s^2$

=4047N

Similarly for side impact the dynamic force will be

F = 110x24.148 m/s²

=2541N

F_i=4047N & F_s=2541N

G= F/(m*g)

where G= Gravitational Constant

F = dynamic force

m = cart weight

g= gravitational force

G= F/(mg.)

for front & Rear Impact

$G_i=4047/110*9.8m\backslash s^2$

G_i=2.82

Similarly for side impact

$G_s=2.54/110*9.8m\backslash s^2$

$G_{s=}2.45$

4) F=G(mg.)

Where F = impact force

G = Gravitational Constant

m = kart weight (with driver)

g gravitational fore.

F_{if} =2.82 (180X9.81)

=4979.556 N

$F_{is=}$2.45(180*9.81)

=4149.64N

For maximum impact force we use standard & values for front & rear side G value is 4G & Side is 3G

F_{if} = 4×9.81 x 180 =**7,064.2 N**

F_{is}=3*9.81*180 = **5297.4N**.

For analysis consider the maximum impact force.

e) Analysis of chassis

ANSYS 19.1 software is used for analysis of chassis. The chassis which is designed in CATIA V5 software is saved in .igs format and the analysis process is carried out.

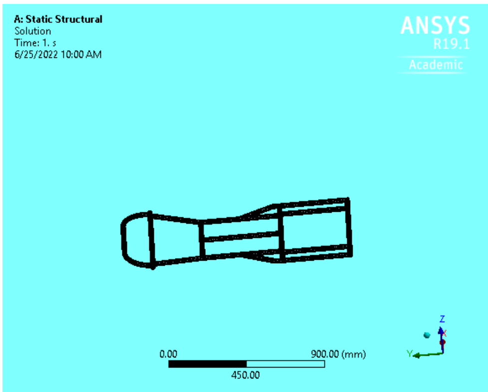

Fig-6:Meshing of chassis

After meshing of chassis the fixed points to the chassis should be given and then apply the force and find the solution.

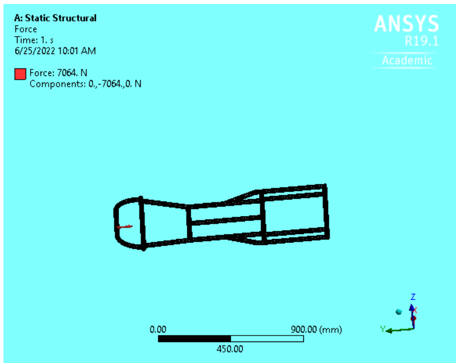

Fig-7: Impact Force applied

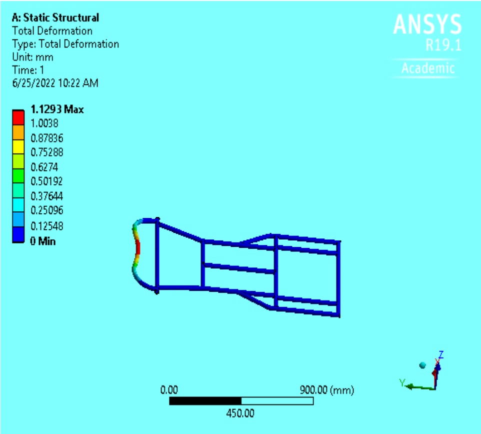

Fig-8: Total deformation due to front impact force

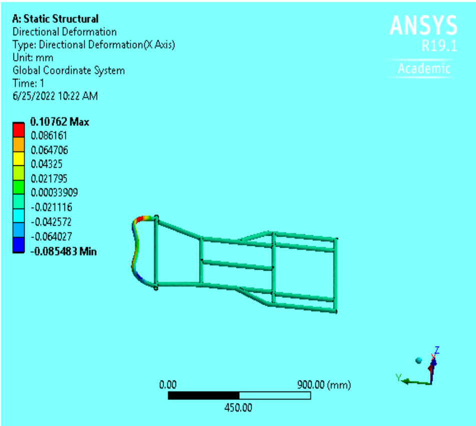

Fig-9: Directional deformation due to front impact force

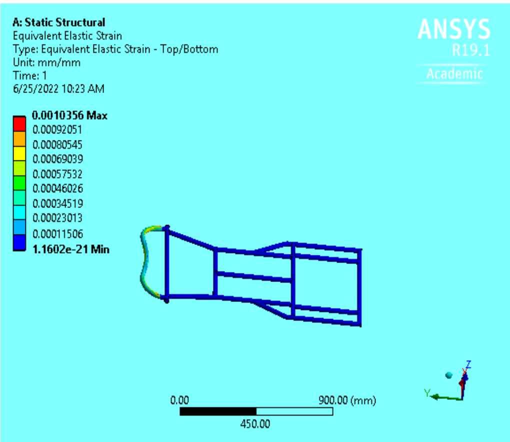

Fig-10: Equivalent elastic strain due to front impact force

Front Impact: From figure 8,9,10, For front impact test, the mass of the vehicle as well as driver mass is considered that is about 180kg and assumed the vehicle is with the impact force at a speed of 50km/h in the front part of the chassis. The maximum force is taken into consideration about 7064.2N, due to which the maximum deformation is about 1.129mm and directional deformation is 0.10262mm,equivalent elastic strain is 0.001

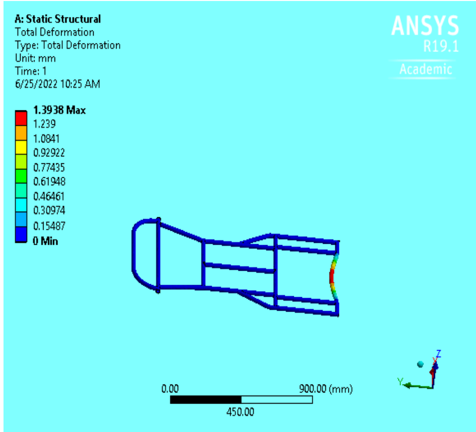

Fig-11: Total deformation due to rear impact force

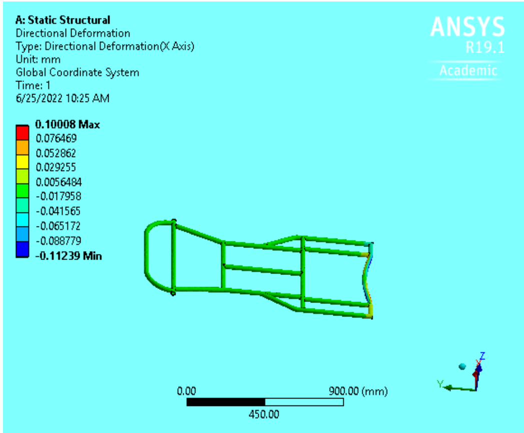

Fig-12: Directional deformation due to rear impact force

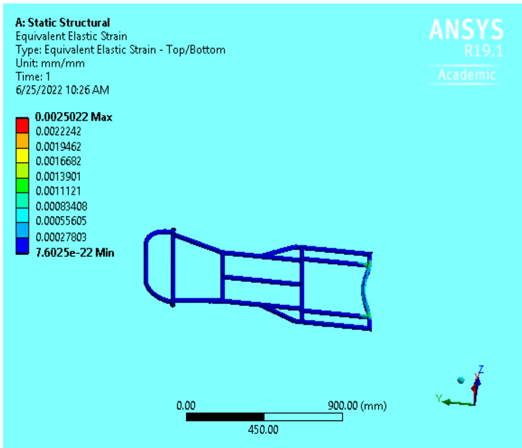

Fig-13: Equivalent elastic strain due to rear impact force

Rear Impact: From figures 11,12,13, For rear impact test, the mass of the vehicle as well as driver mass is considered that is about 180kg and assumed the vehicle is with the impact force at a speed of 50km/h in the rear part of the chassis. The maximum force is taken into consideration about 7064.2N, due to which the maximum deformation is about 1.393mm and directional deformation is 0.10mm, equivalent elastic strain is 0.002.

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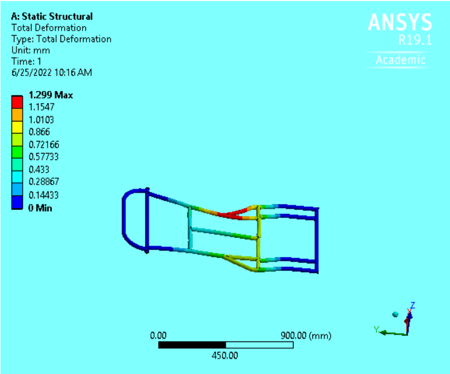

Fig-14: Total deformation due to side impact load

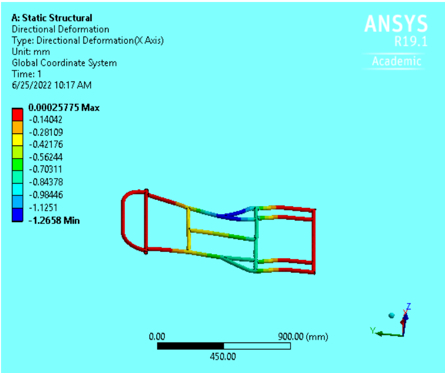

Fig-15: Directional deformation due to side impact load

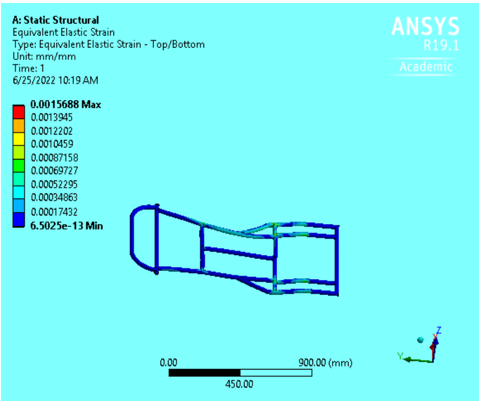

Fig-16: Equivalent strain due to side impact load

Side Impact: From the figure 14,15,16, For side impact test, the mass of the vehicle as well as driver mass is considered that is about 180kg and assumed the vehicle is with the impact force at a speed of 50km/h in the rear part of the chassis. The maximum force is taken into consideration about 5297.4N, due to which the maximum deformation is about 1.299mm and directional deformation is 0.0025mm, equivalent elastic strain is 0.001.

f) Fabrication of chassis

After the analysis of chassis, the next step is to fabricate the chassis with the help of the following machines:

- CNC bending machine
- TIG welding machine

5. POWER TRANSMISSION SUB-SYSTEM

The mechanism that transmits the power developed by the engine to the wheels is called power train. The power is transmitted with the help of set of gears, propeller shaft, universal joint and differential in automobiles. In Go-karts the power is transmitted with the help of sprocket and chain mechanism.

Generally in Go-karts 200cc engines are used, but in our regions, engine capacity should not exceed more than 150cc engine. So we have considered 125cc engine for our Go-Kart. The engine that we have chosen is 125cc Honda Shine SI engine.

Calculations

GEAR REDUCTION RATIOS	
1st gear	2.84
2nd gear	1.82
3rd gear	1.33
4th gear	1.09
Primary gear reduction ratio	4.57

Table-5.1: Gear reduction ratios

We have considered the velocity of kart about 40km/h due to the various losses during power transmission

Velocity (V) = 40*5/18 = 11.11m/s

V=r*w

w = v/r

r=radius of rear wheel

r= 5.5inch = 0.1497m

w = 11.11/0.1497 = 79.57rad/sec

w = 2πN/60

N= w*60/2*π

= 79.57*60/2*π

N = 759.44rpm

Gear reduction ratio required = 7500/760 = 9.86

Gear ratio of 4th gear = primary reduction ratio*gear reduction ratio of 4th gear =4.57*1.09=**4.891**

Gear ratio required for driven and driving sprocket = 9.86/4.891

=2.547

Overall gear ratio

1st gear= primary gear reduction ratio* 1st gear reduction ratio* transmission train gear ratio

= 4.57*2.54*2.84

= 32.96

Acceleration

V = u +at

11.11= 0+a (5)

a = 2.77m/s²

OVERALL GEAR RATIOS	
1st gear	25.56
2nd gear	21.12
3rd gear	15.43
4th gear	12.02

Table-5.2: Overall gear ratios

Optimization in power transmission

Since the engines are produced by industries, there is no optimization in the design of the engine; instead, its efficiency is increased by utilizing the full range of the engine's capabilities.

In the earlier version of the kart, the height of the RRH was more so it was impossible to get enough air to cool the engine..

Fig-17: Old design of assembled kart

Result

The engine's efficiency suffers and fuel consumption rises as a result of the RRH's excessive height, which made it impossible to cool the engine with enough air.

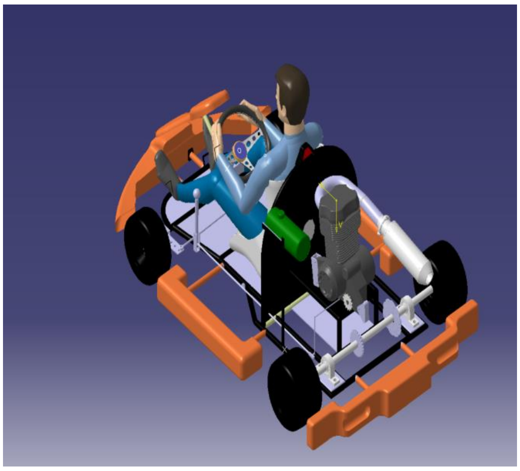

Fig-18: Optimized design of assembled kart

Result

The engine’s efficiency have increased by decreasing the height of RRH and also external fins have been placed in the RRH due to which the cooling of the engine is possible which increases the efficiency of the engine and fuel consumption decreases.

The optimized design and analysis of chassis and power transmission is incorporated in fabrication of kart.

Fig-19: Fabricated Kart

6. CONCLUSION

AISI 1018 is better material in terms of strength reliability, performance and economic when compared with other materials. It is also suitable for large scale production. Successful design optimization was carried out by using CATIA V5 software, as well analysis is also done by using ANSYS WORKBENCH 19.1, the total deformation, directional deformation, equivalent stress and equivalent strain for front, rear and side impact are found. The overall dimension of the kart is also decreased by decreasing its wheelbase which will help the vehicle to take short turns and also help to take autocross and skid pad tasks easily. The engine and the drive train chosen is such as to give maximum performance in terms of speed as well as fuel economy. The efficiency of the engine is also increased by decreasing the height of the RRH as well as placing external fins so that the cooling of the engine takes place which increases the efficiency of the engine as well as the kart.

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