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Design Analysis and Calculations for Economical Electric Go-kart

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***Abstract* - 40% of the world's pollution is caused by automobiles which run on either petrol or diesel. Emergent gases like CO2, CO, SOx etc. from cars play an essential role in global warming.so basically it is crucial to design such vehicles which are entirely eco-friendly, do not produce harmful gases and are cost-effective.**

This paper aims to design simple Go-kart which runs totally on electric power. The primary purpose behind the design and development of the electric Go-kart is to make it simple in design, making it simple in working for non-professional racers, available at a low price and suitable for everyone.

INTRODUCTION

Go-kart is four-wheeled mini vehicles, which was used in western countries (united states)4. Art Ingles4 invented it. A Go-kart is a small four-wheeled mini car without suspension and differential axle. It has a low center of gravity the same as F1 cars. Go-kart is a simple four-wheeled, small engine or electric motor, single-seated racing car used mainly in united states. They initially created in the 1950s post-war period by airmen as a way to pass the spare time. a Go-kart by definition has no suspension and no differential. They are usually raced on scaled-down tracks but are sometimes driven as entertainment or as a hobby by non-professionals.

Go-kart bears a resemblance to formula one cars1, but they are not as fast as standard F1 cars. And also, are very cost-effective as compared to F1 cars in all aspects.

Nowadays, Go-kart is primarily used for karting events, professional races, fun for kids and hobbies. Go-kart is far cheaper than standard F1 cars in terms of manufacturing, fabrication, repairing and events. It is also far safer than a regular F1 car.

LITERATURE REVIEW

Art ingles was a veteran hot rod and race car builder at Kurtis Kraft in California4. In the starting karting was mainly used for the leisure motorsport enjoyed by the airmen during the World War period. It quickly caught in the eyes of the manufacturing corporation and being the first company to manufacture. It produced go-kart for two years with profits.11

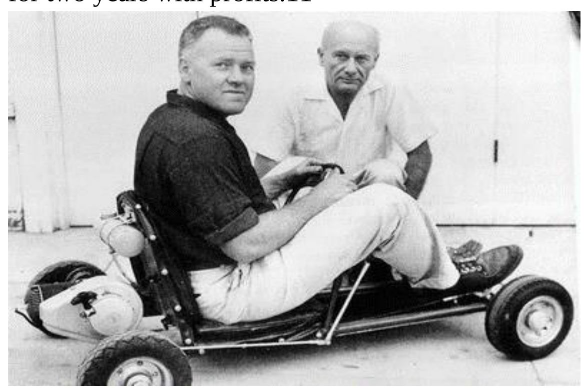

Fig.1 Art ingles with first go-kart

Although it was originated in America soon later, other countries from all over the world took an interest in it. Today, Karting is governed by the CIK-FIA (founded in 1958)11 Main components of the Go-kart are chassis, steering, wheels, engine, battery (electric Go-kart), motor (electric Go-kart) and E.C.U. (electric Go-kart). These are the main components', which are essential for every go-kart.

Technical specification:
Dimension
Overall length:1866.9 mm
Overall width: 1112.5 mm
Front track width: 965.2 mm
Wheelbase: 1270 mm
Ground clearance: 46.99 mm

Battery specification
Battery type: rechargeable battery
Current: 14.5ah

Voltage:36v
Charging time:10hours

Motor specification
Power: 500w
Voltage: 36v
Rpm: 3000 rpm

Transmission
Transmission type: simple chain
Driver sprocket: 42 teeth
Driven sprocket: 14 teeth

Tire specification
Front diameter: 10 inches
Rear diameter: 11 inches
Rim size: 5 inches

Steering specification
Steering type: Ackermann steering
Steering ratio: 1.4:1
Turning angle: 2.7 m

Frame design: The frame design is the most integral part of every Go-kart. It forms the base of the project.

a. It should not bend.
b. It should have torsional rigidity.
c. It should have lightweight.

The objective of the design of this project includes all the above points.

COMPUTER-AIDED DESIGN (CAD): The chassis is designed on Solid works 2018. the chassis is designed for a rear-mounted electric motor. The chassis has the minimum wheelbase of mm and small front track width. The motor and the driver are not in the same line and are separated by the firewall. The design includes the mounting features if the following.

a. Motor mounting
b. Steering assembly
c. Bodyworks
d. Rear-axle assembly
e. Driver seat
f. Battery mounting
g. Electronic controller unit mounting

The design of the chassis is made keeping in mind the dynamics forces and other external forces on the chassis for high performance Requirement.

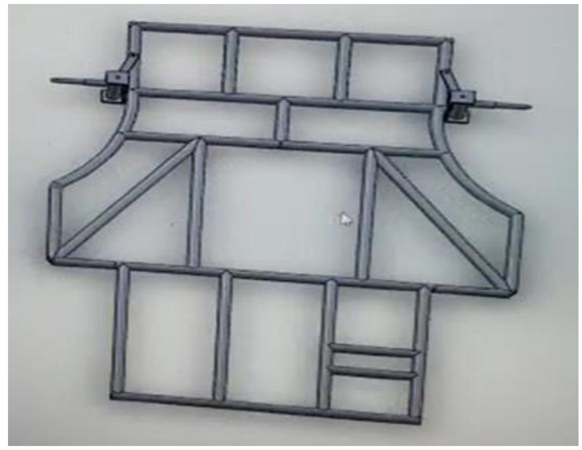

Fig2. Design of chassis

Material Selection
The material that has been used for the chassis is AISI 1018. AISI 1018 mild/low carbon steel has excellent weldability, produces a uniform and harder case, and it is considered the best steel for carburized parts. AISI 1018 mild/low carbon steel offers a right balance of toughness, strength and ductility4. AISI 1018 hot rolled steel has significant mechanical properties, improved machining characteristics and has a high Brinell hardness measure.
Specific manufacturing controls are used for surface preparation, chemical composition.

Material specification

Element	Content
Carbon, C	0.14 - 0.20 %
Iron, Fe	98.8-99.26%
Manganese, Mn	0.60 - 0.90 %
Phosphorous, P	≤ 0.040 %

Table.1 Chemical composition[5]

Mechanical Properties	Imperial	Metric
Hardness, Brinell	126	126
Tensile Strength	440 MPa	63800 psi
Yield Strength	370 MPa	53700 psi
Reduction of Area	40.0 %	40.0 %
Modulus of Elasticity	205 GPa	29700 ksi
Bulk Modulus	140 GPa	20300 ksi
Poisson Ratio	0.290	0.290
Machinability	70 %	70 %

Table.2 Mechanical properties[5]

COMPUTER-AIDED ENGINEERING (CAE) & OPTIMISATION
For C.A.E. of the go-kart frame, we performed different analyses on ANSYS 14.5. Different load

cases were considered to carry out a thorough analysis of the frame, which included front impact, rear impact and side-impact. Based on finite-element and through advanced analysis and optimization algorithms. Mesh size of 10mm was selected to facilitate accurate results and save solving time. R-TRIA and QUAD elements were selected for meshing. Geometry was modelled by using the shell model as shell model can include shear deformations and local buckling effects. SHELL 181 and SHELL 281 were the element types we have used. Beam model has not opted as shear deformation, and local buckling effects play a crucial role in the analysis of the done on ANSYS MECHANICAL APDL Solver.

Front-impact test: The case considered during the front impact of the vehicle is that when our vehicle of 150 kg is moving with its maximum velocity of 60 kmph, it hits a stationary object from the front. The load is calculated by using the equation F=m*v/t.

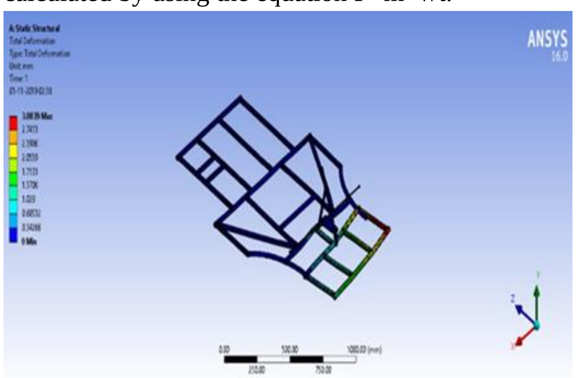

Fig.3 front impact

Side impact test: The case considered during side impact is that during the vehicle is stationary and another vehicle having a mass of 150 Kg travelling with a velocity of 16.66m/s hits it from the side.

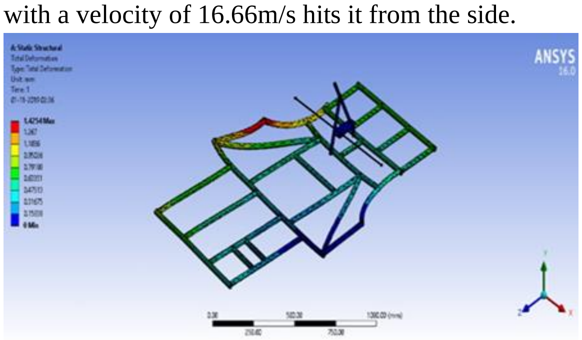

Fig.4 Side impact

Rear impact: The case considered during the rear impact of the vehicle is that when our vehicle is stationary, and another vehicle with a mass of 150kg and moving with its maximum velocity of 60 kmph hits our vehicle from the rear. The load is calculated by using the equation F=m*v/t.

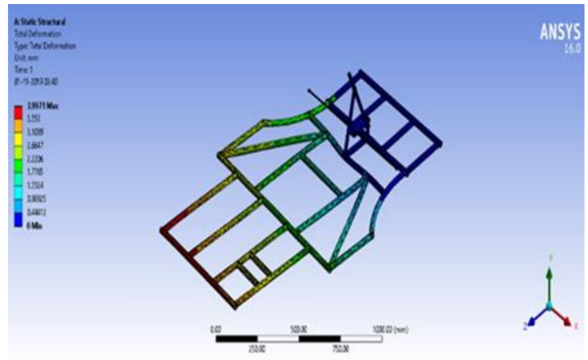

Fig.5 rear impact

	FRONT	REAR	SIDE
Impact Force	5000 N	5000 N	4000 N
Total Deformation	4.2 mm	3.35 mm	1.65 mm
F.O.S.	1.21	1.02	1.1

Table.3 Applied forces

Torsional rigidity

To measure the overall frame rigidity, torsional rigidity analysis was conducted through F.E.A. The objective of the torsional rigidity analysis was to manipulate the chassis design within the F.E.A. software to increase the amount of torque per degree of chassis deflection. By theoretically increasing this value, the actual vehicle could have the ability to be more torsion-ally rigid, making it able to withstand more intensive without failure. To achieve this analysis, a simulated torque of which is equivalent to the gross weight is calculated, i.e. Gross weight = 150 kg and the equivalent force that is –

F = M x (V^2)/R

F = 150 × 8.32/2

F = 2697.5 N

The calculated force is placed on two knuckle ends of the frame while the rear of the frame was constrained. The deformation of the analysis was coming out to be 41.34 mm.

Hence according to the result obtained the frame would be torsionally rigid.

CALCULATIONS

1. Speed calculations

Gear ratio (G.R.) = Zg/Zp

=42/14 = 3

Unloaded motor rpm = 3100 rpm
Loaded rpm = 2800rpm
Tire radius = 278/2=139mm

- Loaded

Speed= (Nmotor/G.R.) * 3.14*(2R/60)
= (2800/3) *3.14*(2*139/60)
Speed= 13.56m/s
Speed=48.816km/hr

- Unloaded

Speed=(Nmotor/G.R.) * 3.14*(2R/60)
= (3100/3) *3.14*(2*139/60)
Speed=15.028m/s
Speed= 54.10km/hr

2. Go-kart axle rotational speed

We chose 42 driver teeth sprocket and
14 driver teeth /R428-108 L chain
Pitch(p)=12.07mm
T2 = 42
T1= 14
N1= 3100
N2=?

T2/T1=N1/N2
42/14=3100/N2
N2 = 1033 rpm
w.r.t 1033 R428 means p=12.07

- Velocity ratio= N1/N2

=3100/1033
=3.0009 ~ 3
= 3

- Power=rated power*service factor

Ks=K11*K2*K3
=1.25*1*1
=1.25
Rated power= 500=0.5KW
Power= 0.5*1.25
=0.625 KW
=625W

- Diameter of pinion gear

D1=(P/sin(180/T1))
= (12.07/sin (180/14))
D1= 60.35mm
Similarly
D2=201.16mm

- Length of chain (L)[7]

Let's consider the distance between sprocket and pinion 30 times the pitch
=30P = 30*12.07= 362mm
Due to the initial slag, center distance is reduced by the 2mm-5mm. we take 4mm
X= 362-4= 358mm

Number of chain links
K=((T1+T2)/2)+(2X/P)+((T2-T1)/2*3.14)^2 * P/X
K=((42+14)/2)+(2*358/12.07)+
$((42-14)/2*3.14)^2*12.07/358$
K=87.975
L=K*P= 87.975*12.07= 1.06M= 1061MM

3. Braking calculations[1]

We chose tandem master cylinder, pulsar180 rotor and apache rear calliper. DOT3 oil is used for the braking oil
Gross wt.: 180*9.81= 1765.8 N
Pedal ratio: 5:1
The normal force of pedal:180*5=900N
Tandem master cylinder (TMC) bore:19.05
Area of T.M.C.:286mm^2
Calliper diameter:25.4
Area of calliper:1013.85 mm^2

- Brake line pressure (B.L.P.)

BLP= $(900*5)/ (3.14/4(19.05)^2)$
=15.78 N/mm^2

- Clamping force (C.F.)

CF= BLP* area of calliper* no. of a piston
= 15.78*1013.85*2
=31997.1 N

- Rotating force (R.F.)

RF= CF*no. of pistons*coefficient of friction
=31997.1*2*0.4
=25597.68 N

- Braking torque (B.T.)

BT= RF*effective disc radius
=25597.6*0.087
=2226.9 Nm

- Braking force (B.F.)

BF= BT/tire radius

= (2226.9/0.41) *0.8
=4345.36

- Deceleration

BF= -ma
a= -BF/m
= 4345.36/180
=-24.1 m/s^2

- Stopping distance

$V^2 - u^2 = 2aS$
V=0   U=15.02
S= -(15.02) ^{2}/-(2*24.16)
S= 4.68 m

4. Steering calculations

Track width (W)= 964 mm
1/tan Θ_o - 1/tan Θ_i = W/B
Θ_o=38^o Θ_i = 27^o
1/tan 38^o - 1/tan 27 = 964/B
B= 1377.14mm
B= wheel base
b= 610mm
R_1 = B/tan Θ_i + W/2
= (1377.14/tan 88) + (964/2)
=2244.65

- Turning radius= $\sqrt{R^2 + b^2}$
= 2326mm

- Outer angle

=(Tanx=L)/R-d/2
=1377.14/ (2326-1377.14/2)
=29.03^o

- Inner angle

=(Tanx=L)/R+d/2
=1377.14/ (2326+1377.14/2)
= 20.8^o

5. Battery calculation

- Charging of the battery

1. Ideal case (neglecting losses)

Amp-hour rating of the battery=14.5ah Charging current should be 10% of it of Ah rating of the battery
Charging current (CC)= (10/100) *14.5
=1.45 A
Charging time of the battery= AHR/CC
AHR= ampere-hour rating
CC= charging current
= 145/1.45
=10 hours

2. Practical case (considering 50% losses)

In this battery, 50% losses occur.
Actual required charging time = ideal charging time + additional charging time when losses occur
=10 + (50/100) *10
= 15 hours

- The discharge time of the battery

1. Ideal case

Battery voltage = 36 v
Applied voltage=1000v

Discharge time = AHR*battery voltage/ Applied voltage
= 14.5*36/1000
= 0.522 hours

2. Practical case (considering 50% losses)

Actual discharge time= ideal discharge time - loss in discharge time when loss occurs.
=0.522 - 0.522* (50/100)
=0.261 hour

ELECTRICAL CONNECTIONS

The central unit of the electrical system is E.C.U. (electronic control unit). It consists of different port for battery, motor, on/off switch, reverse, brake, lights etc. battery, accelerator pedal, on/off switch and motor are connected to derailleur in E.C. U. The battery needs to be connected in series if we were using 12v*3 batteries but should be connected normally if we were using one unit of a battery.

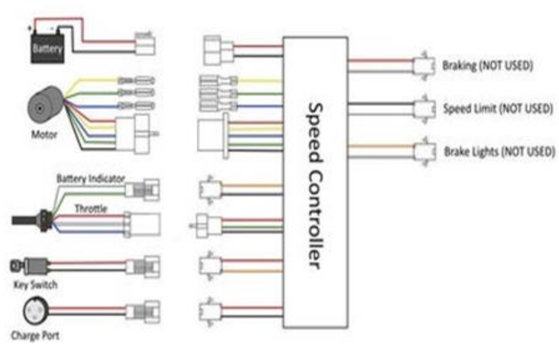

Fig.5 electrical connections

RESULT

The design of electric Go-kart has been completed successfully as planned. It is designed according to the calculations and can handle the weight and able to achieve speed around 35-40 kmph.

CONCLUSIONS

Through this paper, we aimed to design a vehicle with a combination of both electronics as well as mechanical models and also to present it aesthetically and ergonomically strong. With a very light and robust frame, pure steering, efficient braking system and optimum power to mass ratio, the kart can easily fulfil all the static and dynamic tests put through.

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