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Vibrational and Computational Analysis of Gokart Chassis

Conference Article

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Abstract

This report deals with the design and analysis of components for a go-kart. The forces acting on the vehicle from various directions influence structural integrity, potentially leading to deformation and failure. Therefore, stress analysis is crucial to ensure safety and performance. In this report, an attempt is made to identify critical stress areas through various simulations and optimizations. The design and analysis processes have been conducted using SOLIDWORKS 2022, ANSYS. The go-kart design adheres to the regulations specified in the HFKC 2025 Rulebook.

Keywords: Go-Kart Chassis Design, Finite Element Analysis (FEA), Vibrational Analysis, Impact and Torsional Analysis, AISI 4130 Space Frame Chassis

1. Introduction

Go-karts are lightweight, high- performance vehicles designed for racing and recreational use. Their design emphasizes speed, manoeuvrability, and stability, requiring careful engineering to achieve optimal performance. The key factors influencing go-kart design include chassis strength, weight distribution, aerodynamics, and braking efficiency, all of which contribute to safety and handling. This study focuses on the critical design considerations and analytical techniques involved in developing a go-kart. By analysing key components such as the chassis, steering, suspension, and braking systems, the report aims to provide insights into the engineering principles that enhance performance and reliability. Through structural analysis and optimization, the objective is to refine the design for improved handling, durability, and overall efficiency on the track

ROLL-CAGE

Chassis Material Considerations As per Rule book:

Material Selection:

The material of the Chassis is chosen to minimize the weight, maximize the impact strength, bending strength, low price and easily of availability of the dimension and pipe. As per required properties We selected AISI 4130 grade Chromium-Molybdenum alloy steel tubing. AISI 4130 has good strength, toughness, machinability, and weldability. It has a lower carbon content than 4140, which gives it improved weldability but reduces its thickness strength. AISI 4130 is often used in the aerospace, oil and gas, automotive, agricultural, and defense industries.

Material Properties of AISI 4130: Table 1:

PROPERTY	METRIC
Tensile Strength	560 MPa
Yield strength	460 MPa

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Elongation at break	21%
Modulus of elasticity	200 GPa
Density	7.85g/cm^3
Percentage of carbon	0.28%
Hardness (Brinell)	197 HB

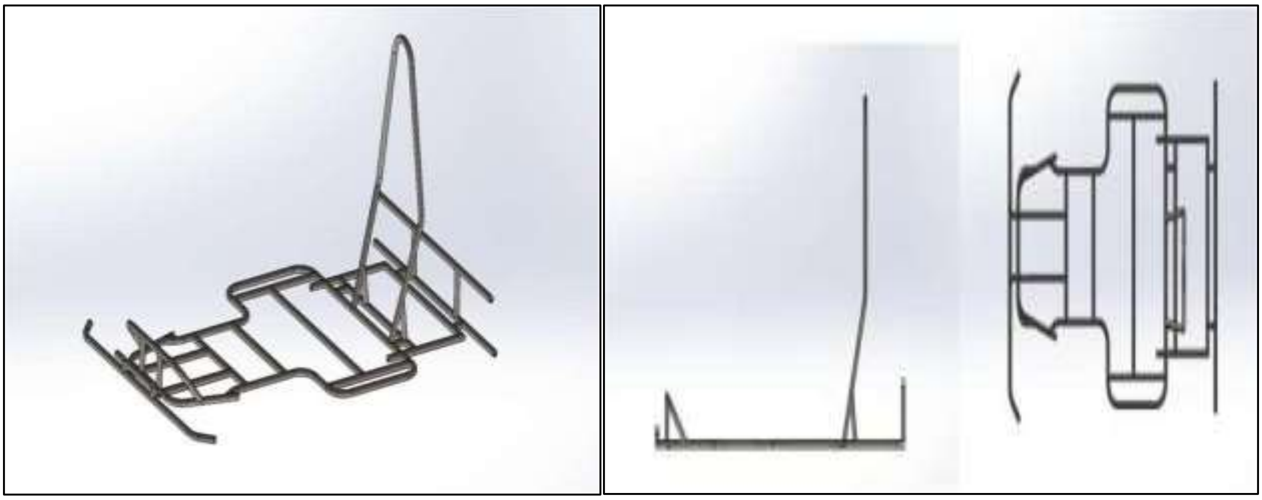
- Good Weldability
- Corrosion Resistance
- Fatigue Strength is High
- Formability is High

Type of pipe: Circular pipe in shape, with outer diameter of 25.4 mm and a wall thickness of 2 mm as per the calculations done according to the formula given in the rule book for the bending strength of the tube.

Area Moment of Inertia(I):
It is a measure of an objects resistance to bending and flexure. Its calculated as: I= (π/64) *(D4 – d4)
Where, D = Outer diameter = 0.0254m d = Inner diameter = 0.0214m I= 1.01x10-8 m4
Bending Stiffness (Kb):
It is a measure of a beam's resistance to bending deformation. Its calculated as: K b = E*I
Where, E = Modulus of Elasticity (200 GPa for all Steels) I = Moment of area for the structural cross-section
K b = 200x109x1x10-8 K b = 2000 N-m2

Bending Strength (Sb):
It is the maximum stress a material can withstand when subjected to bending forces before failing or breaking Sb = Sy I /c
Where, Sy = Yield strength (460 MPa for AISI 4130)

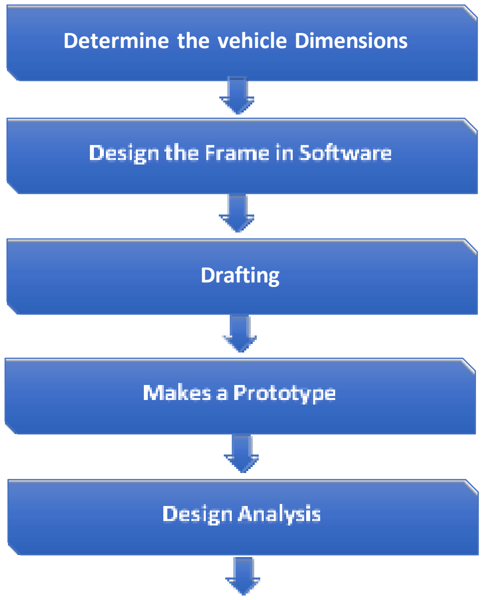
C= Distance from the central
axis of the pipe Sb = 362.2047 N-m
Chassis Design
The chassis is the structural framework of a vehicle that supports all other components such as the body, engine, wheels and transmission. Chassis Design determines how weight is distributed, how vibrations are absorbed, and how forces are transferred during acceleration, braking, and cornering.
Type of chassis: Tubular space frame, it is a light weight, rigid structure made from interconnected tubes welded together, commonly used in racing and performance vehicles.



CHASSIS Specifications: Table 2:

S. NO	SPECIFICATIONS	VALUES
1	Length	66 inches
2	Width	48 inches
3	Wheelbase	40 inches
4	Trackwidth (F)	33 inches
5	Trackwidth (R)	42 inches

Methodology:

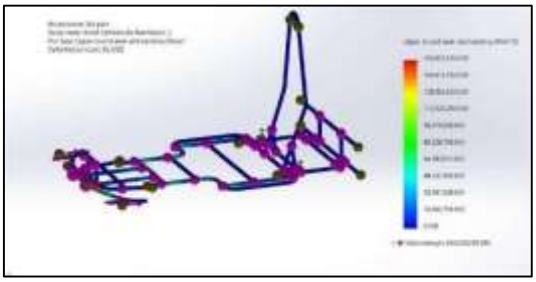


Finite Element Analysis:
The Analysis has been done using SOLIDWORKS different analysis like Static analysis, frequency analysis and torsion analysis has been carried in order to ensure the strength of the frame from collisions in different directions. The SOLIDWORKS software is used to predict the failure and stress concentration in the design before going into manufacturing and also shows whether a product will break, wear out, or work the way it was designed. Therefore, the cost of manufacturing will be optimized. Here, depending on the element size the chassis is divided into small elements to form a perfect mesh so that the results obtained will be more accurate. The computer analyses and solves by the computational method provided. For analysis some points were kept fixed and the load was applied and we obtain the total deformation & equivalent stresses. For finding Factor of safety.

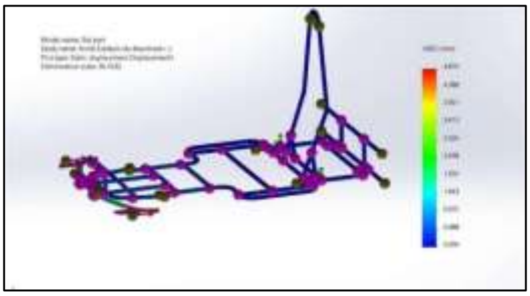
Choosing the type of analysis in preferences (static analysis):
- Given input on material properties such as density, young’s modulus and Poisson’s ratio.
- Inputs on section properties are outer diameter, inner diameter, wall thickness.
- Creating nodes in working plane. (2407)
- Joining nodes with elements. (1948 elements).
- Applying loading and boundary conditions as per respective impact tests.
- Element Size 25.08 mm

Front Impact Analysis:

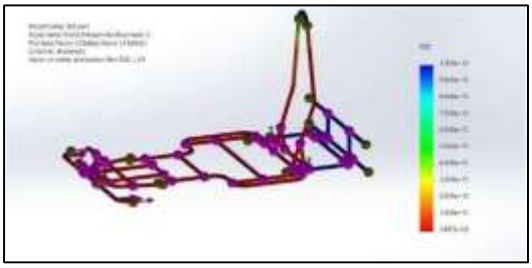
For the front impact, engine and driver load was given at respective points. The rear wheels position kept fixed. Front impact was calculated for an optimum speed of 70kmph. From impulse momentum equation, 8G force has been calculated. Time of impact considered is 0.25 seconds.
Boundary conditions:
. Total vehicle weight is assumed as 180 Kg in order to analyse the vehicle at max G load the vehicle weight is assumed high.
Where, G=180 kgs g= 9.81
. u (initial velocity) =19.44m/s
=u/t
=19.44/0.25
=77.76 m/s2
= 77.76/g
=7.92 approx. equal to 8G,
equally distributed load is applied Now, the Dynamic load of Front Impact is 8G= 8*180 = 1440 N



Upper bound axial and bending stress



Static displacement



Factor of safety

Results:
1. Maximum von-misses stress = 160 MPa
2. Factor of safety = 2.9
3. Deformation = 4.876 mm

Rear Impact Analysis:
Considering the worst-case collision for rear impact, force is calculated as similar to front impact for speed of 70kmph. The value of 8G force has been calculated. Time of impact considered is 0.25 seconds. The kingpin mounting points kept fixed.

Boundary conditions:
. Total vehicle weight is assumed as 180 Kg in order to analyse the vehicle at max G load the vehicle weight is assumed high.
Where, G=180 kgs g= 9.81
. u (initial velocity) =19.44m/s t (impact time) =0.25. Deceleration suffered by the vehicle.
=u/t
=19.44/0.25
=77.76 m/s2
= 77.76/g
=7.92 approx. equal to 8G, equally distributed load is applied.
Now, the Dynamic load of rear Impact is 8G= 8*180 = 1440 N

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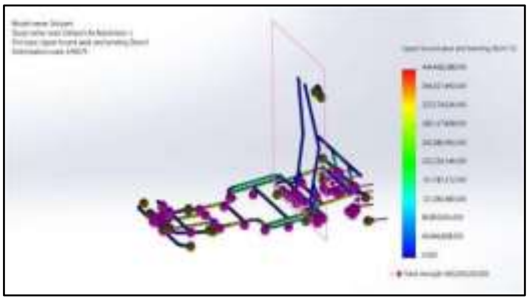
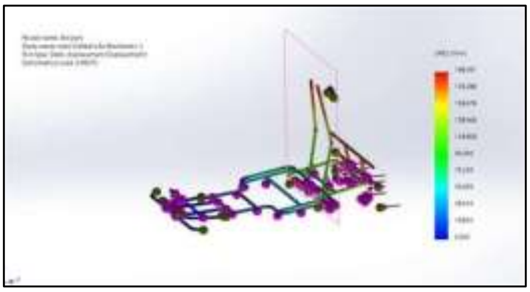
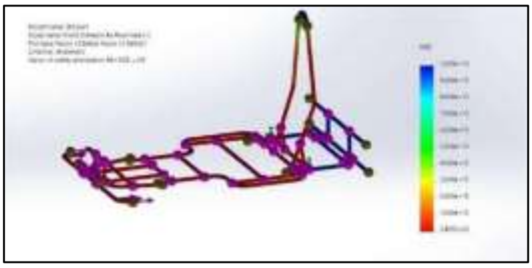


Upper bound axial and bending stress



Static displacement



Factor of safety

Results:

1. Maximum von-misses stress = 91.9 MPa
2. Factor of safety = 3
3. Deformation = 1.103 mm

Side Impact Analysis:

The most probable condition of an impact from the side would be with the vehicle already in motion. So, it was assumed that neither the vehicle would be a fixed object. For the side impact, the velocity of vehicle is taken 70kmph and time of impact considered is 0.25 seconds.

Impact force was applied by constraining left side and applying load equivalent to 8G force on the sides. The Engine and kingpin mounting points of Right side kept fixed for left side impact. The Engine and kingpin mounting points of Right side kept fixed for left side impact. The Engine and kingpin mounting points of Left side kept fixed for Right side impact.

Boundary conditions:

. Total vehicle weight is assumed as 180 Kg in order to analyse the vehicle at max G load the vehicle weight is assumed high.

Where, G=180 kgs g= 9.81

. u (initial velocity) =19.44m/s t (impact time) =0.25. Deceleration suffered by the vehicle.

=u/t

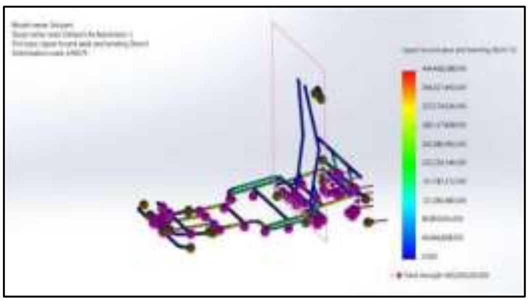
=19.44/0.25

=77.76 m/s2

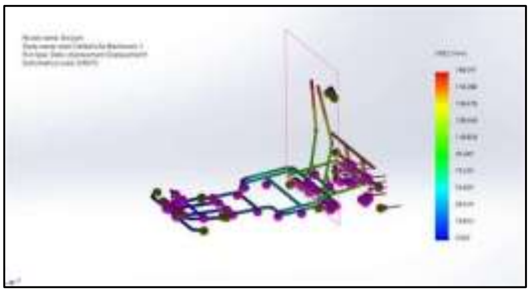
= 77.76/g

=7.92 approx. equal to 8G,

equally distributed load is applied. Now, the Dynamic load of left side Impact is 8G= 8*180 = 1440 N



Upper bound axial and bending stress



Static displacement

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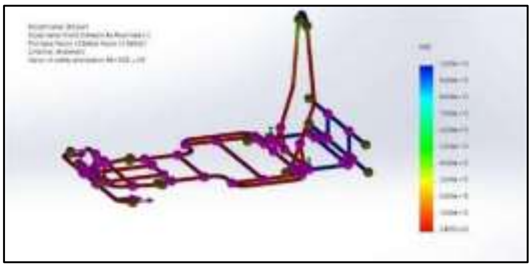


Factor of safety

Results:

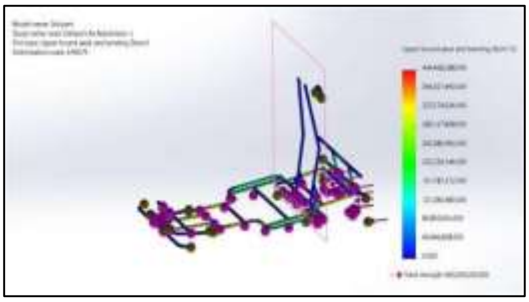
1. Maximum von-misses stress = 105 MPa
2. Factor of safety = 4.4
3. Deformation = 1.74 mm

Torsion Analysis:

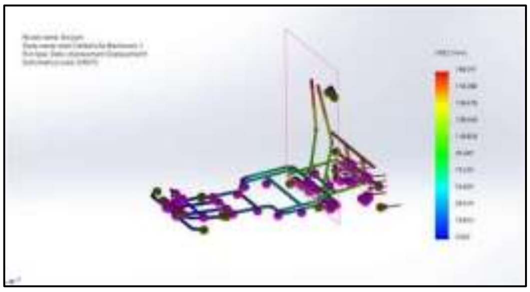
Torsion analysis is a type of structural analysis that evaluates the twisting or rotational behaviour of an object under external loads. In the context of a go- kart chassis, torsion analysis helps engineers understand how the chassis responds to twisting forces, such as those encountered during cornering or braking.

Boundary conditions:

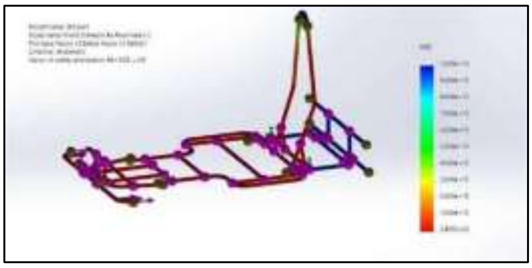
. Total vehicle weight is assumed as 180 Kg in order to analyse the vehicle at max G load the vehicle weight is assumed high.
Where, G=180 kgs g= 9.81
. u (initial velocity) =19.44m/s t (impact time) =0.25.
Deceleration suffered by the vehicle
=u/t
=19.44/0.25
=77.76 m/s2
= 77.76/g
=7.92 approx. equal to 8G, equally distributed load is applied.
Now, torsion Impact load is 8G= 8*180 = 1440 /2 = 720N
We kept the rear axial points and applied the load at front axial points each point in opposite directions as shown in the figure.



Upper bound axial and bending stress



Static displacement



Factor of safety

Results:

1. Maximum von-misses stress = 134.7 MPa
2. Factor of safety = 3.4
3. Deformation = 21.3 mm.

TRANSMISSION

Introduction: -

An engine or motor is a machine designed to convert one or more forms of energy into mechanical energy .Available energy sources include potential energy (e.g. energy of the Earth's gravitational field as exploited in hydroelectric power generation), heat energy (e.g. geothermal), chemical energy, electric potential and nuclear energy (from nuclear fission or nuclear fusion). Many of these processes generate heat as an intermediate energy form; thus heat engines have special importance. Some natural processes, such as atmospheric convection cells convert environmental heat into motion (e.g. in the form of rising air currents). Mechanical energy is of particular importance in transportation, but also plays a role in many industrial processes such as cutting, grinding, crushing, and mixing. The Bajaj Pulsar 150 UG4 engine is a 4- stroke, single-cylinder engine with a displacement of 149.5 cc. It's a popular engine model used in the Bajaj Pulsar 150 motorcycle, known for its reliability, performance, and fuel efficiency. The engine features an air -cooled design, which helps regulate its temperature, and a single cylinder that provides a balance between power and fuel efficiency. With its 4-stroke technology, the engine delivers efficient combustion and smooth performance, making it a popular choice for commuters and enthusiasts alike.

Components Selection:

Engine:

As per rule book given specifications of engine:

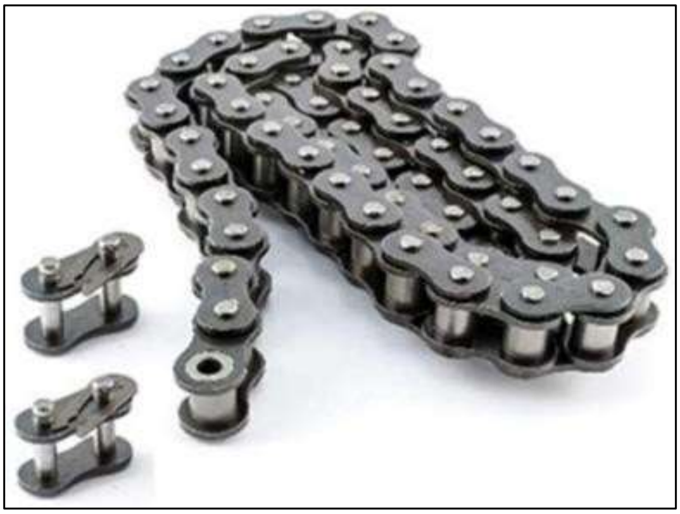
Teams are free to use any type of 4 Stroke Engines (Generator Engines or OEM Motor Cycle engines). However, teams are restricted to use only Gasoline engines. Capacity of engine shouldn't exceed 160cc.

As per rule book constraints Engine Specifications:

Engine – Bajaj Pulsar 150 DTsi (Digital Twin Spark Ignition) UG4 4-STROKE
Displacement-149.1 cc
No. of Cylinders – 1 Bore=58mm Stroke=56.4mm
Max power – 11.032 KW @8500 RPM
Max torque – 12.5 N-m @6500 RPM Fuel- Petrol
Cooling system – Air Cooled Drive Train – Chain drive
Transmission Type: constant mesh Compression ratio – 9.5:1

Chain:

The drive belt or chain transfers power from the engine to the rear axle. Chain drives are more efficient at transferring power, but they require more maintenance. (material: Carbon steel)



Sprockets:

Sprockets are wheels with teeth that mesh with the chain or belt. The size of the sprockets determines the gear ratio of the drivetrain. A larger engine sprocket and a smaller axle sprocket will create a higher gear ratio, which is good for high speeds. A smaller engine sprocket and a larger axle sprocket will create a lower gear ratio, which is good for acceleration. (material: EN8)

Axle:

The axle is a shaft that the wheels are mounted on.The axle transmits power from the drivetrain to the wheels. (Shaft dia=30mm,length=1016mm)

Wheels:

The wheels are the final components in the power transmission system. They are what makes contact with the ground and allow the go-kart to move.

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Gear Reduction (GR):
Primary reduction ratio(prr) = 3.47
Secondary reduction ratio(srr) = no. of teeth on shaft sprocket/no. of teeth on engine sprocket = T2/T1=28/15 = 1.86

GEAR	1	2	3	4	5
GEAR RATIO AT EACH GEAR	2.92	1.88	1.38	1.08	0.92

RPM of Go-kart Wheel (N):
Wheel Diameter (d) = 0.2794m Speed(V) =70 km/h = 19.44m/s
Angular Velocity(ω) = 2V/d = 2*19.44/0.2794 = 139.1553 rad/s ω =2πN/60 N = ω*60/2π = 1328.835 rpm

Required Sprocket Ratio:
RSR=[[Ermp/PRR]/GR5]/ Wrpm= [[8500/3.47]/0.92]/1328.78=2.003

Reduction Ratio:
RR=PRR*SRR*GR
=3.47*1.86*2.92
=18.84

Rpm At Each Gear:
N/Ni =Reduction Ratio Ni=8500/18.84 = 451.6 rpm

GEAR	REDUCTION RATIO AT EACH GEAR	RPM
1	18.84	451.6
2	12.13	700.74

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3	8.9	900.05
4	6.97	1219.51
5	5.93	1433.38

Max Velocity:
V= (π*D*N)/60=(π*0.2794*1433.38)/60 =20.96
m/s =75.45 km/h

Torque Generated by the Engine (Te):
TE=(P*60)/(2*π*N)
=(11.032*103*60)/(2*π*8500)
=12.39 N-m

Calculating shaft Diameter(D):
Torque transmitted on shaft, TS=TE*PRR*SRR*GR1
=12.39*3.47*1.86*2.92
=233.5 N-m

MATERIAL OF THE SHAFT:
Tensile Strength, (Sut)=800 MPa Yield Strength, (Syt)=600 MPa Shear Strength, (Sst)= 0.5*Sut = 0.5*800 =400 MPa

FROM TORSION FORMULA:
TS/J = Ʈ/R (Where, Ʈ=Sst/2=200/2=100*106 N/m)
233.33/ ((π*d4)/32) = 100*106 /(d/2) d=0.022m
Shaft Diameter, d = 22.04 mm

Sprocket Diameter:
Engine sprocket (d1): p*cosec(180/T1) = 12.7* Cosec (180/15) =61.08mm
Axle sprocket (d2): 12.7 * Cosec (180/T2) =12.7 * Cosec (180/28) = 113.42mm
Centre to Centre distance (C)= 12.1 inch
=0.307 m

Chain Length:
Length of the chain(L) = K*P
No. of links(K) = (T1+T2/2) +(2*C/P) + [(T2-T 1/2π)
*P/C]
No. of teeth on engine sprocket (T1) = 15
No. of teeth on shaft sprocket (T2) = 28 P = pitch of the chain link = 12.7 mm K=69.98 ~ 70 links
L = K*P=0.889 m

Rolling resistance force (Fr):
The forces opposing the motion of the vehicle due to the tries rolling on the road. Fr = C*W
C = coefficient of rolling resistance = 0.02 W=180*9.81 Fr= 0.02*150*9.81
= 29.43 N

Air Resistance Force (Fa):
The force opposing the vehicle's motion due to air resistance.
Fa=0.5*ρ*A*Cd*V2
ρ = density of air = 1.225kg/m3vat sea level V = 19.44 m/s Cd = coefficient of drag = 0.8 L = 7 inch = 1.2 m
b = 5 inch = 0.127 m A = 0.135 m2 Fa = 0.5*1.225*0.1524*0.8*(22.22)2
= 25.07 N

Torque required to overcome resistances (Tr):
Tr = (Fr +Fa) * wheel radius
= (29.43+25.07)

*0.1397
= 7.61 N-m

Power required:
The amount of power needed to overcome all resistances and keep the vehicle moving at a given speed's P = (Fr+Fa) *Vmax
P = (29.43 + 25.07) *19.44
P = 1,059.48 Watt (or) 1.0594 KW

Torque @ wheel:
The turning force available at the vehicle's wheels after passing through the gearbox and final drive reductions. Tw=Te*srr*T. E*GR
Engine Torque (Te)=12.39N-m SRR=Secondary reduction ratio
T. E=Transmission efficiency=85% (assume)
GR=Gear ratio of selected gear (Suppose first gear ratio) Tw=12.39*1.86*0.85*2.92 Tw=57.19Nm

Tractive Force:
The pulling force developed at the wheels of the vehicle due to engine torque after gear reductions.
T. F=TW/Wheel radius Tw=Torque at wheel
=57.19/ (0.2794/2) = 409.37N

Tractive Effect:
The power available at the wheels to move the vehicle.
T. E=T.F*V
T. E=Tractive Effect
T. F=Tractive Force
V=speed of vehicle=19.44m/s
T. E=409.37*19.4
=7958.15W (7.9kw)

Conclusion:
The go-kart design and analysis carried out in this study demonstrate a structurally efficient and mechanically robust system. The chassis, fabricated from AISI 4130 chromium-molybdenum alloy steel, exhibited favorable mechanical properties including high yield strength, excellent weldability, and superior fatigue resistance. Computational simulations under static, dynamic, and torsional loading conditions confirmed that the structure maintains stress levels well below the material limits, with factors of safety ranging between 2.9 and 4.4. The transmission system, driven by a bajaj pulsar 150 engine, achieved a peak velocity of approximately 75 km/h, with optimized gear ratios ensuring effective torque multiplication and reliable tractive force generation. Overall, the integration of finite element analysis and performance calculations validates the chassis and drivetrain as lightweight, durable, and optimized for high stability, impact resistance, and efficient power delivery, making the design technically sound and performance-oriented.

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