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Design and Development of Transmission and Braking Systems in Go-kart

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Abstract: ***We have completed this paper as per rulebook of kart racing competition. It involves 5 different departments which are Transmission, Roll cage, Brake, Steering, Wiring. This karting has no suspension and differential. It is generally recognized as small scale or economic way of motor sport. Transmission is the most important system in any vehicle. In go kart, there is no differential therefore we have to transmit power directly to shaft. Braking is a system which is used to stop transmitting power at instant. This involves stopping revolving transmission shaft by applying force on pedal.***
Keywords: Departments, Transmission, motor sport, Go kart, Brake

I. INTRODUCTION

The main concept of go-kart racing to create sport which is economically less and made with low cost parts either self-designed or from scrap. This concept is originally started at USA as a fun game now today this racing are recognized as basic criteria for bigger motor sports. Karting is considered as sport which usually raced on scaled down tracks. It involves 5 different departments like Transmission, roll cage, braking, steering, and wiring. It is 4 wheeled vehicle on which don't have suspension and differential. So it is designed carefully by selecting proper material. In go-kart transmission system, we transmit power from engine to wheel. A braking system used to stop the motion of machine by applying frictional resistance. This system ensures safety and smooth riding of vehicle. We used Disc brake in which, the friction between two surfaces pressed together to convert kinetic energy of moving object into heat energy so the vehicle stopped.

II. TRANSMISSION SYSTEM

A. Definition

Transferring power throughout the body or mechanism transmission system is used. Different linkages are used to convert and transfer power. In this paper Go-kart transmission system is explained where Engine power is transmitted to the vehicle wheels.

B. Purpose of transmission system:

There are 3 reasons for having a transmission in the automotive power train or drive train. The transmission can:

1) Provide torque needed to move the vehicle under a velocity of road and load condition. It does this by changing the gear ratio between the engine and crankshaft and vehicle drive wheel.
2) Be shifted into neutral for starting the engine and running it without turning the drive wheels.
3) To provide different speed variations.8168140930

C. Systems Used in go Kart Transmission

Like every automobile, go kart also have various systems. Mainly there are 4 systems in this kart.

1) Fuel System: the purpose of fuel system in SI engine is to store and supply fuel and then pump to carburettor. The fuel supply system also prepares the air-fuel mixture for combustion in the cylinder and carries the exhaust gas to the rear of the vehicle. The basic fuel supply system used in the vehicle consist of following fuel tank, fuel strainer or fuel filter, air cleaner, carburettor.
2) Ignition System: the ignition system used for small two stroke engine is flywheel magneto type. The advantages of this system are that is set combined. The flywheel magneto is basically used only for a single cylinder engine through ones suitable for multi cylinder engine have also been developed. The contents of this system is as follows :

a) *Ignition Coil:* this coil is made of two coils which are connected separately where both are wound on same iron core and share common terminal. One is known as primary and secondary. The voltage required to cause a spark between the sparking plug points depends upon both the pressure of the mixture with the cylinder where voltage of 10000 volts is needed.

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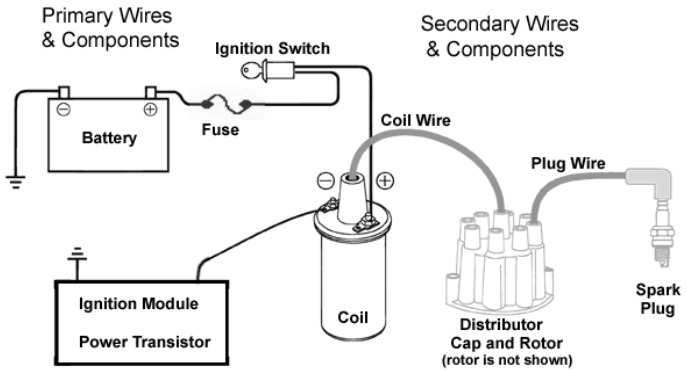

Fig.1 Ignition coil

b) *Spark Plug:* It is an important part of ignition system which act as an electrode to generate spark discharge. These are easy to access. The ignition voltage is about 25000 volts and the distance between central and earthed electrodes is about 0.202 inches and can be adjusted as per requirement.

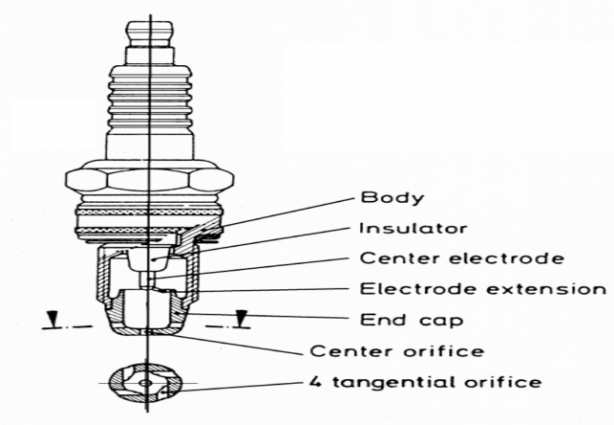

Fig. 2 spark plug

3) *Lubrication System:* engine is required to have change in lubricant oil time to time so engine oil poured into the engine as per the grade For our engine we have used oil grade of 20-w-50 which is recommended by the engine manufacturing company.

4) *Cooling System:* go kart is an air cooled system where open air environment is used as a cooling factor.

D. Wheel Assembly

1) *Introduction:* A tire have important function to take the load of the vehicle and provides tractive forces to move the vehicle thorough survey was made on the availability of different tires suitable for a go kart. It was decided to use standard go kart traded tires which available in the market which provide better traction on dry and wet conditions. The rear tires are wider and bigger in diameter than the front tires as the load is biased towards the rear and to minimize rolling resistance.

2) *Goals*

a) To provide maximum grip at ground.
b) To transmit power from the shaft to the rear wheels with maximum efficiency.
c) To acquire maximum torque at the starting and continues.
d) Reduce the major and minor power losses as much as possible.
e) Selecting of parts carefully to avoid the power losses.
f) To achieve higher torque from low rpm.
g) To achieve high efficiency.

3) Front wheel assembly: Front wheel assembly comprises of hubs, and wheels. The arms are connected to the hub which is connected to the wheels which is welded on to the chassis. The fixture provides adjustability in caster angle. The dimensions are selected that there should no interference between the steering components and the chassis in the dynamic condition. The 3D simulation of the steering mechanism was done in the solid works. The dimensions and the inclination of the steering link are so selected that it complies to the kinematics of steering designed. It is designed to assist the wheel hub and a positive stop is given to secure the hub in place.

Table.1. Front Wheels Dimensions

Tire	Standard go-kart traded tires
Wheel diameter	10”
Wheel width	4.5”
Rim diameter	5”

4) Rear wheel Assembly: The rear wheel assembly made up of a single shaft, hubs, bearing unit and wheels.

Fig. 3. Typical go-kart slick tire.

Table.2. Rear Wheel Dimensions

Tire	Standard go-kart traded tires
Wheel diameter	11”
Wheel width	7.10”
Rim diameter	5”

E. Engine Selection

There are many Go-Kart racing competitions and they organize different types of engines according to power e.g. 150 cc, 200 cc, 250 cc, or electrical powered. We selected 150 cc power type where we used Bajaj Pulsar 150 cc, 4 stroke, twin spark petrol engine, which produces about 14 BHP of power at 8500 rpm.

Table 3 engine comparison

	Honda CB Shine	Bajaj discover 125	Hero Glamour 125	TVS Phoenix	Bajaj Pulsar 150
Displacement	124.7 cc	124.6 cc	124.7 cc	124.53 cc	149 cc
Max. Power	10.57 Bhp @ 7500 rpm	10.9 Bhp @ 8000 rpm	9 Bhp @ 7000 rpm	10.8 Bhp @ 8000 Rpm	13.8 Bhp @8000rpm
Max Torque	10.30 Nm @ 5500 rpm	10.80 Nm @ 5500 rpm	10.35 Nm @ 4000 rpm	10.8 Nm @ 5500 rpm	13.4NM @6000 rpm
Compression Ratio	9.2:1	9.8:1	9.1 : 1	9.4:1	9.5 :1
Bore	52.4	57	52.4	57	57
Stroke	57.8	48.8	57.8	48.8	56.4

Selection of Engine:
P= $F_{resistances}$ x Velocity.
P = 120.616 N x (80 kmph)
P = 9.6493 kW
P = 12.9397 BHP
Thus, engines with power more than 12.9397 BHP were shortlisted.

F. Systems In Engine

1) *Clutch:* It is a mechanism that when we apply pressure on pedal which we retracts pressure plate which helps ofpressure spring from friction plate and allows free play between engine and transmission shaft.
   - Functions of Clutch:
     i. Clutch allows free play between engine and shaft.
     ii. While disengagement of clutch the driver can have time to change or shift gears.

When engaging clutch provides momentarily sleep which done engagement smoothly which lessons the shock while changing gears.
Let,
L_1 = 18 cm
L_2 = 3.5 cm (travel ratio = 8 cm)
F_c = 20 KgF
F_h = 20/8
=2.5N

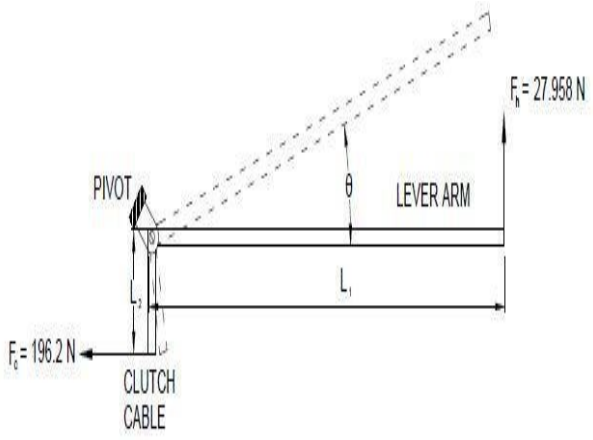

Fig. 4. SMD

2) *Gear Box:* Most of the two wheelers use sequential gearbox. Now-a-days modern vehicles (except scooters) change gears (4 to 5 gears) Normally, 1st and 2nd gear can be chosen from neutral, but for high speed gears shifting is done in order. As we selected pulsar 150 cc engine which permits to shift at most 4 gears. This shifting between gears can be made in single click and acceded in order.

3) *Transmission Shaft:* Transmission shaft is designed as per following stresses.
   i. Shear stress formed due to torsion load by shaft
   ii. Bending stresses (tensile or compressive) acting on sprockets and self weight of shaft due to forces acting on them.

Weight distribution is assumed for rear and front = 60 : 40
The rear track width = 940
Mounting positions of different parts like engine and bearings. After determining positions, bending and twisting moments are calculated. The shaft diameters are determined as per selection criteria.
To achieve positive drive keys are used. Nut and circlips are used to restrict axial motion.

➢ Types of Shafts :

The shafts are broadly divided into two groups

1. Transmission shafts
2. Machine Shafts

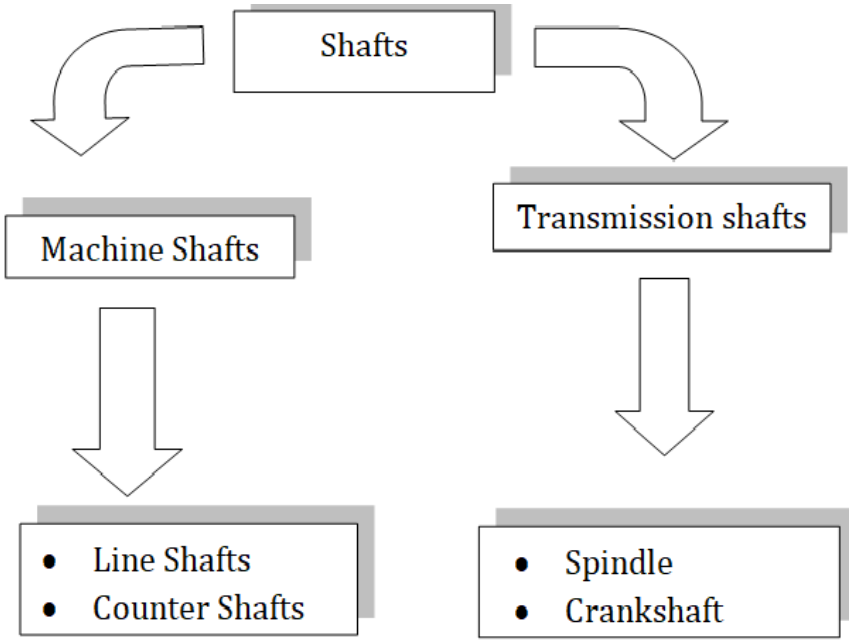

Fig.5 Types of Shafts

Weight of kart = 150kg
Therefore, weight on the rear shaft = 0.6*150=97.5 kg
Wheelbase=1070mm Rear Track width = 940mm
Total tractive force on rear wheels = m x g x 0.6 = 882.9 N

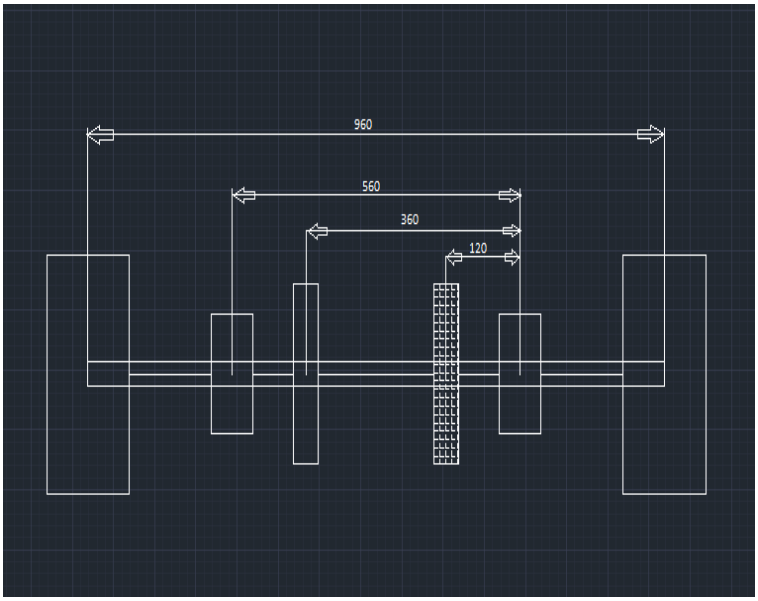

Fig.6. Dimensions of shaft

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➢ Key & key way

Due to relatively less load, availability and cost factor, square used.
Material used: mild steel,
Ultimate tensile stress =330 MPa.
Yield stress Permissible compressive Stress = 0.55 MPa.
Permissible shear stress: 127.5MPa.
Diameter of shaft = d = 30 mm
Breadth = b = 5mm
Length - 1 = 30mm
Depth= h = 5mm
Max. torque = Mt = 123.341 Nm
load on key = P = (2 * Mt)/d
= (2*123.34)/30
= 8222.73N
shear stress on key
= (2*Mt)/(d*b* l)
= (2*123.341)/ (30 *5 *30)
= 54.31MPa
compressive stress on key
= (4*Mt) /(d*h*l)
= (4*123.341) (30*5 *30)
= 109.63 MPa

Factor of safety = FOS = yield stress /compressive stress = 1.938 = 2

Hence the key & key way are safe.

➢ Material Selection

Table 4. Material Selection

Material	Theoretical Diameter (mm)	Diameter corrected to available bearing diameters (mm)	Mass (kg)
Solid EN8	29.06	30	5.79
Solid EN19	24.11	25	4.02
Solid EN24	25.465	30	5.79
Hollow SS316	66	70	8.36
Hollow A106	49.13	50	5.789

The weight, diameter and the initial cost of the shaft have to be optimized for good performance/ output.
Thus, EN19 is selected.

4) Gear Shifter

The pros and cons of the shifter is explained below

a) The total linkages have play via clearances.
b) Force transmitted is not accurate.
c) More linkages are required.
d) Less ergonomic considering the amount of travel of hand from steering wheel.
e) But it has the lowest frictional resistance due to pivot design.
f) It has fixed linkages to transmit the force
g) Force is transmitted accurately.
h) Fewer linkages are required.

Thus, we selected the design with fixed linkages.

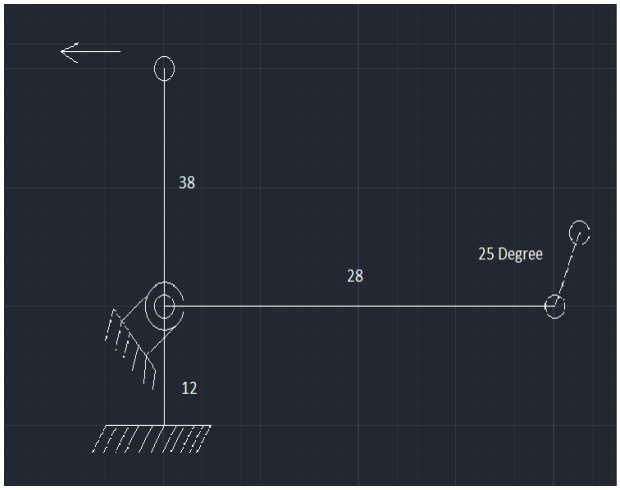

Fig.7. Gear Shifter Dimensions

Comparing the overall diameters of shafts from different theories, we have selected 25mm diameter.[3]

Force at shifter pedal of bike = 3 kgF
Length of shifter pedal of bike = 10.5 cm.
∴ Torque required to change gear = 3.9 Nm
Length of link at engine side = 60 cm
∴ force required to change gear at engine side = 7 kgF
For ease of shifting, force of shifter is required to be approx. = 5kgF
Travel of shifter at engine side = 9 cm
Let ,
T = travel at engine side,
T = travel at shifter side,
∴ $t = L_2 * \sin\boldsymbol{\theta}$.
$T = L_1 * \sin\boldsymbol{\theta}$.
$F_h * L_1 = F_g * L_2$
$F_h = (F_g * L_2) / L_1$
Now,
$F_h = 5$ kgF
$F_g = 7$ kgF
∴ $L_2 / L_1 = 1.5789$
∵ $L_1 = 60$
$L_2 = 38$
For driver comfort, ease of shifting, length of shifter is taken as 60 cm.
∴$L_2 = 38$ cm.

5) Pedestal Bearing: It is also known as pillow block bearing or Plummer block. These are used as support for a rotating shaft with help of ball various accessories. Assembly of this bearing consist of mounting block with houses ball and cage, seals, grease hole, inner and outer rings. Inner diameter of bearing is 0.025 mm larger than shaft to ensure clearance fit. Housing material for pillow block is made of cast iron. Pillow block refers for housing which include anti friction bearing, where the shaft is parallel to the mounting surface, perpendicular to Centre lift of holes. Block consists of several types of rolling elements.

ISO113 specifies international acceptance for pedal blocks.

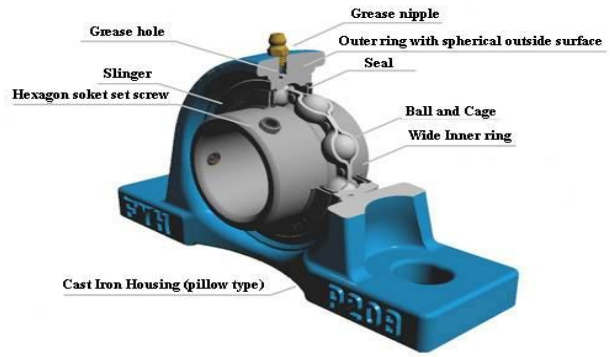

Fig.8 Pedestal Bearing

➢ Selection of bearing:

The relation between the dynamic load carrying capacity, the equivalent dynamic load, and bearing life given by,

$L_{10} = [C/P]^p$

∵ L_{10} = rated bearing life (in million rev)

C =dynamic load capacity(N)

P = 3 (for ball bearing)

p = 10/3 (for roller bearing)

rearranging,

$C = P (L_{10})^{1/p}$

For all types of ball bearings:

$C = P(L_{10})^{1/3}$

For all types of roller bearings:

$C = P (L_{10})^{0.3}$

The relationship between life in million revolutions and life in working hours is given by,

$L_{10} = 60nL_{10h} / 10^6$

∵ L_{10h} = rated bearing life (hour)

n = speed of relation (rpm)

Given,

F_r = 50 KN

L_{10h} = 8000 h

n = 6000 rpm

Step 1 :Bearing life (L_{10})

$L_{10} = 60\ n\ L_{10h} /10^6$

$=(60* 6000* 8000)/ 10^6$

L_{10} = 2880 million rev.

Step 2 : Dynamic load capacity :

Since the bearing is subjected to radial forces.

$P = F_r = 50000N$

$\therefore C = P (L_{10})^{0.3}$

$=50000 *(2880)^{0.3}$

L = 545.49 KN

6) *Chain Calculation:* After determining the sprocket ratio and its position, the chain of 12.7 mm pitch was selected. The chain selected is an automobile chain and not industrial. It was selected because of its availability and the front sprocket has the same pitch. Following are the calculation which show the no. of links required, Centre distance and FOS of the chain.

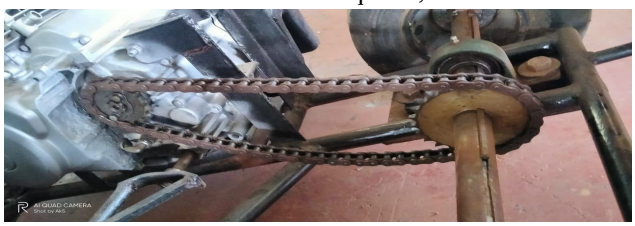

Fig. 9. Chain

Chain Parameters 12.7 mm pitch-
Width = 7.85 mm
Roller Dia. = 8.51 mm
Tensile strength = 21390 N
Chain = 94.5 cm = 0,945 m
Sprocket to sprocket = 30 cm
Larger sprocket radii = 5.5 cm
Tensile strength of chain = 21390

Sprockets:
No. of teeth (smaller)= 15
No. of teeth (larger) = 1.6666
Assuming angle as 12.606 degree
Max. engine torque =13.4 Nm
Chain drive = 1.6666
Primary = 3.4
Gearbox 1^{st} = 3.42
Total gear ratio = Primary * gear box * chain drive ratio
= 3.4 * 3.42 * 1.666
= 19.3792
Calculation based on tensile load :
Max. torque = Max. engine torque * Total reduction ratio
= 13.4 * 19.3792
= 259.6812
But max. tractive torque = 123.341 Nm
Therefore,
Load on chain = (max. tractive torque / reduction of larger sprocket) * 1000
= (123.341 / 0.055) * 1000
= 2242.56 N
Factor of safety = 8 (Assume)
For 1^{st} gear load,
FOS = Tensile strength of chain / Load on chain
= 21390.09/ 2242.56
= 9.5382
Therefore, Assumed FOS is smaller than actual FOS, Hence design is safe
Actual center distance = 30 cm
Length of chain = No. of links * pitch (P)
945 / 10 = No. of links
No. of links = 9.45 = 10

III.BRAKING

A brake is system which absorbs kinetic energy of vehicle to convert into heat energy which is helpful to slow down or stop motion of moving object. It uses artificial friction resistance by means of friction pads or brake shoe.
In this paper explains about disc brake system which uses friction pad as resistive factor which generate heat energy to stop vehicle. This heat energy is then dissipated into atmosphere. Since disc brakes are more effective and less area consumptive system than drum brake and it helps to reduce weight on the kart so we selected disc brakes as braking system.

A. Different types of Brakes

1) Disc brake system
2) Drum brakes system
3) Regenerative braking system
4) Air brake system
5) Electromagnetic braking system
6) Rotor brake control system

B. Objective

1) To reduce speed of kart and stop it effectively with minimum distance.
2) Brake should apply force of resistance on both wheels equally.
3) Centre of gravity of vehicles must keep constant when brake applied.

C. Selection of Brakes

We have used a Hydraulic Disc Brake considering the following advantages, availability, and their limitations.
For selection of best braking system in go-kart you have to keep some points in your mind:

1) Hydraulic system
2) Disc brake - Apache RTR rear 200mm
3) Master cylinder- Apache RTR rear master cylinder
4) Brake lines- Apache RTR front
5) Calliper- Apache front double piston calliper

Table 5.specifications of components

COMPONENTS	SPECIFICATION
Brake Disc	150 mm (dia) of Yamahafascino125
Master cylinder	$2.01*10^{-4}$ m^2 (area) of TVS apache
Brake fluid	Dot-3
Calliper	26 mm (dia) of Bajaj pulsar

D. Design Calculations

Parameters: Mass of vehicle = 150 kg
Maximum speed of vehicle (s) = 80kmph (22.22m/s)
Tire radius (r_{tire}):= 139.70mm
Height of C.G from ground surface (h) = 200mm

1) Calculation of Stopping Distance and Time

u=initial velocity in m/s;
v=final velocity in m/s;
a=deceleration rate in m/s2;
s=stopping distance; t=braking time;
v=0; u=80 kmph (22.22m/s)
Assuming deceleration a=1 x g=9.81m/s2

(i.e. a=μxg; μ=the coefficient of friction between road and tyre Assuming μ=1 for asphalt and slick tires)
Using Newton's 3rd Kinematic equation,
v2=u2+2as s=25.17m Using Newton's 1st Kinematic equation

v = u + at t=2

The stopping distances and braking time while stopping the kart to rest from various speeds are listed in following table:

Table 6. Stoping distance and time

Speed (km/hr)	Stopping Distance(m)	Braking time (seconds)
40	6.29	1.13
50	9.83	1.42
60	14.16	1.69
70	19.27	1.98
80	25.17	2.56

2) Dynamic weight Transfer

Dynamic weight transfer is the amount of change of vertical loads of the tires due to longitudinal acceleration imposed on Centre of Gravity of the car. Total static mass of vehicle including driver =150 kg (Static weight distribution is assumed to be 40%front and 60% rear) Height of C.G from the ground surface (h) =200mm Wheelbase (b) =1070mm
(Fs)F =Static weight on front wheels = 150 x 9.81 x 0.4 = 588.6N
(Fs)R =Static weight on rear wheels = 150 x 9.81 x 0.6 = 882.9N
F_d = Force due to dynamic weight transfer

$$F_d = \frac{m\,a\,h}{b}$$
$$= \frac{150\ X\ 9.81\ X\ 200}{1070}$$
= 275.05 N
Total dynamic weight on Front axle $(F_d)_F=(F_s)_F+F_D$ = 588.6 + 275.05 = 863.65N
Total dynamic weight on Rear axle $(F_d)_R=(F_s)_R-F_D$=882.9 - 275.05=607.85N

3) Master Cylinder & Caliper Selection

As only one disc is used on rear rigid driving axle weight on only rear wheels is considered. Maximum driving torque without slipping condition is:
$T_f = (F_d)_R \times \mu \times r_{tire}$ = 607.85 x 1 x 0.1397
=84.9N-m

4) Rotor Specifications

We are going to manufacture disc of our own design. Specifications of disc are:
Material = EN8
The reason behind selecting EN8 is to obtain high strength, specific heat, better heat transfer and good thermal conductivity of the disc.
Outer dia. = 150 mm
Effective radii = 75 mm
Thickness =4 mm
PCD= 80mm (3 bolts of dia 8)

Fig 9 disc rotor and hub

Design of Rotor Hub:
Material: EN8
For EN8 σ_{yt}=323.23 MPa
Torque to be transmitted (M_t)= Torque due to traction
= μ x m x g x 0.6 x radius of tyre
= 123.3411 N-m
=123341.1 N-mm
Fixing the hub length as 30mm,
Shaft diameter = 25mm
Hub diameter (d_h) = 41mm
Thickness of flange (t) = 6mm
Force on hub=M_t / radius of hub
=123341.1/20.5
=6016.64N
Shear stress=F / A
=6016.64/ (π x d_h x t)
=6016.64/(3.14 x 41 x 6)

IV. CONCLUSION

In this work, detailed methodology of design and testing has been presented including the selection of engine. Also the defined path for the calculation and the assumptions those to be considered are descried in detail. This work provides the basics for the development and advancements in the transmission and braking systems of Go-kart. Thus after all the required test and calculation we have concluded that this transmission system will help to enhance stability and also obtain maximum speed. Whereas braking system is safe and effective for installation and ready to use in Go-kart.

V. ACKNOWLEDGEMENT

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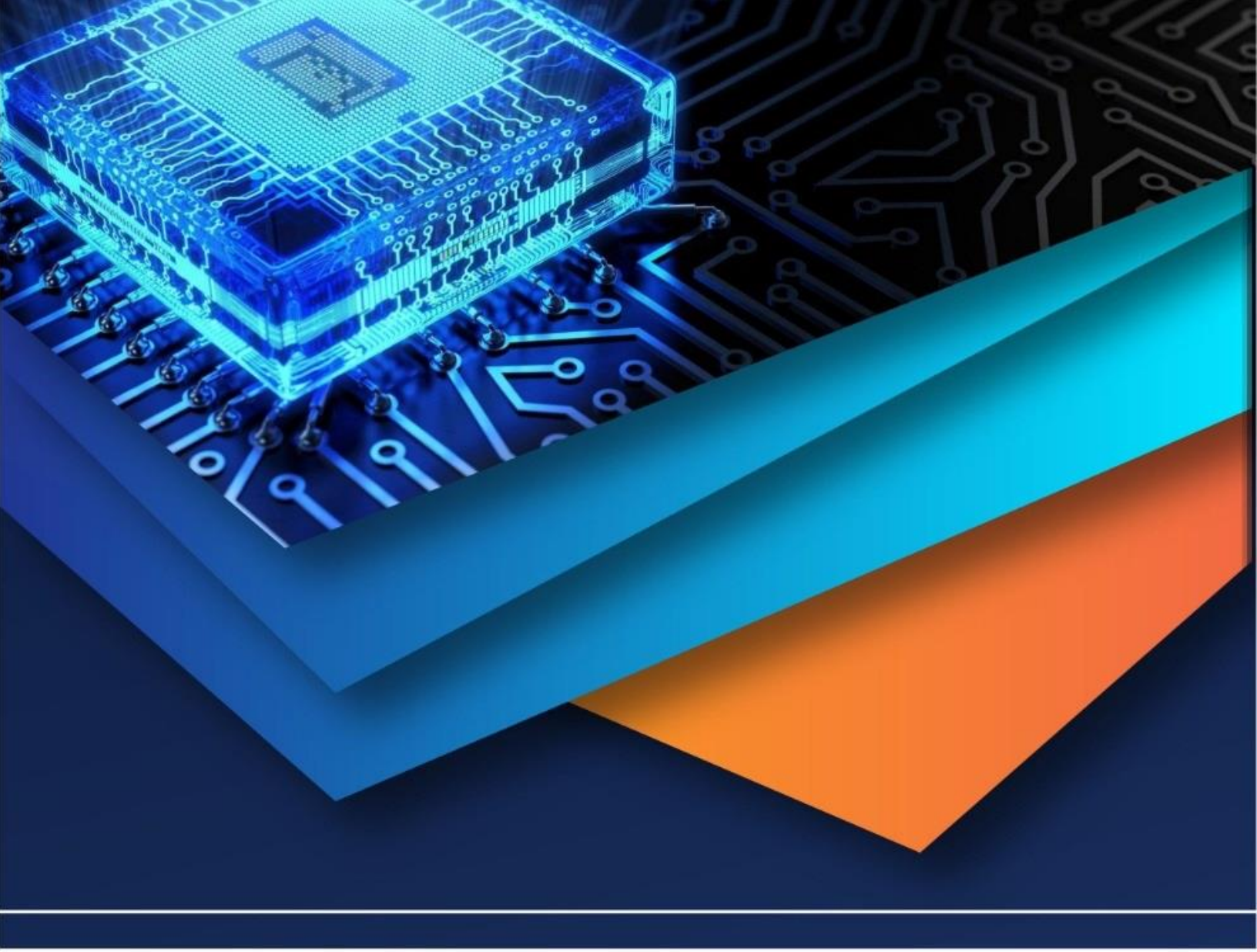

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