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Design and Predictive Analysis of Go-Kart Steering System

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Abstract - *A Go-kart is a four-wheeled vehicle, and it has no suspension and no differential. They are mainly raced on scaled-down tracks. In this paper the aim is to design an optimized steering system for the Go-Kart where the steering column is offset from the Go-kart's center axis and provide optimum dimensions for the wheelbase and track width. The primary realistic approach of geometry selection for the steering mechanism is made with the help of CATIA models and MSC ADAMS simulation. The HPERMESH analysis of critical components of the mechanism was also done.*

Key Words: *Ackermann, Go-kart, MSC Adams, Pitman arm, steering assembly, Turning radius.*

1.INTRODUCTION

Motorsport could be a world term used for encompassing the cluster of competitive sporting events that primarily involve motor vehicles, whether or not for sport or non-racing. The language may also be wont to describe the type of competition in motorized machine vehicles underneath the banner of motorsports racing.

There are several motorsports within the world. Bikes, cars, formula one is samples of them. The drivers in these are terribly skilled and accurate, and they'll drive it in no time.

There are motorsports that don't want professional drivers and not that prime speed. The vehicles used are also very cheap. Such motorsport is thought of as motor vehicles. They tally the formula one car, however it's not quicker than F1, and its value is considerably lower. The drivers in go-karting are not skilled even youngsters may also drive it. Go-karts has four wheels and also a tiny engine.

They're widely utilized in sport within the US, and also, they are also obtaining widespread in India. A go-kart could be a small four-wheel vehicle. Go-karts are factory-made altogether shapes, sizes, and forms, from motorless models to high-powered machines to beat racing cars on the long circuits. Automobile racing has become one in every of the most widespread sports among children these days.

Consequently, go-karting begins to achieve much attention, as there's no ordinance to the current sport. Furthermore, motor vehicle today needs investment meagerly, creating it cheap for many individuals to get it from the general public distributor or construct one during a workshop. Amusement parks having go-karts are supercharged by 4-stroke engines, electrical motors or CVT. In contrast, sport karts use tiny 2-stroke or 4-strokes engines. Most of them are single seated, however recreational models will typically accommodate a passenger. In some countries, go-karts are often accredited to be used on public roads. Naturally, there are some restrictions, e.g., at intervals in the ECU Union, a motor vehicle on the road wants a light source (high/low beam), tail lights, a horn, indicators, and a most of 20HP.

1.1 Objective

1. To reduce cost, human effort, and human fatigue.
2. To achieve minimum turning radius to 1.5m, including skid-pad test.
3. To improve comfort of vehicle driver.
4. To enhance driver vehicle judgement with high accuracy.
5. Provide high steering actuation with minimum effort.

2. Literature Survey

Suwin Sleesongsom1 et al. [3] suggested method to synthesize the steering linkages which can minimize the maximum steering error which can reduce the skidding and wear of the tires.

Chunke Liu, Xinping Song, Jiao Wang et al. [4] approached towards the tests to be performed to check if the parts will sustain a crash. Different types of methods and how to improve the design so that the impact on the part is less during a crash.

L. Angel, C. Hernández and C. Díaz-Quintero et al. [5] proposes the process for simulation on Adams software. The parameters to be select and methods of optimization.

3. DESIGN METHODOLOGY

3.1 Ackermann Steering Mechanism:

Ackermann Steering Mechanism a linkage arrangement that generates an appropriate angle for inner and outer wheels while turning the vehicle and the inner front wheel has different radii with respect to the outer wheel while turning. As per its design, Ackermann's steering system is placed within the backside of the front wheel axle, and its gear consists of turning pairs. In the Ackermann steering mechanism, skidding is high, and it does not require effort for turning.

3.2 Davis Steering Mechanism:

Davis Steering Mechanism is a mechanism in which slotted links are related to the front wheel axle, which turns about pivotal points. In Davis Steering Mechanism, as in step with its design, the mechanism is positioned on the front thing of the front wheel axle, and its steering gear consists of sliding pair. Compared to Ackermann Steering Mechanism, the skidding in Davis mechanism is extra diminutive and requires extra try to reveal the vehicle.

Initially, Ackermann steering was chosen over Davis for better efficiency as it includes rolling pairs instead of sliding ones. Triangular plate provided better optimization in the speed of actuation and cost-efficient over rack and pinion. The steering ratio is 1:1 forquick steering response. From task interdependency with other sub-systems, the following data were ideal for the purposes assigned by respective sub-systems.

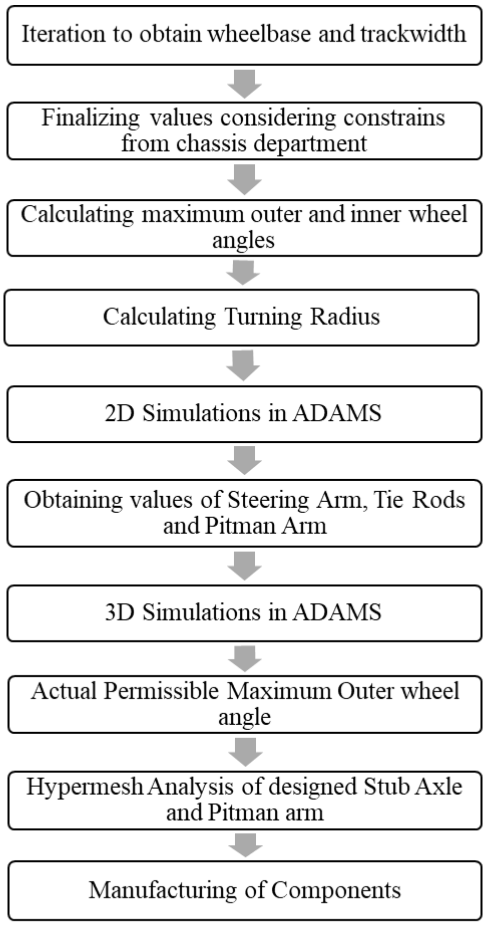

Fig. 1. Flowchart of Steering Mechanism

4. Simulation, Calculation and Analysis

4.1 MATLAB calculation

The wheelbase and track width of the kart were decided after several iterations in MATLAB. The variables were computed for a fixed turning radius of 1.5 m and the corresponding achievable turning angles were observed. Considering the space and comfort, selected the optimum values of wheelbase of 1100 mm and track of 900 mm.

The following formulae were used for the same:

Where,

$$\delta \text{ outer} = tan^{-1}\left[\frac{L}{R+\frac{t}{2}}\right] \qquad \delta \text{ inner} = tan^{-1}\left[\frac{L}{R-\frac{t}{2}}\right]$$

δ outer = outer turning angle

δ inner = inner turning angle

L = wheelbase

R = Turning radius

T = track

WB	TW	Outer Angle	Inner Angle	Rear Turning Radius	Front Turning Radius	Turning Radius at CG
1.100000	0.825000	28.755178	43.000000	1.434704	1.807865	1.504856
1.100000	0.825000	29.251343	44.000000	1.404313	1.783842	1.475910
1.100000	0.825000	29.744881	45.000000	1.375000	1.760859	1.448047
1.100000	0.825000	30.236040	46.000000	1.346693	1.738845	1.421196
1.100000	0.825000	30.725061	47.000000	1.319325	1.717736	1.395290
1.100000	0.830000	28.695022	43.000000	1.440066	1.812123	1.509969
1.100000	0.830000	29.189279	44.000000	1.409490	1.787921	1.480837
1.100000	0.830000	29.680899	45.000000	1.380000	1.764766	1.452796
1.100000	0.830000	30.170130	46.000000	1.351522	1.742587	1.425772
1.100000	0.830000	30.657213	47.000000	1.323988	1.721320	1.399700
1.100000	0.835000	28.635096	43.000000	1.445428	1.816387	1.515083
1.100000	0.835000	29.127455	44.000000	1.414668	1.792006	1.485766
1.100000	0.835000	29.617167	45.000000	1.385000	1.768679	1.457546
1.100000	0.835000	30.104480	46.000000	1.356350	1.746335	1.430350
1.100000	0.835000	30.589635	47.000000	1.328650	1.724909	1.404111
1.100000	0.840000	28.575398	43.000000	1.450790	1.820657	1.520200
1.100000	0.840000	29.065869	44.000000	1.419845	1.796096	1.490697
1.100000	0.840000	29.553684	45.000000	1.390000	1.772597	1.462298
1.100000	0.840000	30.039088	46.000000	1.361179	1.750088	1.434930
1.100000	0.840000	30.522326	47.000000	1.333313	1.728503	1.408524
1.100000	0.845000	28.515928	43.000000	1.456152	1.824932	1.525317
1.100000	0.845000	29.004520	44.000000	1.425023	1.800192	1.495629
1.100000	0.845000	29.490447	45.000000	1.395000	1.776520	1.467052
1.100000	0.845000	29.973954	46.000000	1.366007	1.753846	1.439511
1.100000	0.845000	30.455283	47.000000	1.337975	1.732102	1.412938
1.100000	0.850000	28.456684	43.000000	1.461513	1.829213	1.530437
1.100000	0.850000	28.943408	44.000000	1.430201	1.804293	1.500563
1.100000	0.850000	29.427456	45.000000	1.400000	1.780449	1.471807

Fig.2 Matlab calculation Result

Hence, the Wheel Base (WB) = 1100mm, Wheel Track (WT)= 850mm were selected from the calculations and simulations performed on MATLAB and Adams View.

4.2 Simulation

2D Simulation is performed in ADAMS from the finalized wheelbase and trackwidth values obtained from the MATLAB software. Finalized dimensions of various links like tie rods, steering arm and triangular plate were obtained by various combinations and simulations in ADAMS.

The dimensions and simulations were obtained with an offset of the steering column 30 mm left from the central axis of the kart. This was primarily to give comfort and proper spacing to the driver as the seat of the driver needed to offset from center to utilize better space and provide room for the mounting of engine.

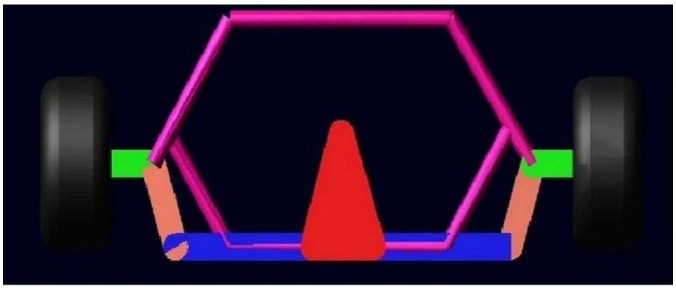

Fig. 3. ADAMS Model of Steering

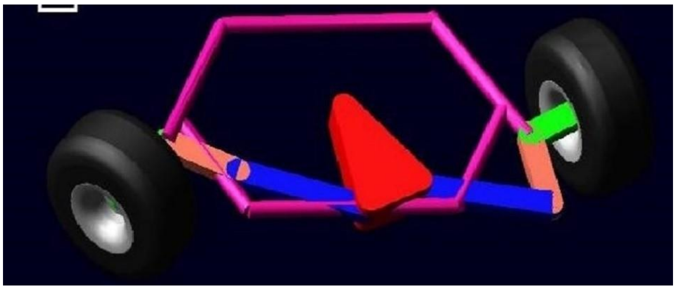

Fig. 4. Full Steer Mechanism of Steering

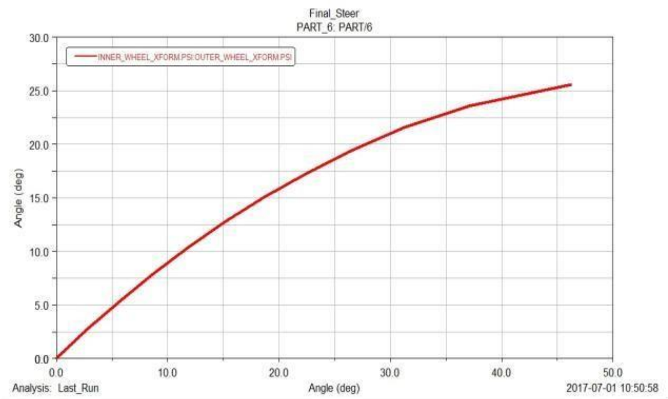

Fig. 5. Inner Wheel Angle vs Outer Wheel Angle

Hence, Inner Wheel Angle ‘θ’ = 46.1906°

Outer Wheel Angle ‘θ’ = 25.5355°

So,

$$\text{Ackermann ‘}\alpha\text{’} = \tan^{-1}\left[\frac{WB}{\frac{WB}{\tan\theta} - WT}\right]$$

α = 32.5051°

$$\text{Ackermann Percentage} = \frac{\theta}{\alpha} \times 100$$

= 149.90% (Over - Steer)

4.3 Finite Element Analysis

4.3.1 Triangular Plate

The analysis of triangular plate was carried out by fixing one ball joint end of the triangular plate and applying the maximum steering effort which is given by:

$$T = F \times r$$

Where, T = steering torque

F = Steering force

=15 kg x 9.81 m/s^2 = 147.15 N

r = radius of steering wheel

= 0.2542 m

Thus, T = 147.15 x 0.2542

= 37.4 Nm

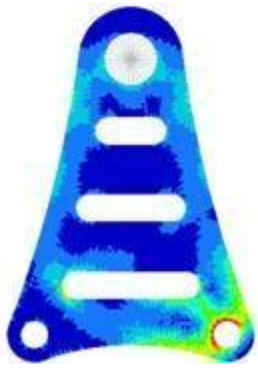

Fig. 6. Element Stresses in Pitman Arm

This torque was applied at the steering rod end of the triangular plate and fixing any one bottom hole. The material used for triangular plate is EN8. The maximum stress induced was in permissible limits.

4.3.2 Front Axle

Analysis of front axle was done considering the vehicle is taking a turn of radius 5 m at a speed of 60 kmph. Extreme condition was taken in which the outer wheel is lifted due to caster and KPI inclusion and complete dynamic weight is on the inner wheel while turning which was calculated by following formula:

$$F = \frac{Wlv^2h}{bgra}$$

Where,

W= weight of the vehicle, 1373.4N

l = horizontal distance of C.G from rear axle, 0.43m

v = velocity at turn, 16.66 m/s.

h = height of C.G from ground, 0.19 m

b = wheelbase, 1.1 m

g = acceleration due to gravity, 9.81 m/s^2

r = radius of turn, 5 m

a = wheel track, 0.9 m

Thus,

F = 679.076N.

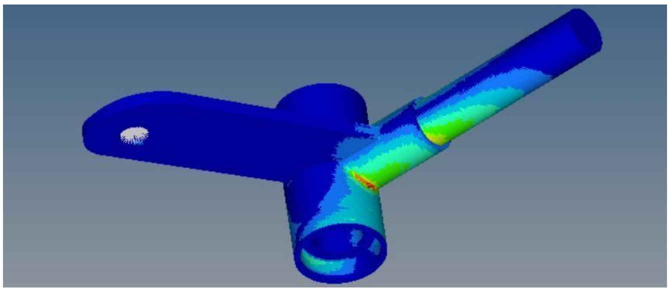

Fig. 7. Stress Analysis of front axle

This upward force was been exerted at the bearing end of the stub-axle and fixing the king pin from bottom and the steering arm hole. The material used for front axle is EN8. The maximum stress induced was of the range 135 N/mm^2 at the joint which is within permissible limits. Hence, after careful considerations of parameters and implementation of direction of forces, the result obtained were found to be safe for working for the desired spell.

4.4 Wheel Alignment Angles

4.4.1 Caster Angle: -

A positive caster helps in increasing the normal reactions on inner front tire during a turn compared to outer front tire by diagonal shift of weight known as jacking effect resulting in over steer of the vehicle. After proper study and survey, a positive caster of 2° is included in the kart.

4.4.2 King Pin Inclination Angle

King Pin Inclination facilitates in raising the vehicle from front irrespective of the turn. More the KPI more would be lifted from the ground. King Pin Inclination of 2° is included in the steering geometry.

4.4.3 Camber Angle:

Camber is adjusted by rotating the camber adjuster at the stub axle mounting. Generally slick tire should not have camber angle (i.e. 0° camber angle) and open CIK seat at 0-2 mm positive (wider at top of tire).

4.4.4 Toe Angle:

Generally, Toe in angle for a rear wheel drive is usually preferred. The reason being, the inside front wheel moves down in relation to the chassis more than it will with zero toe or toe out. This configuration makes kart directionally stable.

5. Result

Sr. No.	Parameters	Magnitude
1.	Wheel Base	1100 mm
2.	Wheel Track	850 mm
3.	Ackermann Angle	16.22°
4.	Max. Inner Wheel Angle	46.1906°
5.	Max. Outer Wheel Angle	25.5355°
6.	Turning Radius at CG	1.47m
7.	Caster Angle	2° (Positive)
8.	King Pin Inclination	2° (Positive)
9.	Chamber Angle	0°
10.	Toe Angle	Toe In

6. Conclusion

We have successfully designed the steering system for the go-kart by using modelling software CATIA simulated on ADAMS and analyzed using HYPERMESH. We have kept the turning radius under 1.5M which was the aim of the steering design. Also, have fixed the wheelbase and track width of the go-kart.

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