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STRESS ANALYSIS & OPTIMIZATION OF ECO KART BY USING TAGUCHI METHOD

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Abstract:

A go- kart is small four –wheeled vehicle. Go – kart can be powered by 4- stroke engine or electric motor. Most of the go-kart used for racing is 4-stroke engine which emits toxic gases due to combustion process. But to concentrate in global warming and to have a eco-friendly concepts we design a "ECO CAR". Electric go- karts are low maintenance, requiring only that the lead-acid batteries. Since they are pollution-free and emit no smoke, the racetrack can be indoors in controlled environments. To convert a4-stroke Go-kart to electrically powered eco kart we need to concentrate in many parameters. Because the electric motor cannot pull the kart if it is more weight. So we need to design our eco kart in less weight to pull with more torque and to analyse the frame with optimizing with different materials.

Our Eco-car which is designed and analysed will be less weight, more strength, highly efficient, Eco friendly, comfortable, low maintenance, high speed and torque

.

KEYWORDS: Solidworks, Ansys, Minitab 17.0.Eco Car, Etc.

1. INTRODUCTION:

The design process of this single-person vehicle is iterative and based on several engineering and reverse engineering processes. Following are the major points which were considered for designing the racing track vehicle:

1. Endurance
2. Safety and Ergonomics
3. Market availability
4. Cost of the components
5. Standardization and Serviceability
6. Manoeuvrability
7. Safe engineering practices.

Team King's Eco Racers began the task of designing by conducting extensive research for main parts of the vehicle. Our team members did a global market search for the desired parts of the KART. Including the market of Chennai, we also went to Kart racing places and visited go kart. Chennai Industrial Estate is the home to one of the India's largest industrial zones and other automobile related areas for direct interaction to them. We contacted numerous auto part dealers in different parts of the country to know the availability of required parts. Then keeping the voluminous list of available parts in mind, the designing team initiated their work to achieve the best standardized as well as optimized design possible. Solid Works 2013 was the CAD software used for designing and used to analyses the deflection test and all. Specifications laid down by the rulebook were the foremost concern while designing and selection of the parts. Besides racing performance, eco-friendly which we got to know through the internet research and reviews for all kart vehicles. Finally the design was presented in the Virtual event of SAE ECO KART 2015 and we were through it. This is the first time participation of our team, if we are selected in the prelims then our team's enthusiasm drastically increases and we will start the fabrication part of our ECO car with all the blazing spirit and exhilaration.

2. LITERATURE REVIEW:

BASIC GO KART CHASSIS THEORY

According to Martin B, (2000), it is the responsibility of the karted to determine his own requirement and to obey the rules stated by the organization. This is true because the option of setting up the go kart such as which type of chassis preferable depends to the convenience of the karted. The combination of knowledge and experienced would the best requirement to set up a good chassis. The understanding of basic chassis setup would assist the rookie on setting up the chassis but experienced will lead to improvement and development in tuning up the chassis. Furthermore, the fundamental of go-kart needed crucially as a main reference for the author to design new chassis.

3. FRAME DESIGN:

The design was made based on the driver economics. A material of the less weight without compensating the strength was taken in to consideration to make the vehicle lesser in weight and optimizing the overall performance the material was found to suit our consideration well as it had yield strength 303mpa and density of 8:6mg/m^3.the simulation was done with Ansys with SS304 and its physical properties were given as input parameter the dimensions we settled for the frame material was 1.04 inch 26.67mm thickness. The thickness was made minimal to have possible weight reduction on and the section is tubular with above mentioned dimensions.

3.1. Vehicle Technical Specification:

S.no	Technical description	Specification
1.	**Dimensions** Overall length Overall width Overall height	 1325mm 1190mm 600mm
2.	Frame Material SS304	Yield strength = 303 MPa Carbon = 0.3 % Density=7700Kg/m^3
3.	Weight	30 kg

Table.1.Vehicle Technical Specification

The strength is good and the weight is comparatively very less to other available materials as per specification move over the material we chose is easily available in local markets. Hence this becomes the ideal section of material for frame.

3.2. Chassis layout:

We have designed the frame keeping in view the safety and aesthetics. These are the two factors which matters us the most, therefore they are given utmost consideration. The design complies with the rules mentioned in the SAE ECO KART 2015 RULE BOOK.

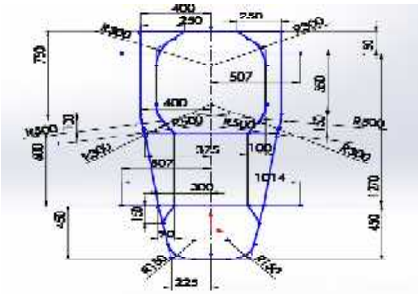


Fig.No 1. Chassis Layout

3.3. Vehicle dimensions:

A wider track width at the front than at the rear will provide more stability in turning the kart into comers decreasing the tendency of the kart to trip over itself on comer entry and more resistance to diagonal load transfer wheel base is 1325mm and track width is 1190mm.This has been chosen to ensure better balance and straight line stability. This has also created ample space for the driver and other systems.

4. TYPES OF SECTIONS USED IN FRAMES

Three types of steel sections are most commonly used for making frames:

(a) Channel section,
(b) Tubular section, and
(c) Box section.

In our project we selected a tubular section frame which is high strength.

5. FRAME:

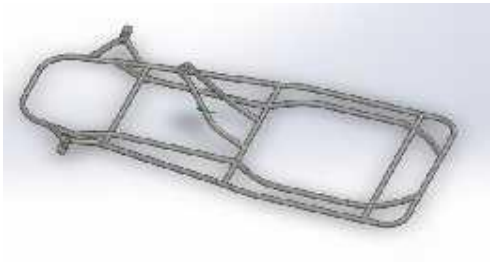


Fig. No.2.Frame

6. COMPONENTS TO BE SEATED IN FRAME

1. Steering assembly
2. Rear axle
3. Front wheel assembly
4. Rear wheel assembly
5. Brake system
6. Bumpers
7. Driver seat
8. Motor
9. Batteries
10. Transmission systems

7. FRAME MATERIAL SELECTION:

- The material to be selected for frame should be feasible for manufacturing and strong enough to support all the components attached in frame.
- The Frame material should be less weight and highly efficient.
- The frame material should have less maintenance and corrosion resistance.
- The frame material should bear the impact and load.

SS304:

Yield strength is 190MPa and stress acting on the frame is 29.8535N/mm^2. So factor of safety is 6.36 and it is above 5. So design is safe and SS304 will not corrode and it is maintenance free.

SS400:

Yield strength is 205MPa and stress acting on the frame is 22.3286N/mm^2. So factor of safety is 9.18 and it is above 5. So design is safe and SS400 will corrode because of ferric content in it and it will not withstand welding.

MILD STEEL:

Yield strength is 210MPa and stress acting on the frame is 22.3204N/mm^2. So factor of safety is 9.40 and it is above 5. So design is safe and Mild steel will corrode and it is difficult for maintenance.

8. SOFTWARES USED:

Some of the software's that are used for modelling and analysing the above mentioned composite gear box are

- ❖ Solid works Software
- ❖ Ansys Software & Minitab

8.1. SOLIDWORKS:

The Solid Works CAD software is a mechanical design automation application that lets designers quickly

sketch out ideas, experiment with features and dimensions, and produce models and detailed drawings.

- Defined by 3d design
- Based on components

8.2. TAGUCHI'S METHOD DESIGN OF EXPERIMENTS:

1. Define the process objective, or more specifically, a target value for a performance measure of the process. The target of a process may also be a minimum or maximum. The deviation in the performance characteristic from the target value is used to define the loss function of the process.

2. Determine the design parameters affecting the process. Parameters are variables within the process that affect the performance measure that can be easily controlled. The number of levels that the parameters should be varied at must be specified

8.3.MINITAB:

Minitab is a general purpose statistical package designed for easy interactive use. Minitab was originally designed as a tool to be used in teaching statistics. Its interactive features make it well suited to instructional applications, and Minitab's greatest popularity remains as a teaching tool. However, Minitab is sufficiently powerful that it is also used by many people in analysing research data.

8.4. ANALYSIS OF VARIANCE:

The purpose of product or process development is to improve the performance characteristics of the product or process relative to customer needs and expectation. The purpose of experimentation should be to reduce and control variation of a product or process and decide which parameter affects the performance of the product or process. Analysis of variance (ANOVA) is a statistical method used to interpret experimented data and make decisions about three parameters.

9. SELECTION OF CONTROL FACTORS:

The control factors can be identified using different tools. Characteristics that you can control in the product or process you are designing. Factors (or control factors) are the design parameters of a concept or technology that need to be optimized.

9.1. DESIGN OF EXPERIMENTS:

MATERIAL	DIA	THICKNESS
Mild steel	21.3	1.65
SS304	26.7	2.11
SS400	33.4	2.77

Table.No 2. DOETable

9.3. DESIGN OF EXPERIMENTS:

Exper. Number	Diameter (mm)	Thick (mm)	Material
1.	**21.3**	**1.65**	Mild steel
2.	**21.3**	**2.11**	Mild steel
3.	**21.3**	**2.77**	Mild steel
4.	**26.7**	**2.11**	**SS304**
5.	**26.7**	**2.77**	**SS304**
6.	**26.7**	**1.65**	**SS304**
7.	**33.4**	**2.77**	SS400
8.	**33.4**	**1.65**	SS400
9.	**33.4**	**2.11**	SS400

Table.No.3. DOE.L9 Table

9.4. MODE FOR DESIGN PARAMETERS OF FRAME:

As per the above mathematical calculation, the design parameter of gearbox is calculated and designed. As per the calculated design parameters, a frame is modelled using modelling software, Solid works. The below mentioned figure shows the model 3D diagram of the frame.

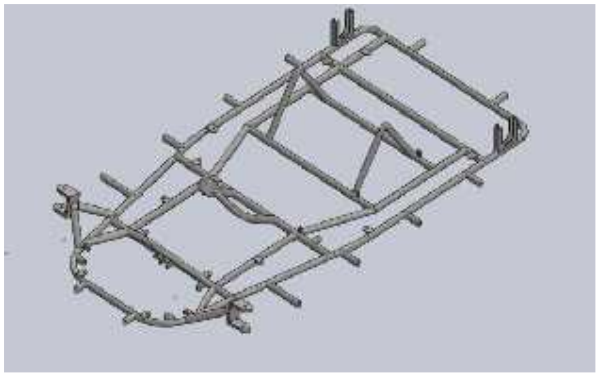


FIG.3:3D model of gearbox

9.5. STEPS INVOLVED IN ANSYS WORKBENCH:

1. Modelling
2. Defining element type
3. Defining real constant
4. Adding material properties
5. Meshing
6. Specifying contact
7. Setting initial condition
8. Setting constraints
9. Specifying loading options
10. Setting global data
11. Setting time and frequency controls
12. Solving
13. Viewing and interpolating results

10. FRAME ANALYSIS:

The material to be selected for frame should be feasible for manufacturing and strong enough to support all the components attached in frame. The Frame material should be less weight and highly efficient. The frame material should have less maintenance and corrosion resistance. The frame material should bear the impact and load.

10.1.ITERATION.NO1:SS304DIA21.3MM THICKNESS 1.65MM:

Von mesis stress

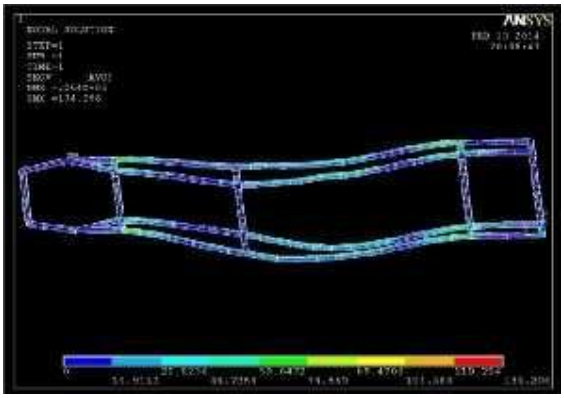


Fig.No.4.Ansys Result

10.2. ITERATION.NO2:SS304DIA26.7MM THICKNESS 2.11MM:

Von mesis stress

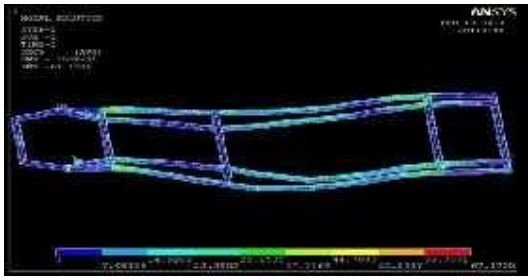


Fig.No.5. Ansys Result

10.3. ITERATION.NO.3:SS304DIA33.4MM THICKNESS 2.77MM

Von mesis stress

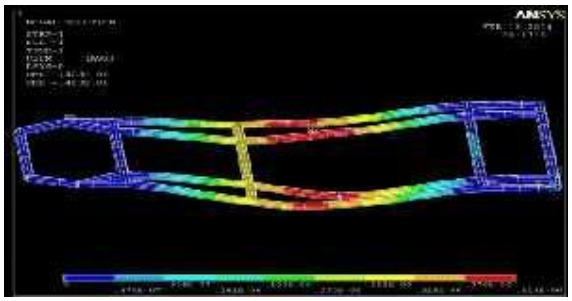


Fig.No.6. Ansys Result

11. RESULT FOR VON MISES STRESS:

EXPERIMENTS NUMBER	VON MISES STRESS N/mm^2
1.	69.647
2.	52.480
3.	38.970
4.	29.835
5.	32.340
6.	35.210
7.	30.472
8.	24.732
9.	22.820

Table.No.4.Result for Stress

11.1. ANOVA VERIFICATION FOR VON MISES STRESS:

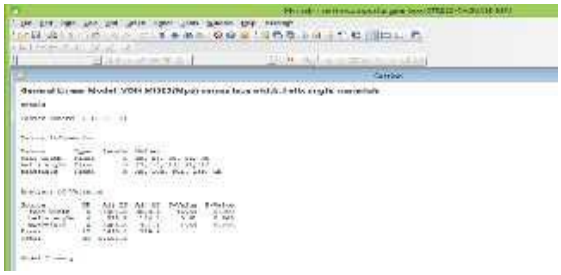


Fig.No.7: STRESS Result For Minitab

11.2. ANOVA TABLE:

Sum Of variance	**Sum Of Square**	**DOF**	**Mean Sum of square**	**F_{cal}**	**F_{table} At α=0.05**	**REMARKS**
A	2.0×e9	3	0.6×e9	4.9	4.76	**Sign**
B	577.2×e6	3	0.1×e9	1.3		In sign
C	733.2×e6	3	0.2×e9	1.7		In sign

Table.No.5.Anovatable

In factor **'A' $F_{cal} > F_{table}$** i.e. It is clear that the factor A have **significant** effect on the Stress. Since F_{cal} for the factor A is greater than F_{table}. Hence factor A is the best factor among the three factors available to us. So by increasing the value of factor A.

12. RESULTS:

MATERIAL	VON-MISES STRESS
SS304	29.835N/mm^2
SS400	30.472 N/mm^2

Table.No.6.Result Table

Fig No.8. Minitab Chart

For an effective performance, the ss304 should have minimum stress. Among these materials, the ss304 has minimum stress. It clearly shows that 58% of the material can be reduced using the optimised material than the existing one without much changes in Von-Mises stress both helps to improve the efficiency of the frame performance.

13. REGRESSION EQUATION:

VON MISES (σ) =171.3 -3.685b - 1.49β + 0.164 M

14. STEERING SYSTEM:

The steering system used in our vehicle has is tie rod directly connected to the steering rod in the ratio of 1:1. The Ackermann angle of this type of steering is calculated as follows.

Track width (TW) =1168mm

Wheel base (WB) =934mm

The value of turning radius is assumed to be 2.3m.Also the values of TW and WB are 1168 and 934mm.

The steering of an Eco Kart is very sensitive because the lack of a differential it is very difficult to change. The two rear wheels are attached by a solid axle, during turning one of the wheels needs to skid over the track surface. In the kart we use the special kind of steering system, disc and link mechanism.

In this system the steering spindle is connected to a disc or plate and the disc is connected to the front two whelks using two links. When steering rotates disc also rotates and as the results the link actuates and the wheel will turn according to the rotation of steering.

There are three different factors when deciding on the steering geometry for Eco karts.

1. Castor angle
2. Camber angle
3. Ackermann angle

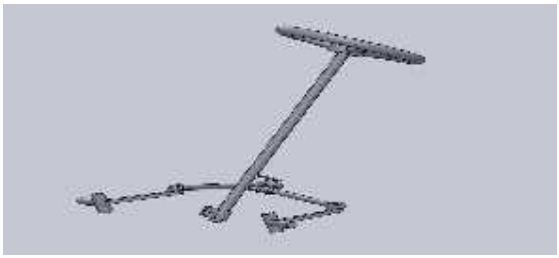


Fig.No.9. Steering System

15. BRAKING SYSTEM:

An excellent braking system is the most important safety feature of any land vehicle. Competition regulations require pure mechanical braking systems, so we selecting the disc brake system. The main requirement of the vehicle's braking system is that it must be capable of locking all four wheels on a track.

Ease of manufacturability, performance and simplicity are a few important criteria considered for the selection of the braking system.

15.1. DESIGN METHODOLOGY:

- List design criteria and requirements.
- Calculate tyre forces in static conditions.
- Assign maximum deceleration of vehicle.
- Calculate target stopping distance and target braking force.
- Select optimum brake parts which in combination help achieve target.

Optimize brake design.

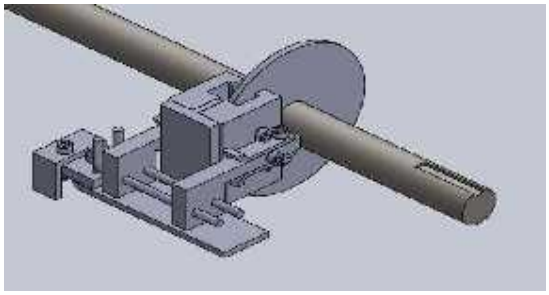


Fig.No.10. Brake Design

15.2. CALCULATION OF TARGET PERFORMANCE:

Maximum deceleration = 1.32 kg.

Total weight of the vehicle = 175 kg. Maximum velocity of the vehicle = 16.67m/s. Tangent braking force = deceleration*total mass

= 12.98*17.

= 2271.5N.

Target stopping distance = max velocity * /(2*maximum deceleration)

=10.94m.

15.3. CALCULATION OF STOPPING DISTANCE WITH SELECTED COMPONENTS:

Declaration = force/mass

= 2271.7914/17.5
=12.98 m/s.

Stopping distance = (max velocity)^2 / (2*deceleration).
=16.67^2/ (2*12.98)
=10.74m.

Since this system meets the target performance, we go ahead with the design.

16. MOTOR:

Motor is the heart of our vehicle. it is the drive unit. Motor is fixed rigidly with the help of motor bed with the frame. Smaller sprocket is connected with the motor shaft and power to the vehicle is given by the motor using chain drive..

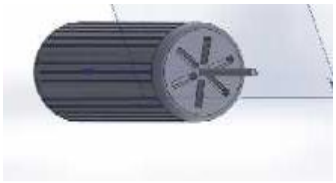


Fig.No.11.Motor Design

Specification:

Model	**:** series
Power	**:** 1hp
Max speed	**:** 1440 rpm
Initial torque	**:** 12.8 Nm
Required voltage	**:** 24V
Required current	**:** 42 Ah

17. Batteries:

Battery is the power source to our vehicle. Battery delivery the needed current to the motor .we chooses our battery in the manner of safety, long lasting, supply rated current. Our battery is shield. Type battery and acid will never leaks at any accident.

Specification:

Nominal Voltage: 12V
Rated Capacity **:** 42Ah
Dimension:
Height **:** 175mm
Length **:** 199mm
Width **:** 167mm
Weight **:** 20Kg

18. Break Light:

Break light is used to indicate that the vehicle is slowing down, and its also alerts the back coming vehicle to determine that vehicle is going to stop this is indicated by red light it is present in the back side of the vehicle.

Fig.No12..Light

19. Head Lamp:

It is used to show the road track visibly and helps the focus the road clearly during dim light condition. It is located in the front portion of the kart.

20. INDICATOR LIGHT:

It is used to indicate the direction of the vehicle in which it is going to turn this is indicating in light yellow colour.

21. Wire:

All the electrical circuits are connected through wires, wires which are mainly made up copper and it also helps in indicating signals, forward and backward motion of the kart.

FIG.13

22. Kill switch:

The kart is equipped with a kill switch, which is capable of cutting down all electrical circuits including the power coming from the battery to the motor

23. TYRES AND RIMS:

TYRES:

Keeping in mind all the above mentioned aspects we studied about the various types of tires available in market. After enough market research and guidance from our faculty advisor we have decided to use tubeless tires and that have got specific tread pattern so as to provide a very strong and firm grip on all kinds of surfaces as well as sturdy enough to absorb various bumps and depressions on track. After going through the motor, transmission and some basic torque and angular velocity calculations we have finalized the diameter of tires to 13 inches which would help us to transmit maximum power. This calculation is also in accord with the requirements of Acceleration, Hill climb, Manoeuvrability and Endurance events. The dimension of front tires may be 13x 4.5 inches where diameter is 13 inches and width is 4.5 inches. The dimension of front tires may be 13 x 4.5 inches where diameter is 13 inches and width is 4.5 inches. (These are normal go kart tires.)

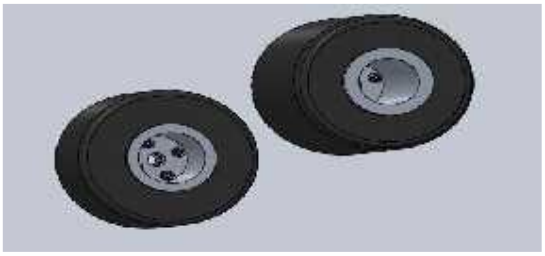


Fig.No.14. Types

24. RIMS:

The Rims shall be made up of Aluminium to minimize unsprings weight. By reducing the width of the rim the inertia will be directly decreased and subsequently this will also reduce the overall weight. The diameter of all four rims will be 10 inches. Thicknesses are respective tire sizes.

25. FIRE EXTINGUISHER:

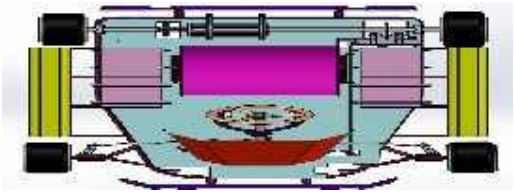
A multipurpose ABC type fire extinguisher equipped with co2 gas is fitted in the vehicle which can be used to put off fire due to fire accidents.

Fig.15. Fire Extinguisher

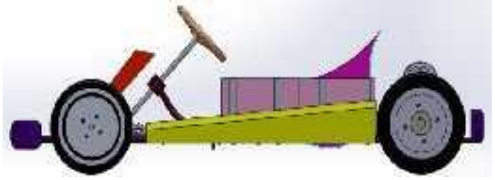
26. CHAIN DRIVE:

The chain drive is intermediate between the belt and gear driven. It has the major advantages of gear drives. Chain drives are popularly used in the automobile vehicles. We are using transmission chain and sprockets. It is also called as roller chains. A roller chains provides a readily available and efficient method for transmitting power between parallel shafts. They can be used for long as well as short Centre distance. They are more compact than the gear drives. There is no slip between chain and sprocket. So they provide positive drive. Chain drive can be operated under adverse temperature and atmospheric condition. In gear drive the manufacturing and maintenance costs are comparatively high. When compared to gear drive weight of the chain is very less. So we are using chain drive in our eco kart.

27. DESIGN VIEWS:

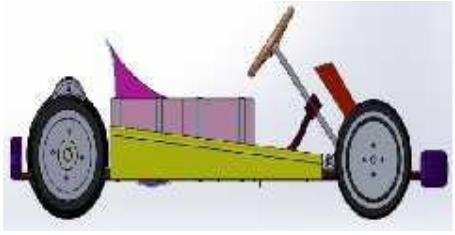


TOP VIEW

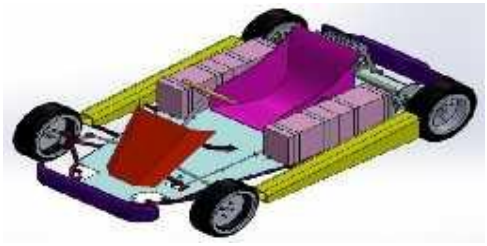


RIGHT SIDE VIEW

FRONT SIDE VIEW



LEFT SIDE VIEW



3D CAD MODEL

Fig.No.16. 3-D View

28. CONCLUSION:

Our Eco-kart which is designed and analysed will be less weight, more strength, highly efficient, Eco-friendly, comfortable, low maintenance, high speed and torque. This project aims at the development of Eco vehicles. This study comes up with the development of Eco vehicles. A literature review is provided in the following chapters in order to present the research undertaken on this topic to date, and demonstrate what further research is required on this issue

28.1. FUTURE SCOPE:

This design should be developed more to make the Eco vehicles more efficient and to manufacture this design highly efficient and feasible manner. This eco vehicle should be designed as a hybrid Eco vehicle in future developments.

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