Design of Powertrain System of an E-Kart

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Abstract — In today's automotive landscape, major vehicle manufacturers are placing significant emphasis on developing and incorporating electric vehicles (EV's) into their product portfolios, and the reasons are abundantly clear. Amidst the pressing global issue of climate change, exacerbated by the widespread concern over air pollution, the automotive industry is at a critical juncture. Traditional combustion engines, notorious for emitting harmful exhaust gases, contribute significantly to air pollution, further exacerbating the problem of global warming. The proliferation of vehicles worldwide only exacerbates this issue, necessitating a shift towards more sustainable transportation solutions. The transition to electric vehicles represents a pivotal step in combating pollution and mitigating the effects of global warming. Unlike their combustion engine counterparts, EVs produce zero exhaust emissions and boast greater operational efficiency. Furthermore, the electric motors powering these vehicles possess the capability to regenerate energy through mechanisms such as back electromotive force (E.M.F), enhancing overall efficiency and reducing environmental impact. While it's true that electric vehicles may not currently match the range offered by traditional combustion engines, the trade-off is negligible when considering the broader environmental benefits. Moreover, ongoing advancements in mechanical and automotive engineering promise continued improvement in EV technology, offering a glimpse of a more sustainable future.

Keywords: Electric Vehicles (EV's), EV Technology, E-Kart

I. INTRODUCTION

Originating in the United States during the 1950s, Go-Karting emerged with engines repurposed from discarded lawn equipment. This sport involves driving and racing miniature, skeletal frame, rear-drive vehicles known as karts around scaled-down or professional motorsports circuits. With no suspension, the chassis must strike a balance, being flexible enough to function as a makeshift suspension and rigid enough to withstand turns without braking.

Widely embraced as a recreational activity globally, go-karting serves as a stepping stone to higher echelons of motorsports, including Formula One Racing and Endurance Racing. Renowned Formula One champions such as Lewis Hamilton, Sebastian Vettel, and Michael Schumacher trace their roots back to their exceptional skills honed in kart racing. Traditionally powered by combustion engines running on petrol or diesel, these karts can attain speeds of up to 100 km/h, contingent upon the power unit's make and model. Go-kart chassis are meticulously crafted using Chromoly steel tubes for optimal strength and performance.

Fig. 1: Traditional Go-Kart

A. *Objectives*

Selection of Appropriate Motor with proper specifications
Selection of Appropriate Battery considering various parameters

B. *Project Methodology*

The methodology to achieve each objective is as follows:

- Objective 1: Various types of Battery and Motor Comparison will be done and a suitable motor giving the required and the optimum output.
- Objective 2: Battery will also be selected according to its various parameters and also keeping in mind its energy output and cost.

II. LITERATURE REVIEW

Sr. No.	Title of the paper	Findings/Methodolgy used
1.	"Comparison of Different Battery types for Electric Vehicles" by C Iclodean, B Varga, N Burnete, D Cimerdean, B Jurchis Publisher: Institute of Physics (IOP).	Various types of Battery packs are discussed in this paper. This paper discusses the advantages and disadvantages that each type of battery packs shows They are also compared n terms of energy consumption and energy storage capacity.
2.	"Selection of Battery pack Parameters for an electric vehicle based on	This paper discusses the issues of batteries selection for electric vehicle, taking into account many operation criteria.

	performance" by "M Koniac, A Czerepicki". Publisher: Institute of Physics (IOP).	Selection of a battery for an electrically powered vehicle requires detailed analysis of many factors, such as: weight and volume, charging currents, route characteristics, depth of discharge, operating temperatures related to seasons of the year in the given area, potential integration of conditioning and heating.
3.	"An overview of Electric Vehicle concept and Power management strategies" by "Dr. Chokri Mahmoudi, Dr. Aymen Flah, Dr Lassaad Sbita" Publisher: Institute of Electrical and Electronics Engineers (IEEE).	This paper emphasizes on the types of Electric Vehicles that have been developed till now all over the world and also discusses its Advantages and disadvantages
4.	"Recent Development on Electric Vehicles" by "K.W.E Cheng" Publisher: International Conference on Power Electronics Systems and Applications	This paper discusses the recent development in electric vehicle. The paper first describes general structure and discusses the energy storage. It then extends to the future vehicle components. The paper provides an overview of the recent EV developments. This paper also discusses the various types of motors that can be used for power transmission in an EV.
5.	"Motor Torque Calculations For Electric Vehicle" by Saurabh Chauhan Publisher: International Journal of Scientific and Technology Research	This paper presents the various calculations that are required to find the Final Motor Torque which will be transmitted to the drive shaft. The paper shows that the motor torque for an electric vehicle can be determined if some parameters of the vehicle like required grade ability and acceleration are known. Further, if the required torque calculated is not produced by the available motor specifications then modifications can be made in vehicle parameters like Gross Vehicle Weight, Wheels size, Material of the wheels and transmission system
6.	"Regenerative Braking System" by "A. Sai Krishna Rama Chander Raju, Bh. Sri Surya Vamsi Raju, Ch.Dharanesh, Y. Anil Reddy, Venkata Phanibabu.V" Publisher: International Journal & Magazine of Engineering, Technology, Management & Research	• This paper discusses the basics of Regenerative braking system. • The types of Regenerative braking system are also discussed i.e., Electrical Regenerative System and Hydraulic Regenerative System. • The use of Hydraulic Regenerative System is more feasible in this project keeping in mind the brake system to be designed. • Also the basic components to be used in the System are also discussed in this paper

III. Selection of Battery and Motor

A. *Selection of Battery*

Battery Selection is an integral part of this project. The Battery which is to be selected should provide maximum performance for minimum losses. In our case, the important parameters that we needed to compare to select our battery are Cost and Specific Energy.

The three batteries we have compared are Nickel Cadmium (Ni-Cd), Lithium-Ion & Lead Acid Battery. On Comparing, we tabulated the following results:

Type of Battery	Specific Energy (W.h/kg)	Specific Power (W/kg)	Energy Density (W.h/L)	Cost
Nickel-Cadmium	40-60	150	50-150	Low
Lithium-Ion	100-265	250-340	250-693	High
Lead-Acid	35-40	180	80-90	Low

Table 1: Comparison of Various Batteries

Fig. 2: Li-Ion Battery

Based on the above results, we have inferred that Lithium-Ion Battery is the best choice for our project considering its energy Parameters. Despite High Costs it provides us with Good performance and power to be used as an input to motor.

B. Selection of Motor

An Electric motor is the major driving unit in an electric vehicle. Choosing the right type of motor is a very important parameter in the design process of an Electric Vehicle.
The Motors used mainly in Electric Vehicles are:-

- DC Series Motor
- Brushless DC Motor
- Permanent Magnet Synchronous Motor (PMSM)
- Three Phase AC Induction Motors
- Switched Reluctance Motors (SRM).

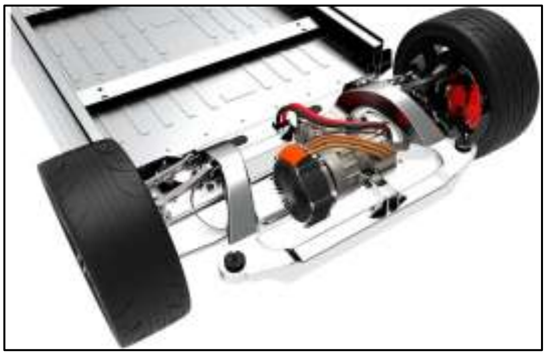

Fig. 3: Motor in an Electric Vehicle

For this project, we have done a comparative study on all these motors and have tabulated their results. The table is graded on a point grading system of 1 to 5 of which 1 is the worst and 5 is the best. The comparison is done based on major parameters such as Power Density, Efficiency, Controllability etc.

Features	DC Motor	Induction Motor	Switched Reluctance Motor	Permanent Magnet Synchronous Motor	Brushless DC Motor
Power Density	2	3	3.5	5	5
Efficiency	2	3	3.5	5	5
Controllability	5	4	3	4	4
Reliability	3	5	5	4	4
Cost	4	5	4	3	3
Noise Level	3	5	2	5	5
Maintenance	1	5	5	5	5

Table 2: Comparison of Various Motors

From the above table, we have realized that Brushless DC Motors, PMS Motors and Induction Motors are the best choices for use in an EV. But, Induction Motors and PMS Motors are not that efficient in Low-load applications which are present in our project. Therefore, we have selected Brushless DC Motors for our kart. It also has very high-power density and efficiency and very good control over speed and torque.

C. Motor Torque Calculations

We have selected BLDC as our choice of motor for our project. Therefore, we need to numerically analyse what kinds of load the motor will be subjected to. Motor torque calculations are done to compute exactly how much torque will be required to launch the kart from rest into motion. The starting torque of any vehicle is the maximum torque that the vehicle requires in its whole cycle. Therefore, the motor that we will select will be based on the torque that is to be calculated in this section

There are two for calculating the final torque on the drive shaft. In one case, we have considered the Air Resistance and, in another case, we have not considered the Air Resistance. But in real world applications, air resistance always needs to be considered.

Consider,
C= Rolling resistance coefficient = 0.025 (tire on asphalt)
A_f= Frontal Resisting Area
ϱ= Density of Air = 1.225 kg/m3
C_d= Drag Coefficient = 0.25
V = Velocity of Vehicle = 55 km/h =15. m/s
Consider Vehicle mass to be 170kg

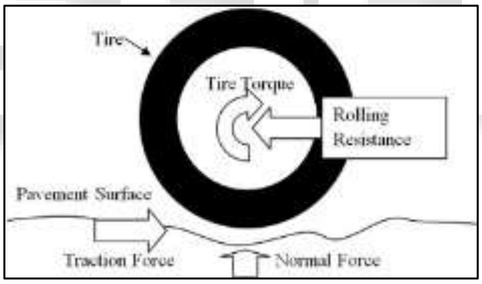

Fig. 4: Resistance on tyre

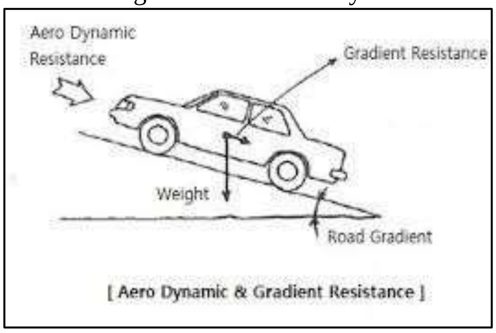

Fig. 5: Aerodynamic & Gradient Resistance

First, we calculate the rolling resistance that is faced by the body

$$\text{Rolling Resistance } (F_R) = m \times g \times C \quad (3.1)$$
$$= 170 \times 9.81 \times 0.025$$
$$= 41.692 \text{ N}$$

Now, Considering Frontal Area of Kart as $0.92m^2$
Thus, Air resistance becomes,

$$\text{Air Resistance} = 1/2 \times \varrho \times A_f \times C_d \times (V)^2 \quad (3.3)$$
$$= 1/2 \times 1.225 \times 0.92 \times 0.25 \times (18.05)^2$$
$$= 45.89 \text{ N}$$

Now, we calculate Gradient Resistance considering a road gradient of 5 degree

$$\text{Gradient Resistance} = W \times \sin \Phi \quad (3.4)$$
$$= 170 \times 9.81 \times \sin (5)$$
$$= 145.34 \text{ N}$$

Now we calculate Acceleration force,
For this we consider the Acceleration of our kart as 0.85 m/s^2

$$F_A = m \times a \quad (3.5)$$
$$= 170 \times (0.85 \text{ m/s}^2)$$
$$= 144.5 \text{ N.}$$

Now, we calculate Total Resistance that is acting against the kart and restricting it from coming into motion.

$$\text{Total Resistance} = \text{Air Res.} + \text{Gradient Res.} + \text{Rolling Res.} + \text{Acceleration force.} \quad (3.6)$$
$$= 45.89 + 41.69 + 145.34 + 144.5$$
$$= 377.42 \text{ N}$$

Now, we calculate the minimum Torque required at the Rear wheels to overcome the Total Resistance against the kart.

$$T_w = \text{Total Resistance} \times R_w \quad (3.7)$$

where, R_w = Radius of the wheels= 0.1397 m

$$T_w = 377.42 \times 0.1397$$
$$= 52.725 \text{ N-m}$$

Now, we calculate the maximum Torque required by the motor (T_m) to bring the kart into motion.
Considering, Gear ratio = 3.07:1, Efficiency = 80 %

$$T_m = (T_w \times \text{Efficiency}) \quad (3.8)$$
$$= (52.6154 \times 0.8)$$
$$= 42.18 \text{ N-m}$$
$$T_m = T_w/\text{Gear Ratio} \quad (3.9)$$
$$= 42.18/3.07$$
$$T_m = 13.73 \text{ N-m}$$

Thus, The Minimum Motor torque required with considering air resistance is 13.73 N-m

D. Motor Power

To compute the power delivered by the motor at various speeds, we entered the values of Aerodynamic Resistance, Rolling Resistance, Gradient resistance, Acceleration Force into an Excel sheet and tabulated the following results.

GEAR RATIO 3.07

Time (s)	Speed (kmph) cut off to 65kmph	Acceleration (m/s^2)	Aero Force (N)	Rolling Resist (N)	Grade Force (N)	Accel Force (N)	Total Force (N)	Power Required by vehicle (W)	Torque at wheel (Nm)	Torque at motor (Nm)	RPM of motor
0	0.0	0.00	0	41.6925	58	0	99.8649	0	13.9511261	0	0.00
1	0.0	0.00	0	41.6925	58.1724	0	99.8649	0	13.9511261	0	0.00
2	0.0	0.00	0	41.6925	58.1724	0	99.8649	0	13.9511261	3.832727	0.00
3	0.0	0.00	0	41.6925	58.1724	0	99.8649	0	13.9511261	3.832727	0.00
4	0.0	0.00	0	41.6925	58.1724	0	99.8649	0	13.9511261	3.832727	0.00
5	0.0	0.00	0	41.6925	58.1724	0	99.8649	0	13.9511261	3.832727	0.00
6	0.0	0.00	0	41.6925	58.1724	0	99.8649	0	13.9511261	3.832727	0.00
7	0.0	0.00	0	41.6925	58.1724	0	99.8649	0	13.9511261	3.832727	0.00
8	0.0	0.00	0	41.6925	58.1724	0	99.8649	0	13.9511261	3.832727	0.00
9	0.0	0.00	0	41.6925	58.1724	0	99.8649	0	13.9511261	3.832727	0.00
10	0.0	0.00	0	41.6925	58.1724	0	99.8649	0	13.9511261	3.832727	0.00
11	0.0	0.00	0	41.6925	58.1724	0	99.8649	0	13.9511261	3.832727	0.00
12	3.8	1.06	0.147741	41.6925	58.1724	178.2851	278.2978	291.2847026	38.8781094	10.60082	261.07
13	7.6	1.06	0.295481	41.6925	58.1724	178.2851	278.4455	584.031737	38.8988387	10.60649	522.15
14	11.3	1.06	0.443222	41.6925	58.1724	178.2851	278.5933	876.512429	38.9194781	10.69216	783.22
15	15.1	1.05	0.590961	41.6925	58.1724	178.2851	278.741	1169.505	38.9401175	10.69785	1044.29
16	15.1	0.00	0.590961	41.6925	58.1724	0	100.4559	421.40675	14.0336836	3.855408	1044.29
17	15.1	0.00	0.590961	41.6925	58.1724	0	100.4559	421.40675	14.0336836	3.855408	1044.29
18	15.1	0.00	0.590961	41.6925	58.1724	0	100.4559	421.40675	14.0336836	3.855408	1044.29
19	15.1	0.00	0.590961	41.6925	58.1724	0	100.4559	421.40675	14.0336836	3.855408	1044.29
20	15.1	0.00	0.590961	41.6925	58.1724	0	100.4559	421.40675	14.0336836	3.855408	1044.29
21	15.1	0.00	0.590961	41.6925	58.1724	0	100.4559	421.40675	14.0336836	3.855408	1044.29
22	15.1	0.00	0.590961	41.6925	58.1724	0	100.4559	421.40675	14.0336836	3.855408	1044.29
23	15.1	0.00	0.590961	41.6925	58.1724	0	100.4559	421.40675	14.0336836	3.855408	1044.29
24	12.8	-0.70	0.492304	41.6925	58.1724	-118.585	-18.6262	-66.099385	-2.60208114	-0.71486	870.06
25	10.1	-0.70	0.393708	41.6925	58.1724	-118.585	-18.7248	-52.338445	-2.615858	-0.71864	695.82
26	6.7	-0.93	0.26251	41.6925	58.1724	-158.391	-58.2838	-108.37027	-8.13940242	-2.23611	465.88
27	3.4	-0.93	0.131256	41.6925	58.1724	-158.391	-58.3951	-54.407427	-8.15778875	-2.24125	231.94
28	0.0	-0.93	0	41.6925	58.1724	-158.391	-58.5260	0	-8.17612508	-2.24629	0.00

Table 3: Tabulation of Motor Parameters in Excel

As per motor torque calculations, we have selected torque of motor as 14 N-m. We have calculated motor power by considering gear ratio 3.07:1. In the following excel sheet we have formulated a table in which we get Torque required by motor, Torque at wheels, Motor power, Motor RPM at every instance of speed. We have calculated for every instance till 60 km/hr with an increment of 1km/hr. We have then obtained the following Graphical results from the above tabulation.

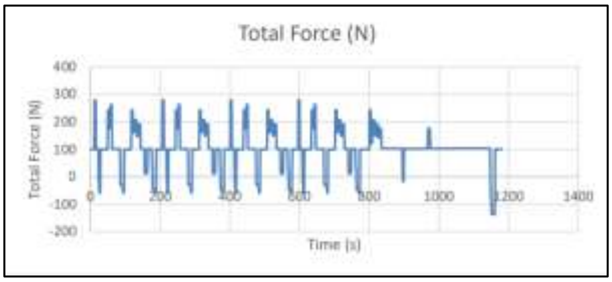

Fig 6.Total Force vs Time

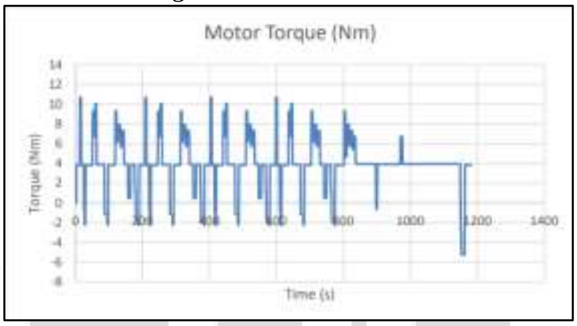

Fig 7. Motor Torque vs Time

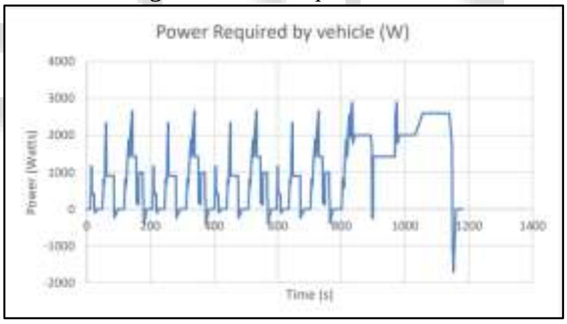

Fig. 8 Power vs Time

From these graphs, we evaluated the maximum Motor Power as 3.9kW at Maximum RPM i.e., 3000RPM.

Hence, we have selected a motor having the following parameters

- Max. Output Torque = 14 N-m
- Max. Output Power = 4kW
- Max. RPM= 3000 RPM

The following motor is easily available and within selection parameters.

E. Battery Pack Parameters

In this section, we will calculate the required Capacity of the battery i.e. the A-h rating of the battery.

For the following calculations, we require the following parameters which we have calculated in the previous section.

Consider, Motor Output Power- 4kW
Max. RPM of motor- 3000 RPM
Max. Speed of motor- 65km/h = 18.05m/s

Also, we have considered the battery to be of 48V

The electricity consumed by electric vehicle to travel a distance of 1 km is given by,

Wh/km = 4000/65

= 61.538 W-h/km

To get the A-h/km rating of the battery, we divide the above value by Voltage

A-h/km = 61.538/48

=1.2820 A-h/km

Considering a range of 100km per charge for our kart

Also, Peukerts rating for Li-Ion Battery = 1.04

Taking Efficiency (η) of battery as 80%

$$\text{A-h rating} = \text{A-h/km rating} \times \text{Peukerts rating} \times \eta \times \text{Range} \quad (3.10)$$

$$= 1.2820 \times 1.04 \times 0.8 \times 100$$

A-h rating = 106.6624 A-h

Therefore, according to the above calculations, a battery of 110 A-h capacity can be selected

IV. CONCLUSION

The following conclusion is drawn from our Paper:

- Selection of Battery is completed
- Selection of Motor is completed
- Motor Torque Calculations are computed.
- Motor Power is calculated
- Battery Pack parameters are formulated

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