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Research Article

Design of the Personal Electrics Vehicle

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Abstract

In this study, three wheels personal electric vehicle system has been conducted with two 250-Watt reduction gear dc motors. The vehicle can move front, back, left, and right sides according to the rider's directions. The directions which speed and turning movement have been provided with 2 different potentiometers to the vehicle. To understand the carrying capacity of the system mechanical analysis has been realized with Catia Computer-Aided Drawing Software. This analysis was conducted with different two types of load (1,5 and 5kgN) on the two different structures that are with Z ax-is support bar and without. The best result was gotten from without a Z-axis support bar because it was sufficient to carry till 150 kg load.

Keywords: Electrics Vehicle, Personal Transporter, Speed Control, Turning Movements.

Kişisel Elektrikli Araç Tasarımı

Öz

Bu çalışmada, iki adet 250-Watt redüktörlü DC motor ile üç tekerlekli kişisel elektrikli araç sistemi gerçekleştirilmiştir. Araç, sürücünün yönlendirmesine göre öne, arkaya, sola ve sağa hareket edebilmektedir. Araca hız ve dönüş hareket bilgisi iki farklı potansiyometre ile sağlanmıştır. Catia Bilgisayar Destekli Çizim Yazılımı ile sistemin taşıma kapasitesini anlamak için mekanik analiz gerçekleştirilmiştir. Bu analiz, Z ekseni üzerindeki destek çubuğu olan ve olmayan iki farklı yapı üzerinde farklı iki tip yük (1,5 ve 5kgN) ile gerçekleştirilmiştir. En iyi sonuç, 150 kg yüke kadar taşımak yeterli olacağından Z ekseni destek çubuğu olmadan elde edilmiştir.

Anahtar Kelimeler: Elektrikli Araç, Kişisel Taşıyıcı, Hız Kontrolü, Dönüş Hareketleri.

1. Introduction

Increasing of air pollution, consumption of natural source day by day causes researchers to search and design personal transporter which works with other energy source. Electricity is a good preference due to reducing dependence on fossil fuels, CO2 emission, and pollutants. According to "IEA's Sustaina-ble Development Scenario" global greenhouse emissions from transport is shown in Fig.1. In the future, for the name of avoiding environmental disasters, sales of electric vehicles were realized exceeding 2.1 million globally in 2019 and this rate is increasing every year. (1). Although, personal transport-ers take up a small space at this rate usage of it does not dam-age nature, working, and maintenance expenses are lower when it is compared to traditional ones. However, Fuel as elec-tric in transporters idea is not a new one. This thought has been considered many times. Production cost of battery, durable of the battery and life-time performance criteria are main prob-lems of such transporters. Improvement of engineering in cur-rent decades permits to solve these problems.

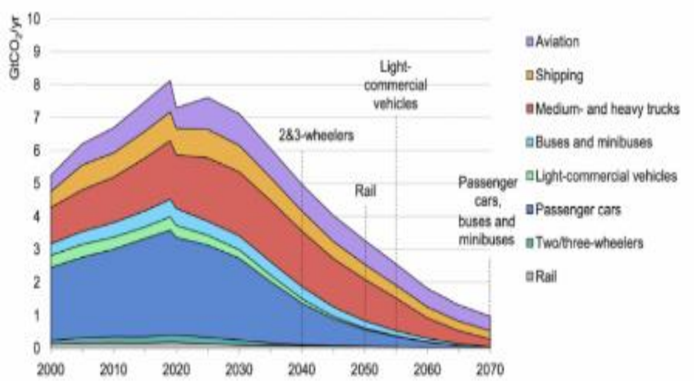

Fig. 1. Global CO2 emissions from transport(2)

In the light of these improvements, there are many studies that were realized in the literature about the personal electric vehicle (PEV) transports systems. Hyunjune Yim and Keun Lee conducted a study about per-sonal vehicles and they realized a modular personal electric vehicle. Their design and manufacture were related to the common midportion of the platform. It was appropriate for vehicles which have two front wheels or have two rear wheels. It is one of the primitive designs of modular vehicles (3). Although, thougt of the moduler platform has been used in the automotive sectors (4-5). Hongwu Wang et al. Developed a robotic wheelchair for re-search purposes and climbing stairs. The specification of this system are weighs 90,72 kg and has a max. Speed of 6 miles per hour. Also, it has provided users with high mobility perfor-mance for personal transport (6). Shuro Nakajima developed a personal mobility vehicle that has four wheels and avoids obstacles with a leg motion mech-anism feature (7). In addition, he developed another personal vehicle for usage in daily life (8). Investigation of electric vehicle usage in urban land was conducted by Amelie Ewert et al. Their findings show that 30% of personal private trips could be done with light electric vehicles (LEVs) (9).

In this study, personal electrics vehicle was conducted and it includes two independent electric motors and their drivers, a control card, a steering wheel, batteries, and two pneumatic tires. In addition, its mechanical analysis was realized to confirm durability in computer-aided 3D solid modeling and de-sign software.

2. System Overview and Modeling

2.1. Personal Electrical Transport Vehicle (PETV) Structure

Our study' design and development methodology are given in Fig.2. After the selected conceptual design depends on the lit-erature studies, has been determined required components. Then, the selected model has been fabricated, end of this was realized assembly of the vehicle. Besides this, in the fabrica-tion time, mechanical structure analysis in the 3D computer-aided drawing software program has done, too. There are three wheels of our personal vehicle. One of the wheels is used to balance the system. There is no connection with the motor. The others have two coaxial wheels driven independently by two motor. Speed of the vehicle could be adjusted by the rider with a potentiometer. The left and right movement of the sys-tem is provided with the help of another potentiometer that is taking place on the handlebar of the vehicle. The personal electrical transport vehicle' structure is shown in Fig3.

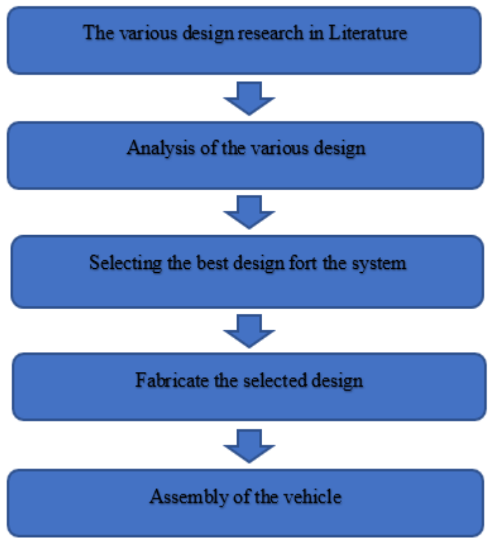

Fig. 2. Methodology

Fig.3. Personal electrical transport vehicle

2.2. Personal Transport Vehicle (PTV) Dynamics Model

To better understand dynamics behavior of the vehicle was used longitudinal and rotational directions equation of the single wheel as follows:

The longitudinal directions equation;

$$M\dot{v} = \sum F_{Xi} \tag{1}$$

The rotation dynamic equation;

$$J_w \dot{\omega}_i = T_{mi} - T_{hi} - rF_{Xi} \tag{2}$$

For each wheel rotational dynamics model is shown in Fig 3. The wheel slip ratio is introduced as the relative difference between the angular velocity of the wheel and the vehicle velocity (10).

$$\lambda_i = \frac{r\omega_i - v}{v} \text{ x } 100\% \tag{3}$$

During braking; $\lambda_x = \frac{r\omega_i - v}{v}$ (4)

During acceleration; $\lambda_x = \frac{r\omega_i - v}{r\omega_i}$ (5)

The tire longitudinal force F_{Xi} is dependent on F_{Zi} and λ_i (11). Dug off model is used in this study and it could be described as $F_{Xi} = f\ (F_{Zi}, \lambda_i)$. From it slip dynamics equation of the wheel can be extracted as (12);

$$\dot{\lambda}_i = -\frac{r^2}{vJ_w} f(F_{zi,}\lambda_i) + \frac{r}{vJ_w} T_{hi} - \frac{r}{vJ_w} T_{mi} \tag{6}$$

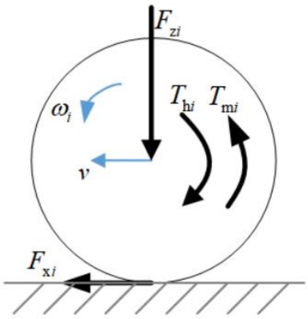

Fig. 3. Single wheel rotational model

Fig. 4. shows the typical relation curve between slip ratio (λi) and driving force (Fxi) (11).

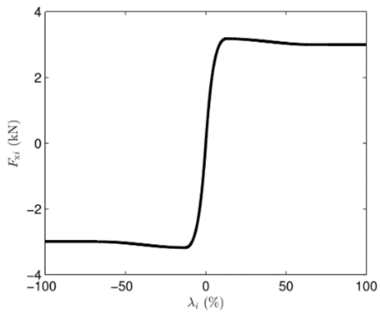

Fig.4. Relation curve: slip ratio (λi) -driving force (Fxi)

3. System Overview and Modeling

The personal electrical transport vehicle consists of following parts; arduino uno board, two with reduction gear dc motor and motor's drivers, accelerator and turning potentiometers. For our vehicle control system framework Free Body Diagram (FBD) are shown in Fig.6, 7. The working principle of our system based on the directions given by riders. Because system' speed and turning movement provided by two different potentiometers. Both of them have been worked similar idea. First of all, sensors provide input data for the system. Then, the controller converts the signal comes from sensors from Analog to Digital, and a control algorithm was worked to control the vehicle speed and directions.

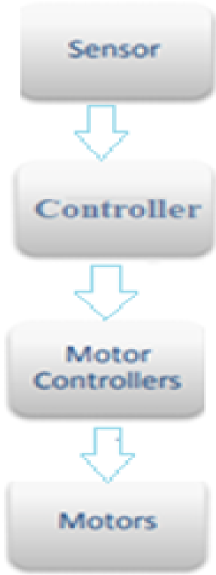

Fig. 6. Control System framework

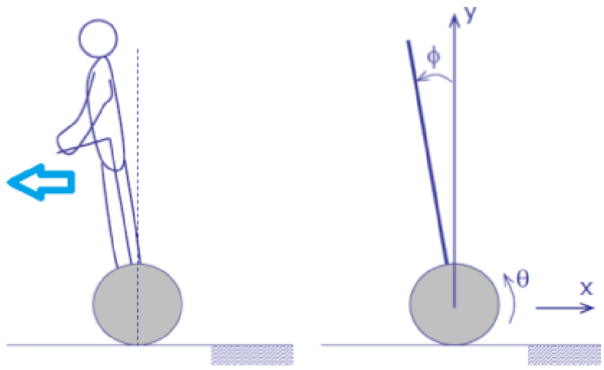

Fig. 7. Free body diagram of the vehicle

Flow chart of the system is shown in Fig.8. The speed of the system is given as m/s because of required conversion was done before depending on ADC. The Arduino has 10-bit ana-log reading resolution so input signal data vary from between 0 and 1023. Its writing resolution value is 8-bit so output signal data could be max 255. The reason of start the vehicle lower speed than 2m/s is the security of the rider.

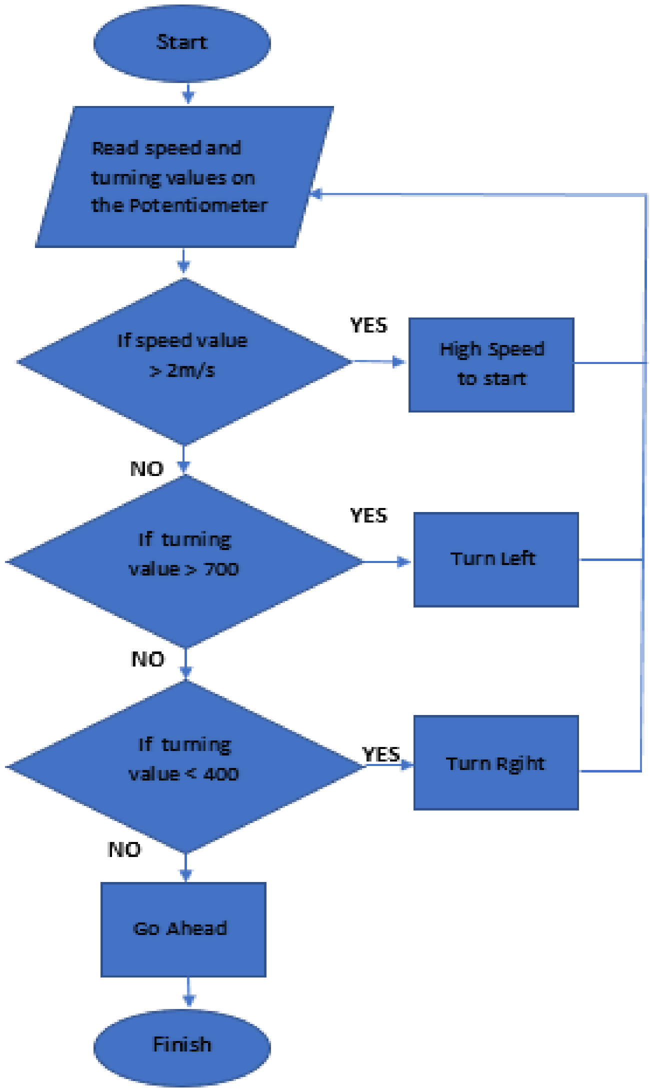

Fig. 8. Flow chart of the system

4. Results and Discussion

Analysis studies were done in Catia Computer Aided Draw-ing Software. Structure was analyzed with applying 5kN force firstly and some parameters are changed due to analysis re-sults to strength structure. 30 x 30 mm. aluminum box profile without using any middle support along Z axis. Deflection is as much as to be paid attention under 5kN. After added support at the middle of the structure along Z axis, deflection and stresses decreased but still there is noticeable deformation on material. 30 x 30 mm aluminum box profiles which are lying on X axis may be changed with 50 x 30 mm aluminum box profiles and observe results of analysis. Depending on previous analysis, horizontal profiles were changed to 50 x 30 mm alu-minum profiles to increase strength of the chassis. This is best result of the analysis results under 1.5kN which is possible force is applied by driver's mass. As you see from the analysis; there is no critic field in the range of human weights. Therefore, system is safe for transportation. 30 x 30 mm aluminum box profile without using any middle support along Z axis. There is no Z axis support bar in Fig. 9. a and b. However, Z axis sup-port exist in Fig. 9. c and d.

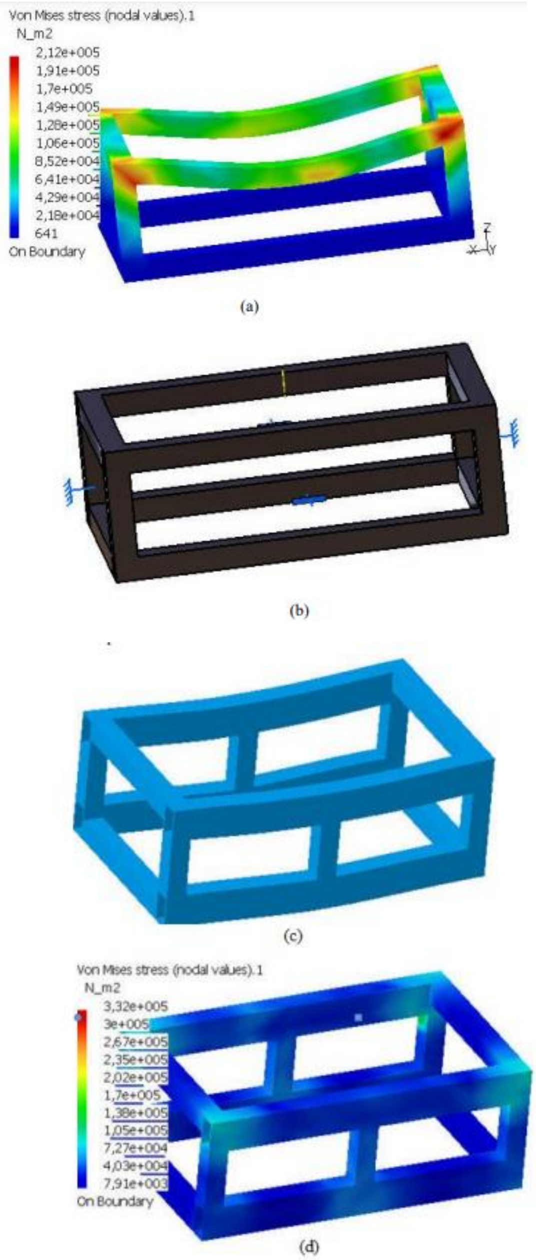

Fig. 9. a) without Z axis support bar under the load, b) without Z axis support bar when non-load, c) with Z axis support bar under the load, d) with Z axis support bar when non-load

The plate on which riders set foot is given in the Fig.10. The plate could carry approximately 500kg. load.

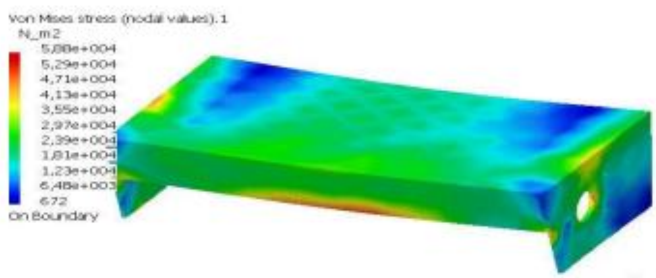

Fig.10. The plate on which riders set foot

5. Conclusions

In this study, to be able to understand riders' direction and speed response, three wheels personal transporter electric vehi-cle system has been developed as physical. The system can move front, back, left, and right sides according to the rider's directions. Another aim of this study is to show potential benefits to consumers and to society including lower transportation costs, reduced trip times, and lower environmental impact, too. The Personal Electrical Vehicles, therefore, offer many intriguing possibilities for extending the human range of mobility.

Nomenclature

M	: mass of the system (kg)
v	: velocity of the system (m/s)
$\dot{v}$	: derivative of the speed (m/s^2)
ω_i	: Angular velocity of the wheel (rad/s)
F_{Xi}	: tire longitudinal force (N)
F_{Zi}	: tire horizontal force (N)
λ_i	: wheel slip ratio
J	: wheel rotational inertia (kg. m^2)
T	: brake torque applied to the wheel (Nm)

Conflict of Interest Statement

The authors must declare that there is no conflict of interest in the study.

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