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Design and Fabrication of a Pilot Scale Remote Controlled Electric Car Using Additive Manufacturing Approach

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ABSTRACT

The study employed an additive manufacturing approach to model the parts of a pilot-scale electric car. A 3D Sketchup tool was used to model the parts of the model electric automobile and was printed using Any cubic i3 Mega 3D printer. A robust design analysis was carried out to determine the necessary parameters required for the motion and stability of the automobile. These include friction, thrusts and aerodynamic forces as well as the power required. The 3D printed parts were then assembled using powerful adhesives. The rechargeable battery-powered car was integrated with a "C" programming language with the aid of ATMEGA 328P-PUmicrocontroller. The results of the performance assessment of the automobile show that the car travelled at the rate of 1 m/s under the monitoring signal receiving a range of 3 m as observed from the infrared remote control. The results obtained from the design calculation indicated that a 3.975 Nm magnitude of torque is required to drive the shaft. Thus, it was possible to achieve an optimal performance since a motor of 10.787 Nm torque specification was used. The study demonstrates the feasibility of indigenous development of emerging autonomous electric cars at a lower cost.

Keyword: 3-D Printing, Fueless Car, Design, Prototyping, Car automation

1. INTRODUCTION

Electric vehicle manufacturing industries are faced with problems of cost optimisation due to high automation and efficiency demands[1]. The methods and processes of developing the individual components contribute to the resultant overall performance and production cost of the automobile [2 – 3]. Matta et al. [4], reported that the approach of automobile part production indicates the potential performance of the components. However, the cost of achieving high automation in the automotive industries is very challenging [5]. Three-dimensional modelling (3D) is recognised as an additive manufacturing technique which involves the use of the cutting-edge technology in prototyping and also in product development in the manufacturing sector [6 - 9]. It can also be integrated with different software to model the flow behaviour of molten metal during the casting of automobile components. This has contributed significantly into the mechanical performance and growth of the automobile industry [10 – 11]. The 3D modelling has been employed in ensuring the safety of the automobiles using the design of the body shape [12]. This was made possible because of its ability to integrate extensive materials of different physical, chemical and thermos-mechanical properties [13- 15]. Despite the benefits as mentioned earlier of 3D modelling, standard methodology for adoption and fabrication of automobile components is one area lacking attention.

Different parts of the automobile are susceptible to deformations via drags, vibrations, frictions, amongst other forces involved, depending on the built and purpose of the automobile [16 – 18]. Thus, the need for an interactive 3D model to facilitate the body shape of the automobile becomes a necessity [19]. This study employed 3D printing techniques to model a prototype of a miniaturised electric car. The approach is based on component-integrated fixture-functions to accommodate a complete fixtureless assembly and coupling of the parts. Hence, bringing about structural flexibility, improved performance and cost reduction. The study confirmed that the 3D technique would enhance the potentials of automated automobile design concepts as well as helping in making informed design decisions by indigenous electric car designers.

2. METHODOLOGY

2.1 Design calculation

In automobile design, several parameters are necessary to determine the driving force required by the system. These parameters include; Force, friction, torque and power. This helps in understanding the performance of the engine system.

2.1.1 Force

Five (5) forces acting on a car were considered for this design. These include; Weight, reaction, driving (thrust) frictional force and air resistance (drag) forces.

i. Weight of the car **= mg** (1)

Where;

W is the weight, m is the mass of the car, and g is the acceleration due to gravity. From the 3D printer, the total mass of the car is m = 0.35kg and since g is taken to be 9.8 m/s^2.

$W = 0.35 x 9.81 = 3.43N$

ii. Reaction Force

$R_f = (m \times g)/4$ (2)

Where;

R_f is the reaction force

$R_f = (0.35 x 9.81)/4 = 0.858N$

iii. Driving force (thrust)

$$F_t = ma = m(v\text{-}u)/t \quad (3)$$

Where; F_t is the thrust, 'a' is the acceleration, 'v' is the final velocity, 'u' is the initial velocity, and 't' is the time. Also, it is assumed that the initial velocity of the car is taken as zero, u = 0, i.e. at the static condition and taking the maximum final velocity of 5m/s.

$$F_t = m(v\text{-}u) \quad (4)$$

$$F_t = 0.35(5\text{-}0) = 1.75 \text{ N}$$

iv. Frictional Force between the tyres and the road: the frictional force effect between the tyre and the road is determined using the following equation:

$$F_r = N\times\mu = (M\times g\times\mu)/4 \quad (5)$$

Where;

μ is the coefficient of the friction i.e μ = 0.6 (μ between tyres and the road)

$F_{r\,max}$= 2×{(M×g×μ)/4} = ½× (M×g×μ = ½× (0.35x9.81×0.6) =1.03N

v. Air resistance (drag force)

$$F_d = ½(\rho \text{ x } V^2 \text{x Cd x A}) \quad (6)$$

Where;

ρ is the density of air, A is the reference area, v is the velocity (taken as the maximum value), and C_d is the drag coefficient. The standard values of ρ and C_d are 1.225kg/m^3 and C_d= 0.27, respectively.

Also, V is 5m/s as assumed from above. The reference area of the car is 0.001m^2

$$F_d = ½ \text{ x } 1.225 \text{ x } 5^2 \text{ x } 0.27 \text{ x } 0.001$$

$$F_d = 0.00413 \text{ Nm}$$

Therefore, the total forces acting on the car is;

Weight + reaction force + driving force + frictional force + air resistance

= 0.34 +0.858 + 1.75 +1.023 + 00413= 3.975N

Calculation of the required torque

$$T= F \times R \quad (7)$$

Where;

T is the torque; F is the total force acting on the car and R is the distance of the tyre.

R=18mm = 0.018m and F is 3.975N

T= 3.975 × 0.018 = 0.072Nm

T = 0.0000965hp (1Nm = 0.00134 hp)

2.2 Body shape modelling

The study employed a Sketchup computer-aided design (CAD) tool to model the individual body shape of the automobile. This particular CAD tool was selected due to its robust tools, the flexibility and ability to correct errors during the design. The modelled parts were tested for printability and then exported in stereo lithography (STL) file format for the slicing process. STL file format was used in order to have an accurate description of the modelled geometry of the automobile parts. The slicing was done using Cura 4.3 Poly Lactic Acid (PLA) with a filament of thickness 0.75 mm was used for printing the car body parts due to their light weight. While Any cubic i3Mega 3D printer was used due to its excellent quality and proper layer resolution. The different body shape model is presented in Figures 1- 8.

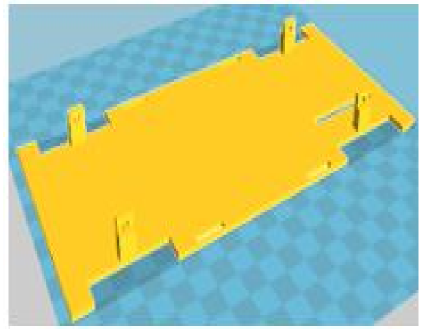

Figure 1: Chassis

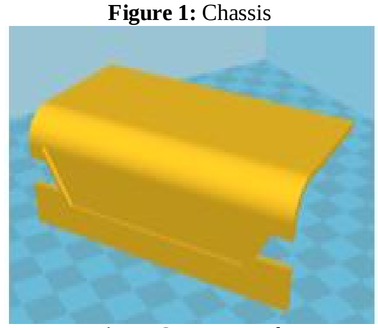

Figure 2: Rear Trunk

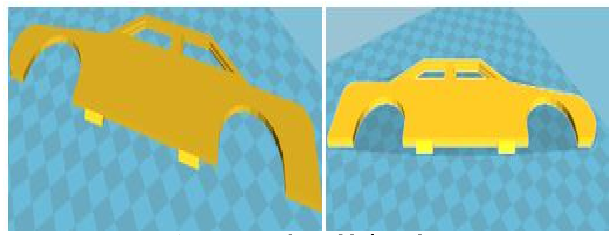

Figure 3: Right and left wedge

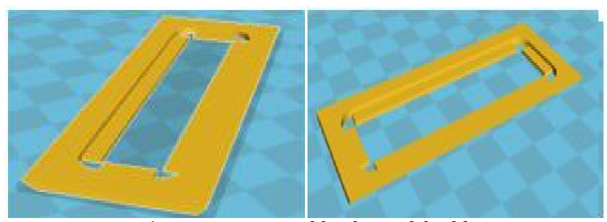

Figure 4: Front and back windshield

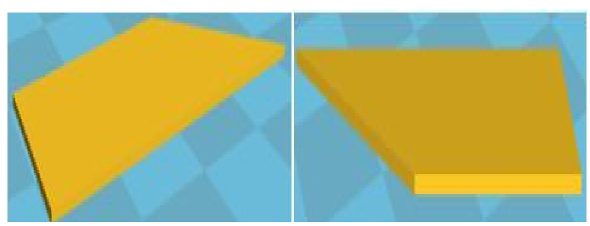

Figure 5: Window

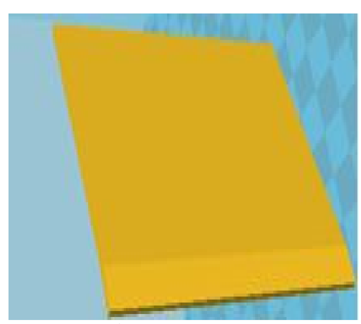

Figure 6: Bonnet

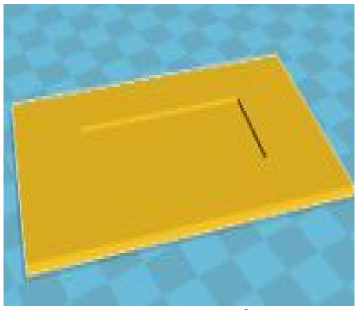

Figure 7: Roof

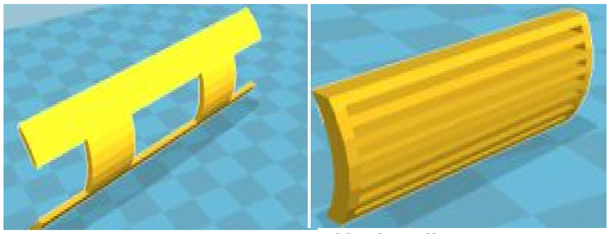

Figure 8: Front and back Grille

2.3 Part assembly

The printed parts were assembled carefully using "Alteco glue" together with 3mm mild steel rod, tyres and spur gears. Figure 9 presents the picture of the complete car assembly.

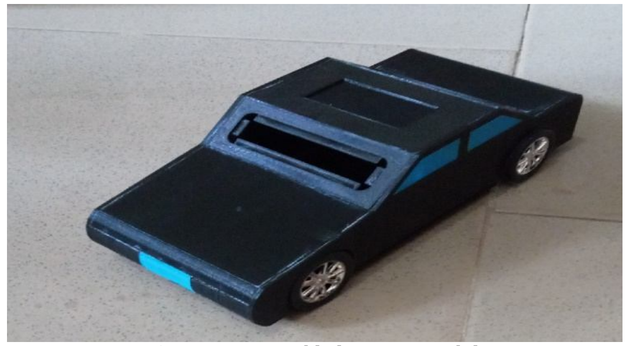

Figure 9: Assembled 3D Automobile

2.4 Process automation

The automation part consists of making the bare Arduino board (Cloned Arduino Board) which consists of the microcontroller and further interfaced with a DC motor drive which is also connected to the motor driver as shown in the flowchart below Figure (10)

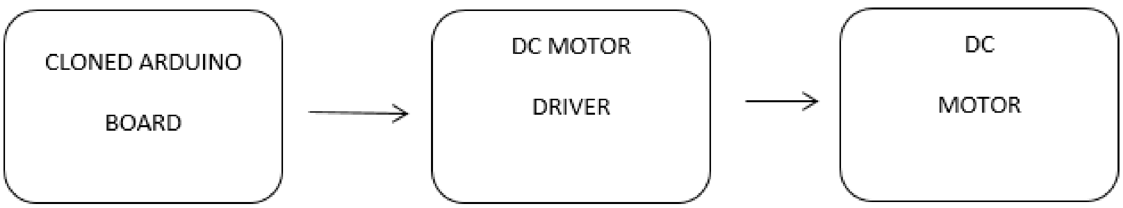

Figure 10: Flowchart of the process automation

3. RESULTS AND DISCUSSION

3.1 Modes of operation

The 3D automated car was tested to examine its operation and performance. he car has four tyres with only the two front wheels driven by an electric motor. The chassis of the car serves as the base for mounting the electric motor, the automated board and the battery. The bidirectional DC-DC converter is an essential component to control the energy flow between the battery and the motor [19].A shaft connected the two front tyres with spur gear of 8mm diameter at an appreciable distance between both tyres. A larger spur gear of diameter 14mm is fixed to the drive shaft of the MG995R motor which drives it. This spur gear transmits the rotary motion of the motor shaft to the smaller spur gear which rotates the drive shaft thus propelling the car. The power from an 18 VDC mains is stepped down by a relay, and regulated to desired voltages. The motor generates 10.787 Nm of torque. Since the speed and the torque were reasonably balanced, the car moves at an average speed.

The **ATMEGA 328P-PU** microcontroller sends a velocity command to the electric motor. The control switches on the remote are activated according to a study by [20]. The programming language used for the microcontroller is the C language which is well suited to the microcontroller. According to calculations, the torque required on the drive shaft is 3.975 Nm so that it can move optimally. The prime mover used generates a torque of 10.787 Nm, which is way higher than the minimum required torque, thus, making the car perform optimally. The car was able to move at a speed of 1 m/s, using a direct front wheel drive mechanism. The car also received signals within a range of 3m from the infrared remote control used.

4.CONCLUSION

Overall, the study employed an additive manufacturing technique to produce a 3D car. More so, the automation of the car demonstrates precision and also contributed to the clean technology and innovation. The needed torque (3.975 Nm) as observed from the result showed that efficiency in the automobile performance ensues. Invariably, this has addressed some key points in the present pursuit of sustainable development goals. The study demonstrates the feasibility of indigenous production of autonomous fuel-less cars at a lower cost through additive manufacturing.

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