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Innovative Design and CFD Analysis of Human Powered Eco-Friendly Trike

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***Abstract*—Drives running on petrol and diesel produce large amount of chemicals to pollute the air. Thus, a healthy environment is becoming unhealthy for human beings. There is increasing concern over congestion and pollution associated with the use of vehicles which uses conventional fuels for personal transport. On the other side Battery driven drives are free from exhaust of pollutants. This work aims to design an Eco friendly trike that could be viable alternative to cars for short distance journeys. The designed vehicle is an innovative trike. It is powered by a hybrid human-electric drive system. The vehicle can seat one adult of whom could power it via foot pedaling. This cycle consists of two drive mode mechanical and electrical mode of driving system. A mechanical drive system – which on its own could power the trike – has also been designed, as has an electrical drive system that can be fitted in future at the rear side. The main goal is to create a new design structure of top frame for better aerodynamics, stress distributing base frame fish bone structure, ergonomically accessible feature like pigeon head roof top & utilization of solar panels at top frame. Furthermore, using the software *FLUENT*, Two Dimensional analysis of the side contour of the vehicle was achieved, and possible correction of trike geometry was made in purpose to improve the design in terms of reducing air resistance and improve aerodynamics.**

Keywords—Eco-Friendly Vehicle, Aerodynamics, FLUENT.

I. INTRODUCTION

As the burning of fossil fuel is becoming an unsustainable issue in lieu of the environmental degradation and increasing energy prices, automobile manufacturers are introducing more fuel efficient cars to the market. One of the main contributors to fuel consumption is the aerodynamic drag since it accounts for more than half of the engine power at highway speeds. There is a considerable increase in the emission of greenhouse gases in the earth's atmosphere that is creating changes in the global climate. A third of greenhouse gas emissions in the world originate from the combustion of fossil fuels in internal combustion engines that is reflected in recent studies [1].

So, there is a need to focus and improve changes on issues related to transportation. This work focuses on a great alternative for the future transportation that does not harm the environment and also provides the user with health benefits. [2]

This paper focuses on Human powered trike with a dual mode driving system with a facility to place solar panels at top frame.

Human Powered trike is a pedal powered mode of transportations therefore its success is measured by the effective transfer of pedal power to forward motion. Mechanical power losses will not be considered in this study [3]. Various positive impacts were obtained by using a solar panel as a power source. By using solar panels, the greenhouse gas emission is eliminated and operation cost is reduced. The future of power generation depends only on renewable resources. Thereby we conclude that solar-powered tricycle is both environmental and user friendly. The cost of fabricating such type of trike is also less, thereby making it a suitable mode of transportation for handicapped people [4].

The physically challenged people face many problems in day to day life; they always depend on assistive devices like sticks to move. Thereby making it impossible for them to move to longer distances. This Trike helps them move to longer distances (5). The main objective of this work is to develop a vehicle operated by eco-friendly and less expensive renewable sources of energy [4].

A. Trike

In literature, there are two available designs of vehicle:

(1) Delta: The delta type of trike has one wheel in the front and two wheels in the rear. These types of trike can give its best in steering as it can have a zero turning radius. The power to the rear wheels of the delta trike ensures no slipping during cornering.

(2) Tadpole: The tadpole type of trike has two wheels in the front and one wheel in the rear. Both the trikes have their pros and cons. But tadpole configuration always has certain advantages over the delta configuration in almost every field. Being a rear wheel driven configuration, the tadpole configuration will have all the tractive effort available from its share of the weight. Also because of the major weight on the front side of the vehicle there is much grip available for both steering and braking. Electrically assisted tadpole trikes are much more stable when compared during cornering. Delta trikes on the other hand has less front weightage due to which it can't give its best in both braking and steering. Electrically assisted delta trikes are more

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unstable. After analyzing both the designs it is preferred to choose tadpole over the delta. [6]

Pollution being the emerging issue all over the world, there should be an alternative for transport. Trike could be the appropriate answer for the issues regarding the same. [7]

Alam studied the significance of aerodynamic design and comfortable riding of human powered tricycle. In literature, there are two available designs of vehicle. The delta type of trike has one wheel in the front and two wheels in the rear [8].

These types of trike can give its best in steering as it can have a zero turning radius. The power to the rear wheels of the delta trike ensures no slipping during cornering. The tadpole type of trike has two wheels in the front and one wheel in the rear. Here basically considering the constraints of dimensions we first of all assumed the dimensions of the vehicle. After assuming the dimensions our main area of interest was to make the vehicle ergonomic for an average adult person. Here we actually designed the vehicle in modeling software AutoCAD [9].

B. Aerodynamic Force Coefficients

The aerodynamics of the trike are sometimes more important than the mechanical aspects of the vehicle. This hindrance causes a loss of effectiveness of power transfer to motion. The current study was aimed at understanding the aerodynamics, and in turn helping to achieve better efficiency of these vehicles and increasing the appeal of the Human Powered trike Drag Coefficients: The magnitude of aerodynamic drag significantly varies with the test vehicles' physical profiles [2].

In fluid dynamics, the coefficient of drag commonly denoted as: c_d, c_x or c_w is a dimensionless quantity that is used to quantify the resistance of an object in a air or water environment. It is used in the drag equation, where a lower coefficient of drag indicates the object will have less aerodynamic drag. The coefficient of drag is always associated with a particular surface area. The coefficient of drag of any object comprises the effects of the two basic contributors to fluid dynamic drag: skin friction and form drag. The coefficient of drag of a lifting airfoil also includes the effects of lift-induced drag. The coefficient of drag of a complete structure such as an aircraft etc. also includes the effects of interference drag.

The coefficient of drag C_d is defined as:

$$C_D = \frac{2\,F_d}{\rho\,u^2\,A} \qquad (1)$$

Where F_d is the drag force, which is by definition the component of force in the direction of the flow velocity, ρ is the mass density of the fluid, u is the flow speed of the object relative to the fluid, A is the reference area.

The coefficient of drag quantifies the resistance of an object in a fluid environment. The efficiency of the car is more when the coefficient of drag is low. the more. It is obvious that vehicle emission have to be reduced; automotive manufacturers are looking for ways to achieve this goal.

C. Computational Fluid Dynamics

There are two possibilities to analyze the aerodynamic features of vehicles and especially the turbulences: the wind tunnel and computational fluid dynamics (CFD). The efficiency and the financial aspect make CFD a better solution. Even the visualization and the accuracy are other aspects which show the advantages of CFD.

II. DESIGN INNOVATIONS/CONSIDERATIONS

A. Fish Bone Frame Structure

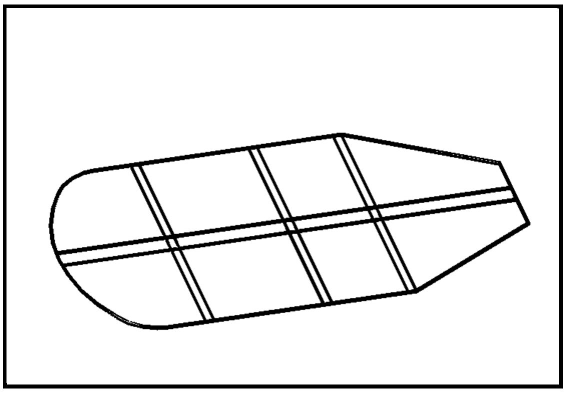

Figure 1: Fish Bone Frame Structure

Fish bone base frame helps in equal distribution of stress for the applied load vertically. Fish bone structure used in the frame with little deviation instead of using cross members we use straight members it result effective stability [9].

B. Pigeon Head Roof Top

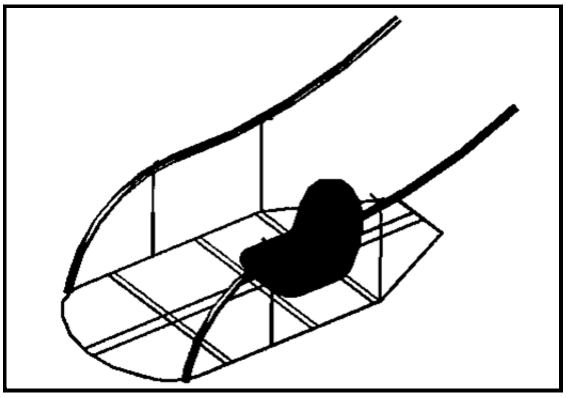

Figure 2: Pigeon Head Roof Top

Pigeon head structure is used to reduce the drag and increase aerodynamic effect [9]. The pigeon head structure enhances the speed with ease of air flow to enhance drag reduction with pitching movement.

C. E-Trike Overview

The trike has an innovative delta design which is aerodynamic, ergonomically designed so that it can be used for travelling far areas.

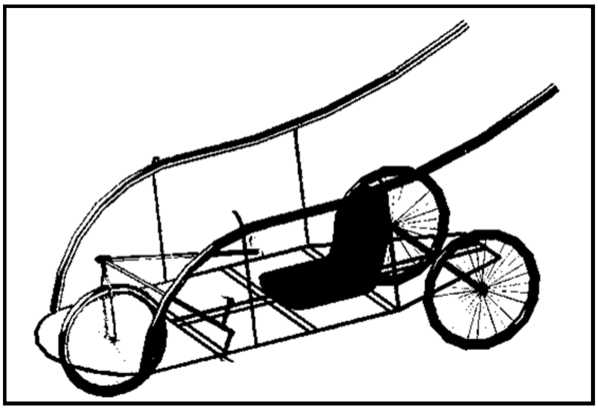

Figure 3: 3D view of E-Trike

Table I TRIKE SPECIFICATIONS & DIMENSIONS

S. No	*Specifications*	*Dimensions/Name*
1	Length of the vehicle(l)	284.7377 mm
2	Height of Pigeon head top roof(h)	133.5533 mm
3	Velocity of the vehicle	25 Kmph or 6.9 m/sec
4	Trike	Wall
5	Frame Material	Aluminium Alloy 6061 T6
6	Wheel Configuration	Delta (front-1, rear-2)
7	Motor	PMDC 1500rpm & 48 Volts
8	Weight of the driver	100 Kg (max)

III. SIMULATION

A. Mathematical Modelling

The mathematical modelling selected for this work is standard K-ε models which are based on the Reynolds averaged Navier-Stoke (RANS) model available in Fluent.
Standard K-ε Model – It is a two equation model which gives a general description of turbulence by means of two transport equation (PDEs) to simulate mean flow characteristics for turbulent flow conditions.

$$\frac{\partial(\rho k)}{\partial t} + \frac{\partial(\rho k u_i)}{\partial x_i} = \frac{\partial}{\partial x_j}\left[\frac{\mu_t}{\sigma_k}\frac{\partial k}{\partial x_j}\right] + 2\mu_t E_{ij}E_{ij} - \rho\epsilon \quad (2)$$

$$\frac{\partial(\rho\epsilon)}{\partial t} + \frac{\partial(\rho\epsilon u_i)}{\partial x_i} = \frac{\partial}{\partial x_j}\left[\frac{\mu_t}{\sigma_\epsilon}\frac{\partial \epsilon}{\partial x_j}\right] + C_{1\epsilon}\frac{\epsilon}{k}2\mu_t E_{ij}E_{ij} - C_{2\epsilon}\rho\frac{\epsilon^2}{k} \quad (3)$$

The first transported variable determines the energy in the turbulence and is called turbulent kinetic energy (K). The second transported variables is the turbulent dissipation (ε) which determines the rate of dissipation of the turbulent kinetic energy.

B. Meshing & Boundary Conditions

According to Rajesh Bhaskaran, Cornell University upstream length is taken as 12.5L, downstream length is 20L and zone diameter is 25L. Where L is the length of the Trike Pigeon Head Roof top.

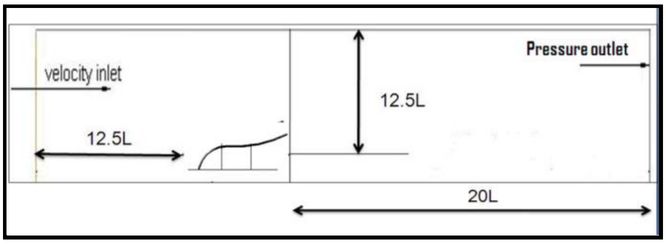

Figure 4: Computational Domain

Model Geometry, meshing and assigning specific boundary conditions was done using GAMBIT pre-processor software. The mesh is read as a case in the fluent choosing 2ddp, in order to arrive at accurate results, the double precision parameter is chosen. Ideal gas was used as containing fluid whereas its specific heat was set as 1006.43 J/(Kg. K), molecular weight was set as 28.966 Kg/(Kg. mol).

For the present work the solver software used was FLUENT. Pressure Based Solver was considered and viscous model considered being Standard K-ε Model. The Standard method is considered because it is popular and is chosen for interpolation of pressure. Among the three methods for pressure-velocity coupling in the segregation method, SIMPLE algorithm is used.

Table II MESH BOUNDARY CONDITIONS

Edge Position	***Name***	***Type***
Left	Inlet	Velocity Inlet
Right	Outlet	Pressure Outlet
Top & Bottom	Wall	Wall
Trike	Wall	Wall

Table III SOLVER PROPERTIES

CFD Simulation	***2d dp (2D Double Precision)***
Solver	Fluent
Space	2D
Formulation	Implicit
Time	Steady
Velocity Formulation	Absolute
Gradient Option	Cell-Based
Porous Formulation	Superficial Velocity

C. Results

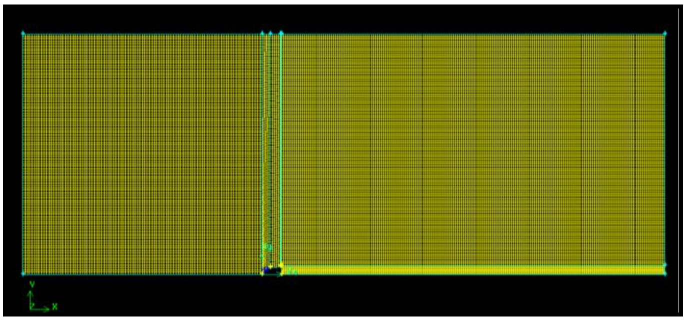

Figure 5: Mesh in GAMBIT

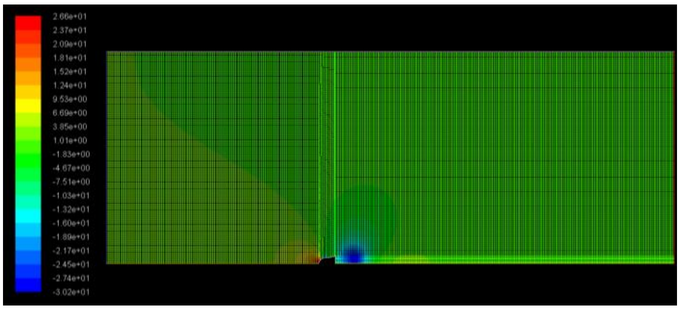

Figure 6: Contours of Static Pressure

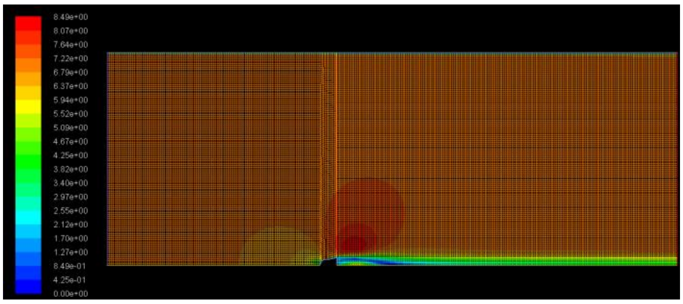

Figure 7: Contours of Velocity Magnitude

IV. CONCLUSIONS

Modelling of Fishbone frame, Pigeon head roof top and final assembly has been done very carefully in AutoCAD Software as shown in figure 1, 2, 3. Fish Bone structure used in the frame with straight members which results in effective stability and Pigeon head structure is used to reduce the drag and increase aerodynamic effect.

CFD analysis has been done for the 2D contour of Pigeon head roof top in Gambit Preprocessor and FLUENT 6.2 Solver. From the Figure 6, contours of static pressure, it is observed that pressure is maximum at front and minimum at rear portion of pigeon head. The pressure drag which highly depends on vehicle geometry is because of boundary layer separation from rear trailing end and consequent formation of wake region behind the trike. The location of separation determines the size of wake region and consequently it determines the value of aerodynamic drag coefficient. From the Figure 7, contours of Velocity, it is observed that velocity is maximum at top of pigeon head, indicating a good aerodynamic effect (less Drag). The obtained value of drag coefficient 0.49 helps to increase the friction between the wheel base and the track to attain maximum acceleration; this is done to achieve a speed of 20-30km/hr approximately.

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