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A BIOMIMETIC APPROACH ENHANCED WITH CREATIVITY TO DESIGN A HYDROGEN FUEL CELL POWERED VEHICLE'S BODY

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Abstract: The present research envisages the creativity involved in design of hydrogen fuel cell powered vehicle's outer shell through a biomimetic approach. A study of Hawk Bird wings is implemented to design the two sides doors of a three wheeler single seater prototype vehicle. The vehicle, named as Unfrozen Hawk, is designed to resemble hawk wings while opening and closing of doors. Also, the tear drop aerodynamic structure is designed to reduce the drag force on vehicle body. The research concludes to show that biomemetics can enhance the aesthetics and aerodynamic performance of a three wheeler vehicle through a creative approach of design.

Keywords: *Aesthetics,Aerodynamics,Biomemetics,Hawk Wings*

1. Introduction

Green vehicles are equipped with a low and limited power generating units like human power, fuel cells, battery etc. A highly efficient aerodynamic body structure is required to reduce drag force and thus power consumption. For a sustainable design of vehicle, a creative design approach is required with an aesthetically pleasing look. A creative approach enhanced with biomimetics can provide aesthetic vehicle design with stability. Biomimetics or biomimicry (Bar-Cohen, 2011) is the art of imitation of nature elements for solving various problems of engineering design. The creative mimicry of natural design for automotive application is the key concept of the present research.

Figure 1. Unfrozen Hawk vehicle design and prototype

The Vehicle- Unfrozen Hawk, as shown in Figure 1, is an ergonomically (Gkikas, 2012) designed hydrogen fuel cell powered three wheeler vehicle. Gull-wing doors are provided with tadpole configuration as a result of biomimetics from Hawk bird.
The concept of biomimetics, equipped with aesthetics and creativity is implicated to design the aerodynamic outer shell of the vehicle. Biomimicry of flapping wings of bird can be encorporatd to design the gull-wing doors of a vehicle, with a streamline aerodynamic shape mimicking the shape of falling water droplet from sky.

Bird flights have inspired humans from ancient times in dynamic mimimcy as well as creativity (Pennycuick, 2008). The aerodynamic priciples as well as flight mechanism are copied from nature to develop aerial vehicles. The motion of wing pattern during forestroke and backstroke is the basis of door designing in this research. The mechanics of hinge attachment and the priciples of creative shapes are the basis of present research. The dimensional analysis methods are implemented to perform the shape analysis and mimetics. Further, the muscurar hinges are mimicked for attachment of doors with body. Fig 2(a) shows the morphology of the bird wings.

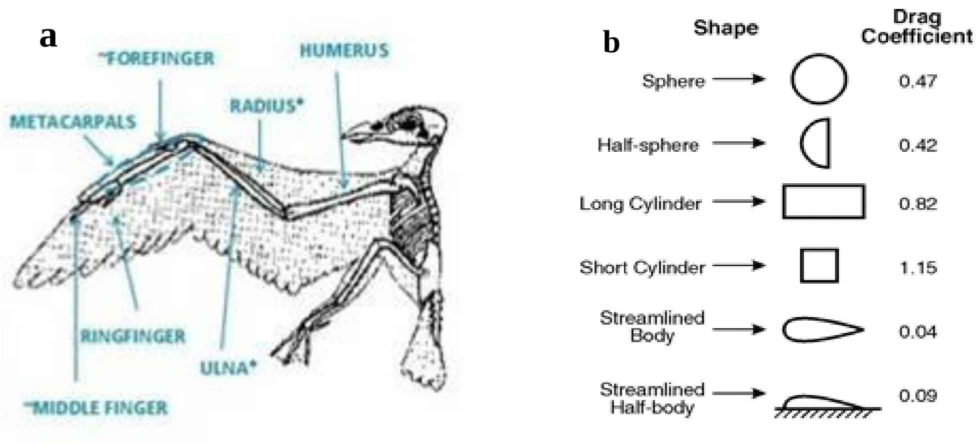

Figure 2. (a) Bird wing morphology, **(b)** Drag comparison for various shapes

Aerodynamic shape reduces the drag force on a vehicle (Barnard, 2001). The streamline shape of vehicle body with reference to the Fig. 2(b) is desired for design of vehicle. The concept of streamline shape is a result of water droplet falling from sky in an aerodynamic behaviour. The shape attained by water droplet shows low separation of air as well as lery low drag coefficient. The shape obtained by nature in this way helps a lot to shape the vehicle outer structure. Outer shell modelling of the vehicle is done to follow the conceptual design while considering the aerodynamics and ergonomics calculations also. With the average speed of a vehicle competing in the Shell Eco-marathon (Santin, 2007) at around 25 km/h, drag is for all intents and purposes the parameter of interest. For proper ventilation of rear compartment, vents and openings are provided on the body. The body and frame combine to make a sturdy and structurally safe aerodynamic shell.

2. Outer Shell Design

Outer shell of a vehicle body serves the purpose of external protection as well as to provide aerodynamic shape to the vehicle. The shape of Vehicle unfrozen hawk is inspired from nature water drop falling as discussed in the previous section. The aerodynamic structure with wheels behaves as a stramline half body. The falling droplet aerodynamic shape is implemented as a tool of side view and top view of design which is modelled in CAD tool Autodesk Inventor to obtain the surface.

2.1. Biomimetic Approach

The aerodynamically sustainable body is designed by employing computational design optimisation strategy. Fig. 3(a) shows the flow around a streamline shape. The body as shown in Fig. 3(b) is the artistic impression of flow for Unfrozen Hawk. Further the shape is analysed for aerodynamic behaviour in Ansys Fluent Software through computational fluid dynamics.

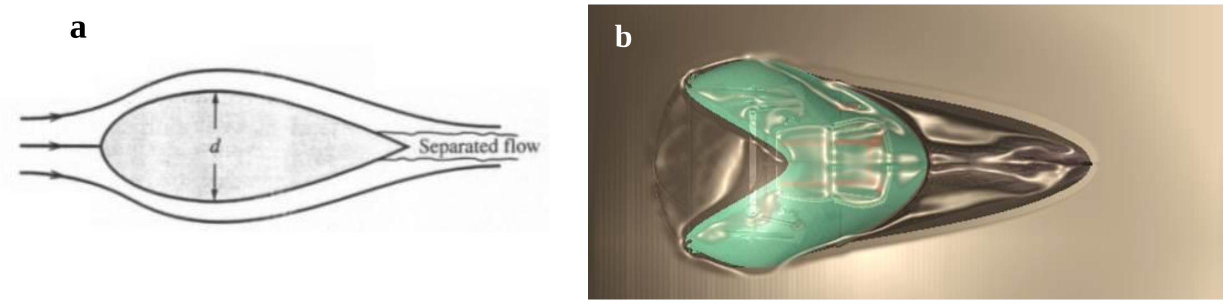

Figure 3. (a) Flow around streamline drop shape, **(b)** Flow impression on Unfrozen Hawk

The complete modelled surface with isometric view is shown in Fig. 4(a) and the aerodynamic flow in Ansys Software is represented in Fig. 4(b) below. As the vehicle is symmetric across th vertical planne, half body analysis is done.

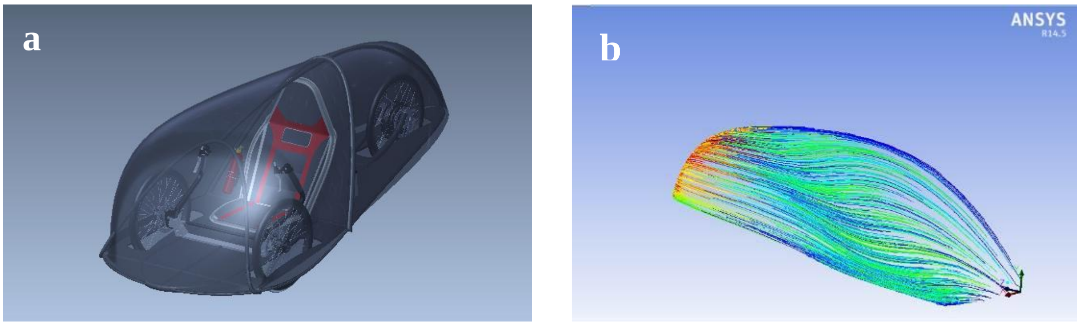

Figure 4. (a) Surface model of vehicle body, **(b)** Flow across model in Ansys software

The biomimetic approach of copying the falling water droplet shape provided an aerodynamic shape with 0.33 as coefficient of drag value. Also the flow across the vehicle shell resembles the flow across water droplet thus prodiding an streamline design approach.

3. Vehicle Door Design

The next step involved after outer shell design is to implement the door openings in the vehicle. A creative approach to mimic the bird wing forestroke and downstroke is applied to design the gull-wing doors of Unfrozen Hawk. The vehicle is divede into two compartments, driver compartment at the front and powertrain compartment at the rear. The doors are to to be provided for both side opening in front compartment. A hawk wing opening and closing is shown in Fig. 5.

Figure 5. Hawk bird wing strokes

3.1. Creative Biomimetic Approach

The base surface model was corelared with the body and wings of Hawk bird and analysed for the possibility of a wing shaped door. The two hinge lines were first implemented to represent blade of scapula extention as shown in Fig. 6(a) below.

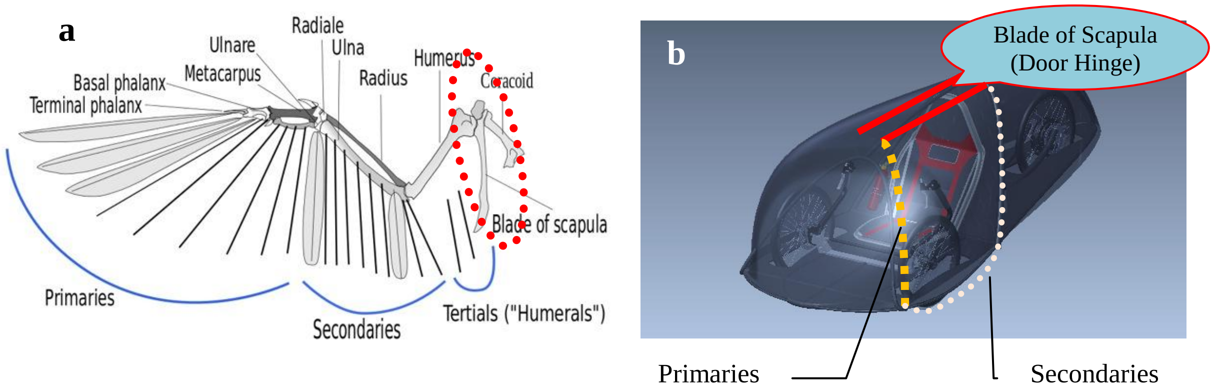

Figure 6. (a) Bird wing structure, **(b)** Mimicking the wing shape on body

At the top of surface model in driver compartment, the two cut lines were marked for hinge attachment as shown in the Fig. 6(b) above. Blade of scapula of two sides of a bird is mimicked as the two lines for door attachments. Futher the wing shape study projected to define the primaries and secondaries of the bird wings as the boundaries of door. The structure of wing bones and feather are mimicked to provide rigidity to door shape thus acting as reinforcement in composite design.

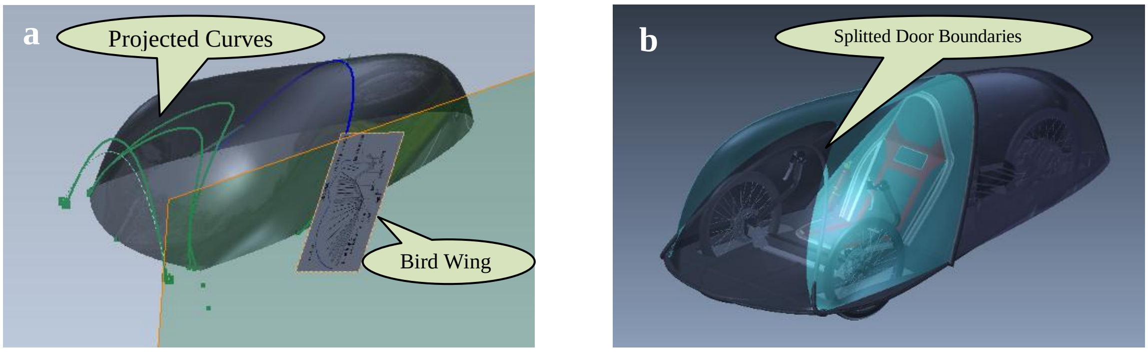

Figure 7. (a) Curve Projection on body, **(b)** Split door boundaries on body

As shown in Fig. 7(a) above, the 3D curves with respect to the bird wing outlines are projected on the outer shell to define the door boundaries. Further, the blade of scapula, the primaries and the secondaries are mimicked to define the projected boundaries of doors and then the surface is splitted across the projected curves to define the doors as shown in Fig. 7(b).

Figure 8. Unfrozen Hawk prototype resembling bird wings

The creative design of biomimetic door shape was developed using glass epoxy composite material as per the design. The developed prototype as shown in Fig. 8 is compared with the natural hawk bird which resembles the opening and closing of door as flapping strokes.

4. Conclusion

The present research shows a creative approach enhanced with biomimetics to design the outer body of a single seater vehicle. The biomimetics of falling water droplet shape is implemented to provide the basic aerodynamic shape followed by a gull-wing door shape by copying the wing structure of Hawk bird. The enhancement of aerodynamic performance as well as aesthetics is implemented through a creative approach of curve and surface modelling. Thus it can be concluded that biomimetics with an enhanced creative design can provide solution to various automotive advancements in terms of aesthetics and structural stability.

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