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Aerodynamic Wing Design with Biomimetic Approach and a Practice

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Abstract

Since the industrial revolution, the use of energy has become indispensable in our lives. Besides the increasing world population increases the need for energy, our need for petroleum-derived fuels, which are mostly obtained from underground sources in transportation vehicles, has increased. Limited, expensive, non-recyclable and insensitive to the environment, these fuels harm humanity for various reasons. Nowadays, besides the efforts to find alternative fuels for these fuels, the ways of using these fuels in the most economical way are being investigated. One branch of this research and development is aerodynamic design. In this study, in vehicle design, aerodynamic rim wing design is discussed. The aerodynamic structure of the wings minimized the swept air resistance. Thus, energy saving and wheel surface quality is improved.

1. INTRODUCTION

The Industrial Revolution is a major and radical change in the production structure and economy that has been achieved through the use of new power sources such as steam and mechanization. It is also referred to as Industrial Reform. Started in England in the second half of the 18th century [1].

In the early stages of the industrial revolution, steam-powered machines and vehicles (trains, ships, etc.) emerged. Later, electric, gasoline machines and vehicles began to be used. When energy is obtained from fossil fuels, combustion products (gases such as CO_2, NOx and SO_2) are dispersed in the atmosphere as flue gas. The flue gases also contain fly ash and hydrocarbons. Toxic metals such as nickel, cadmium, lead, arsenic are other substances that are thrown into the atmosphere as a result of burning of fossil fuels. CO_2 plays an active role in greenhouse effect formation. The increasing amount of CO_2 causes the temperature of the earth to rise, which leads to deterioration of the climate balance. SO_2 and NOx, combined with water vapor in the atmosphere, mainly lead to acid rain, which leads to deterioration of the ecological balance of the world. All fossil fuel residues cause air pollution that affects many of our cities during the winter months. Forests, agricultural lands and similar natural resources cause destruction [2].

As can be seen in Table 1, fossil fuels have been increasingly used since the industrial revolution. In These fossil fuels, the highest increase was seen in petroleum and its derivatives. With recent studies, it is still the most used energy source in the world, even if the rate of increase has declined. Table 2 envisages the use of energy sources that we will consume from 1990 to 2040. According to this study, fossil fuels are still at the peak. This is proof that savings in fossil fuel use need to be further increased.

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Table 1. *Global fossil carbon emissions graph [3]*

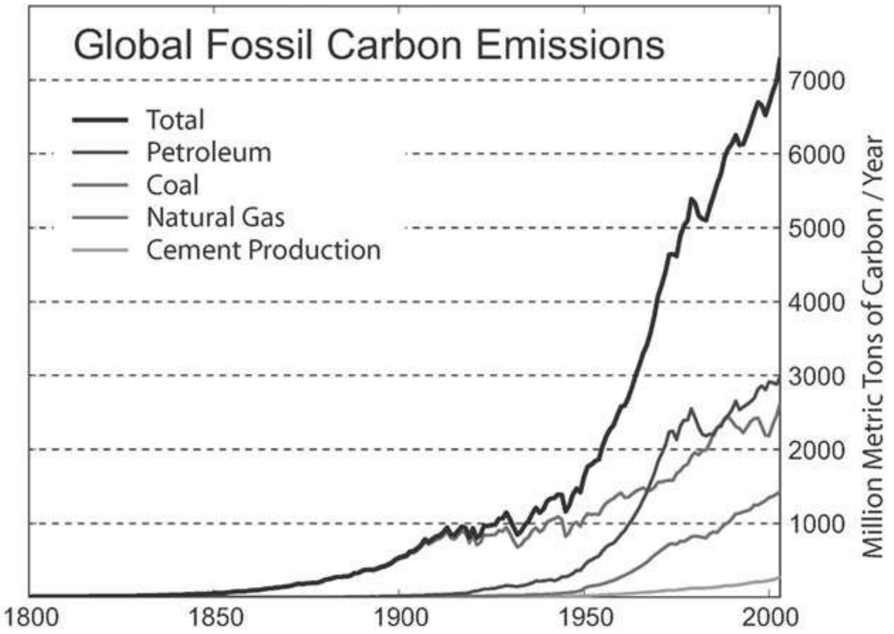
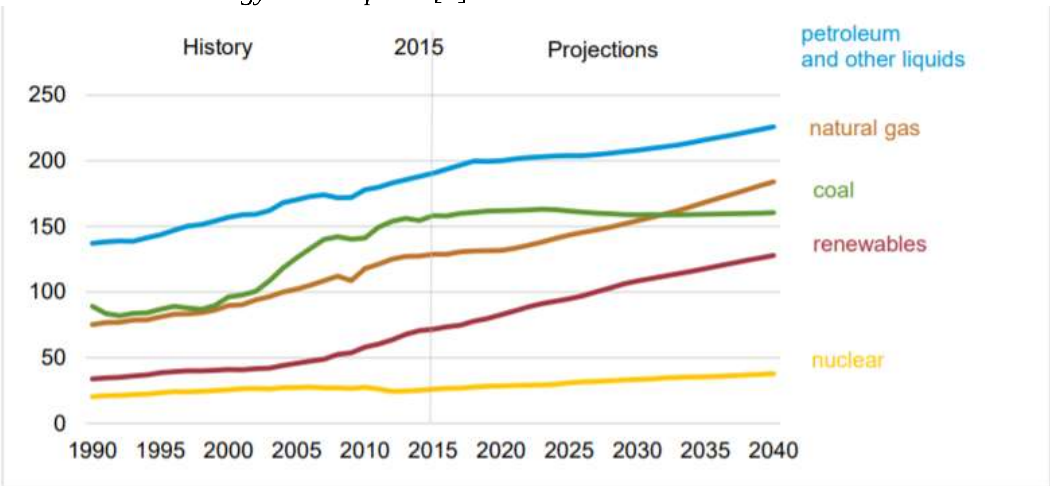


Table 2. *Global energy consumption [4]*



2. BIOMIMETICS

Developing vehicle designs with the invention of transportation vehicles began to give importance to aerodynamic structure. Many of today's designs have been made by adapting to the design thanks to the research of nature and alive. This branch of study is called Biomimetic.

Today, birds, fish inspired by aircraft, aircraft wings, wind turbine wings, cars and different types of designs are made. In our study, we will try to design the rim wing with these observations.

3. WING DESIGN

Besides there are rims of different structures as visual, these rims may be used for different purposes. One of them, in order to save fuel against wind resistance, it is desirable to optimize aerodynamics in vehicles. For this purpose, the rim design affects the aerodynamic structure. The wheel consists of body and wings. In this area, the rim design affects the aerodynamic structure to a small extent. The rim body is connected to the axles and the rim blades are connected to the tire. Since the wheel rotates with the body axis, there is no volume of air swept by the body. However, because of the gap between the rim blades, there is air inlet and outlet and this air forms resistance to the blades in motion. This resistance can be minimized by a suitable blade design. At the same time, the heat between the lining and the brake disc can be reduced with the imported air at a suitable angle. Thus brake performance can improve. In addition to being a uniform design, these blades can also be movable. During braking, the blades can be automatically angled and adjusted to sweep the air in and braking performance can be improved. Such studies can be increased and optimized. In this study, it is aimed to minimize the resistance forces acting on the aerodynamic structure and caused by the rim only.

In the study, commonly the most used in the market 5-wing model was selected as the number of rim wings. We were inspired by bird wings as wing structure and raindrop having the most perfect structure as wing cross section structure. Raindrop in Wing Design; Minimum Friction, Maximum Acceleration, Maximum Energy Saving, Minimum Energy Consumption, Maximum Power Production. For such reasons, the raindrop profile is the most important profile used in aerodynamic designs. A designer who cares about these factors must use the raindrop profile. Designing wings makes it possible to stay true to all of these factors. Therefore, our wing section must be in the raindrop profile.

In 1933, NACA published a publication about wing profile studies. In this publication, NACA described the 4-digit wing profile. These four steps according to this definition define the general shape of the wing profile. There are raindrop profiles that NASA has created as a result of its experiments for aircraft. These profiles were named by NACA, whose previous name is NASA. NACA 4415 who has minimum cw (air friction coefficient) is also used in the wing profile.

We have chosen design the wing section based on the raindrop shape which has the most appropriate aerodynamic structure.

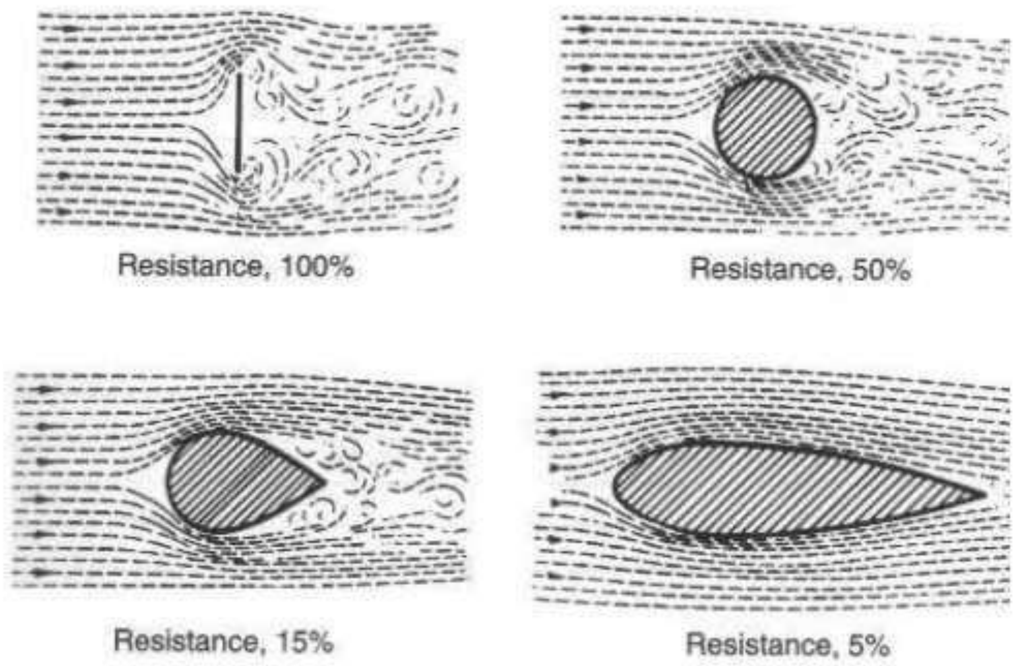


Figure 1. *Aerodynamic behavior of different geometries*

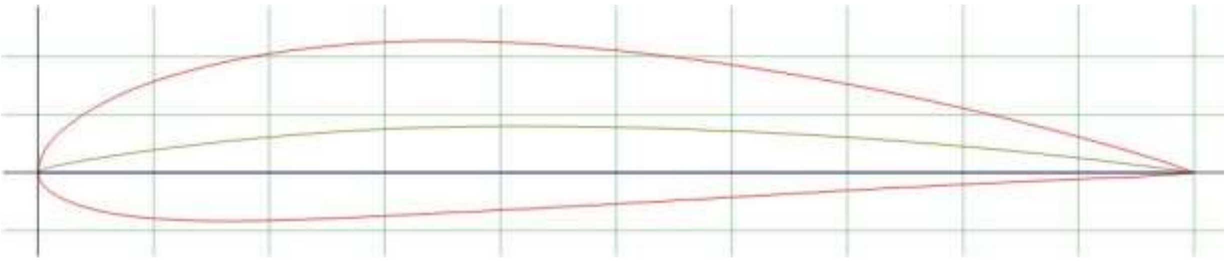


Figure 2. *NACA 4415 Raindrop profile [5]*

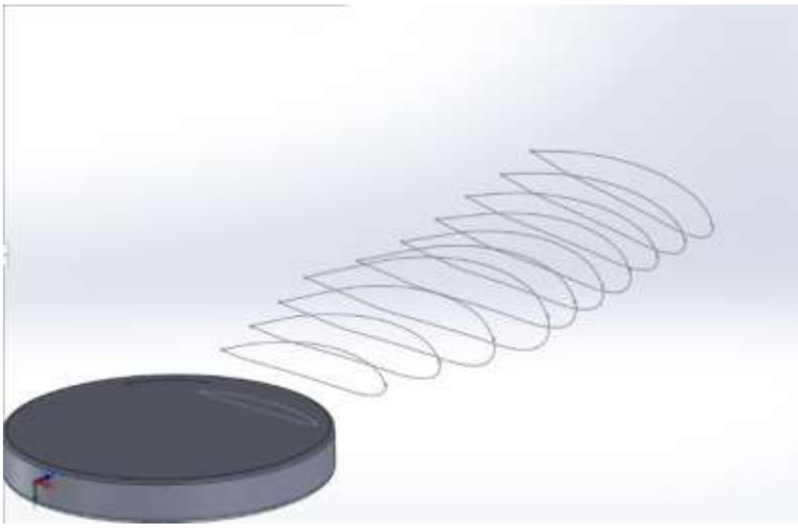


Figure 3. *Designed wing section structure*

As seen in the figure, when birds want to fly fast and they glide, slightly bend their wings in a V-shape. This reduces the contact surface of the flowing air to the wings and provides the most economical flight while increasing the air flow velocity from the body to the wing tips.

Figure 4. *The world's fastest flying bird Hen harrier*

Figure 5. *Eagle*

Figure 6. *Swallow*

Figure 7. *Hawk*

In fact, migratory birds fly together in a V-shape to achieve optimal aerodynamic movement. The researchers showed that birds used the airflow in the most efficient way by adjusting the wing movements to the nearest bird in the flock during the flight. During the 'V-shape' flight, it was understood that the birds' wing movements were compatible with each other, thus making the most of the upward airflow, when a bird was flying just behind the other, the harmony between the wing movements was lost and the effect of the downward airflow was minimized [6].

Figure 8. *Migratory birds*

With this observation, we were inspired by birds' wing design. The design was created in the form of raindrop wing section. 205/55 R16 wheel dimensions are used in our design. Design works were carried out in Solidworks program.

Figure 9. *Design with biomimetic approach*

4. FLOW ANALYSIS AND RESULTS

In 1999, researchers developed a software system called Hyperroad. They tested the Ferrari F550 and achieved consistent results. CFD software analysis data down to 1.8% error with updates [7]. This application can help improve an automobile's fuel economy and lower its emissions, reduce the environmental noise of aircraft, and increase the efficiency of wind turbines for power generation [8].

The analysis was performed in the Fluent Simulation command of the Solidworks program. Together with the rim we designed for analysis, we designed a standard rim model with the same dimensions. By comparing the analysis of these two rim models, we had the opportunity to observe the advantages of our design.

Figure 10. *Wing model designed for the analysis results*

The analysis parameters were 1 atm environmental pressure, 20 ° C temperature, wind speed of 33 m / s which affects to the wind speed of 120 km / h while the vehicle is going at 120 km / h. The wheel speed of 110 rad / sec, which corresponds to the vehicle's speed of 120 km / h, was used.

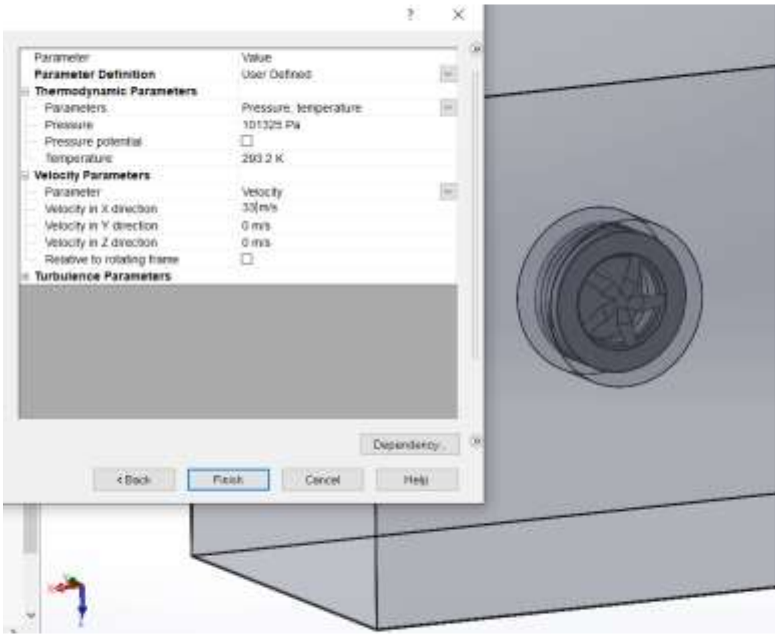


Figure 11. *Analysis parameters*

Our analysis results are shown in the following figures.

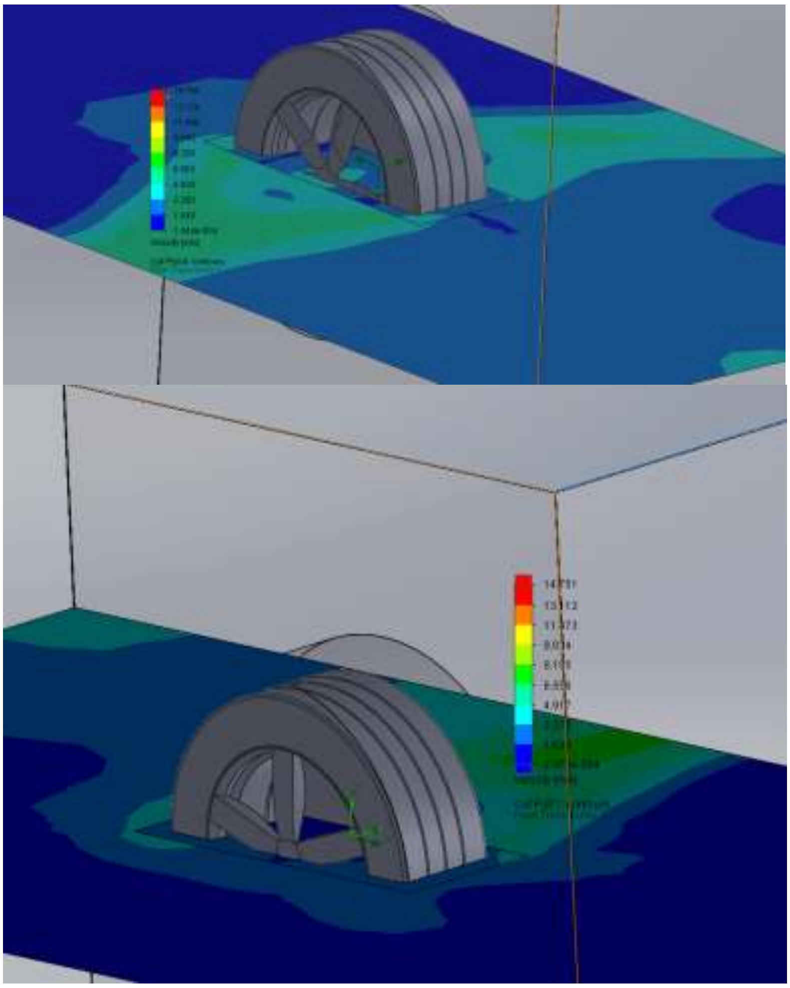


Figure 12. *Change of air in the analysis applied to the standard rim with the designed rim*

As shown in Figure 12, the air acting on the designed rim tends outwardly perpendicular to the whell. The amount of air entering is minimized relative to the other. In the other design, the air is filled into the rim.

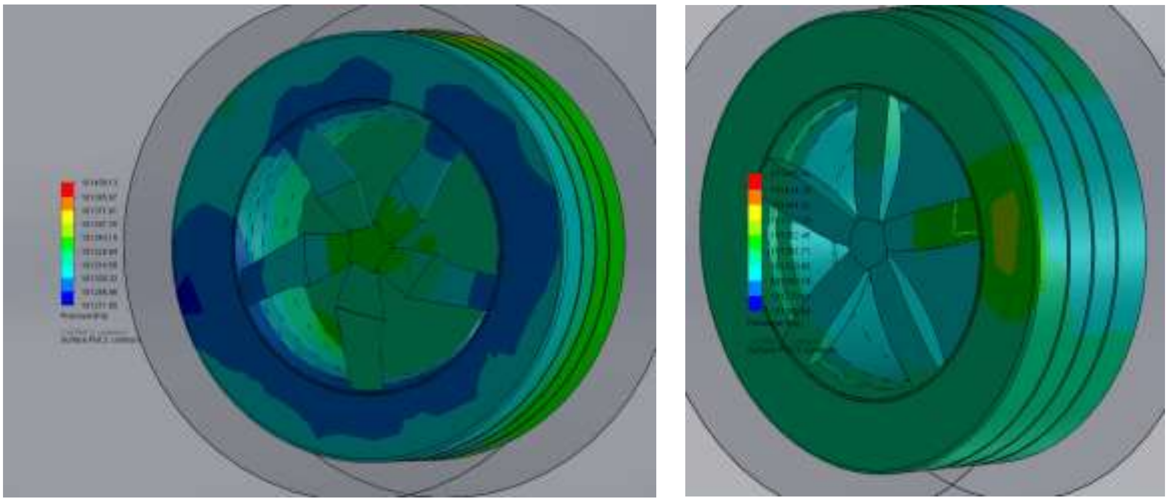
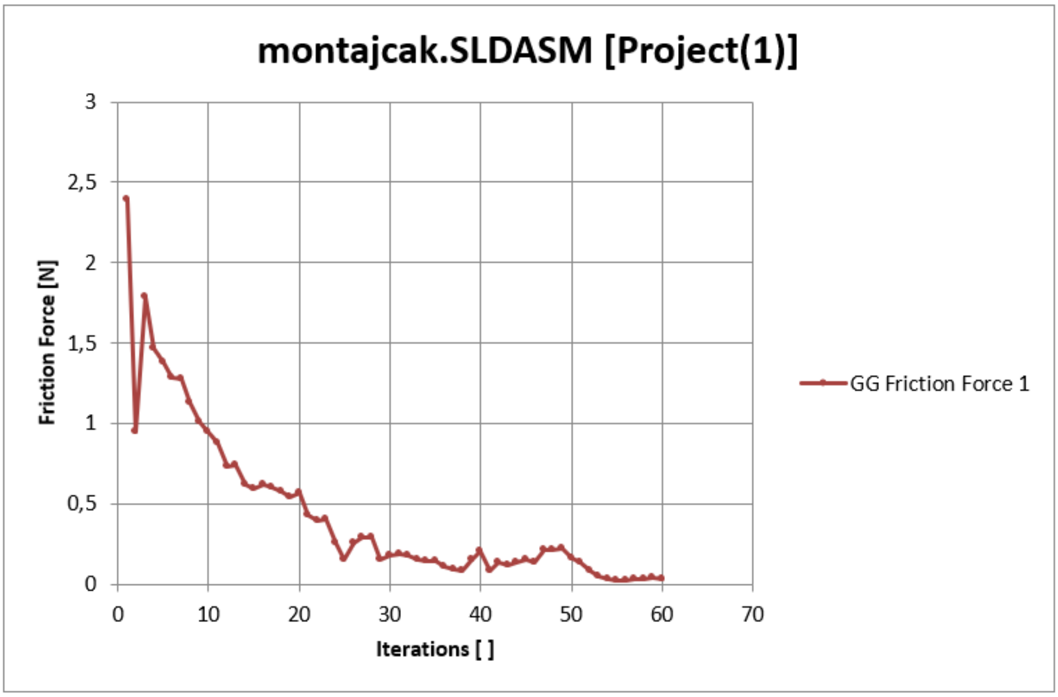


Figure 13. *Pressure force affecting on wheels*

In Figure 13, the regions shown in blue in our design on the left side are the regions where the pressure is the lowest. The pressure is highest in the wheel surface and in the rim hub, is the lowest on the rim wing tips. The pressure force in the right side on standard wheel is shown to be almost the same level everywhere.

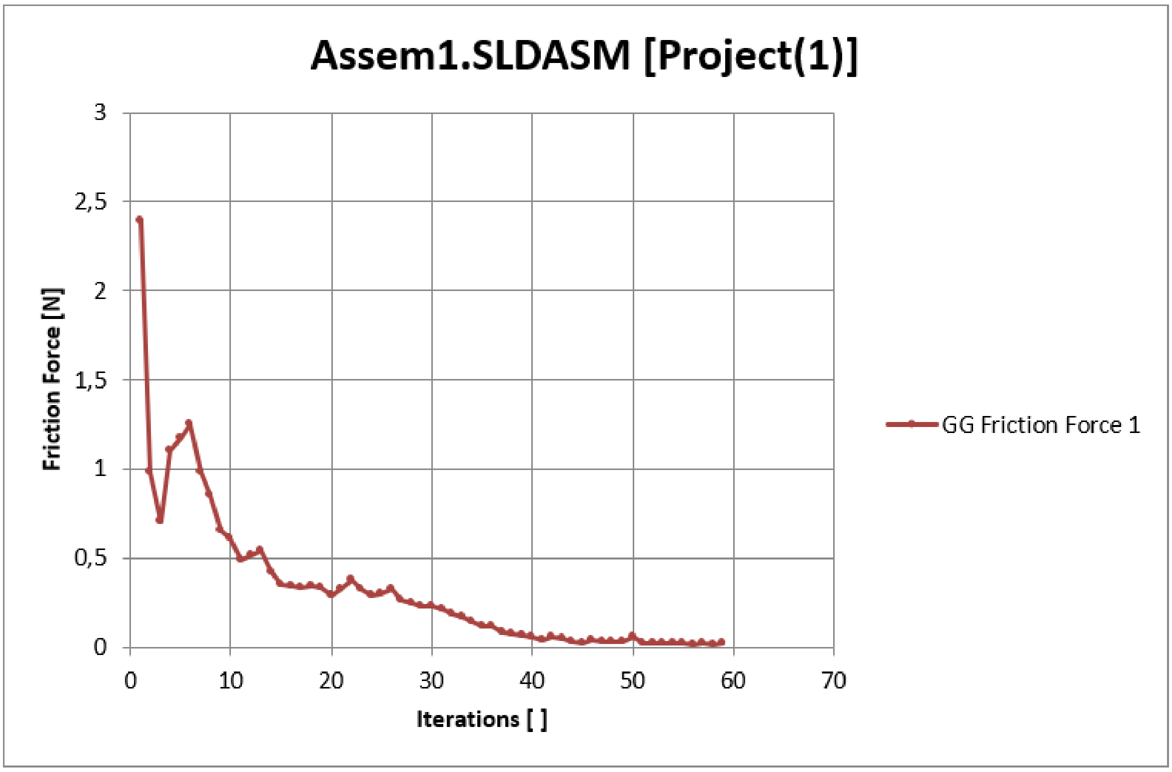
5. CONCLUSION AND DISCUSSION

Table 3*. Friction force and graph of the standard rim in the analysis*



Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value	Progress [%]	Use In Convergence	Delta	Criteria
GG Friction Force 1	[N]	0,033599914	0,1066891	0,020209924	0,218468025	100	Yes	0,106393681	0,25525732

Table 4. *Friction force and graph of the designed rim in the analysis*



Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value	Progress [%]	Use In Convergence	Delta	Criteria
GG Friction Force 1	[N]	0,020172636	0,033711883	0,016079807	0,0656147	100	Yes	0,049534893	0,178829691

In Table 3, the average friction force of the standard rim in the analysis was calculated as 0,1066891 N. In Table 4, the average friction force of the designed rim in the analysis was calculated as 0,033711883 N. It is seen that there is 68,4% gain in the friction force of the rim designed by taking the wing shape from the birds and the cross-sectional surface of the raindrop, according to the analysis parameters compared to a standard rim designed.

These analyzes show that the design inspired by birds' gliding wing movements reduces air resistance and has a positive effect on the aerodynamics of the wheel. Reducing this resistance force caused by air on the wheel will increase the fuel economy of the vehicle. Air entering the wheel will improve the braking performance by cooling the brake system during braking.

This design resulting is possible adapting to automotive, aerospace, renewable energy sources and similar sectors. This design can be further improved and optimized. In this way a design can result the lowest air friction.

CONFLICT OF INTEREST

No conflict of interest was declared by the authors.

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