Designing Shell Eco Marathon Car Bodies with Solid Work

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Abstract. The Shell Eco Marathon is a world-class car competition for students. Through this competition, students compete to create innovation and creativity in the development of vehicle technology. The final result of this competition is the birth of vehicles that are economical, environmentally friendly, including a lightweight and aerodynamic body. This study aims to produce an urban concept car body design for racing purposes, with several provisions that comply with the Shell Eco Marathon competition regulations, have a low drag coefficient and turbulence value. This research includes research and development (R&D), using the ADDIE development model (Analysis, Design, Development, Implementation, and Evaluation). The test object is the 3D urban concept body shape design. The development of the urban concept body design uses the Solid work 2018 software with a flow simulation feature to analyze 3D urban concept body shape designs. The results of this research and development are (1) the design of the car body shape has met the competition regulations, (2) the drag coefficient value can be achieved at 0.1965, and (3) the value of turbulence intensity can be achieved at 0.133%. The results showed that the development of the urban concept body shape design was as planned.

1. Introduction
Shell Eco Marathon is a unique global program where students design, build, and drive ultra-energy-efficient cars. After the students have succeeded in making an energy efficient vehicle, then the vehicle is competed in a certain category, the winner is the vehicle that uses the least energy. This competition is not only about a race for energy efficient cars but also about environmentally friendly materials. The committee will give prizes if the vehicles are produced using recycled or environmentally friendly materials.

The SEM competition demands student creativity in realizing energy efficient vehicles. This competition is divided into two groups, namely Prototype and Urban Concept". Prototype is a future vehicle that is specially designed to have maximum fuel efficiency. This type has 3 wheels, is long and has a low height, unlike cars in general. A prototype energy-efficient car, designed with the driver in a position to tend to sleep with his head on the back and facing forward. Urban concept is an energy efficient car that has four wheels, but is smaller in size compared to vehicles in general.

SEM is competed in three categories of energy used, namely Internal Combustion Engine (ICE), Hydrogen Fuel Cell, and Battery-Electric. This is also in line with the opinion of the Shell Eco Marathon Team (2020) "The Shell Eco-marathon competition is currently divided into three energy categories: internal combustion, battery-electric, and hydrogen fuel cell". The ICE category is divided into three more categories, namely gasoline, diesel and ethanol. In the ICE category, fuel is generally mixed with air and detonated to generate power like a typical vehicle. For the Hydrogen Fuel Cell category, the hydrogen liquid will be reacted with air (O2) to generate electricity. The flow of electricity is used to
rotate the electric motor as a driving force for the vehicle. As for the Battery-Electric category, the flow of electricity from the battery will be used to drive the electric motor as direct driving power for the vehicle.

The winner of this competition is determined by the team with the vehicle that can cover the farthest distance (the least energy consumption). The fuel used is Shell Petrol/Gasoline 95 for the ICE class. As for the Hydrogen Fuel Cell category, what is measured is the consumption of liquid hydrogen used. For Battery-Electric, what is measured is the number of KWH (Kilo Watt Hour) that is measured to cover a certain distance.

Garuda UNY Team (GUT) participated in the 2018 Shell Eco Marathon Asia competition which was held at the Changi Exhibition Center on March 8 - 11 2018 for the urban concept type, named Urban Gasoline 18 (UG18). Garuda UNY Team in the competition was able to achieve the best results with an urban concept vehicle, namely 215 km/l, 100 km/l adrift of the best results of the competitor team with 315 km/l. This striking difference is one of the reasons it is suspected that one of them comes from the vehicle body.

Based on the results of observations and analysis in the field, there are three things that need to be evaluated on the urban car of the GUT Team, namely adjusting the legs of the vehicle, adjusting the ECU, and designing the body shape. The things that need to be done in adjusting the legs of the vehicle are to use the bearings with the lowest friction, adjust the wheel angle so that when walking straight and turning has low resistance, and use tires with the lowest rolling resistance. The ECU (Engine Control Unit) setting functions as a fuel regulator, in order to be able to produce the least fuel consumption but have sufficient power. The design of the energy-efficient car body shape has a great influence on energy-efficient cars. Efficiency of fuel consumption in energy efficient cars can be achieved by making a vehicle with a low wind resistance (drag coefficient), and designing a lightweight vehicle structure.

The UG18 vehicle body has a fairly high wind resistance, namely 0.4087. The main factor that makes the drag coefficient high is the force generated after being analyzed with a certain speed, the value is quite high, namely 37.54 N (GG Normal Force X). If the force value resulting from the analysis is getting smaller, the drag coefficient value will also be smaller. The large cross-sectional area of the vehicle is thought to be a factor in the high value of the drag coefficient.

The UG18 vehicle body has quite high turbulence on the sides of the front wheels as well as the rear of the vehicle. Turbulence has a big effect on the vehicle's glide power. If a car has a relatively low turbulence, then the car has a great glide power. Another problem that arises is the total mass of the UG18 vehicle, which is 98 Kg. Based on observations during the race, the competitors' urban concept cars weigh around 65-85 kg on average. The total mass of the vehicle is divided into several parts of the vehicle, namely: (1) vehicle body, (2) chassis and wheels, and (3) engine. To reduce the total mass of the vehicle, it is necessary to reduce the weight of the parts above. Reduction of body mass can be done by using composite materials such as carbon fiber. In order for the vehicle body to have a smaller mass, the vehicle body is made not too thick (0.8-1.5 mm) but strong. The reinforcement of the vehicle body that is not too thick can be made with indentations in areas that are deemed less strong. Reduction of chassis mass is done by choosing a lightweight frame material and a strong design, for example Series-7 aluminum, including the wheel mechanism. This study seeks to obtain a lightweight body with good aerodynamics, thus realizing fuel efficiency.

2. Research Methods
This research includes development research with the Analysis, Design, Development, Implementation, and Evaluation or ADDIE models (Branch, 2009). Virtual trials in the Solidworks system, held in July - August 2018 and November 2019 - June 2020. The test object is a three-dimensional design of the urban concept body called Urban Gasoline 19 (UG-19), which is a development of a car design. UG18. The instrument used was Solidworks 2018 software with data collection techniques using the observation method with observation sheets. The observation sheet is obtained from the final results of a three-dimensional design product analysis using the flow simulation feature with solidwork software.

The analysis stage is a literacy study stage regarding body shape, especially for the needs of energy-efficient car competitions, as well as an analysis of the UG18 body and examining the regulations of
Shell Eco Marathon 2019 (vehicle body). The design stage consists of (1) making a 3-dimensional urban concept body shape design or UG 19 V1 using Solidworks 2018 software, (2) product analysis (design of a 3-dimensional urban concept car body called UG 19 V1) using the flow simulation feature in the software Solidworks 2018, and (3) ask for input from experts or experts regarding the UG19 V1 body shape design. The development stage, is the stage of developing the first product that has been redesigned after receiving input from experts by designing the UG19 V2 urban concept body shape. The implementation stage is the analysis of the 3-dimensional urban concept car body design after input from the expert (UG19 V2) using the flow simulation feature. The evaluation stage aims to measure the achievement of the target values for the coefficient of drag (CD), the coefficient of lift (CL) and the intensity of turbulence (IT). If the target is not achieved, a re-design and re-analysis is necessary.

3. Results
After seeing the data and some shortcomings in the UG 18 concept car, researchers designed a three-dimensional model of the UG19 urban concept car body shape. To save costs and do not yet have a wind tunnel for testing the actual workpiece, the car body is designed in soft file, and analyzed using 2018 Solidwork.

![Figure 1. Isometric View and UG Specifications 19 V1.](image)

After designing the first three-dimensional UG19 V1 product, it is analyzed using the flow simulation feature, and the results can be seen in Figure 2.
After being designed and tested, then the results are known as in Figure 2. Then input from the expert was asked, and the following input was obtained: (1) the front end of the body was made more oval, (2) the right front end and the left front end were designed to be more radius (curved), (3) shorten the length of the back, and (4) the rear side is designed to be more sloping or curved. After getting input from the expert, the next process is to design the UG 19 V2 body shape according to input from the expert. Figure 3 is the result of the body shape design after getting input from the expert or UG19 V2.

**Figure 2.** Simulation Results of UG 19 V1.

**Figure 3.** Isometric View Design Forms and Body Specifications UG 19 V2.
4. Discussion
UG19 V1 is an initial development design according to the study, while UG19 V2 is a development design after receiving input from experts. Comparison of the results of CD, CL, and IT body design UG 19 V1 and V2 can be seen in table 1.

Table 1. Coefficient lift, Coefficient drag, and Turbulence Intensity Body Shape Design UG19 V1 and V2.

| Goal Name          | Body UG19 | Velocity 40 km/h | Velocity 30 km/h | Velocity 20 km/h |
|--------------------|-----------|------------------|------------------|------------------|
|                    | V1        | V2               | V1               | V2               | V1               | V2               |
| Coefficient of lift| 0.3542    | 0.2642           | 0.3491           | 0.2379           | 0.3598           | 0.2175           |
| Coefficient of drag| 0.2684    | 0.1945           | 0.2695           | 0.1940           | 0.3221           | 0.2010           |
| Intensity of turbulence | 0.10     | 0.11             | 0.10             | 0.11             | 0.10             | 0.13             |

Figure 4. Simulation Results of UG 19 V2 Body.
Based on Figure 5, the CD of the vehicle body generally decreases from a speed of 20 km/h, to a speed of 30 km/h and 40 km/h for both UG19 bodies. On the UG19 V2, the difference in CD for various reduction speeds is relatively small, this shows that the body already has an ideal shape. Meanwhile, between the UG19 V2 and UG19 V1 forms, the CD decrease is quite significant by 32%. Decreasing the value of the CD is a target for the development of energy-efficient vehicles, because the smaller the CD value, the higher the efficiency of fuel consumption.

From this figure it is also known that the UG19 body design in general the CL number increases linearly with each increase in speed. When compared to the UG19 V2 and V1 bodies, the results have significantly improved, namely a decrease of 33%. The decrease in CL value affects traction when the vehicle accelerates. When the CL value is too high, the vehicle body will tend to lift and will cause low traction of the vehicle. This has a slight disadvantage; therefore, energy efficient vehicles do not require high CL values.

There was an increase in the turbulent value of about 0.013% of the turbulence value of the UG 19 V1 body shape design. The increase in turbulent value is due to several design changes to the body shape design of the UG19 V2. A significant change is in the rear of the vehicle. The tail length is cut after getting input from the expert. Cutting the length of the tail is intended so that the total body mass of UG 19 is not too high. However, cutting the tail causes the negative pressure to increase slightly so that turbulent flow also increases in the area. Overall, the turbulent value in the UG 19 V2 body shape design averages only 0.133%.

The evaluation stage, is the stage where the data results will be an indicator of target achievement. The target in this study is to reduce the CD value and the turbulence intensity of the UG
When compared to the UG18, the UG19 V2 has drastically decreased the turbulence intensity compared to the UG18 body shape design, which is a maximum of around 91%. Decrease in the value of the CD, and turbulence in the development of the UG 19 V2 body shape design based on the results of the UG18 problem analysis, supported by theoretical studies and also input from experts. Thus, this research has met the target, and the UG19V2 urban concept body design can increase the efficiency of fuel consumption.

5. Conclusion
The design of the UG 19 V2 body shape meets the design regulations, this is because all parts of the design begin with a sketch or outline of the regulatory limitations of the urban concept vehicle, including the maximum length of the vehicle, the maximum height of the vehicle, the maximum width of the vehicle, the minimum height of the door, the minimum width. doors, minimum wheel base length, front track width, rear track width, designed at the beginning of the 3D design step with solidwork 2018 software. Development of the UG 19 V2 body shape design is better than UG 18, marked by the drag coefficient results (CD) and turbulence which has decreased. The UG 19 V2 body design has a CD value of 0.1965 or lower than the previous body shape (0.4087) or a decrease of 52%. The UG 19 V2 body shape design has an average turbulence intensity value of 0.133% or lower than the previous body shape (92%) or a decrease of 91%.

6. References
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