Energy Saving Strategy and Realization of Honda Eco-car body

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Abstract: How many miles can an eco-car run with 1 liter gasoline? The saving fuel requirement is presented by Honda Eco Mileage Challenge (HEMC) to the competing teams. In order to save fuel of eco-car during the race, each team adopts different methods and strategy. In this study, kinds of saving fuel methods of car body are put forward. According to automobile design theory, the car shell with low coefficient of aerodynamic drag and frontal area is designed and made. The frame model is built and simulation analysis with enough torsion rigidity, strength, and light weight is finished in the software UG and ANSYS. The material object of frame and car shell are made.

1. Introduction
Honda Eco Mileage Challenge (HEMC) is sponsored by Mr. Koichiro who is the founder of Honda. It was founded from 1981. There are more than 500 teams all over the world every year. In China, it starts from 2007 and has been hosted 13 times from then on. From the regulation [1], the HEMC is a competition events to challenge the energy-saving extreme with racing car made by the teams independently. In which the engine is supplied from Honda company and can be modified according to the regulation at will, which is 125CC, 4 strokes, single cylinder, air-cooled. The competition result ranks based on the fuel consumption by running 4 cycles at the velocity of above 25km/h. There are kinds of methods of energy-saving on the vehicle.

Xie [2] proposed the carbon fiber composite application advantages in the development of automobile cooling. The key technology problem is analyzed. The result showed that it can improve the fuel economy of the vehicle well and realize the lightweight with the carbon fiber composite materials.

Yu et al.[3] studied the energy consumption. The results demonstrate that the fuel consumption presents in the damper configuration, friction factor, vehicle mass, the road roughness and the vehicle speed. Under the urban driving cycle the energy regenerative suspension has a hopeful potential.

Yao et al. [4] analyzed the principle of energy flow of electric vehicle and studies the potentials energy-saving of different vehicles under different driving conditions. By comparison of AVL/Cruise simulation, the method of the paper can analyze the potential of vehicle energy-saving.

Ma et al.[5] optimized and designed the aluminum alloy frame of energy-saving vehicle by combining static analysis and optimization procedure with the finite element analysis software ANSYS and Hyperworks. The stiffness and strength of an energy-saving vehicle aluminum alloy frame were analyzed under typical condition. The frame quality reduced by 16.6%, which has realized light-weight of the energy-saving car.
Rahul K. Jape et al.[6] achieved lightweight of automobile wheel rim with Finite Element analysis (FEA). Result showed that the weight optimized of wheel rim reduced to around 50% as compared to the solid disc type Al alloy wheel. Meanwhile the FE analysis indicated that mechanical properties could also meet the requirement of material.

Zhu [7] concluded that lightweight structure design and analysis is the main way of lightweight. It could reduce the mass of vehicle frame and suspension by optimization design of structure. It was a main trend to use the high-purity magnesium alloys, because the magnesium alloys have distinct advantages over aluminum and ferrous materials. Besides, another advantage of the lightweight automobile body is safety for its little mass inertial.

Sun et al. [8] studied the lightweight materials on vehicle to save energy. A new approach to lightweight materials instead of mild steel was introduced. The result showed that fuel consumption was decreased by reducing weigh of vehicle. It concluded that if the costs of lightweight materials were as much as traditional materials, lightweight materials would be widely used in the automobile industry.

Gu [9] analyzes the characteristics of car external flow field based on Fluent. The differences of flow field of the car without wheels and with wheels are comparatively studied, a theoretical basis for Characteristics of Car External Flow Field is provided.

2. Lightweight design of carbon fiber composite car shell

Carbon fiber composite (CFC) body is more advantageous than traditional material especially in weight. The density is usually 1.7g/cm³, which is much lower than the normal steel. In the environment of 2200°C, CFC can still keep the strength of room temperature. Its toughness, anti-fatigue performance, creep resistance, tensile strength, and elastic modulus are higher than general carbon material.

2.1. Air drag(AD)

Air drag(AD) is one of the four running drags of automobile [10]. It affects the fuel economy of the automobile to a great extent. In order to improve the fuel economy, it’s necessary to reduce the AD. The direct way is to decrease the frontal area(FA). According to the reference [10], the AD can be available by the formula below.

\[
F_w = \frac{1}{2} \rho A C_D \mu_r^2
\]  

Where \( F_w \) is AD; \( C_D \) is air drag coefficient; \( A \) is FA; \( \rho \) is air density, defined as 1.2258kg/ m³; \( \mu_r \) is relative velocity between the air and automobile(m/s). \( \mu_r \) is the running velocity with unwind; \( \mu_r = \text{running velocity} - \text{wind velocity} \) when following wind; \( \mu_r = \text{running velocity} + \text{wind velocity} \).

From the formula (1) above, \( F_w \) is proportional to the FA. To reduce FA is the key to decrease the AD of car shell.

2.2. The optimized car shell model

Based on the ergonomics, aerodynamics, streamline and fuel economy requirements, driving space, and rearview mirror arrangement, steering angle, and visual field, the 3D model of racing car shell is made, which is shown in Fig.1 . The original design inspiration is from the drop. The smooth head and convergent posterior part can reduce the AD and avoid the vacuum.

![Fig.1 3D model of the racing car](image-url)
2.3. Mesh and calculation
The optimized model of car body shell is imported into ANSYS Workbench, and flow field is established around car shell. The dimension of the flow field are identified to be 6 times of car length, 4 times of the car width on the sides, 4 times of the car height [11,12]. In ICEM of ANSYS, tetrahedral mixed mesh type, octree method are performed in the model mesh generation. Structured grids are encrypted locally as Fit. 2. The total mesh quantity is 36792267. In this study, k-ε viscous model are adopted for the simulation of drag and lift calculation. The inlet velocity of boundary condition is set to 13.9m/s, which is the highest sliding speed of racing car. The FA of racing car is 0.52 m² which is measured in UG and AutoCAD. The ground is set as the moving wall in wall motion. The speed is also 13.9m/s.

Fig.2 Mesh generation

2.4. Simulation result and analyses
The distribution result of pressure on surface of the car is shown in Fig.3. There is distinct positive pressure area in the front windward area of the car. The pressure and windward area are the largest of all the surface of car. The front part encounters air flow when running, which results in the high pressure at the front end of the car body. The airflow runs along the top and bottom surface. The airflow accelerates much more as there is no obstacle. Therefore, negative pressure forms at the top and bottom of the car body.

The shape of car body is designed as the tail fin of a fish or water-drop. The tail tapers at the end of the tail. The result is that when the air flow runs into the tail, there is no negative pressure, but positive pressure.

Fig.3 Static pressure contour on the car at 50km/h

Fig.4 shows the vector of airflow velocity at 50km/h. The airflow velocity of front and tail of the car body is the lowest, and the velocity of top and bottom is the highest, which is relative to the static pressure contour. From the velocity vector and streamline figures of Fig.4 and Fig.5, it can conclude that the optimized shape of car body will not form the negative pressure at the tail which will decrease the speed of the car. The air drag coefficient decrease from 0.18 to 0.11.
By processing and making form piston, female die, tube layout, vacuum pumping, resin injection, the material object of CFC car shell is finished as Fig.6.

3. The optimized aluminum alloy application on the frame
The frame is to load most of the weight of the racing car. Therefore, it is necessary to reduce the weight and also guarantee strength and rigidity. It needs to realize loading, location, spatial arrangement, and operation path requirements from all of the related parts of the car. In this paper, Binhai team selects the material of strength aluminum alloy 6061 to make the frame. Considering lightweight, strength, and machine work convenience, aluminum alloy 6061 square tube (section size: length-40mm, width-20mm, wall thickness-2mm) is adopted into the frame work. The frame model is shown as Fig.7.
The mesh is generated in workbench and the grids nodes is 1399396, elements is 5679447. Load and support are shown as Fig.8. A is the standard earth gravity. B and C are supports in direction X and Y. D and E are the forces from the driver (441N) and engine(147N). From the Fig.9, it can be concluded that the max total deformation is 0.14128mm and the max equivalent stress is 40.283MPa, which is much smaller than the yield strength 280MPa. The deformation is also acceptable and occurs at the load of frame. The material object of the frame is made and shown as Fig.10.
4. Other methods

4.1. Start and acceleration strategy
The racetrack includes uphill and downhill roads, sharp turns, straight roads. A good start and acceleration strategy is very important. The driver should start engine only once and accelerate the car up to about 50km/h. When uphill and other racetrack conditions, engine shutdowns and skidding. With inertia, the racing car can rush through the uphill and other racetracks. When downhill, start and accelerate again. Repeat this process, until the race ends. So the principle is that the less times of start and acceleration, the better result.

4.2. Racing driver selection
Lightweight is mainly aimed at total weight, including racing car and racing driver. Therefore, racing driver weight is a factor that cannot be neglected. The racing driver has to be familiar to the racing car, racing track, and driving. He or she also should be brave and careful, and has good mentality. The more important is that the driver has light weight, so that fuel consumption will reduce evidently.

5. Conclusions
Carbon fiber composite car shell is lighter than the original one. The weight decreases from 25kg to 13kg. The aluminum alloy frame is much lighter than the last one. The weight reduces to 8.5kg. According to the simulation and field test, results show that the strength is enough. Besides, the strategy of start and acceleration, and drivers’ selection can greatly improve the economy of the racing car.

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