Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 90 (2014) 308 – 313

Procedia Engineering

www.elsevier.com/locate/procedia

10th International Conference on Mechanical Engineering, ICME 2013

Numerical Study on Aerodynamic Drag Reduction of Racing Cars

S.M. Rakibul Hassan*, Toukir Islam, Mohammad Ali, Md. Quamrul Islam

Department of Mechanical Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh

Abstract

Aerodynamic drag is one of the main obstacles to accelerate a solid body when it moves in the air. When a racing car or road vehicle burns fuel to accelerate, drag force pulls it from back to reduce the speed and hence the fuel efficiency is adversely affected. About 50 to 60% of total fuel energy is lost only to overcome this adverse aerodynamic force. To win a race, which may be decided by fraction of second, the racing cars need a faster acceleration, which is possible by reducing the drag force by optimizing its shape to ensure stream-lining or reducing the separation. Reduction of aerodynamic drag has become one of the prime concerns in vehicle aerodynamics. This article is concentrated on different aspects analysis of aerodynamic drag of racing cars and different drag reduction techniques such as rear under body modification and exhaust gas redirection towards the rear separation zones. Through a numerical process (Finite Volume Method) of solving the Favre-averaged Navier-Stokes equations backed by k–epsilon turbulence model, the drag coefficient of the car under analysis is found to be 0.3233 and it is evident that the drag can be reduced up to 22.13% by different rear under-body modifications and up to 9.5% by exhaust gas redirection towards the separated region at the rear of the car. It is also evident that if somehow the negative pressure area and its intensity at the rear of the car can be minimized, the separation pressure drag is subsequently reduced.

Selection and peer-review under responsibility of the Department of Mechanical Engineering, Bangladesh University of Engineering and Technology (BUET)

Key Words: Aerodynamic drag; separation; coefficient of drag; under-body diffuser; exhausts gas redirection.

1. Introduction

Aerodynamic drag of racing cars has probably received highest attention over last five decades in experimentaland practical field of fluid dynamics. Many researchers and authors have described different forms of

* Corresponding author. Tel.: +8801920795748
*E-mail address:*rakibulhassan21@gmail.com

Selection and peer-review under responsibility of the Department of Mechanical Engineering, Bangladesh University of Engineering and Technology (BUET)
doi:10.1016/j.proeng.2014.11.854

drag, possible reasons behind them and several ways of minimizing the drag. Katz's [1] work was fully devoted for the racing car aerodynamics and he described the different aspect of car design or streamlining starting from the first generation automobiles to most recent models, but no numerical or experimental procedure was explained to measure the drag. Computational analysis to reduce the drag is performed by Barbut et al. [2], Rouméas et al. [3] on road vehicle and by Guilmineau [4] on the simplified car body (Ahmed body). Islam and Mamun [5] performed numerical and experimental study to measure the aerodynamic drag, but their work was concentrated on sedan car only and they did not investigated any drag reduction technique. Aerodynamics of sedan cars and racing cars are different in many aspects like speed and effects of body constructions. Koikeet al. [6] introduced vortex generators to reduce the drag of racing cars. But effectiveness of vortex generator is restricted by the body shape of the car. Work of Krishnani [7] is not only very informative about the sport utility car, but also for drag reduction techniques. But this work does not concern with racing cars specifically.Adem [8] worked on vehicle aerodynamics and described the aspects of aerodynamic drag, but his work was subjected to a pick-up truck.Work of Damjanović et al. [9] is one of the recent studies on race car aerodynamic drag that includes both two dimensional and three dimensional analyses. But they only described the reduction of drag by using spoiler. Islam et al. [10] worked on calculating the drag force of racing car. A comparative drag analysis of sedan and square back car is performed by Bijlani et al. [11] and found that sedan car produces less drag than square-back car. A very few research paper has clear indication about the specific area that has to be used in drag calculation as different drag force is subjected to different area.In this work, numerical simulations are performed to analyse the drag of a racing car and some procedures to reduce it by reducing the flow separation.

2. Numerical Method

Favre-averaged Navier-Stokes equations are used here, where time-averaged effects of the flow turbulence on the flow parameters are considered. Flow simulation employs transport equations for the turbulent kinetic energy and its dissipation rate, the so-called k-ε model. Flow simulation employs one system of equations to describe both laminar and turbulent flows and transition from a laminar to turbulent state or vice versa is possible. The set of equations for Newtonian fluids are:

$$\frac{\partial(\rho u_i)}{\partial x_i} = 0$$

$$\frac{\partial(\rho u_i u_j)}{\partial x_j} + \frac{\partial \mathrm{P}}{\partial x_i} = \frac{\partial}{\partial x_i}\left(\mu(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} - \frac{2}{3}\delta_{ij}\frac{\partial u_k}{\partial x_k}) + \mu_t(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} - \frac{2}{3}\delta_{ij}\frac{\partial u_k}{\partial x_k}) - \frac{2}{3}\rho k\delta_{ij}\right) - \rho g_i$$

$$\frac{\partial(\rho u_i \mathrm{H})}{\partial x_i} = \frac{\partial}{\partial x_i}\left[u_j\left(\mu(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} - \frac{2}{3}\delta_{ij}\frac{\partial u_k}{\partial x_k}) + \mu_t(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} - \frac{2}{3}\delta_{ij}\frac{\partial u_k}{\partial x_k}) - \frac{2}{3}\rho k\delta_{ij}\right)\right] - \rho g_i u_i - \mu_t(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} - \frac{2}{3}\delta_{ij}\frac{\partial u_k}{\partial x_k}) - \frac{2}{3}\rho k\delta_{ij}\frac{\partial u_i}{\partial x_i} + \rho\varepsilon$$

$$H = \mathrm{h} + \frac{u^2}{2}$$

Here δ_{ij} is the Kronecker delta, h is the thermal enthalpy, μ is the dynamic viscosity coefficient, μ_t is the turbulent eddy viscosity coefficient and k is the turbulent kinetic energy. Point to be noted that both k and μ_t are zero for laminar flow.In the frame of k-ε turbulence model, $\mu_t = f_\mu \frac{C_\mu \rho k^2}{\varepsilon}$. Here f_μ is the turbulent viscosity factor; defined as,

$$f_u = [1 - \exp(-0.025\,R_y)]^{2} \times [1 + \tfrac{20}{R_T}]; \qquad \text{where,} \quad R_T = \quad \text{and} \quad R_y = \frac{\rho k}{\mu}$$

Here *y* is the distance from the wall. This function of allows us to take into account laminar-turbulent transition. Two additional transport equations are used to describe the turbulent kinetic energy and dissipation at steady state,