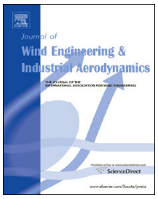
J. Wind Eng. Ind. Aerodyn. 134 (2014) 30–43

Contents lists available at ScienceDirect

Journal of Wind Engineering and Industrial Aerodynamics

journal homepage: www.elsevier.com/locate/jweia



Passive drag reduction of square back road vehicles

Alamaan Altaf[a], Ashraf A. Omar[b], Waqar Asrar[a,*]

[a] Mechanical Engineering Department, Kulliyyah of Engineering, International Islamic University Malaysia (IIUM), Jalan Gombak,
53100 Kuala Lumpur, Malaysia
[b] Department of Aeronautical Engineering, University of Tripoli, P.O. Box 13154, Tripoli-Libya

ARTICLE INFO

Article history:
Received 10 April 2014
Received in revised form
10 August 2014
Accepted 11 August 2014
Available online 14 September 2014

Keywords:
Bluff body
Passive drag reduction
Road vehicles
CFD
Elliptic flaps

ABSTRACT

Bluff body vehicles such as trucks and buses do not have a streamlined shapes and hence have high drag which can be reduced to make great savings in operational cost. While rectangular flaps have been widely studied as both passive add-ons and in active drag reducing systems for bluff bodies, changing the basic geometry of the flap has not been explored in literature. In this work, a baseline drag value is obtained for a simplified MAN TGX series truck in a CFD software, and the drag reduction of a proposed elliptically shaped flap is compared to aerodynamically equivalent rectangular flaps. The optimal mounting angle for both flaps is found to be 50°. A parametric study of changing the ellipse semi-major axis is carried out to find the optimal length for drag reduction. A maximum drag reduction of 11.1% is achieved using an elliptical flap with 0.12 m semi-major axis; compared to 6.37% for a length equivalent rectangular flap, and 6.84% for a surface area equivalent rectangular flap. Results of the pressure distribution and velocity flow behind the rear of the truck are also given and analyzed.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

While the importance of reducing aerodynamic drag of cars is well known and researched, the case of bluff (and/or square back) road vehicles such as trucks and buses has received less attention. In Malaysia alone, there are more than 20.18 million road vehicles, of which about 7.57% are heavy and light duty vehicles (Ministry of Transport Malaysia, 2010). These figures are suggestive of the economic size of the trucking industry. The commercial vehicle sector unlike the private car industry discourages frequent releases of new models due to different market dynamics. New models take longer to design, produce and release to market, and are expected to stay in the market much longer than new models of cars. Also, due to the function they perform, and because of their relatively uniform prevalence all over the world, a great deal of money is spent on trucks and buses, especially in developing countries. Reduction of the aerodynamic drag of these vehicles can result in great savings by decreasing fuel consumption.

Overcoming aerodynamic drag on long haul journeys is the cause of most of the fuel consumption of trucks and buses. Heavy vehicles, due to their large frontal area and bluff shapes are aerodynamically inefficient and take up to 65% of fuel to overcome drag. As mentioned by Hsu and Davis (2010), it is estimated that with a drag reduction of about 40% for trucks, a saving of $10,000 per vehicle can be made every year.

Aerodynamic drag force on a body is caused by the body's profile, and its surface area. The corners of square back vehicles cause air flowing past the moving vehicle to separate, leading to a major pressure drop which induces a large wake behind the vehicle. The separation can be attributed to two factors – first, the inability of flow to move past sharp corners and second, lack of energetic flow at this point. For such bluff bodies, the profile drag (wake) contributes to 80–90% of total drag, while the remainder is due to skin friction drag. Thus, it is imperative that more attention be paid to drag reducing add-ons that reduces the rear wake.

Rectangular flaps have been widely studied, both in isolation affixed on the roof as well as on all four edges of the rear of a truck to mimic boat-tailing. However, no significant research has been conducted on the effect of changing the basic shape of the flap. This work proposes the use of an elliptically shaped flap for drag reduction. As far as the authors know, elliptically shaped flaps have not been employed for bluff body drag reduction.

Furthermore, most studies are conducted on a generic Ahmed body (Ahmed et al., 1984) rather than a realistically modeled truck. In this work, Computational Fluid Dynamics (CFD) simulations are conducted on a simplified truck model based on the MAN TGX truck series to establish a baseline drag value. An elliptically shaped flap is then designed and added on to the roof of the truck to study its drag reducing potential. A parametric study of the flap angle is conducted to determine the best angle for

---

* Corresponding author. Tel.: +60361964557.
E-mail addresses: alamaan@gmail.com (A. Altaf), waqar@iium.edu.my (W. Asrar).

http://dx.doi.org/10.1016/j.jweia.2014.08.006
0167-6105/© 2014 Elsevier Ltd. All rights reserved.

mounting the flap. A comparison is made with two similarly sized rectangular and triangular flaps – one with a laterally equivalent dimension; and a second with an equivalent surface area. Results showing the velocity distribution and pressure gradient behind the truck are given. The remainder of this paper is organized as follows: Section 2 reviews literature on studies of flaps, Section 3 provides details of the model and simulations, Section 4 presents results and their discussion and Section 5 concludes the paper.

2. Related work

Drag reduction techniques are divided into two main categories: active and passive. Active methods involve energy expenditure and usually a sophisticated control-feedback mechanism, while passive methods require no energy input and are more robust. Factors to be considered while choosing either of these techniques include industry standardization (weight/size), cost effectiveness (fabrication, installation, driver training, modifications-compatibilities), energy/power consumption, maintenance and vehicle usage.

Mohamed-Kassim and Filippone (2010) conducted a numerical study of fuel saving potential of various drag reducing retrofits. They found that vehicle parameters alone do not affect total drag; operational parameters have a large effect as well. It was found that using aerodynamics devices is optimal when these vehicles travel at high speeds on long haul driving cycles, as weight does not have any direct effect on drag. Driving through urban areas utilizes most fuel for acceleration and deceleration. These factors are important because every part of a truck contributes, positively or negatively, to the total drag of the truck. While studying the use of back-flaps on a full-sized truck, they found a reduction of 4–5% of total drag. This is one of the few studies conducted on a full-sized truck, however it did not address the shape or design of the flap, or approach the topic of optimizing the dimensions for maximum drag reduction.

Lee and Ko (2008) studied the flow field behind perforated Gurney-type flaps and concluded that perforated flaps are better than solid ones to reduce drag and wake width and unsteadiness. However the study was done on flaps alone, without any actual three dimensional (3D) body. Fourrié et al. (2010) in their experimental study using deflector on a generic car model found that drag reduction of up to 9% was obtained depending upon the deflector angle. Beaudoin and Aider (2008) did the experimental study on a 3D bluff body called Ahmed body, a commonly used 3D bluff body for benchmarking purposes, using flaps at all the edges on the two rear surfaces and found that the most efficient configuration was the two flaps on side edges of rear slant. Depending on various configurations, the drag could be reduced by 25% and lift by 107%. Ha et al. (2011) carried out an experimental and computational study of the drag reducing capability of a rear downward flap on a pickup truck. They found that the drag coefficient (C_d) was reduced with increasing the flap length. They deduced that the flap displaced the flow attachment enabling more downwash, hence reducing the reverse flow in the wake. With the increase in downward angle, there was an increase in drag reduction. They proposed that this happens because the cabin back pressure increases with the increase in downward angle, which reduces the drag coefficient. However the performance does not stay constant with increasing flap length and downward angle. It was suggested that the rear downward flap needs to be designed which would have an optimum downward angle.

Active control is usually obtained by blowing, suction, synthetic jets, actuated flows, etc. Nayeri et al. (2009) experimentally studied the effect of active and passive control in combination on a generic tractor trailer. Solid flaps with constant/oscillatory suction and blowing were used. Techniques such as flow visualization, six component balance, Laser Doppler Anemometry (LDA) and Particle Image Velocimetry (PIV) were applied. It was found that the smaller flaps with active control are more efficient than longer flaps without active control. Smaller flaps with constant blowing gave the best drag reduction of 8.81%. Also it was found that the flaps at the sides of the truck did not produce any significant drag reduction. This was attributed to the ground effect and ineffective slot length. However, as is pointed out in the paper the slot length for blowing was not optimized. Also the interaction of the lower part of wake with the ground boundary layer needs to be studied further.

Although it is seen that flaps have been widely studied in literature, little work has been done to investigate the change in the basic shape and dimensions of the flaps. The next section describes the methodology used to develop the CFD models of the truck and attached elliptical flaps.

3. Models

In this section, the baseline and modified models are described along with the simplifying assumptions employed and the general numerical procedure is outlined. The main simplifications made are:

i. Simplified geometry: since the major part of drag for bluff bodies is contributed by the frontal area the shape of cab, appendages, underbody, etc. are not considered (Leuschen and Cooper, 2009).
ii. Effect of cab-tailer gap is not studied in this work, hence the cab and trailer are considered to be one continuous segment.
iii. Simplified cut tires: the circular geometry of tires is simplified to rectangular shape near the road. These cut tires are used (a) to reduce computational load, and (b) rolling motion of truck is not considered in this work.
iv. Speed: as mentioned in Section 2, Mohamed-Kassim and Filippone (2010), showed that on long hauls, the major part of fuel is used to overcome aerodynamic drag. Thus the common highway speed limit of 30 m/s (108 km/h) is used throughout the paper.

3.1. Baseline model

The model used for this paper shown in Fig. 1 is based on the MAN TGX series – a common long haul class 8 truck often used to transfer heavy freight. All the models in this work adhere to the dimensions detailed in the blueprints of the truck (MAN Truck and Buses UK Ltd, 2011).

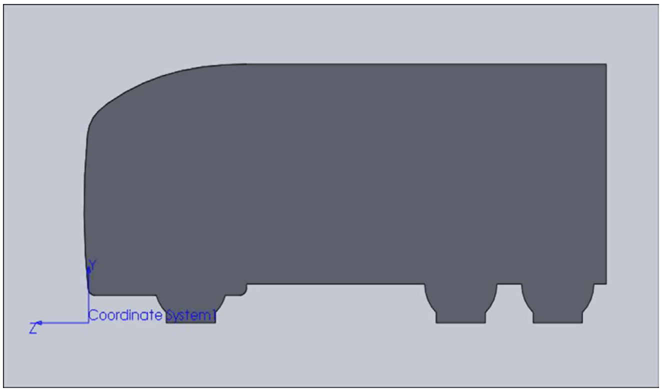


Fig. 1. Baseline truck.

Download English Version:

https://daneshyari.com/en/article/292834

Download Persian Version:

https://daneshyari.com/article/292834

Daneshyari.com