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Research Article

Installation of a Rear Fan on RC Race Car Body to Improve Drag

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Abstract:
Lola style body 1:10 scale radio-controlled electric race cars are one of the most popular categories among enthusiasts in Thailand. These cars usually have wedge-like body shells which generate large downforces but with a large wake downstream contributing to large pressure drag. This work aims to improve the car aerodynamic performance by installing a rear fan in a similar manner to Gordon Murray Automotive T.50, which has not been attempted on an RC racecar before. Wind tunnel experiments are successfully conducted to evaluate the effects of the rear mounted fan with different rotor diameters and rotation speeds. Test results suggest that the car aerodynamic downforce enhancement by the rear fan is most effective at low Reynold's number of 4.63×10^4*, where the downforce is observed to increase by 1,440%. Downforce increments at high Reynold's numbers of* 2.18×10^5 *and* 3.72×10^5 *are less effective as increases of 104% and 33% are observed, respectively. Drag forces are, however, observed to increase at all three sample Reynold's numbers. The highest increase in drag force of 242% is observed at low Reynold's number and, 16.7% and 8% at high Reynold's number. It can be concluded that the rear mounted fan helps improve the downforce through the extra suction under the body but does not reduce the pressure drag by narrowing the wake as had been anticipated.*

Keywords: *Racecar aerodynamics, Wind tunnel experiments*

1. Introduction

One of the most popular Radio Controlled (RC) racecar competition categories in Thailand RC is the 1:10 scale with a Lola body – a car body whose wheels are covered and aerodynamic forces are largely controlled with the car upper body without any under tray. A 3D model of such a car body which will be used in this study is shown in Fig. 1. Its dimensions measure 435 mm, 215 mm and 118 mm in length, width and height, respectively. This model is one of the most used by competitors in Thailand RC racecar competitions based on the data from Aunza Racing community from 2020.

The body shell is of a wedge design made of Crystal Clear Lexan. Its rear is significantly higher than the front with a considerably steep slope at the back. The wedge shape creates large aerodynamic downforce which helps the car achieve high cornering speed. However, the wedge design also creates a relatively wider wake downstream in comparison to other racecar bodies. Flow reattachment is not possible due to the steep slope at the rear edge which results in a large pressure drag which significantly reduces the car acceleration and top straight line speeds.

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In order to narrow down the wake and reduce the pressure drag, this study proposes to install an axial fan at the rear of the race car to induce flow over the car body to reduce the downstream separation or even generate a flow reattachment which will aid in pressure recovery and lowering the pressure drag. This idea is inspired by a similar fan installation on the GMA T50 car as shown in Fig. 2 and is a novelty in RC racecar application.

A smaller wake is favourable in longitudinal pressure recovery, hence will result in pressure drag reduction. Fan flow causes a pressure reduction downstream of the car body by Bernoulli's principles, and this suction effect in turns draws the flow over the car body so that the wake becomes narrower [1]. The profile drag or skin friction drag will not be affected because this study does not involve changes in car body skin roughness or car body profile. This paper only investigates the effects of total drag, separate assessments of profile drag and pressure drag are not attempted. The GMA T50 documentation [2] claims that the rear fan system can reduce up to 10% drag force. Hence, it is assumed that a similar fan installation on an RC race car should provide similar benefits to its performance too. In this study, the focus will be on quantitatively evaluating the effects of a rear-mounted axial fan on a 1:10 scale RC race car aerodynamic forces, namely drag reduction and increase in downforce.

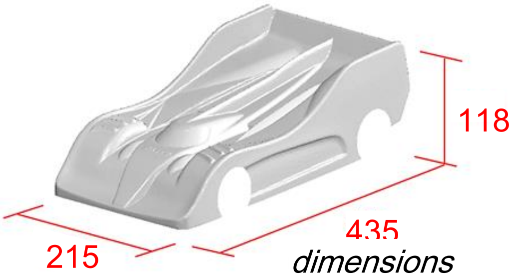

Fig. 1. Dimensions and exterior of 1:10 scale Lola body race car used in this study

The study only focuses on the 1:10 scale Lola body race car as depicted in Fig. 1. Wind tunnel experiments are conducted to analyse the race car aerodynamic forces with and without the effects of a rear fan. There are three fan parameters to be investigated (1) diameter of the rear fan blades (2) speed of the rear fan and (3) speed of the free stream velocity or the speed of the race car. Detailed scopes of each parameters are described below.

1. The diameters of the rear fan propellers are 2.0, 2.5 and 3.0 inches HQProp Durable [3-5]. Each propeller has the same profile and pitch.
2. The fan rotation speed is controlled by a 7.40 V regulated DC power supply. The current is manually controlled between 0-2.50 Amp to adjust the fan rotation speed.
3. The 1:10 scale RC race car is tested in an open section wind tunnel located at Department of Mechanical Engineering, King Mongkut's University of Technology Thonburi whose free stream velocity ranges between 2.0 - 12.0 m/s.

Note that the work presented in this paper is taken from an undergraduate thesis where all details of this work is fully given.

Fig. 2. Reduction of wake and flow reattachment over the rear of GMA T50 due to the induced flow by the rear fan [2]

2. Methodology

2.1 Experiment Setup

This section describes the laboratory equipment set up to accurately determine the aerodynamic drag and downforce on an RC race car with a rear-mounted fan. The open section wind tunnel with a rectangular opening of 90 x 70 cm and all installed test equipment are shown in Fig. 3. The maximum wind speed the wind tunnel is capable of is approximately 15 m/s.

An actual RC race car with Crystal Clear Lexan Lola Body is rigidly mounted on a customized load cell kit. The two-directional load cell mounting orientation, as taken from Ref [6, 7], is suitable for measurements of aerodynamic drag and downforce in the horizontal and vertical directions, respectively. The RC race car tyres hover about 1mm above the tabletop which is flush with lower edge of wind tunnel exit nozzle. There is, however, no moving floor at the same flow speed to eliminate the ground boundary layer effects therefore the experiments will contain some errors from them.

A 3D-printed constant cross section shrouding with 79.2mm diameter is installed around the propellers to avoid flow recirculating within the Lola body as the fan axial position is forward of the rear shell. A photograph of the rear fan duct is shown in Fig. 4.

The fan power source during an actual race comes from the race car main battery, however for simplicity, a DC power supply will be used as the fan source power in this experiment. This is to avoid the effect of battery voltage drop during the use and to keep the fan system voltage relatively constant during the entire experiment. The rear fan control diagram is shown in Fig. 5.

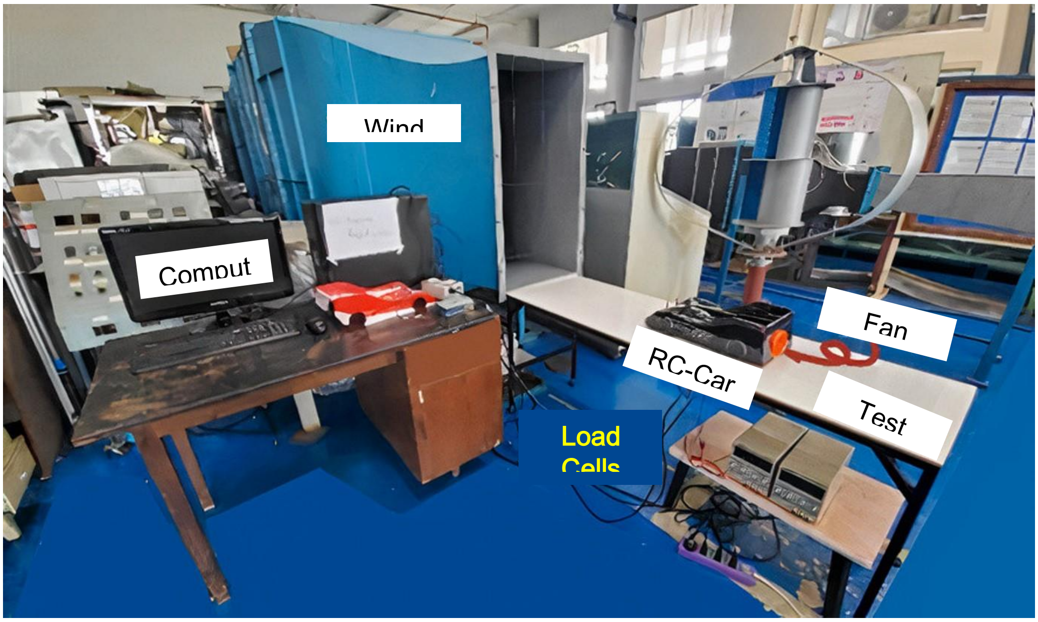

Fig. 3. Photograph of the wind tunnel experiment setup to measure aerodynamic loads on the RC racecar model

Fig. 4. Installation of a constant cross section duct over the rear fan

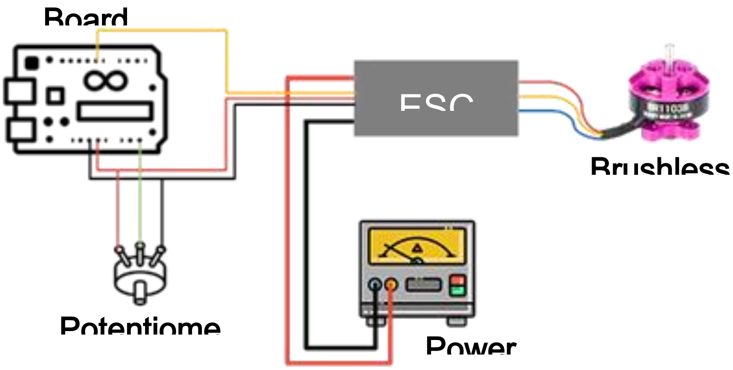

Fig. 5. Rear fan schematic control diagram

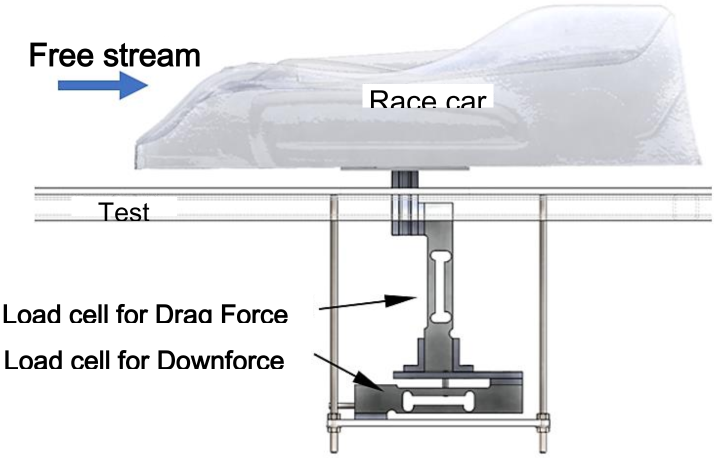

Fig. 6. Schematic side view of load cell configuration as suggested in Reference [6]

2.2 Load Cell Calibration

Aerodynamic loads are measured by the pair of load cells arranged in an L-shape setup as show in Fig. 6. In order to calibrate the load measuring setup, a set of standard masses ranging between 10-270 grams are placed on the car body or attached horizontally to the rear of the car with a string and a pulley to simulate aerodynamic downforce and drag, respectively. These known masses are used to calibrate the load cell readings via the use of Flexlogger software. It is found that the downforce readings achieve 99.77% accuracy with ±0.051 N uncertainty and a 99.85% accuracy for drag force with ±0.004 N uncertainty, hence all results presented in the following section are measured with the given accuracy levels.

3. Results and Discussions

Aerodynamic loads on the RC race car with various rear fan configurations from wind tunnel tests are presented in this section. Two separate load cells record the downforce and drag forces acting on the RC race car. These forces are ultimately presented in negative lift and drag coefficients. All aerodynamic loads presented in this section are mean values of 200Hz readings of data collected over 60 seconds when the flow around the RC race car has reached a steady condition.

The focus of the experiments is to assess the effects of the rear fan on the race car aerodynamics, hence the results will present the effects of the fan flow speed, fan diameter and the free stream speed. Free stream flow speeds are presented in Reynold's numbers.

3.1 Effects of Rear Fan Speed

Given that the study focuses on the effects of the rear fan speed, the fan diameter is kept constant in all experiments in this section at 2-inch. The fan speed is controlled by adjusting the current on a DC power supply where the maximum fan rotation speed corresponds to Reynold's number of 5.56 x 10^4. There are 6 fan speeds in the experiment including 'off' position. All fan speeds are tested under three different free stream Reynold's number to simulate three different car velocities.

Drag coefficients at different flow speeds are shown in Fig. 7. It shows that the total aerodynamic drag reduction is present at low free stream Reynold's number. The effect is so pronounced that the drag coefficient reverses from positive with the fan off to become negative at high fan speeds indicating a resultant thrust force is observed. However, its effects become negligible as the free stream increases beyond Re = 50 x 10^4. Greater fan speed shows larger reduction of drag coefficients where a maximum fan stream Reynold's number of 5.56 x 10^4 gives approximately 6 time greater than the drag coefficient at the lowest fan setting.

Lift coefficients of the RC race car show a similar trait as the drag coefficient. The desirable effects of the fan are most pronounced at low free stream velocity as the fan decreases the drag coefficient and increases the downforce coefficient as shown in Fig. 8. The drastic decrease in lift coefficient can be explained by the ground effect phenomena, where the fan sucks out air form under body lowering the pressure inside the body shell.

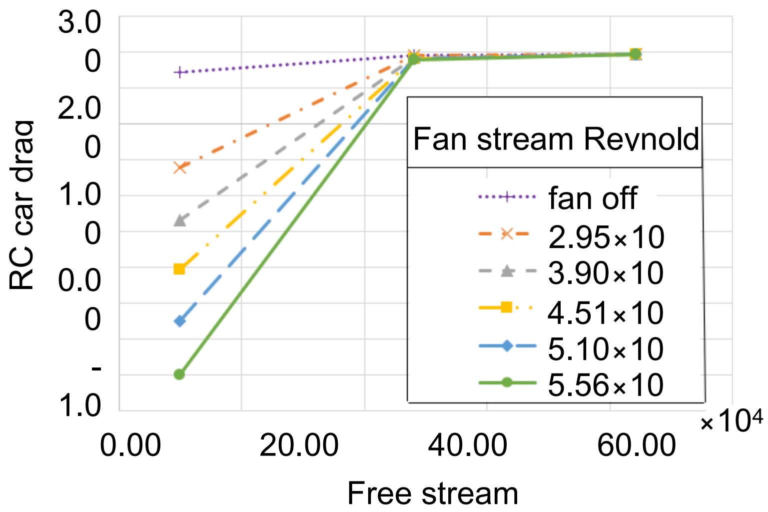

Fig. 7. Racecar drag coefficient decreases with greater fan speed at low free stream Reynold's numbers

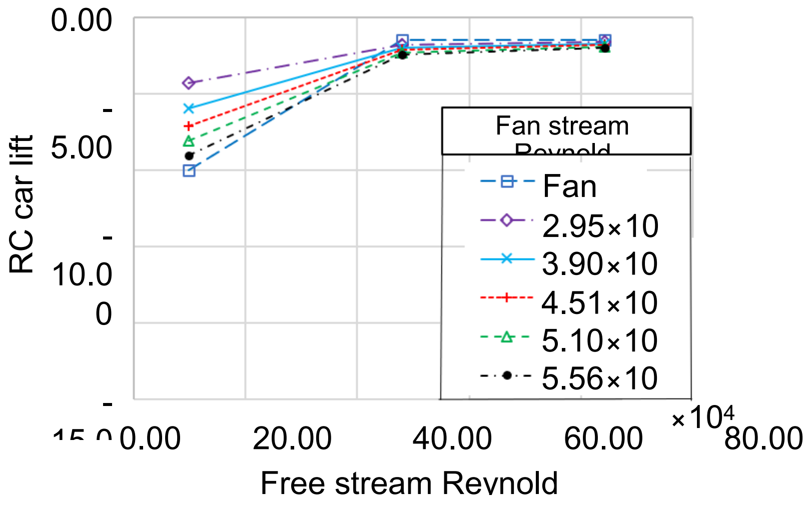

Fig. 8. Effects of fan speed on racecar downforce are more pronounced at low freestream Reynold's numbers

3.2 Effects of Rear Fan Diameter

A similar trend as the effects of fan speed is observed with the propeller blade length that aerodynamic effects of the fan are muted at high free stream Reynold's number. At low free stream Reynold's number, the 2-inch propeller shows the largest drag reduction and smallest gain in downforce in comparison to the 2.5-inch and 3-inch blades. An increase in lift coefficient when the propeller blade extends from 2-inch to 2.5-inch is approximately double the magnitude, but further extending the length to a 3-inch blade does not produce additional effects.

It is believed that the tip clearance [8] is the reason why there is little difference between the effects of 2.5-inch and 3-inch blades. A 79.2mm constant diameter duct which encases the fan allows very little tip clearance to 3-inch blades. Tip clearances for 2-inch, 2.5-inch and 3-inch blades are 14.2mm, 7.9mm and 1.5mm, respectively. Therefore, tip clearance and the boundary layer thickness effects for 2-inch blades are less felt and can possibly allow flow recirculation within the wide tip clearance, which results in less restricted flow and hence greater drag reduction.

However, both effects on drag and downforce are reduced to becoming insignificant at high free stream Reynold's numbers as shown in Figs. 9 and 10. Effects of the fan are negligible when compared to the drag and lift coefficients of the car without fans.

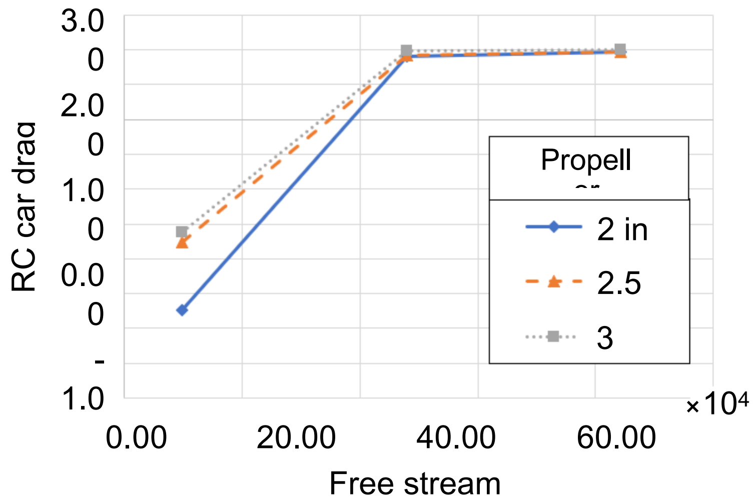

Fig. 9. Shorter propeller blades show greater reduction in drag coefficient at low free stream Reynold's number

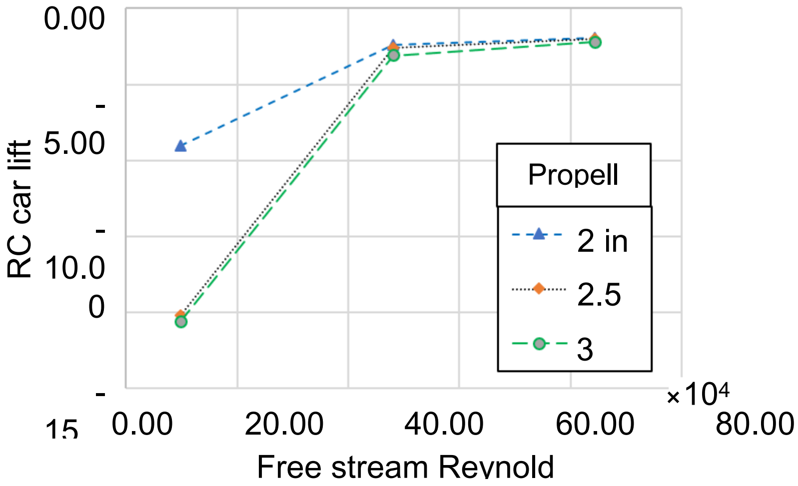

Fig. 10. Shorter propeller blades show lower downforce at low freestream Reynold's number

4. Conclusions

Results from the experiments demonstrate that installing a fan at the rear of a Lola body RC race car can produce a significant change in the car aerodynamic characteristics at car free stream Reynold's number below 20×10^4. The downforce, as indicated by the negative lift coefficient, can double in magnitude when compared to a car without fan. Benefits in drag reduction are also recorded in the region of Reynold's number below 20×10^4. Drag coefficients are negative showing that the thrust produced by the fan overcomes the aerodynamic drag. This effect is, however, reduced to negligible significance at Reynold's number greater than 40×10^4.

Finally, it can be concluded that there can be significant contributions to the car aerodynamic characters by installing a fan in the rear of a Lola body RC racecar. Drag reduction and downforce increment are favourable features to any racecar. However, these effects are limited to low free stream Reynold's numbers only. Further studies on the true benefits of rear fan installation might need a further look into application on RC racecar in an actual circuit. Many courses feature a number of tight corners so RC racecars operate under low Reynold's numbers where the fan can be beneficial.

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