

A STUDY ON AERODYNAMICS OF ATHLETIC SPIKE SHOES

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INTRODUCTION

With the recent sophistication of track and field sprint, spike shoes have become varied in function and design. Although many studies have been made with athletic spike shoes (Oda et al., 2003), few studies have been done with the aerodynamic characteristics of spike shoes. In this study, we analyzed the aerodynamics of athletic spike shoes using wind tunnel tests and CFD analysis, and examined the effects of the aerodynamics of the shoe's upper cover.

METHODS

The wind tunnel used in the test was the Goettingen low speed wind tunnel(attached with six-component automatic balance, maximum wind velocity: 40 m/s, test section: 1.5 × 1 m) that was prepared by the Department of Aeronautics and Astronautics School of Engineering at Tokai University. An athletic spike shoe was set in this wind tunnel held by a wing-covered stainless shaft (Fig. 1). From the preliminary test, we decided to set two wind velocity conditions, 20 m/s and 15 m/s, by considering the shoe movement velocity. We set shoe attacking angles to 0°, which was the angle where the initial wind direction and the sole orientation was parallel, and to 90°, where the wind direction and the sole orientation was vertical. Measuring attacking angles were at three settings: 0°, 37°, and 90°. The shoes used in the test were of two models; with and without upper covers.

CFD meshes were prepared using MSC. Patran (MSC. Software Inc.) and GAMBIT (Fluent Inc.) from two CAD design sets of data for the non-upper-covered and upper-covered spike shoes. From the result of the preliminary test, the initial flow and the shoe attacking angle () had four conditions; 0°, 35°, 65°, and 90° in this analysis model. Also, the initial flow velocity was 20 m/s, and steady-state analysis was calculated by digitizing a Navier-Stokes equation of incompressible viscous fluid by the finite volume method. The turbulent flow model was the RNG k- model and the solver was Fluent 6.1 (Fluent Inc.).



Figure 1: Set up of wind tunnel test.

RESULTS AND DISCUSSION

In the wind tunnel test under the condition of a wind velocity of 20m/s, the drag force, in the non-upper-covered model, was 1.24 N at the attacking angle of 0°, 2.51 N at 35°, and 3.50 N at 90°, while in the upper-covered model, the force was 1.04 N at the attacking angle of 0°, 2.23 N at 35°, and 3.28 N at 90°. Under the condition of a wind velocity of 15 m/s, in the non-upper-covered model, the force was 0.70 N at 0°, 1.39 N at 35°, and 1.95 N at 90°. In the upper-covered model, the force was 0.58 N at 0°, 1.27 N at 35°, and 1.82 N at 90°. When comparing the non-upper-covered shoe with the upper-covered shoe, we could not find any clear dependency on the attacking angle, and the

upper-covered model was approximately 10% smaller than the non-upper-covered model in drag force resistance.

When the non-upper-covered and the upper-covered shoes were compared in the pressure distribution on the surface of the shoe by the CFD analysis, a leap was observed in the non-upper-covered shoe at areas where there was a step difference such as shoe laces and sidelines, while a smooth change was seen in the upper-covered shoe in pressure. Also, both types had a big negative pressure in the vicinity of the sole edge of the upper front foot. Taking the contour of the shoe and the wind direction into consideration, a boundary layer separation might be developed at these areas. When comparing the models in the basic flow line, the upper-covered model had slightly less disturbance in the flow than the non-upper-covered model at the back of the sole (Fig. 2).

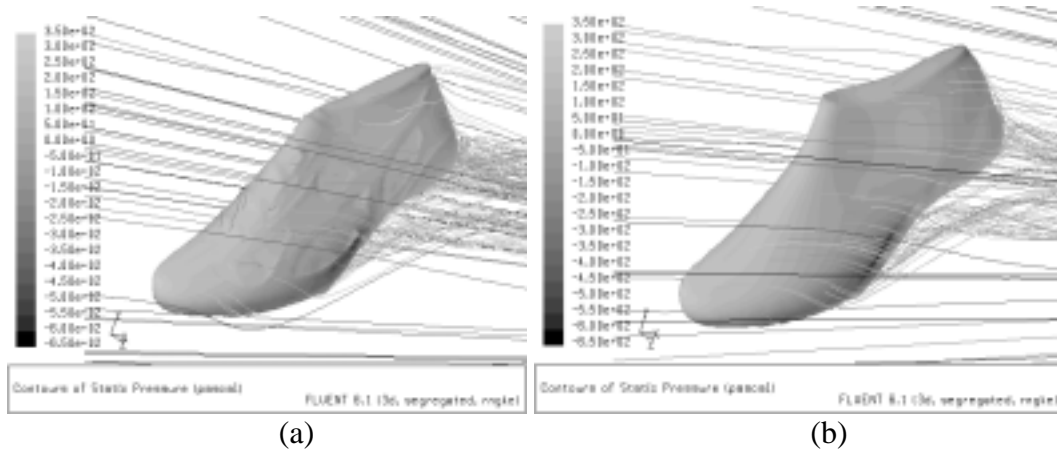


Figure 2: Contours of pressure on the non-upper-covered model (a) and that of the upper-covered model.

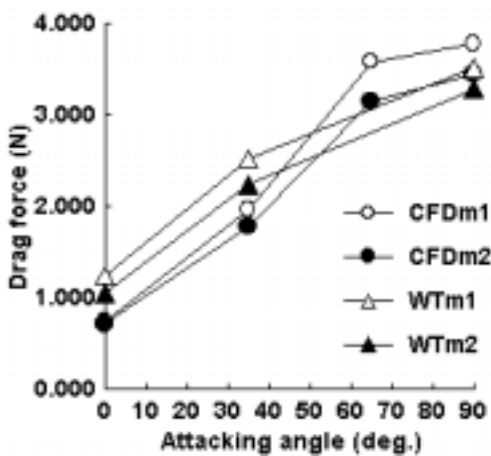


Figure 3: Drag forces of wind tunnel test and CFD.

In comparing the drag force obtained from the wind tunnel test with that of the CFD analysis, the value of the wind tunnel test was greater at around the attacking angle of 0° and, to the contrary, the value of the CFD analysis was greater at around the attacking angle of 90°. The drag force of the upper-covered model showed smaller values than the non-upper-covered model in all attacking angles both in the wind tunnel test and the CFD analysis (Fig. 3). From the results of this study, the air resistance of the upper-covered shoe was approximately MAX 10% smaller than the non-upper-covered shoe. The causes might include rectification effects on the surface of the upper or reduction of eddy area that was developed at the back of the shoe by setting an upper cover.

REFERENCES

Oda T. et al., (2003) Running shoes development using a finite element ankle/joint model, *Proc. of 6th Symposium on Footwear Biomechanics*, ISB, 72-73.