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NUMERICAL SIMULATION AND EXPERIMENTAL STUDY OF DRAG-REDUCING SURFACE OF A REAL SHARK SKIN*

ZHANG De-yuan, LUO Yue-hao, LI Xiang, CHEN Hua-wei
School of Mechanical Engineering and Automation, Beihang University, Beijing 100191, China,
E-mail: zhangdy@buaa.edu.cn

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Abstract: It is well known that shark skin surface can effectively inhabit the occurrence of turbulence and reduce the wall friction, but in order to understand the mechanism of drag reduction, one has to solve the problem of the turbulent flow on grooved-scale surface, and in that respect, the direct numerical simulation is an important tool. In this article, based on the real biological shark skin, the model of real shark skin is built through high-accurate scanning and data processing. The turbulent flow on a real shark skin is comprehensively simulated, and based on the simulation, the drag reduction mechanism is discussed. In addition, in order to validate the drag-reducing effect of shark skin surface, actual experiments were carried out in water tunnel, and the experimental results are approximately consistent with the numerical simulation.

Key words: numerical simulation, experimental study, biomimetic surface, shark skin, drag reduction mechanism

Introduction

Through millions of years' competition for survival of the fittest, a creature has formed his own unique functional surface, such as for drag reduction, wear resistance, self-cleaning and so on. Shark is one of the fastest swimming animals in the ocean, with many micro-grooves on the surface of shark skin scales. In the 1970s, Michael in NASA Langley Research Center found that the ribbed surfaces can effectively reduce the wall friction[1], which is greatly out of the traditional way of thoughts, and which has also opened up new ways of drag-reducing technology for mankind.

The direct numerical simulation is an important tool to study turbulent flow, and many studies are closely related with fluid engineering[2-11]. The mechanism of grooved drag-reducing surface has been one of important topics[12-16]. However, the simulations so far are mainly confined to simple straight grooves, such as triangle groove, semicircular groove and other simple straight grooves[12-16], and to the authors' knowledge, the flow simulation over a real shark skin surface has not been reported, additionally, the influence of attack angle is not considered. Moreover, in order to verify the drag reduction effect of shark skin, actual experiments are carried out in water tunnel.

1. Building model of shark skin

Shark skin is composed of many small scales, and the micro morphology of surface is shown in Fig.1. The extension direction of scale is approximately parallel with its swimming direction, the groove tips can stick out of the viscous sublayer and inhabit the occurrence of turbulence, so the wall friction can be reduced.

To study the drag reduction mechanism of a real shark skin surface, a model is built in the following steps: (1) high-accurate scanning of a single biological scale, (2) data analysis and processing, (3) building of the three-dimensional model of single scale and shark skin in a large area, (4) building of the computational domain, (5) building of CFD model and numerical

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Biography: ZHANG De-yuan (1963-), Male, Ph. D., Professor
Corresponding author: LUO Yue-hao,
E-mail: luoyuehao1985@163.com