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Macro-surface Modification through Exploitation of Rivets and Dimples – Numerical and Experimental

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1. Introduction

Research related to rivets and dimples has been conducted as early as the 1930s. The irregularities of surfaces have believed to be a factor to fuel consumption increase of airplanes. NASA reported that it is vital to eliminate the surface irregularities or other protuberances from the surface that is exposed to the airflow [1]. This is believed to due to the extreme increase of the drag coefficient.

On the other hand, surface irregularities research for example in sport such as golf where dimples are present, show that the effect can contribute to increase in length of the flying distance of golf balls [2]. These improvements of aerodynamic characteristics by manipulating the surface irregularities have increased the number of research [3]~[5]. In this paper, the effect of dimples and rivets on surfaces is investigated, numerically and experimentally. Both results gave a surprising result where surfaces with rivets gave approximately 10% better surface aerodynamics comparatively to those with dimples.

2. Numerical Modeling of Macro Dimples and Rivets

2.1. Macro Dimples and Rivets

The effects of these macro-surface modifications are conducted using Solidworks Flow Simulation. The diameter of dimples and rivets were both set at 7.0 [mm]. The size and dimension of these dimples and rivets are determined taking application assumptions of bolts and rivets used in metal-jointing processes involved in machine designs and fabrications [6][7]. During simulation analysis, dimples, rivets and plain surface of planes are being constructed for numerical comparison.

As can be seen from Fig. 1, the plain surface is being introduced as a control parameter for this simulation analysis. Focusing on the upper surface of the plane shows that approximately 1.1 [MPa] of highest pressure is generated.

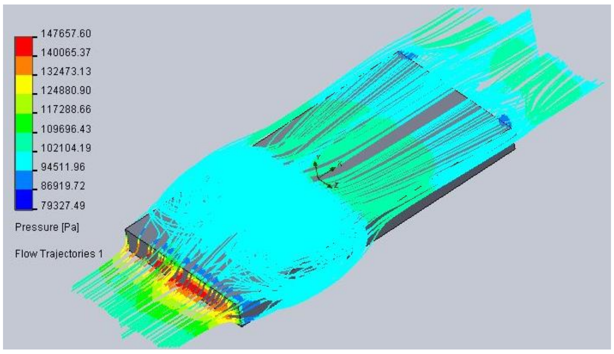
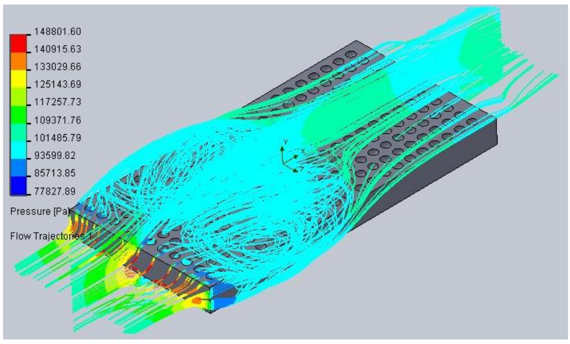
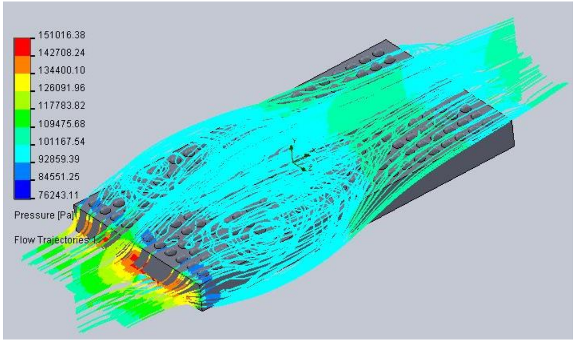


Figure 1 Plain surface with flow trajectories



(a) Dimples plane



(b) Rivets plane

Figure 2 Macro-scaled modified surfaces with its flow trajectories

However, if we compare with the next figure of Fig. 2, the pressure distributions show lower pressure distribution for both modified surfaces with (a) dimples and (b) rivets. The effect can be seen clearly particularly in the frontal region of the surfaces. Both dimples and rivets have low pressure of 0.078 [MPa] and 0.076 [MPa] at its maximum, respectively.

These numerical results will be supported by an experimental analysis results explained in details in the following section 3.

2.2. Dimples and Rivets in a Non-Newtonian Flow of a Human Blood

In order to make the numerical comparison of effects between dimples and rivets on applied surfaces, planes with dimples and rivets are immersed in blood flow. Human blood is considered as an ideal example to represent a non-Newtonian flow of a substance. There