EXTENDED ABSTRACT of

Effect of The Geometry of Film Cooling Holes on Heat Transfer Coefficient in Condition of Various Mainstream Pressure Gradients

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For any an aero-engine of high performance, the cooling system has become an indispensable part after the Second World War because a higher temperature before the gas turbine T_3^* offers a atrocious work condition to the blades and vanes of the gas turbine. The film cooling technique has been generally used in cooling of the blades and vanes of the aero-engine from 1970. A large number of literatures have been presented concerning on film cooling. Studies have been conducted focusing on the influence of the the geometry of film cooling holes on film cooling recently. The pressure of the gas on the blade surface are not uniform in the flow direction resulted from the variety of the blade surface curvature, which causes the various pressure gradients effecting the mixing between the coolant and the gas, which brings the various characteristics of film cooling.

According to the pressure distribution on the blade surface, three various test sections of the flat plate producing the zero, favorable and adverse mainstream pressure gradients respectively have been made of polymethyl methacrylate.The leading edge rigs and the flat plate rigs have been designed, and experiments have been conducted in the heat transfer laboratory in NorthWestern Polytechnical University(NWPU) supported by Rolls-Rocyce company and Oxford.

Measurements have been conducted in a large-scaled closed-loop wind tunnel with a secondary flow system for film cooling that CO_2 is adopted as the coolant to make the high density ratio. The cylindrical hole, fanned hole and 3-in-1 hole are tested in simulating film cooling on the flat plat in the presence of various mainstream pressure gradients. The measured film holes are 25 times as large as that in the aero-engine based on the similarity theory. Each hole has a diameter of 7.5 mm at their cylindrical section. The leading edge Reynolds number based on the diameter of the cylindrical leading edge and the velocity magnitude of the free-stream is 46000. The flat plate Reynolds number based on the diameter of the hole and the local velocity magnitude of the mainstream at the hole exit is 6400. The momentum flux ratios vary from 0.5 to 8.0, the density ratios of 1.0 and 1.5 and the mainstream turbulence intensities of 0.4% and 8.0% are considered. The grid is located in the upstream region of the test model to produce the high turbulence intensity.

The 9 configurations with cylindrical film holes on the leading edge rig are tested under the radial angles β of 0°, 45° and 65°, the nominal spaces between film holes(the ratio of the pitch between film holes to the diameter of film holes) P/d of 2, 3 and 4 respectively. Furthermore, the 29 configurations of film holes on the flat plate are tested in which the configurations of cylindrical and fanned film holes are tested only in the condition of the plane angle α of 45°, β of 0° and P/d of 3, but the bidirectional expanded holes are tested in the condition of α of 20°, 45° and 90°, β of 0°, 30° and 65°, and P/d of 2, 3 and 4, respectively.

The primary goal of the present work is to investigate the effect of the geometry of film cooling holes on heat transfer coefficient in the conditions of the various mainstream pressure gradients. The heat transfer coefficient denotes the capability of energy transfer between the channel walls and the fluid. In this paper a new parameter of the enhancement heat transfer coefficient (the ratio of the heat transfer coefficients with and without film cooling) of the film cooling system is defined. Turbulence intensities have been measured by the anemoscope and pressure distributions by the manometer in the wind tunnel. Turbulence intensity is about 8.0% near the stagnation line of the leading edge. The uncertainty of the experimental result is also analyzed.

The results of the present study are given as follows:

(i) The effect of the hole shapes on the enhancement heat transfer coefficient in the presence of the favorable pressure gradients that the difference of the enhancement heat transfer coefficient in the conditions of the cylindrical holes, the fanned holes and the bidirectional expanded holes is about 5% is not such remarkable as in the presence of the zero and adverse pressure gradients. The enhancement heat transfer coefficients of the cylindrical holes are the highest and those of the fanned holes are the lowest, however, the bidirectional expanded holes give the middle values. Compared to the enhancement heat transfer coefficients of the cylindrical holes, the differences of those of the fanned holes and the bidirectional expanded holes are decreased from 5% to 10% and from 20% to 30%, respectively.

(ii) Comparison of the enhancement heat transfer coefficients in the conditions of the zero, adverse and favorable pressure gradients, the difference of the first one from the second one is not so distinct and the third one is the highest. The effects of the plane angles and the radial angles on the enhancement heat transfer coefficients are noticeable compared to one of hole pitches.

(iii) The enhancement heat transfer coefficients are decreased with the plane angles increasing in the condition of the favorable pressure gradients, and the effect of the plane angles on the enhancement heat transfer coefficients is very intricate in the conditions of the zero and adverse pressure gradients. The enhancement heat transfer coefficients are

increased with the radial angles increasing in the condition of the favorable and adverse pressure gradients, and the effect of the radial angles on the enhancement heat transfer coefficients is weak in the conditions of the zero pressure gradients. The effect of the pitch on the enhancement heat transfer coefficients is weak in the conditions of the zero pressure gradients, and the enhancement heat transfer coefficients are decreased with the pitch increasing in the condition of the favorable pressure gradients, but the effect of the plane angles on the enhancement heat transfer coefficients is very intricate in the condition of the adverse pressure gradients.