Generation of surface pattern by using a patch division milling and its influence on the flow-field around the aerofoil

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Abstract
This study describes a new machining strategy to make a regularly aligned micro dimples or grooves by a micro milling process. A patch division milling technique is used in this study. The spacing and the depth of the grooves can be controlled by its machining location, and interrupted grooves can also be made efficiently. The machined surfaces are transferred to a plastic film and it was adhered to the aerofoil. The flow filed, especially the separation zone of the flow line from the aerofoil, was observed in the wind tunnel, and the effect of the surface pattern was evaluated.

1 Introduction

The surface pattern can control some specific physical functions of the surface, for example, the fluid drag force [1, 2], wettability, frictional characteristics, etc. The surface pattern can usually be generated by a chemical method such as etching or by machining methods such as cutting, grinding and shot-blasting. In this paper, a micro milling process is employed to make surface patterns because the milling process is highly efficient. As the key idea of this study, some of the authors of this paper proposed "a patch division milling technique" [3], which can make well aligned cutter marks on the machined surface. The alignment of cutter marks can be controlled by the setting of the machining conditions. This technique is applied to make a riblet shape or a crescent shape which is similar to the shark skin on the flat surface with a developed point angle milling tool. Then the surface patterns were printed on the wing surface using a plastic film, and the laminar separation zone of the flow line from the aerofoil was observed in the wind tunnel.

2 Machining of surface pattern

The longitudinal groove structure that looks like the shark skin, which is called as riblets, is reported as surface shape that contributes to the flow resistance decrease [1]. The technique for machining surface patterns including the riblet shape with high efficiency is described below. Figure 1 shows the developed rotating tool for machining short grooves. Its point angle is 45° and it can make "ship bottom shape groove" as a cutter mark. A square patch is machined along a helical tool path with appropriate feed rate and cross feed, then cutter marks are aligned on the longitudinal direction [3] and the grooves will be formed as shown in Fig.2. As these short grooves are transferred to plastic film, it will be riblet shapes

Figure 3 is a machined example of crescent shapes by using the square end mill. The entire machined surface is covered with square patches, and the cutter marks of the crescent shape well align in the microscopic sense.

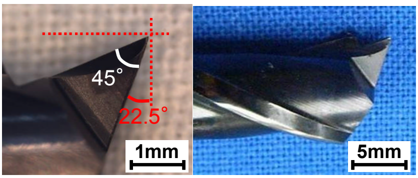

Figure 1: Point angle tool

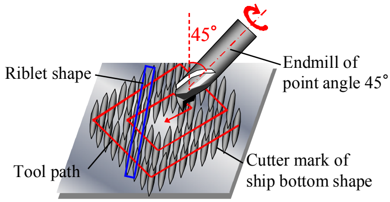

Figure 2: Groove machining with helical tool path

Figure 3: Regularly aligned crescent shape dimples machined by patch division milling (f_t =0.40 mm/tooth, S =400 min^{-1}, f_c =0.80 mm)

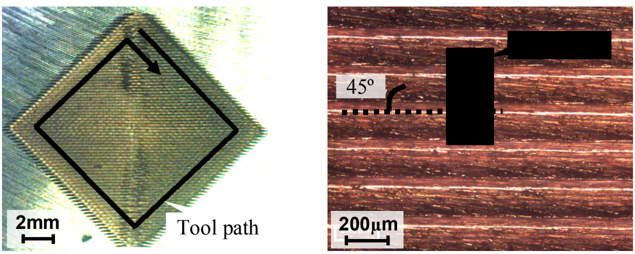

Figure 4: Regularly aligned continuous grooves machined by patch division milling (f_t =0.25mm/tooth, S =1000min^{-1}, f_c =0.25mm)

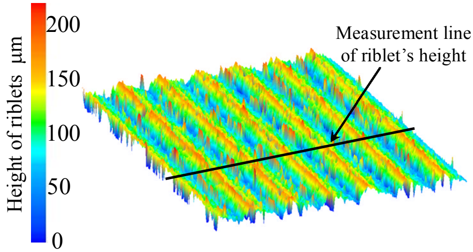

Figure 5: Measured surface profile

Figure 4 and 5 shows a machined example of continuous grooves. Depth of the groove is 150µm, angle of the groove wall is 62 ° and the groove pitch is 180 µm.

3 Effect of the surface pattern on the flow-field around the aerofoil

Three kinds of surface pattern were machined on the metal surface, then the pattern was transfered on the plastic film and the wing surface was covered by it as shown in Fig. 6. The stream lines around the wings were examined in the wind tunnel. Tested surface patterns are as follows;

1) Patch A: Alligned crescent shape projections which are similar to shark skin. Long axis length is 500 µm, projection height is 150 µm.

2) Patch C: Interrupted riblet shapes. Pitch and width of riblets are 200 µm and projection height is 130 µm.

3) Line E: Continuous riblet shapes. Pitch and width of riblets are 300 µm and projection height is 160 µm.

4) Smooth surface without any surface patterns.

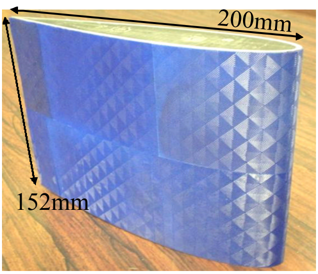

Figure 6: Aerofoil NACA2418 with surface patterns

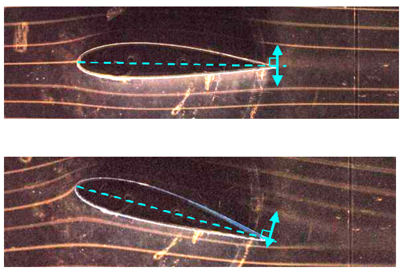

Figure 7: Flow line and separation zone

Figure 7 shows examples of the observation results of the flow field. Width of the laminar separation zone of the stream line was measured to evaluate the effect of the surface patterns. As the separation zone becomes large, the drag force acting on the aerofoil increases. Figure 8 shows the results when the air flow speed is 5 m/s. It shows that the laminar separation zone is smaller in the cases of Patch A and Patch C comparing with the smooth surface without pattern.

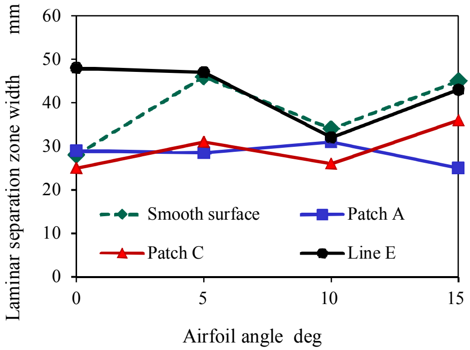

Figure 8 Effect of surface pattern on laminar separation zone width

4 Summary

Series of micro grooves or dimples could be successfully formed on the metal surface by employing a patch division milling technique with a developed point angle cuter. It was shown that the crescent shape projections and the interrupted riblet shapes are effective for the reduction of laminar separation zone, which leads to the reduction of the drag force acting on the aerofoil.

References:

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