Novel micro-grooving technique for machining of novel chevron sharkskin riblets on flat surface

W.K. Neo#, A.S. Kumar, M. Rahman
Department of Mechanical Engineering, National University of Singapore
9 Engineering Drive 1, Singapore 117575
weekeong.neo@nus.edu.sg

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Abstract

This paper presents a novel micro-grooving technique to machine chevron sharkskin riblets in a single setup. It employs a hybrid of micro-grooving and micro-chiselling techniques, which performs chiselling action after a diamond tool reaches at the point of chevron intersection during the grooving process, leaving a smooth chevron intersection line. The proposed micro-grooving method also exhibits its capabilities to fabricate an array of chevron sharkskin riblets in a single setup, without having separated cavities to be assembled as a master mold. The experimental results demonstrate the successful machining of chevron sharkskin riblets with ultraprecision accuracy and excellent surface quality. On top of that, no tool interference has been observed. These further credit the capabilities of novel micro-grooving technique as a promising manufacturing process for serial production of parts incorporating bio-inspired surface structures.

1. Introduction

Over the past decades, researchers have been bio-mimicking the nature-inspired designs of the world's surface textures to solve technical challenges. Thus, greater attention is given to mimic structures and materials in order to harness the power of Nature for the benefit of society. Designs inspired by principles of living Nature are acting as the fundament for many new innovations. Sharkskin riblet is one of the most upstream research topics which commonly employs for reducing fluid drag. Several patterns of sharkskin riblets have been studied for optimizing the performance of drag reduction[1]. In this paper, a novel chevron pattern has been designed for its unique directional flow properties[2]. The most possible methods for

fabricating chevron patterns are employing lithography techniques, micro-EDM and molding processes. Unfortunately, lithography techniques do not produce consistent quality surfaces due to poor surface smoothness during the layered formation of surface in the processes. Micro-EDM process is commonly known for poor machined surface roughness due to heat affected zone. Notwithstanding the fact that molding processes are capable of mass producing replicates from master mold cavities, the unnecessary parting lines may appear on molded replicates due to assembly misalignment of separated diamond-machined cavities.

2. Hybrid Micro-grooving and Micro-chiselling Technique

This paper presents a novel machining technique to fabricate chevron sharkskin riblets by means of hybrid micro-grooving and micro-chiselling processes in single setup. A 60° V-shaped monocrystalline diamond tool which employs for fabrication of sharkskin riblets, has a 15° front clearance angle and a 0° rake angle. The experiments are performed using an ultraprecision machine tool with three translation axes and one rotation axis. In the cutting principle as described in Fig. 1, the proposed method performs a ruling action along a v-groove in the y-axis direction until the tool reaches the point of chevron intersection. Then, a chiselling action takes place by moving the tool outwards in a combined motion of the axes x, y, and z along the chevron intersection line. This method shall be repeated on the opposite v-groove after the workpiece rotates to the opposite side. As the cuts always perform from the same side, the accuracy of the machine tool and setting up process is crucial for the tool to re-positions accurately after the workpiece rotates for the next cut. Therefore, angular setup errors which would accumulate several micros of errors should be minimized for good accuracy results.

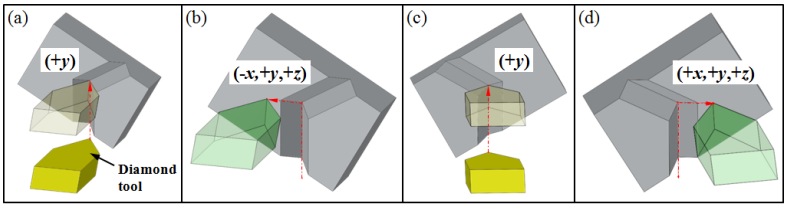

Fig. 1: Principle cutting kinematic of the proposed technique

A major advantage of proposed hybrid micro-grooving and micro-chiselling technique is that the chevron patterns can be easily realized without having separated sections to be assembled as a single master mold.

3. Experimental Verifications

The designed chevron sharkskin riblet (Fig. 2) consists of an array of 60° v-grooves with depth of 0.10 mm on a flat aluminium (AA6061-T6) surface. The cutting parameters cutting speed = 400 mm/min and depth of cut = 4 μm have been applied.

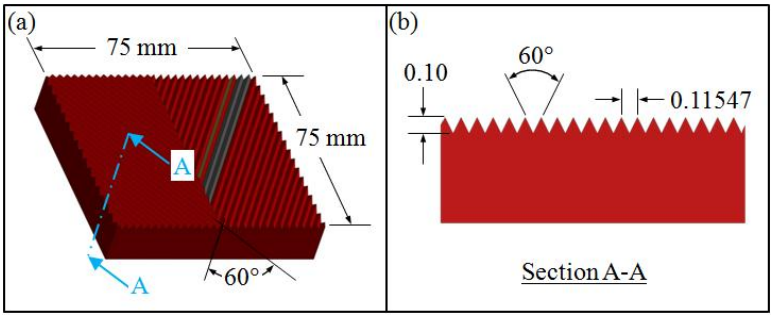

Fig. 2: Geometries of chevron sharkskin riblets

A mist coolant served as lubricant to prevent excessive tool wear and to improve surface quality. Fig. 3 demonstrates the successful machining of chevron sharkskin riblets with the implementation of proposed hybrid micro-grooving and micro-chiselling technique. It can be seen that a mirror surface finish (insert figure) has been achieved.

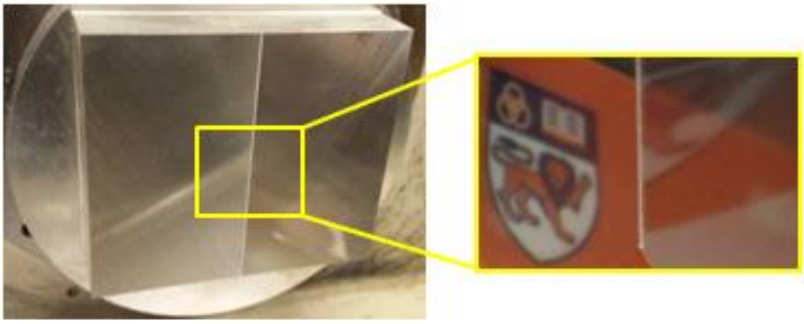

Fig. 3: Machined chevron sharkskin riblets with mirror surface finish (insert)

A confocal laser 3D measuring device and a digital measuring microscope have been employed to measure the v-groove geometries and chevron angles respectively.

Figure 4 illustrates that good accuracies have been achieved by the proposed machining technique, only about 0.2 μm errors for v-groove geometries and up to 0.03° for chevron angles. Furthermore, there is no tool interference can be observed. These further validate the creditability of the hybrid micro-grooving and micro-chiselling technique for an array of chevron sharkskin riblets, without having separated sections to be assembled as a master mold.

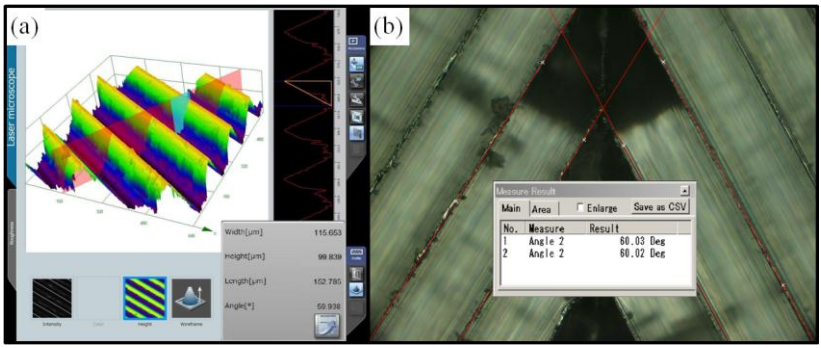

Fig. 4: Measurements of machined chevron sharkskin riblets

4. Conclusions

The results have demonstrated that the successful manufacturing of the chevron sharkskin riblets (v-grooves) with the implementation of the hybrid micro-grooving and micro-chiseling technique. The fabricated chevron v-grooves array not only meets the required ultraprecision accuracy and excellent surface quality, but also does not require two separated cavities to be assembled as a single master mold. Most importantly, no tool interference has been observed at the chevron intersections. These further credit the capabilities of novel micro-grooving technique as a promising ultraprecision machining process for freeform parts.

References:

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