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On the effect of machining strategy in micro milling of tool steel surface micro features with optical functionality

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Abstract

This paper presents a new micro milling strategy for manufacturing optical functionality on steel surfaces. The micro structures, a combination of arrays of micro-ridges, have been machined on tool steel surfaces. The desired function is to maximize the contrast of the reflected light from orthogonally patterned features. The micro-ridges are 800 µm long, 50 µm wide and 5° tilted.

In order to obtain such micro structures on tool steel, a five axis ultra-high precision milling machine was utilized. The potential application is the replication of the structures on plastic components by means of injection moulding or other polymer replication methods. However, many burrs formed on the edges of the micro features during the micro milling process. The burrs covered the working surfaces and drastically decreased the surface functionality of both the steel features and the polymer replicated structures.

In order to reduce the burr formation, the micro milling strategy was investigated. In particular, a new machining strategy was developed, validated and compared with the conventional strategy, both executed in the same machining conditions. In the conventional strategy, from the side view of the micro-ridges, the features were machined from right to the left (as shown in Figure 1 on the left). In the new strategy, a reversed ridge machining order was applied, with the result that the burrs formed during machining a micro-ridge were removed by the following cut. As shown in Figure 1, the experiments proved that the burrs were removed during the micro milling process, which decreased the cost by avoiding the possible post-processing such as micro de-burring.

The evaluation of the structural geometries and the tool wear were based on the measurements carried out with a confocal laser 3D scanner (Olympus Lext OLS4000) and a scanning electronic microscopy (SEM), respectively. The results proved that the new strategy could also improve the micro milling tool life while producing relatively higher quality when compared with the results obtained with the conventional machining strategy. For example, when considering the dimensional stability of the micro features as criteria, e.g. when the ridge height decreased by 13%, the milling tool life achieved by the new machining strategy was 10 times longer than that obtained by applying the conventional one. The new machining strategy will be applied for machining such micro structures on large areas.

The machining strategy will be further validated by correlating the surface functionality with feature geometry and tool wear.

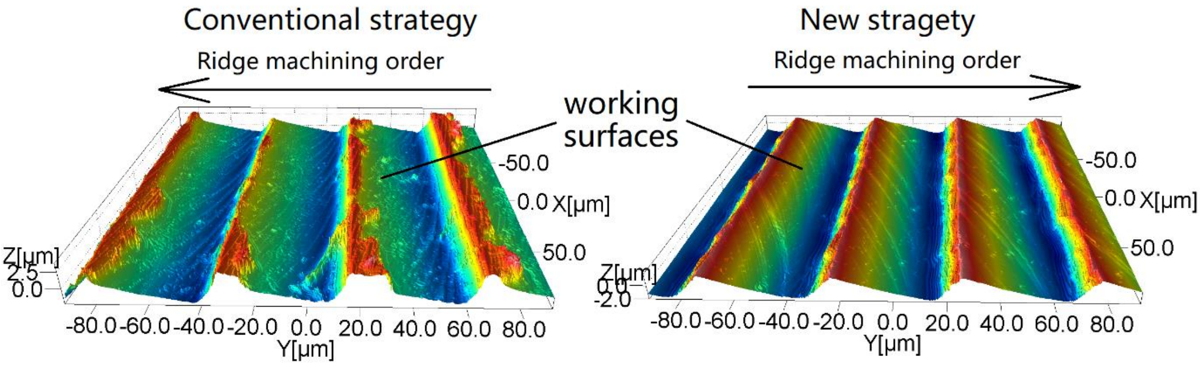

Figure 1: The geometries obtained by applying the two micro milling strategies, scanned by a confocal Laser 3D scanner (Olympus Lext): (left) micro features by the conventional milling strategy with burrs formed on the edges and (right) the burr-free features by the new milling strategy.