Microdrilling of Biocompatible Materials

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Introduction

Product miniaturization trend is inevitable. The needs for minimum invasive surgery, smaller sensors for smart machinery, packing more features on a product… require mass production of smaller components from engineering materials. Fabrication of microcomponents requires knowledge of micromachining to avoid costly tool failure and part damage. This research investigates microdrilling of commercially pure titanium, nickel titanium (Nitinol), and 316L stainless steel.

Approach

A surface was polished and drilled in rows of ten holes. Through hole drilling at 6:1 aspect ratio was performed on NiTi sheets while blind holes were drilled at 10:1 aspect ratio on Ti or 316L blocks. Microdrills of 100-127 µm diameters and 1.8-2.3 mm flute lengths, were tested on Haas OM2 system equipped with a 50,000 rpm air spindle and an Unist micromist. Finite element models were developed to find upper limits of drilling parameters. Flank wear of 15µm on fine grained WC-Co uncoated tools and peeling of coating layer were used as tool life criteria. Tool life modeling and hole quality were performed to evaluate and compare tool performance.

Results

Although successfully drilling all materials at 10:1 aspect ratio (Fig. 1), excessive built-up-edge (BUE) was found on microdrills at all drilling parameters. Such BUE:

- Effectively blunted the drill tips and caused drill wandering
- Degraded hole quality when rubbing against the drilled wall
- Work-hardened the drilled surface and accelerated drill wear
- Formed burrs at both entrance and exit ends (Fig. 2)

The wear of microdrill at the outer corner was more pronounced when drilling CP titanium, but attrition wear at chisel edge was more significant for 316L stainless steel (Fig. 3).

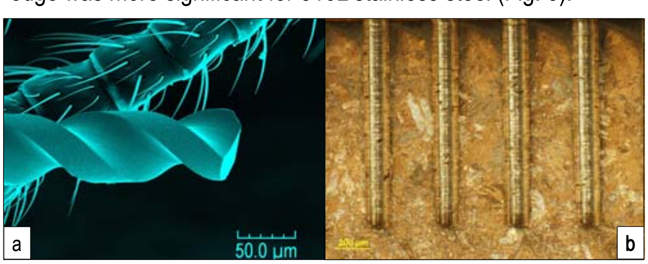

Fig. 1: (a) A microdrill and an ant's leg in the background, (b) Sectioned and etched row of holes (Φ127µm, 10:1 aspect ratio) drilled on 316L stainless steel.

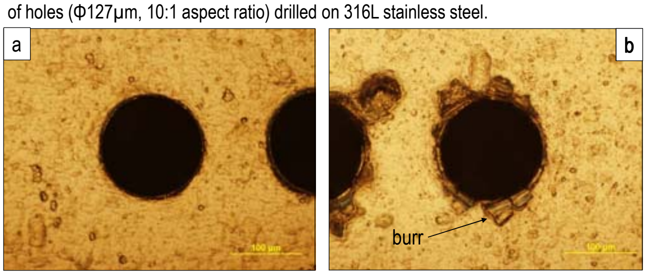

Fig. 2: Exit hole ends after drilling (a) the 1st and 2nd holes, (b) the 20th and 21st holes. NiTi 0.85 mm thick, 50 krpm, 0.02 µm/flute, uncoated 127µm drill.

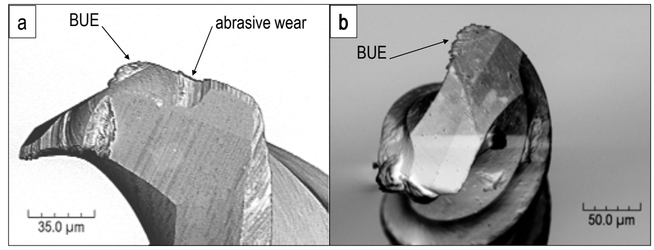

Fig. 3: (a) Uncoated microdrill after 10 holes and (b) AlTiN coated microdrill after 140 holes. 35 krpm, 127µm drill, 10:1 aspect ratio, 316L stainless steel.

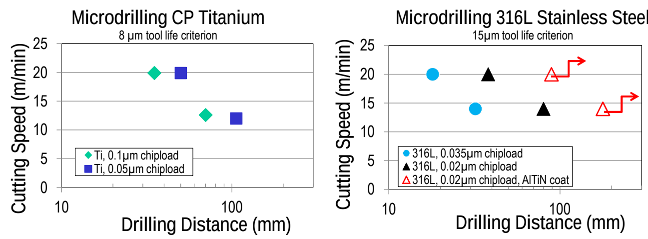

Fig. 4: Tool life plot for microdrilling of titanium (left), and 316L stainless steel (right).

The classical Taylor's equation for macromachining was applicable in microdrilling to rank tool performance and machinability of titanium and 316L. For the same cutting speed of 20 m/min and comparable drilling distance of about 35 mm, CP titanium can be microdrilled 400% faster than 316L stainless steel since the chip load for the former is 0.1 µm/flute and that for the latter is 0.02 µm/flute. Also, AlTiN coated drills improved tool life by at least 122% (Fig. 4). This coating reduced BUE, drastically improved hole position accuracy by 115%, and decreased hole diameter variation from 0.110% to 0.003% for each mm of drilling distance (Fig. 5).

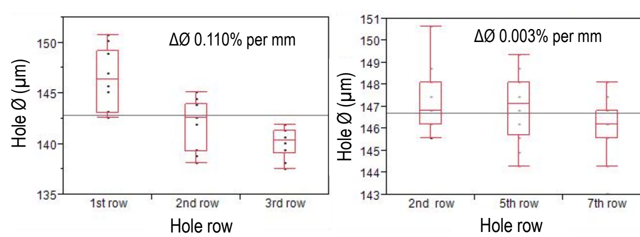

Fig. 5: Variation of hole size after microdrilling with uncoated tool (left) and AlTiN coated tool (right). 127µm drill, 316L, 14 m/min, 0.02 µm chip load.

Summary

1) Micromachining parameters were developed for each microdrill geometry. Using these parameters with progressive pecking cycle and micromist allowed successful microdrilling of 100-127 µm deep holes in 316L, Nitinol, and titanium.
2) Proper tool coating, such as AlTiN, minimized BUE and significantly enhanced tool life and hole quality more than 100%.
3) Other tool coatings and techniques to remove burrs after microdrilling should be developed.

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