Analysis of the mechanical performance and durability of adhesively bonded joints used in the milling tool industry

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Introduction

Adhesives are being introduced in the milling tool industry seeking to replace brazing and mechanical fastening when joining the cutting bits to the tool body [1]. Steel (St) and aluminum (Al) bodies were studied, due to the versatility of steel and the market's preference for lightweight tools, respectively. But the durability of these joints is still a big concern. This work aims to evaluate and characterize the effect of environmental factors associated with the tool's life cycle on the performance of these bonded joints [2].

Experimental methodology

Several stages of the tool's life cycle can be a source of degradation, as seen in Figure 1.

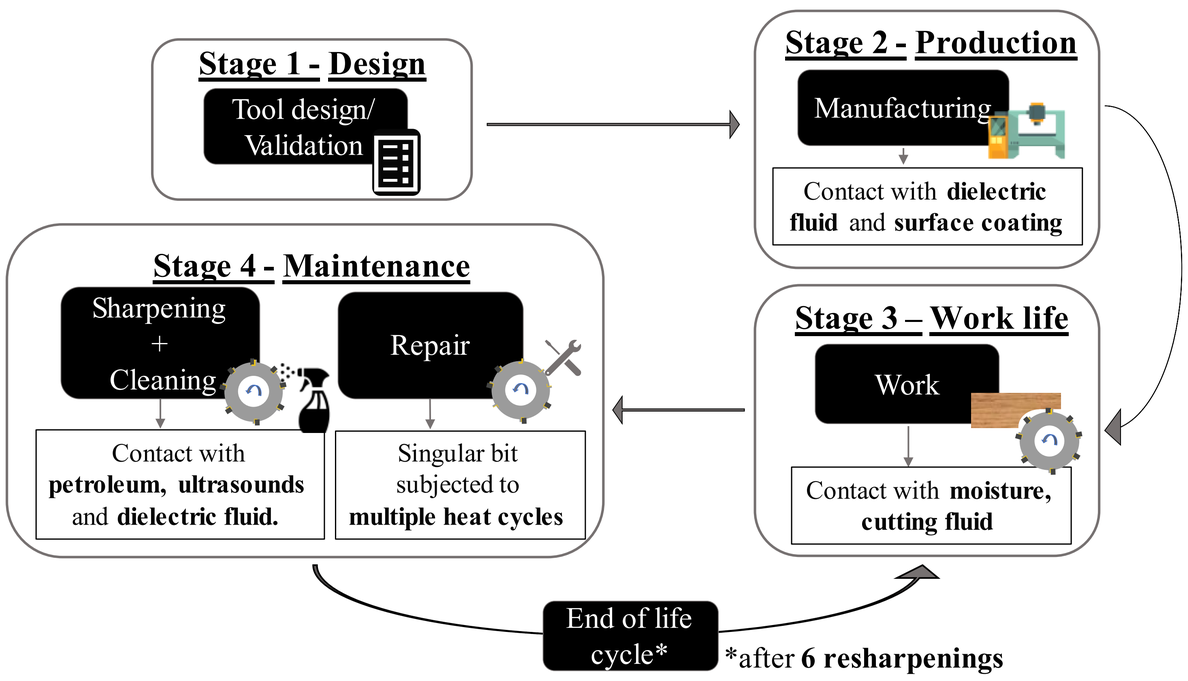

Figure 1 – Typical life cycle of a milling tool [2].

Gravimetric (Grav) and real joint shear (RJS) tests were performed to access the degree of adhesive and joint degradation in each medium, respectively. As such a testing plan, presented in Table 1, was devised to understand this issue in both continuous and cyclic ageing conditions.

Table 1 – Ageing testing plan for each life cycle stage [2].

Stage 2		Stage 3	
Dielectric fluid (DF)	Oxidation (Oxi) Nickle-plating (NiP)	Water (W)	Cutting emulsion (CE)
Grav/RJS test (St/Al)	RJS test (St)	Grav/RJS test (St/Al)	Grav/RJS test (St/Al)
Stage 4			
Petroleum (PO)	Ultrasound (US)	Sandblast (SB)	Repair at 150ºC (Rep)
RJS test (Al)	RJS test (Al)	RJS test (Al)	RJS test (St/Al)

Experimental results

The gravimetric test results can be seen in Figure 2, for water, cutting fluid and dielectric fluid, respectively.

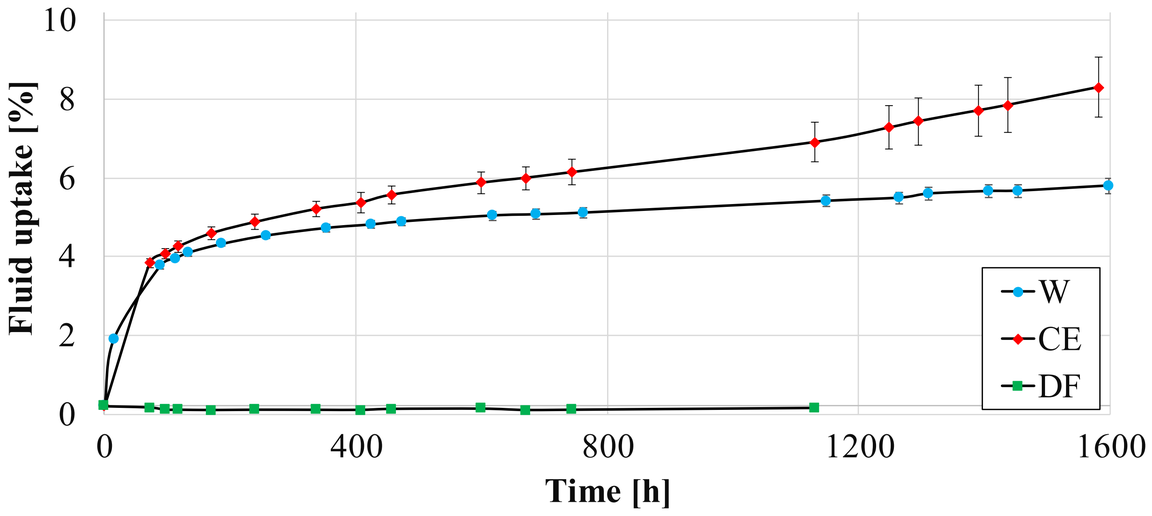

Figure 2 – Experimental results for the gravimetric analysis [2].

From the gravimetric analysis water and the cutting emulsion presented similar behaviors (Dual-Fickian) having, the second, a higher uptake in the relaxation dominated stage.
The dielectric fluid was not absorbed by the adhesive proving that only the first two can damage the adhesive itself.

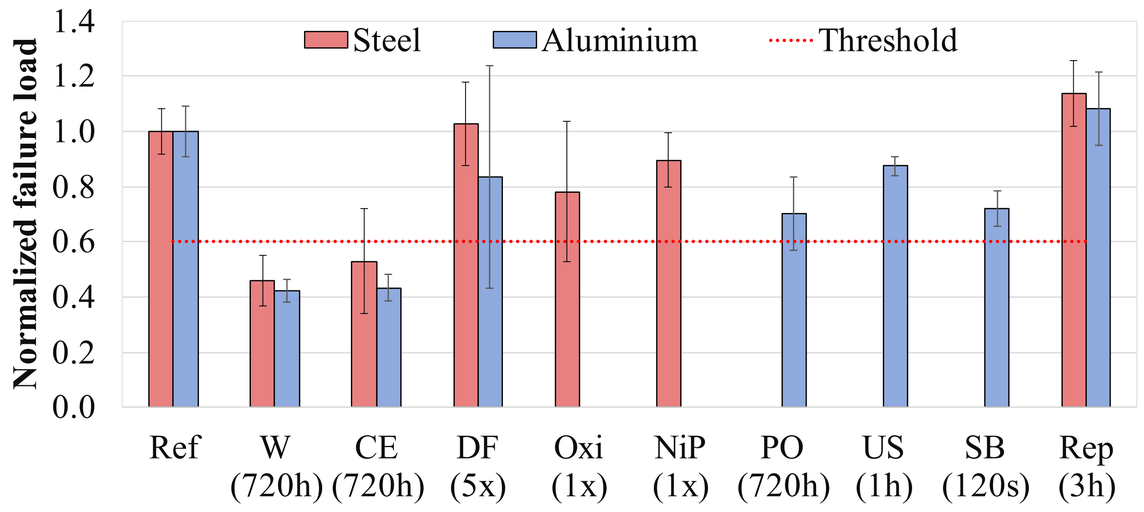

Figure 3 – Normalized shear strength of RJS joints continuously aged [2].

The normalized continuous aging results are presented in Figure 3, for each respective maximum exposure time chosen, depending on the usual exposure time of each fluid.
A limit threshold value of 60% of the reference joint strength was set by the partner company as a safety measure.
The most severe continuous ageing appended for water-based fluids, as their strength went below the threshold value.
As depicted in Figure 4, six petroleum and ultrasound cleaning cycles, as well as 3 repair cycles were also tested.

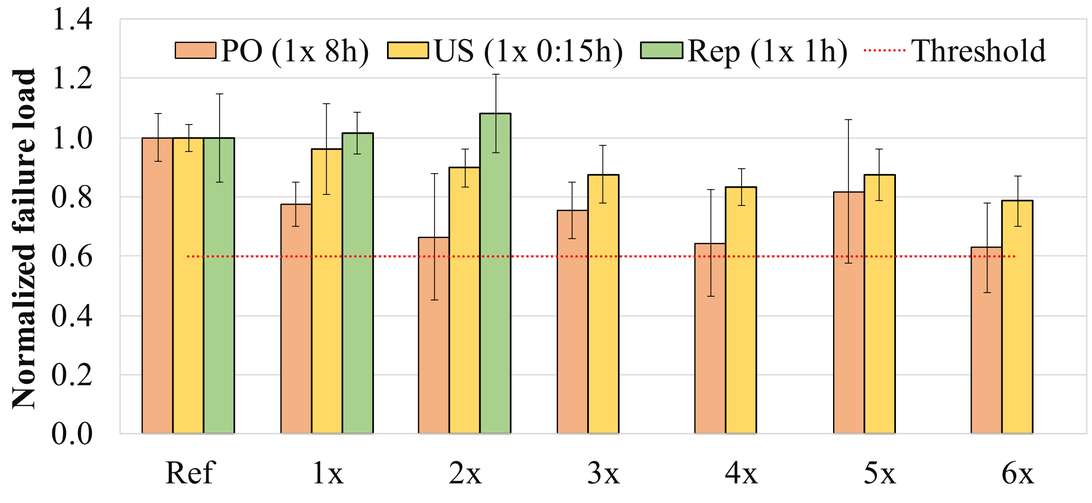

Figure 4 – Normalized shear strength of RJS joints cyclicly aged [2].

Results showed that repairing a broken insert does not affect the strength of the undamaged bits due to thermal cycles. From the cyclic cleaning procedures, ultrasounds presented a smaller and more progressive degradation, in comparison to the petroleum fluid which did not present a clear cyclic trend.

Conclusions

Unlike brazing, adhesives are much more susceptible to long term degradation. The most severe cases were due to water-based fluids (**W**/**CE**) both in adhesive and joint degradation. Nonetheless, although the adhesive might not be affected by other fluids (**DF**,...) in a real joint the interface can be degraded. Tool cleaning is recommended using ultrasounds and repair can be implemented with no real effect on the pristine inserts.

References

[1] Correia et al., Practical imple. and valid. of a novel process for manufacturing milling tools using adhesive bonding. 2nd International Conference on Advanced Joining Processes: Selected Contributions of AJP 2021, 2021.

[2] de Sousa et al., Analysis of the mechanical perform. and durability of adhesively bonded joints used in the milling industry. Applied Sciences, 2022.

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