Practical implementation and validation of a novel process for manufacturing milling tools using adhesive bonding

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Introduction

Since the 1980's few studies have been carried out on the use of adhesive bonding as a milling tool joining process, none of which were focused on woodworking tool applications. Due to the market's preference for lightweight tools, aluminium (Al) bodies were used in the production of induction cured bonded tools, nevertheless, steel (St), a heavier body material, was also tested, since both present interesting advantages in specific areas of the tooling industry. All materials used followed the work presented by Correia et al. [1].

Experimental methodology

Differential scanning calorimetry (DSC) tests were performed to fully define the cure cycle. As for the manufacturing step an induction curing setup was used, Figure 1, with an optical temperature control set to the defined cure cycle parameters.

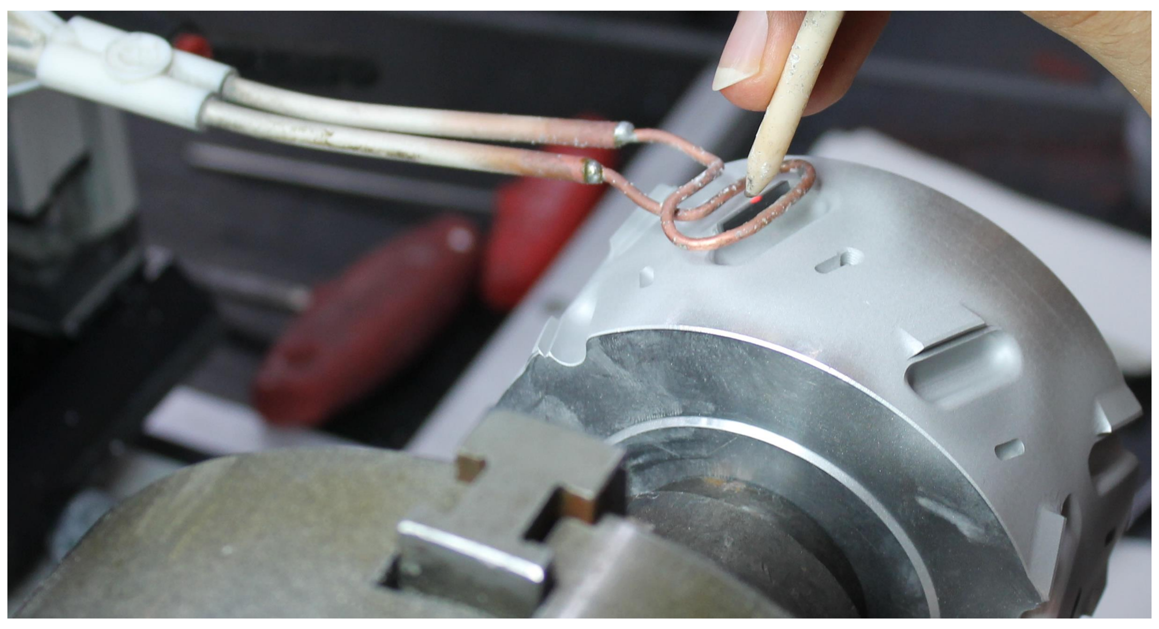


Figure 1 – Induction cured prototype manufacturing.

The milling tools were firstly produced and tested with bodies of 100 mm of diameter and then, finally, 180 mm. All steel bodies were solely grit blasted (St-Gr), and the aluminium ones had three treatment configurations: only grit blasted (Al-Gr) or anodized (Al-An), and a combination of both (Al-Gr+An).

Speed state	v_c / ms^{-1}	d / mm	η / rpm	η_p / rpm
Typical	70	100	13000	26000
		180	7400	14800
Maximum	90	100	17000	34000
		180	9500	19000

Table 1 – Overspeed (η_p) values for each cutting speed (v_c) state, and standardised diameters (d) used.

All the prototype configurations were tested for electrical discharge machining (EDM) capability and the standardised overspeed centrifugal test [2] for safety validation, Table 1.

Experimental results

The DSC curves shown that, to quickly but also safely cure the adhesive, a pre-cure induction cycle between 180ºC and 230ºC should be used, as can be seen in Figure 2.

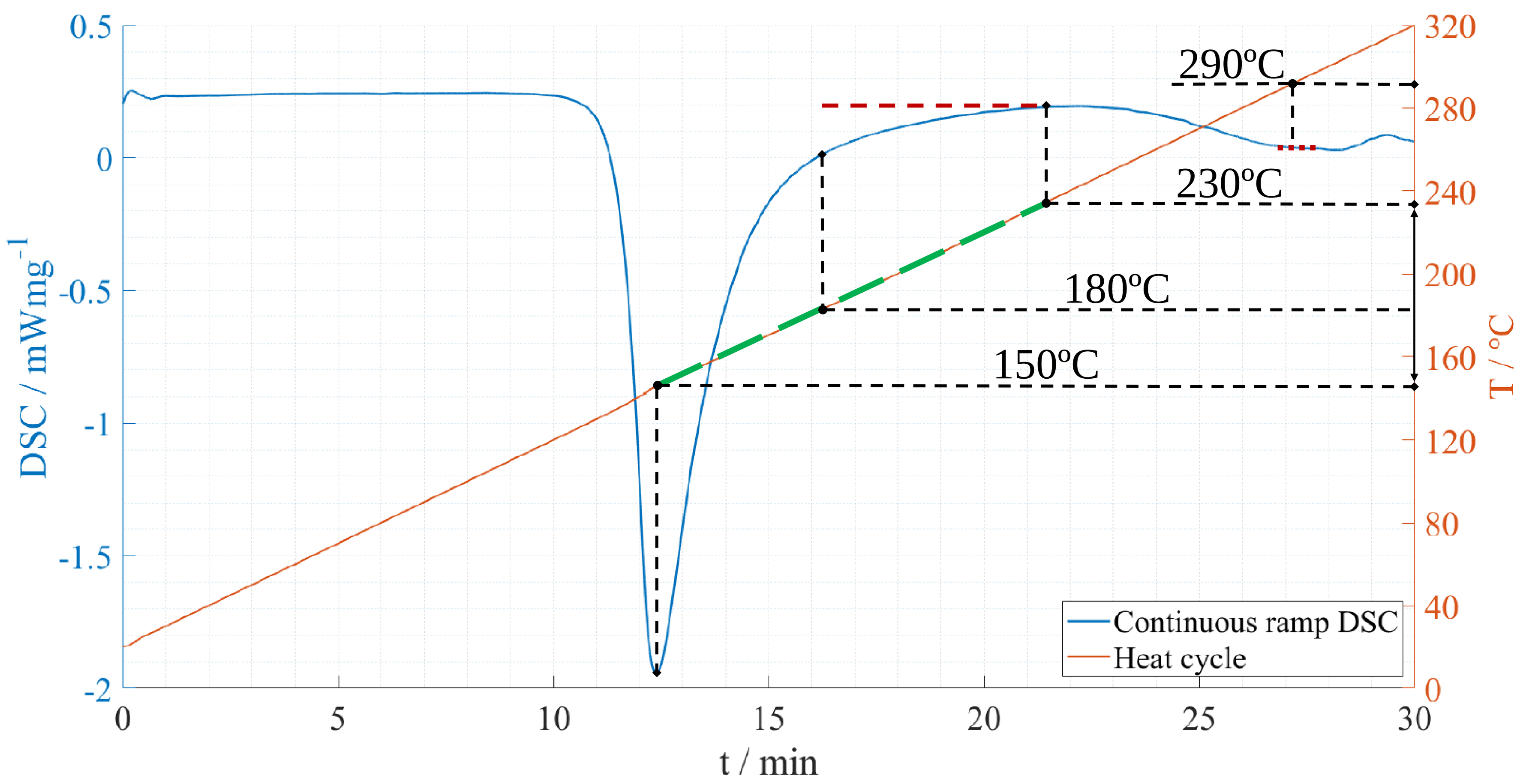


Figure 2 – DSC curves for the continuous ramp heating cycle.

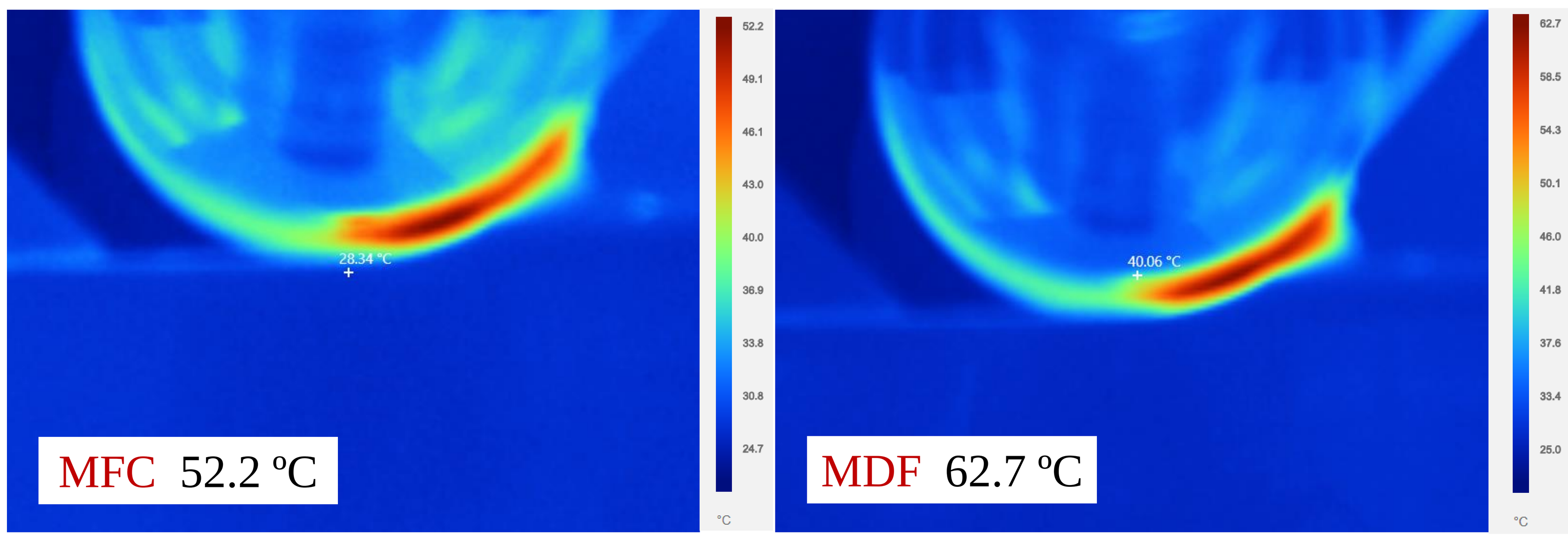
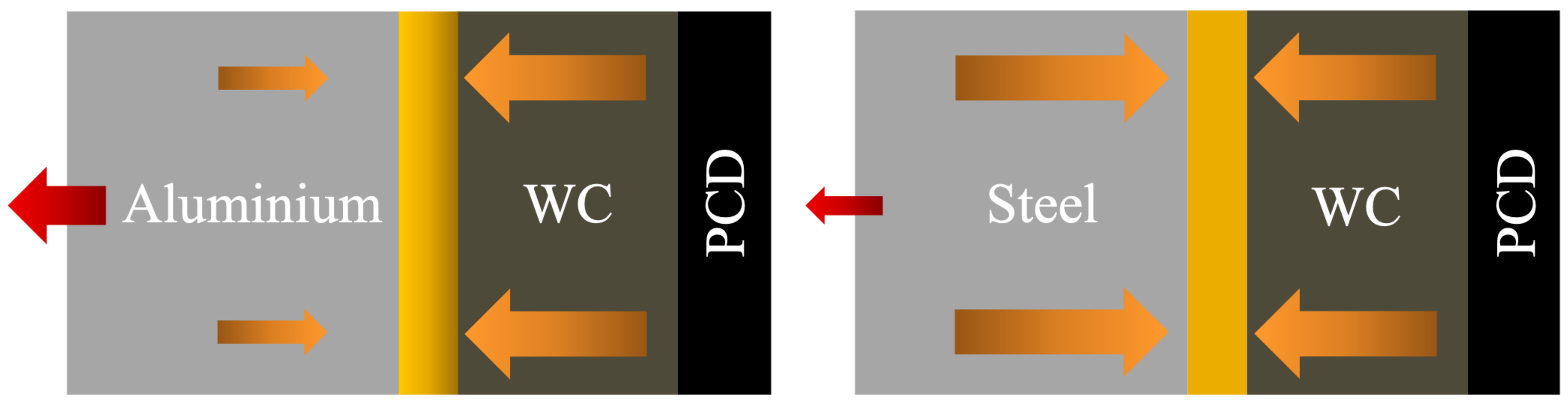


Figure 3 – Thermal imagery of different woodworking scenarios, MFC (melamine faced chipboard) and MFD (medium density fiberboard).

The work temperatures observed in Figure 3 did not rise much concern when considering possible thermal degradation.

As depicted in Figure 4, aluminium body tools showed signs of longer nonuniform cure cycles due to their high thermal diffusivity and low inductive efficiency, the reverse phenomenon was observed for the steel prototypes.



(a) Nonuniform cure (Al-PCD). (b) Uniform cure (St-PCD).

Figure 4 – Induction cure process heat flux scheme, supplied by the coil (orange) and diffused by the body (red).

The anodization process did not permit EDM sharpening. Also, only steel tools allowed 180 mm prototypes, making aluminium bodies not able to be validated at this diameter. Nevertheless, no bit failure was detected in any prototype for the machine's limit velocity (21500 rpm). All these are summarized in Table 2.

Prototype	EDM test	Overspeed test		Joint failure
	Yes/No	Typ. / η_p %	Max. / η_p %	Yes/No
100Al-An	N	82	63	N
100Al-Gr+An	N	82	63	N
100Al-Gr	Y	82	63	N
180St-Gr	Y	100	100	N

Table 2 – Summary of the validation test results for each prototype.

Conclusions

Unlike brazing, induction cured bonded tools shown the need for a pre-cure process. Aluminium tool bodies, contrarily to steel, posed a few production challenges. Nevertheless, both shown to be suitable for industrial practical implementation.

As for future developments, new methods to increase the efficiency of the induction process, as well as alternative curing methods should be more thoroughly evaluated.

References

[1] Correia et al., Experimental study on aluminium to WC/PCD adhesive bonding for milling tools. Submitted to International Journal of Adhesion and Adhesives, 2021.

[2] EN847-1. Tools for Woodworking - Safety requirements. CEN, 2019.

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