Optimization of curing processes for the manufacturing of adhesively bonded milling tools

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Introduction

Following the work of Correia et al. [1], the production of adhesively bonded tools fit for wood milling applications was further developed, optimizing the curing process in order to make it compliant with the needs of the industry. Since previously a few difficulties in the induction cure process were observed, mainly due to heat dissipation in aluminium tools, several improvements on manufacturing where tested, mainly for this material. Nonetheless, both aluminium and steel tools were used to produce test specimens.

Experimental methodology

The induction curing setup used followed the work of Correia et al. [1], resorting also to the same process parameters. For strength testing purposes, real joint specimens (Fig.1a) were produced replicating the same geometry utilized in the original milling tools, allowing for a more accurate analysis of the induction heating process.

Real joint specimens were used to test the influence of ferromagnetic particles in the induction heating rate, as well as allowing for a direct comparison of the induction pre-cure with the oven full cure, using a scanning electron microscope (SEM).

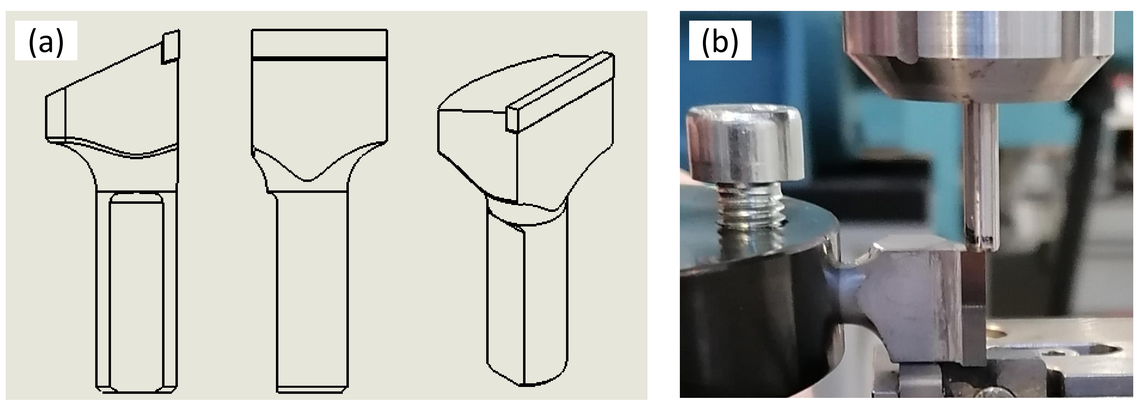

Figure 1 – Real joint specimen geometry (a) and shear testing setup (b).

Being the main objective of this study, the aluminium tool bodies were used to test two new induction coil configurations – pancake and vertical, both with three turns – in order to improve the induction heating performance of this material. In addition, several aluminium milling tool prototypes were produced solely by oven curing to be tested under normal work conditions. (Fig.2)

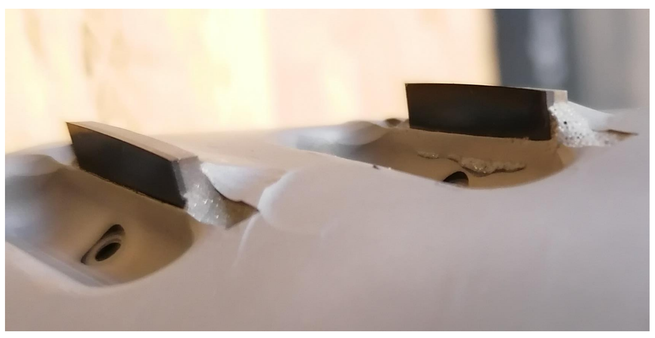

Figure 2 – Aluminium milling tool prototype after EDM sharpening.

These prototypes were sharpened using electrical discharge machining (EDM) and tested in an overspeed centrifugal test, according to standard [2], before being sent to a client for preliminary cutting tests.

Experimental results

The addition of ferromagnetic particles to the adhesive mixture resulted in a decrease of the pre-cure time, from 90 to 75 seconds, but did not improve the production time for steel, which remained at 45 seconds.

The single turn coil already in use produced a heat rate of 0.49°/s. The vertical coil showed virtually no improvement, while the pancake coil nearly doubled the heating rate. (Fig.3)

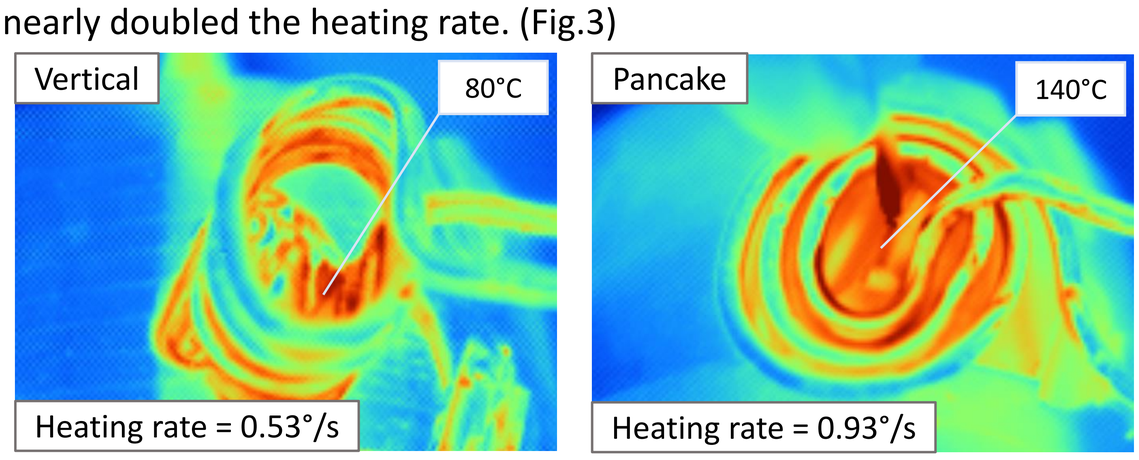

Figure 3 – Thermal imaging of a vertical and a pancake coil.

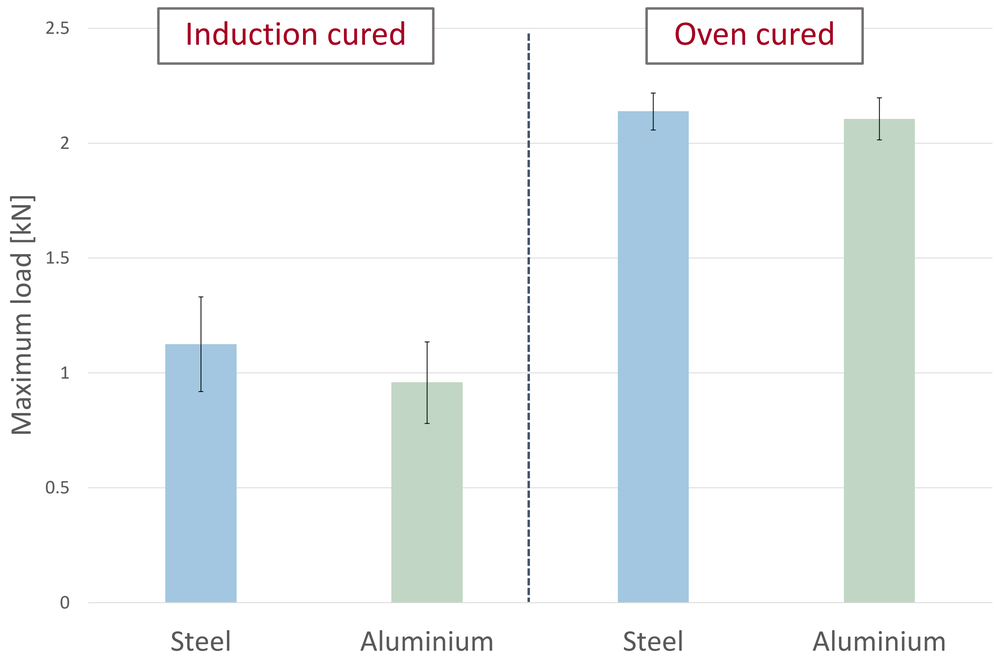

Figure 4 – Maximum shear load [kN] for induction cured and oven cured steel and aluminium specimens.

Strength testing showed a reduction of joint strength in induction cured specimens, when compared to oven cured samples. (Fig.4)

A SEM analysis revealed that the induction-cured joints featured a large presence of voids (Fig.5), which led to this difference in strength. This was expected, since the rapid cure time of the induction process may have prevented any gas buildup inside the joint from escaping.

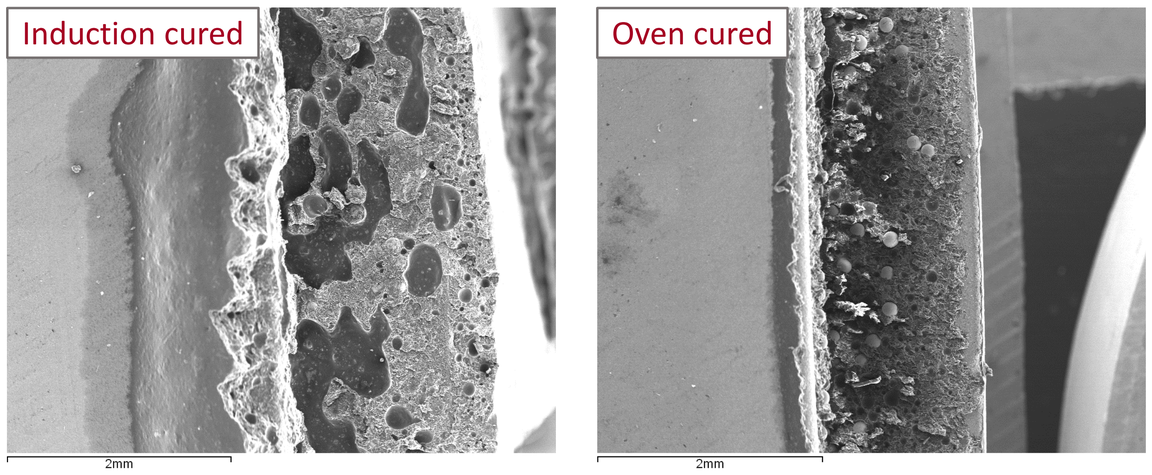

Figure 5 – Scanning electron micrograph of the fractured surfaces of induction cured and oven cured specimens

The milling tool prototypes were able to be sharpened by EDM. The overspeed validation of the tools was set at 16000 rpm, and no bit failure was observed. The tools were tested in real world use and produced a good quality of cutting with no damage to the bonded joints.

Conclusions

From a productive standpoint, it was not possible to make the induction cure process more productive, while maintaining good performance. Oven curing seems to be the optimal method to guarantee high joint strength, although it is not competitive when it comes to manufacturing time. Preliminary client testing of prototypes showed adequate cutting performance and compliance with the safety requirements.

Future studies should assess different pre-curing processes, such as UV light fixation, which could improve production time.

References

[1] Correia, D.S., Marques, E.A.S., Carbas, R.J.C., das Neves, P.J.C. and da Silva, L.F.M., “Practical implementation and validation of a novel process for manufacturing milling tools using adhesive bonding”, 2nd International Conference on Advanced Joining Processes (AJP2021): Selected Contributions of AJP 2021, 1st edition, Springer International Publishing, 2022.

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