Predicting interfacial temperature during Friction Wood Welding through a thermo-tribologic approach coupling experiments and finite element modelling

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Friction Wood Welding allows for achieving a glue-free joint, making this process an environmentally friendly technique. In this study, a tribological approach [1] was conducted to determine the fraction of mechanical energy useful for increasing the temperature at the interface, leading to the necessary local modification of wood primary constituents to achieve welding. Experimental measurements of friction and temperature close to the interface on the one hand and numerical thermal simulations on the other hand were performed to access the temperature inside the contact during the process, a data difficult to reach experimentally.

Keywords: tribology, friction wood welding, contact temperature, finite element modelling, experiments

1. Introduction

Friction wood welding (FWW) is an innovative process allowing wooden parts to be joined without any external material addition. This process achieves assemblies having mechanical resistance comparable to those obtained with glues [2]. Basically, the frictional heat generated during FWW induces the local transformation of wood into a molten material which then solidifies. This study focuses on the interface temperature estimation throughout the process. For the first time, a tribologic approach is conducted to address this key information thanks to the coupling between (i) friction force and temperature measurements, (ii) and 2D finite element modelling (FEM).

2. Methods

Pin-on-block linear reciprocated friction tests were conducted on beech-wood samples using a Cameron-Plint TE77 tribometer (Figure 1c). Tests were operated under an initial 4 MPa contact pressure with 0.35 m/s mean sliding speed (~7s of friction) until the welding of the two parts (comprising ~13s subsequent contact holding). During experiments, the pin displacement, the friction force, and the normal force were acquired at 10 kHz. The temperatures at 1.4 and 1.9 mm from the interface were simultaneously measured in the block and the pin, respectively, thanks to thermocouples embedded into the two parts. In parallel, a 2D thermal FEM model of the contact was developed using an adaptive Gmsh meshing and the implicit code Elmer CSC 8.3. Characterization of beech-wood physical and thermal properties as a function of temperature was also carried out, to inform the model.

From the experimental measurements, the total frictional power dissipated per unit surface P_{tot} was first injected in the model as a boundary condition. Assuming that αP_{tot} and βP_{tot} are the power density respectively transferred to the block and the pin, α and β were then determined by fitting the temperatures numerically calculated far from the contact with the experimental ones, which were measured with the thermocouples (Figure 1a-b). Wear depth characterization at different step of the process was also performed to adjust the actual position of the thermocouples from the interface. Finally, the model allowed to determine the interfacial temperature evolution throughout the FWW process (Figure 1d).

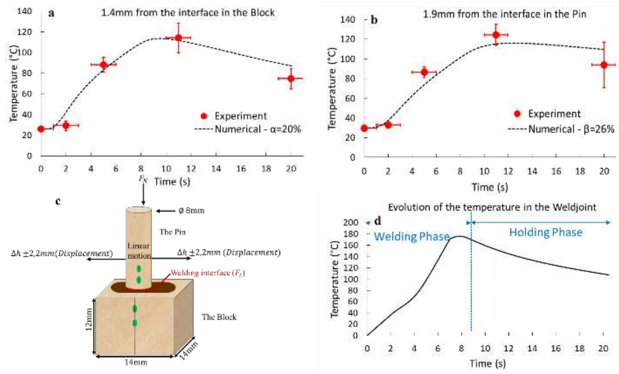

Figure 1: experimental and numerical temperature estimation at from the contact in the block (a) and the pin (b), tribologic contact studied (c), temperature prediction in the contact (d).

3. Discussion

Main results show that approximately 26% and 20% of the total frictional power dissipated in the contact are thermally transferred into the pin and the block, respectively. This suggests that a substantial amount of energy should be associated to wear, damages, and phase transformation processes close to the interface. Ultimately, the study concludes that maximal temperature close to 180°C is reached inside the contact. This is consistent with the activation of physical and chemical processes reported in the literature such as hydrolysis, pyrolysis, condensation, cellulose depolymerization and lignin melting

4. References

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