

# ULTRASONIC WELDING OF THERMOPLASTIC COMPOSITES: INVESTIGATING THE FLOW OF ENERGY DIRECTING STRIPS

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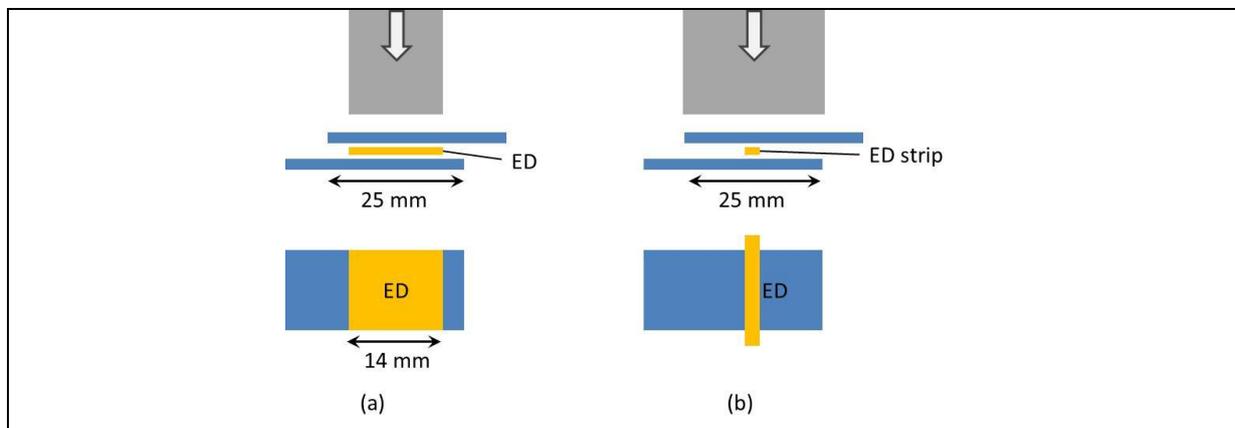
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**Keywords:** *thermoplastic composites, ultrasonic welding, energy directors.*

## Introduction

Previous work at the Delft University of Technology on ultrasonic welding (USW) of thermoplastic composites established a solid understanding of the process when joining lab-scale single lap shear specimens with a simple, flat energy director shape, made of a loose, 0.25 mm-thick, thermoplastic film, covering the entire overlap area. It has been shown that for such samples, it is possible to rapidly define optimum welding parameters and consistently produce welds of excellent quality, when controlling the process through the vertical displacement of the sonotrode [1]. Further up-scaling of the process for small to medium-sized parts requires the overlap to be larger than the welding area. Preliminary research using a 25 mm-wide overlap with a 14 mm-wide ED (same width as sonotrode, shown in Figure 1 (a)) revealed issues such as surface damage, and uneven fracture surfaces with a combination of unmolten and overheated areas [2]. It was found that using thermoplastic strips as an ED, as well as a sonotrode covering the entire overlap (Figure 1 (b)), could significantly reduce these problems, allow better investigation of resin flow and provide welds of good quality.



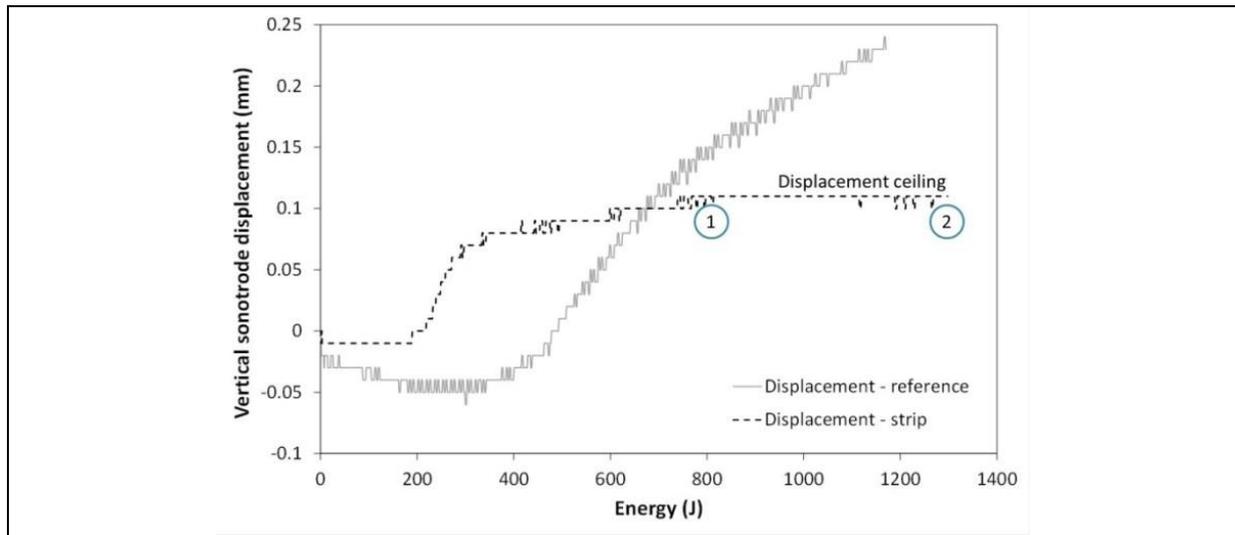
**Figure 1:** (a) 25 mm overlap and energy director with the same width as sonotrode (14 mm) [2], and (b) ED strip in a 25 mm overlap with sonotrode covering the entire overlap. Dimensions are not to scale.

## Results and discussion

In this work, the use of flat energy directing strips is investigated with respect to their flow at the interface and the corresponding welding output. Carbon fiber/polyether ether ketone (CF/PEEK) coupons were welded in a single lap configuration with an overlap of 25 mm (Figure 1 (b)). Preliminary analysis of the output curves, i.e. power and sonotrode displacement, however revealed an issue regarding the control of the process: as seen in Figure 2, a “ceiling” in the displacement curves is present early on in the vibration phase, preventing the use of the sonotrode displacement as a control mode.

To further explore the causes of this displacement ceiling and provide insight into up-scaling of the USW process, the effect of welding force and strip width on the flow of the energy director was examined by using energy as the control mode. It was observed that an increase of welding force pushed the ceiling to a higher displacement value, but did not eliminate it. A similar trend was experienced when varying the strip width from 2 mm to 8 mm, while keeping the welding pressure constant by increasing the force. It was first believed that the ED flow stopped when the ceiling was reached. However, this assumption was disproved when observing an increase in fracture surface area for specimens welded at two different stages of the process illustrated in Figure 2. This behaviour was confirmed for both narrow (2 mm) and wide (8 mm) ED strips.

A more detailed examination of the flow fronts and ceiling development was carried out through fractography and cross-sectional microscopy analyses. They revealed that the flow fronts did not completely come into contact with the substrates surfaces, suggesting they solidify during the process and cannot be melted again. They could therefore create a physical barrier, potentially causing the displacement ceiling.



**Figure 2:** Comparison between displacement curves of a regular single lap shear weld with ED covering the entire overlap area (reference, [1]) and a 25 mm overlap with an ED strip (as shown in Figure 1 (b)). Circled numbers show the two stages where the welding process was stopped to investigate changes in the fracture surfaces.

## Conclusion

As a next step toward up-scaling of the USW process, our deeper understanding of the flow of the energy directors with respect to the displacement ceiling can help identify a solution to overcome it. It then becomes possible to optimize the control mode for high quality welds of larger components.

## References

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