ON THE ENVIRONMENTAL STRESS CRACKING OF VIBRATING-WELDED THERMOPLASTIC-BASED NANOCOMPOSITES

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ABSTRACT
Vibration welding and environmental stress cracking (ESC) represent two relevant and thus well-defined and researched subjects within the realm of polymer science. However, the susceptibility of vibration-welded parts, and more importantly, the potential improvement of ESC resistance of such parts is scarcely being reported in the literature. With the help of an online optical crack measurement approach, the fracture behavior of vibration-welded nanocomposites was investigated. Results show that the addition of nano-sized silica particles leads to a significant increase in their ESC resistance.

Keywords: vibration welding, polymer nanocomposites, ESC, fracture mechanics.

INTRODUCTION
As one of the commonly used welding methods to join thermoplastics in industrial series production, vibration welding has been intensively studied in the past 40 years. The welding process in particular leads to high gradients in stress and temperature in the weld region, and therefore majorly influence the local material morphology, which in turn determines the weld quality in service. Gehde et al. [1] as well as Potente and Übbing [2] have reported that the ultimate weld strength of the reinforced materials under optimized welding conditions can only reach the strength of the non-reinforced polymer matrix making the reinforcement unnecessary and even harmful from the mechanical standpoint. In practical applications of such joined parts, they are often used as containers, and pharmaceutical packaging, which are usually in contact with distinct fluids. Contamination of the welds with these fluids is inevitable, which can lead to the environmental stress cracking (ESC). ESC is considered a great challenge for polymer materials, as it is responsible for about 25% of serious product failure cases in service [3]. Our previous studies have revealed an improved ESC resistance with the addition of nanoparticles [4]. As the use of nanofillers has been proven effective in the enhancement of ESC resistance, it is of great interest to fundamentally investigate the ESC behaviour of vibration-welded thermoplastic parts under special consideration of the nano-reinforcements.

RESULTS AND CONCLUSIONS
For the investigations of their ESC behavior, an online optical measuring system leads to a better interpretation of the ESC phenomenon of such polymer materials. The propagation of damage area, crack opening displacement (COD) or a macroscopic crack can subsequently be used to characterize the ESC behavior [4]. Results of our research have shown that the
implementation of nano-sized particles in amorphous and semi-crystalline thermoplastics has a notable effect on ESC behavior due to the enormous internal interfaces between nanofillers and polymer matrix. Considering the morphology of vibration-welded semi-crystalline thermoplastics and their nanocomposites, there exists a multilayer structure from the bulk material to the weld center, as is reported in [5]. It is believed that the single layer with different spherulite sizes in the weld region should exhibit different ESC resistance, which could affect the ESC resistance of the welded parts in service.

After welding, the ESC resistance of the welds was investigated by using DI-water and methanol as ESC agents. In Figure 1, the evolutions of the crack opening displacement (COD) as a function of the testing time in both environments were shown. Similar to the non-welded samples [4], the welded specimens undergo a stable propagation stage after the initial phase state, and before the catastrophic failure occurs. The results in welded samples reveal that the addition of 1 vol.-% nanosilica, into polypropylene (PP) matrix significantly reduces the growth rate of the crack opening displacement. This can be observed by the decrease in the slope within the linear region. Furthermore, the addition of nanosilica into PP also leads to an obvious improvement of the ESC resistance of the welded parts. The time to failure increases by approximately 580% and 310% in DI-water and methanol, respectively.

![Fig. 1 – Evolutions of the crack opening displacement (COD) of vibration-welded PP and PP/silica nanocomposite as a function of testing time in DI-water (left) and methanol (right).](image)

REFERENCES


