Development of a method for determining tool damage in friction stir welding tools using linear damage accumulation

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State of the art:

In addition to the unique weld seam properties, FSW includes specific challenges like comparatively high static and dynamic forces and torque during welding. In the literature review to date, the geometric design of the tools is mostly based on empirical values, which can result in two extreme cases called over- and undermatching. An overmatching for example results in an increased heat input, comparatively high process forces and limited accessibility. On the other hand, an undermatching increases the risk of premature tool failure which reduces the process reliability and leads to unplanned set-up and downtimes in production.

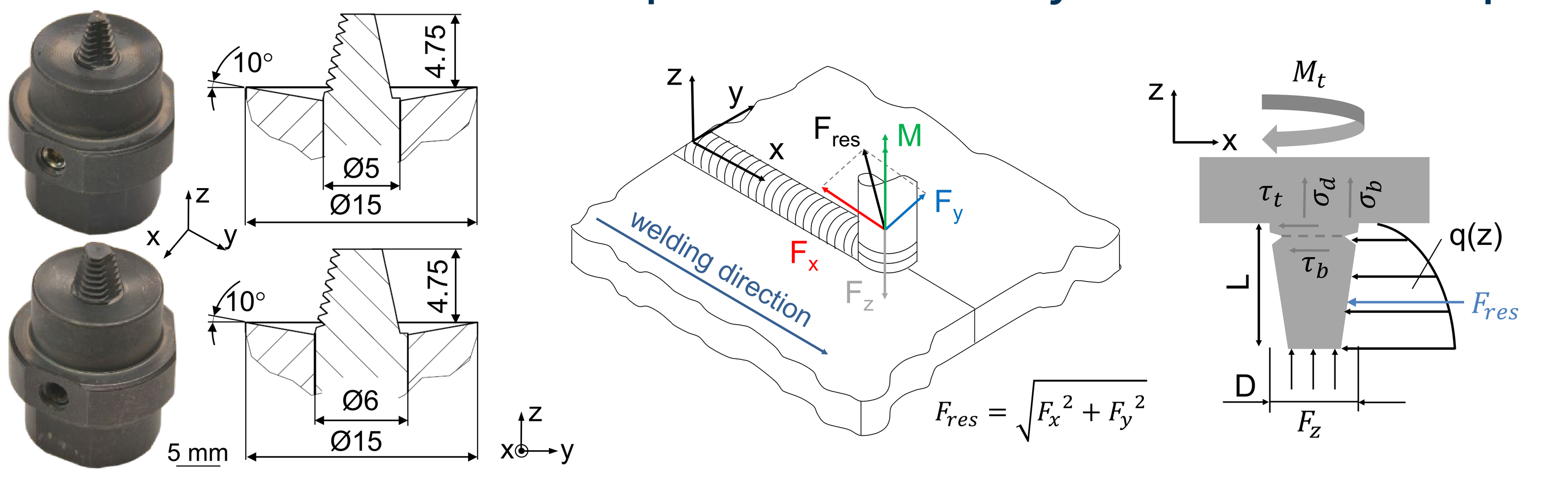

Fig. 1: Friction stir welding tools and stress components on the probe (according to Arora et al.).

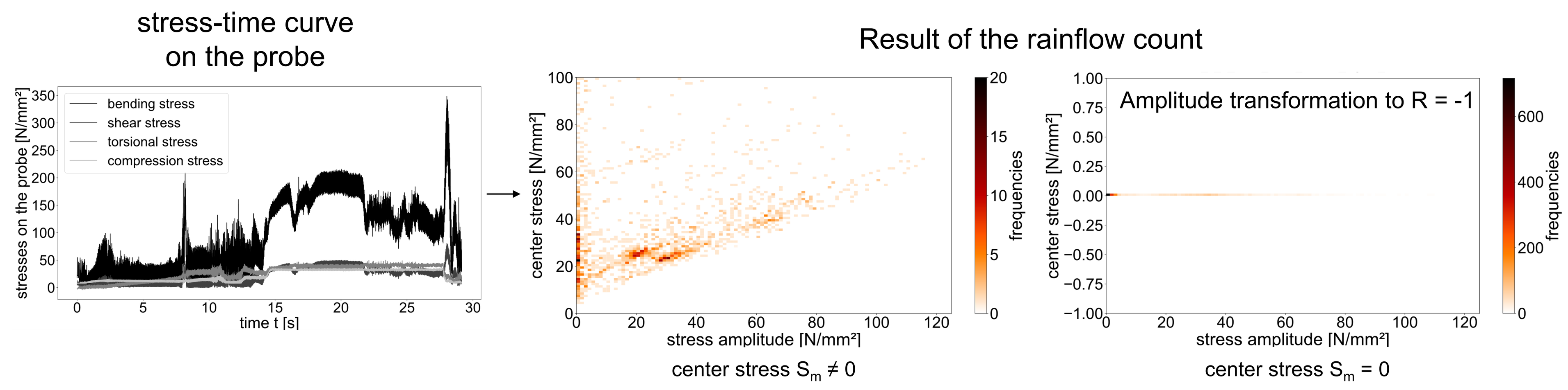

Fig. 2: Classification of the friction stir welding process using rainflow counting.

Implementation and goals of current research:

Currently there is no standardised calculation rule for the design of friction stir welding tools based on the dynamic loads in the welding process. The aim of the research project "DimFSW" is to systematically analyse the dynamic tool damage and the respective failure mechanisms in relation to the tool dimensions and process temperature, accounting weld seam length and quality. The determination of partial tool damage enables classification of the maximum tolerable tool life, considering the impact of process temperatures on permissible stresses of FSW tools made of H13 steel (1.2344). The results indicate that dynamic stresses can be significantly affected by rotational speed, welding speed and the tool dimensions used.

Procedure and results:

The investigations were carried out with a force-controlled robotized welding setup from Grenzebach Maschinenbau GmbH in which AA 6060 T66 sheets with a thickness of 5 mm were joined. The friction stir welding tools have probe diameters of 5 and 6 mm and a shoulder diameter of 15 mm (see Figure 1). A Kistler multicomponent dynamometer type 9139AA was used to measure the cartesian forces. The spindle torque was measured using a contact free stain gauge-based transducer system from Artis. Tool characterization by means of visual inspection and stripe light projection enable to determine the stresses on the probe. An extended approach by Arora et al. was used, which considers the different stress components on the probe (see Figure 1).

In the next step, a classification was carried out using rainflow counting which enables a categorization with regard to the occurring center stresses, stress amplitudes and frequencies (see Figure 2). The methodology for estimating tool damage during friction stir welding is shown in Figure 3.

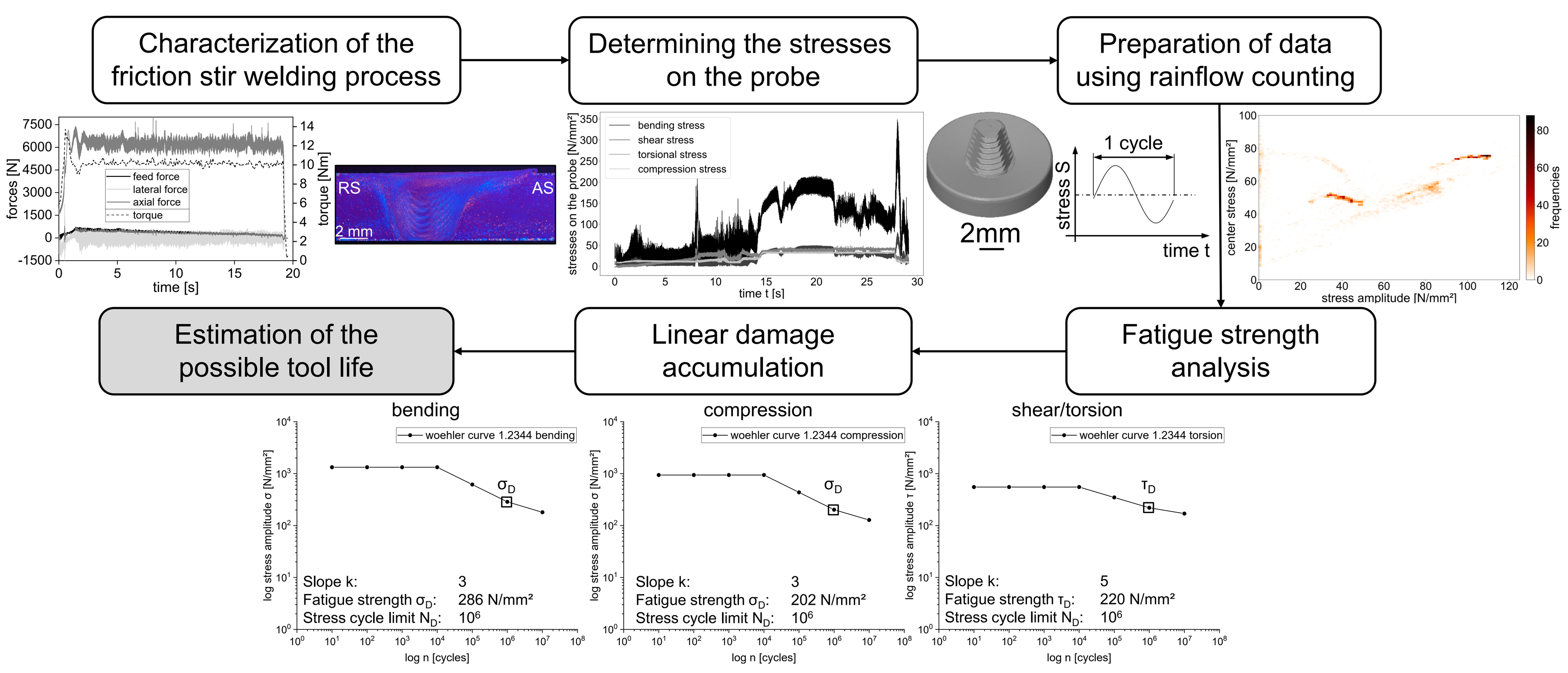

Fig. 3: Methodology for determining damage of friction stir welding tools in the welding process.

<u>The main priorities and approaches of the research project "DimFSW" :</u>

- Separation of process forces and torques between probe (assumed to be relevant to failure) and shoulder (see Figure 4)
- Linear damage accumulation to estimate the tool damage
- Determination of the influence of the process phases on tool damage
- Increased process reliability by avoiding unplanned set-up and downtimes

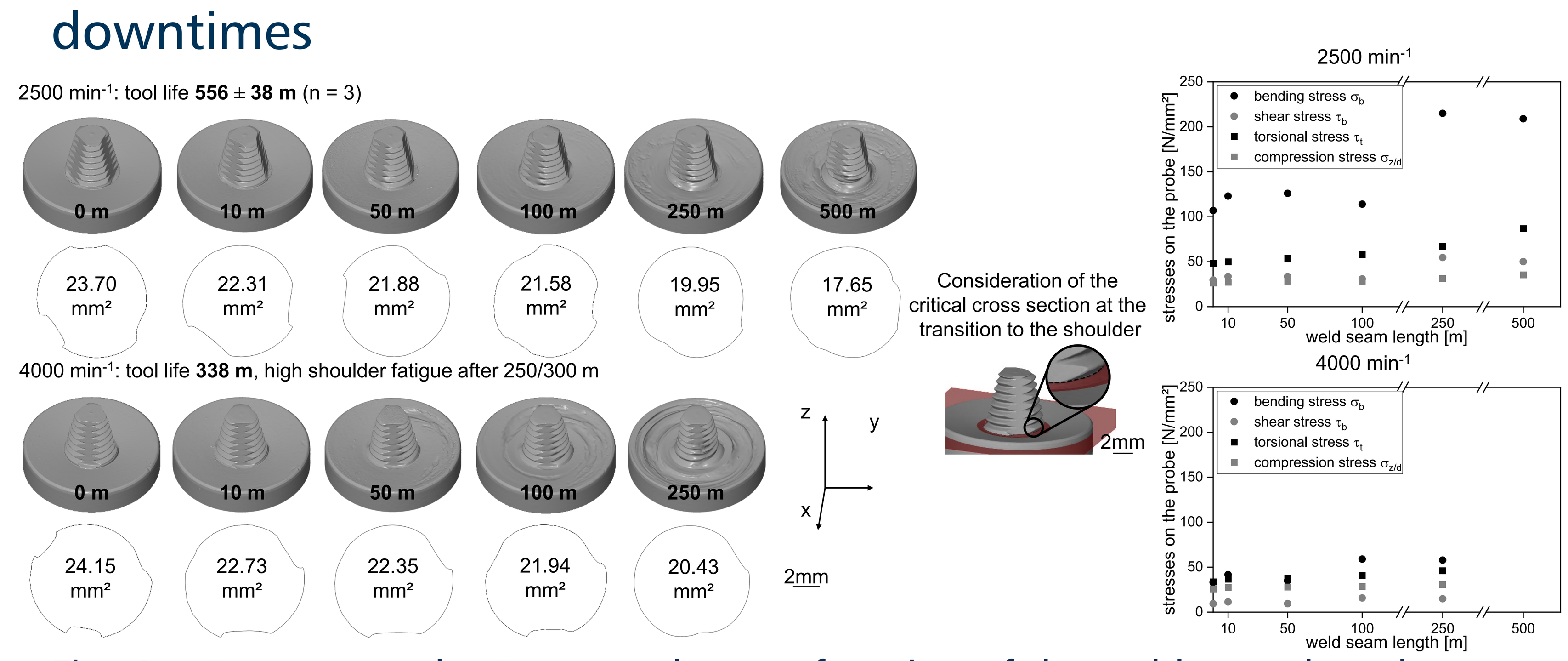

Fig. 4: Stresses on the 6 mm probe as a function of the weld seam length.

Friction stir welding tools and in particular probes with their effective structures such as threads or flats increase the process window, but lead to an increase in stress due to the notch effect. This is considered in the context of a fatigue strength analysis. The results are synthetically generated woehler curves for the main stresses of the probe (bending stress σ_b, shear stress τ_b, torsional stress τ_t and compression stress σ_d) at process temperatures of approx. 530 °C. The data processed using rainflow counting can be compared with the woehler curves to determine partial damage. The step-by-step summation leads to the total tool damage.

The result is a possible prediction of the tool life depending on the setting variables, the tools and the materials to be joined. The aim is to reduce unwanted set-up and downtimes in order to further increase the process efficiency of FSW.

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