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Effect of varying strain rates on the local mechanical properties of aluminum alloy welded joints

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Introduction

- In ocean engineering and aerospace, welded structures often bear dynamic loads at different strain rates. However, traditional overall tests cannot reveal the local failure mechanism of joints. This paper combines multi - physical field welding simulation and DIC technology to uncover the synergistic mechanism of residual stress and heat - affected zone softening under dynamic loading.

- To establish a quantitative relationship between strain rate and local mechanical properties, the Ramberg - Osgood equation is used to perform non - linear fitting on the constitutive parameters of each region (base metal, heat - affected zone, and weld). The variation law of local strengthening/softening behavior of the joint with strain rate is clarified.

- Based on the dynamic strain aging theory, the microscopic mechanism of the strength improvement of AA5052 welded joints at low strain rates is elucidated. The influence of strain rate on the PLC effect and work - hardening behavior is revealed, providing a theoretical basis for dynamic strength assessment.

Experimental Method

Process and Specimen Preparation

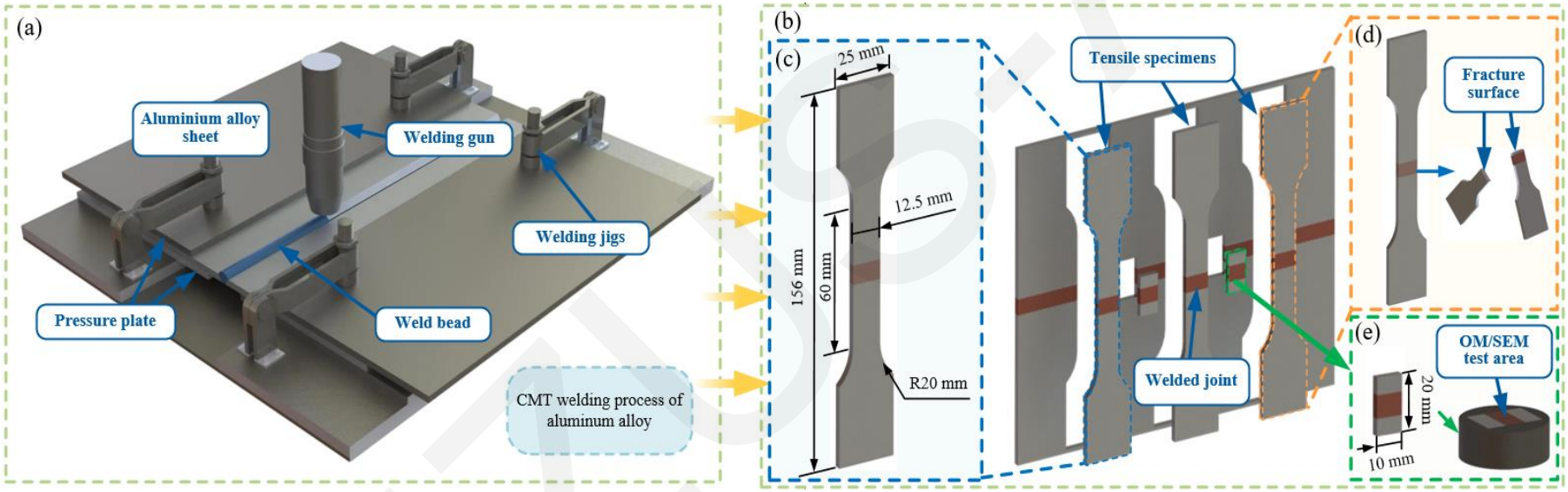


Fig. S1 Specimen preparation: (a) Welding process; (b) Schematic diagram of tensile specimens cutting; (c) Dimensions of tensile specimen; (d) Schematic diagram of fracture morphology testing; (e) OM/SEM specimen.

Digital Image Correlation-DIC

- **Digital Image Correlation (DIC), a non-contact full-field deformation measurement technique, enables the quantitative analysis of displacement and strain fields by tracking the geometric position changes of speckle patterns on the material surface.**

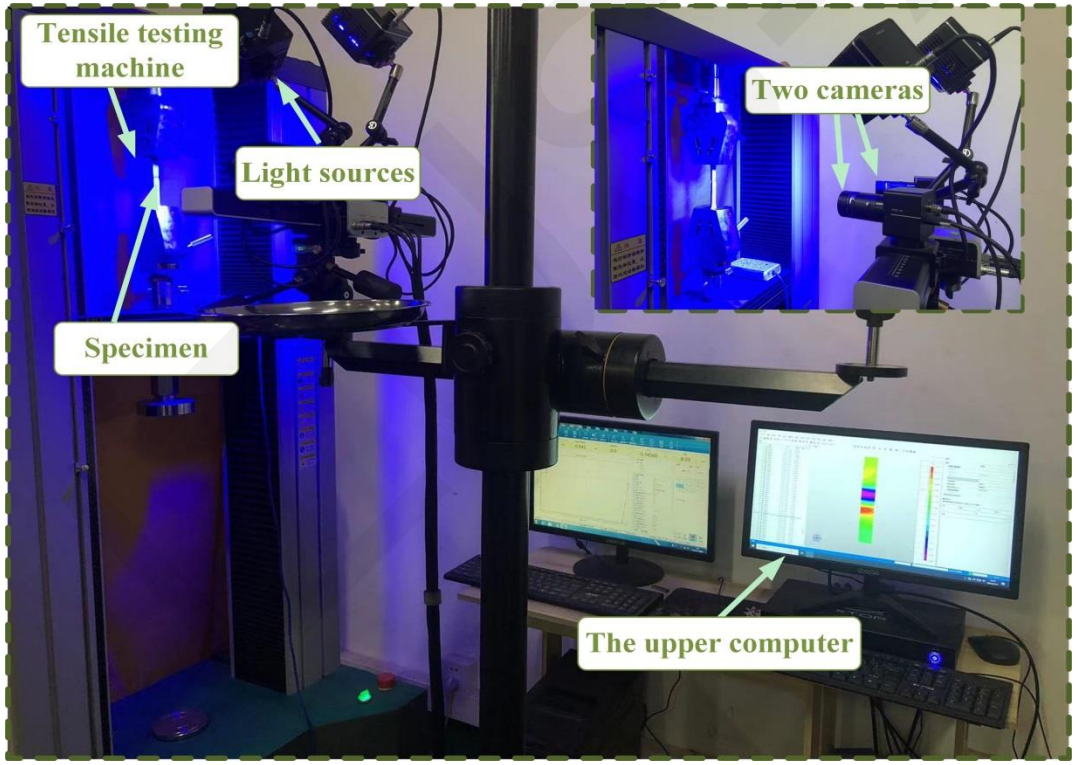


Fig. S4 Schematic diagram of the DIC test system.

Stress Strain Result

Stress–strain curves and strain distribution map

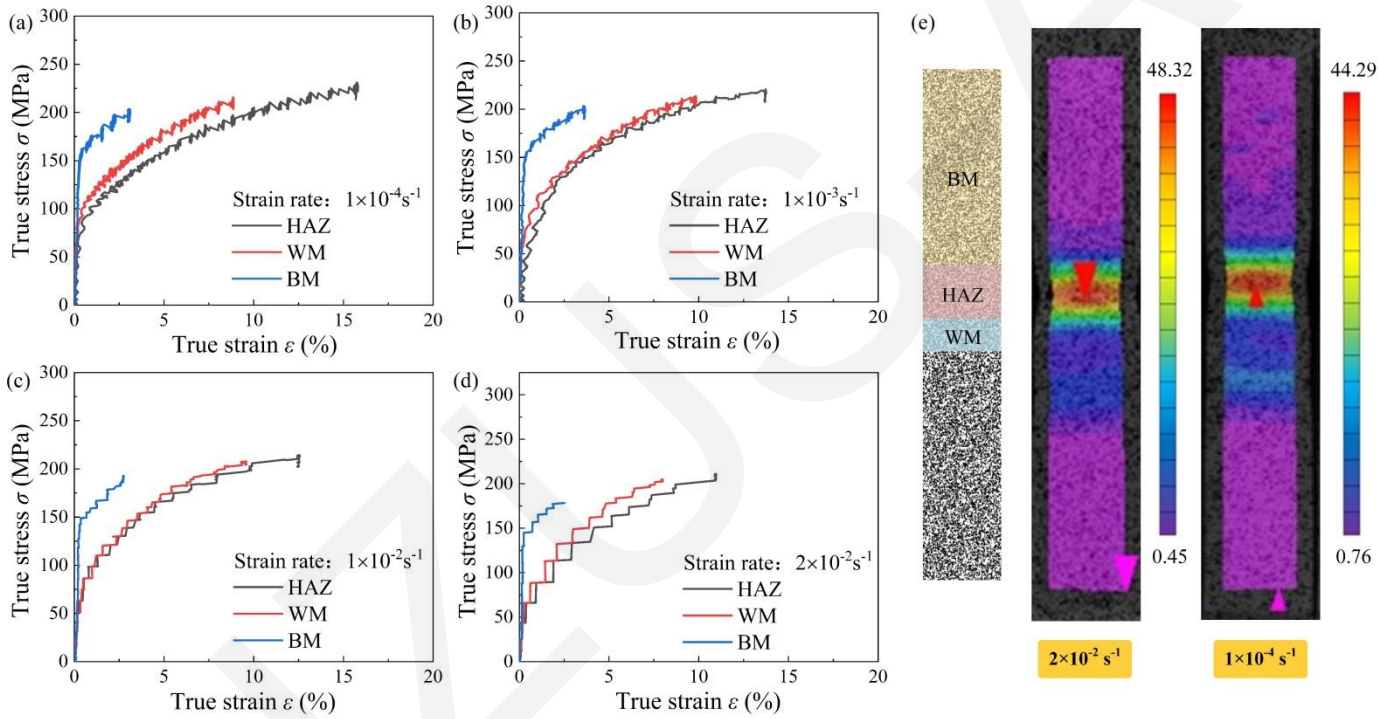
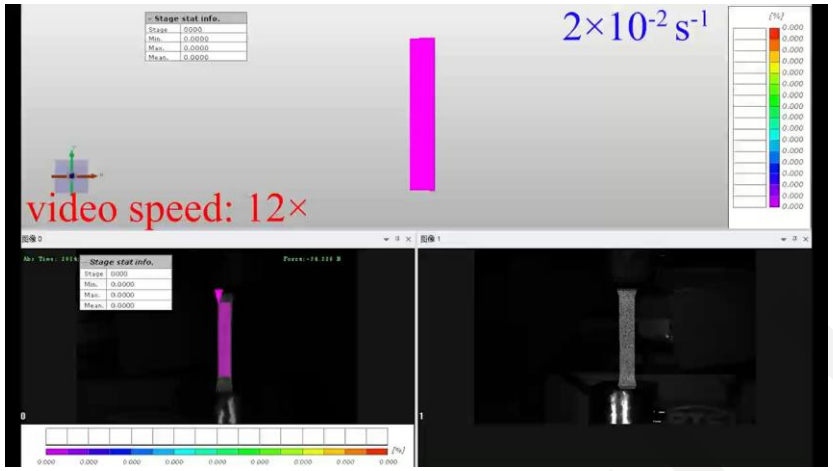
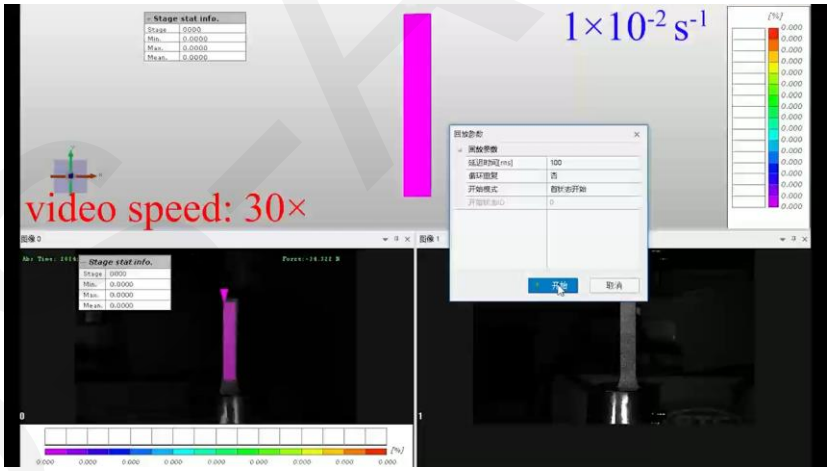


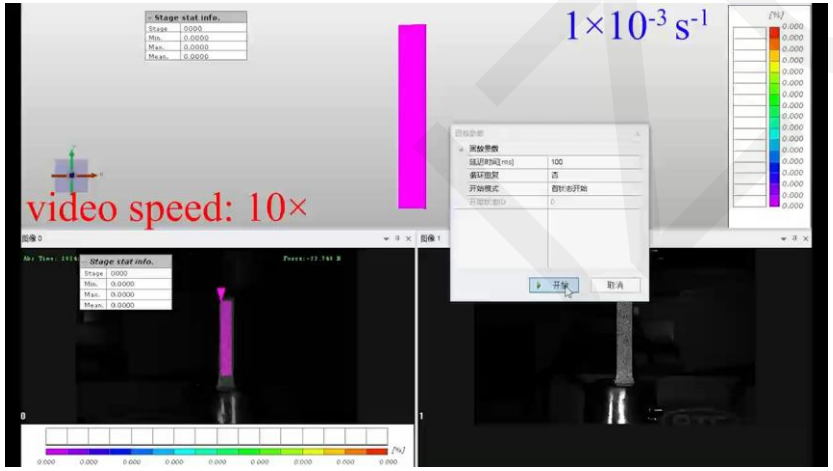
Fig. 3. Stress–strain curves of welded joints at different strain rates: (a) 1×10^{-4} s^{-1}; (b) 1×10^{-3} s^{-1}; (c) 1×10^{-2} s^{-1}; (d) 2×10^{-2} s^{-1}; (e) Welded joint strain distribution map.

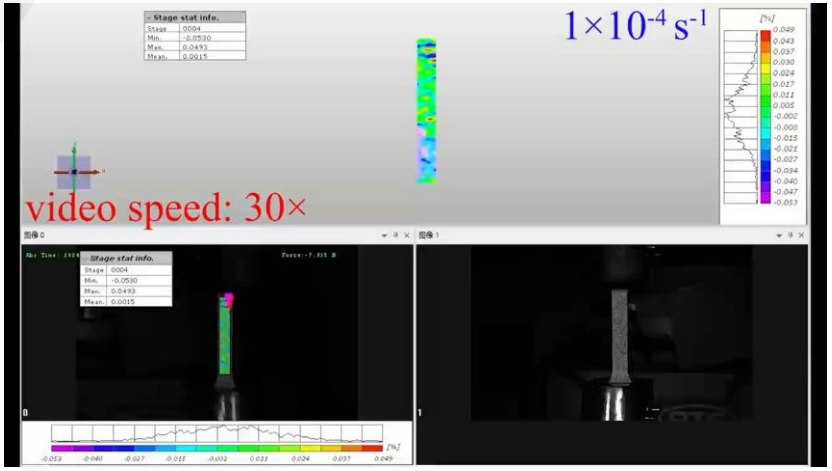
Video Results

- **Video results of DIC at different strain rates**









Conclusions

- The welding thermal cycle leads to the softening of the microstructure and the concentration of residual tensile stress in the heat-affected zone, forming a "softening - stress concentration" dual mechanism, which makes it the preferential area for tensile fracture.
- Within the quasi - static strain rate range of 1×10^{-4} ~ 2×10^{-2} s^{-1}, reducing the strain rate can improve the yield strength and tensile strength of each region of the welded joint. Among them, the yield strength of the weld zone increases the most, reaching 31.54%.
- Dynamic strain aging is the dominant mechanism for the strength improvement at low strain rates. When the strain rate decreases, the interaction between solute atoms and dislocations is enhanced, and the work - hardening ability is improved. An excessively high strain rate will weaken this effect and reduce the uniform deformation ability of the material.