E2E

Finite element modelling of resistance spot welding including validation

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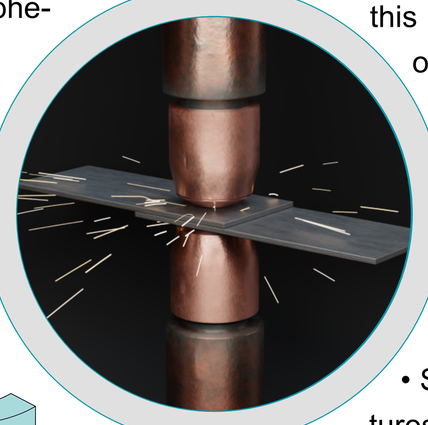
Digitized Production enabling end-to-end design-operation

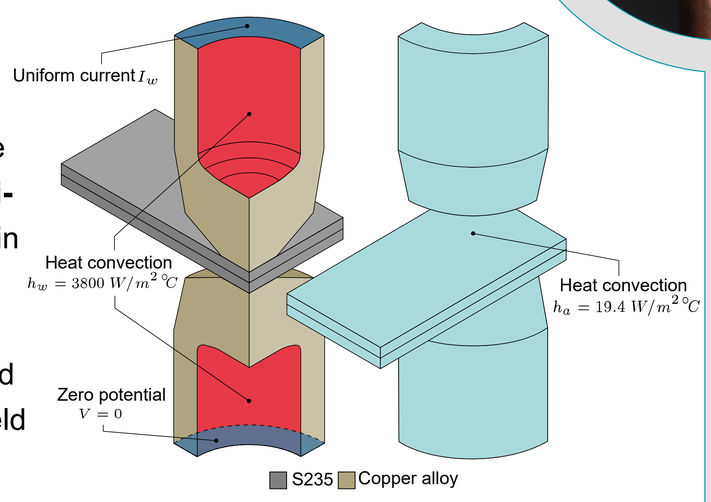
Introduction

Resistance spot welding (RSW) is a widely used method in sheet metal welding due to its **economic viability** and **efficiency.** Understanding the complex phenomena occurring during RSW is crucial for **process optimisation** and **quality assurance.** Numerical models can help in this regard, however the **validation** of such model is a crucial step in assessing its accuracy and reliability in predicting weld quality. Aiming at an industrial applicability, this research focusses on non-destructive (ND) validation approaches.



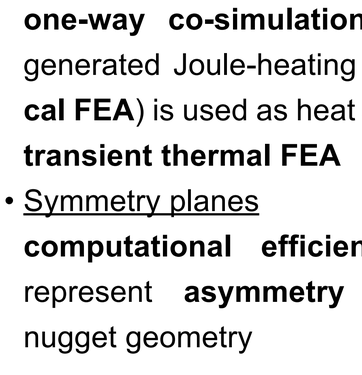
Approach

- Simplified multiphysics coupled FEM of RSW
  one-way co-simulation where generated Joule-heating (**electrical FEA**) is used as heat source in **transient thermal FEA**
- Symmetry planes
  computational efficiency and represent **asymmetry** in weld nugget geometry



Non-destructive validation techniques

- Ultrasonic testing (phased array) as ND alternative to metallurgical nugget diameter measurement
- **D-scan** distinguishes **welded** and **non-welded regions**
- Three measurements per welded sample
- Nugget shape not always perfectly circular, but **more eliptical**
- Method of **corresponding nugget diameter** deals with this :



$$d_{UT} = 2\sqrt{\frac{\sum_{i=1}^{n} A_i}{\pi}}$$

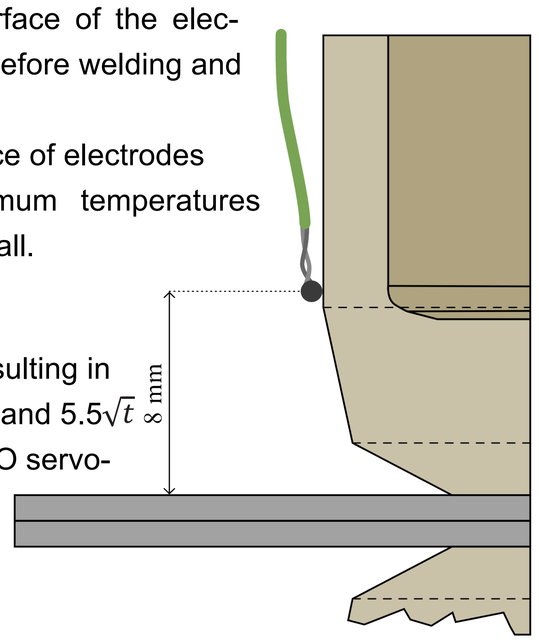
Welded area (A_1 ... A_n)
Non-welded area
Cladded area

Thermal validation

- Thermocouples attached to the outer surface of the electrodes measure temperature one second before welding and 5 seconds after
- Heat conduction from fusion zone to surface of electrodes
- Analysis included comparison of maximum temperatures reached and rate of temperature rise and fall.

Experimental design

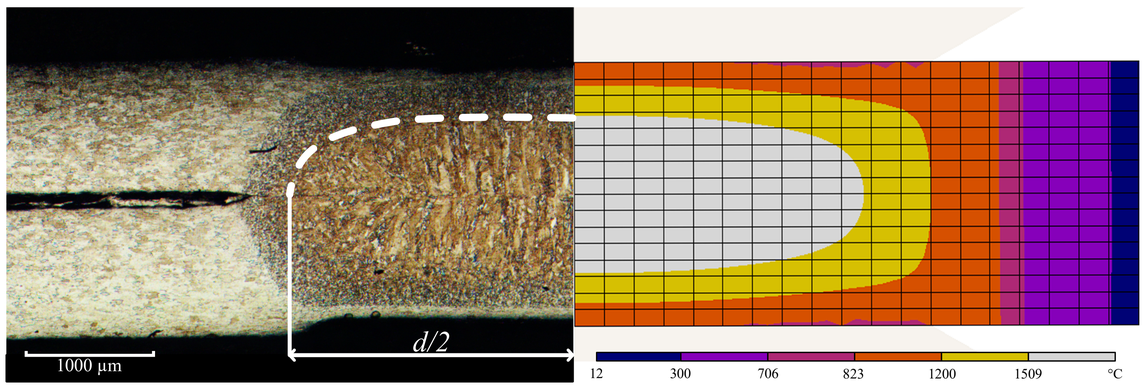
- Three welding parameters sets chosen resulting in nominal nugget diameters of $3.5\sqrt{t}$, $4.5\sqrt{t}$ and $5.5\sqrt{t}$
- Ten samples per set are welded on an ARO servo-actuated RSW machine of pedestal type with a MFDC power source



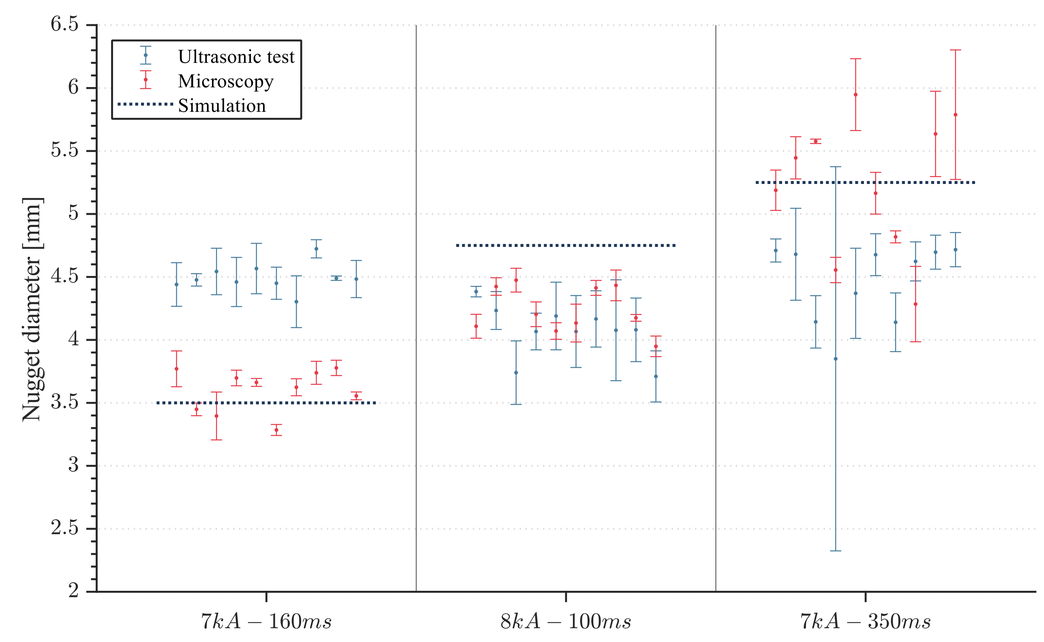
Results

Destructive and non-destructive validation techniques are compared to each other in this research. In current literature, the destructive metallurgical inspection is often used as a validation approach. The temperature field of the numerical model is compared with the microstructure of cross-sectioned welds.

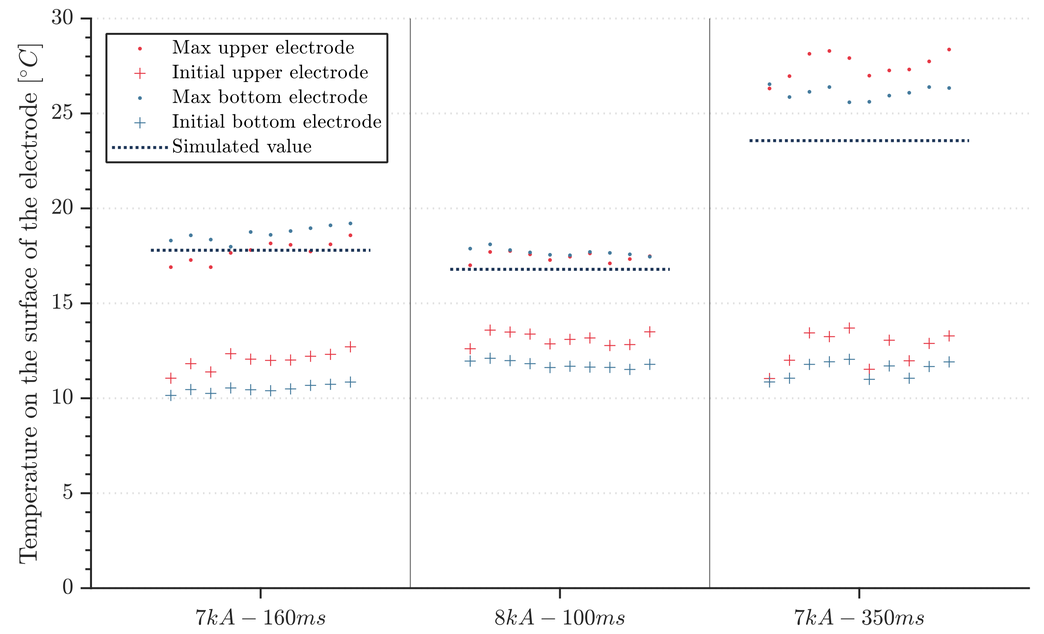
- Destructive metallurgical inspection offers valuable insights but can be **labor-intensive** and **time-consuming**
- Variation in location of the fusion zone may lead to **potential underestimation** of true weld geometry dimensions
- Simplified model lacks mechanical analysis capabilities for post-welding features, like the **indentation**, but provides essential weld geometry dimensions



Weld nugget geometry



Heat flow through electrodes



Further reading

Verkens, B., Faes, M., Van Rymenant, P., Moens, D. (2023). Multi-physical modelling of resistance spot welding including validation.

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Key take-aways

- **Discrepancies** in weld nugget diameter measurements highlight **challenges** in **validation techniques**
- Comparison between measured and predicted data indicates that a **simplified** model can provide an **initial estimate** of the **weld quality**