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Scaling of Heat Treatment Behaviour of Low Alloy Steels

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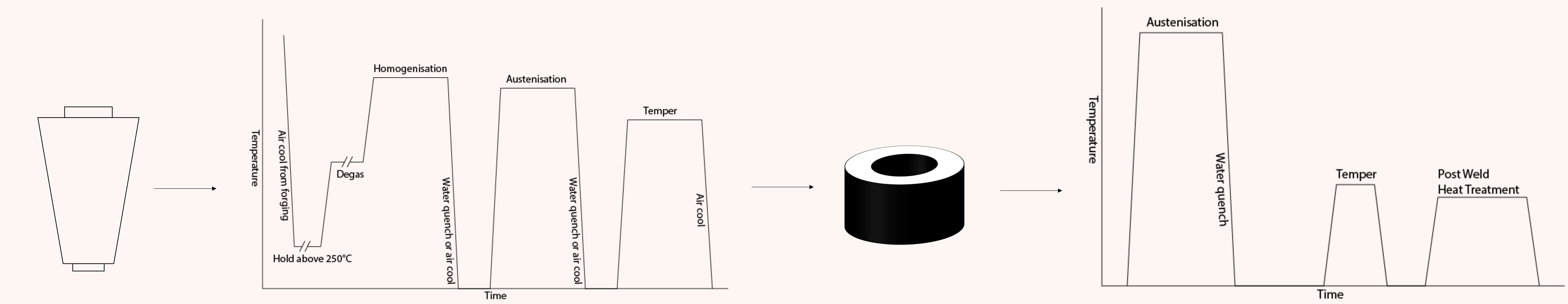
Introduction

Nuclear pressure vessels (NPVs) are the core components of a nuclear power plant, responsible for housing the fuel and encasing the nuclear reaction itself. With higher power requirements and next generation reactors on the horizon, the material behaviour and properties of materials used in these reactors requires attention.

To develop components, and design materials, utilised in next generation pressure vessel reactors, a more sophisticated understanding of material behaviour at the component manufacturing level is required. Small scale, laboratory, behaviours of materials in the order of grams, is not always directly relevant to components weighing up to hundreds of tonnes [1] and understanding the reason for these differences is essential in relating properties that can be measured routinely in a laboratory to optimising processing routes on an industrial scale. A component goes through many heat treatment and machining processes, however the one predominantly responsible for resultant microstructure and mechanical properties is the quality heat treatment (step 4. in **Fig. 1**).

While only SA508 Grade 3 is shown here, the work has been carried out with SA508 Grade 4N, SA540 and SA723 steels also.

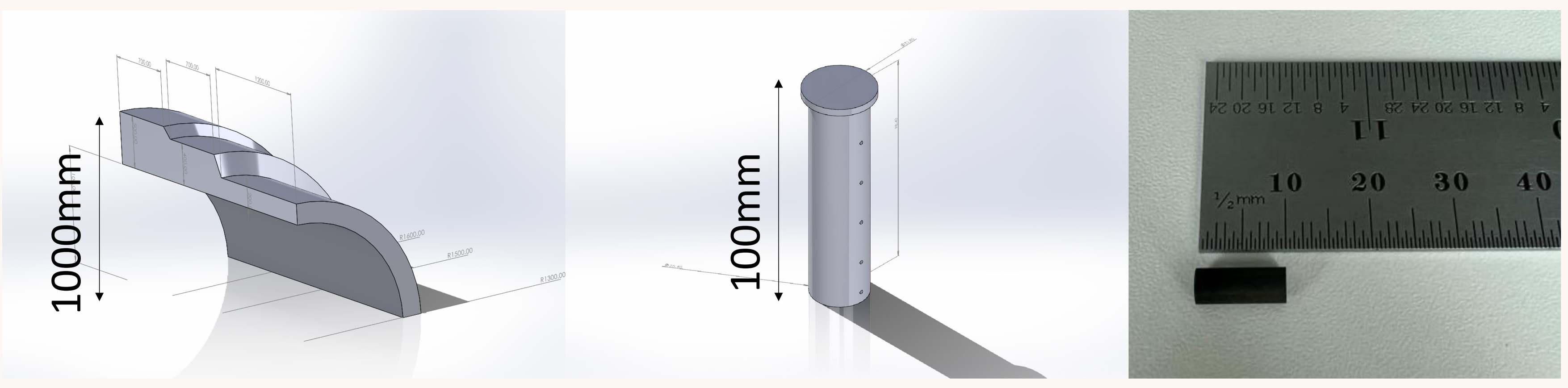


1. Ingot Making
2. Primary/Solution Heat Treatment
3. Machining and Rough Shaping
4. Quality Heat Treatment

Fig. 1 (Reproduced from [2]) Simplified production route of a typical RPV forging.

Results

To explore variation in material properties at different scales, FEM modelling, Jominy End-Quench Tests and Dilatometry were used **(Fig. 2)**.



1. FEM Modelling 2. Jominy End-Quench Tests 3. Dilatometry

Fig. 2 Scale comparison of methods used

- FEM Modelling will be adjusted via modelling of Jominy End-Quench Tests to find parameters that fit to experimental data. A first fit attempt can be seen in **Fig. 3**.
- Thermocoupled Jominy End-Quench Tests data was used as the quench profile for the Dilatometry specimens.
- Hardness and microstructural comparisons will be drawn across the larger Jominy and smaller Dilatometry specimens.

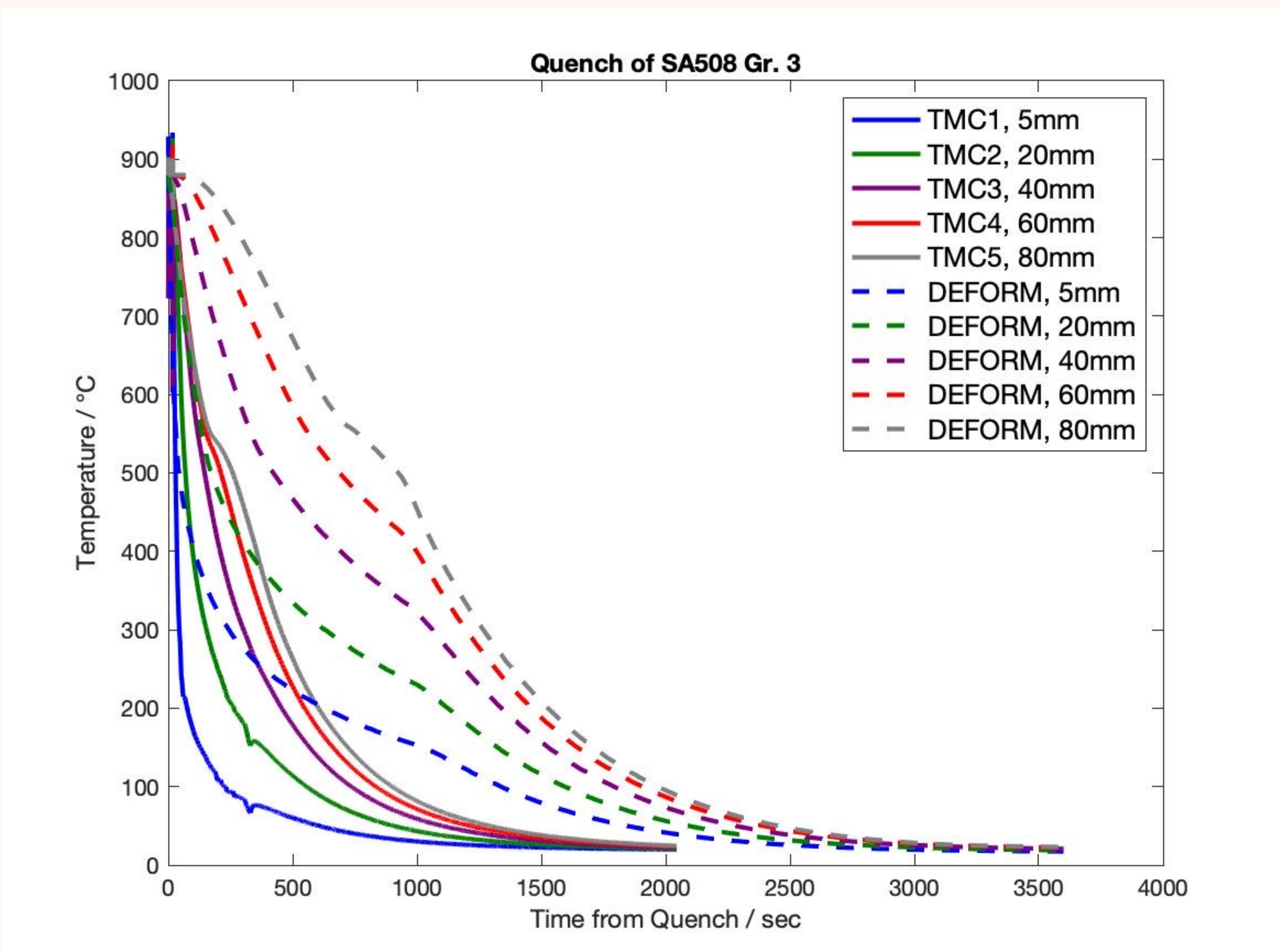


Fig. 3 FEM Modelling of a Jominy End-Quench Test (long profile) plotted against experimental data (short profile). TMC1 – 5 represent thermocouple data.

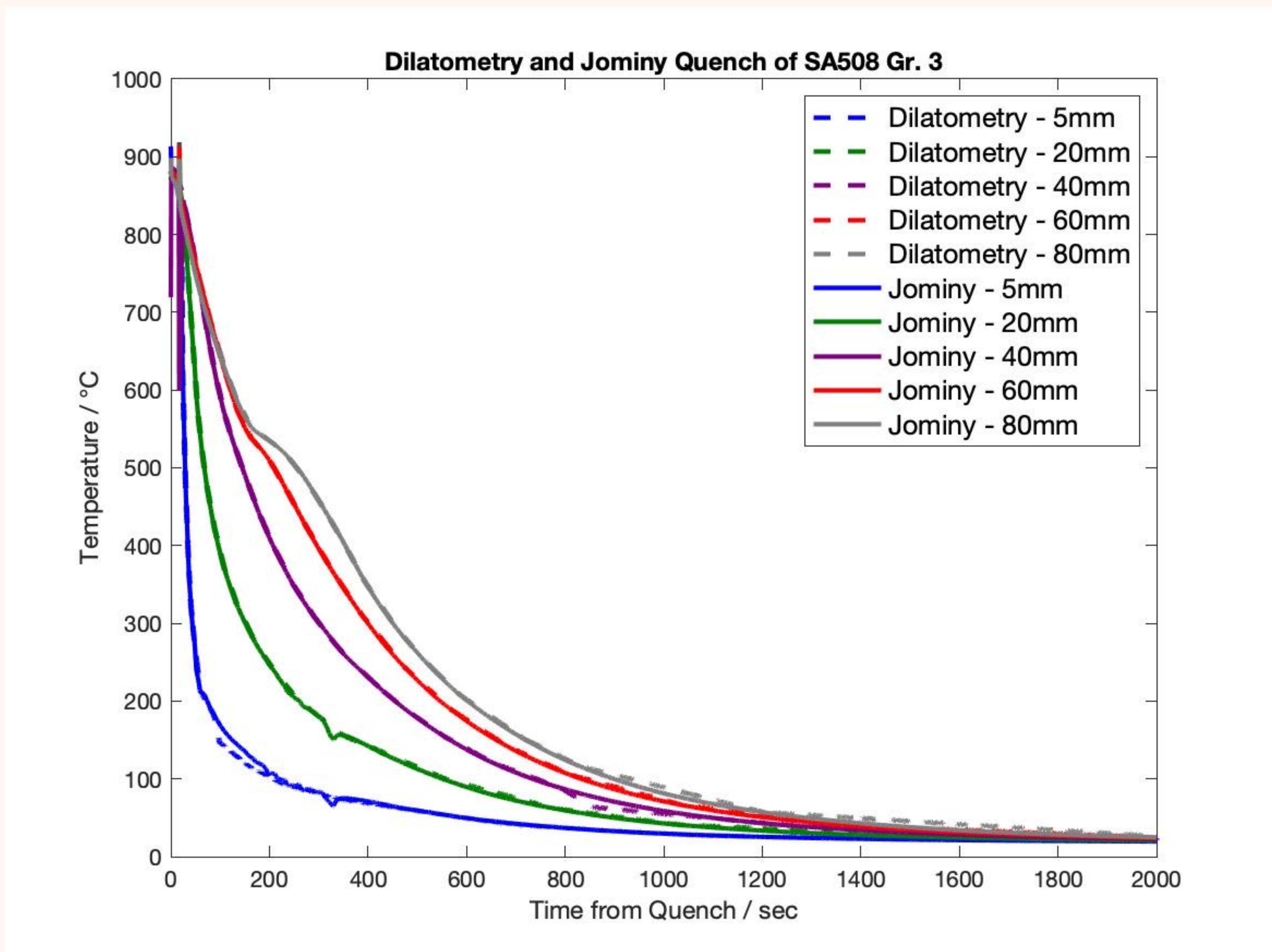


Fig. 4 Jominy End-Quench test data plotted against the profile reconstruction in Dilatometry.

Future Work

- Achieve better agreement between FEM Modelling and thermocoupled Jominy End-Quench Tests.
- Complete hardness and microstructural data collection of Jominy End-Quench Tests and Dilatometry specimens.
- Work with industrial sponsors to implement models and check fits to component manufacture data.

References

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