Integrated Computational Materials and Mechanical Modeling for Additive Manufacturing of Alloys with Graded Structure Used in Fossil Fuel Power Plants

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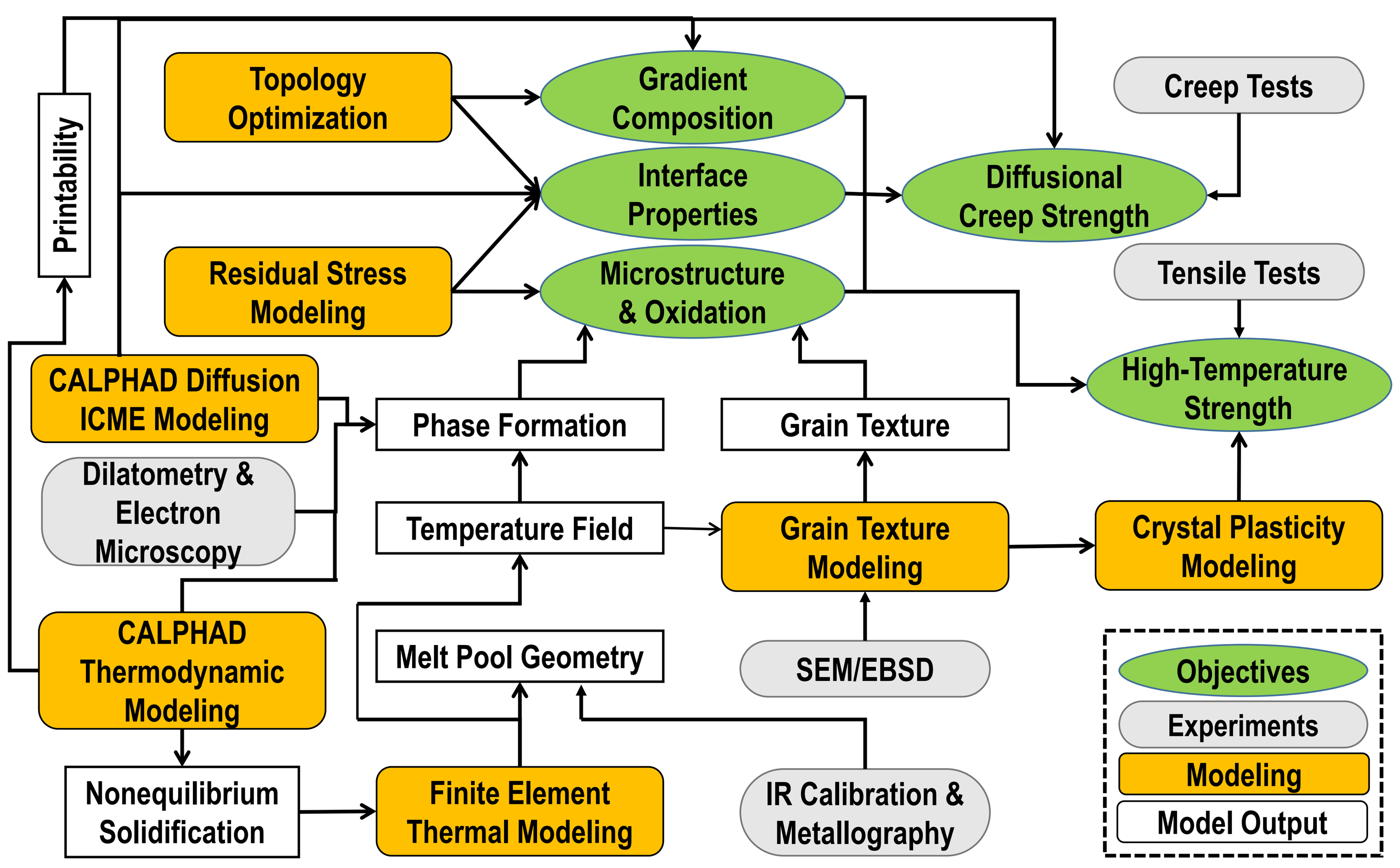
ICME Design of Additive Manufacturing for Graded Alloys

The proposed work is a response to the grand challenge of manufacturing complex components in Advanced Ultra-Supercritical (AUSC) power plants at shorter lead time and lower costs. Due to its much faster deposition rate and lower feedstock material cost compared with powder-based additive manufacturing, the Wire-Arc Additive Manufacturing (WAAM) is a promising technique to address this challenge. However, existing computational design tools are not adequate for such technique when applied to joining/welding or fabricating/assembling components with satisfied quality. The overall goal of this project is to develop an innovative ICME (Integrated Computational Materials Engineering) modeling framework through a seamless integration of materials and mechanical models for relevant AUSC components and materials processed by WAAM. The expected outcome will allow further development of WAAM for high-quality parts build and repair.

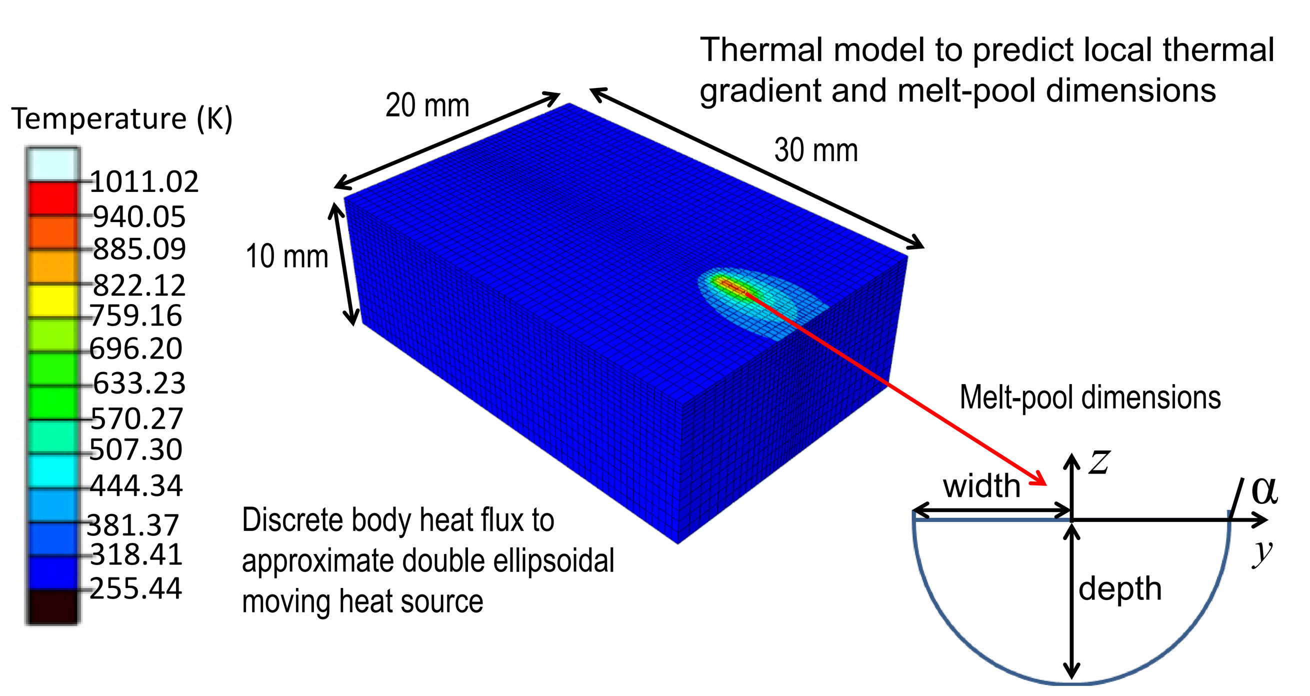
ICME Model Development

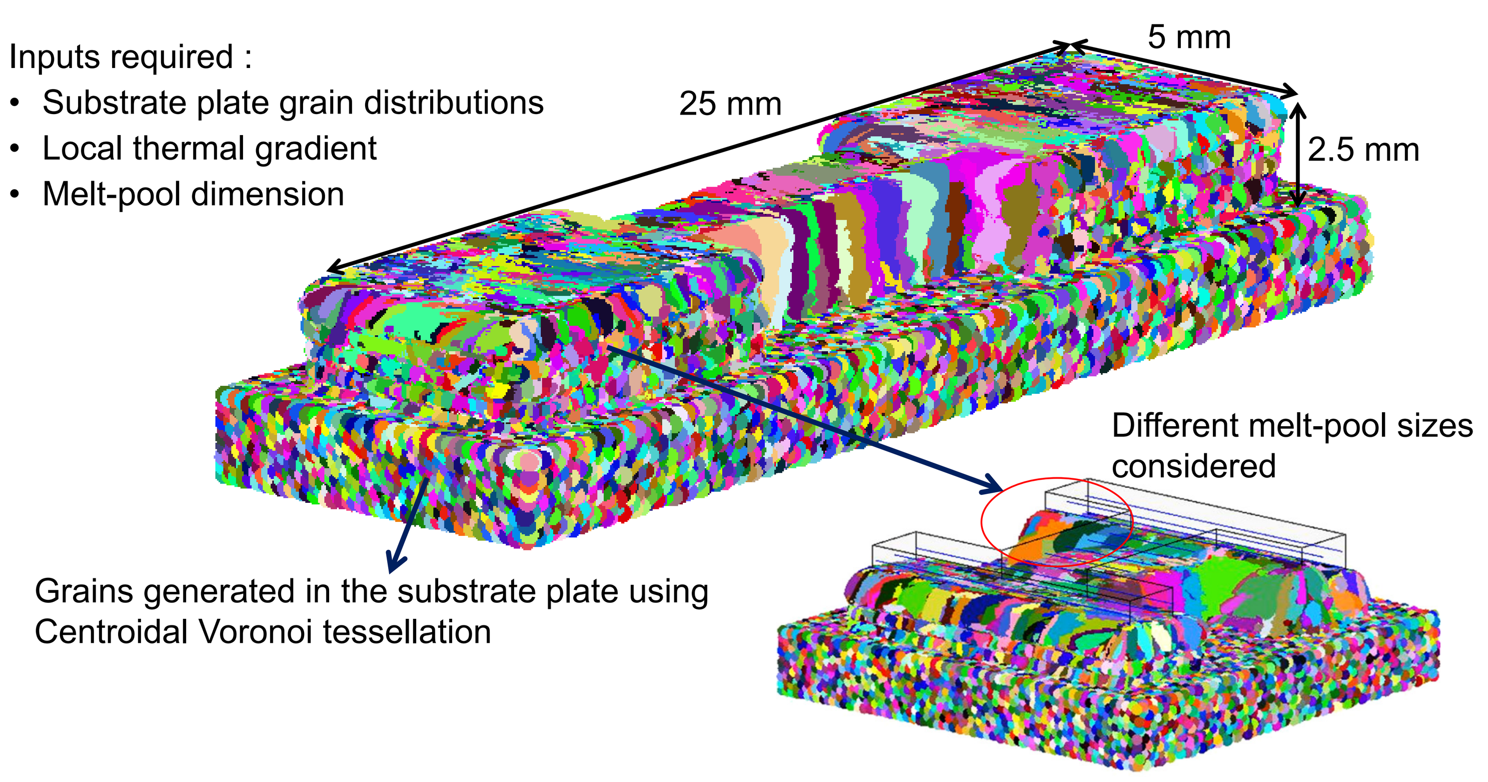
In the ICME model development, both materials and mechanical models are developed for graded alloy build using the WAAM (Wire-Arc Additive Manufacturing) process. The CALPHAD method will provide thermodynamic and diffusion model of the multicomponent interface. Experimental techniques will be applied for model verification.



Finite element modeling for thermal history and grain texture

The finite element thermal model predicts the quasi-steady melt-pool geometry, and the local thermal gradient to determine the columnar dendrite arm growth direction at a location. The grain growth model integrates the dendrite lines grown along the same direction to determine the grain texture and shape of the solidified metal.

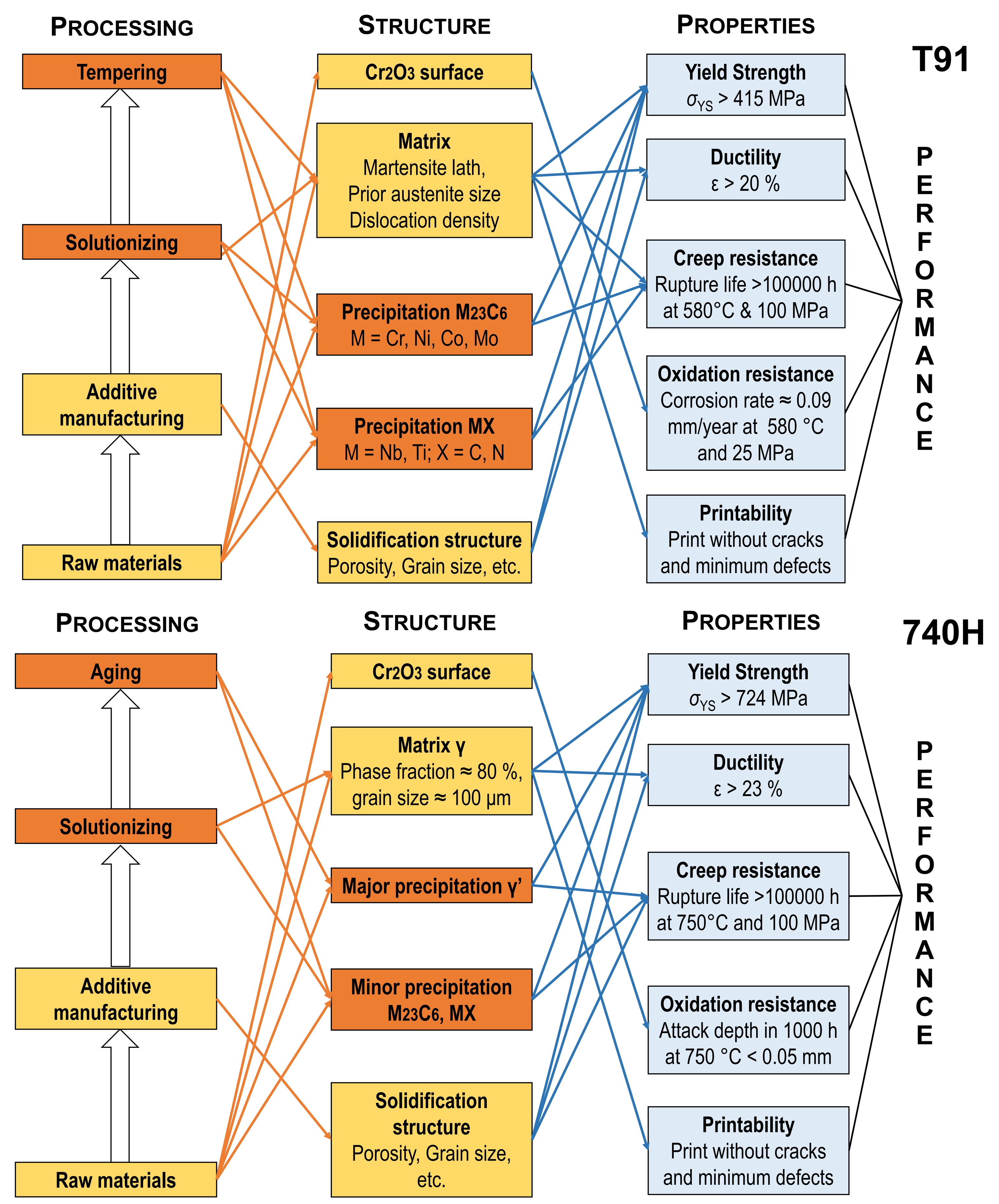




The variations melt-pool size and shape in Wire-Arc AM, is employed by considering different melt-pool dimensions in the grain growth model

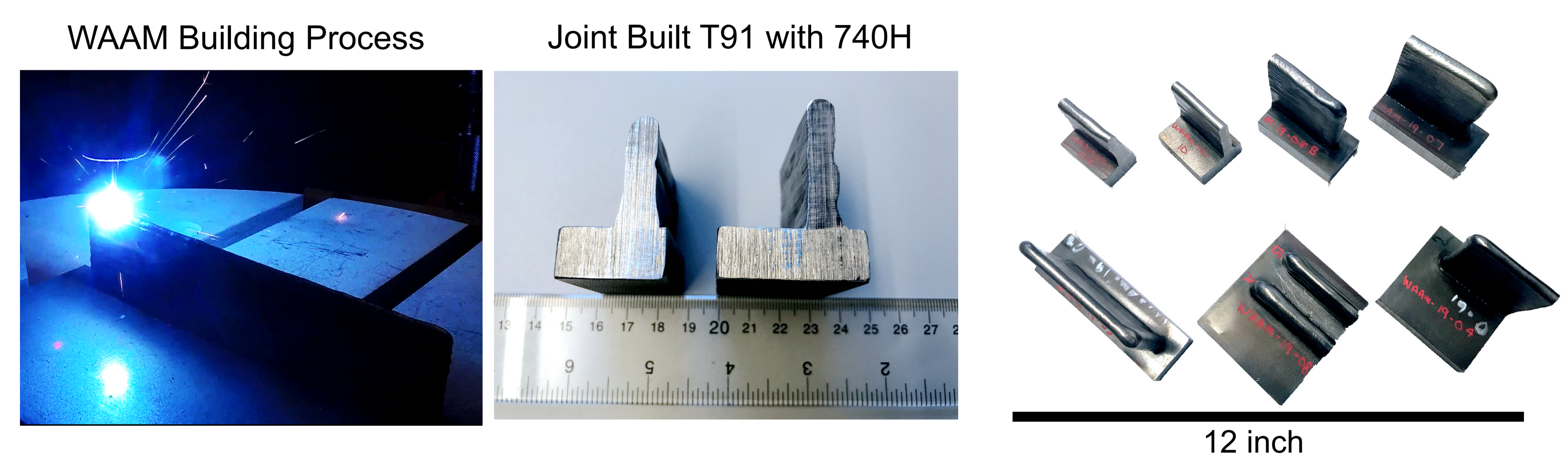
Systems Design Charts of Steel T91 & Ni Superalloy 740H

For each alloy system, we will have to understand the linkage of process-structure-property, and thus construct a systems design chart making sure all models will be properly used, calibrated, and verified. The CALPHAD-based ICME models are adopted to predict and control the microstructure during processing.

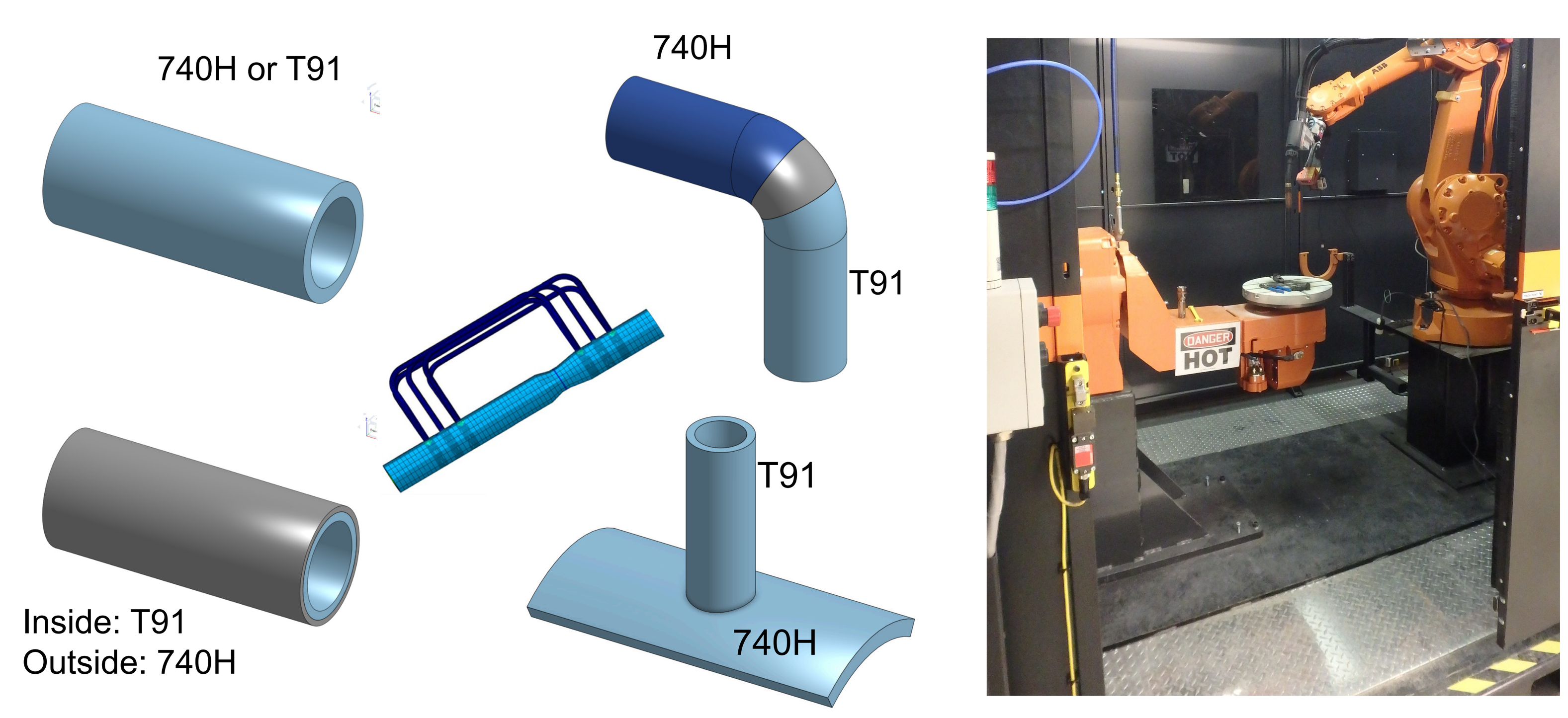


WAAM test build of T91 & 740H alloys

Three different types of single wall builds have been accomplished:
(1) T91, (2) 740H, (3) joint between T91 and 740H



Application of the ICME model development for different graded alloy component build using WAAM



Acknowledgements

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