Reduced-Basis based S-FEM and G-FEM for the Efficient Simulation of Processes Involving Moving Heat Sources

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ABSTRACT

The numerical simulation of manufacturing processes involving moving heat sources such as welding or surface treatments are of great interest in industry. It allows reducing the design cycle time and optimizing the process without the need of costly and time consuming test campaigns.

Using traditional finite element methods (FEM) to simulate these processes may lead to solve systems of an enormous number of degrees of freedom with a high computational cost. This fact has motivated the research for more efficient solutions to address these problems in recent years, focusing on one key idea: the large temperature gradients are confined to a relatively small area, near the heat source, compared to the size of the piece (heat affected zone, HAZ). Thus, simulations with a local/global approach [1] or a refinement moving mesh technique [2] can be found in the literature. The latter strategy is implemented in the widely used commercial code SYSWELD.

This paper explores various strategies to increase the efficiency of these simulations using three basic ingredients: superposition, solution enrichment and reduced-basis. The feasibility of a coupled formulation between FE and reduced-basis was previously studied in [3-4]. The general scheme of the proposed procedure is as follows. First, a background coarse FE discretization is established along the entire piece. Then, a patch that moves with the heat source is superimposed, covering the HAZ area. At this point, several possibilities can be considered. One option is to introduce a very fine FE discretization, resulting in the so-called s-version of the FEM [5] (FEM-FEM approach). Another choice can be to construct a moving reduced-basis in the patch using information from experiments or previous simulations (FEM-POD approach). Finally, a Generalized Finite Element (G-FEM) approach can be followed considering an enriched interpolant on the patch area thanks to the partition of unity property [6]. These three strategies are compared in terms of robustness and computational cost.

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