# Application of space-time refinement for droplet formation during GMA welding

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Gas Metal Arc Welding (GMAW) belongs to the family of arc welding processes and uses a plasma arc discharge between the wire and the weld pool, as presented in Figure 1. The plasma arc discharge develops high temperatures at the electrodes, which results besides the heating of the cathode-workpiece, in the anode wire melting and the formation of droplets. The droplet is afterward detached and advected through the arc plasma to the workpiece. While the main driving forces for the droplet detachment in GMAW are of electromagnetic nature, gravity, surface tension, arc pressure and non-isothermal phenomena have also an influence on the droplet formation and detachment by regulating the shape, volume, frequency and acceleration of the detached droplet [1–5]. Since the gradients on the fluid-gas boundary within the droplet are very high, due to the thermal and electromagnetic arc-droplet attachment processes, a fast and robust method is desired that allows for local refinement in both time and space.

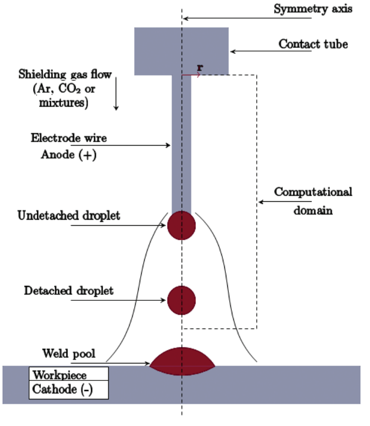


**Figure 1.** Schematic description of gas metal arc welding (GMAW).

The droplet formation and detachment during GMA welding is described by an incompressible non-isothermal two-phase flow, with phase transition effects, while not considering the electromagnetic processes, in a first approach. This flow is governed by the transient incompressible Navier-Stokes equations since we assume that the fluids of our interest are incompressible and Newtonian, which are coupled with the heat equation. For the description of the moving droplet front, an interface capturing method based on the Eulerian formulation, such as the level-set method, is used, because of its inherent ability to account for topological changes of the interface [6]. The interface is described implicitly by the level-set field on a fixed mesh.

For reducing the dimensionality and consequently the complexity of our problem, we make use of an axisymmetric description of the governing equations. A stabilized finite element method is also adapted for unstructured space-time meshes, allowing us for a space-time refinement in the vicinity of the evolving interface. The space-time method has inherent ability to admit completely unstructured meshes with varying levels of refinement not only in spatial dimensions but also in the time dimension, giving us the flexibility to use a type of local time-stepping for our simulations [7–10].

Several numerical examples have been used for validating the unstructured space-time mesh solver, the axisymmetric formulation of the governing equations and the refinement scheme. The benchmarks in question involve a fully developed Couette flow, a dripping droplet and finally the more complicated GMA example.

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