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FLUID DYNAMIC – THERMAL COUPLED MODEL BETWEEN FLUID AND SOLID CONTOURS

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ABSTRACT

Numerical fluid dynamics is nowadays a powerful and reliable tool for simulating different thermo-fluid dynamic processes. Hence, it permits to analyze different operative variables and geometrical configurations to investigate technological windows of different processes in metallurgical industry. In some cases, the industrial process involves moving solid contours like rotating cylinders or circulating strips. This solid contours exchange momentum and heat with the surrounding fluid. In this paper a fluid dynamic – thermal coupled numerical model was presented. This model takes into account the movement of solid contours and the thermal coupling between the different model domains (solid or liquid).

In order to obtain the field of velocities, pressures and temperature in a turbulent incompressible fluid flow the equations of Navier Stokes and energy using the Boussinesq approximation are solved. The mathematical description of the turbulent flows using mean quantities equations makes necessary the use of turbulence models to close the problem. For industrial problems modeling the k-ε model is commonly used, where k is the turbulent kinetic energy and ε is the turbulent kinetic energy dissipation rate). To obtain the field of temperatures in the solid, the energy equation are solved. The convection term included in the energy equation allows modelling a moving solid seen from an eulerian point of view as to be rotating cylinders or plates moving in the direction of its axis.

The Navier Stokes and scalar transport equations are solved using the streamline upwind Petrov Galerkin method (SUPG) and are linearized using a Newton Raphson scheme. The pressure P is replaced in terms of the velocity in the equation using the penalty of the incompresibility condition. The domain was discretized using 8 nodes linear isoparametric hexahedral elements.

Due to it is solved a reduced domain for the fluid, the meshes that discretize the different domains (solid and fluid domains) are not connected. In order to connect the solid domain and the fluid dynamic model it is necessary to know, for each contour node of the fluid mesh, the solid contour velocity value in that point. Taking this velocity, it is obtain the equivalent tangential tension to apply in the contour fluid

domain due to the relative movement between solid and fluid. For it, each fluid mesh contour node is projected on the solid contour. The thermal connection between the fluid and the solid exists due to the heat exchange between both domains through the fluid - solid interphase. This heat exchange is modeled by means of a Newton cooling law. The model gives the possibility that the different meshes are not connected; this generates a great flexibility in meshing and in geometry modification.

The domains coupling algorithm could be validated using simple problems. Finally, the model developed was validated and applied successfully to the simulation of the fluid dynamic thermal behavior of hot dip galvanizing bath.

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