Jet quenching

Multiphase numerical modeling for water jet quenching of the stationary and moving metal plate

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In Short

- Liquid jet quenching
- Stationary and moving plate
- Multiphase numerical modeling
- Euler-Euler numerical (bubble crowd) model
- Moving plate by sliding mesh approach
- Heat flux, heat transfer coefficient etc.
- Wetting front behavior

Intensive cooling of metal plates or quenching is widely used in the metal industry to improve material properties. The metal plate is heated to a temperature higher than the Leidenfrost temperature and cooled by a water jet or an array of water jets. The final material property such as hardness depends on the thermal history during quenching. As the metal plate is cooled from a very high surface temperature, boiling heat transfer dominates over the quenching surface. This creates difficulties in establishing wetting across the surface due to the Leidenfrost effect. Thereby, higher temperature gradients develop and lead to deformation and cracking of the metal plate. Therefore, an in-depth knowledge especially with the spatial and temporal heat transfer during quenching is desirable to identify the process parameters. In addition, in applications such as hot rolling, chill casting etc., the metal sample moves under the water jets, which can significantly affect the heat transfer behavior. In industrial applications, the metal plates are also quenched from the top and bottom simultaneously, where experiments are not feasible. In addition, investigating this process at these higher temperatures by experiment alone is technically limited and challenging. Therefore, a numerical model is desirable to analyze this conjugate heat transfer problem.

In this scenario, a multiphase numerical (bubble crowd [1, 2, 3, 4]) model based on an Euler-Euler approach has been developed in this work to simulate the quenching of liquid jet with stationary and moving metal plate. Single and multiple jets are considered in this study. This bubble crowd model has two phases where water acts as the continuous phase and the water vapor acts as the dispersed phase. The modeling is accomplished by using ANSYS Fluent 19.2 software and the phase transfer phenomena are modeled using the user defined functions. The secondary phase is modeled as spherical particles and the diameter is obtained from experimental relations. The concept of sliding mesh is incorporated for the simulation of the moving plate.

The developed simulations are validated by high-speed and infrared imaging. The validated model can be used to investigate the influence of process parameters such as jet Reynolds number, plate velocity, plate materials etc. The simulation directly provides the technical parameters of the impinging surface like the heat flux, heat transfer coefficient, wetting front behavior etc., which cannot be obtained directly from an experiment. Due to the complexity of the developed numerical model, all the simulations are performed with the support of HLRN/NHR systems.

In this project, the investigations are sub-divided into four stages.

In **stage 1** the single jet quenching is investigated for a stationary plate. The numerical model is extended to the 3D domain. The influence of different plate material, jet Reynolds number etc., are investigated in this stage. A numerical result from a single full jet quenching is shown in Fig. 1.

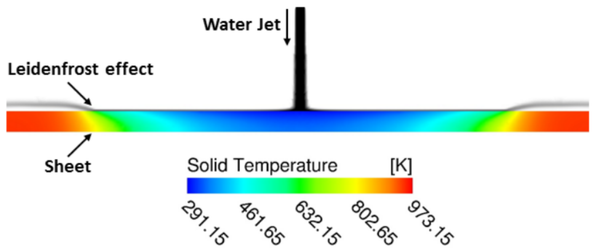

***Figure 1:** Numerical result of a single jet quenching of stainless steel sheet.*

In **stage 2** the jet quenching with two water jets is analyzed. The aim is to identify the influence of the jet Reynolds number as well as the nozzle spacing. The simulations help to identify the sufficient nozzle spacing, which can significantly reduce the water consumption as well as increase the cooling area with the same number of jets. Furthermore, the hydrodynamic and thermodynamic behavior at the fluid film interaction zone can be analyzed. A numerical result of two-jet quenching is shown in Fig. 2.

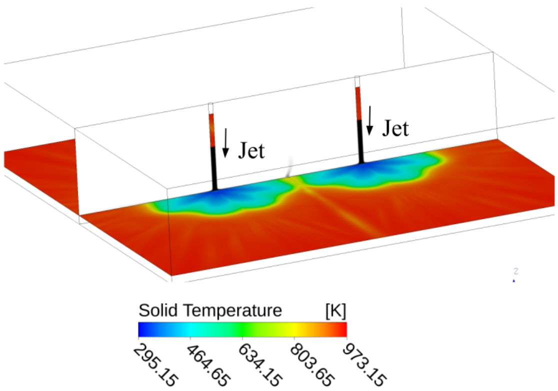

Figure 2: *Numerical result of two jet quenching of a stainless steel sheet.*

In order to verify the transferability of the results to water jet arrays, a four-nozzle configuration with in-line and staggered arrangements is investigated in **stage 3**.

Finally, in **stage 4** the quenching of moving plate with single full jet is investigated. The process parameters such as jet Reynolds number, plate velocity etc. are varied to analyze their influence on the quenching process. A numerical result from the quenching of a 5 mm thick Al-alloy plate moving at 20 mm/s can be seen on Fig. 3.

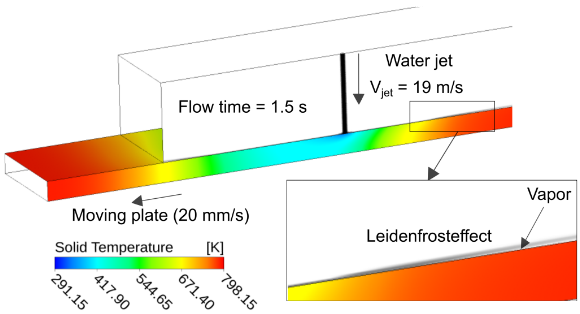

Figure 3: *Numerical result of quenching a 5 mm Al-alloy moving at 20 mm/s.*

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More Information

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Project Partners

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DFG Subject Area

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