

Public summary of PhD-thesis of Hormando Leocadio

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High cooling capacity from water jet impinging on highly heated steel surface

When a water jet comes into contact with a hot steel surface, it cools much faster, called the 'rewetting process'. This thesis proves that the rewetting occurs at surface temperatures above 800°C.

Water jets, that are directed towards a surface without confinements, cool materials faster and are used as an effective means of cooling in many industrial applications, requiring rapid cooling such as emergency core cooling in nuclear power plants and power dissipation in electro-mechanical devices. Steel industries widely employ it for temperature control to ensure proper mechanical and metallurgical properties. In all these processes surface temperature cooling rates are typically very large. Furthermore, high cooling rates start when a solid-liquid contact is established during the cooling process. However, boiling on high temperature surfaces can be quite complex due to the existence of different boiling regimes simultaneously at the zone of impingement of the water jet. Therefore, the understanding of the heat transfer regimes in water jet impingement on high temperature steel is crucial for enhancing the quenching processes and the development in ultra-fast cooling technology (over 100°C/s). Jet cooling experiments have shown a wetted surface well above the critical water temperature, but a concrete explanation for this phenomenon is still lacking.

We designed and constructed a jet cooling setup that yields high-speed imaging (20,000 fps) inside of water jet impinging vertically on a hot steel plate. This is the first time images like those have been produced and allow a direct observation of boiling phenomena within the impingement zone. We can now see what really happens in the early stages of quenching on such high surface temperatures. The results prove that rewetting takes place on surface temperatures above 800°C which are well above critical point of water. With great surprise, we observed gas bubbles, from a degassing process, on top of a vapor film. This phenomenon has never been seen before.

Using test conditions, I have analyzed the effects of the initial steel plate temperature, water temperature and speed of the jet on surface heat flux rewetting temperature. In my thesis I have proposed a reason why there's a delay in cooling as a result of rewetting linked with the test parameters. Results show that high heat removal capacity (6 MW/m²) and cooling rates (above 100°C/s) are achieved only after rewetting occurs and the strong influence of the temperature of water and surface on them.

Based on the results and knowledge acquired by jet quenching experiments, I designed and build an accelerated cooling pilot plant, large enough to simulate industrial conditions at the R&D center of Usiminas Steel. This system allows various cooling strategies and promotes uniform cooling rates up to 100°C/s for steel plate lengths up to 2000 mm. The system is totally automated with thermal cameras and a mathematical model to simulate cooling strategies. The successful operation of the system has been demonstrated by several cooling tests relevant for the development of new products and provides parameters for industrial scale production.

Title of PhD-thesis: Interfaces and heat transfer in jet impingement on a high temperature surface.

Promotors: Cees van der Geld (TU/e) and Hans Kuerten (TU/e).