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INFLUENCE OF WATER TEMPERATURE ON HEAT TRANSFER COEFFICIENT IN SPRAY COOLING OF STEEL SURFACES

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Abstract: *Cooling of stainless steel surfaces with flat fan nozzles was studied experimentally. Several configurations of jets and pressures were tested. Tests were done with variable coolant (water) temperatures (20 °C, 40 °C, 60 °C and 80 °C). The influence of coolant temperature on the heat transfer coefficient was investigated. An increase in coolant temperature caused a significant decrease of the Leidenfrost temperature (temperature at which the character of boiling is changed - the film boiling is changed into nucleate boiling). Changing the water temperature from 20 °C to 80 °C caused a change of the Leidenfrost temperature of about 140 °C. Furthermore it was observed that in a high temperature region (above Leidenfrost temperature) the heat transfer coefficient has the highest value for the lowest water temperature and for the high coolant temperature (80 °C) the cooling intensity is the lowest.*

Keywords: ***Spray cooling, Heat Transfer, Leidenfrost temperature, cooling with hot water***

1. Introduction

The cooling of stainless steel surfaces with flat fan nozzles and the influence of different factors on heat transfer coefficient (HTC) was studied. Because the water temperature in cooling processes in the metallurgical industry changes during the year, one of the goals was to find if the cooling intensity and the Leidenfrost temperature is influenced by the water temperature.

In the experimental study in the Heat Transfer and Fluid Flow Laboratory (Raudenský et al., 2011) the influence of water temperature on cooling with mist nozzles for an austenitic steel plate was measured. In addition the research at the University of British Columbia in Canada (Xu & Gadala, 2006) showed the influence of coolant temperature on cooling in spray cooling for 7 mm thin carbon plates.

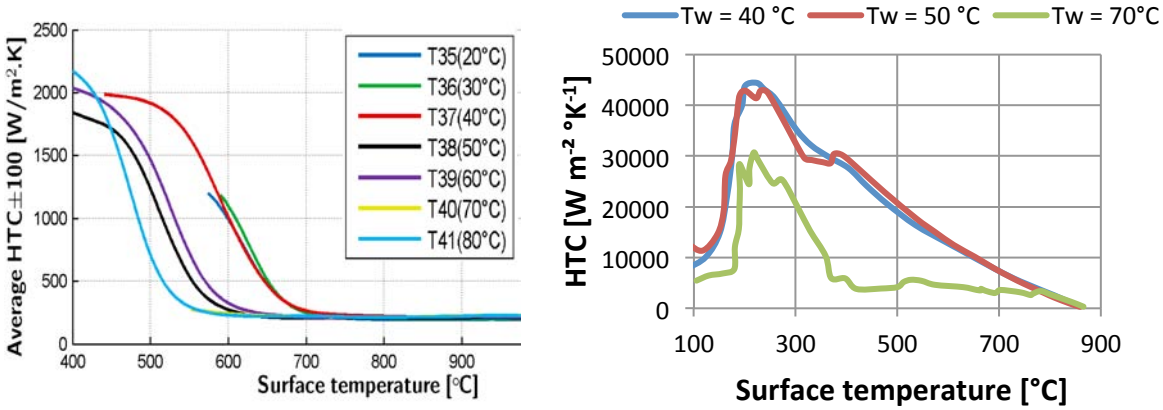

Fig. 1: Influence of water temperature on heat transfer coefficient. Left graph adapted from paper (Raudenský et al., 2011). Right is adapted from paper (Xu & Gadala, 2006).

The change of cooling intensity is mainly caused by changing the type of boiling. As it was shown in Raudenský et al. (2011) and Xu & Gadala (2006), the increase of coolant temperature caused the decrease of the Leidenfrost temperature, which is connected with changing of type of boiling.

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2. Experimental measurements

An experimental apparatus developed for linear moving of the hot test sheet under nozzles was used in experiments. Commercially available flat fan nozzles were used for experiments with different water temperatures. The initial temperature of stainless steel sheet was 900 °C. All experiments were conducted with water pressure 3 bar and velocity of the test sheet 0.8 ms^{-1}. Some experiments were conducted with upper cooling and others with bottom cooling. Each experiment was conducted with a different temperature. The temperatures tested in the experiments were 20 °C, 40 °C, 60 °C and 80 °C for upper cooling and 40 °C and 60 °C for bottom cooling.

3. Results

The measured temperatures were recomputed to the surface temperatures and the heat transfer coefficient was computed by the inverse task. The dependence of the heat transfer coefficient on the surface temperature for various water temperatures in top and bottom cooling experiments is shown in Fig. 2. These graphs show shift of the Leidenfrost temperature to lower temperatures with increase of the coolant temperature. The change of water temperature from 20 °C to 80 °C caused the change of about 140 °C of the Leidenfrost temperature (upper cooling). A similar result was obtained for bottom cooling experiments. These results match results for austenitic plate presented in Raudenský et al. (2011) and for carbon steel in Xu & Gadala (2006). Furthermore it was observed that in a high temperature region the heat transfer coefficient decreases with increasing coolant temperature. It is interesting that the value of the heat transfer coefficient is nearly the same for water temperatures 40 °C and 60 °C

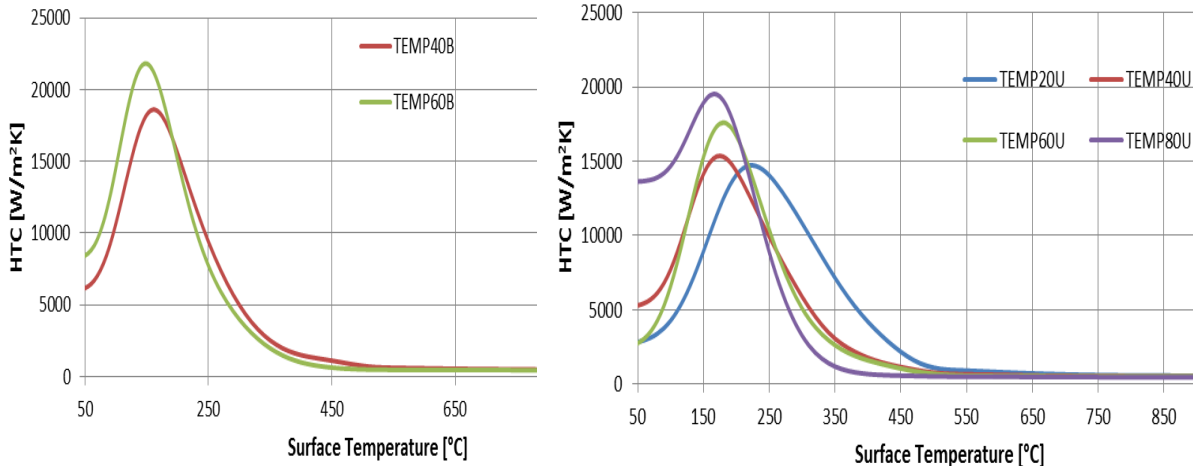

Fig. 2: Influence of water temperature on heat transfer coefficient. Bottom cooling (left) upper cooling (right).

4. Conclusion

Experimental investigation showed the influence of coolant temperature on Leidenfrost temperature in cooling stainless steel sheets. The change of water temperature from 20 °C to 80 °C caused the change of 140 °C of the Leidenfrost temperature. This result has applications in the metallurgical industry, where the temperature of cooling water changes during the year. This change of coolant temperature causes a change of cooling intensity and it leads to undesirable material properties. Furthermore it was observed, that in the high temperature region the heat transfer coefficient decreases with increasing coolant temperature and the value of the heat transfer coefficient is nearly same for water temperatures 40 °C and 60 °C.

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