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Quenching Of Moving Aluminum Sheets In Fields Of Flat- And Full-Jet Nozzles

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Abstract - The cooling rate of moving aluminum alloy sheets (AA6082) was experimentally investigated. For this purpose, 5mm thick sheets were electrically heated in a furnace to a temperature of 520 ° C and then cooled with water using different nozzle fields. The nozzles were located at a distance of 50 mm from the sheet. A combination of flat and full jet nozzles was used in two different nozzle configurations, each with the nozzles of one type arranged horizontally, resulting in two rows of nozzles. In the first configuration, two nozzles of each type 70 mm distance from each other were used. For the second configuration, three flat jet nozzles and three full jet nozzles, 35mm apart from each other were combined to form a nozzle field. Flat jet nozzles with a jet angle of 45 ° and full jet nozzles with a diameter of 1.05 mm were used. The pressure at the nozzle outlet was kept constant at 2 bar in each case. During the cooling process, the sheet velocity was varied from 5 mm/s to 10 mm/s and the temperature field of the black-coated rear side of it was measured with a high-resolution infrared camera. The high frame rate of 200 fps of the IR camera allows for precise determination of the thermal temporal and spatial data of the sheet. The infrared images and the corresponding cooling curves are qualitatively analysed as a function of the sheet speed and nozzle configuration. The investigation aimed to gain knowledge about the choice of nozzle spacing and the cooling intensity of the nozzle type that results in homogeneous cooling. This study can be used for the optimization of existing plants and the design of new plants.

***Keywords*:** quenching, AA6082, flat jet, full jet, infra-red thermography

1. Introduction

Nowadays, quenching of moving hot metals with water is dominating in various industrial applications. The optimal cooling rate should be chosen to achieve the required material properties of metals, such as strength, hardness, etc. Simultaneously, it should be assured uniform and homogeneous cooling to avoid thermal stresses and strains, which lead to cracks and distortion of the end product.

Generally, full jets are known for intense cooling, and for the sake of homogeneity, the field of full jet nozzles has been practiced in the metal industry for a long time. The heat transfer and cooling mechanism of the full field of the jet nozzle have been studied by many authors [1], [2], and [3]. The nozzle field consisting of flat and full jet nozzles has not been investigated yet; therefore, in the present study, the cooling rates of moving AA6082 sheets in the field of flat and full jet nozzles are experimentally studied. The two different nozzle configurations can be seen in figure 1 below.

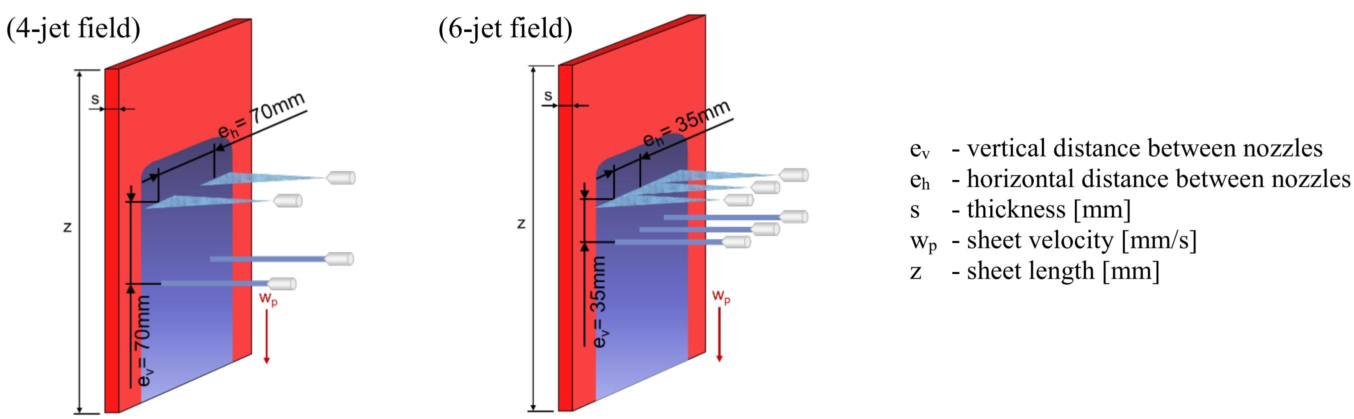

Fig. 1: Schematics of nozzle arrangements

2. Experimental Set-up

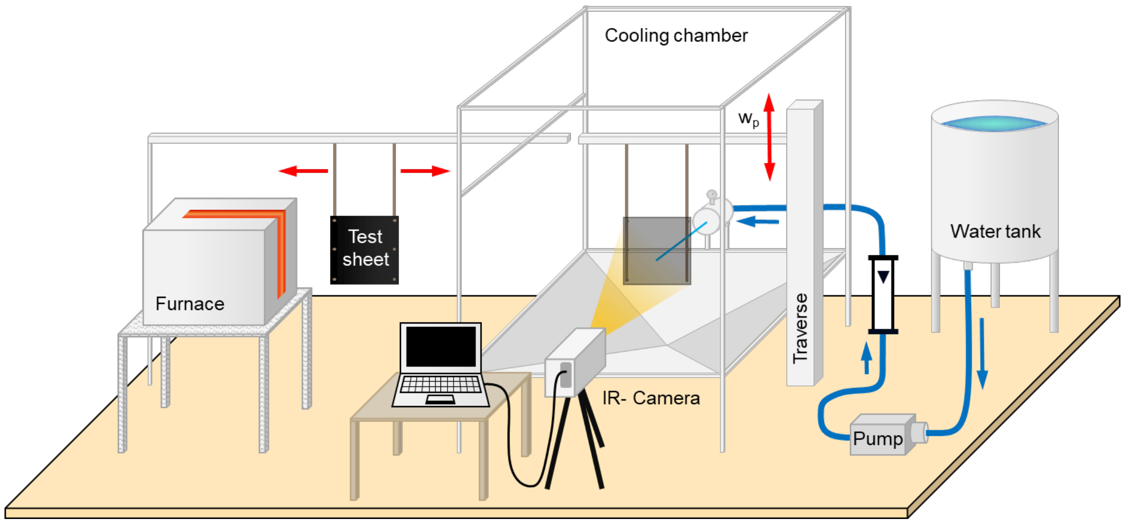

Fig. 2: Experimental facility

The experimental facility is shown in Figure 2. The 5 mm AA6082 sheets are heated to desired start temperature (520°C) in an electric furnace and quickly moved to the quenching chamber, where the vertical moving sheets are quenched within the nozzle field in a controlled manner. During the cooling process, the temperatures of sheets are recorded from the black-coated rear side with an infrared camera.

3. Analysis Method and Results

In Figure 3, the infrared images for two different investigated nozzle configurations at sheet speeds 5 and 10 mm/s are shown.

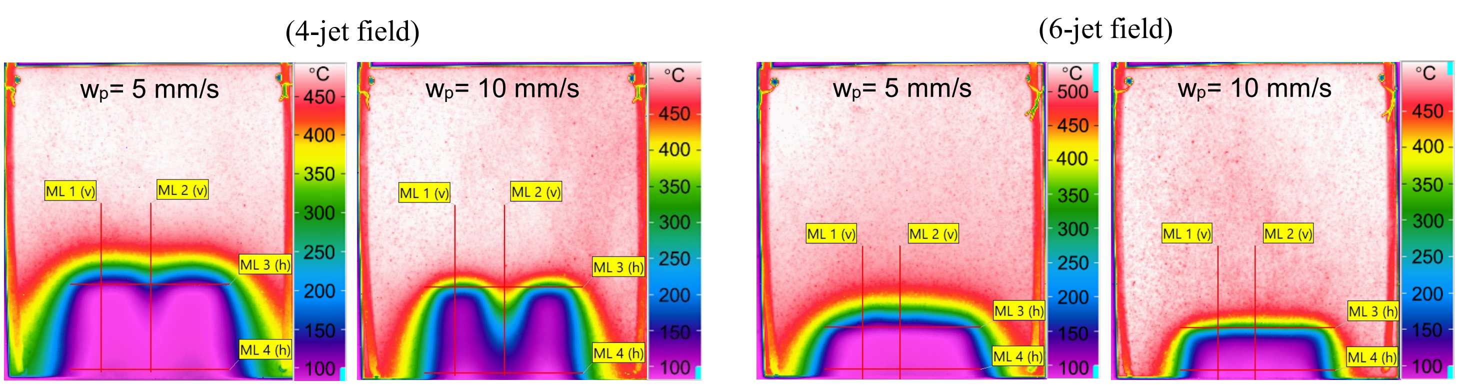

Fig. 3: IR images of the cooling of AA6082 in two different nozzle fields

IR images are chosen at a specific cooling time so that the product of the sheet speed w_p and the cooling time t always results in a value of 75 mm for the 4 jets field and 40 mm for 6 jets field. The vertical measuring lines are positioned so that they are aligned in front of the nozzles (ML1) and between the nozzles (ML2). The ML3 measuring line indicates the position of the flat jet nozzles, and the measuring line ML4 is the position of the full jet nozzles.

Despite the relatively large distance of 70 mm between the nozzles for the 4-jet nozzle field, a uniform wetting front is formed at a sheet speed of 5 mm/s. As, the sheet speed increases to 10 mm/s, the uniformity of the wetting front and cooling decreases. The IR images for the 6-jet nozzle field with a nozzle-to-nozzle distance of 35 mm show relatively uniform quasi-stationary cooling at both sheet velocities.

Figure 4 shows the cooling curves for two vertical and two horizontal measurement lines at a sheet speed of 5 mm/s.

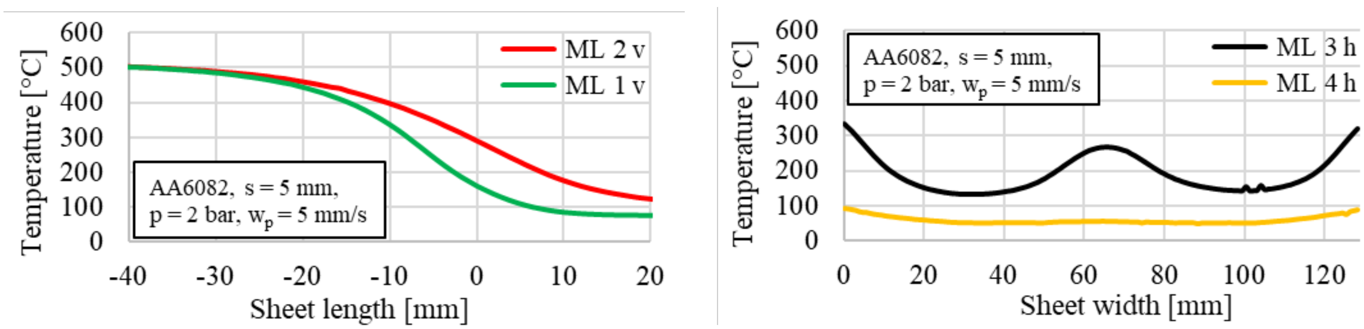

Fig. 4: Cooling curves of AA6082 with the 4-jet nozzle field at w_p= 5 mm/s

The temperature profiles for two vertical measuring lines ML1 and ML2 can be seen on the left side, and the temperature profiles for horizontal measuring lines ML3 and ML4 are depicted on the right side.

The ML1 temperature profile cools down faster than the ML2 because the ML1 measuring line is drawn where the vertical nozzles are positioned and the ML2 shows the temperature profile between the nozzles. ML3 shows the temperature profile horizontally for the row of the full jet nozzle, and similarly, ML4 represents the cooling curve of the flat jet nozzles row.

It can be seen that ML4 shows homogeneous cooling while in the ML3 curve temperature increases in the middle of the nozzles resulting in non-uniform cooling.

A direct comparison of the cooling curves at various sheet velocities for two nozzle fields is shown in figure 5.

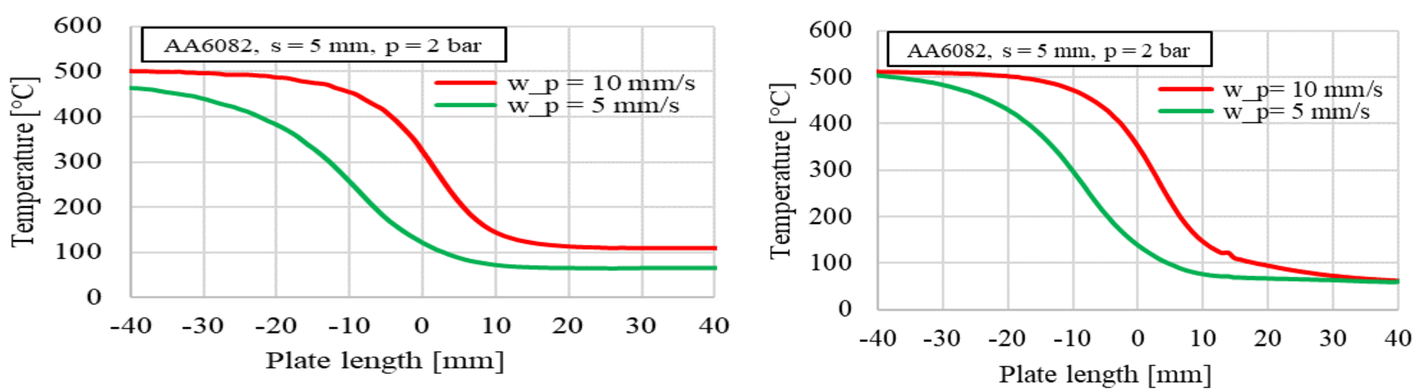

Fig. 5: Influence of the plate speed for 4-jet field (left) and 6-jet nozzle field (right)

On the left side of figure 5, the influence of sheet velocities for a 4-jet nozzle field (left) and 6-jet field (right) is shown. The temperature profiles are plotted at the quasi-stationary time for both velocities. The sheet is cooled from a high temperature of 500 ° C to 100 ° C, as can be seen in figure 5. The 0 mm on the sheet length represents the position of the first row of nozzles. The sheet with 5 mm/s velocity cools faster as compared to 10 mm/s velocity but the temperature gradient is smaller. The reason for that is the pre-cooling effect due to high axial heat conduction in the case of slow velocity, temperature starts decreasing before the wetting front reaches. However, as the sheet velocity increases, the pre-cooling effect decreases, and as a result, the temperature gradient along the sheet length increases.

4. Conclusion

Using a 70mm nozzle spacing and a sheet speed of 5 mm/s, the flat spray nozzles cool the sheet to below 100 ° C before the full jet nozzles approach. Therefore, the full jet nozzles have an insignificant influence on this arrangement. However, cooling is comparatively homogeneous. If the sheet speed increases to 10 mm/s, it is not possible to achieve uniform cooling of the metals due to the large nozzle spacing of 70 mm and the different cooling capacities of the nozzles used.

With a lesser nozzle spacing of 35 mm and a sheet speed of 5 mm/s, the main cooling effect comes from the flat-jet nozzles like the 4-jet nozzle field. As the sheet speed increases to 10 mm/s, the influence of the full-jet nozzles on the cooling process becomes more dominant.

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