THE COOLING PROCESS IN SPRAY OVERLAP DURING HYDRAULIC DESCALING

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Abstract

The manufacturing of high quality steels is connected to high temperatures at which the material reacts with the surrounding atmosphere. A layer of iron oxides (scales) is formed on the surface of the steel. To ensure a high quality product, the layer must be removed prior to any metal forming operation. The mass production of steel requires a quick and effective method of descaling. In the overwhelming majority of cases, the descaling is performed by high pressure flat jet water nozzles placed in a row. This article builds on the previous texts on the process optimization and further studies the effect of the offset angle of the nozzles on the uniformity of the cooling impulse on the surface of the hot rolled steel strip. Current research has brought a significant improvement in the area of measurement of the heat transfer coefficient. The article compares two configurations of nozzles and presents the impact pressure measurements and corresponding heat transfer coefficient measurements for both of them. The results obtained so far show that the commonly used configuration is not optimal from a cooling point of view. The new suggested configuration presents a new method of making the cooling impulse and the cooling rate more uniform along the width of the hot rolled steel strip of the descaled surface.

Keywords: Hot rolling, descaling, heat transfer coefficient, scales

1. INTRODUCTION

High pressure hydraulic descaling is a very common way of removing the iron oxides (scales) from the surface of the steel plate before the plate undergoes the hot rolling process. Descaling is performed by a descaler, which is a row of high pressure flat jet nozzles that creates a water knife along the width of the steel plate.

Since one nozzle cannot usually cover the whole width of the steel plate, the water jets must overlap in certain parts of the descaled area. These areas are called overlap areas and are illustrated in **Figure 1**.

The overlap areas are connected with intense cooling that can also influence the microstructure of the hot rolled steel [1]. Uniformity and stable conditions for descaling (and cooling) are the key for a quality product that can be used in future production [2].

So far the heat loss during descaling has been studied right under the nozzle in a wide range of experiments [3-6]. The heat loss can be quantified by heat transfer coefficient h which is the ratio of heat flux and the temperature difference between the water and the descaled surface. The heat transfer coefficient h depends on several factors in the process, mainly on the water pressure, water flow and height of the nozzle and also on the speed of the hot rolled steel in the mill and its temperature [7].

The published simulations assume a constant heat transfer coefficient along the steel strip [8].

This article builds on previous publications [9] and [10], which introduced the impact pressure measurements, the erosion measurements and heat transfer coefficient measurements of the suggested configurations. Since then a new measurement method has been implemented that has significantly improved the distinguishability of the heat transfer coefficient as a position dependent variable. This article puts into context the results of the impact pressure of the water jet and its corresponding heat transfer coefficient in the overlap area of the water jets.

2. NOZZLE CONFIGURATION

The descaling nozzle is characterized by its spray angle and flow rate at a given water pressure. Our tested nozzles had a spray angle of 45° and a flow rate of 58 l/min at 40 MPa. Two nozzles were tested in the inclined standard configuration that is shown in **Figure 1**. The configuration is summarized in **Table 1**. The new inline configuration had an offset angle of zero. All other parameters were the same as in the previous test. The offset angle of zero means that in practice the water jets collide above the surface of the steel.

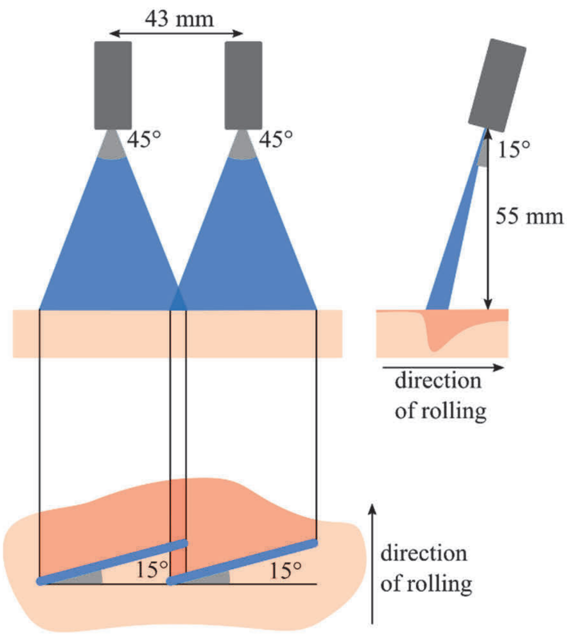

Figure 1 Inclined nozzle configuration

Table 1 Nozzle configuration

Spray angle (°)	Flow rate (l/min)	Pressure (MPa)	Pitch (mm)	Height (mm)	Offset (°)	Inclination (°)
45	58	40	43	55	Inclined = 15 Inline = 0	15

3. EXPERIMENTS

Two types of experiments were performed in order to illustrate the connection between the water impact pressure and the corresponding heat transfer coefficient. The data regarding water impact pressure was already presented in article [9].

3.1. Impact pressure measurements

The measurements of the impact pressure were made on a laboratory device that consisted of a circular moving plate with a pressure sensor that was placed in the center of the plate. The diameter of the sensor was 1 mm. The plate slowly moved in X/Y direction and the pressure is measured as a position-dependent value.

3.2. Heat transfer coefficient measurement

The determination of the heat transfer coefficient consists of two steps.

First the descaling conditions are tested on the laboratory test bench (**Figure 2**). The descaled steel specimen is equipped with a thermocouple that is placed inside the specimen, very near to the surface. The relative positions of the thermocouple and the nozzles are set in such a way that the thermocouple records the temperature under the surface of the overlap area (see **Figure 1**). The specimen is heated to 900 °C, placed on the moving carriage and moved along the bench at a speed of 2 m/s. After the experiment, the temperature history is gathered in the computer and the inverse heat conduction algorithm is used for further data processing. The algorithm produces the computed temperature at the surface and the corresponding heat transfer coefficient (see **Figure 3**). The principle is outlined in [6].

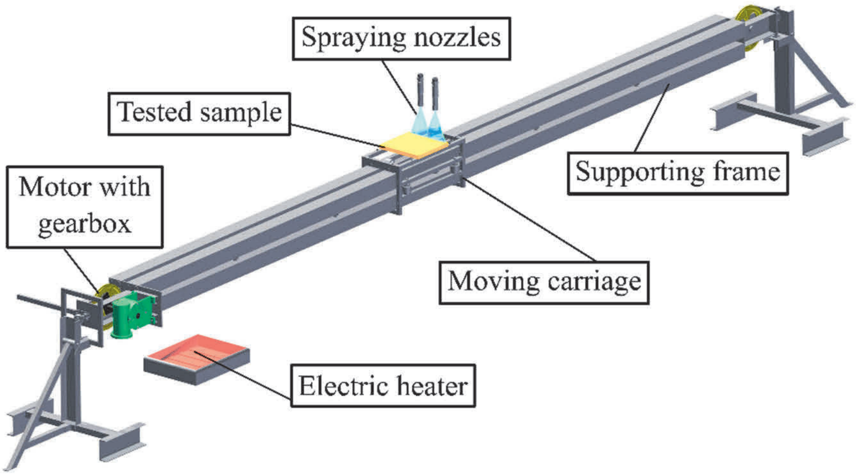

Figure 2 Scheme of laboratory test bench

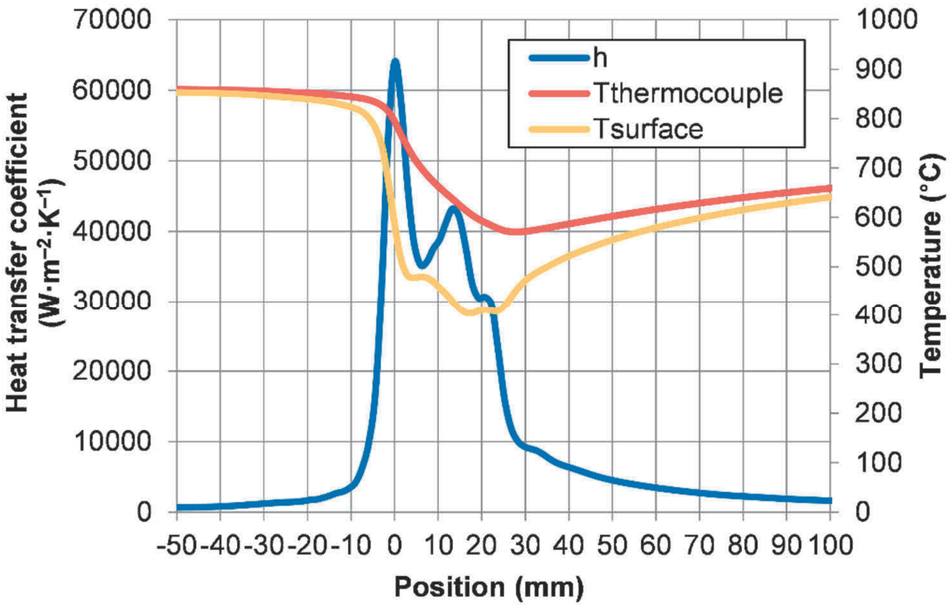

Figure 3 HTC explanation

4. DATA EVALUATION

The impact pressure outside the overlap area moves within a range from 3.5 MPa up to 5 MPa. The gradual rise in the pressure in the inclined configuration is caused by the positive offset angle.

The overlap area of the inclined configuration is 18 mm in length in the rolling direction and the distance between the jet footprints is approximately 15 mm (see **Figure 4**). The maximal impact pressure in this area is ranges from 4.8 MPa to 5 MPa. The reduced impact pressure of the second nozzle ranges from 1.9 MPa to 2.1 MPa.

The overlap of the inline configuration was only 4 mm in length (see **Figure 5**). The area had one peak. The maximum pressure measured was 10.7 MPa.

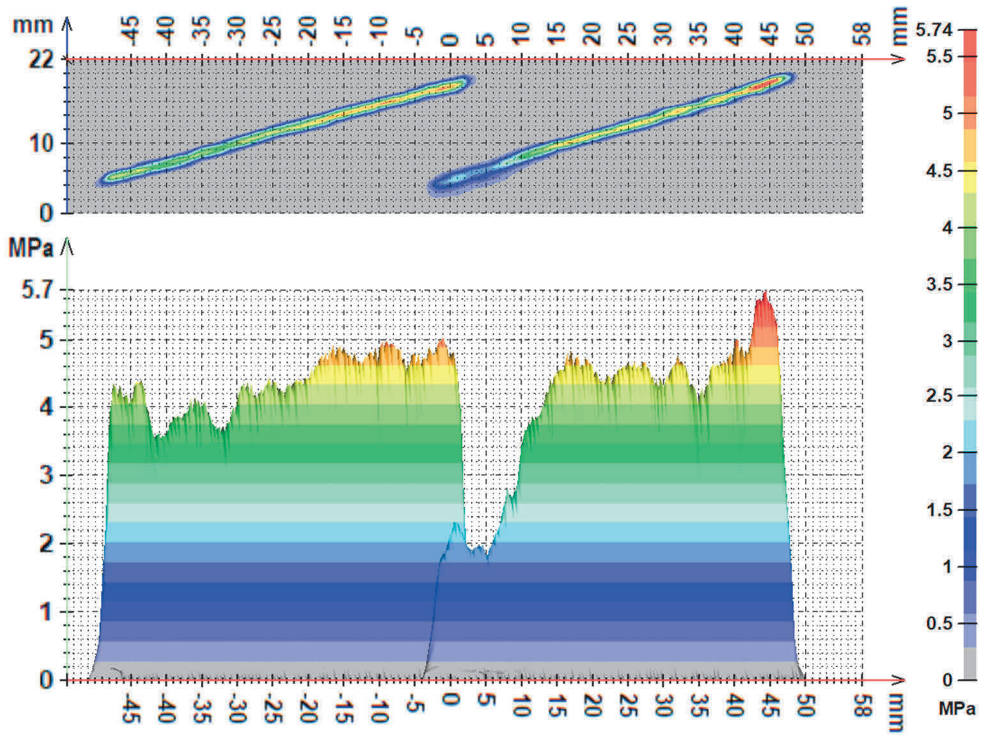

Figure 4 Impact pressure distribution of the inclined configuration

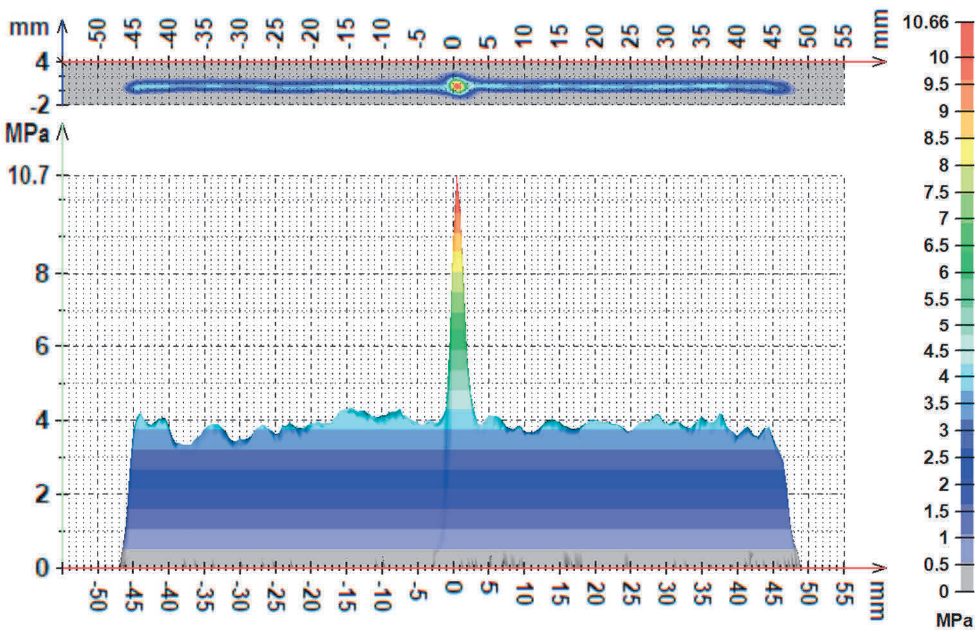

Figure 5 Impact pressure of the inline configuration

The measured temperature drop is shown in **Figure 6**. The dotted line represents the computed temperature drop on the descaled surface. The measurements are set in such a way that the zero position corresponds to the place where the water jet hits the surface. The heat transfer coefficient was determined as a position dependent value and is shown in **Figure 7**.

The inclined configuration led to the surface cooling down to 400 °C. The graph of heat transfer coefficient shows two peaks that correspond to the water jet footprints on the surface. Even though the first peak is higher than the second, the first one corresponds to the reduced impact pressure of the right nozzle with an average impact pressure of 2.2 MPa in overlap area. The distance between these peaks is 15 mm (the same as the measured distance of the water jet footprints) which confirms the accuracy of these measurements. The maximum values at the peaks were 64,040 $Wm\cdot^{-2}K\cdot^{-1}$ and 43,253 $W\cdot m^{-2}\cdot K^{-1}$.

The inline configuration had only one peak. This intensive cooling causes the decrease of the surface temperature down to the 477 °C. Nevertheless, it is a very short impulse and the temperature is recovered very quickly. The maximum value at the peak was 67,448 $W\cdot m^{-2}\cdot K^{-1}$.

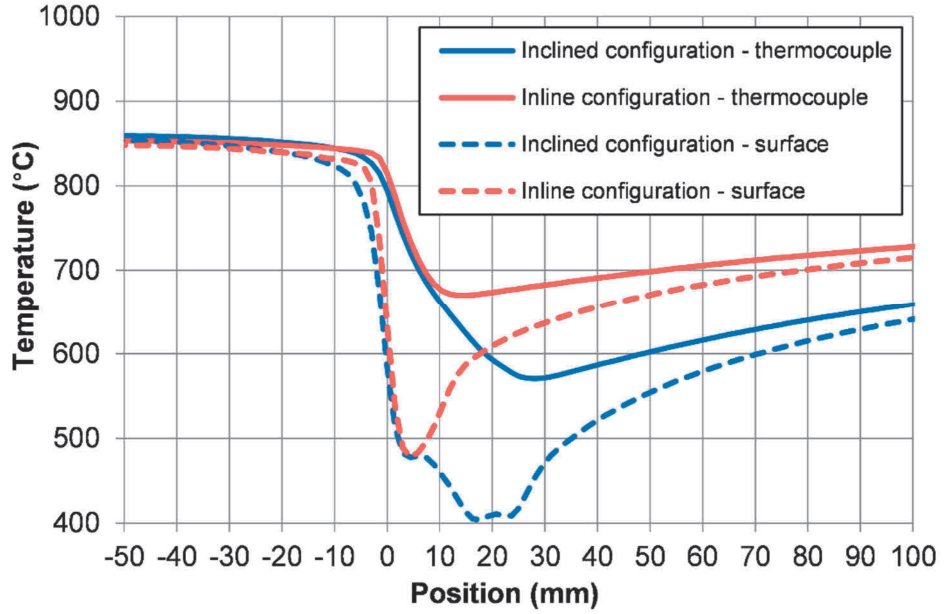

Figure 6 Temperature

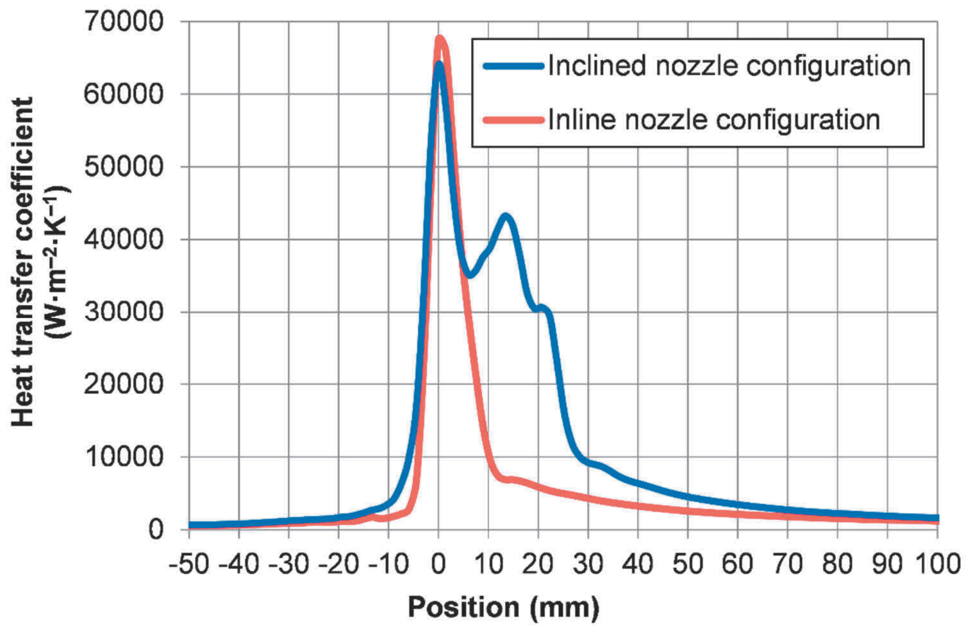

Figure 7 Heat transfer coefficient as a position dependent variable

5. DISCUSSION

The outcomes of the experiments show that the most important heat loss is caused by the cooling length of the configuration (i.e. by the positive offset angle). The positive offset angle caused two peaks of maximum heat transfer coefficient and led to unnecessary long cooling of the surface.

The first maximum of the heat transfer coefficient was very similar in both experiments despite the fact that the impact pressure was very different. The corresponding impact pressures were approximately 5 times higher in the inline nozzle configuration in comparison with the inclined configuration. The heat transfer coefficient in the case of the inclined configuration was higher when the impact pressure was reduced. This behavior can be partially explained by the water that is reflected by the surface and gathers in the area between the jet footprints.

6. CONCLUSION

The observations presented in this article strongly suggest that the offset angle contributes significantly to the unnecessary overcooling of the surface during descaling and should be minimized. The positive offset angle also causes inhomogeneous cooling along the descaled surface. An offset angle with a range of 0° to 5° is recommended since the setting of the operating nozzles in descalers is very coarse.

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