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Experimental Study on Effect of Nozzle Bank Distance on Cooling Behaviour of a Flat MS Plate in a Laboratory Scale ROT

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Abstract—*Run-Out Tables [ROTs] with water or air jet are an effective and widely used method in industries for cooling hot steel billets. The cooling behaviour is affected by several factors, of which the initial temperature of the billet, air and water jet flow rate as well as the distance of jets from the billet are the vital ones. To achieve desired mechanical and metallurgical properties of steel, one needs control over the cooling behaviour which can subsequently be achieved by controlling the above-mentioned factors.*
The present study is an experimental investigation of the cooling behaviour of a mild steel plate under air jet in a laboratory scale ROT. The initial temperature of the plate and the flow rate of air from the jet is kept constant, the plate is static, while the distance of the jet nozzle banks from the plate are varied.The variation of average plate temperature with time is presented for different nozzle bank distances.

1. INTRODUCTION

Uniform cooling of hot rolled billets under desired conditions take place in Run Out Tables (ROTs) [1,2,3] in industries. Parameters of importance which essentially allow us to achieve the desired cooling rates required for obtaining steel of a particular grade are Initial Temperature at which cooling starts (*Ti*), the air flow rate (*Q*), the upper nozzle bank distance (*du*), the lower nozzle bank distance (*dl*) and the velocity (*v*) of the billet under cooling bay. Significant improvement on the base quality produced is brought about by combining Ultra-Fast Cooling techniques [4] and precise spray techniques [5] with controlled cooling [6] parameters. The effect of change in *Ti* on the cooling rate of a static mild steel plate on a laboratory scale ROT, with constant *Q* and *d*, has been shown by Sarkar et al. [7] The objective of the present work is to examine the cooling characteristics of a mild steel (MS) heated to a certain temperature and then cooled under varying nozzle bank distances. The work is done on a static MS plate and parameters such as *Q* and *Ti* are kept constant.

2. SYSTEM DESCRIPTION

The laboratory scale Run Out Table (ROT) setup, used by Sarkar et al [7] is used for the present set of experiments. The system used for the experiment consists of a furnace, nozzle bank setup, source of cooling elements and a computer system.

The test MS plate of dimensions 597x202x6 mm that is used for this particular experiment is heated in a chamber type furnace with 18 nos. of heating elements on the two inner walls. The temperature is controlled from a control panel provided alongside the furnace. It has provisions for a safety controller to regulate voltage and current and a dial to set the maximum temperature. Fig. 2(a) shows the experimental furnace setup.

Fig. 2(a).Experimental Setup.

A: The Furnace with heating elements

B: The Furnace Control Panel

C: The Nozzle Bank setup

Fig. 2(b). The Data Acquisition Setup.

D: NI cRIO input module
E: Host PC running LabView

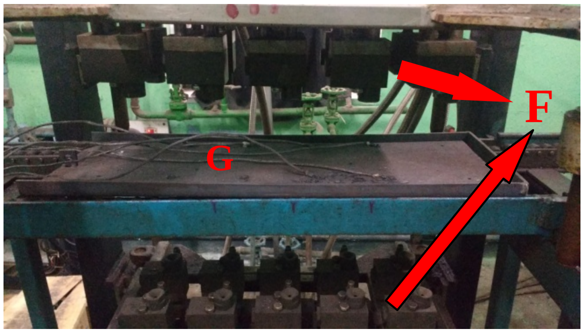

Fig. 2(c). The Cooling Bay.
F: The upper and lower nozzle banks
G: The test MS plate

The MS plate is cooled under compressed air which is fed from an air compressor through a flow circuit and regulated by valves. This leads to a nozzle bank cooling bay setup. This consists of two sets of nozzle banks with 10 nozzles mounted in each set all facing the center of the setup. Fig. 2(c) shows the MS plate in the cooling bay while it is being cooled by compressed air from the nozzle banks above and below.

The cooling characteristic of the MS plate is recorded by means of a data acquisition system which consists of 8 nos. of K-Type thermocouples attached along the upper surface of the MS plate, along the length of the plate and at equal distance from the center line of the plate and from each other. The thermocouple positions are taken so as to cover maximum positions of the MS plate and to determine its temperature in real time.The temperature is recorded in real time using a NI 9211 Input Module in an NI cRIO that acts as the interface device between the hardware and a host PC. NI LabView is used as the software platform in the PC. Fig. 2(b) shows the data acquisition system.

The results have been taken varying the nozzle bank distances (*du* and *dl*) at certain graduations while keeping the initial temperature of the plate and the compressed air flow rate constant. The MS plate was kept static.

3. RESULTS AND DISCUSSION

Curves of the experimental data are plotted with T_{avg} (°C) as the ordinate and time(seconds) as the abscissa. The initial temperature of the plate is in the range of 480°C to 500°C (approximately constant) and Q is maintained approximately at 5.5 m^3/hr. The plates are cooled up to approximately 100°C.

Fig. 3(a) shows the curves with *du* changing from 55mm to 115mm to finally 175mm, while *dl* is kept constant at 115mm. In Fig. 3(b), *du* is kept constant at 115mm, while *dl* is changed from 55mm to 115mm to 175mm and corresponding curves are plotted. In Fig. 3(c), all the curves from the former two figures are plotted for comparison.

From the first two figures, it can be clearly seen that bringing one nozzle bank closer to the plate while the other is held in place increases cooling rate of the plate. From the Fig. 3(c), we note something very interesting: bringing the upper nozzle bank closer to the plate improves cooling rate more than bringing the lower nozzle bank closer does.

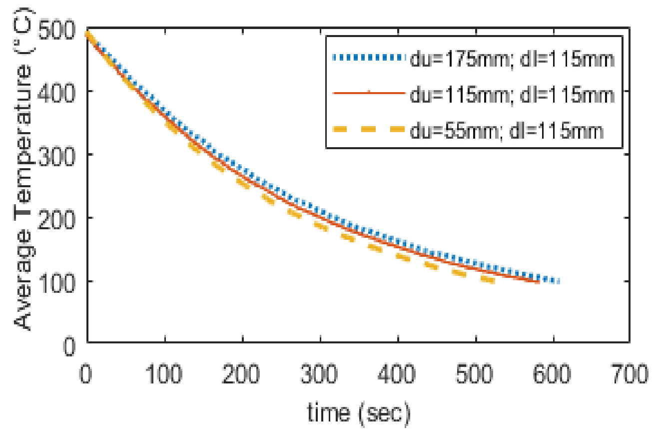

Fig. 3(a).Cooling behaviour forvariation in *du*.

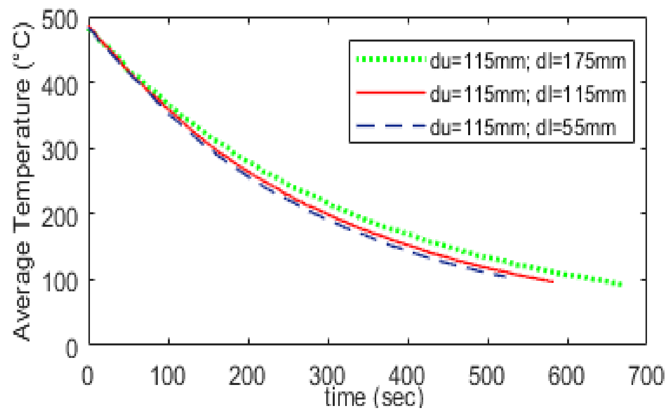

Fig. 3(b). Cooling behaviour for variation in *dl*.

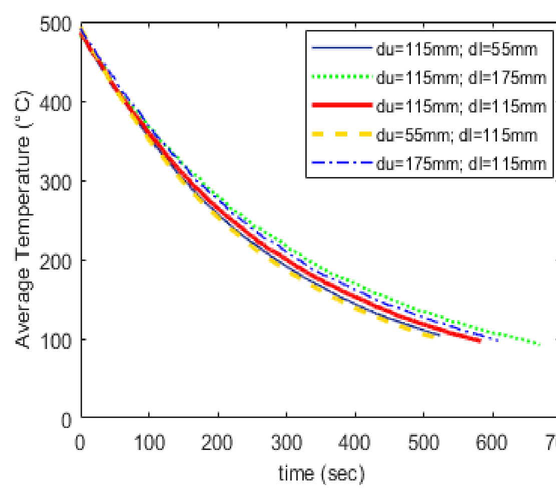

Fig. 3(c). Comparison of cooling behaviour from Figures 3(a) and 3(b).

There can be a simple explanation for this phenomenon. The air jet from the lower nozzle bank has to work against gravity to reach the plate, while the air jet from the upper nozzle bank is assisted by gravity in reaching the plate. Thus, from the same distance of the nozzle banks from the plate initially, bringing the upper nozzle bank closer would result in faster cooling compared to bringing the lower nozzle bank closer by the same distance, while the other is kept constant.

4. CONCLUSION

The nozzle bank distance is found to have a very significant effect on the cooling behaviour of the steel plate on the basis of experimental data, and the orientation of the jet also affects how much improvement can be made in the cooling rate by bringing the corresponding nozzle bank closer to the plate. Further studies can be done where both the nozzle banks are moved closer or farther simultaneously. This data can help develop faster and more efficient cooling in industrial ROTs.

Future work will also include use of water and air mixture to carry out cooling rate tests, and providing motion to the plate using an Electro-Hydraulic Actuation System (EHAS) to study effect of velocity on cooling behaviour.

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