EXPERIMENTAL STUDY OF COOLING RATE VARIATION UNDER LOW AIR JET FLOW RATE IN A LABORATORY SCALE ROT

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Abstract: Cooling of hot steel sheets under air-water mixture jet is carried out in steel industries in Run Out Tables (ROTs). In general, higher jet flow rates are required to get higher cooling rates. Studies have been conducted till date to get different cooling rates for achieving various microstructures of steel. However, all these have been concentrated for higher jet flow rates. Experimental study of getting cooling rates under lower air flow rates is thus a requirement. This may result in achieving some new microstructure. The present study carries out the same observation under a number of air jet flow rates of lower values in order to observe the cooling rate of an MS plate under the same in a laboratory scale ROT.

***Index Terms* - air jet , lower air flow rate, Run Out Table**

I. INTRODUCTION

In Steel industries cooling of hot steel sheets is carried out under air or water jets in a Run Out Table (ROT) setup to impart desirable mechanical and metallurgical properties [1]. Modern cooling techniques employ the Ultra-Fast Cooling technology to attain optimum cooling rates and increase the efficiency of the production line [2-4]. Not only pure water but dissolved additives such as mixture of ethanol and surfactants have been used to improve microstructure as well as the cooling rates [5]. In another study it is shown that cooling rates can be influenced by the angle of inclination of the spray [6]. Higher cooling rates are generally obtained at higher mass flow rate of the cooling fluid [7]. While higher mass flow rates certainly are widely studied the region of lower mass flow rates of the cooling fluid is less widely used for ultra-fast cooling purposes. The higher flow rates of the fluids impart greater momentum to it which can lead it to bounce back after colliding with the steel plate and obstruct the incoming cooling fluid reducing the cooling rates overall.

On that note the present study on a mild steel plate using a laboratory scaled Run Out Table, air jet flow rates have been kept at low values between 1 to 5 m^3/hr. The time recording in these sets of experiments have been started when the average temperature was in the range of 505°C and 495°C. They have been cooled up to a temperature of 100°C. The results obtained have been used to draw some interesting insights into cooling patterns at low flow rates where the flow can be assumed to be in a laminar zone.

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II. SETUP AND METHODOLOGY

A chamber type closed furnace is used for high-temperature heating of a flat mild steel plate. A laboratory scaled Run Out Table setup is used to perform the experiment. The setup is made up of an air compressor, furnace, control panel, digital air flow meter, globe valve, air-nozzle bank and a PC as shown in Fig. 1. There are 18 Silicon Carbide heating elements on the two inner side walls of chamber of the heating furnace. The furnace has dimensions of 800 mm in length, 800 mm in width and 300mm in height. The maximum temperature of furnace can be 1200°C. The control unit of the furnace is beside the chamber and it consists of a safety controller to regulate the desired temperature. The furnace is manually operated by a switch and also contains a voltmeter and ammeter, as represented in Fig. 1(a). The furnace door can be lifted and is attached to a chain drive system.

First, air is pressurized in a centripetal compressor and that is driven by an induction motor, as shown in Fig. 1(b). This air supplied to the nozzle banks is through an air circuit which is operated by the globe-valve and air flow rate is measured by a digital flow meter. The Mild Steel plate of dimension 597mmx202mmx6mm, is heated in furnace to achievable temperature and after that, its cooled under air jet which comprises of twenty nozzle banks in total. They are placed on both upward and downward side so that both surfaces can be sprayed uniformly at the same time. All the hydraulic nozzles are circular cross sectional in shape as shown in Fig. 1(c). The experiment is performed when there is a distance of 115 mm and 25 mm of air nozzle bank from the upper and lower surface respectively, of heated MS plate.

There are four 8 nos. of k-type thermocouples to record the temperature data in real time, fixed on the upper surfaces of the sample Mild Steel plate along the length and equidistant from each other and center line also. The results have been taken varying the air flow rate (Q), while keeping the initial temperature constant at 500°C and the specimen have been kept static. National Instruments LabVIEW is the software is used to record the experimental data in a PC as depicted in Fig. 1(d).

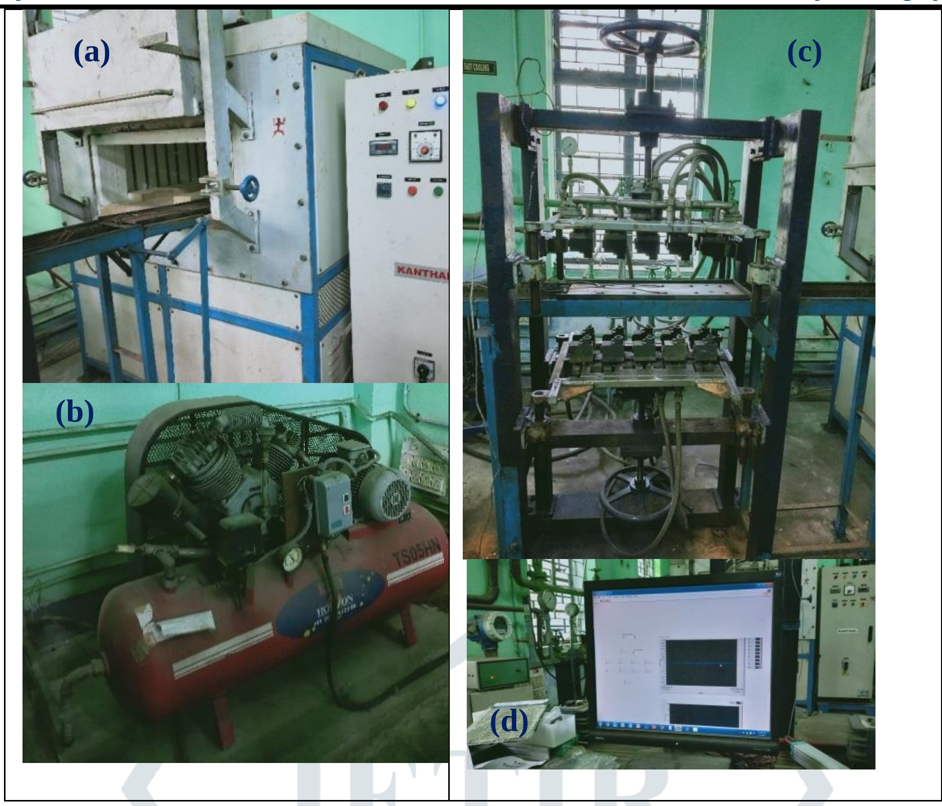

Figure 1: Set up components: (a) Furnace (b) Air Compressor (c) Nozzle banks (d) PC

III. RESULT

The time recording in these sets of experiments have been started when the average temperature was in the range of 505°C and 495°C. The plate has been cooled up to an average temperature of around 100°C. Throughout the series of experiments, the distance between the plate and upper nozzle bank has been maintained at 115 mm and the distance between the lower bank and the plate at 25 mm. The experiments have been conducted at lower air flow rates beginning from 1.4 m^3/hr. to 5.3 m^3/hr., the exact values of which are noted from the graph below, with same experiments being repeated multiple times.

In order to get a parameter to compare the relative rates of cooling, the following procedure has been adopted: the areas under the cooling curves are evaluated using trapezoidal rule for each experimental run from 500°C up to a temperature of 120°C. It can be intuitively observed that smaller the area, greater would be the decrement of temperature within a specified cooling interval, and therefore is an indication of a higher average cooling rate. In Fig. 2 the areas are evaluated and plotted against the respective air flow rates. A 4th order best-fit polynomial trend-line has been used to get the curve.

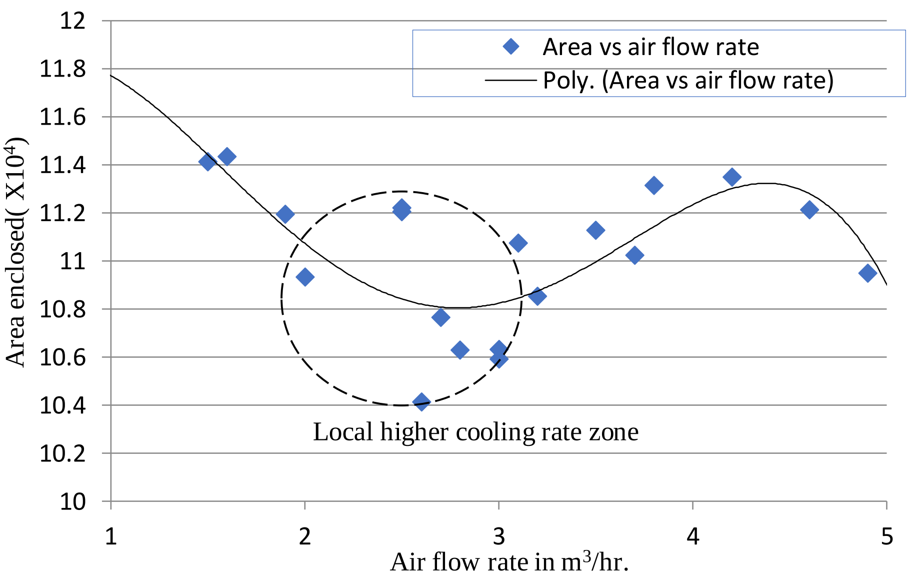

Figure 2: Variation of enclosed area with air flow rate.

Certain interesting phenomena have been observed from Fig. 2 in the zone of low air flow rate. The general trend as expected from previous experiments [7-8] in the region of high air flow is that the cooling rate should increase with increase in air flow rate. However, it is seen that between air flow rates of 2.5- 4 m^3/hr, the average cooling rate decreases with increase of air flow rate. Therefore, a minima has been observed in the region of low air flow rates which is against the expected trend. This lower air flow zone of can thus be identified as having higher cooling rates.

IV. CONCLUSION

Several experiments have been conducted under low air flow rates in the range of 1 to 5 m^3/hr. It has been observed that for air flow rates between 2.5 and 4.5 m^3/hr, the average cooling rate decreases with an increase in the air flow rate. A zone of higher cooling rate has been found near an air flow rate of 3 m^3/hr. However, in the region of higher air flow rates beyond 4.5 m^3/hr, the cooling rate increases with an increase in air flow rate as expected from theoretical understandings.

V. ACKNOWLEDGEMENT

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