The Thermal-Hydraulic Characteristics of a Double-Jet Flow over a Flat Plate

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***Abstract*—This study investigates the heat transfer and hydraulic phenomena of the double-jet impingement on a hot steel plate with different flow rate and spray-angle of the flat fan nozzle. The heat transfer coefficients for 2 different kind of flat fan nozzles and 3 different flow rates(2.5L/min to 8 L/min) are calculated by the 3-D inverse heat transfer models solved by an algorithm developed with the conjugate-gradient method. The conjugate gradient method was an iterative method for solving an equation and used to optimize the heat transfer coefficient distribution.**

A test piece of steel plate was electrically heated from below heat pipe, its top surface was spray cooled and sides' heat transfer through natural convection. The spray was produced from a nozzle supplied with water from a pressurized pump and experimental temperature was measured by thermocouples connect to the data processor.

First, the flow field observation will show the hydraulic phenomena with a single nozzle jet impingement on a flat plate. Second, the cooling rate and heat transfer effects will be discussed in detailed.

Keywords—hydraulic phenomena, Double-Jet, Inverse Heat Transfer, conjugate-gradient method

I. INTRODUCTION

In recent years, countries around the world have paid more and more attention to the issues related to global warming and the environment. Energy conservation, carbon reduction, and green energy have gradually become an important indicator of engineering. China Steel Corporation also attaches more importance to the effective use of energy and environmental pollution. Today, the development of the steel industry in the global market is increasingly prosperous. More and more steelmaking plants have been set up around the world, with the pressure of global competition in the market. The quality requirements of steel products are also highly valued. In order to enhance the competitiveness of the steel industry in the global market while reducing the pollution to the environment, the improvement in the quality of steel products, as well as the control and evaluation of individual steelmaking process monitoring and production lines, which are the front line for improvement and breakthrough.

Most of steel products are produced by high-temperature steel embryos through rolling process. Because of the high temperature of high-temperature steel embryos, they are constantly reacting with the air to undergo high-temperature oxidation during the air-cooling process and the steel embryos are constantly being rusted. Therefore, during the rolling process, the steel blanks emerging from the continuous casting machine need to be cooled after entering the hot rolling process to reach a specific coil temperature and at the same time avoid the phenomenon of corrosion, so as to obtain the required mechanical properties. The mechanical properties of steel are mainly determined by the proportion of alloying elements contained in the crystal structure and the grain size. When the elements of the alloy are fixed, the growth and size of the crystal grains and the surface flatness of the steel material can be controlled by the temperature distribution of the steel when cooled and the jet impingement's cooling rate. Therefore, the control of the cooling rate in the rolling process of steel has become one of its key technologies.

The jet spray jet cooling with nozzles on the steel plate is a practical technique for rapid cooling in the industry. In the steelmaking plant, hot-rolled steel billets are now used as the main cooling method for jet cooling in the cooling process. The main principle is to use a fluid with high-speed and high-strength impact force to hit the high temperature object directly. The surface of the object, followed by the rapid flow of the fluid to the surface, takes a large amount of heat away from the surface of the object and produces an extremely high heat transfer rate to facilitate rapid cooling of the steel material. At present, the common cooling methods in the industry include laminar cooling, curtain cooling, spray cooling, and ultra-fast cooling. The cooling method in this paper belongs to nozzle fan spray. The high-speed cooling, however, different cooling methods have their advantages and disadvantages and their scope of application.

This study mainly focuses on the rapid cooling of high-temperature steel plates subjected to fan-shaped nozzles, and analyzes its cooling and heat transfer effect. The relationship between the distribution of heat convection coefficients and the corresponding flow rates in the cooling process is further explored. The equipment measures the physical quantities such as temperature in an experimental manner and combines the Fluent module in the commercial software ANSYS with the simple conjugate gradient method for Fortran calculation to calculate and analyze the optimization theory and then find out the distribution of the h value. In order to achieve the desired