mechanical properties and high quality goals for steel products, fast cooling is used to control the phase transition state of the steel in order to increase the mechanical properties and quality of the steel to increase the added value of the material to enhance its competitiveness in the global market.

II. Theoretical Analysis

In this study, the cooling of the fan-shaped atomization nozzles to the high-temperature plate was further investigated experimentally. As shown in the Fig.1, the flow fields at different nozzles were compared and the flow fields of two different types of nozzles were compared. Further experiments and the 3-D inverse heat transfer conjugate gradient method were used to calculate the heat transfer coefficient distribution of the stainless steel flat plate.

In terms of the type of nozzles, our experiments mainly used standard flat spray nozzles to perform experiments. Two types of nozzles were selected for nozzles with larger spray angles under standard pressure.

The part that is cooled by the nozzle is mainly a flat stainless steel with a size of 300mm×300mm×40mm to perform the experiment. The physical model is shown in Fig.2 and the 1/4 model is taken for the analysis in the calculation part of the inverse heat transfer process, and its governing equation is heat conduction equation as following:

$$\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial y}\left(k\frac{\partial T}{\partial y}\right)+\frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right)=\rho C_p\frac{\partial T}{\partial t} \tag{1}$$

A. Assumption

(1) Steady-state turbulent flow field.
(2) Incompressible flow.
(3) The fluid properties are constant.
(4) Ignore thermal radiation effects.
(5) No heat generation
(6) Free liquid surface characteristics between air and liquid water
(7) Transient heat conduction process

B. Boundary & Initial Conditions

(1) Bottom surface boundary conditions: adiabatic boundary conditions: $\frac{\partial T}{\partial n}=0$

(2) Plate side boundary conditions: natural convection, let constant heat convection coefficient : h=50 W/m2-K

(3) Plate symmetry boundary conditions: adiabatic boundary conditions: $\frac{\partial T}{\partial n}=0$

(4) Top surface boundary conditions: Fourier Law &Newton cooling Law

$$q''=-k_n\left.\frac{\partial T}{\partial n}\right|_{n=surface}=h\,(\mathrm{T}-\mathrm{T}_\infty),\ \mathrm{T}_\infty=27\,(^\circ\mathrm{C}) \tag{2}$$

(5) Plate initial conditions: $T\left(t=0\right)=400\pm10\,(^\circ\mathrm{C}\ )$

(6) Cooling time: 20(s)

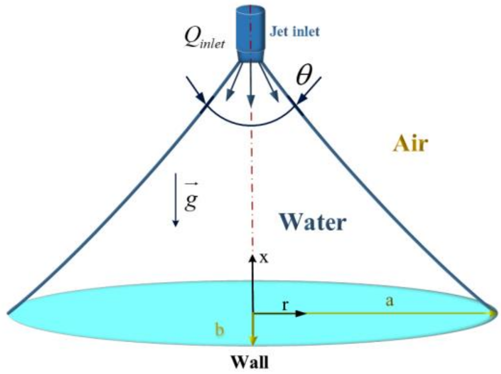

Fig. 1. Schematic diagram of nozzle flow filed

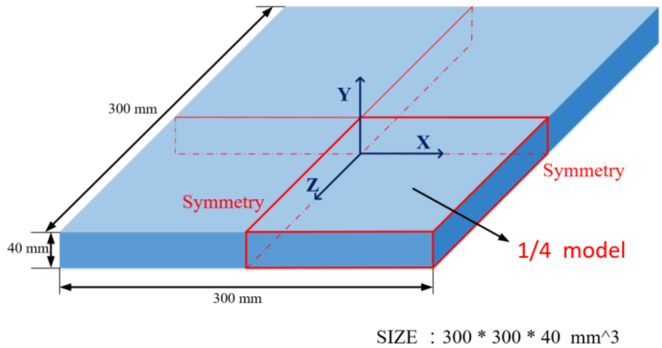

Fig. 2. Physical model of inverse heat conduction

III. Optimization Method

A. Simplified conjugate-gradient method

The Simplified conjugate gradient method was proposed by Prof. Zheng Jinxiang of Cheng-Gong University in 2003. The simple conjugate gradient method separates the step distances with the advantage of retaining the conjugate gradient method and gives it as manual input to avoid complicated calculation steps and geometric limitations. This method makes this method more widely used in the field of multi-variables. The simple conjugate gradient method directly uses the perturbation amount to calculate the gradient function by direct numerical differentiation without solving the gradient equation. Therefore, compared to the complex procedure of conjugate gradient method, we use the simple conjugate gradient method as the search tool to optimize the optimization of the heat transfer coefficient distribution on the plate surface.

The part of the experiment optimized for inverse heat transfer uses a simple conjugate gradient method to bring the objective function within the error of a relative temperature difference of less than 3%. Let $X_n^{(k)}$ be the nth design variable of the kth iteration. The gradient function is the partial differential derivative of the objective function $F(X_n^{(k)})$, ie $\partial F/\partial X_n$, can be obtained directly from the sensitivity analysis via the perturbation method. Sensitivity analysis can use the forward solution subroutine to find the objective function before