AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
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# Heat Transfer Characteristics of Horizontal Cylinder Cooling Under Single and Multiple Impinging Water Jets

**A THESIS**

SUBMITTED FOR THE PARTIAL FULFILLMENT OF DOCTOR OF PHILOSOPHY DEGREE (Ph.D.) IN MECHANICAL ENGINEERING

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# STATEMENT

This dissertation is submitted to Ain Shams University for partial fulfillment of the requirements for the Doctor of Philosophy (Ph.D.) degree in Mechanical Engineering.

The work included in the thesis was made by the author during the period from September 2009 to June 2012 at Mechanical Power Engineering Department, Faculty of Engineering, Ain Shams University.

No part of this thesis has been submitted for degree or qualification at any other university or institute.

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***To***
***my parents***
***the only people who always sacrifice for me. To my wife, sons, daughter, sisters and brother.***

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Hamdy Ahmed
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# ABSTRACT

This research is to study the heat transfer characteristics of jet impinging hot circular cylinder. Cooling is designated to be under single and triple jets. The effects of initial specimen temperature, cooling water temperature, jet velocity, and jet diameter and jet height are examined.

Experimental and numerical investigations have been conducted for quenching of a hot cylinder with initial temperature of 300 to 400 $^{o}$C by a subcooled water jet. Water is injected perpendicularly on cylinder circumference via a round jet. Jet diameters of 3 and 4mm are examined. Injected water temperature is controlled to cover range of subcooling from 20$^{o}$C to 60$^{o}$C.

An original experimental device allowing the measurements of metal temperature variation with time inside the specimen is used. The distance between the jet and outer cylinder surface is 5 and 10cm. The water velocities are 4 to 8m/s. A numerical model is used to verify the experiments results. Heat fluxes and surface heat transfer coefficients are represented. In reference to the results, the transition from film boiling to nucleate appears clearly, before reaching the forced convection stage.

The present work is focused on studying the parameters that affect the cooling rate of cylindrical steel specimens, and thus affect the steel hardness. As coming in next chapters, the effect of initial surface temperature, water flow rate, number of jets and water temperature will be examined. The study quantifies the effect of changing the initial surface temperature and water flow rates on cooling of steel cylinder at different radial locations, and hence the hardness. Also, the effect of changing cooling water temperature on controlling steel cylinder cooling at different radial locations, and hence the hardness is studied. The study also covers also conclusions concerning how to control cooling rates in order to achieve the intended hardness of the specimen and how to select this rate as needed.

From the results analysis, a numerical model is used and shows good agreements with experimental works of water jet impinging free cylinder surface. Triple jet achieved homogenous metal temperatures and heat flux, when compared to single jet. As specimen initial temperature increases, the transition from film to nucleate boiling occurs at higher temperature, greater time lapse and gives higher extracted heat fluxes. Also, as the water increase, the transition from film to nucleate boiling occurs at significant higher temperature, significant lower time lapse and gives significant higher extracted heat fluxes. Cooling increases with the parameters of jet diameter and water velocities, but this impact is less observed especially deep in metal. Finally changing jet height from 5cm to 10cm does not affect the stagnation velocities and achieved nearly the same cooling rates.

**Keywords**: Water quenching, Impinging jet, Boiling mechanism, Steel cylinder heat treatment.

# SUMMARY


This dissertation demonstrates the heat transfer characteristics of single and triple water jets impinging hot steel cylinder. The dissertation is in six chapters organized as follows:

**Chapter One** is an introduction to jet impingement heat transfer. It includes a background about the jet impingement cooling process and the main industrial applications for which this process could be of crucial importance.

**Chapter Two** presents a literature survey of the previous research work that tackled the study of jet impingement heat transfer.

**Chapter Three** delineates a detailed description of the experimental test facility constructed for the current study and the experimental procedures conducted.

**Chapter Four** includes a brief discussion of the numerical analysis software that has been used to interpret the experimental data.

**Chapter Five** demonstrates the experimental observations and numerical results along with the corresponding interpretation and discussion sections.

**Chapter Six**, finally, drives the final conclusions and the recommendations for future work.

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