TEMPERATURE EFFECT OF IMPULSIVE MOTION IN AN AIR FLOATATION NOZZLE

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To my beloved wife

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ABSTRACT

This project examines the temperature effect of impulsive motion for an air floatation nozzle in three-dimensional using computation fluid dynamics approach. The nozzles were first modelled in two-dimensional and then extruded into three-dimensional. Some variations to the nozzle's geometry were made in order to study the effects of various geometry setups such as variation in web distance, lip separation and adding holes along the side bar. The results indicate that non-linear relationship between the web distance and temperature distribution across the web. The results also show that the pressure decreases non-linearly as the web distance increases. The results for lip separation case studies also show non-linear relationship between the lip separation and the temperature distribution across the web. Finally, additional holes along the side bar produces more uniform temperature and pressure distribution on the web.

ABSTRAK

Projek ini mengkaji kesan suhu gerakan impulsif muncung pengapungan udara di tiga dimensi menggunakan pendekatan pengiraan cecair dinamik. Muncung mula dimodelkan dalam dua dimensi dan kemudian dibentukkan ke dalam tiga dimensi. Beberapa perubahan geometri muncung telah dibuat untuk mengkaji kesan penyusunan geometri dari beberapa variasi seperti dalam jarak web/jaringan, pemisah/pengasingan bibir dan menambah lubang di sepanjang sisi bar. Keputusan menunjukkan bahawa hubungan bukan linear antara jarak web dan taburan suhu di seluruh web. Keputusan juga menunjukkan bahawa tekanan menurun tidak linear kerana kenaikan jarak web. Keputusan bagi pemisahan bibir kajian kes juga menunjukkan hubungan linear antara pengasingan bibir dan taburan suhu di seluruh web. Akhir sekali, lubang tambahan di sepanjang bar sisi yang dihasilkan suhu lebih seragam dan taburan tekanan di web.

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LIST OF ABBREVIATIONS

Nomenclature

α	-	Thermal diffusivity
β	-	Thermal expansion coefficient
C_p	-	Specific heat capacity
k	-	Thermal conductivity
m	-	Mass flow rate
μ	-	Dynamic viscosity
η	-	Efficiency
ρ	-	Density
Q	-	Volumetric flow rate
Ø	-	Volume fraction
ν	-	Kinematics viscosity
x, y, z	-	Directions
U, v, w	-	Velocities in x, y an z
u'	-	Fluctuating velocity
$\bar{u}$	-	Mean velocity $\tilde{u}$
$\tilde{u}$	-	Velocity vector (x, y,z)
Grad	-	Total derivative of ϕ
Φ	-	Dissipation function
M	-	Dynamic viscosity
Re	-	Reynolds number

Unit

K	-	Kelvin
Kg	-	Kilogramme
m^3	-	Cubic meter
S	-	Second

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Unsteady conditions of motion and heating of fluids is important in many applications which involve engineering fields of aerodynamics and hydrodynamics. For example, standard types of aerodynamics experiments have been carried out in shock tunnels for the past few decades, however, the experiment duration are generally too short that do not allow the solid surfaces to heat up to temperatures simulating the actual conditions. With the aid of transient development process, therefore design model configurations can be obtained. [1]

Analytical solutions of exact problems of physical relevance are very useful even though they are limited to simple geometries. Physical parameters governing the phenomenon can be identified clearly. Besides that, analytical solutions are the fundamental test cases for the verification of numerical methods. [2]

Analytical analysis of the problem above can be found in literature, Amilcare Pozzi and Renato Tognaccini [3] mentioned that incompressible flow arising in a two-dimensional channel when the imposed time law of the pressure gradient has a power expression. Due to the linearity of the Navier Stokes equations in the case of fully developed parallel flows, the solution in the case of arbitrary pressure gradient can be obtained by the aid of Taylor Series. Besides that, the temperature profile of the parallel wall involves the effects of the dissipation of kinetic energy. An exact analytical solution of the unsteady impulse thermo-fluid dynamic was also presented by them when thermal field in the fluid is coupled with the thermal field in the solid. The temperature and heat flux at the solid-fluid interface are analyzed as function of time and of the non-dimensional parameters governing the problem. [2]

Brereton and Jiang [4] investigated the convective heat transfer associated to unsteady laminar flows in pipe and channel with axial temperature gradient. The thermal energy equation can be determined analytically, yielding solutions for the instantaneous temperature field for arbitrary time unsteadiness in both the flow and the wall flux.

Numerical solution for unsteady heat transfer on boundary later growth was presented by Pop and Katagiri [5] in 1976. The study utilizes an alternative combination of an expansion method into power series of small time and a very efficient numerical method using the difference-differential method. Highlight of the study is the transient phenomena from initial flow to the final steady-state distribution.

An impulsive Falkner-Skan flow was presented by Harris, Ingham and Pop [1]. Analytical solutions for the simultaneous development of the thermal boundary layers are determined for both small and large times. These solutions are then compared using a very efficient finite-difference method.

To relate impulse flow to an industry application, drying process is considered in this paper. There are quite a number of drying methods, however in this paper, we are focusing on air impingement dryer as figure shown below:

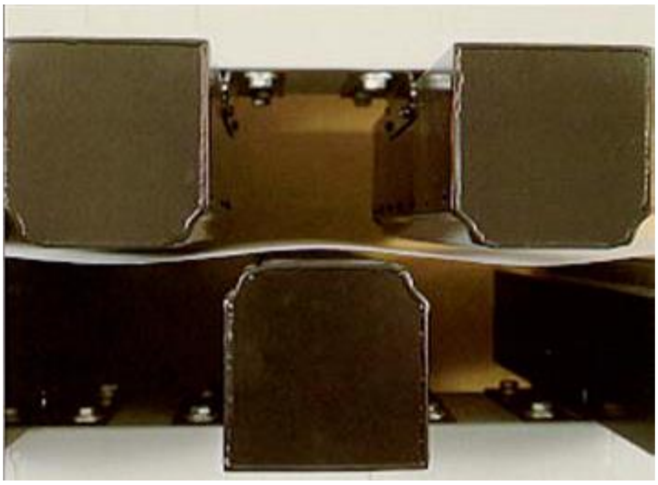

Figure 1.1 – Air Impingement nozzles

A complete model for the simulation of the drying process of a binary system in a modular air impingement dryer is presented by Aus, Durst and Rasziller [6]. The influence of the operating parameters on the drying process and the energy efficiency was investigated. However, in this paper, a single air impingement nozzle with impulsive motion will be investigated.

1.2 Research Objective

The objective of this thesis is:

1) To determine the temperature effect of an air floatation nozzle with impulsive motion

2) To investigate the effects of specific geometry changes to the nozzles
   - Change in web distance
   - Change in lip separation(Pressure outlet)

1.3 Problem Statement

The drying of moving substrates is the main procedure and the manufacture of many daily products such as paper and board, photographic films and pressure sensitive adhesives. It usually cost the most during the drying process and can have a major effect on the quality of the product **[7].** A unique nozzle system for non-contact flotation drying, high porosity webs on its width up to 9 meters. Air is forced from the nozzle to form an air cushion to support the web in order to convey it and the air will impinge onto the web in order to dry or the coatings instead of conveyor belts, air flotation provides advantages, such as: avoiding belt cleaning issues, reducing cost, accurate temperature and pressure profiles, and low maintenance **[11].**

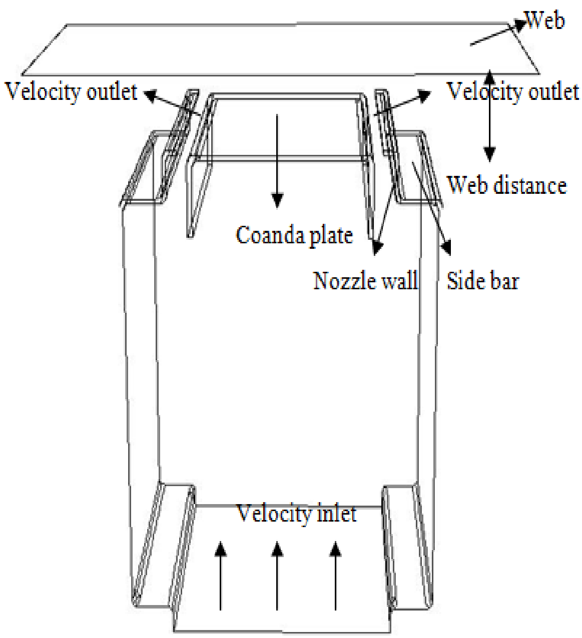

Figure 1.2 – Air Impingement nozzle schematic diagram

Hot air will be ejected from the velocity inlet and then pass through the gap between the nozzle wall and the Coanda plate. The air is then impinged onto the web so as to carry out the drying or coating process.

The heat transfer problem is idealized as follows. The nozzle and the fluid are assumed to be initially at the same temperature. A thermal boundary layer is then produced by the sudden increase of the temperature of the fluid.

Temperature effect of the flow within the nozzle and web will be investigated. Besides that, several changes had been made in the geometry of the nozzle such as the distance between the nozzle and the web, lip separation of the nozzle and the magnitude of velocity inlet in order to investigate the effects on the overall flow. The aforementioned parameters and properties will be further discussed in later chapter.

1.4 Scope of Research

This thesis is to conduct a research on the application of impulsive flow in air flotation nozzle. By integrating the existing information of air flotation nozzle and impulsive flow, simulation of heat transfer of an air flotation nozzle with impulsive start-up and finally to verify and validate the simulation results. The scopes of this thesis are as follows:

i) Analytical solution on a flow with impulsive motion past through a channel
ii) Identification of impulsive start up properties.
iii) Identification of air floatation nozzle design parameter.
iv) Development of an single air floatation nozzle model.
v) Numerical solution on the velocity, pressure and temperature of the nozzle

1.5 Significant of study

i) To obtain uniform temperature and pressure across the nozzle.
ii) To improve the efficiency of the drying process

1.6 Organization of Thesis

To complete this project, the following steps are required to be implemented,

i) Data collection from the published journals.

ii) Design air flotation nozzle by using the aid of SolidWorks.

iii) Simulation of 2D and 3D models by using the aid of Fluent

iv) Setting of boundary conditions.

v) Numerical analysis of temperature and pressure across the channel

vi) Analysis of temperature and pressure profiles onto the web.

vii) Analysis of uniform temperature and pressure across the nozzle.

viii) Discussion

ix) Conclusion

A weekly activity of this thesis has been presented in Gantt chart and appended in Appendix 1 and 2 for thesis 1 and 2 respectively.

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