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"I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for award of degree of Bachelor of Mechanical Engineering (Thermal -Fluid)

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Date : 28 JUNE 2013

EXPERIMENTAL OF FLOW MEASUREMENT OVER DIFFERENT SHAPE OF CAVITIES FOR LOW REYNOLDS NUMBER

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DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledge."

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Dedicated to my beloved parents.

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ABSTRACT

Experiments are carried out in order to investigate the flow structure past rectangular, triangular and semicircular cavity of length-to-depth ratio 2:1 using Particle Image Velocimetry (PIV) technique. The experiments are performed in large scale water channel with constant upstream velocities of Reynolds numbers which is low Reynolds number flow. Contours of constant averaged streamwise and transverse components of velocity, contours of averaged vorticity, Reynolds stress and streamline plots for each cavity are presented. In addition, streamwise velocity, Reynolds stress values are compared for all cavity types. Effect of cavity shape on flow structure within cavity is discussed in details. Moreover, spectrum of instantaneous streamwise velocity fluctuations in shear layer near the downstream of the leading corner and the upstream of the trailing corner of cavity are the most focal point to this research in order to determine the organized oscillations present in the flow for rectangular, triangular and semicircular cavity shapes. The usage of Particle Image Velocimetry (PIV) will become the medium is determination of flow measurement within each cavity and determine the most efficient cavity shapes in removing the contaminants.

ABSTRAK

Eksperimen ini dijalankan untuk menyiasat struktur aliran melalui struktur berbentuk segi empat tepat, segi tiga dan separuh bulatan dengan nisbah 2:1 menggunakan Pengimejan Halaju Zarah (PIV). Teknik eksperimen yang dilakukan di dalam saluran air berskala besar dengan halaju malar huluan nombor Reynolds yang rendah .Kontur komponen yang berterusan berpurata mendatar dan halaju melintang, kontur vortisiti berpurata, tekanan Reynolds dan plot aliran untuk setiap struktur bentuk dikaji. Di samping itu,dengan halaju tetap, tekanan nilai Reynolds dibandingkan untuk semua jenis struktur kajian. Kesan bentuk struktur terhadap aliran air dalam kawasan kajian dibincangkan secara terperinci. Selain itu, spektrum perubahan halaju seketika di dalam lapisan tekanan berhampiran hilir sudut terkemuka dan hulu sudut belakang struktur adalah fokus utama untuk kajian ini bagi menentukan kadar putaran berpusat di dalam aliran bagi bentuk struktur segiempat, segi tiga dan separuh bulatan. Applikasi Pengimejan Halaju Zarah (PIV) akan menjadi medium dalam menentukan analisis perubahan pengaliran terhadap ketiga-tiga struktur bentuk dan menentukan struktur bentuk yang mana lebih effektif dalam menghapuskan bahan tercemar di dalam sistem.

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CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

Engineering is being known as one of the important parameter towards the world's globalization as well. It's clearly being proved by its role in developing the world in term of science, technology, economic and more. There are lots of divisions under engineering term and one of that is being known as fluids engineering. It was one of the important terms in engineering field. Fluids engineering is relatively related to the motion of fluids, behavior of fluids and more. The most commonly application of this fluids engineering in industry is about the usage of piping system, ducting system and more. In industry, piping system plays a main role as the important of backbone towards human body where it's become the medium of transporting, transmitting, transferring of system from one point to the another point. Thus the critical perception towards this indicator is very important in order to develop a good engineering environment.

Flow past cavities have received great attention in the past decades in both experimental and numerical investigation due to its relevance to many practical engineering applications. High speed example of this flow type are flows over aircraft hulls, weapons bays, wheel wells and gas turbine channels while flow over surfaces with ribbing in heat exchangers and microelectronic chips, electronic devices on printed circuit boards are some low speed examples. The shape of cavities used in power

engineering equipment varies vastly. In industry nowadays, the applications of flow past cavities being relatively related to the usage of piping system being apply. Considering the term of loses and the other aspects, the application of piping system need to be maintenance efficiently in order to provide the good system. Commonly the most critical problems due to this piping system is the present of contaminants that clearly reduces the efficiency of the piping system. This happen because as the number of contaminants increase it will reduces the surface area of the piping system and will reduce the total power being transmitted along the piping system towards its destinations. This resulted the decreases of production and increases the cost of maintenance as well.

In real case of engineering world the term of removing the present of contaminants is being called as flushing. Flushing is the process was the piping system is being flush by greater water pressure by using water jet with the present of removal material such as sodium and more. By this process, the greater impact of pressure will slightly remove the present of contaminants in piping system. From the other term, in different usage of piping system such as piping system in cold area, the usage of cavities with thermal heater is very important in order to prevent the flow of fluids from stuck or freeze. Besides plays a main role in preventing flow from stuck, the present of cavities in piping system also can be used as the medium in process of contaminants removal as well.

In the term of fluids dynamic, flow past an open cavity is known to give rise to self-sustained oscillations in a wide variety of configurations and these cavity oscillations are the origin of coherent and broad band sources of noise and if the flow is sufficiently flexible, flow induced vibration as well. Due to this research the main indicator is to determine the rate of contaminants removal for different shapes of cavities. Three shapes of cavity were prepared, semi-circle, triangular and rectangle with respective dimension. The influence of cavity shape on the flow structure within

and immediate neighborhood of the cavity is the focal point of this paper as well. The behavior of fluid mechanism such as contour of stream wise, components of velocity, average vortices, Reynolds stress, streamline plots, intensity values are the important parameter for this research. The application of Particle Image Velocimetry (PIV) was used as the medium to analyze the behavior of flow measurement over different shape of cavities.

1.1 PROBLEM STATEMENT

Flow past cavities received great intention in the past decades in both experimental and numerical investigations due to its relevance to many practical engineering applications. The applications of low Reynolds number widely being used in engineering field such as aerodynamics flow, electronic industry, petroleum industry and more. The shape of cavities used in power engineering equipment varies vastly. Flow past an open cavity is known to give rise to self-sustained oscillations in wide variety if configuration and these cavity oscillations are the origin coherent and broadband source of noise and, if the structure is sufficiently flexible, flow induces vibrations as well{1)most of the studies in literature related to cavity are concerned with the square or rectangular cavity flow, although the cavities may non rectangular in applications. Thus, this research proposed the analysis on three different shapes of cavity to investigate the effect of irregular cavity shapes on flow structure past the cavities. The influence of cavity shape on the flow structure and immediate neighborhood of cavity is the focal point of this research. To obtain the imaging image of flow pattern, Particle Imaging methods with High Speed Camera has been used in this experiment. Particle Image Velocimetry (PIV) is non-intrusive measurement technique used to simultaneously determine the velocities at many point if fluid flow. To get the better documentation of result, we are comparing the result tabulated from PIV methods with results from Particle Imaging methods that being applied by usage of High Speed Camera.

1.2 OBJECTIVE

The objective for this research is:

1. To investigate the flow structure over different shapes of cavity of rectangular, triangular and semicircular with low Reynolds numbers flow.

2. To determine the effects of cavities shapes on rate of particle removal by using High Reynolds numbers flow.

1.3 SCOPE

The scopes of this research are:

1. To study the influence of cavity shape on the flow structure within and immediate neighborhood of the cavity in analysis.

2. To analyze the behavior of low Reynolds numbers flow in particle removal phenomenon using Particle Imaging instruments.

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

This literature review is a study based on existing information to be used as a reference and guide for an academic research. These studies include a review of previous studies concerned with research studies. The study information will be used to provide added value or a reference to the research to be undertaken. Information can be obtained for example from reference book, internet, journals, working paper, news and more. In addition, the originality of this research will be guaranteed attach evidence of existing or statements. In this chapter, all the attach evidence is regarding on review of flow measurement over different shapes of cavities. This will cover up all the aspects through this research.

2.1 EXPERIMENTAL PERSPECTIVE

There are lots of ways in order to discover a solution towards respective problems. One ways to determine the solution is by using experimental procedure. This is the most efficient ways through the world nowadays. An experiment is a methodical procedure carried out with the goal of verifying, falsifying, or establishing the validity of a hypothesis. Experiments provide insight into cause-and-effect by demonstrating what outcome occurs when a particular factor is manipulated. Generally experiment is the medium to arbitrate the hypothesis and competing models. In the other hands, experiment also becomes the medium to identify the validity of the theories or hypothesis towards relative scope of research. By this, the validity of the theories or hypothesis could be proving in scientific manner without argument. In analogy concept its usually tests a hypothesis, where it determine an expectation about how a particular process or phenomenon works. However, an experiment may also aim to answer a question, without a specific expectation about what the experiment will reveal, or test previous results to replicate results. There are three types of experiment being apply, which is controlled experiments, natural experiments and field experiments. In this research the experimental methods were applied to study the behavior of flow measurement over different shape of cavities from the experimental output. By having this types of analysis, all the collective theories about flow measurement will be discover. For an example the prediction of contaminants removal for each shape will de determine clearly during experimental periods. Thus, the most efficient types of cavity shapes will be discovered along this experiment by having an analysis on its respective behaviors. The respective behavior is such vortices, velocity contours, stream wise and more. The suitable experimental procedure need to be prepare before started this analysis in order to get the most precise and accurate data at the end of experiment as well.

2.2 FLOW MEASUREMENT

Flow measurement is become one of the main concern towards fluid dynamics analysis. There are lots of parameter could be discovered by flow measurement analysis. Flow measurement does not cover the flow analysis in term of fluids only but it's discover all the terms that moving into a medium such as gaseous and more. In fluids dynamics there are several classification in determine the flow measurement. For an example is about the flow rate measurement in term of volume flow, mass flow, fluid velocity and also flow visualization. Kuo and Jeng [17] discovered the effect of surface mounting upper plate towards oscillation flow within the structure. From the research, they determine that surface mounting on upper plates creates a stream wise elongated and transversely recirculating on the lower surface of the plate. This is one of the important being study in flow measurement analysis.

On another research, Kuo and Huang [18] study the effect of sloped bottom at the bottom of oscillation cavity by using numerically method. From the research they discovered that the present of sloped bottom will effects the oscillating characteristic of the flow measurement. This clearly determine that flow characteristic of the system could be alter with the present of flow path modifier. It will result to the changes of flow pattern from one to another as well. From the research by Grace [5] on flow characteristic within shallow wall cavity ,its discovered one of the main parameter in flow measurement which is the formation of vortex along the analysis. The result clearly discussed the formation of single vortex within the downstream of the cavity for both Reynolds numbers.

From experimental measurement of flow past cavities of different shapes by C.Ozalp [12], there are lots of important parameter of flow measurement being discovered. The variations of shapes clearly determine the respective flow characteristic through this experiment. Three types of cavity were used such as rectangular, triangular and semicircular along the experiment. The collective result shown the respective parameter such as contours of averaged stream wise and transverse components of velocity, contours of constant averaged vorticity, Reynolds stress and streamline plots of each cavity type by using three different Reynolds numbers. Other than that, there are comparison between each cavity shapes upon stream wise velocity, Reynolds stress and turbulence velocity.

Following to this experiment, the main objective is to discover the flow measurement over three types of cavity shapes for usage of low Reynolds numbers. The finding of this experiment is to study the behavior of flow characteristic along three types of cavity by comparing the rate of particle removal along the experiment. The comparisons between each cavity were compared by several parameters such as velocity profile, vortices generation, streamline plots and Reynolds stress.

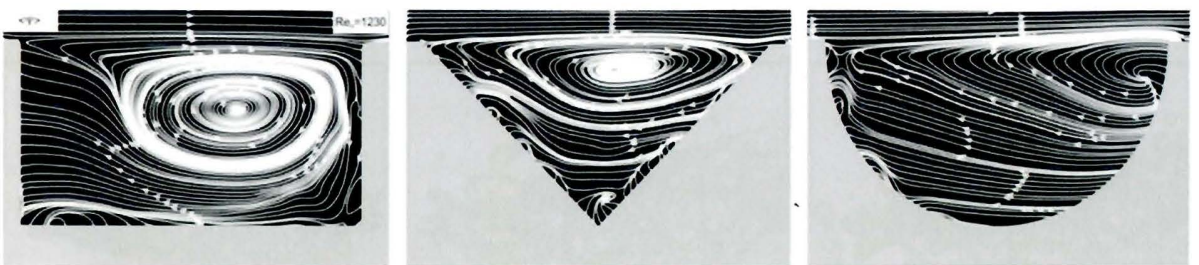

Figure 1: Time averaged streamline for each cavity [12]

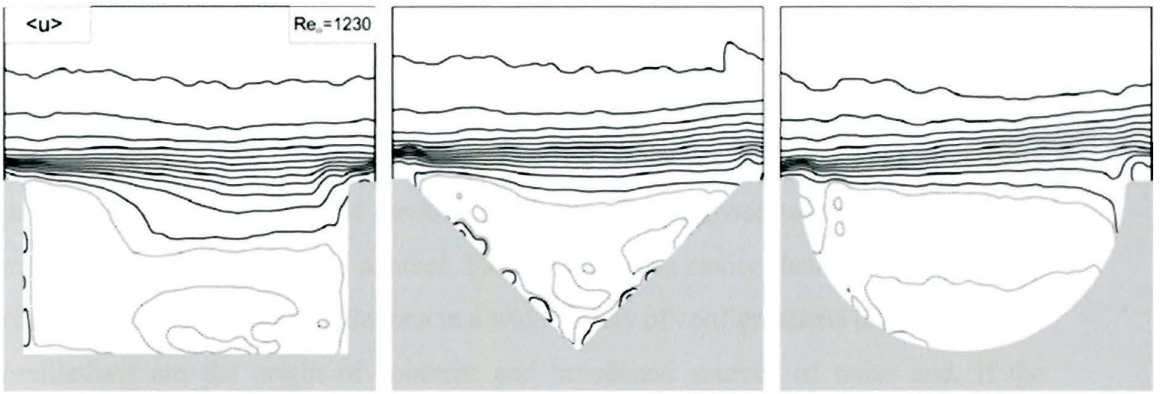

Figure 2 : Time averaged streamwise for each cavity [12]

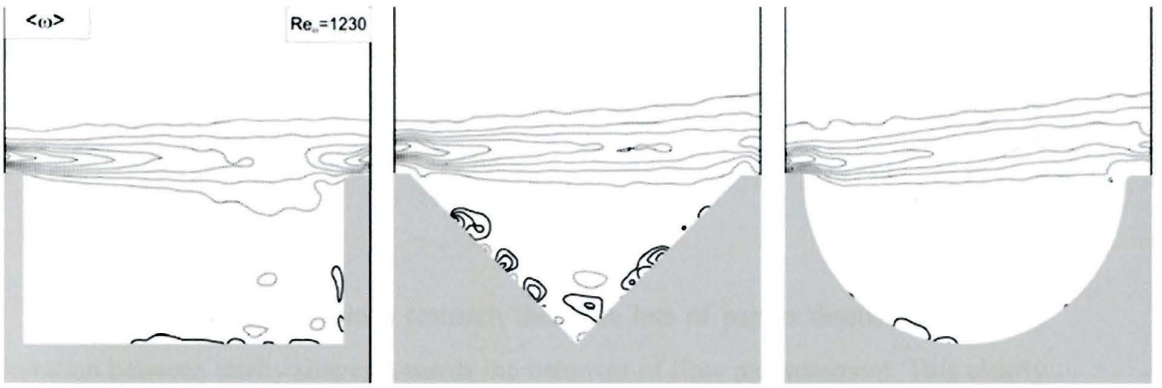

Figure 3: Time averaged streamwise velocity for each cavity [12]

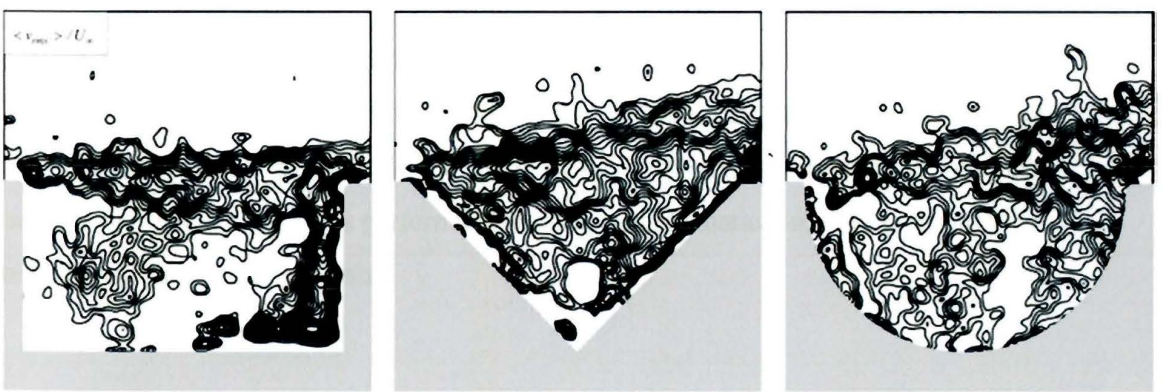

Figure 4: Time averaged Reynolds stress for each cavity [12]

2.3 SHAPE OF CAVITY

The focal point of this research is to determine the iteration between cavity shapes with the rate of contaminants removal from the system. Thus, the main parameter is the variation of cavities shape and its behavior towards contaminants removal by comparing one to another. Flow past as open cavity clearly described to the rise of the self-sustained oscillations in a wide variety of configurations and these cavity oscillations are the origin of coherent and broadband sources of noise and, if the structure is sufficiently flexible, flow induced vibration as well [1]. In the flow past a cavity there are lots of flow parameter could be determine by beginning of an analysis until the end of experiment. This is called as the flow measurement analysis where the behavior of flow movement either in gaseous of fluids could be determine along the analysis process. From the research performed by Rockwell and Naudasher [2] they discover the analysis in order to understand well the mechanism and problem resolve towards cavity investigations and analysis.

Lately from the previous research there are lots of papers discussed about the iteration between cavity shapes towards the behavior of flow measurement. This clearly being determined by the experiment and also simulations as well. The effect of horizontal top plate and its oscillating behavior towards rectangular cavity was investigated experimentally by Kuo and Chang [3]. From the research, the most valuable outcome is they discover the present of powerful external perturbation of oscillation aspects through the cavity. In the different research Kuo and Chang also discovered the behavior of fluid measurement by using a circular cylinder of a small diameter located near to the upstream edge of cavity by using variation of Reynolds number [4]. The analysis was performed by using a mathematical modeling through the technique of numerical analysis.

In the other hands, the study of flow characteristic through shallow wall cavity by using turbulent and low Reynolds number being discovered by Grace [5]. From the analysis, it determined that the present of vortex being generated within the downstream of the cavity for each types of flow either laminar or turbulent. This is one of most important key analysis to be compared through this research where we need to differentiate the behavior of flow in different types of Reynolds number aspects. Besides having an analysis in experimental manner, another option to investigate behavior of flow measurement is by using Computational Fluids Dynamic (CFD). Even though the technique is different but the outcome is still the same and become an effective medium in determining the realistic investigation outcome by comparing one to another. Ertuk and Gokcol [6] performed an analysis on fourth-order compact formulation to discover the flow within driven cavity with specific parameter such as steady and 2D incompressible flow of medium. Besides that in different research, Ertuk and Dursun [7] represent their analysis on 2D and driven skewed cavity flow by incompressible flow with variation of different angle of skewed angle.

Most of the previous studies determined the effect of cavity shape towards flow behavior by referring towards commonly classical shapes. For an example the most common shapes being used is classical rectangular and square. Ertuk and Gokcol, performed and analysis on rectangular cavity shapes with respective scope such as 2D, incompressible and steady flow by using high Reynolds numbers flow of water [8]. From the research they discovered the differences on vorticiy potential of triangular shapes and the other respective parameters. Besides that, the variation of aspect ratio of driven cavity being discovered by D'yanchenko [9]. Through this research the focal point is to study the effect of changes of cavity aspect ratio towards the flow behavior along the system as well. The research on semicircular cavity shape being discovered numerically along incompressible viscous flow by Glowinski [10]. By this paper, the outcome result becomes a significant parameter that being compared by other researcher to analyze the differences between cavity shapes towards flow measurement aspect.