ASSESMENT OF VORTEX DYNAMIC OF BLOOD FLOW IN MECHANICAL HEART VALVE

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This report is submitted
in fulfillment of the requirement for the degree of
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DECLARATION

I declare that this project "Assessment of Vortex Dynamics of Blood Flow in Mechanical Heart Valve" is the result of my own work except as cited in the references

Signature	:..................................
Name	: Siti Saiyidah Binti Syed Zainuddin
Date	:..................................

SUPERVISOR DECLARATION

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature	:..................................
Supervisor’s Name	: Dr. Mohamad Shukri Bin Zakaria
Date	:..................................

ABSTRACT

These paper represent a computational fluid model. The flow of velocity when blood passes the leaflet in the aortic valve is analysed using computational fluid dynamics. The results show the cause of blood clots. The blood clots happen because of the high velocity occurs. Besides that, wall shear stress with high value also contribute to the blood clotting. Finally, the way to suggest to improve blood clots or reduce the result of velocity and wall shear stress by add the vortex generator on leaflet in MHV. In order to reduce a blood clots, the design of vortex generator also have to be suitable with the leaftlet. There are two method applied to find the result. First step using solid work to design the MHV and software Ansys to find the result.

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LIST OF ABBEREVATIONS

MHV	Mechanical Heart Valve
BMHV	Bileaflet mechanical heart valves
CFD	Computational Fluid Dynamic
AHV	Artificial Heart Valve
VG	Vortex Generator

LIST OF SYMBOLS

ρ = $fluid\ density$

μ = $velocity$

k = $turbulent\ kinetic\ energy$

ε = $turbulent\ kinetic\ dissipation$

Eij = $rate\ of\ deformation$

μt = $eddy\ viscosity$

CHAPTER 1

INTRODUCTION

1.1 Background

The heart is a muscle organ that pumps blood to all the organs and cells for them to function. In a healthy heart, the blood flows always in the same direction through the heart. Heart valves keep unidirectional blood flow by the opening and closing of their leaves, which depend on the pressure difference on both sides of the valve leaflets. Artificial Heart Valves (AHV) can be a mechanical or biological substitute to restore the biological function of blood flow transport when anything occurs with natural heart valves such as severe defect or disease (Zhou et al., 2016).

Bileaflet mechanical heart valves (BMHVs) are usually used for valve replacement because their design reduces flow disturbances (Khalili, Ppt, & Ha, 2017). Mechanical valves consist of mechanical components with good mechanical behavior and biocompatibility. BMHV is the most widely used clinical among the various types of mechanical valve (Zhou et al., 2016). This project to study the hemodynamic blood flow in mechanical heart valve for example separation and recirculation.

The present study investigates the blood clotting in mechanical heart valve using ANSYS software. The blood clotting system is the first line of protection of the human body against vascular injuries. When blood vessels are violated, various complex molecular and cellular reactions lead to the formation of spatial-spherical structures comprising mainly small blood cells are platelets and fibrin fibrils, which include the site of injury and stop bleeding (Govindarajan, Rakesh, Reifman, & Mitrophanov, 2016). In ANSYS software can get the result of flow velocity and pressure.

Feng et al in the experiment result found that lower average pressure difference will lead to lower shear pressure in the bloodstream, and thus useful for reducing the damage to the blood component (Khalili et al., 2017). These projects also to study about vortex generator applies to the mechanical heart valve. Vortex generators to gain passive flow control which hypothesis to minimize the shear stress experienced by the blood elements flowing across the BMHV. In this present study also to find the suitable design of vortex generator to apply on the leaflet in MHV. In order to find the right design of vortex generator have to obtain result of lower velocity compare with the design of without vortex generator. If the result is still in high velocity, this present study have to try new design that can reduces the velocity.

1.2 Problem Statement

Mechanical heart valve is prone to blood clotting. Blood clot occurs due to abnormal flow. When blood vessels are violated, various complex molecular and cellular reactions lead to the formation of spatial-spherical structures comprising mainly small blood cells are platelets and fibrin fibrils, which include the site of injury and stop bleeding. The blood clotting system is important because of the first line of protection of the human body against vascular injuries (Govindarajan et al., 2016). The previous study also states that the blood element has been damaged when platelet aggregates are activated because of blood clots (Zakaria et al., 2017). It also shows that another cause of blood clotting occurs because the MHV design is a sharp edge that can contribute to a recirculation area as it is in the increase of the sinus area.

Besides that, the performance of variation of flow velocity and pressure when blood passes the leaflets in the aortic valve. Fluid structure interaction problems due to the opening angles and the internal orifice diameter are not maximized.

In addition, the problem about adds vortex generator on leaflet because to reduce the turbulent flow and pressure differently. In the research of (Dasi, Murphy, Glezer, & Yoganathan, 2008) states that the design of MHV without vortex generator can contribute to thrombosis. From this study also states that in order to avoid the large leaks destroying the structures by adding the rectangular vortex generator. It is just not destroying the large leakage structures but also can decrease local shear of the structure.

1.3 Objective

The objectives of this project are as follows:

a) To study the hemodynamics blood flow in mechanical heart valve for example separation, recirculation

b) To analyze the blood clotting in mechanical heart valve using ANSYS software

c) To study function of flow control vortex generators on leaflets.

1.4 Scope of Project

The scope of present study are:

a) Vortex generator applies to heart valve

b) The flow use in this project is turbulent.

c) The flow field conditions for this study valve are fully opened.

d) The type of heart valve used in this project is the Mechanical Heart Valve.

e) Use of numerical simulation

CHAPTER 2

LITERATURE REVIEW

2.1 Mechanical Heart Valve

Mechanical heart valve (MHV) is a concern for the formation of thrombus because it is necessary to take anticoagulant therapy for the rest of their lives but for the bioprosthetic heart valve (BHV) does not require anticoagulant therapy but the performance decreases after 10 to 15 years (Hedayat, Asgharzadeh, & Borazjani, 2017). In the research (Qiao et al., 2018) found that the formation of thrombus because the shear stress of the pathologist is not normal and changes of blood flows such as blood flow inside arteries were stuck. However, in the studies (Hedayat et al., 2017) found that the formation of the thrombus is started because of the MHV flow through the hinges and leakage in diastole. The condition when the ventricular diastole is completely closed is to ensure the flow is one direction for a healthy aortic valve (Qiao et al., 2018). Based on that statement, the performance MHV and BHV in terms of platelet activation caused by shear stress is in the same state. In this statement it is also possible to see MHV is a better performance than BHV because MHV is required to take therapy for a long time but for BHV performance will decrease after 10 to 15 years.

Another study from (Zakerzadeh, Hsu, & Sacks, 2017) states that important consideration in the choice of MHV or BHV because reintervention due to worsening BHV and it is related to MHV that a long period of anticoagulation. The factor of patient age is having to take seriously because the bad structure of BHV is larger in younger patients but in older patients the risk of bleeding from higher anticoagulation. As can be seen in Figure 2.1, The BMHV is made of round housing and two semi-circular discs, which are installed in housing through a hinged mechanism. Both of these leaflet rotate passively in response to fluid dynamics due to periodic contraction and left ventricular expansion (Spühler, Jansson, Jansson, & Hoffman, 2018).

Figure 2.1: Mechanical Heart Valve, (Spühler et al., 2018)

2.2 Hemodynamic Blood Clot

The leakage blood circulates high velocity values due to the small gap between the two leaflets and the valve housing and the flow circulation significantly located on the head of the valve. Figure 2.2 shows that jet flows occur regularly at first open, close, and completely closed corners. Previous research has found that the occurrence of jet flows is the most harmful flow to the blood cells, which causes blood clots and hemolysis. (Kadhim, Nasif, Al-Kayiem, & Al-Waked, 2017). From this research, fully closed situations are through high velocity values jet flows.

Based on the above statement, we know that high velocity will occur from circulating blood leaks due to small gaps. The higher the velocity value causes blood clotting. In this research that must find a solution to reduce the high velocity.

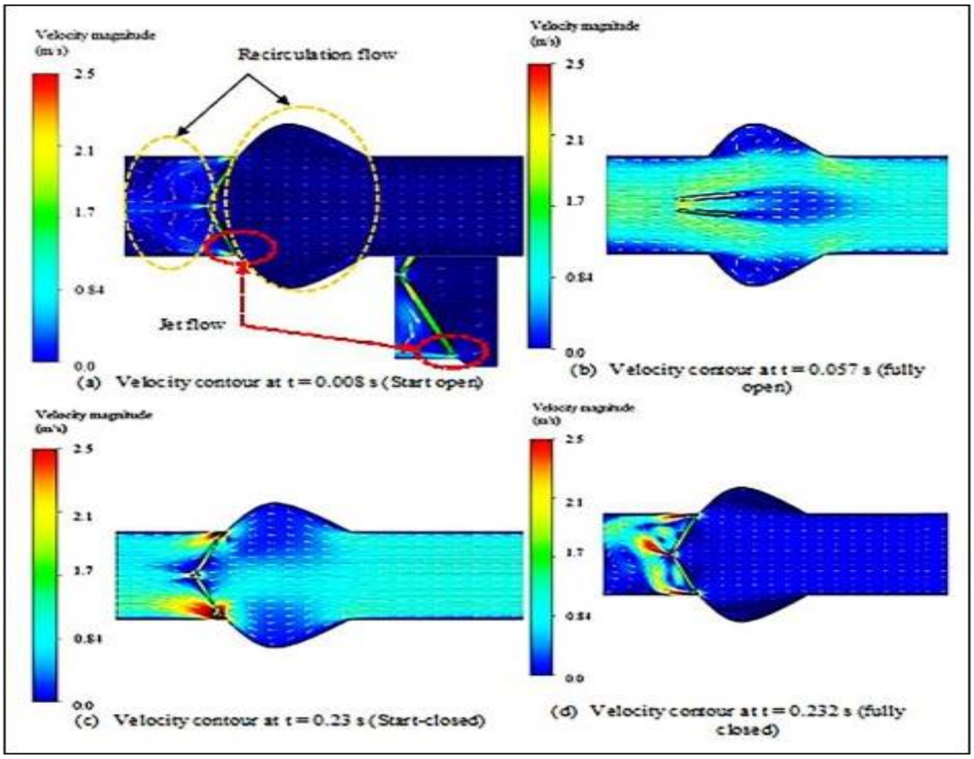


Figure 2.2: Velocity contour during phases of BMHV, (Kadhim et al., 2017)

According to Kadhim et al (2017), "the time value of 0.008 s leaflet valve at the initial open corner, the leakage zone among the leaflet tip and valve housing is at high shear stress value. The shear pressure on the surface of the leaflet is 104.58 Pa. However, the magnitude of the shear stress magnitude between the valve pivot and the housing is 52.3 Pa". In this research it is found that when taking a long time there will be a high shear pressure. The front of the valve of the mechanical valve has a high shear stress due to the back-blood flow.

This study also shows that the shear stress near the surface of the mechanical valve leaflet continues to increase and reaches 209.13 Pa (Kadhim et al., 2017). Based on Figure 2.3 (b), when the bileaflet is in a fully opened angle, the result of the blood velocity exits at 2.3m / s with 0.057s. It is show that this part has a higher shear stress value. The factors that prove has higher shear stress around the mechanical heart valve are due to the blood flow over the full leaflet strength. Based on the above statements, blood platelet damage will occur as the shear stress values on the valves and pivots are continuously higher than threshold friction pressure.

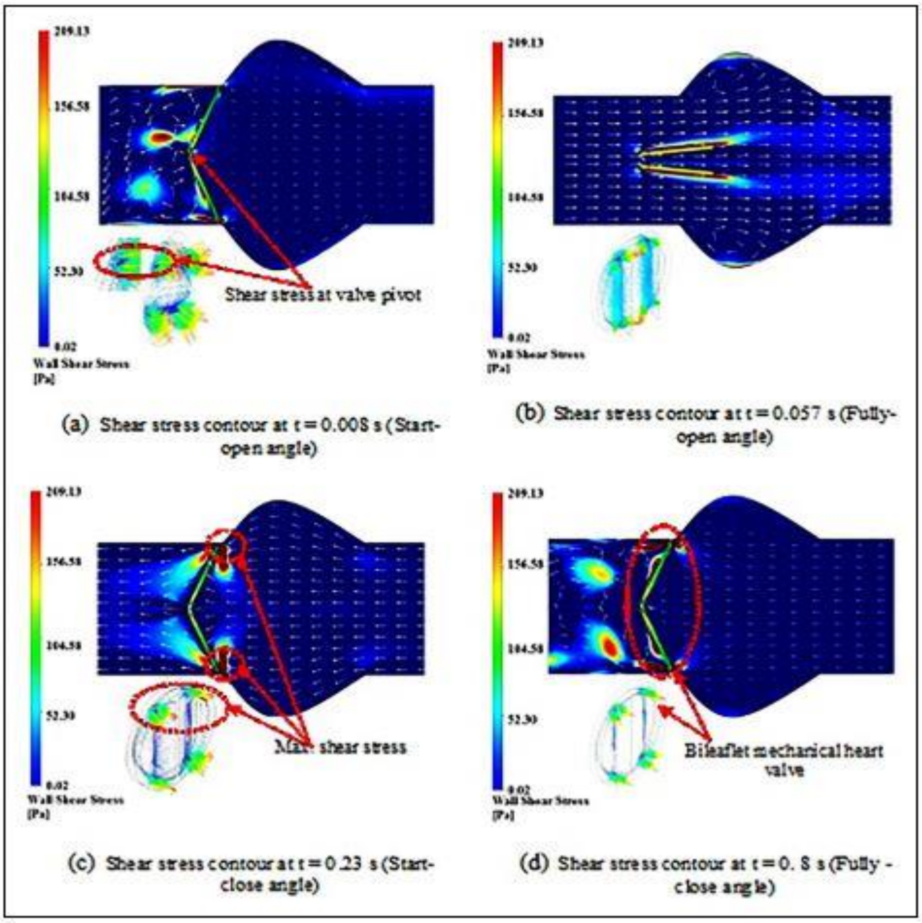


Figure 2.3: Shear stress contour during cardiac cycle for BMHV, (Kadhim et al., 2017)

In the Zhou (2016) study finds that the results for transvalvular pressure difference at various maximum opening angles are shown in Figure 2.4. Based on this result, it shows that the average pressure across the valve decreases significantly when the maximum opening angle increases from 80 to 90. These results show that a greater maximum opening better for lower average pressure difference. (Zhou et al., 2016)

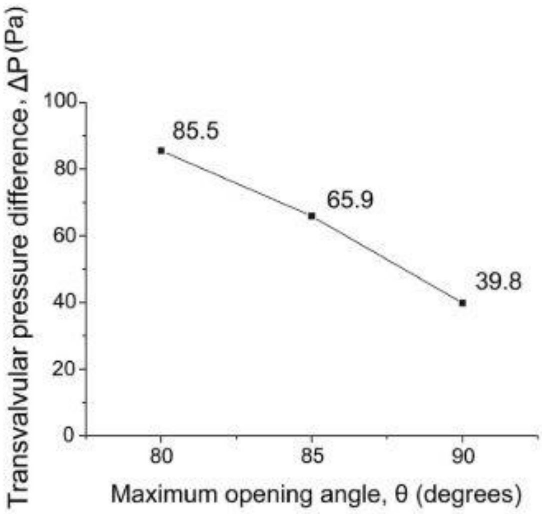


Figure 2.4: Average pressure difference, (Zhou et al., 2016)

2.3 Vortex Generator Application

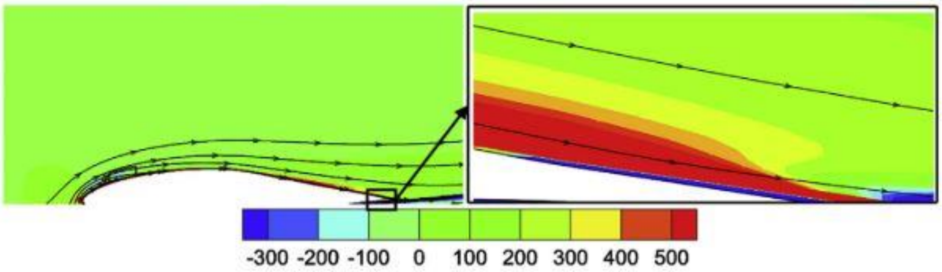
There are three application of vortex generator which is vortex generator effect on aerofoil, vortex generator effects on ship stern flow and vortex generator effects on Mechanical Heart Valve

2.3.1 Vortex generator effect on aerofoil

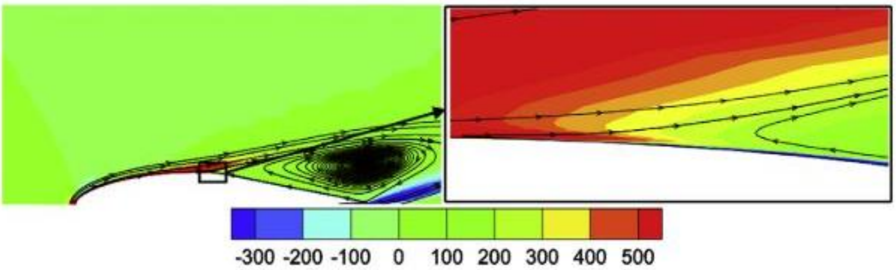
It can effectively improve the aerofoil lift coefficient due to the vortex generator and delay the emergence of the phenomenon. The vortex generator effects in the velocity of inlet and wind turbine rotation speed under uncertain conditions and other effects increase the power of the wind turbine significantly. Torque and thrust are calculated by the momentum theory of blade elements with and without vortex generators and increased by vortex generators. The vortex generator produces a separate vortex. The main region has high momentum fluid that is involved in the boundary layer but for the main region by a separate vortex has low momentum fluid of the boundary layer. This result shows that the vortex generator is efficiently controlled the separation of the flow.

The effect of the vortex generator can decrease the thickness of the boundary layer and drag coefficient also can reduce at a certain angle. If the angle of attack is high, it can improve the coefficient of lift and double vortex generator can reduce the thickness of the boundary layer. This result shows good control separation of the flow when has double vortex generators.

Figure 2.5 shows the angle of attack is equal to 14° and streamline near the aerofoil with the vortex generator. There is no reverse flow phenomenon because of the vortex generators in the boundary layer of the suction surface. The x velocity gradient is greater than zero when the vortex generator is mounted on the edge of the aerofoil suction surface. The condition of the clean aerofoil when x velocity gradient is less than zero and separation of the flow occurs. In the same position, the fluid keeps the flow direction and the x-velocity gradient of the fluid is greater than zero. Based on this result, the effect of adding a vortex generator can alter the boundary layer flow. Besides that, in order to maintain the flow direction and stagnation fluid particles not occurs in the boundary layer must ensure that liquid momentum is sufficient for the boundary layer.. Then, it controls the flow separation and transforms the fluid flow properties around the aerofoil by adding a vortex generator (Wang, Zhang, Qiu, & Xu, 2016).



(a)



(b)

Figure 2.5: Aerodynamics flow characteristic at aerofoil for (a) with vortex generator (b) without generator, (Wang et al., 2016)

2.3.2 Vortex generator effects on ship stern flow

A utilize of vortex generators as a stream control gadget is broadly utilized to decrease division in different streams such as aircraft wing, car, truck, train and airplane. The small wings with different plan geometry are called vortex generators. The separation of the stream can be delay in a thick boundary layer with a vortex generator in the full shape hull flow. Based on this study, the transfer of high energy liquids to the surface of the hull is due to the value of the vortex generator that expands the vortex at the top of the boundary layer. This result shows the smooth surface is improved as the kinetic energy on the surface, the flow can endure greater different pressure gradient before separation occurs (Falchi et al., 2014).

2.3.3 Vortex generator effects on Mechanical Heart Valve

According to the (Dasi, Murphy, Glezer, & Yoganathan, 2008), the factor occurred of coagulation is because of high shear stress. It will affect red blood cells or platelets will become active. If active platelets occur, they can cause coagulation as well. In this study also states that red blood cells are exposed to damage at shear stresses of 10-100 dyn/cm2 to 500 dyn/cm2 ability of platelets to combine several elements can cause thrombosis. Besides that, this research found that the effect of a rectangular VG case not only scatter and destroys the structure of a large leakage flow structure but also reduce the local shear. Based on the figure 2.6 d-f, it indicates that the amount of vortex attention is obviously the lowest for a rectangular VG case while in based on figure a-c is a case of without VGs indicates of a coherent vortices structure which is strong transient jet emanating. This vertical distribution shows high shear and high rotating shear flow that forms the flow of