IMPROVEMENT ON PRESSURE DISTRIBUTION FOR VENTURI TUBE FLOW

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ABSTRACT

A goal driven optimization process has been undertaken for a venturi tube. Venturi tube create a constriction within a pipe that builds backpressure upstream and effects a negative pressure downstream of the constriction. The passage of a fluid through a constriction, causing a pressure drop and increase in velocity is termed the venturi effect. During operation as the fluid continuing flow in at certain pressure, the flow inside the venturi changes thus give the impact on the venturi wall. The pressure on the wall are then was studied and the geometry are improved. In this paper, Computational Fluid Dynamics (CFD) method was used to simulate the pressure distribution along the venturi wall and the relationship among the structure parameters (venturi inlet, venturi outlet and venturi throat) using different pressure inlet of 0.21MPa, 0.41MPa, 0.61MPa, 0.81MPa and 1.01MPa. This CFD model also has been used in ANSYS Workbench 'Design Exploration' software to establish an optimised design using Box-Behnken Design (BBD) for Design of Experiment (DoE), 2nd Order Standard Response for Response Surface and Screening for Optimization considering 3 geometrical parameters and their effect on two Objective Function, to reduce the pressure and velocity in the venturi. The results show that the pressure distribution curve along the wall for the improved geometry of venturi tube is better than current geometry and the tendency to vibrate cause of pressure is minimise. The optimization process using Screening shown that the suggested candidate point based on the design point to determine the design optimization can be used to develop a new geometry of venturi tube.

ABSTRAK

Proses pengoptimuman telah dijalankan kepada tiub venturi. Tiub venturi mempunyai penyempitan di dalam paip yang mewujudkan aliran tekanan kebelakang di hulu dan memberi kesan negatif pada hilir ruang penyempitan tersebut. Aliran bendalir yang melalui ruang penyempitan menyebabkan penurunan dalam tekanan dan peningkatan dalam halaju yang dipanggil kesan venturi. Semasa sistem beroperasi, aliran bendalir yang berterusan dan tekanan yang berubah menyebabkan aliran berubah dan memberi kesan ke atas dinding venturi. Tekanan disepanjang dinding venturi kemudiannya dikaji dan geometri venturi juga dioptimumkan. Di dalam kajian ini, Dinamik Bendalir Komputeran (DBK) telah digunakan untuk mensimulasikan taburan tekanan di sepanjang dinding venturi dan hubungan diantara parameter struktur (venturi masukan, venturi keluar dan tekak venturi) menggunakan tekanan yang berbeza iaitu 0.21MPa, 0.41MPa, 0.61MPa, 0.81MPa dan 1.01Mpa. Model ini juga telah digunakan dalam perisian ANSYS Workbench 'Eksplorasi Rekabentuk' untuk mewujudkan reka bentuk yang dioptimumkan dengan menggunakan Rekabentuk Kotak Behnken (RKB) untuk Rekabentuk Eksperimen (RE), Perintah Kedua Darjah Gerak Balas Permukaan untuk Permukaan Sambutan dan Saringan untuk Pengoptimuman dengan mengambil kira 3 parameter geometri dan kesannya pada dua fungsi objektif iaitu untuk mengurangkan tekanan dan halaju di dalam venturi. Hasil kajian menunjukkan bahawa taburan tekanan di sepanjang dinding geometri venturi yang telah dioptimumkan adalah lebih baik daripada geometri venturi sedia ada dan kecenderungan untuk bergetar disebabkan oleh tekanan dapat dikurangkan. Kaedah pengoptimuman menggunakan teknik saringan menunjukkan titik pencalonan berdasarkan titik rekabentuk yang dikaji untuk menentukan geometri optimum boleh digunakan untuk membangunkan geometri baru tiub venturi.

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ρ	-	Density
t	-	Time
$\vec{v}$	-	Velocity Vector
p	-	Pressure
$\bar{\bar{\tau}}$	-	Viscous Stress Tensor
$\vec{g}$	-	Gravitational Acceleration
$\rho\vec{g}$	-	Buoyancy Force
E	-	Total Energy
k	-	Fluid Thermal Conductivity
S_h	-	Source Term
Φ	-	Dissipation Function

CHAPTER 1

INTRODUCTION

1.1 Research Background

People in the fertigation industri often exposed to poor venturi tube operation for aquatics systems. The constriction and its resulting backpressure can substantly reduce flow and burden the pump with unnecessary load increasing energy costs and shortening its serviceable life. Thus, the pressure drop through a venturi must be sufficient to create a negative pressure (vacuum) as measured relative to atmospheric pressure.

Venturi injector is widely used in fertigation system due to its obvious advantages such as cheap system, simple structure, and robust system without mobile pieces, convenient to operation, labor saving, stable performance and needless of external energy for operation. Venturi injector is one of the basic types of injector in subsurface drip irrigation system.

For better understanding, the venturi tube principal are presented as in Figure 1.1. A venturi tube create a constriction within a pipe that builds backpressure upstream and effects a negative pressure downstream of the constriction. The passage of a fluid through a constriction, causing a pressure drop and increase in velocity is termed the venturi effect. During operation as the fluid continuing flow in at certain pressure, the flow inside the venturi changes thus give the impact on the venturi wall. The pressure on the wall are then was studied and the geometry are improved.

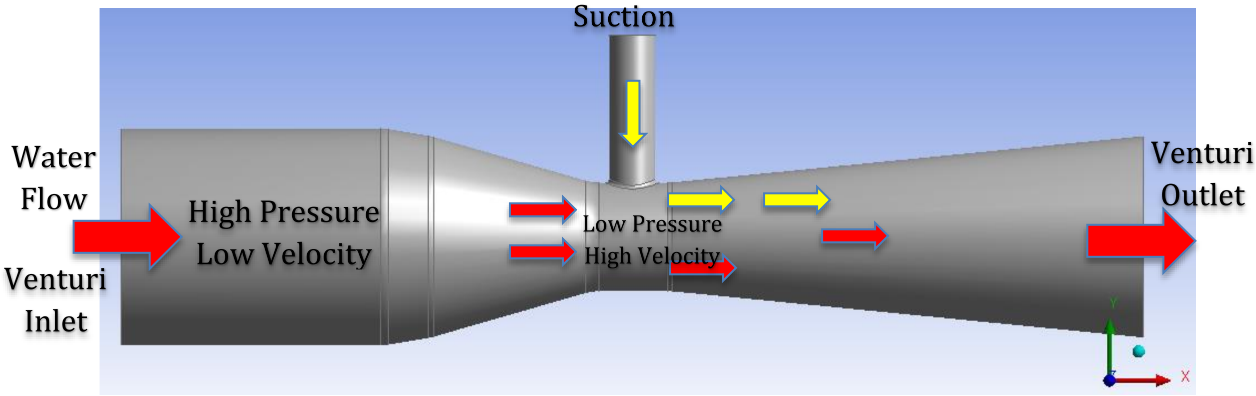

Figure 1.1: Venturi Tube Principal

The venturi tube geometry and parameter is shown in Figure 1.2. The highlighted red arrow along the venturi shows the pressure impact along the venturi wall.

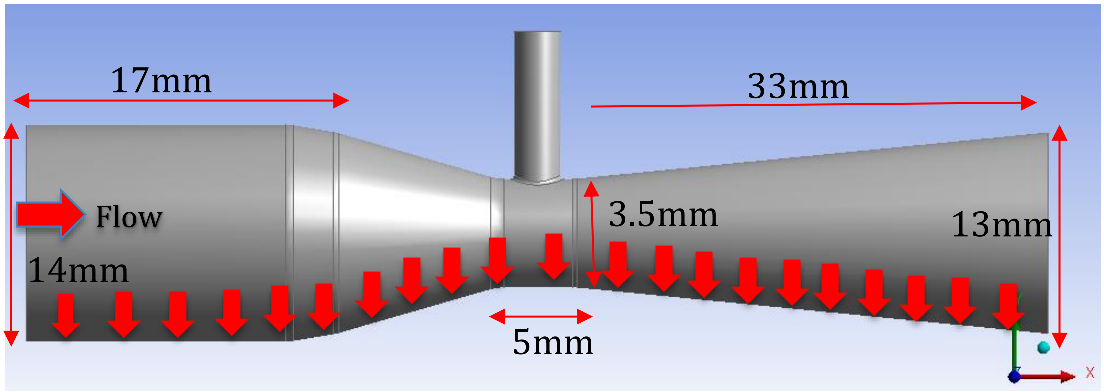

Figure 1.2: Geometric Profile of Venturi Tube

A conventional venturi carries with it penalties for aquatics systems. The constriction and its resulting backpressure can substantly reduce flow and burden the pump with unnecessary load increasing energy costs and shortening its serviceable life. Another common problem occurs when the incoming water is too warm and less effective at condensing the steam in the combining cone. This can also occur if the metal body of the injector is too hot from prolonged use.

In this research, the area of concern is on the wall surfaces along the venturi. As mentioned earlier, upon operation as the fluid continuing pump in at certain pressure, the flow inside the venturi changes thus the impact on the venturi wall changes. Therefore, in order to ensure the venturi tube is operating within the required condition, the boundary condition of the pressurized fluid must be maintain by controlling certain parameters.

However these parameters are subject to change if the initial condition changes. Being stated so, optimum geometry of the venturi is required to avoid vibration occurs on the surface which may contributes to failure. In order to identify pressure distribution along the venturi wall, five different velocity and pressure inlet are observed and the geometry of the venturi was optimize using Box-Behnken Design (BBD) for Design of Operation (DoE), Standard Second Order for Response Surface and Screening for Optimization. Our goal is then is to study the pressure distribution as it is affected by flow velocity and to demonstrate the influence of venturi size before and after optimization process.

1.2 Research Objectives

Research objectives are as follows:

1. To determine the optimize geometry for improved venturi
2. To verify the pressure distribution affected on the wall of venturi before and after optimization

1.3 Problem Statement

Venturi tube usage often experience problems such as head losses, cavitation phenomena and sometimes cannot inject fertilizer solution. Therefore replacing the venturi involved a high cost and not a suitable method. These issues could be solved by using the right choice and the accurate design favor in order to ensure the good performance of the system.

Providing a consistent speed increase causes a pressure decreases which allows the intake of other liquid through a hole/suction and mixture with the motive current is a fundamental criterion in designing a reliable venturi injector. Not well designed of venturi might lead to increasing of more labor usage and energy. Therefore, the geometry of the current geometry was optimize and the flow and pressure distribution along the wall before and after optimization was investigated.

1.4 Scope of research

Scopes of research are as follows:

1. To model the venturi flow using Computational Fluid Dynamics (CFD)

2. To optimize the geometry of venturi using:

   a. Design of Experimental – Box-Behnken Design (BBD)
   b. Response Surface – 2^{nd} Order Standard Response (RSM)
   c. Optimization – Screening Method

3. To compare the pressure distribution on the wall of venturi before and after optimization

4. Limitation and consideration:

a. The research will be carried out on steady flow models (Steady RANS) due to the lower computation time.

b. The research will be conducted on computational approaches and it will validate with the establish literature experiments (He 2012).

c. Optimization of venturi geometry is restricted to specified analysis using BBD for DoE, 2nd Order Standard Response for RSM and Screening for Optimization. Others method will not be considered.

1.5 Theoretical Framework

The theoretical framework of this research is presented in Figure 1.3.

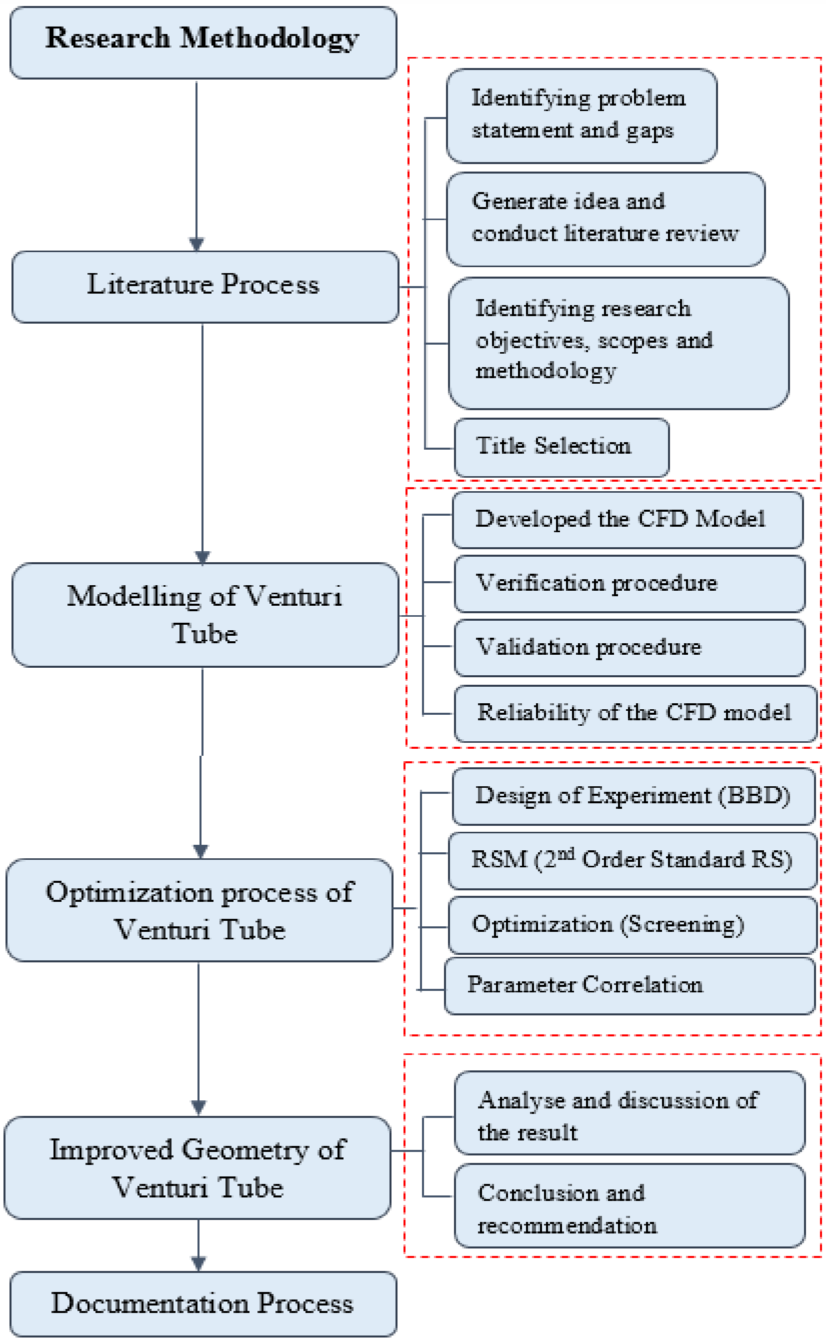

Figure 1.3: Theoretical Framework

1.6 Organization of Thesis

Chapter 1: Introduction

This chapter describes the research background of this. The objective of this project also been started in this chapter.

Chapter 2: Literature Review

In this chapter, the item that will be discussed is the related works and literature review that will supported this study.

Chapter 3: Methodology

The most significant chapter that is chapter 3 detailing on the research methodology variables and equations involved in the modelling and simulation part. Data collection method and the accuracy of the result are been listed in this chapter.

Chapter 4: Result and Discussion

For this chapter, results and findings obtained from the CFD modelling are listed out and discussion is carried out for the result obtained. Verification process, validation process, turbulence model and optimization result will also be discussed.

Chapter 5: Conclusion and Recommendation

In this last chapter it is dedicated for conclusion of the study and recommendations on future improvements for venturi research, design and manufacturing.

This paper will have the reference list post and also the appendices.

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