FORCE CONVECTION FLOW AND THERMAL ANALYSIS IN COMPOSITE CURING AUTOCLAVE

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DECLARATION

I declare that this project report entitled "Force Convection Flow and Thermal Analysis in Composite Curing Autoclave" is the result of my own work except as cited in the references.

Signature : ....

Name : WONG YONG HAN

Date : 25/6/19

APPROVAL

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 with Honours.

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SUPERVISOR'S DECLARATION

I have checked this report and the report can now be submitted to JK-PSM to be delivered back to supervisor and to the second examiner.

Signature :……………………….

Name of Supervisor :……………………….

Date :……………………….

ABSTRACT

An autoclave was a sealed welly container which used for the process involved high temperature and pressure. Past researches focused on the efficiency of autoclave by reduction of cycle time and other properties. This project aimed to investigate the velocity and temperature distribution inside the autoclave, determined the suitable fan and heater position for uniform velocity and temperature distribution inside the autoclave. To illustrate the velocity and temperature distribution inside the autoclave, CFD simulation apps such as Computational Fluid Dynamic, FLUENT ANSYS was used. From the result gained from simulations, the required parameter that velocity distribution for achieving the uniform flow was 1m/s. While the temperature distribution was in stable that surrounded the mold with the required velocity of air flow above 1m/s. From the comparison of different velocities towards each temperature distribution, the recommended was air with 1m/s velocity.

ABSTRAK

Autoklaf adalah wadah penyerlah yang digunakan untuk proses yang melibatkan suhu dan tekanan tinggi. Penyelidikan yang lalu memberi tumpuan kepada kecekapan autoklaf oleh pengurangan masa kitaran dan sifat-sifat lain. Projek ini bertujuan untuk menyiasat pengedaran halaju dan suhu di dalam autoklaf, menentukan kedudukan kipas dan pemanas yang sesuai untuk halaju seragam dan pengedaran suhu di dalam autoklaf. Untuk menggambarkan halaju dan pengedaran suhu di dalam autoklaf, aplikasi simulasi CFD seperti Computational Fluid Dynamic, FLUENT ANSYS telah digunakan. Daripada hasil yang diperolehi dari simulasi, parameter yang diperlukan bahawa pengagihan halaju untuk mencapai aliran seragam adalah 1m/s. Walaupun pengedaran suhu berada dalam keadaan stabil yang mengelilingi acuan dengan halaju yang diperlukan aliran udara di atas 1m/s. Daripada perbandingan halaju yang berbeza ke arah setiap pengagihan suhu, yang dicadangkan adalah udara dengan halaju 1m/s.

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LIST OF ABBREVIATIONS

FLUENT	Fluent-Ansys apps
CFD	Computational Fluid Dynamics
2D	Two Dimensional
3D	Three Dimensional
LDPE	Low-Density Polyethylene

LIST OF SYMBOLS

A	=	related area
ρ	=	density of fluid
u	=	velocity of fluid
L	=	characteristic linear dimension
μ	=	dynamic viscosity of fluid
v	=	kinematic viscosity of fluid
t	=	time taken
$\emptyset$	=	diameter of circle
ω	=	vorticity

CHAPTER 1

INTRODUCTION

1.0 BACKGROUND

An autoclave is a pressurized chamber which used to carry out industrial processes such as curing, body piercing and other processes that required elevated temperature with different pressures. While the heat flow is the pattern of the temperature of the air that flows through the whole chamber with different temperature and velocity.

The normal dimensions of the autoclave chamber for common usage such as the cooling process for small scale, medium scale, and large-scale productions respectively. With the aids of Computational fluid dynamics (CFD) simulations, the purposes for improvement of the curing process in the autoclave chamber are being done. CFD simulations are able to analysis the fluid flow in a certain space with several parameters like velocity, density, pressure, temperature, and viscosity. To analysis the aeroplane wing in the autoclave curing chamber, the represented model is put inside the chamber and analysis through CFD.

In this research, the objectives of the autoclave have to fulfill a requirement of the model of an aeroplane wing size about 2m weight,1m height, and 5mm thickness. Therefore, the design of the autoclave chamber dimensions must be wider than the aeroplane wing's dimensions with 13m length and 3m of radius cylindrical shape chamber.

Nowadays simulation has used as a prediction for most of the specialized categories not only included for the industry. Simulation acts as a second chance to avoid any mistakes that happened before the actual test-drive experiment that cost expensively. The problems of the curing process for aeroplane wings need a huge concrete chamber that cost significantly. Thus, the simulation is the best choice to estimate the dimensions and other related properties of the chamber before the real construction of it.

The autoclave chamber has several scales for different type production purpose such as range of 12 inches diameter X 24 inches length for small scale production, 60 inches diameter X 240 inches length for medium scale production inches and 120 inches diameter X 240 inches length for large scale production. These standard models type autoclaves are normally used for composite curing autoclave technology. There is custom-made autoclave with for another process that includes wood, glass, dewaxing, and AAC concrete. Normally, the chamber is made up of stainless steel with the cylindrical shape-like tube.

1.1 PROBLEM STATEMENT

Nowadays, air transportation used for crossing from one country to another. The process of improvement and sub-parts of airplane has to be fast produced and easy to change for commercialized purposed. Therefore, the new autoclave chamber has to be designated for the curing process of the composite parts. To achieve fast curing process for an aeroplane wing, the inlet air flow velocity and temperature distribution in the chamber should be controlled to cure the composite at the specified condition. When the heat distribution in the chamber is not uniform, the flow of fluid inside the chamber will not flow smoothly throughout the whole chamber but will form vortexes along the path of flow. At the center of circulate flow, the stagnation area appeared and it caused the velocity approximate to zero. Therefore, the elimination of the stagnation area should able to improve the curing efficiency inside the chamber. The efficiency of the autoclave is based on reduction of cycle time. Reduction of cycle time basically based on both the temperature uniformity of airflow and achieving uniformity in the velocity of the airflow inside the chamber in this project.

1.2 OBJECTIVES

- To investigate the velocity and temperature distribution inside an autoclave
- To determine the suitability of exhaust fan or pressure outlet at outlet boundary condition for uniform temperature distribution
- To determine the stagnation area inside the autoclave

1.3 SCOPE

The research project will be priority focus on the controllable variables that not customized such as the fan size with radius of 1m, inlet size dimension of air flow (nozzle), model size dimension of 2m X 1.6m X 5mm, inlet air velocity in range of 1 to 5 m/s and the chamber dimension about 4.5m X 4.5m X 4.0m. Moreover, the temperature inside the chamber has to be fixed accordingly due to the material of the chamber to avoid any additional heat lost to the surrounding. Other aspects such as detailed pressure distribution, the detail function of autoclave and improvements on design are not covered in this project.

CHAPTER 2

LITERATURE REVIEW

2.1 THE CONCEPT OF OVENS AND AUTOCLAVES

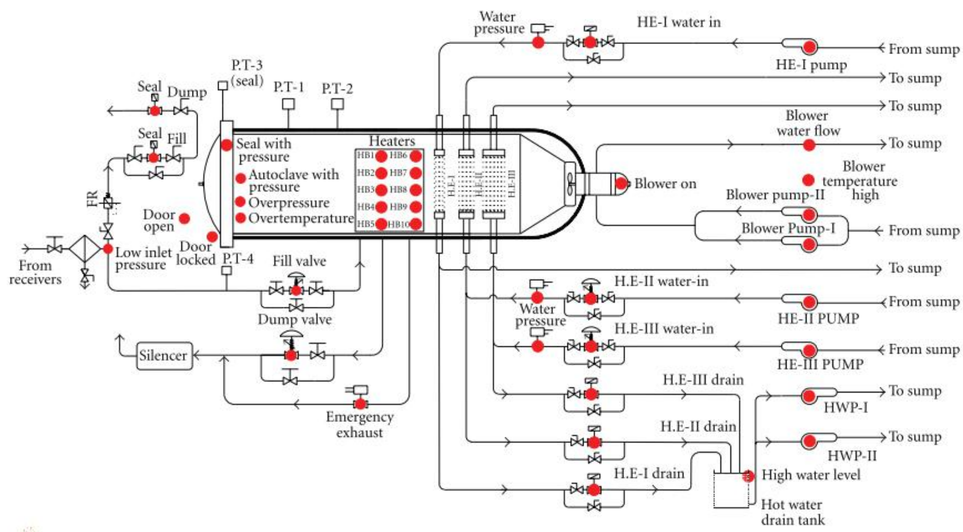

Figure 2.1: The mimic of autoclave systems (Ramaswamy Setty *et al.*, 2011)

Basically, autoclave consists of several main systems that contain certain parts of autoclave machine. The main part of the system is the pressurized system which correlated towards the heating system. The pressurized system which contains the main shell and quick-lock door to create a completely sealed space for sterilization where the temperature increases together with pressure inside the main shell. The heating system is built up from some heating coils which attached on the inner wall of the main shell. The heating system provided indicates the result of one megawatt of heater capacity is needed for an autoclave with a size of diameter about 4.5m and length of 9m. To maintain the uniformity of the air flow inside the autoclave, the air circulation system is provided with aids of the blower fan. There is a cooling system inside the autoclave not simply to reusing the condensed water while for another extra process like cooling progress and icing process. (Ramaswamy Setty *et al.*, 2011) Furthermore, the pressurization system of the autoclave is using a rate of 2 bar/min with the inlet gas of nitrogen as the medium instead of air. Due to air is far more inflammable inside autoclave which in the end cause massive loss towards the sterilized instruments, therefore the nitrogen gases able to ensure the autoclave cure cycles run in a fire-free condition. Figure 2.1 is a mimic of the autoclave.

Furthermore, due to the large scale of actual refers autoclave, the used autoclave is on a smaller scale with a certain ratio compared to the actual. Therefore, a validation by using the previous model is made through simulating the same dimension of autoclave model. The validation is purposely to indicate the feasibility of the simulation on that particular case and to determine the result of the made simulation with the references to have a comparison. Figure 2.2 is the view of the sample of the model used for validation, it consists of a cylinder act as autoclave with a size of 2000mm×4000 mm, with a large frame mold with the size of 3200mm×1600mm×850 mm. (Xu *et al.*, 2017)

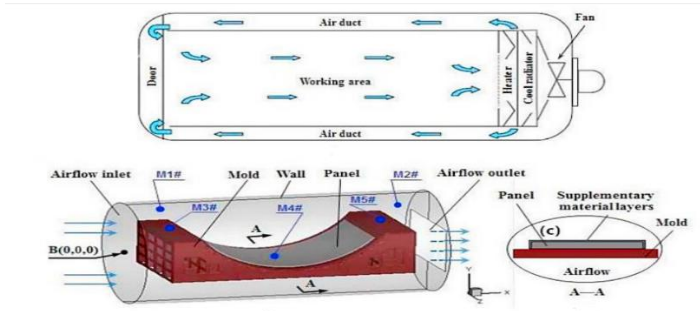

Figure 2.2: The model of the sample used for validation purpose (Xu *et al.*, 2017)

Autoclave also capable in curing of composite material which strengthening the material through the reposition of inner particles under high temperature. The phenomenon that causes the exposing metal under a high-temperature environment to achieve the enhancement of metal is called stress relaxation. (Holman, 1989) With the assists of thermal stress relaxation, the contour of the metal specimen remains and the inner fiber of metal is protected from the stress beyond their yield stress. It is used to retain all of the properties of a metal specimen while changing its shape. The slightly changing of shape after curing process is due to the elasticity of the inner metal fiber. It has said that the autoclave is suited to be used for forming panels for the aircraft and aerospace structures. Figure 2.3 shows the curing process of the specimen.

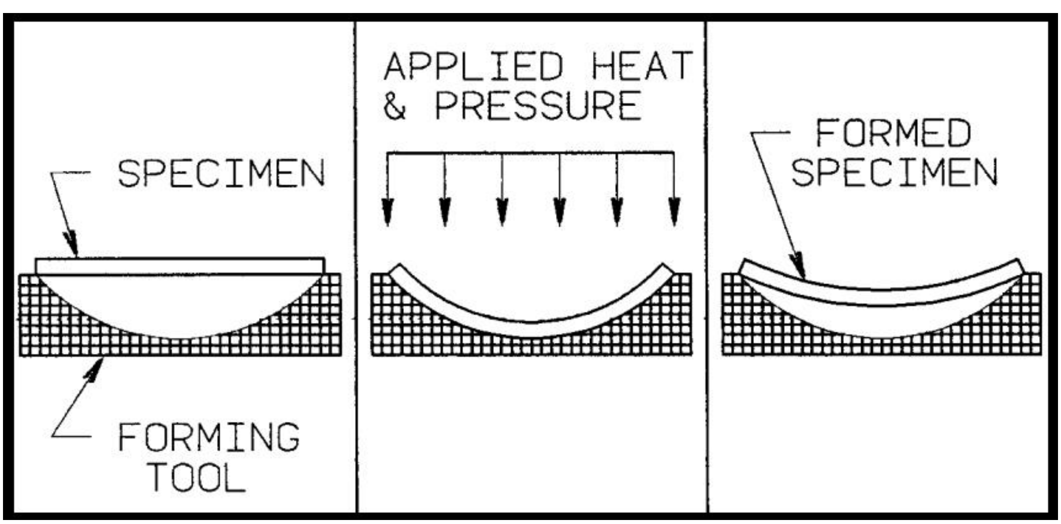

Figure 2.3: The curing process for metal specimen inside the autoclave (Holman, 1989)

Basically, the oven is considered as a machine for heating up things to achieve different purpose like microwaving the food. Figure 2.4 shows the main element of oven included five walls (bottom, right, left, rear and top), glass door and the air cavity. (Lucchi and Lorenzini, 2019)

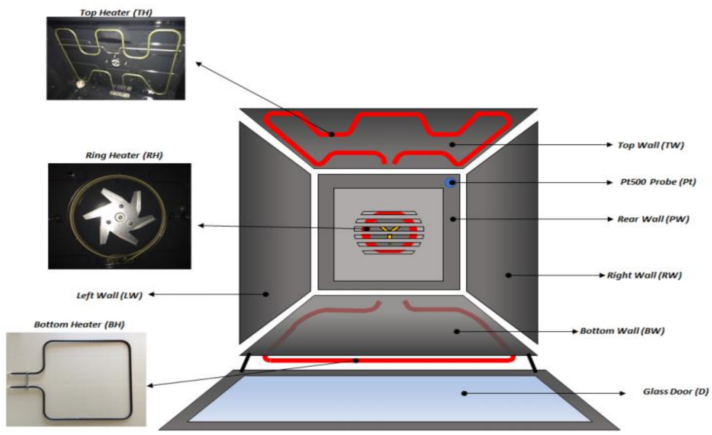

Figure 2.4: The oven and its main parts (Lucchi and Lorenzini, 2019)

The study of the oven is made to understand the specific setting inside the oven which related to its result. (Burlon *et al.*, 2017) By studying the research on the oven, the heat flow inside is able to comprehend clearly. Figure 2.5 is an example of the oven to study the evaluation of energy performance during both steady state and transient state operation.

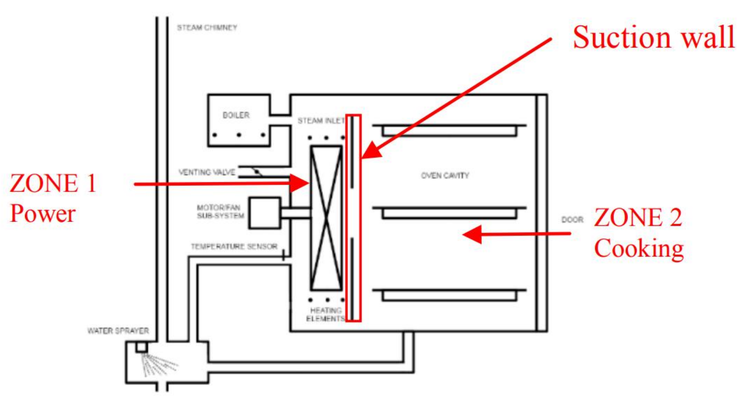

Figure 2.5: The cross diagram of the oven and its particular usage (Burlon *et al.*, 2017)