FLOW MODELLING OF SIMPLIFIED HUMAN NASAL CAVITY

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SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis 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 (Thermal Fluids)"

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FLOW MODELLING OF SIMPLIFIED HUMAN NASAL CAVITY BY USING COMPUTATIONAL FLUID DYNAMICS (CFD)

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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 acknowledged."

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Specially dedicated to beloved Mom and Dad, Sibling and Family

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ABSTRACT

Nasal cavity is a main part of the respiratory system. The understanding on how its works and the flow behavior may help medical practitioners to come out with a new dignose or treatment. Therefore, the objective of this study is to analyse the airflow in a simplified three dimensional (3D) model of human nasal cavity. By using Computational Fluid Dynamic (CFD) analysis, a simplified 3D model is to be simulate by using FLUENT. The simulation shows a good result of velocity inside the nasal cavity, the airflow pattern and the pressure drop throughout the nasal cavity. The Result obtained is also being compared to the actual 3D model done by previous researchers for validation purposes. The simplified 3D model performs well during the simulation process and were able to simulate the airflow inside the nasal cavity either inhalation or exhalation process. The study fullfill its objective to simulate the flow inside simplifoed 3D model of human nasal cavity

ABSTRAK

Rongga hidung merupakan bahagain penting bagi sistem pernafasan manusia. Dengan memahami bagaimana ianya berfungsi, para pengamal perubatan boleh memperkenalkan cara rawatan yang lebih cekap bagi pesakit. Tujuan kajian ini dibuat adalah untuk mengkaji lairan di dalam model 3 Dimesional (3D) ringkas rongga hidung manusia. Dengan menggunakan kaedah Perkomputeran Dynamic Bendalir (CFD), model 3D ringkas rongga hidung akan disimulasikan menggunakan perisian FLUENT. Simulasi telah menunjukan keputusan yang baik dari segi halaju, corak aliran serta penurunan tekanan di dalam rongga hidung tersebut. Keputusan yang diperoleh telah dibandingkan dengan keputusan-keputusan yang didapati oleh pengkaji-pengkaji sebelum ini. Disebabkan model 3D ringkas ini telah berjaya mengsimulasikan keadaan di dalam rongga hidung secara tepat, maka objecktif kajian telah tercapai

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CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

The nasal cavity is one of the main components in a human nasal cavity [Mazumdar, 1992]. The ability to humidify and heats inspired air to match the body-core temperature is one the many function of the human nasal cavity [Mazumdar, 1992]. It also filters smokes and pollutants from reaching and hurting the lungs or any other delicate organs/components in a human respiratory system. Several significant sections in human nasal cavity are nasal valve, turbinates region and the nasopharynx. The study on the human nasal cavity is becoming more popular due to the fact that understanding the flow inside the nasal cavity would lead to a better yet accurate diagnose and treatment scheme. Since 1950, studies on the human nasal are beginning to rise [Proetz, 1953] and [Stuiver, 1958]. This is then followed by the studies of trajectory fluid in the nostril using cinematographic techniques by Massing [Masing, 1967]. Most of these studies were done to resolve problems that involve the complex geometry of the nasal cavity together with their small size.

Throughout the years, there are a few studies on nasal cavity using analytical methods. However, analytical method is becoming more and more popular today.

This is mainly because the cost and time constraint that had to be consider by most of the researcher. Therefore, using Computational Fluid Dynamics (CFD) software will reduce these constraints with a better result. By using CFD, there are two types of model that being used in the study of human nasal cavity. It is either an actual three dimensional (3D) model or a simplified 3D model. A simplified model is a model constructed based on the actual 3D model without the specific detail. According to Zubair et al, a simplified model is constructed based on several actual models [Zubair (2010)].

The pattern of the flow inside a human nasal cavity still obeys the basic fluid flow laws [Mazumdar, 1992]. This characteristic is what enables the application of CFD to predict and investigate the flow behaviour and patterns inside the human nasal cavity. Past researchers show that the flow behaviour inside a human nasal cavity can be predicted by using CFD analysis. This is confirmed by Mylavarapu et al that uses both experimental and CFD analysis and compared both of the results obtained [Mylavarapu, 2009].

Therefore the main objective of this study is to analyse the airflow inside a simplified model of a human nasal cavity.

1.1 PROBLEM STATEMENT

Bio fluid mechanics, a study that relate both medical and engineering in one point of view [Zubair,2010]. The study help doctors to came out with a better way of diagnose and treatment for a patient. Nasal cavity is an important component to the respiratory system [Mazumdar,1992,Zubair,2010].

Studies on the airflow in the human nasal cavity using an actual 3D model are currently rising. However, because of a few limitation and constrains, the actual 3D modelling are patient-specific thus limiting the data acquired to be used on a different patient. Therefore, this study uses the simplified model of the human nasal cavity to overcome these limitations. The objective of this study is to analyse the characteristic of airflow in the human nasal cavity using a simplified 3D model.

1.1.1 Objective

The objective of this research is to analyse the airflow in a simplified 3D model of a human nasal cavity.

1.1.2 Scope

This research will have a few scopes in order to achieve the objective given. First of all, during the research, a simplified 3D model of a human nasal cavity will be reconstructed. This model will be used throughout the research as the main platform of the research. Then, the simplified 3D model is simulated using CFD software with various flow rates. These flow rates are used to simulate the various

breathing condition of a normal human. Based on previous study [Zubair,2010], there are 3 different flow rates measured in litre per minute (lpm) which are 15 lpm (normal), 40 lpm (vigorous) and 5 lpm (relaxed).

CHAPTER 2

LITERATURE REVIEW

2.0 ANATOMY OF HUMAN NASAL CAVITY

Human nasal cavity is a crucial part in the respiratory system. It helps in heating and humidifying inspired air to match the body-core temperature. It also filters potential harmful substances from entering the airway [Zubair,2010]. Nasal cavity consists of 3 main parts which are nasal valve, turbinate region and nasopharynx.

Nasal valve serve as the inlet of the nasal cavity. This sections contains nasal hair functioned to trap unwanted particles or substances in the inhaled air [Mazumdar, 1992].

Turbinates is one of the crucial components existed in nasal cavity. These spongy bones in the nasal cavity exist to protect the inner nasal anatomy [Mylavarapu, 2010]. The common function of turbinates is for the airflow control inside the nasal cavity [Clemente, 1985].Turbinate can be divided into 3 major parts which is inferior turbinates, middle turbinates, and superior turbinates. [Mylavarapu, 2010]. Inferior turbinates is the largest turbinates in a turbinates region. The inferior turbinates is important for most of the airflow direction, humidification, heating and filtering

inhaled air. Middle turbinates are smaller than inferior turbinates serves as a protection to shield sensitive sinuses from direct exposure of the incoming pressurized airflow. Superior turbinates is the smallest turbinates and it is connected to the middle turbinates by the nerve endings. Middle turbinates functioned to control the airflow in order to protect the old factory bulb.

Nasopharynx, located in the end of the nasal cavity connects the back of the nose to the back of the mouth, according to cancerresearchuk.org. The function of nasopharynx is to direct the air into the trachea after it passes through nasal cavity. According to a research done by C. Xu, the pharyx area is the area that has the highest pressure drop in a minimum area [Chu, 2006]. Usually, the velocity or air in this particular region is high compared to the other region [Clemente, 1985]

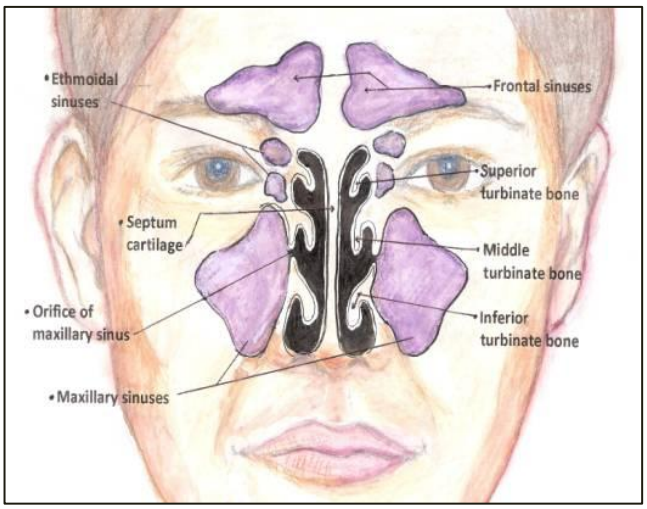

Figure 2.1 Front view of the human nasal cavity. (Source: Painneck.com)

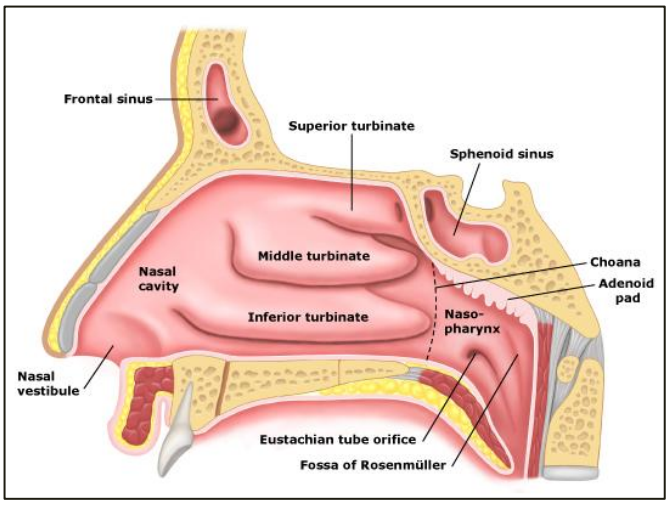

Figure 2.2: Side view of the human nasal cavity. (Source: Sinus-cure.com.au)

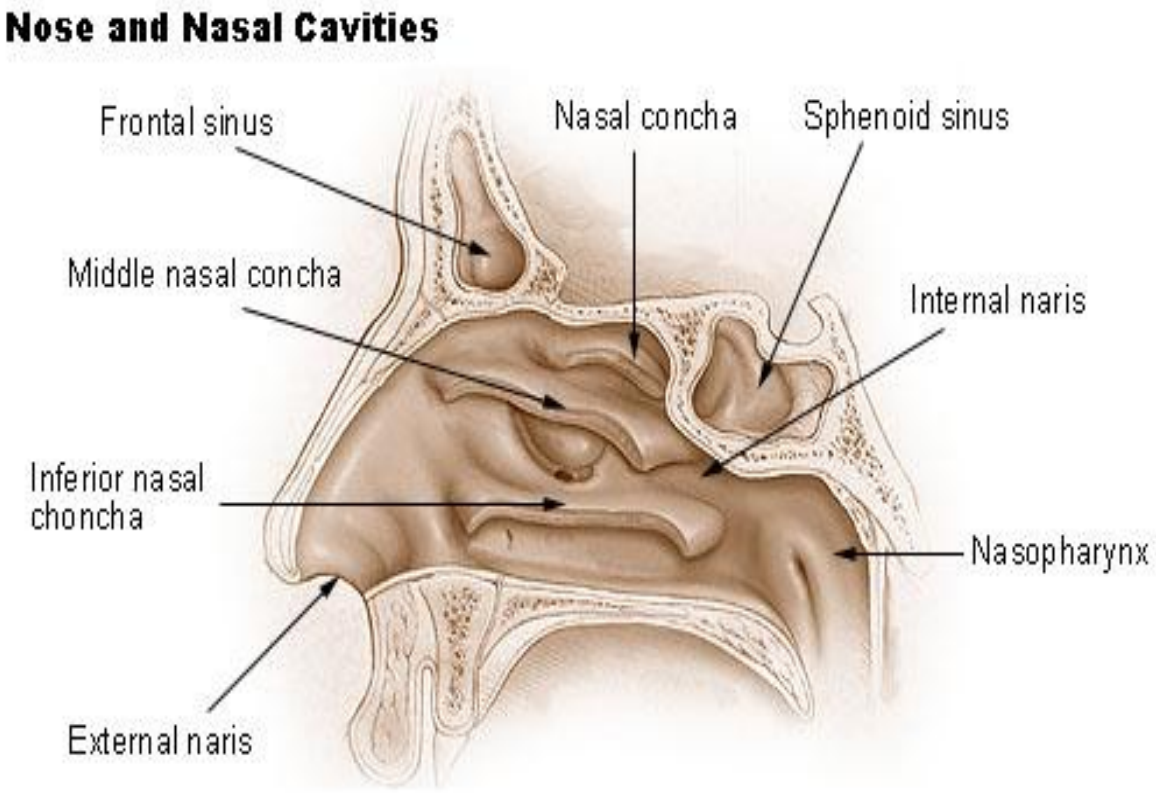

Figure 2.3: Graphical visualisations of turbinates inside human nasal cavity.

(Sorce :wikipedia)

2.1 SIMPLIFIED MODEL

By referring to Appendix A, the matrix of journals, all the researches that are listed there were using an actual model. An Actual model is the model that is generated by using data from an actual human specimen. The actual model, or sometimes also referred as anatomical 3D model are used because of the accuracy of the data are more valid. This is proven in many studies such as Zubair et al , Catro Ruiz et al, Proetz,and Stuiver, but the actual model is only valid on a certain patient, thus, becoming a limiting factor if the model is to be used to a different patient.

The construction of a simplified 3D model of human nasal cavity helps to eliminate the limitation by assuming the average size of patient. This way, the 3D model could be used to simulate the airflow inside every patient generally, without having to generate a new model.

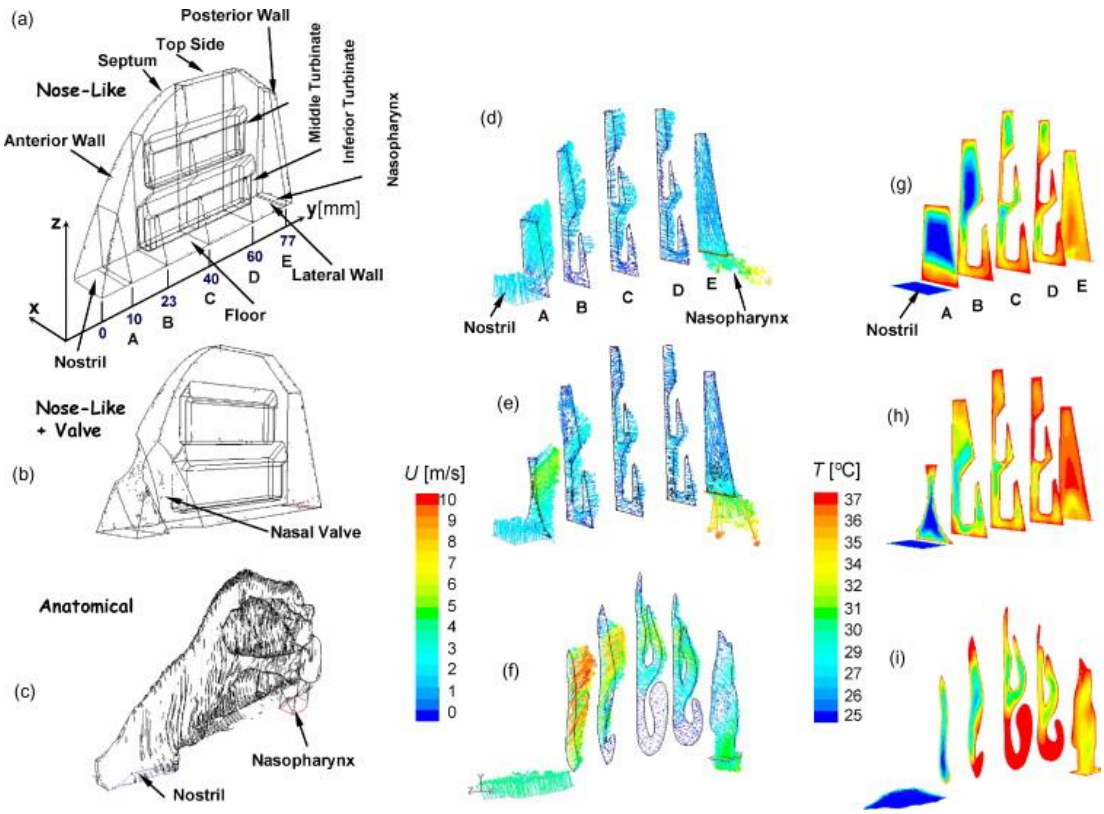

Figure 2.4 The example of simplified 3D model from David Elad study.

(Sorce: Elad, 2008)

2.2 PARAMETERS STUDIED

2.2.1 Velocity

Velocity is one of the parameters that we need to observe in the study. Velocity has a significant impact on the nasal cavity and the respiratory Studies like P Castro Luiz [Castro Luiz, 2005] and Shigeru Ishikawa [Ishikawa, 2006] focused more on velocity inside the nasal cavity. For example, if the velocity of air is high inside the superior turbinate, the sensitive sinus could be damaged and would lead to the in ability to smell.There are few areas in the nasal cavity that varies in velocity distribution. K. Hemtiwakorn [Hemtiwakorn, 2009] states that the velocity distribution on both set of nasal cavity differs due to the uniqueness of the human nasal cavity geometry. Since K. Hemtiwakorn uses an actual model, the variations on the velocity distribution could be seen in his results.

2.2.2 Airflow

Usually in most cases/studies, the airflow pattern is plotted so that it could be analysed and the behaviour of the flow could be predict. Studies like Zubair [Zubair, 2010] and Vizy Nazira [Nazira, 2010] shows the flow pattern inside the human nasal cavity. Since the flow pattern is affected by the velocity in that particular area, it also fluctuates and has different values when compared with the other set of nasal cavity (left and right). Airflow pattern can also help researcher to to track particle easily just by looking at the pattern. It is important to understand how particles moves inside a nasal cavity in to order give better diagnosis and treatment [Inthavong, 2006]

2.2.3 Pressure

Another important parameter that needs to be studied in the nasal cavity is pressure. A significant amount of pressure drops occurs inside the nasal cavity, especially in the nasal valve area during inhalation process. Zubair et al states that the pressure will affect a numbers of parts in the nasal cavity, for example, the vestibule region [Zubair, 2010]. The pressure drop across the nasal cavity is important to be monitored. The pressure drop that is less than a normal pressure drop indicates that inability to breathe properly. Zubair et al states that the high pressure will exert higher stress on the nasal wall that can affect the cell linings and bllod vessel along the wall [Zubair, 2010].