CHAPTER 1 INTRODUCTION

1.1 Research Background

One of the most critical requirements for materials used in advanced industries are high strength and lightweight, and for that reason, composite materials were made. The composite material is a unique material that consists of two or more components with significantly different physical or chemical properties. According to Hale, (1976), some of the benefits from those characteristics are it provided a highly attractive combination of stiffness, toughness with lightweight and corrosion resistance properties. With these properties, composite materials are currently being used in various fields such as automotive, mechanical, construction, biomedical, and aviation industry. In the aviation industry, composite materials have major roles to play in establishing an aircraft component. As you can see in Figure 1, three types of composite material are now commonly used in wings and tails, propellers, rotor blades, and aircraft internal structures, namely AFRP (Aramid), CFRP (Carbon), and GFRP (Glass). In addition, aircraft manufacturers such as Eurofighter, Airbus and Boeing have been aiming to use composite materials in their products. For example, Boeing developed the Boeing 787-Dreamliners in which approximately 97 percent of the component structures are composites. On the other hand, Airbus has used up to 15% of the overall aircraft frame weight for the A320, A330 and A340 series of composite materials. Applications of these composite materials may have arisen since there are more studies and developments in this field.

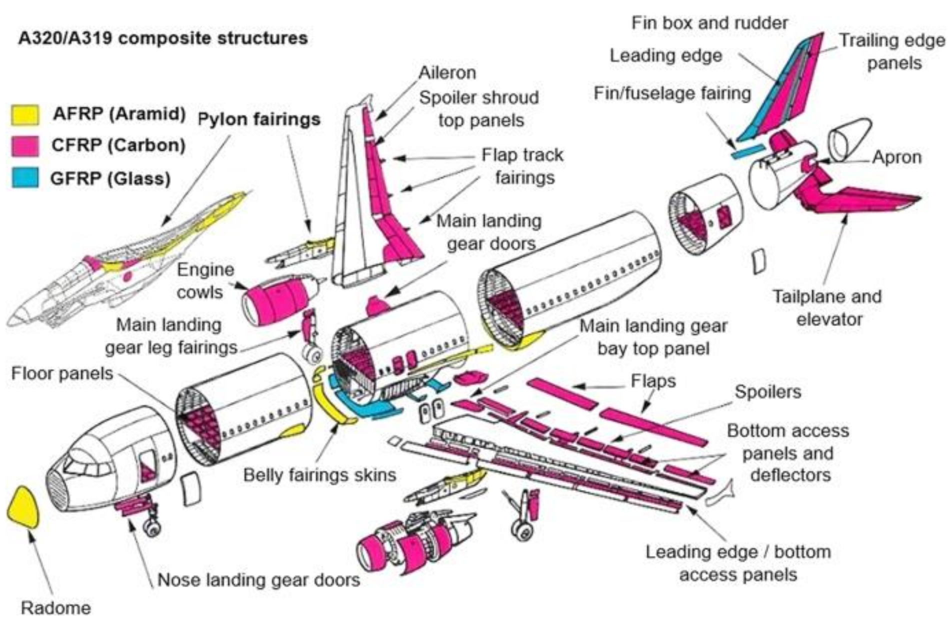

Figure 1. Carbon Composite Application in An Aircraft

(Aamir et al., 2019; Soutis, 2005)

Research and development about composite material were having a significant transformation in the recent years. The form of composite material development will continue to grow, this is in line with the development process and related research. In a research conducted by Rajak et al., (2019) was defined and classified based on the design and development into some categories which are based on matrix phases, reinforcements, and scales. Different type of composite will create a different material property, while different property means that a material would act differently if it applied by any external forces. A study that discuss composite material properties in detail were done by Hale, (1976). According on it, he tried to define a standard calculation or formula from different type of composite material properties. Some of those properties are thermal expansion, sweling and srinkage, heat transfer, and magnetic. Furthermore, to meet the physical and mechanical needs of an industry, it does not rule out any possibility to develop a composite material which inspired by nature.

Nature-inspired innovation in the development of composite material was becoming common in these years since the invention of Biomimicry. According on Farzaneh, (2013), Biomimicry is a science that combines knowledge of biological systems with technological developments and innovations. Combination of these two fields enables humans to provide system and technology-related innovation through the adoption of nature, since nature is a system that always evolve, it will create other new inspirations for human. That circumstance will support human needs which keep transforming too as the times changing. Some examples from the application of Biomimicry into the human life are the invention of aircraft, a bird-inspired transportation that made human can fly and travel faster, the application of beak shape from Kingfisher bird into the design of Shinkansen train in Japan to create a better aerodynamic effect (Valdecasas et al., 2018), and honeycomb shape application in biomedicine that contribute in the development of tissue engineering (Zhang et al., 2015). Nowadays, Biomimicry has a very wide scope usage, including the application in the design of a structure and material, along with composite materials.

The development of composite materials using biomimicry is a rapidly progressing innovation. It was proven by the existence of previous studies discussed the application of biomimicry into the process of developing composite materials. A study by Li et al., (1995) explaining that an application of bamboo structure in composite can increase interlaminar shear strength of glass fibre or epoxy resin. Another study from Dai et al., (2013) whose tried to systematically describes the structure, sssproperties, processing, and applications of wood fibres as reinforcements in natural fibre composites. Also, a recent study by Gohal et al., (2020) about natural fibre composite material and the technique of hybridization to create a hybrid composite. Overall, biomimicry applications in composite material are so diverse. The diversity came from different sources of inspiration, scope of development, and application. From those areas, one of the natural structures to be build along with thse composite materials is Helicoidal Structure.

Helicoidal Structure is a nature-inspired structure that has spread widely across many biological organisms. Includes its existence on animals such as snail shell, crustacean, beetle elytron (Jiang et al., 2019) also plants, for instance of *Pollia condensata* fruit and algae (Wilts et al., 2014). The characteristics utilization can be seen clearly in helicoidal structure of crustacean dactyl club *(stomatopod-Odontodactylus scyllarus) on Figure 1 below*. As reported by Yaraghi et al., (2019), that crustacean dactyl club has a hammer-like structure that can reach, upon impact, accelerations as high as 10400 g and speeds close to 23 m/s, generating forces up to 1500 N when it hit the preys. Although with that circumstances, as a strong structure, the dactyl club can receive the impact many times without broken. That conditions may happen since the structure establishing the dactyl club is Helicoidal structure, which has high strength and stiffness.

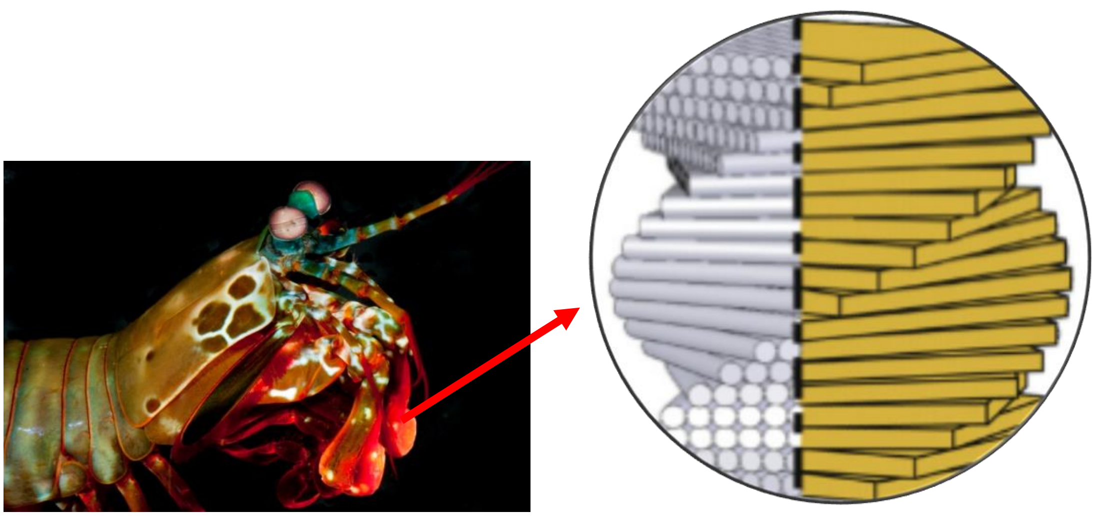

Figure 2. Helicoidal Structure in a Crustacean Dactyl Club

(Dai & Fan, 2013)

The characteristics of helicoidal structure which has high stiffness, strength, ductility, and durability has been recorded. A study by Patek et al., (2005) using several experiments, whom carried out using standard tension tests, plate bending tests, impact tests, and double cantilever beam tests against helicoidal structure on composite materials. He found that despite of the given significant forces, the structure is fracture resistant by prevent the development of cracks and able to tolerate thousands of such blows. According to Jiang et al., (2019) and Apichattrabrut et al., (2006), the reason behind that event is because of its rotated architecture which limits the cracks propagation so that it has a great ability to absorb the given energy. That structure performance is affected by several factors, and one of the most important parts is the structure design parameter.

Structure design parameter is an aspect on the specific part of a structure that will have an impact on how the structure's shape and performance. Usually, structure design parameter used as an experiment's setting to find the wanted responses during a study, since it has measureable scale which relatively easier to arrange. On helicoidal structure, there are four design parameter that have been recorded according to (Guarín-Zapata et al., (2015) , which are pitch distance, layer thickness, number of layers, and fiber orientation. The combinations between all those 4 will determine how the helicoidal structure's shape and performance which already tested by several studies and research.

Past studies and research about helicoidal structure design parameter have been done before within their specific aims. On a study by Shang et al., (2016) whom want to assess the ability of helical configuration as a structural design to produce advanced material systems. The focus of this study was on comparing different laminate configurations. These laminates are a cross-ply pattern, a single helical with a rotation angle of 18 ° and a single helical with a rotation angle of 10 °. Using the unidirectional T700/2510 carbon-epoxy prepreg as a material to produce the specimen were later tested using a Quasi-static indentation bending method. The outcome of this test is that the ply rotation angle must be low (e.g. 10 ° or less) in order to maximize the stress distribution and therefore increase the load-bearing ability. Another study from Ginzburg et al., (2017) was aiming to examine the behavior of twisted composite configurations arranged in plates of various width-to-thickness ratios. By comparing the results of three-square plates with different planar sizes, it was shown that the helicoidal layups are more effective at absorbing energy while minimising through the thickness failure than standard quasi-isotropic and cross-ply laminates. On related topic, (Liu, Lee, & Tan, 2018) have focusing their study about cracks initiative, how damage grows, and what causes final failure in helicoidal composite. This study was using a Quasi-static indentation test by utilizing a fabricated unidirectional rectional T700/2510 carbon-epoxy prepregs as a specimen. The foundings of this study is that the helicoidal specimens do not experience multiple loads drops and can attain high peak load before catastrophic failure. It is also shown that even higher peak load is achieved by selectively seeding delamination in helicoidal laminates to further delay the merging of transverse cracks with the dominant delamination.

However, those studies about helicoidal structure design parameters only focusing on a specific design parameter. Since it is not clear whether the development of these configurations is related to the performance of the helicoidal structure as a whole or not in order to optimize the structure performance. Also, those researches have not determined which design parameters are significant for a specific response. Meanwhile, each design parameter has its specific measurable role against the structure's response of any given force. Over the facts, the helicoidal structure usage on composite material has an opportunity to be developt further. Through the research and innovation in structure and material fields, it will create a higher quality material as the demand for lightweight, high performance and new material design are growing rapidly. Furthermore, the usage of composite material in many different fields will not only establish a better material structure, but also other advantages such as work quality and safety enhancement. For instance, the implementation in aircraft production can be optimized using composite material to reduce the weight and increase the quality of fligth safety all at once. Finally, in order to optimize the helicoidal structure performance, this study aims to find out the best arrangement of helicoidal structure design parameters and levels on a specific response, then determine the significant parameter of helicoidal structure against the output.

1.2 Problems Definition

According to the background explained, the problem definitions are stated as:

1. What is the optimum configuration of design parameters for the helicoidal composite structure to reinforce the material?
2. What is the significance of each parameter against the strength enhancement of the structure?

1.3 Research Objectives

Based on the problem definitions, the research objectives are stated below:

1. Determine the optimum design parameter configuration of the helicoidal composite structure to enhance the material strengths
2. Identify the significance of the parameters against its influence on strengthening process the helicoidal composite structure

1.4 Research Boundaries

In order to obtain the result that do not out from the topic discussed, it is necessary to put some research boundaries, the research limitations of this study are as follows.

1. This study focuses on tensile behaviour of the helicoidal structure
2. Data collection processed through CAE simulation using Abaqus
3. CFRP (Carbon Fibre Reinforced Polymer) used as the material during the simulation
4. The responses of simulations are not tested on real experiment

1.5 Benefit of Research

Based on the background, problem equation icon, research objectives, and research limitations set out above, the benefits of this study are as follows.

1. Learning how to evaluate the design concept and optimum model parameters using the Full-factorial method.
2. Apply industrial engineering, to consumer design and development, concerning parameter optimization and model choice.
3. Give references to readers who are interested in developing design concepts or design optimization from this final report.

1.6 Writing Systematics

The preparation of the report in this study consists of several chapters containing the sub-chapters and a more detailed description. Systematic writing is as follows.

Chapter I Introduction

This chapter is an opening report with background problems, research objectives, research boundaries, research benefits, and systematic writing. This chapter describes the research to be performed using the Design of Experiment (DOE) process. The study will explore the choice of optimal design concepts, identify design parameters that have a significant impact on the expected output, and why this is important.

Chapter II Literature Review

This section contains references to the literature review taken from previous studies about the issue raised. This chapter also discusses the relationship between the concepts studied and the development of contributions by previous researchers, as well as the reasons why the chosen theory is included in the study. All theories used in the work of this study will be listed and will become a reference that can be considered.

Chapter III Research Methods

This chapter provides a detailed explanation of the methods used and the steps taken in the study from the initial stage to the final stage. What needs to be done is to describe the conceptual model of the study scheme and the systematic problem-solving that addresses issues ranging from problem identification, data collection, data processing, data analysis to conclusions.

Chapter IV Data Collection and Processing

This chapter includes the collection of data needed to measure design parameters, make 3D design concepts models, and perform steps under the method used. Data collection is carried out using static structural simulations and the results will be tested and statistically processed.

Chapter V Analysis and Discussion

This section contains an overview of the data processing performance. This analysis will discuss in detail the results of the design concept selection, together with the reasons and references that may be responsible for the results of the data obtained.

Chapter VI Conclusions and Suggestions

This chapter contains the findings of the analysis and discussion. Where these results are linked to the initial objectives of the study, whether the research objectives have been achieved. There are also suggestions for further study.