UNIVERSITI PUTRA MALAYSIA

# *INFLUENCE OF STIFFENER ON ALUMINIUM PERFORATED PLATES SUBJECTED TO IN-PLANE SHEAR LOADING*

**MOHD NIZAM HASSAN**

**FK 2018 49**

# INFLUENCE OF STIFFENER ON ALUMINIUM PERFORATED PLATES SUBJECTED TO IN-PLANE SHEAR LOADING

By

**MOHD NIZAM BIN HASSAN**



**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science**

**January 2018**

**DEDICATION**

This thesis is specially dedicated to

My beloved parents,

**HASSAN BIN ABDUL HAMID**
**RAMLAH BINTI ABDUL RAHIM**

My family, supervisor and friends, who always giving me supports throughout my Master journey.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia
in fulfilment of the requirement for the degree of Master of Science

**INFLUENCE OF STIFFENER ON ALUMINIUM PERFORATED PLATES SUBJECTED TO IN-PLANE SHEAR LOADING**

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**January 2018**

**Chairman : Noorfaizal bin Yidris, PhD**
**Faculty : Engineering**

Shear buckling is an important phenomenon as it enables the design becomes more efficient structures which would be possible if the critical buckling load is treated as the maximum allowable load. This is particularly significant in aerospace industry where lightweight, strength and reliability structures are known as the important factors need to be considered when designing and producing the aircraft. A literature review reveals that although there were many information available regarding to the buckling strength of elastic plates, but there is just few information available concerning the effect of shear buckling on the perforated plate. Therefore, the aim of this research was to study the effect of stiffener on aluminium perforated plates when subjected to shear loading.

The research was conducted by using numerical method or known as finite element simulation software which was ABAQUS/CAE 6.10, since this tool were known as the most suitable technique for solving the problems. Aluminium 7075-T6 was the materials which have been selected and used throughout the study. Besides, the geometry of the model which was chosen for this study was square plate and rectangular plate. Before proceed to the main study, the mesh convergence analysis of non-perforated square plates and non-perforated rectangular plates were conducted to verify the method implemented in the research were correct and acceptable. The value of shear buckling coefficient then was validated by comparing the numerical data gained from the analysis with the theoretical data obtained from the literature study. After that, the shear buckling behaviors of perforated plates were studied by varying the diameter of holes and the quantity of holes on the plate structures. Further study was conducted into the buckling performance of perforated plates with stiffener under shear load.

Based on the study, it was found that the design of perforation on the plate structures reduced the strength of that plate structures. However, when the stiffeners was added around the circular hole on the plates regions, it was noted that generally by the presence of the stiffeners improves the strength structure of the plates when compared with perforated plates. Finally, a full study of all design was finally undertaken which emphasizing the addition of stiffener have an effect on the buckling performance of the structure. The research was concludes with evaluations of the analysis and suggestions for future study direction.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk Ijazah Master Sains

**PENGARUH PENGUKUH KE ATAS PLAT ALUMINIUM YANG BERLUBANG DAN DIBEBANI DENGAN DAYA RICIH SESATAH**

Oleh

**MOHD NIZAM BIN HASSAN**

**Januari 2018**

**Pengerusi : Noorfaizal bin Yidris, PhD**
**Fakulti : Kejuruteraan**

Lengkokan ricih adalah satu fenomena yang penting kerana ia membolehkan reka bentuk menjadi struktur yang lebih efisien jika beban kritikal dirawat sebagai beban maksimum yang dibenarkan. Ini amat penting dalam industri aeroangkasa di mana struktur ringan, kekuatan dan kebolehpercayaan dikenali sebagai faktor penting yang perlu dipertimbangkan semasa mereka bentuk dan menghasilkan pesawat. Tinjauan kepustakaan mendedahkan bahawa walaupun terdapat banyak maklumat yang tersedia mengenai kekuatan lengkokan untuk plat elastis, tetapi hanya ada sedikit informasi yang tersedia mengenai pengaruh lengkokan ricih pada plat berlubang. Oleh itu, tujuan penyelidikan ini adalah untuk mengkaji kesan pengukuh pada plat berlubang aluminium apabila tertakluk kepada beban ricih.

Penyelidikan ini dijalankan dengan menggunakan kaedah berangka atau dikenali sebagai perisian simulasi unsur terhingga iaitu ABAQUS/CAE 6.10, memandangkan alat ini dikenali sebagai teknik yang paling sesuai untuk menyelesaikan masalah. Aluminium 7075-T6 adalah bahan yang telah dipilih dan digunakan sepanjang kajian. Selain itu, geometri model yang dipilih untuk kajian ini adalah plat segi empat sama dan plat segi empat tepat. Sebelum meneruskan ke kajian utama, analisis penumpuan mesh pada plat segi empat sama yang tidak berlubang dan plat segi empat tepat yang tidak berlubang telah dijalankan untuk mengesahkan kaedah yang dilaksanakan dalam penyelidikan adalah betul dan boleh digunakan. Nilai pekali lengkokan ricih kemudiannya disahkan dengan membandingkan data yang diperolehi daripada analisis dengan data teori yang diperoleh daripada kajian kesusasteraan. Selepas itu, pergerakan lengkokan ricih untuk plat berlubang telah dikaji dengan mengubah diameter lubang dan kuantiti lubang pada struktur plat. Kajian lanjut dijalankan ke dalam prestasi lengkokan pada plat berlubang dengan pengukuh di bawah beban ricih.

Berdasarkan kajian, didapati bahawa reka bentuk perforasi pada struktur plat mengurangkan kekuatan struktur plat itu. Walau bagaimanapun, apabila pengukuh ditambahkan di sekitar lubang bulat di kawasan plat, ia diperhatikan bahawa secara umumnya kehadiran pengukuh tersebut meningkatkan struktur kekuatan plat apabila dibandingkan dengan plat berlubang. Akhir sekali, satu kajian penuh tentang semua reka bentuk akhirnya dilaksanakan dengan memberi penekanan bahawa penambahan pengukuh mempunyai kesan ke atas prestasi lengkokan sesebuah struktur. Kajian ini disimpulkan dengan penilaian analisis dan cadangan untuk hala tuju kajian pada masa depan.

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Finally, deepest thanks and appreciation to Ministry of Education Malaysia for granting me MyMaster Scholarship under MyBrain15 Program and Universiti Putra Malaysia for some financial support given to me during the early of my Master sutdy.

I certify that a Thesis Examination Committee has met on 10 January 2018 to conduct the final examination of Mohd Nizam bin Hassan on his thesis entitled "Influence of Stiffener on Aluminium Perforated Plates Subjected to In-Plane Shear Loading" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

**Faizal bin Mustapha, PhD**
Professor Ir.
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

**Mohamed Thariq bin Hameed Sultan, PhD**
Associate Professor Ir.
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

**Shahrum Abdullah, PhD**
Professor Ir.
Universiti Kebangsaan Malaysia
Malaysia
(External Examiner)

**NOR AINI AB. SHUKOR, PhD**
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 27 February 2018

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

**Noorfaizal bin Dato Yidris, PhD**
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

**Fairuz Izzuddin bin Romli, PhD**
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

**Mohammad Yazdi bin Harmin, PhD**
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

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**ROBIAH BINTI YUNUS, PhD**
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

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I hereby confirm that:

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Signature: __________________________

Name of Chairman of Supervisory Committee: Noorfaizal Bin Dato Yidris, PhD

Signature: __________________________

Name of Member of Supervisory Committee: Fairuz Izzuddin Bin Romli, PhD

Signature: _____________________________

Name of Member of Supervisory Committee: Mohammad Yazdi Bin Harmin, PhD

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| $A$ | Area |
| $a$ | Length of plates |
| $b$ | Width of plates |
| BC | Boundary condition |
| $d$ | Diameter |
| $E$ | Young's Modulus |
| $F$ | Force |
| $g$ | Gram |
| $h_s$ | Height of stiffener |
| $k$ | Kilo |
| $k_v$ | Shear buckling coefficient |
| $m$ | Mass |
| $mm$ | Millimeter |
| $N$ | Newton |
| $P$ | Buckling load |
| $\rho$ | Density |
| $r$ | Radius of hole |
| $t$ | Thickness |
| $\tau_{cr}$ | Critical shear stress |
| $v$ | Poisson's Ratio |
| $V$ | Volume |
| % | Percentage |
| FEA | Finite element analysis |
| FEM | Finite element method |
| S-1-100a | Non-perforated square plates with plate length of 100 mm |
| S-1-200a | Non-perforated square plates with plate length of 200 mm |
| S-1-400a | Non-perforated square plates with plate length of 400 mm |

| | |
|---|---|
| S-1-10d | Perforated square plate with hole diameter 10 mm |
| SS-1-10d | Stiffened perforated square plate with hole diameter 10 mm |
| R-2-200a | Non-perforated rectangular plates with plate length of 200 mm |
| R-2-10d | Perforated rectangular plate with one hole on that plates |
| R-2-10d$^2$ | Perforated rectangular plate with two hole on that plates |
| RS-2-10d | Stiffened perforated rectangular plate with one hole on that plates |
| RS-2-10d$^2$ | Stiffened perforated rectangular plate with two hole on that plates |
| R-3-300a | Non-perforated rectangular plates with plate length of 300 mm |
| R-3-10d | Perforated rectangular plate with one hole on that plates |
| R-3-10d$^3$ | Perforated rectangular plate with three hole on that plates |
| RS-3-10d | Stiffened perforated rectangular plate with one hole on that plates |
| RS-3-10d$^3$ | Stiffened perforated rectangular plate with three hole on that plates |
| R-4-400a | Non-perforated rectangular plates with plate length of 400 mm |
| R-4-10d | Perforated rectangular plate with one hole on that plates |
| R-4-10d$^4$ | Perforated rectangular plate with four hole on that plates |
| RS-4-10d | Stiffened perforated rectangular plate with one hole on that plates |
| RS-4-10d$^4$ | Stiffened perforated rectangular plate with four hole on that plates |

# CHAPTER 1

# INTRODUCTION

This chapter describes briefly on the research conducted which consist of the overview of the research, background of the research, problem statements, objectives of the research, scopes of the research, and layout of the thesis.

## 1.1 Research Overview

Nowadays, the structure of thin plates has been widely used in many industries such as in civil industry, automotive industry, marine industry and aerospace industry (Dinh-Cong, et. al, 2017). The structure of these plates is commonly used as the basis construction of the buildings, ships, aircraft structures and etc. Figure 1.1 shows some of the examples of plate structure which have been used as the main structural element in the industry. These thin plate structures has been used widely in nowadays industry is due to the light-weight properties of the structures (Kubiak, et. al, 2016).

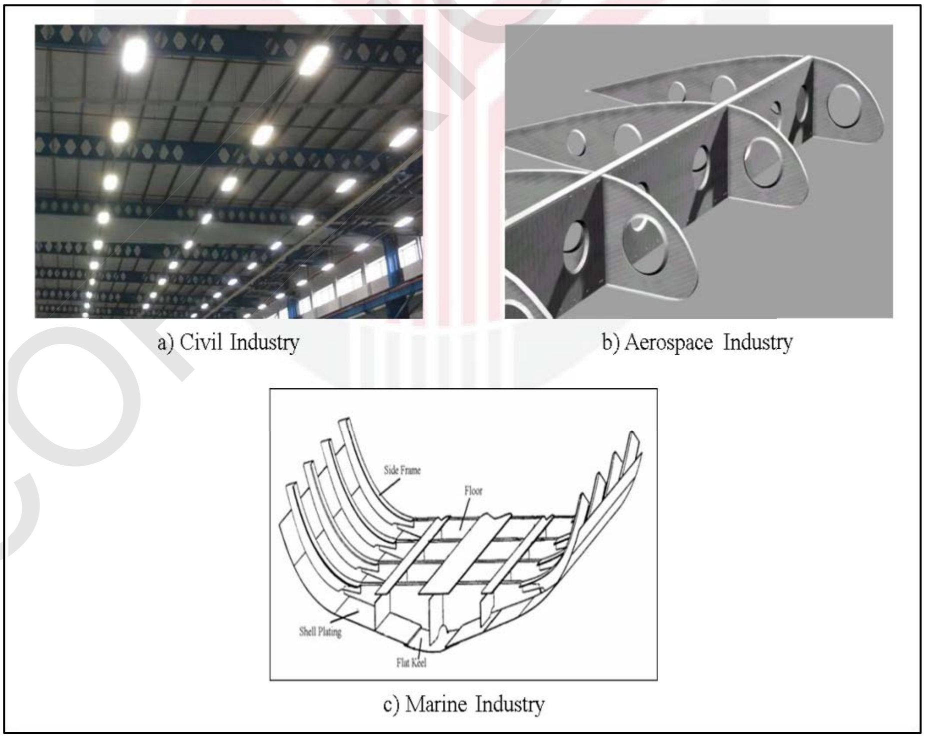


**Figure 1.1: Plate structure application in the industries (Source: (b) Zenith Aircraft Company, 2004; (c) Splash Maritime, 2008)**

In the process of designing and constructing some structure element such as aircraft or buildings, the important factors that have to be considered are weight, strength and reliability. These factors need to be considered early because it will determine the requirements to be met by any material used in the built structure. On top of that, all the materials chosen to construct the structure of the element must be reliable to minimize the possibility of failures (Integrated Publishing, 2013). The wrong selection of the material for the constructions can cause structure failure and may leads to catastrophic effect. Typically, the type of material that are often used in the construction of aircraft is aluminium alloy due to is properties of high strength, high stiffness, light weight and high fatigue resistance (Ravikumar, et. al, 2017). Therefore, a good structure is known as the structure that provides properties of high strength, light weight and good rigidity.

In most of the plate structures, although it has a good strength-to-weight structure, it still tends to experience the buckling phenomenon. These buckling phenomenon are caused by some forces acting on the structure. There are five major types of forces which can act on any surface of the plate structures, which are tension, compression, torsion, shear, and bending as shown in Figure 1.2. These forces are commonly can be found in the structural elements of aerospace structures (Federal Aviation Authority, 2002). Wings, fuselage and landing gear are some examples of aircraft parts which are subjected to these forces. The failure of the structural element to withstand these forces may lead to catastrophic structural failure. Because of this, it is important to identify the buckling capacities for each structural element in order to prevent the premature failure of the structure.

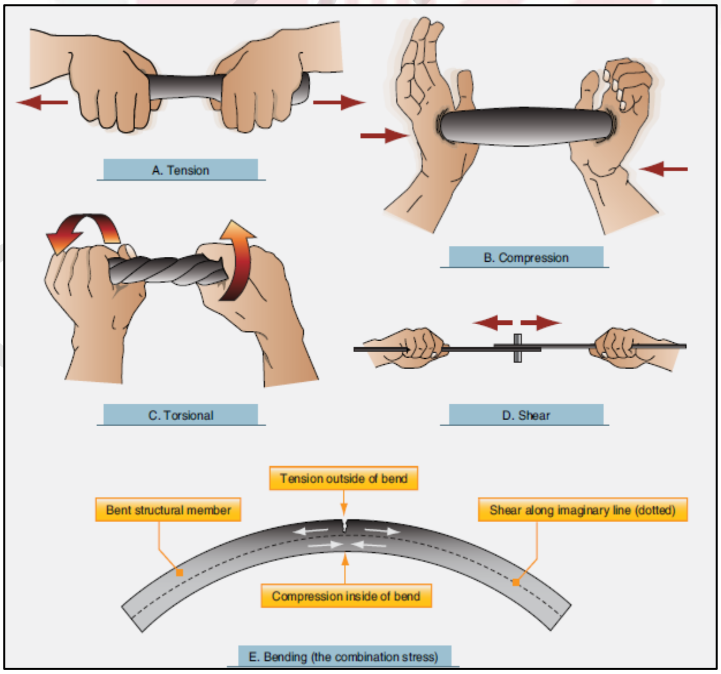


**Figure 1.2: Types of forces (Source: Federal Aviation Authority, 2002)**

Since there are many application of thin plate structures in the industry, therefore this research are specifically choose to focus the study on the aircraft wing structure in flight condition. This is because the wing structure of the aircraft is often subjected to heavy aerodynamics loads and leads to a shear flow over the wing ribs that support it. In addition, most structure of the aircraft nowadays has been widely using the cut-out design as the basic design construction. For example, beam of the fuselage, window of the aircraft fuselage and the wing part, i.e. wing rib. Some of the purposes of applying the cut-out design on the structure are for simplifying the inspection services and to reduce the weight of the structure (Scheperboer, et.al, 2016).

In contrast, the application of the cut-out design in the aircraft structure especially the wing structures are commonly effect the dynamic and mechanical behavior of the plates, as they redistribute the forces (Sivakumar, et. al, 2012). Therefore, it is important to study the effect of shear force and the buckling behavior of cut-out plates to prevent mechanical failure of the structure.

## 1.2 Research Background

In recent time, steel plates are generally being used as the main components of steel structures, especially in aerospace industry. However, the steel plate structures are commonly subjected to many stresses such as tension, shear and compression loads which will give impact to the instability and buckling behavior of the structure. Buckling is considered by a sudden failure of a structural member when the structure is subjected to high loads, where the actual loads at the point of failure is less than the ultimate loads that the material is capable to withstand (Vanquez, 2013). Therefore, the critical buckling loads of steel plate structures are known as one of the most important design criteria in structural element.

Besides that, the materials that are mostly being used as the main structural element in many industries especially in aerospace industry is aluminium. The application of aluminium are frequently have high demand in the industries due to its valuable characteristics such as low weight, good resistance to corrosion, and high electrical conductivity (Estrada-Ruiz, et. al, 2016). On top of that, aluminium plate are often used in aerospace application in a large quantity, which ranging in complexity and performance requirements from the simple component through to main loads bearing structures in aircraft such as the Boeing 737 and Airbus A340 (Morris, 2001). The components and parts of aircraft that use aluminium as one of the construction materials are shown in Figure 1.3 (Skymaster, 2016).

In aerospace industry, the selection of the materials is very important steps before designing and constructing the aircraft. The characteristics of the materials that are typically selected are based on light-weight properties, high strength, and resistance to fatigue and corrosion. The main purpose of selecting these characteristics is to improve the performance of the aircraft and making the next aircraft generation more efficient. In accordance to the materials that have high strength-to-weight ratio and resist to corrosion, aluminium is known as one of the best materials which possess all of these properties when compared with other materials (Ozer & Karaaslan, 2017).

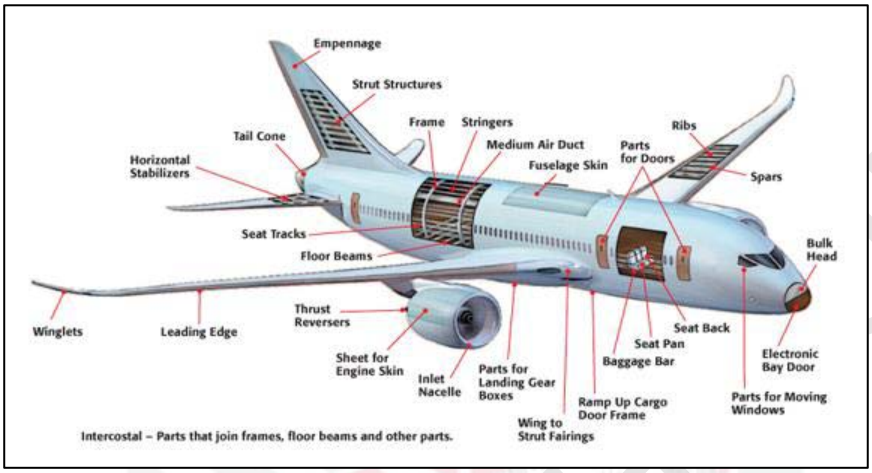


**Figure 1.3: Aluminium used in the aircraft structure (Source: Skymaster, 2016)**

Besides that, there are many possible points can be defined on aircraft to measure the stress. For analyze the internal stresses in structural element especially in aircraft, the amount of shear plane subjected on the structure is very useful information for engineers. This is because it is significant to analyze the shear stress to prevent the structure from mechanical failure. The structure will buckle and literally slip with each other when the structure cannot cater the high amount of shear stress applied on the structure. Screws, rivets and bolts are known as some parts of the aircraft that are often exposed to shear force (Federal Aviation Authority, 2002). The example of buckling analysis on aircraft panel can be seen as illustrated in the following Figure 1.4. Based on the figure, the analysis shows that the panels still can continue to carry more loads even after reach the buckling point in a stable manner.

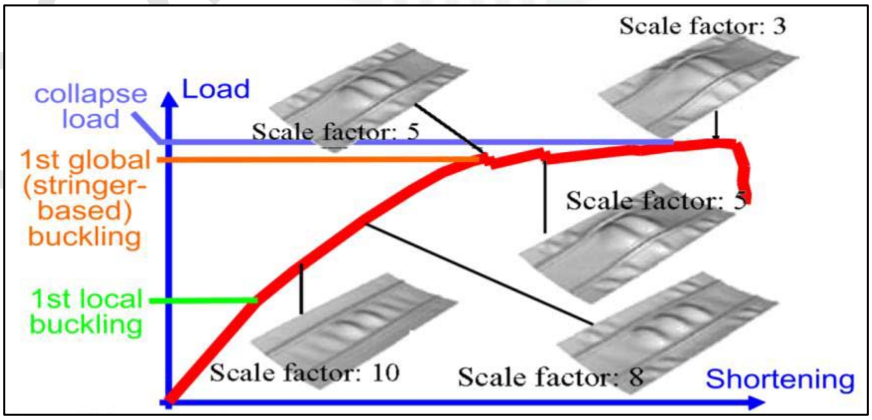


**Figure 1.4: Buckling modes of the aircraft panel (Source: Vakulenko, 2014)**

In addition, the structure of plates also can come in many forms such as square plate, rectangular plate and annular plate. Additionally, these plates' structures also can come out with forms of whether with cut-out design or without cut-out design (Nemeth, 1996). Generally, the plates with cut-out designs or known as perforations is typically required by practical and design consideration in many industry such as civil, marine and aerospace industry. The reasons of cut-out designs are primarily required and selected as structural elements because it can reduce the weight of the structure, and provide spaces for inspection and services (Azmi, et. al, 2017).

In contrast, the presence of the cut-out design on thin plate structure also has its negative effect. Although the presence of this cut-out design on thin plate structure can reduce the weight of the structure, however it also can change the stress distribution and reducing the strength on that plate structure (Yinjiang, et. al, 2015). This phenomenon indirectly will cause the buckling strength of the structure become lower, in which the capacity of the structure to withstand a higher load is decreases. However, the strength for the plate with cut-out design is greatly influenced by the size, shape and location of the cut-out on that structure (Jana, 2016).

Since there have many parts of the aircraft that are exposed to vary stresses due to many loads that may be subjected to the structure, thus this research determine to focus current study on the aircraft panel to investigate the effect of cut-out plates when subjected to shear loading. Therefore, the investigation and improvement on the strength of the structure which is subjected to shear load is important to prevent the mechanical failure of the structure. The failure of the structure can leads into the catastrophic effect.

Since the aluminium plate structures on aircraft are often subjected to many stresses such as compression, torsion and etc., thus this research is focusing only on shear stress. Generally, shear stress is defined as force per unit area. Shear stress is commonly caused by the forces that have a tendency to cause one layer of a material to slip over an adjacent layer. A shear stress that is subjected on the aircraft is known as shear plane, where the direction of the shear stress is parallel to its stress plane.

For current study, the basic geometries considered to conduct the study on the buckling behavior of the aircraft panel are square thin plate and rectangular thin plate as illustrated in Figure 1.5. The thickness of both square plate and rectangular plate are fixed at 1 mm throughout the study. In case for square plate, the geometry are then is modified into the perforated plate design by removing the center part of plates in a circular shape. Then, the size of the centrally circular cut-out on the square plate is changes according to the aspect ratios d/b of 0.1, 0.2, 0.3, 0.4 and 0.5.

For rectangular plates, there are two basic geometries designs for buckling analysis were performed which are known as plate with single hole and plate with multiple holes. The purpose of this study is conducted to investigate the influence of hole quantity on the plate structure when subjected to shear load. Additionally, the types of holes or cut-out on the plate are designed as centrally circular shape to ensure that the load distribution of shear load on the plate structure is uniform. The size of holes on the plates is varying based on the aspect ratios d/b of 0.1, 0.2, 0.3, 0.4 and 0.5. For plates with multiple holes, the quantity of the hole applied on the plates is based on the size of the plates with aspect ratios a/b of 2, 3 and 4. At the final stages, a stiffener is added on both geometries of square plate with cut-out and rectangular plate with cut-out.

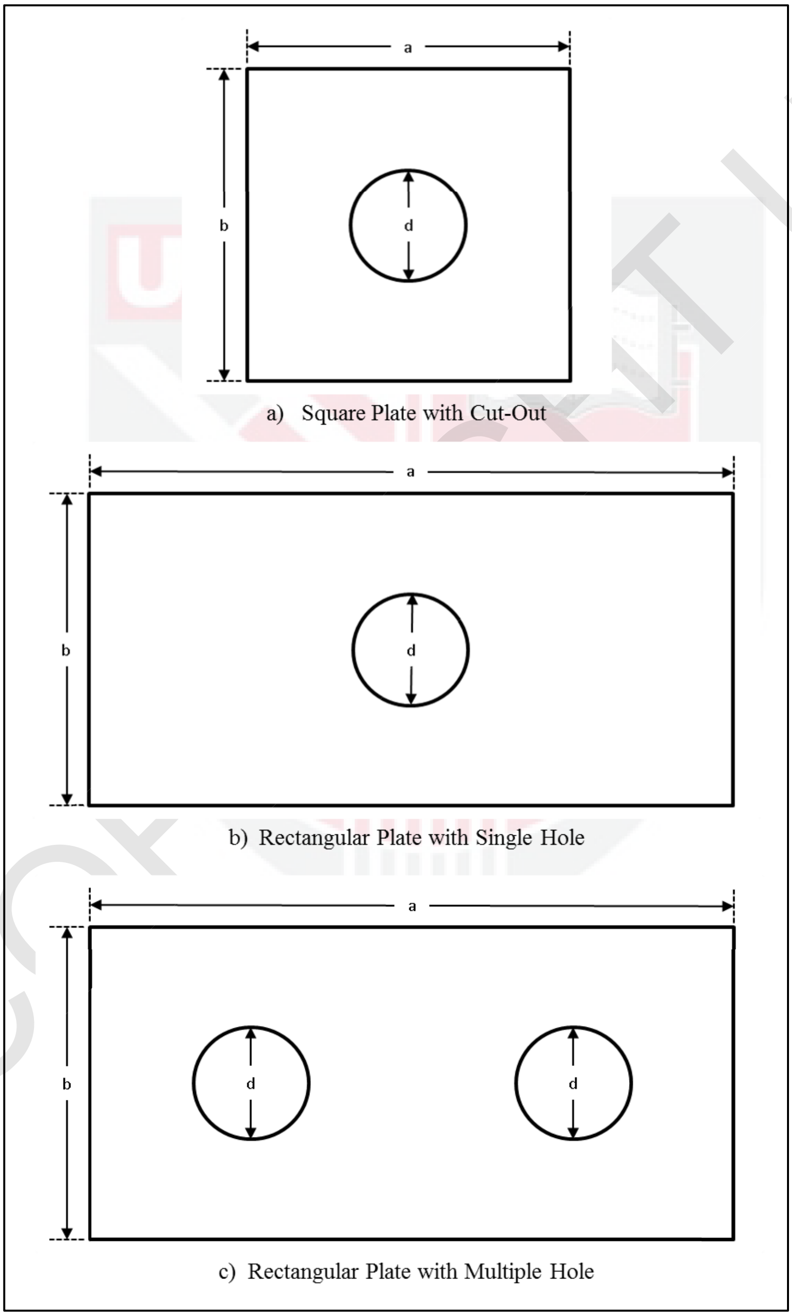


**Figure 1.5: Three different basic geometries of perforated plates**

The main purpose of the research is to investigate the influences of the stiffener on the cut-out plates when subjected to shear loading. Therefore, to obtain accurate results and to overcome the unrealistic problems during conducting the research, the current method was selected which is finite element software, ABAQUS/CAE 6.10. The method by using this finite element software is known as numerical method which will provide more accurate data and saving cost. However, the results obtain from the numerical method will be validate and verify with the theoretical data obtained from previous study before proceed to details study.

Furthermore, other important elements need to be considered before conducting the research is the material used in the research. Since the research is focusing on the wing part of the aircraft, therefore Aluminium 7075-T6 is selected based on its typical application in recent aircraft structure. Besides that, the reason of Aluminium 7075-T6 is selected due to its characteristics of high stiffness and high strength-to-weight ratio. The properties of Aluminium 7075-T6 such as the Young's Modulus, Poisson Ratio and density are referred from ASM Material Data Sheet (2001), which has the value of 71.7 GPa, 0.33, and 0.00281 g/mm$^3$ respectively.

## 1.3 Problem Statements of the Research

In recent times, the application of thin plate structures is widely used in the industries especially in aerospace industry. The thin plate structures have become high demand in the industries due to its light weight structures. In aerospace industry, the thin plate structures often come with perforations or cut-out design to produce more lighter and efficient structure based on the practical requirements. The application of thin plate structures with cut-out are commonly can be found in the wing part of the aircraft such as wing spar and cover panels. Additionally, the cut-out on the plate structure are typically designs in the center of the plates to provide access and services (Azmi, et. al, 2017). The structure of wing in the commercial aircraft and military aircraft are some example which required cut-out designs in its wing spars and ribs to provided access parts for mechanical and electrical systems, and for inspection of the damage.

Besides that, the designs of cut-out plates are also commonly influence the performance of the plates by the type of load applied on the structure (Zhou, et. al, 2017). Based on this matter, some study had been carried out by previous researcher to investigate and comparing the properties and the strength of thin plates structures with cut-out plates structure under some stresses such as compression and shear stress. The finding of the research found that even though the application of cut-out plate's structures contributes many advantages in the industries, however the strength of the cut-out plate's structures are reducing when compared to thin plate structures once its subjected to some stresses.

In aerospace applications, the cut-out structures on the wing of the aircraft are usually will experiences compressive loads that are induced either mechanically or thermally during flying condition, which can results in buckling of the panel (Sahu & Datta, 2003). According to the matters, it is significant to conduct the study on the buckling behavior of plate's structures with cut-out designs. Therefore, this research is conducted to overcome the strength-to-weight ratio problems and buckling behavior of cut-out plate structures by adding stiffeners on the cut-out plate's structures. In the meantime, this research determines to conduct the investigation on influences of the stiffener on the cut-out plate structures under shear loads.

In addition, the study on the influence of the stiffener on cut-out plates under shear loads are chosen based on very few information are available in the literature concerning the effect of stiffener on cut-out plate especially under shear force. This shows that there is no much attention has been given on the shear buckling behavior of cut-out plate with stiffener.

Furthermore, the difficulties in determining the shear buckling strength and behavior of such plates by using experimental method of analysis may be known as one of the reason for the problems. Therefore, a numerical method such as the finite element method would be the most suitable techniques for solving the problem based on the complication of the problems, such as caused by lack of symmetry in the plate thickness and the accuracy of cut-out location.

## 1.4 Objectives of the Research

The investigation is conducted by using numerical method which is known as finite element simulation software, i.e. ABAQUS/CAE 6.10. This software is chosen to be used in the present study due to its simple and consistent interface for creating, monitoring, and evaluating the results from the simulation. Besides that, this software is also known as one of the recommended FEA software to be used in conducting the structure analysis (Systemes, 2014). The main objective of this research is to investigate the effects of stiffeners on cut-out plate's structure when subjected to shear loads. Other than the main objective, several specific objectives come together with main objectives of this research, i.e.:

a) To develop finite element modeling and solution procedure for thin plate structure and perforated plate structure without stiffener and with stiffener under shear loading.

b) To verify and validate the shear buckling coefficient of thin plate structures obtained from numerical method with the existing theoretical value obtained from the literature studies.

c) To investigate the buckling behaviors of perforated plate structure without stiffener and with stiffener when subjected under shear loading.

### 1.5 Scopes of the Research

In order to achieve the objectives of the study, the understanding on basic buckling concept of thin plate is conducted especially when subjected to shear loads. In current study, the method to conduct the analysis is by using the numerical method only, i.e. finite element analysis (FEA) software. This method is considered to be used in present study because it can save time to gain the results and saving cost. Since current study use the finite element analysis (FEA) software, i.e. ABAQUS/CAE 6.10 to conduct the analysis, therefore the technique to use the software is learned.

In determining the best material for the current study, an investigation on the materials that will be used throughout the study is conducted through the literature study. The selection of the material for the study is based on the properties of the materials and its application that are widely used in recent industries especially in aerospace industry. The properties of the materials that have the highest demand in current industries is the material that posess high strength and light weight. Thus, the best material that has been selected to be used in the current study is Aluminium 7075-T6 due to its material properties and its typical application in aerospace industry.

Next, there are 2 types of basic model geometry considered for current study, which are non-perforated square plate and non-perforated rectangular plate. The size of the thin plate designed for current study is limit from plate ratio a/b of 1, 2, 3 and 4. The plate ratio a/b is limit into plate ratio a/b of 4 because based on Reddy (2007) statements, he found that the value of shear buckling coefficient for thin plate structure start to maintain at 5.70 after the plate ratio a/b of 4. The shear buckling analysis for both model geometries, i.e. square thin plate and rectangular thin plate structure are then analyzed by using finite element software, ABAQUS/CAE 6.10. The results predicted from the numerical analysis are verified and validated by referring to the existing theoretical data obtained from the literature study conducted. In order to ensure the results of the analysis is accurate and acceptable, thus the percentage error considered for current study shall be below than 5%.

Meanwhile, the detail study on shear buckling behavior of the plates is continued by removing the center part of the model. In order to provide consistency in the analysis, the type of hole considered throughout the analysis is circular shape. There are 2 cases of perforated plate conducted for the analysis, i.e. plate with single hole and plate with multiple holes. There are 5 sizes of hole considered for current study, i.e. hole ratio d/b of 0.1, 0.2, 0.3, 0.4 and 0.5. After that, the perforated thin plate models are analyzed by adding the stiffener around the circular shape of the hole region. The height of the stiffener added around the hole region is based on 50% of hole mass reduction.

Finally, the results for all investigation conducted for current study is analyzed and discussed to investigate the influence of the stiffener on the perforated plate structure when subjected to shear loads. In the meantime, the best thin plate designs that have high strength-to-weight ratio also are determined. Finally, the outcome for the study is concluded with some recommendation for future study.

## 1.6 Layout of the Thesis

The overall layout of this thesis contains five (5) chapters, and the content of these chapters are organized as following:

- Chapter 1: Introduction
  This chapter is generally summarized the overview of the research conducted on the influence of stiffener on perforated plates under shear loading.

- Chapter 2: Literature Review
  This chapter is discussing the literature review based on the previous study conducted and published paper related with shear buckling of thin plates.

- Chapter 3: Methodology
  This chapter highlights the method implemented in the research by using FEA software with the verification and validation of the numerical data obtained.

- Chapter 4: Results and Discussions
  This chapter provides the results and some discussions of the research which relates to shear buckling behavior of the plates when subjected to shear loads.

- Chapter 5: Conclusions and Recommendations
  This chapter presents a comprehensive conclusion based on the findings of the research conducted and some recommendation for future works.

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## Journals

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