MODAL ANALYSIS OF UAV AIRCRAFT STRUCTURES WITH DIFFERENT TAIL CONFIGURATIONS

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ABSTRACT

This thesis is to analyze the unmanned aerial vehicle aircraft structures using the modal analysis by using ANSYS Mechanical APDL software which requires an experienced student and the fundamental understanding of the ANSYS Mechanical APDL software. The three-dimensional beam element problems are considered to simplify the development which emphasizes on orderly procedure that involves the important element concepts such as natural frequency, and mode shape by using ANSYS Mechanical APDL result. The ANSYS's ability to manipulate the design of the unmanned aerial vehicle with different configurations which makes the analysis more concise and easy to use. The flexibility of the Finite Element Analysis with ANSYS Mechanical APDL through the computer implementation allows most of the problems to be easily modified into design projects.

MODAL ANALISIS STRUKTUR PESAWAT UDARA TANPA PEMANDU DENGAN KONFIGURASI EKOR YANG BERBEZA

ABSTRAK

Kertas kerja ini dihasilkan untuk menganalisis struktur kenderaan pesawat udara tanpa pemandu menggunakan analisis modal dengan menggunakan perisian ANSYS Mechanical APDL yang memerlukan pelajar yang pengalaman dan mempunyai pemahaman asas perisian ANSYS Mechanical APDL. Masalah unsur rasuk tiga dimensi dianggap memudahkan pembangunan yang memberi penekanan kepada prosedur yang teratur yang melibatkan konsep elemen penting seperti kekerapan semula jadi, dan bentuk mod dengan menggunakan hasil ANSYS Mechanical APDL. Keupayaan ANSYS untuk memanipulasi reka bentuk kenderaan udara tanpa pemandu dengan konfigurasi yang berlainan yang membuat analisis lebih ringkas dan mudah untuk digunakan. Fleksibiliti dalam analisis unsur terhingga dengan ANSYS Mechanical APDL melalui pelaksanaan komputer membolehkan sebahagian besar masalah yang perlu diubahsuai dengan mudah ke dalam projek-projek reka bentuk.

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

NURUL AQMAL SYUHAIDA BINTI AZLAN
Date:

STATEMENT 1

This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by giving explicit references. Bibliography/references are appended.

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STATEMENT 2

I hereby give consent for my thesis, if accepted, to be available for photocopying and for interlibrary loan, and for the title and summary to be made available to outside organizations.

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Nomenclature

M	Mass matrix, kg
K	Stiffness matrix, kg
F	Natural Frequency
b	Wingspan
l	Length of the fuselage
C	Damping Matrix
P	Force
$e^{i\omega t}$	Time response
ω	Radial Frequency
{U}	Eigenvector

ABBREVIATIONS

DOF	Degree of Freedom
SDOF	Single Degree of Freedom
MDOF	Multi Degree of Freedom
FE	Finite Element
FEA	Finite Element Analysis
FEM	Finite Element Method
FRF	Frequency Response Function
UAV	Unmanned Aerial Vehicle
RPV	Remotely Piloted Vehicle

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CHAPTER 1

INTRODUCTION

1.1 General overview

The concept is to learn about the natural frequencies affects the strength of the UAVs. The fuselage is one of the components that play the important role in the aerodynamic structure of the UAV aircraft. In nature, most of the flying animal or insect has the aerodynamic body shape that can resist the air resistance. Besides just focusing on the aerodynamic shape, it is also important to look at the structure's strength by measuring the natural frequencies and mode shape of the aircraft.

1.2 Unmanned Aerial Vehicle Aircraft

Any vehicle normally will have a pilot who control it to make sure it perform the function of the vehicle. But this unmanned aerial vehicle does not need any pilot to control it. Basically, the human or the pilot will control it on the ground. This will increase the safety of the pilot to avoid any injury. Most of the UAVs can be expendable or recoverable, it can incorporate in autonomous drones and remotely piloted vehicles (RPVs) and also can carry lethal or nonlethal payload. The UAVs is the segment of the unmanned aircraft system which incorporate a UAV, a ground-based controller and a system of communications between two.

There are six functional categories for UAVs:-

1. Target and decoy
2. Reconnaissance
3. Combat
4. Logistics
5. Research
6. Civil and commercial UAVs

The target decoy purpose is to give the ground and aerial gunnery target that reenacts an adversary aircraft or missile. The reconnaissance is in a combat zone in sight. The combat UAV ordinarily for high hazard missions assault capacity. The research and development to further advancement of the UAV technologies to be incorporated in field deployed UAV aircraft. While the civil and commercial UAVs is outlined, particularly for civil and commercial application only.

Besides, the UAV has also been used in combat as it has the capacity is to transmit to the Warzone administrator, continuous insight, observation, and surveillance data from antagonistic regions. It likewise goes about as a communication relay, assign targets for balance of different resources or assault the targets themselves with locally munitions and then loiter while gushing ongoing battle harm data back to friendly forces without taking a chance the aircrew's lives.

Figure 1.2 a: Ultra Stick 25

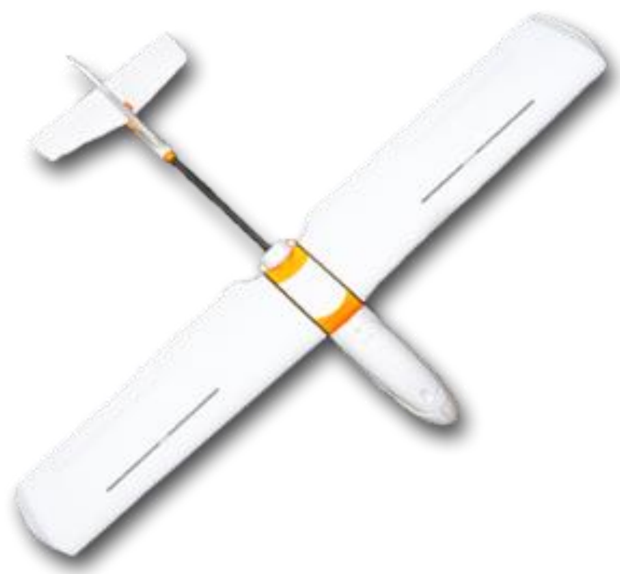

Figure 1.2 b: Skywalker UAV

In *Figure 1.2a* and *Figure 1.2b*, these are the two examples of aircraft that have been used as a guide because of the different type of fuselage. Both have a conventional figure aircraft. They have a straight wing and T-tail. The difference is only the tail configuration of the aircraft.

Specification	**Dimension**
Wing Span, b	1.27m
Fuselage Length, l	1.05m
Horizontal Tail Span	0.42m
Vertical Tail Height	0.21m
Material	Aluminum, Young Modulus = 69GPa Density = 2700 kg/m^3

Table 1.2a: Aircraft Specification

Basically, the manned and unmanned aircraft of the same type are similar physically, but there are exception where the cockpit and environmental control system or life support system. The payload that normally the UAVs carry is the camera which the weight is lighter than a human being. Therefore, their absence of the cockpit area and windows are the primary difference.

The early UAV only has a simple radio controlled aircraft that have been controlled by humans as a ground pilot. Now, the UAV is built in more sophisticated ways by built in control and guidance system which can perform low level human pilot duties like speed, flight path stabilization and simple navigation functions.

Nowadays, the UAVs has been no more just for military purpose. It is now has been used as a hobby of many people. Most of the people use the UAVs especially drone to capture most of the environment or picture from above. There also some people have used the UAVs for school or experiment purpose.

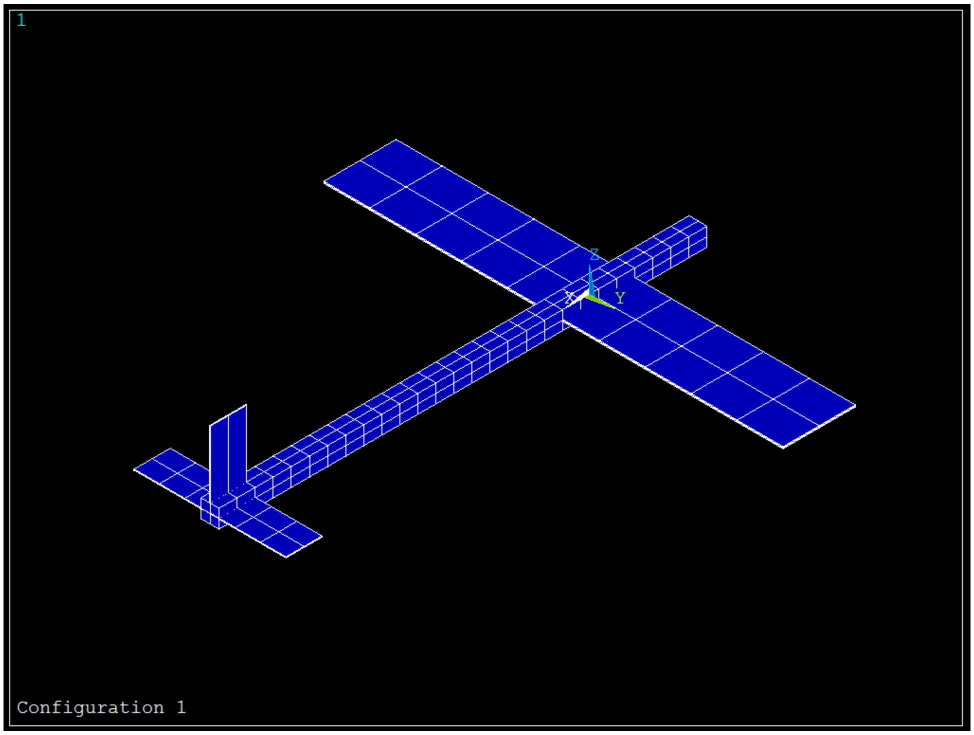

Figure 1.2 c: Fuselage Design for Configuration 1

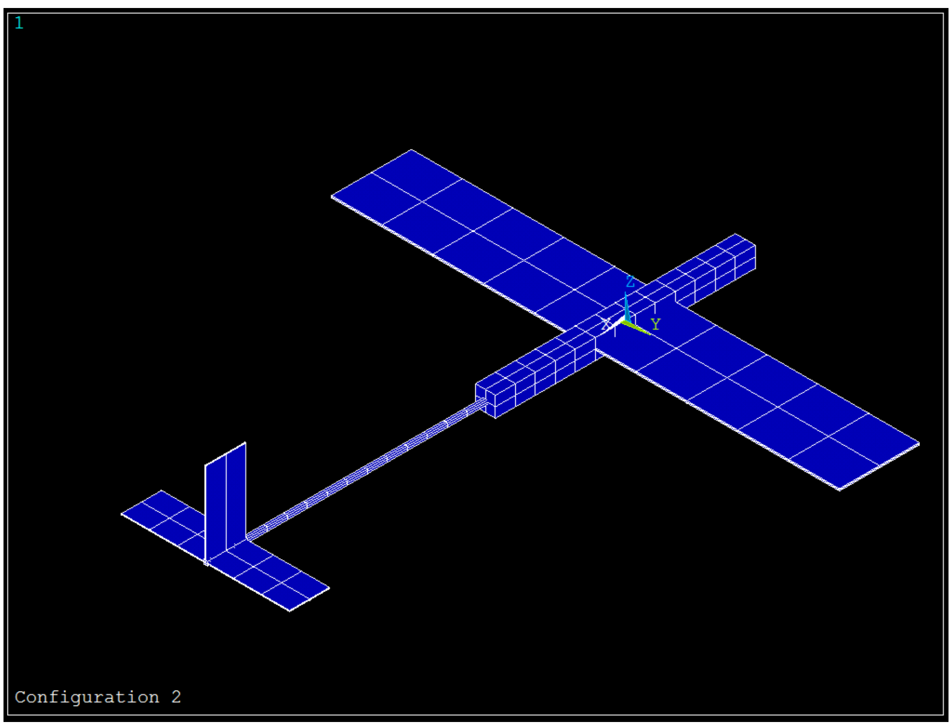

Figure 1.2 d: Fuselage Design for Configuration 2

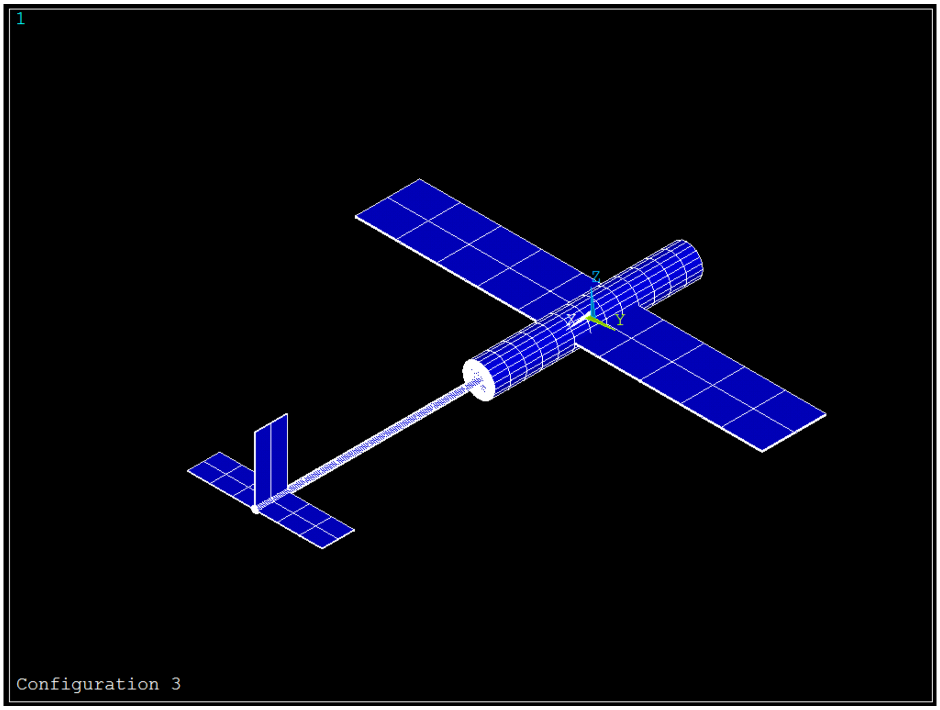

Figure 1.2 e: Fuselage Design for Configuration 3

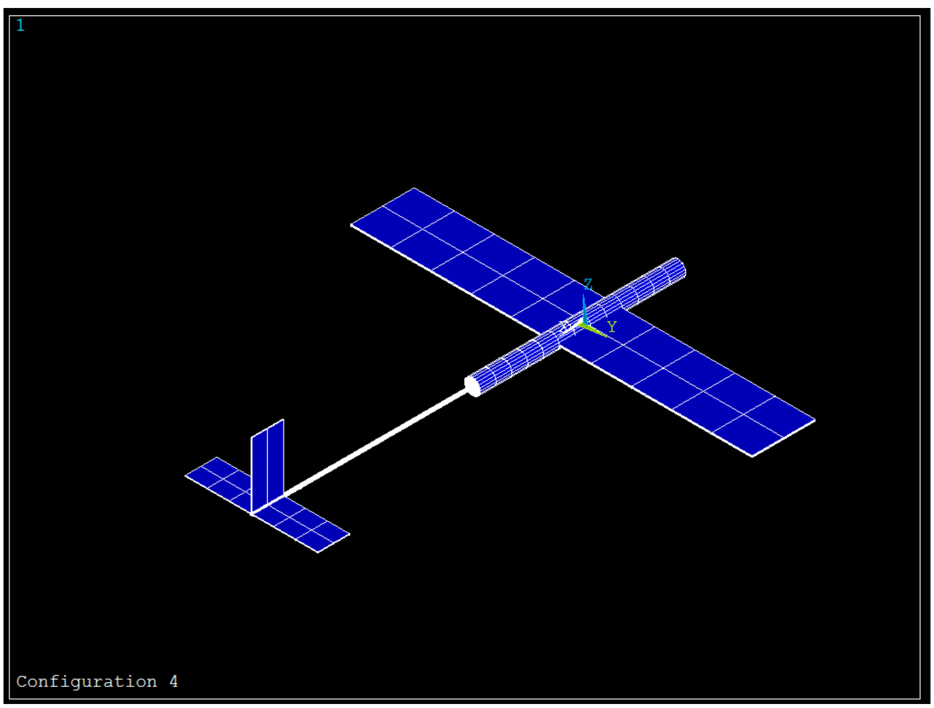

Figure 1.2 f: Fuselage Design for Configuration 4

All the figures from Figure 1.2c to Figure 1.2f are actually the model of an aircraft for this experiment. It is built is ANSYS Mechanical APDL. The benefit of using this simulation is that the geometry model can be built and changes according to the aircraft's purpose and it doesn't involve any money and a lot of time consuming to compute all the analysis.

1.3 Modal Analysis

Structural analysis is the most well-known application of the finite element method. The structural term suggests not just respectful designing structures, for example, as extensions and buildings, aeronautical and mechanical structures like ship hulls bodies, and aircraft bodies and also mechanical segment (cylinder, machine part and instruments). This structural analysis consists of almost seven types, for example, static analysis, modal analysis, harmonic analysis, transient dynamic analysis, spectrum analysis, buckling analysis and explicit dynamic analysis. But the modal analysis is the type of structural analysis that have been focused on.

The vibration characteristics (natural frequencies and mode shapes) of the structure or any machine and UAVs component is investigated by using modal analysis. It additionally can be begin staging for another, more definite, dynamic analysis as a transient dynamic investigation, a harmonic response analysis or spectrum analysis. The natural frequencies and mode shapes give influence on the structure element sensitivities. (Vanhonacker)

The most critical parameter in the design of a structure for dynamic loading condition is natural frequencies and mode shapes. The modal analysis can be done on a pre-stressed structure. In the ANSYS, the modal analysis is a linear analysis. The material properties only can be linear, isotropic or orthotropic or temperature dependent.

There are four steps for a modal analysis:-

1. Build the model
2. Apply loads and obtain solution
3. Expand the modes
4. Review results

The two solution methods are accessible for solving the structural problem in ANSYS, which are the h-method and the p-method. Normally the h-method can be utilized for any type of analysis, but the p-method can only be utilized just for linear structural static analysis. The h-method generally requires a finer mesh than p-method depending on the problem to be solved, but the p-method gives a fantastic approach to solve a problem to a coveted level of exactness while utilizing a coarse mesh. By and large, the discussion in this paper focuses on the procedures that requires for the h-method solution only.

The frequencies where the structure tends to oscillate in the absence of external excitation is one of the definitions for the natural frequencies of the structure while the mode shape is the shape at which the structures oscillate at these frequencies. The oscillation diverse into two categories, free and forced vibration. For the free vibration is no external force of excitation, but either kinetic or potential energy had been already in the system. The forced vibration is when there are external forces applied to the system. The frequencies at free vibration is the natural frequencies while the force vibration produces the excitation frequencies. (Nyyssonen)

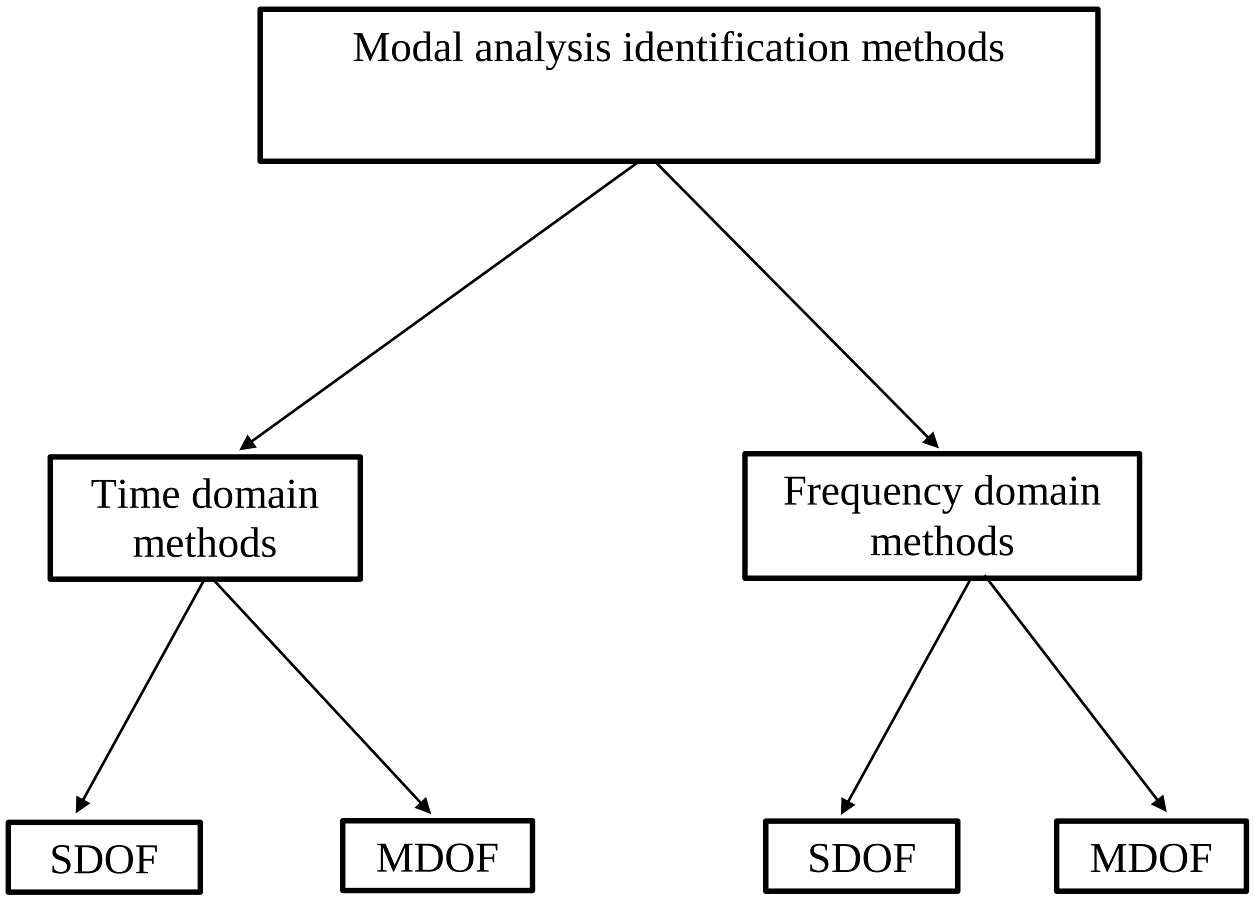

Figure 1.3 a: Classification of identification methods

The three criteria of the modal analysis technique can be classified as, first, the system responses when it can be measured whether in the time domain or the frequency domain. The advantages measuring in frequency domain is the accuracy of the result which can be improved by adding residual terms. But, there is also problem like leakage or the closeness of natural frequencies need to be treated carefully. Due to the problem, that is the reasons why the time domain method is easy to be used.

Secondly, by relying upon the quantity of modes which can be considered in the analysis, the choices between a single-degree-of-freedom (SDOF) and multi-degree-of-freedom (MDOF) method can be made. In the time area, it is unrealistic to isolate the contributions from the distinctive modes and an MDOF analysis has to be performed in the time domain.

Thirdly, there is some frequency domain method that cannot deal with frequency response functions at the same time from the several response locations. But the time domain method can. At the several points, the structure can be excited simultaneously, but this is the exception rather than the rule. (Kerschen)

In this case, the frequency domain have been used as it has the accuracy even though it is a little difficult to be used. From the number of modes that this experiment required for this analysis, the MDOF is used therefore it is impossible to use the time domain.

The purpose of modal analysis is to determine the shapes and frequencies where the structure will amplify the effect of a load. It will give the data at which frequency the structure will absorb all the energy that applied to it and how the mode shape looks corresponds to its frequency. The uniqueness of the modal analysis is that it can solve an equation for which there is no load applied and give the specific data on the behavior of the structure instead just reporting a response.

The reason why the modal analysis is important in the development of the aircraft are to find the loose component, decide the dangerous speed rotational, find the constraint or load structure, find how to move a node and modal dynamically. In addition, it can avoid from the resonance possibility and also to check the proper meshed of the structure. By doing the analysis first before fabricate an aircraft will save a lot of money, workload and time.

The modal analysis is one of the technique that have been proposed involving dynamic measurement in most aircraft development due to its capability of proper sensing systems integrated within the host structures to detect, identify and localize the damage generation.

It is important to gain this information within the structures of the aircraft during their operating life. The proper investigation technique is needed by using the latest technologies to determine the level of structure damages due to severe loading events thus ensuring the safety standard. (Andrea Cusano)