ICMMNT-2021 **ISSN: 2008-8019**

Special Issue on Proceedings of International Conference on Materials Manufacturing and Nanotechnology, June 2021. International Journal of Aquatic Science, Vol 12, Issue 03, 2021

Experimental Analysis of Aircraft Materials

P.Saranya*, S. Paul Arokiam

Assistant Professor, Department of Aeronautical Engineering

Nehru Institute of Technology, Coimbatore.

*nitsaranya@nehrucolleges.com[1]

Abstract: In an aircraft construction it is essential that materials with high strength/weight ratio be used for this reason, a designer tries to get last ounce of strength of each part, so the materials entering in to the construction of aircraft are more thoroughly tested. In this paper we are going to discuss about the commonly used test methods.

Introduction

In testing of aircraft material strength and weight ratio we commonly use two types of testing methods .These two types of methods are used in manufacturing companies .These methods includes testing of the material with various properties of the materials. Apart from these methods, different types of new methods have been imposed in the testing of different types of materials which we used for manufacturing process.

Principle

Testing methods have been imposed in different materials to verify its strength & weight ratio .Many types of modern methods have been used frequently nowadays.

Types of Testing

1. Destructive testing
2. Nondestructive testing

Destructive testing

Destructive testing is one in which the material is destroyed or broken after testing. The material cannot be used further. Below listed are types of destructive testing.

Figure: 1: Testing set up

1. Tension testing
2. Hardness testing
3. Bending test
4. Fatigue test

Nondestructive testing

Nondestructive testing is one in which the material does not undergo any type of destruction, so it can be used further. Nondestructive testing is used in the field of aviation for examining internal cracks, minute surface defects in welded, forged cast, joints. Below listed are some type of nondestructive testing.

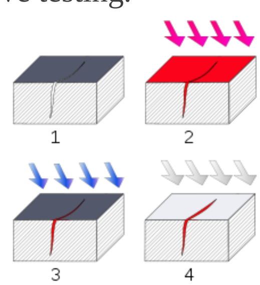

Figure: 2:

Special Issue on Proceedings of International Conference on Materials Manufacturing and Nanotechnology, June 2021. International Journal of Aquatic Science, Vol 12, Issue 03, 2021

1. Section of material with a surface-breaking crack that is not visible to the naked eye.
2. Penetrant is applied to the surface.
3. Excess penetrant is removed.
4. Developer is applied, rendering the crack visible

1. Radiography
2. Ultrasonic flaw detector
3. Magna flux

Destructive testing

Tension testing

Tensile testing, also known as tension testing, is a fundamental materials science test in which a sample is subjected to a controlled tension until failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation and reduction in area. From these measurements the following properties can also be determined Young's modulus, Poisson's ratio, yield strength, and strain-hardening characteristics. Unit axial tensile testing is the most commonly used for obtaining the mechanical characteristics of isotropic materials. For anisotropic materials, such as composite materials and textiles, biaxial tensile testing is required

Hardness testing

The Vickers hardness test was developed in 1921 by Robert L. Smith and George E. Sand land at Vickers Ltd as an alternative to the Brunel method to measure the hardness of materials. The Vickers test is often easier to use than other hardness tests since the required calculations are independent of the size of the indenter, and the indenter can be used for all materials irrespective of hardness. The basic principle, as with all common measures of hardness, is to observe the questioned material's ability to resist plastic deformation from a standard source. The Vickers test can be used for all metals and has one of the widest scales among hardness tests. The unit of hardness given by the test is known as the Vickers Pyramid Number (HV) or Diamond Pyramid Hardness (DPH). The hardness number can be converted into units of Pascal's, but should not be confused with a pressure, which also has units of Pascal's. The hardness number is determined by the load over the surface area of the indentation and not the area normal to the force, and is therefore not a pressure.

Bending test

The **three points bending flexural test** provides values for the modulus of elasticity in bending E_f, flexural stress σ_f, flexural strain ϵ_f and the flexural stress-strain response of the material. The main advantage of a three point flexural test is the ease of the specimen preparation and testing. However, this method has also some disadvantages the results of the testing method are sensitive to specimen and loading geometry and strain rate

Fatigue test

In materials science, **fatigue** is the weakening of a material caused by repeatedly applied loads. It is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. The nominal maximum stress values that cause such

Special Issue on Proceedings of International Conference on Materials Manufacturing and Nanotechnology, June 2021. International Journal of Aquatic Science, Vol 12, Issue 03, 2021

damage may be much less than the strength of the material typically quoted as the ultimate tensile stress limit, or the yield stress limit.

Non-destructive testing

Radiography

Radiographic Testing (RT), or **industrial radiography**, is a non-destructive testing (NDT) method of inspecting materials for hidden flaws by using the ability of short wavelength electromagnetic radiation (high energy photons) to penetrate various materials. Either an X-ray machine or a radioactive source, such as an X-ray computed tomography machine (Ir-192, Co-60, or in rarer cases Cs-137) can be used as a source of photons. Neutron radiographic testing (NR) is a variant of radiographic testing which uses neutrons instead of photons to penetrate materials. This can see very different things from X-rays, because neutrons can pass with ease through lead and steel but are stopped by plastics, water and oils.

Since the amount of radiation emerging from the opposite side of the material can be detected and measured, variations in this amount (or intensity) of radiation are used to determine thickness or composition of material. Penetrating radiations are those restricted to that part of the electromagnetic spectrum of wavelength less than about 10 nanometers.

Ultrasonic flaw detector

In **ultrasonic testing** (**UT**), very short ultrasonic pulse-waves with centre frequencies ranging from 0.1-15 MHz and occasionally up to 50 MHz are transmitted into materials to detect internal flaws or to characterize materials. A common example is ultrasonic thickness measurement, which tests the thickness of the test object, for example, to monitor pipework corrosion. Ultrasonic testing is often performed on steel and other metals and alloys, though it can also be used on concrete, wood and composites, albeit with less resolution. It is a form of non-destructive testing used in many industries
including aerospace, automotive and other transportation sectors.

Magna flux

Magnetic particle Inspection (**MPI**) is a non-destructive testing (NDT) process for detecting surface and slightly subsurface discontinuities in ferromagnetic materials such as iron, nickel, cobalt, and some of their alloys and must be performed to worldwide standards such as EN473 and ISO9712 by qualified personnel.[1] The process puts a magnetic field into the part. The piece can be magnetized by direct or indirect magnetization. Direct magnetization occurs when the electric current is passed through the test object and a magnetic field is formed in the material. Indirect magnetization occurs when no electric current is passed through the test object, but a magnetic field is applied from an outside source. The magnetic lines of force are perpendicular to the direction of the electric current which may be either alternating current (AC) or some form of direct current (DC) (rectified AC).

Newly Emerging Techniques

1. Structural qualifications of unique aircraft structures
2. Finite element analysis
3. Thermal NDT for aircraft repairs
4. Pyro technic testing for shock identification
5. Pneumatic shock system
6. Test method to access the fold ability of flexible structural materials

Special Issue on Proceedings of International Conference on Materials Manufacturing and Nanotechnology, June 2021. International Journal of Aquatic Science, Vol 12, Issue 03, 2021

Structural Qualification of Unique Aircraft Structures

This method is capable of applying static and dynamic loads with up to 18 independent hydraulic actuators. Coupled with this servo-hydraulic load control unit is a fully integrated 256-channel data acquisition system (DAS). Configurable for strain gages, LVDT's, or virtually any other strain gage-based or high level sensor. The DAS and load controller communicate and function simultaneously through software. Traditional test methods and test equipment have proven to fall short when applied to a space structure test requirements. While these test requirements are not limited to structural, static test operations, this paper will focus on conducting only static load tests.

Finite Element Analyses

FEA consists of a computer model of a material or design that is stressed and analysed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.There are generally two types of analysis that are used in industry 2-D modelling, and 3-D modelling. While 2-D modelling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modelling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively. Within each of these modelling schemes, the programmer can insert numerous algorithms (functions) which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to fracture.

FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress. Points of interest may consist of fracture point of previously tested material, fillets, corners, complex detail, and high stress areas. The mesh acts like a spider web in that from each node, there extends a mesh element to each of the adjacent nodes. This web of vectors is what carries the material properties to the object, creating many elements.

Results of Finite Element Analysis

FEA has become a solution to the task of predicting failure due to unknown stresses by showing problem areas in a material and allowing designers to see all of the theoretical stresses within. This method of product design and testing is far superior to the manufacturing costs which would accrue if each sample was actually built and tested.

Thermal NDT for Aircraft Repairs

Special Issue on Proceedings of International Conference on Materials Manufacturing and Nanotechnology, June 2021. International Journal of Aquatic Science, Vol 12, Issue 03, 2021

The purpose of a repair on a damaged area is to transfer through the patch the applied load(s) from one side to the other, by-passing the defected area. Such defects in the past were repaired by the use of metal patches, joined mechanically by the use of pins or screws. Since these repairs implied the formation of stress and strain concentrated areas around the fasteners, leading to additional structural problems, the alternative technique of using composite patches by employing adhesive films in order to attach the repair to the metallic structure is an important maintenance approach. In this technology, the patch is commonly formed from carbon or boron composite, applied onto a wider area of the defect on the metallic structure, with the direction of the fibers in parallel to the direction of the load(s). Composites offer a large number of advantages over the conventional aircraft material of aluminum higher specific strength and stiffness, superior corrosion resistance, improved fatigue performance, etc. Active thermo graphic approaches, using, firstly, a simple heat excitation source with an infrared camera , secondly, pulsed thermography (PT), thirdly, pulsed phase thermography (PPT) and lastly, thermal modeling, were used in the inspection of the composite aircraft repaired panels. PT is a popular thermal stimulation technique where the surface under investigation is pulse heated (time period of heating varying from a few milliseconds for high conductive materials such as metals to a few seconds for low conductive materials such as composites) using one or more pulse heating sources and the resulting thermal transient at the surface is monitored using a thermal camera. PPT combines the pulsed acquisition procedure of PT with the phase/frequency concepts of lock-in thermography for which specimens are submitted to a periodical excitation.

Pyrotechnic Testing For Shock Identification

Traditional methods of qualifying sensitive payloads for flight normally involve shock testing using pyrotechnic or drop testing methods. Pyrotechnic shock methods typically are slow and not very repeatable which add cost to testing as well as damage potential to the payload. Acoustic excitation, particularly with pyrotechnic simulation methods, is quite often ineffective at replicating loads seen in applications. A simple yet uncommon method has been utilized which provides several advantages to pyrotechnic shock testing as well as drop testing. The method uses a pneumatic gun to fire a captive projectile which impacts a mounting block. A picture of the system. Mounting blocks are designed to provide a Shock Response Spectrum (SRS) which is representative of a particular specification. Specifications normally are derived from acceleration response measurements at or near the location of the payload. Mounting blocks may be tuned using damping design techniques to more closely match a specification. The blocks provide a known shock environment for future testing of additional or different components. This method produces a highly repeatable and tenable shock input. The time between sequential shock events can be as little as a few minutes. Qualification in three axes can take less than half a day to complete. This method also provides a practical way to design and test mitigating structural elements such as shock isolators and whole spacecraft isolation systems

.

Pneumatic Shock System

The pneumatic shock test system developed consists of three main parts, the pneumatic gun, the mounting block and the test stand. Each part plays a significant role in the resulting SRS generated using the system. The pneumatic gun consists of an air tank, two air valves, and a captive projectile in the barrel. An input valve controls the amount of compressed air allowed to enter the air tank. The pressure is monitored with a standard pressure gauge. An output valve releases the compressed air from the tank into the barrel. This applies a near constant force on the bullet and propels it down the length of the barrel. The bullet is captive in the barrel. The Bullet's tip extends from the end of the barrel and strikes the mounting block. The mounting block is designed such that the modal dynamics predominantly shape the SRS. A target material is placed between the mounting block and the bullet which controls the pulse width or frequency content of the input. The payload is normally bolted onto the back of the mounting block. Accelerometers located near the payload measure the resulting shock event. Temperature control can be used to qualify articles which experience shock levels at other than ambient conditions. Temperatures below freezing can be accommodated. The test stand provides the boundary conditions for the test. In most cases, the boundary condition is free-free, meaning that the block is supported by a cable and is allowed to rotate about the cable as well as translate in the Horizontal plane, but not the vertical plane.

Test Method to Access the Fold Ability of Flexible Structural Materials

The proposed test method includes a tensile test to measure the tensile modulus of the coupon and an elastic buckling test to measure the material's ability to carry load. Both tests are conducted on the same 2.5 x 25 cm tabbed coupon. An example is shown in Figure: 1. These tests were selected 1) because they assess the coupon level characteristics that most strongly and directly influence a thin laminate's performance in a structural component and 2) because they are readily implemented without the need for extensive specialized tooling. Several additional constraints influenced selection of these tests. The test method needs to be non-destructive so that the same coupon can be tested, folded and tested again. This avoids the requirement that an unreasonably large number of coupons should be tested to achieve statistical confidence between different coupons. Also, folding precludes testing of very small coupons because they must be large enough to fold. The influence of folding can extend well beyond the actual fold region. The two tests necessitate some assumptions. It is assumed that laminate folding damage will manifest as a change in tensile stiffness of the laminate. If a large number of fibres break during folding, it is reasonable that this test would reveal a reduction in modulus. Similarly, delimitation or other matrix failures could result in the fibres retaining waviness after folding. This would also reasonably manifest as a reduction in tensile modulus as the fibres are pulled from a wavy to a straighter condition. A compressive modulus test would also be a good indicator of laminate performance since a compressive load would tend to increase any pre-existing delimitations or fibre waviness. A compression test that meets the non-destructive objectives of this study could not be found. A buckling test was selected for the second test only after careful consideration. Two boundary conditions were examined through finite element analysis simulations of a 38 mm long x 25 mm wide x 0.3 mm thick aluminium coupon with a central 10 mm long reduced elastic modulus fold region. Pinned-pinned boundary conditions were considered first because they concentrate the bending deformations towards the centre of the coupon. However, pinned-pinned boundary conditions require a short coupon and complicate folding. Fixed-fixed boundary conditions were not expected to be as sensitive to a modulus reduction because deformations occur at the coupon ends as well as the centre. Nonlinear load-displacement curves for each case are shown in Figure: 2. As expected, the pinned case is more sensitive to a centre region modulus reduction, though not dramatically. A 10% modulus reduction results in a 5.3% buckling load reduction in the pinned-pinned case and a 4.4% reduction in the fixed case. A 50% modulus reduction results in a 34% buckling load reduction in the pinned-pinned case and a25% reduction in the fixed-fixed case. Due to their ease of implementation and relatively good sensitivity to reduced modulus, fixed-fixed end conditions were selected. The test fixture was fabricated to clamp the coupon with fixed-fixed end conditions and a 38mm long free section. Recessed tab cut outs are included to accommodate the full 25 cm length of the coupon within the clamps. The buckling test must be elastic so that laminate damage does not occur. To ensure this, coupon free length should be 100-200 times longer than it is thick.

Types of engineering analysis

Vibration Analysis

It is used to test a material against random vibrations, shock, and impact. Each of these incidences may act on the natural vibrational frequency of the material which, in turn, may cause resonance and subsequent failure.

Fatigue Analysis

It helps designers to predict the life of a material or structure by showing the effects of cyclic loading on the specimen. Such analysis can show the areas where crack propagation is most likely to occur. Failure due to fatigue may also show the damage tolerance of the material.

Heat Transfer

This models the conductivity or thermal fluid dynamics of the material or structure. This may consist of a steady-state or transient transfer. Steady-state transfer refers to constant thermo properties in the material that yield linear heat diffusion.

Advantages

There are so many advantages in using these types of testing methods

1. It is used to find strength/weight ratio
2. It is used for examining internal cracks and minute surface defects in welding
3. It is used in aircraft manufacturing and repairs
4. It is used for finding different characteristics such as hardness, tension, bending and fatigue of the material

Conclusion

These methods are used for finding high strength/weight ratio of different types of materials that is required for manufacturing process of aircraft and it also includes verifying different material characteristics such as hardness, tension, bending .etc.

General References

1. Pyzdek ,T,"Quality Handbook",2003
2. Godfrey,A.B,"Jurans Quality Handbook",1999
3. Kimothi, S K,"TheUncertainity of measurements Physical and Chemical metrology Impact and analysis",2002