НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

АЕРОКОСМІЧНИЙ ФАКУЛЬТЕТ

КАФЕДРА ПІДТРИМАННЯ ЛЬОТНОЇ ПРИДАТНОСТІ ПОВІТРЯНИХ СУДЕН

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри
канд. техн. наук, доц.
________________О.В. Попов
«_____»_____________2021 р.

КВАЛІФІКАЦІЙНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ
«МАГІСТР»

ЗА ОСВІТНЬО-ПРОФЕСІЙНОЮ ПРОГРАМОЮ
«ТЕХНІЧНЕ ОБСЛУГОВУВАННЯ ТА РЕМОНТ ПОВІТРЯНИХ СУДЕН І АВІАДВИГУНІВ»

Тема: «Зносостійкість авіаційних композиційних матеріалів в умовах вібрацій»

Виконав: __________ **М.Ю. Лисенко**

Керівник: канд. техн. наук, доц. __________ **А.М. Хімко**

Консультанти з окремих розділів пояснювальної записки:

охорона праці: канд. біол. наук, доц. __________ **В.В. Коваленко**

охорона навколишнього середовища: д-р. пед. наук, проф. __________ **Т.В. Саєнко**

Нормоконтролер __________

Київ 2021

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
AEROSPACE FACULTY
AIRCRAFT CONTINUING AIRWORTHINESS DEPARTMENT

PPERMISSION TO DEFEND
Head of the department
Ph. D., Assoc. Professor
_____________ O. V. Popov
«____”_______________ 2021

MASTER'S DEGREE THESIS

(EXPLANATORY NOTE)

GRADUATE OF EDUCATIONAL DEGREE

«MASTER»

FOR EDUCATIONAL-PROFESSIONAL PROGRAM
«MAINTENANCE AND REPAIR OF AIR VESSELS AND AVIATION ENGENS»

Topic: «Wear resistance of aviation composite materials in the conditions of vibrations»

Created by: ___________**M.Y. Lysenko**

Supervisor: Ph. D., Assoc. Professor ___________**A.M. Khimko**

Advisers on Individual Sections:

Labour precaution: Ph. D., Assoc. Professor _____________**V.V. Kovalenko**

Environmental protection: Ed. D., Professor _____________**T.V. Sayenko**

Standards Inspector: _____________

Kyiv 2021

NATIONAL AVIATION UNIVERSITY

Faculty: Aerospace faculty
Aircraft Continuing Airworthiness Department
Educational and Qualifications level: «Master Degree»
The specialty: 272 «Aviation transport»
Educational-professional program «Maintenance and Repair of Aircraft and Engines»

APPROVED BY
Head of the department
Ph. D., Assoc. Professor
_____________ O. V. Popov
«____”______________ 2021

Graduate Student's Degree Work Assignment

LYSENKO MYKYTA YRIYOVYCH

1. The topic of the work: **« Wear resistance of aviation composite materials in the conditions of vibrations»** approved by the Rector's order of October 11, 2021 № 2196/ст.

2. The work fulfillment terms: since October 25, 2021 until December 31, 2021.

3. Initial data for the project (thesis): carbon fiber composite material Элур-П-0.1 and glass fiber composite material E-glass.

4. The content of the explanatory note: introduction, aviation composite materials analysis, composites use in aviation, fretting corrosion, diagnostic of composite materials, defects in composites, composites repair, wear resistance test procedure, methods of testing material and coatings of fretting in accordance with ГОСТ 23.211-80, fractography, composite materials durability under fretting corrosion impact, environmental protection, labour protection, general conclusion, references.

5. The list of mandatory graphic materials: title page, diploma work scheme, histograms that shows the composite samples wear, fractography of the samples and counter samples, recomandations.

6. Calendar schedule

Task	Fulfillment term	Completion mark
Literature review of materials for degree work	25.10.2021-01.11.2021	
Analysis of technological process of work fulfillment	02.11.2021 – 09.11.2021	
Preparation of necessary equipment for research carrying out	10.11.2021 – 14.11.2021	
Work on a special part of degree work	15.11.2021 – 22.11.2021	
Processing of research results	23.11.2021 – 30.11.2021	
Fulfillment of individual sections of degree work	01.12.2021 – 09.12.2021	
Processing of master's degree work	10.12.2021 - 25.12.2021	

7. Advisers on individual sections

Section	Adviser	Date, Signature	
		Assignment Delivered	Assignment Accepted
Labour precaution	Ph. D., Assoc. Prof. V. V. Kovalenko		
Environmental protection	Ed. D., Professo T.V. Sayenko		

8. Assignment issue date «_____»___________ 2021.

Degree work supervisor: __________________ A.M. Khimko
(signature)

Assignment accepted for fulfillment ___________________ M.Y. Lysenko
(signature)

ABSTRACT

Explanatory note to the diploma work «**Wear resistance of aviation composite materials in the conditions of vibrations**»

101 sheets, 38 pictures, 1 table and 45 references.

Object of the Research - the processes of wear of the most common composite materials in a pair with alloys D16T and BT22 under fretting corrosion.

Subject of the Research - composite materials based on carbon fiber and fiberglass Durability.

Aim of diploma work - Developing of the recommendations to improve durability of the composite materials under fretting corrosion impact.

Method of the Research is an analytical and experimental method of study of composite materials with bending under the conditions of freting corrosion using optical and physical methods for assessing surface damage. Practical meaning of diploma work results is determined by the scientific conclusions to the analysis of existing methods and devices application in the modern aviation.

Researching materials is recommended to use by prediction or corrosion managing in a sphere of aviation engineering.

COMPOSITE MATERIALS, FRETTING CORROSION, CRAWLE, FIBERGLASS, WEAR, WEAR RESISTANCE, AVIATION TECHNOLOGY.

CONTENT

INTRODUCTION

Over the past quarter century, the use of advanced composite material (ACM) has become almost commonplace in the aerospace industry - first proven through military applications, then increasingly in commercial and general aviation. As with many high tech systems, they were implemented aggressively into military aircraft production 10 to 15 years prior to widespread use in commercial aircraft [1]. Years of utilizing composite technology naturally precipitated a need to develop repair procedures.

Nevertheless metals still contain huge part of the market, and grounding on its history and strength are widely used at such parts of the aircraft as wings, engines, hydraulic systems, rivets, bolts, and others.

Now the most effective materials are metal and ACM. But during service life of this couple at the one aircraft rises some problem with durability and name of this problem is Fretting. Fretting, occurs when two materials are in contact and a great degree of relative motion, such as vibration, exists between the two. This can erode anti-corrosion coatings, or damage ACM structure thus initiating corrosion with further crack initiation. In metal-composite aircraft weakest points are near the engines. As wings of modern airplane mostly from ACM, spars of wings from the metal and points their connections may be the reason of dangerous fretting propagation.

ACM repair requires more than just the ability to read and follow the often vague steps in a technical manual (chiefly the Structural Repair Manual (SRM). Performing quality repairs demands more than mechanical skills - it requires the skill of a dedicated artisan. The technician must have a broad knowledge of materials and the knowledge of how these materials can and cannot be used to achieve that high quality repair - one that returns the part as close as possible to the original strength and stiffness without adding extra weight or protrusions that could affect airflow and/or the balance of critical flight controls.

In order to produce maximum efficiency from advanced composite materials during its operation we need to analyze existing market and technologies for fast, reliable and cost effective method of composite repair.

In order to provide maximum cost effectiveness from composites usage we can predict some damages and further rapid and sometimes catastrophic cracking of the material.

1. AVIATION COMPOSITE MATERIALS ANALYSIS

1.1 Composite materials

A composite in engineering sense is any materials that have been physically assembled to form one single bulk without physical blending to foam a homogeneous material. The resulting material would still have components identifiable as the constituent of the different materials. One of the advantages of composite is that two or more materials could be combined to take advantage of the good characteristics of each of the materials.

Usually, composite materials will consist of two separate components, the matrix and the filler. The matrix is the component that holds the filler together to form the bulk of the material. It usually consists of various epoxy type polymers but other materials may be used. Metal matrix composite and thermoplastic matrix composite are some of the possibilities. The filler is the material that has been impregnated in the matrix to lend its advantage (usually strength) to the composite. The fillers can be of any material such as carbon fiber, glass bead, sand, or ceramic [1].

Since the composites are non-homogeneous, the resulting properties will be the combination of the properties of the constituent materials. The different type of loading may call on different component of the composite to take the load. This implied that the material properties of composite materials may be different in tension and in compression as well as in bending.

1.1.1 Advantages of composite materials

The main advantage of most composites materials are in the weight savings. A quick way to illustrate this advantage is in the strength to weight ratio.

Different materials has different strength, that is each material can take different of amount of load for the same volume (cross sectional area) of the material. For a given design, the material used must be strong enough to withstand the load that is to be applied. If a material selected is not strong enough, the part must be enlarged to increase the load bearing capacity. But doing so increases the bulk and weight of the part. Another option is to change material to one that has high enough strength to begin with.

1.1.2 Matrix

Role of matrix:

• bond the fibers;

• protect the surface of the fibers from mechanical abrasion;

• provide shear stress transfer;

• provide a barrier against adverse an environment.

Matrix material requirements:

• elongation greater than that of fibers. Should be better then a fibers;

• form strong joint with the fiber (large value of interfacial shear strength);

• and it has to have a low surface tension (easy wetting to fiber);

• processing capability(viscosity, cure temperature, etc.);

• chemical stability;

• thermal expansion coefficient greater than that of fibers.

It means that during manufacturing of composite, matrix will develop a compressive stress against the fibers.

Types of matrix:

• polymeric matrix – thermoset;

o epoxies, has to be cured at a higher temperature and over a long time period so it’s not suitable for mass production;

o polyester, vinyl esters, phenolics;

o polyimides, polybenzimidazoles (PBI), polyphenylquinaxaline (PPQ) – the matrix for high-temperature composite.

When epoxy gets to the 93, 120 degrees of ^{o}C, the mechanical properties drop significantly.

• polymeric matrix – thermoplastic;

o nylons, thermoplastic polyesters (PET, PBT), polycarbonate (PC), polyacetals;

- polyamide – imide(PAS), polyether-ether ketone (PEEK), polysulfone (PSUL), poly-phenylene sulfide (PPS), polyether imide (PES);

• metal matrix;

- aluminum and its alloys, titanium alloys, magnesium alloys, copper – based alloys, nickel – based super alloys, stainless steel.

1.1.3 Fibers

Glass fibers:

- e-glass – most commonly used, good strength, good stiffness, good electrical properties;
- s-glass–more expensive than E-glass, higher young's modulus, more temperature resistant.

Carbon fibers:

Carbon fibers is a material consisting of fibers about 5–10 μm in diameter and composed mostly of carbon atoms.

Properties of carbon fibers are such as:

- high Strength to weight ratio;
- good rigidity;
- corrosion resistant;
- electrically conductive;
- fatigue resistant;
- good tensile strength but brittle;
- fire resistance/not flammable;
- high thermal conductivity in some forms;
- low coefficient of thermal expansion;
- nonpoisonous;
- biologically inert;
- x-ray permeable;
- self-lubricating.

Fiber orientations

Typical composite structure is made of fibers with different fiber orientations. The angle between fibers orientations is called theta (θ) [2].The carbon fiber is extremely strong when $\theta = 0^0$ (zero ply). In the other direction, $\theta = 90^0$ is plastic. And the ratio of the strength to the plastic strength is about 100 times. So the fiber direction is 100 times stronger than the other direction. When we design composite structures, we don't just use zero, because it becomes very weak in the other direction. Dependences of tensile strength versus orientation for a unidirectional tape fiber are shown at figure 1.1 [2].

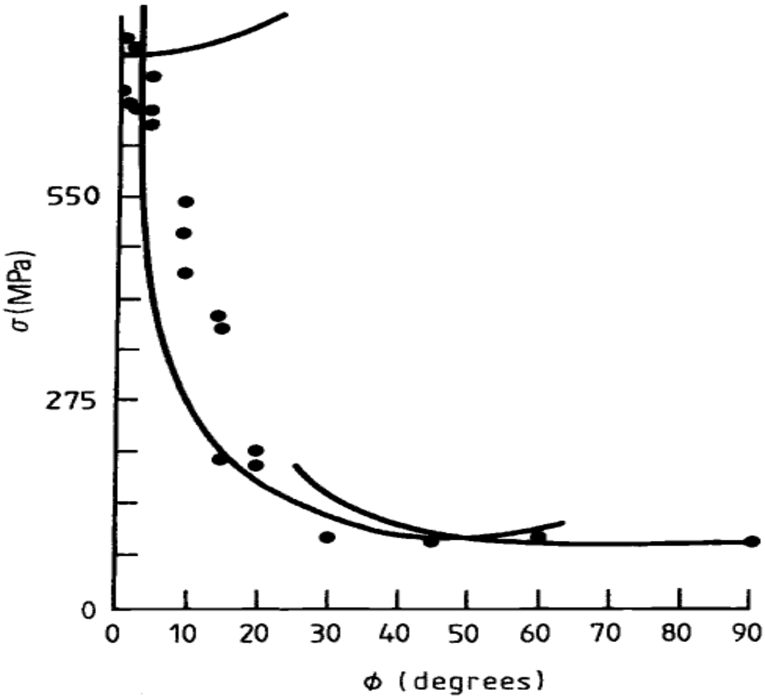

Figure 1.1 –Variation of tensile strength versus orientation for a unidirectional tape

1.1.4 Prepreg

Prepreg is the name given to composite reinforcement materials, such as carbon fiber, that have been pre impregnated with activated resin. The resin system used is almost exclusively epoxy resin, which has already mixed with its hardener at the manufacturing stage, before being impregnated into the dry reinforcement fabric to make the ‘prepreg’ reinforcement.

1.2 Composites use in aviation

Common composite materials used on airplanes include fiberglass, carbon fiber, and fiber-reinforced matrix systems, or any combination of any of these.

According to the FAA, the composite material has been around since World War II. Over the years, composite material has become more popular, and it's now used in many different airplane types, as well as gliders.

About 35 percent of the nation's aircraft structures were made of composite material in 2005. Today, aircraft structures are commonly made up of 50 to 70 percent composite material.

Boeing rolled out its new 787 Dreamliner in 2012, boasting that it was 50 percent composite material. And in 2013, the A350-XWB, which is also made of at least 50 percent composite materials, took flight. New aircraft rolling off the line today almost all incorporate some kind of composite material into their designs.

Composites continue to be used frequently in aviation due to numerous advantages. Some say that these materials pose a safety risk to aviation, though, citing a few drawbacks.

Advantages

Most of the time, the use of composite materials on an aircraft structure reduces weight. Fiber-reinforced matrix systems are stronger than traditional aluminum found in most aircraft, and they provide a smooth surface and increase fuel efficiency.

Composite materials don't corrode as easily at other types of structures. They don't crack from metal fatigue and they hold up well in structural flexing environments. Composite designs also last longer than aluminum, which means fewer maintenance and repair costs.

Disadvantages

Composite materials don’t break easily, but that makes it hard to tell if the interior structure has been damaged at all.

In contrast, aluminum bends and dents easily, making it easy to detect structural damage; the same damage is much harder to detect with composite structures. Repairs can also be more difficult when a composite surface is damaged.

The resin used in composite material weakens at temperatures as low as 150 degrees, making it important for these aircraft to avoid fires. Fires involved with composite materials can release toxic fumes and micro-particles into the air. Temperatures above 300 degrees can cause structural failure.

Finally, composite materials can be expensive, but the high initial costs are typically offset by long-term cost savings.

1.2.1 Composites role in the aircraft engines

Fan

The fan on a modern jet engine drives most of the air entering the air intake round the outside of the jet core and out of the back of the nacelle, in doing so accounting for 70-90% of the engine’s total thrust. The remaining percentage is due to the core, the true jet portion of the engine. This latter also powers the fan which can be likened to a large propeller, however with a greater number of blades and revolving at higher speed. In the latest turbofan engines, up to 12 times more air is driven round the engine core than passes through the core itself, the actual proportion being referred to as the by-pass ratio [3].

Traditionally, fan blades have been made from metal, usually titanium, but aero engine manufacturers can now save substantial weight by substituting composites. Similarly, the containment case, there to contain the results of any blade separation and prevent high-speed debris from impacting the airframe or aircraft systems, can now be composite rather than metal or a metal-composite hybrid (typically aluminium over-wrapped with aramid).

Weight saved in the fan/containment case pairing has a knock-on effect, enabling components such as shafts and bearings, the pylons which attach the engine to the wing and the associated wing structure to be made lighter also. In aggregate, half a ton or more can be saved per engine, a prize well worth having given the high price of aviation fuel today.

Composites are also more durable, notably having greater tolerance to fatigue than metal, and can be moulded into shapes that are nearer to the three-dimensional aerodynamic ideal. They also resist creep, the outward expansion that can occur in metal blades due to centrifugal force generated at revolution rates of around 2500 rpm (typical fan rate in cruise), meaning that the clearance engineered initially between the blade tips and the surrounding duct has to be greater than it should be for optimum engine performance.

Rolls-Royce was a notable pioneer of composite fan blades the first company to successfully introduce a commercial jet engine having such blades was American engine maker GE. Its initial GE90 engine, which first entered service on British Airways Boeing B777 long-range widebody twinjets in 1995, has a by-pass ratio of 8.4 and a 3 m diameter fan having 22 wide-chord fan blades that are moulded in a toughened epoxy resin reinforced with high-grade carbon fibre. A polyurethane surface coating reduces wear on the blade while a titanium leading edge provides protection against strikes from birds, ice chunks and other ‘foreign objects‘. This titanium guard, which also provides the required sharp leading edge that is difficult to engineer in composite, is replaceable and can be re-blended.

Turbine

Also one of the main revolutions in composite technology is the ceramic matrix composites (CMCs). What’s so innovative about CMCs is that they can be made as strong as metal, yet are much lighter and can withstand much higher temperatures. These advantages will lower fuel burn and emissions, while increasing the efficiency of future aircraft engine platforms. CMCs can operate at temperatures exceeding the capability of current nickel alloys typically used in high-pressure turbines. Today’s metal parts require extensive dedicated cooling air. This directly takes away from the primary engine airflow and reduces efficiency. CMCs can operate with little or no cooling, providing a significant efficiency boost to the cycle. CMCs also are one-third the weight of nickel [4].

Because the rotating turbine blades made from CMCs are one-third the weight of conventional nickel alloys used in the high-stress turbine, they allow engineers to reduce the size and weight of the metal disks to which the CMCs system is connected. The lighter blades generate smaller centrifugal force, which means that you can slim down the disk, bearings and other parts. CMCs allow for a revolutionary change in jet engine design.

Nacelle of the engine

Composites are selected for nacelles for several reasons: the most obvious being weight. Most business jets have a rear-mounted engine, as far back from the center of gravity as you can get. By making the engine nacelle and thrust reverser lighter, it not only saves weight at the engine location, it saves overall aircraft weight, because you don't have to add as much weight in the nose to balance the plane.

Temperature resistance is yet another design driver, especially for thrust reversers. The cooler bypassed air tends to insulate the nacelle and thrust reverser panels from the hot core exhaust flux, making high-temperature (177°C cure) [2] epoxies an appropriate choice, as long as components in the immediate vicinity of the engine are protected with insulation. A composite resin system with a service temperature even greater than is required.

Increasing pressure to reduce aircraft noise has driven manufacturers to incorporate sound attenuation characteristics into nacelle and thrust reverser structures. While some panels and smaller access doors are solid laminates, the majority of the parts are structural cored sandwich panels, specifically designed to absorb acoustic energy yet strong enough to transmit loads between the engine and the aircraft. The inner panel skins that are in contact with engine airflow are perforated with thousands of holes, typically in the range of 1 mm in diameter. The perforations help to reduce the jet engine's noise by damping the energy response, directing the sound into the honeycomb core, rather than presenting a hard surface that simply deflects the sound. Most suppliers add a perforated inner septum or porous layer to the honeycomb core, effectively doubling the number of cells, for greater noise suppression and a wider range of attenuated frequencies. Cores are "septumized" using a variety of proprietary methods, such as dipping the core in resin or sandwiching material between two or more honeycomb layers.

1.3 Fretting corrosion

Fretting corrosion has been the cause of countless failures at the contact points of machinery components. Fretting is a special wear process that occurs at the contact area between two materials under load and subject to minute relative motion by vibration or some other force. [5]

When two pieces of material that are contacting each other in an un-lubricated environment (look figure 1.2) are subjected to a large cyclic loading (vibration, dynamically-changing applied load, etc.), so that small oscillatory motions occur with respect to each other, wear will occur on the mating surfaces. Examples of that type of contact include bolted flanges, riveted lap-joints, press-fits such as a gear or bearing on a shaft, and dry (unlubricated) splined components.

If the magnitude of the displacement is less than about 75µm, the wear is termed "fretting".

Fretting occurs when asperities on the mating surfaces continually adhere to each other (see figure 1.2), then tear apart, which causes tiny particles to be pulled free from the surfaces and which leaves minute shallow pits and powdery debris. If the debris is exposed to air, the small fragments of metal which have been boken off will oxidize, forming oxide particles which, for most engineering metals, are harder than the mated parts. These particles become trapped between the mating surfaces and cause abrasive damage and scoring. In ferrous parts, the oxide is a red, rustlike powder or sludge, which led to the term "fretting corrosion".

Briefly, the characteristics of fretting are:

- it is most serious when oxygen is present, although it can also occur in an inert gas;
- it is worst under perfectly dry conditions;
- it increases with contact load, slip amplitude, and number of oscillations;

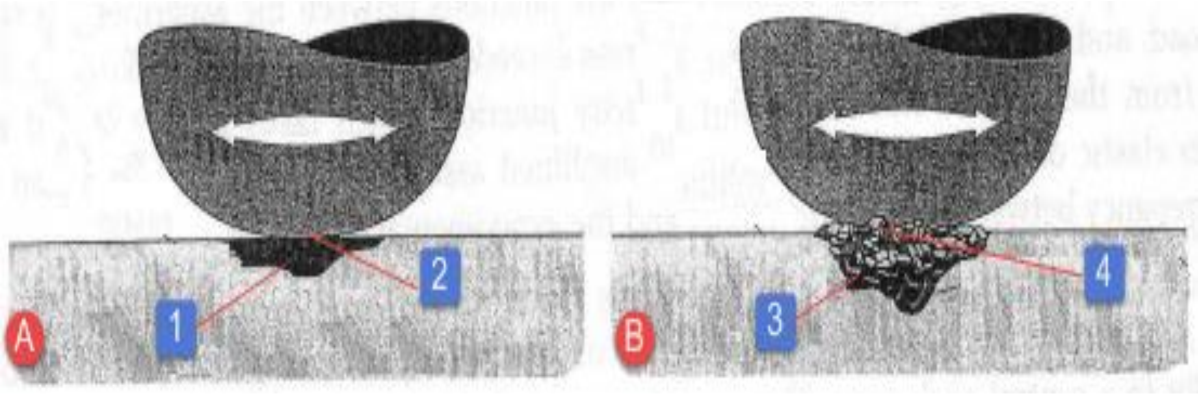

Figure 1.2 – Model of a 'Tribological transformed structure' in fretting.
A) No wear before formation of tribologically transformed structure (TTS)
B) Initial low wear period of fretting reaches completion when wear debris is released from TTS. 1. Plastic deformation; 2.fretting movement between ball and plate;3. fully transformed TTS; 4. superficial fretting debris layer produced by TTS;

Soft materials generally exhibit more susceptibility to fretting than do hard materials of a similar type; Lubricants, particularly when used with surface treatments such as phosphating, reduce fretting damage. Fretting appears to be particularly aggressive in cases of disks (gears, pulleys, wheels, flywheels, bearings, hubs, etc.) which are press-fit (shrink-fit) onto shafts which are subjected to reversing bending stress, and worse yet under the added influence of vibration. The stress concentration which occurs where the shaft just meets the disk compounds the problem. Under fretting conditions, fracture cracks can initiate at very low stresses, well below the fatigue limit of non-fretted specimens. Fretting corrosion can reduce the endurance limit of steels to as little as 18% of their original values [6]. The greatest reduction in fatigue strength occurs when the fretting process and cyclic stressing are applied simultaneously. The fact that fatigue cracks can be formed under low nominal cyclic stresses in the areas where fretting is occurring is dramatically illustrated by the low fatigue limit of a shaft having a pressed-on bearing.

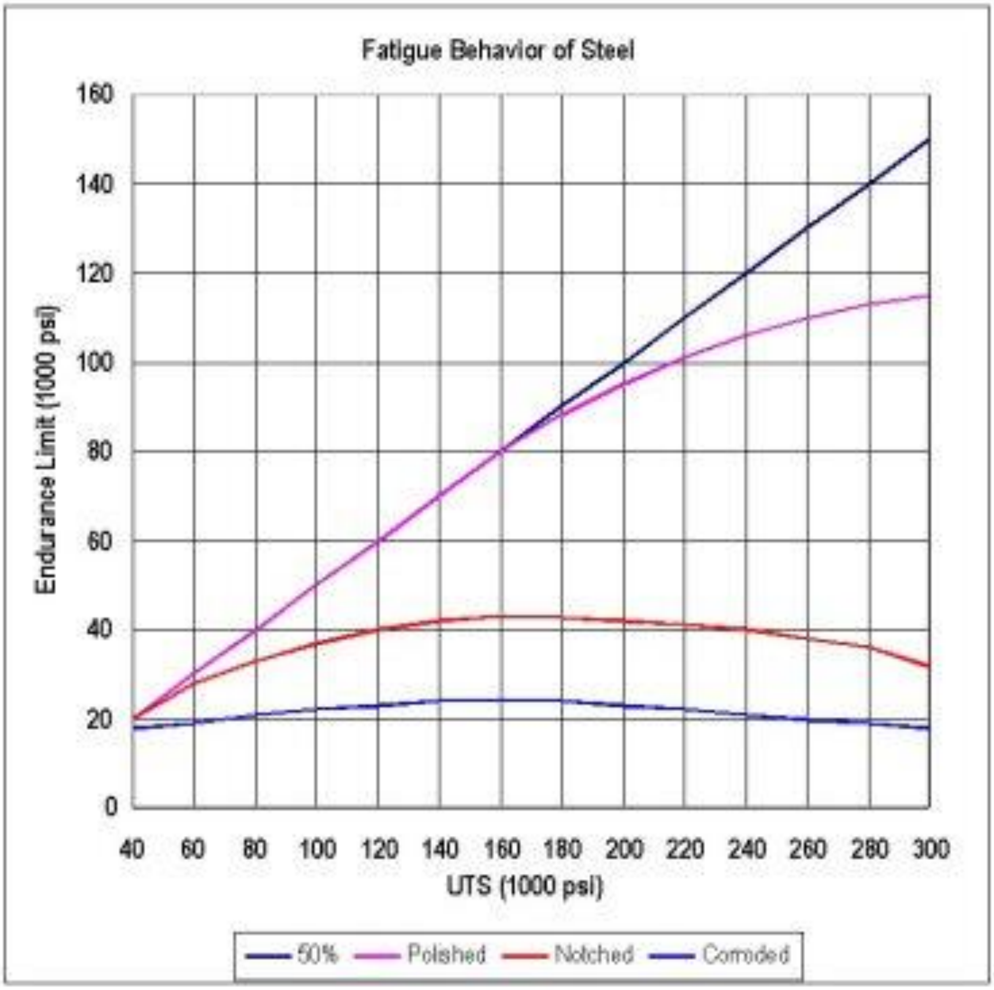

Figure 1.3 – Fatigue behavior of steel

This plot illustrates the dramatic effect that fretting has on the fatigue life of steels. The line titled "Corroded" mirrors the shape of the "notched" curve, but is much lower. The corroded curve shows that, for a badly corroded surface (fretting, oxidation, galvanic, etc.) the endurance limit of the material starts at around 20 ksi for materials of 40 ksi UTS (50%), increases to about 25 ksi for materials between 140 and 200 ksi UTS, then decreases back toward 20 ksi as the material UTS increases above 200 ksi [7].

Prevention of fretting fatigue in the design process is essential. Although there is ample descriptive material on the mechanism and examples of fretting, there is limited availability of generalized techniques or modeling methodology for the prediction of crack initiation due to fretting. Testing is usually required to find and validate a solution to a fretting problem.

1.4 Manufacturing of carbon fibers

The PAN(polyacrylonitrile) fiber offers the best mechanical properties. In another words it is a thermoplastic fiber. It goes to oxidation stabilization process at a temperature about 200 or 300 degrees °C (see figure 1.4). And the purpose is to convert the thermoplastic to thermoset. Then fibers going through a low carbonization temperature around 1,500 degrees °C. The product coming out of this is called carbon.

A typical carbon has the carbon concentration about 95% maximum. With the higher temperature of carbonization at about 2,500 to 3,000 degrees °C, the product coming out of this is graphite. Outcome productis treated with chemicals. Then process of fiber sizing . Carbon fibers are ready.

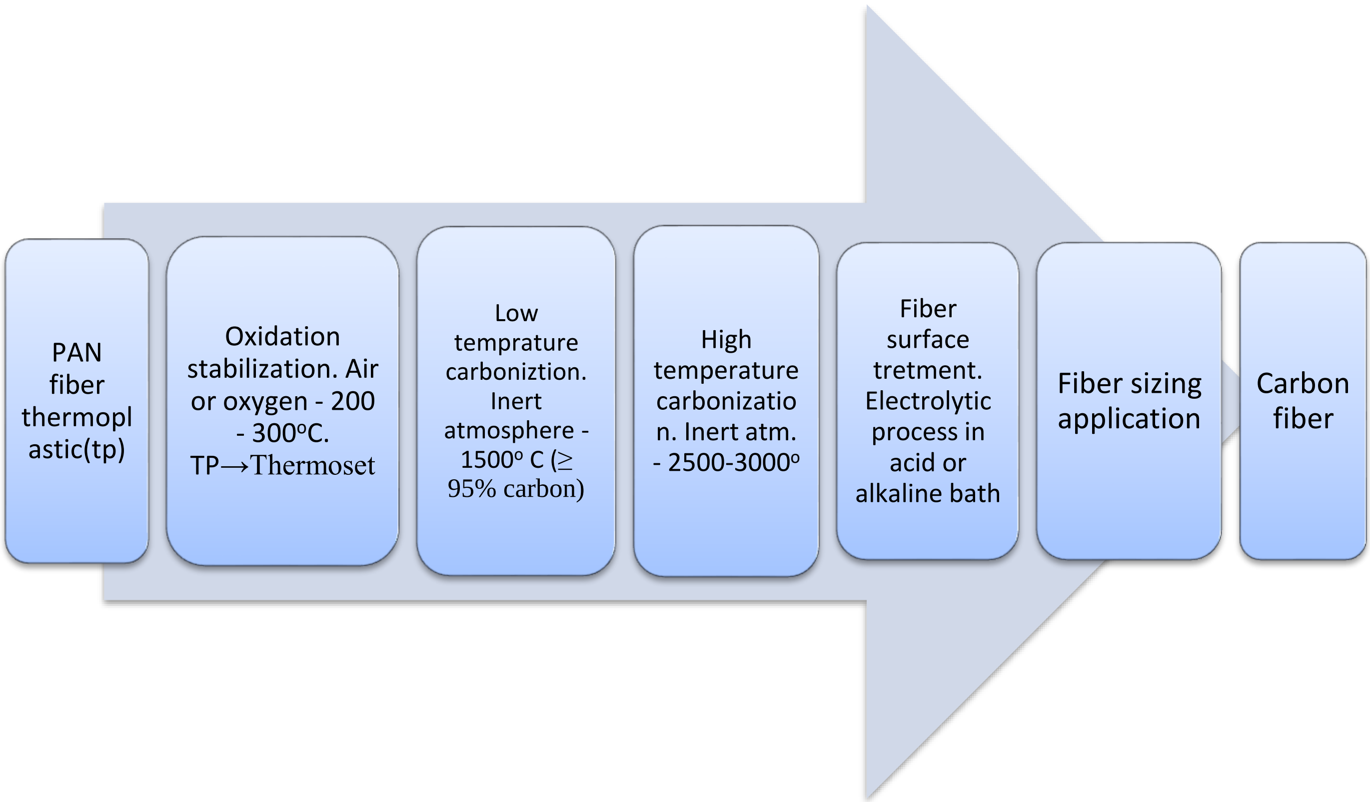

Figure 1.4 – Carbon fiber manufacturing

1.4.1 Prepreg manufacturing

In this process (see figure 1.5), all the fibers are combed to make them parallel. As the resin epoxy is made of thin film the fibers are embedded into the it through hot compactions, and then it collecting in a roll.

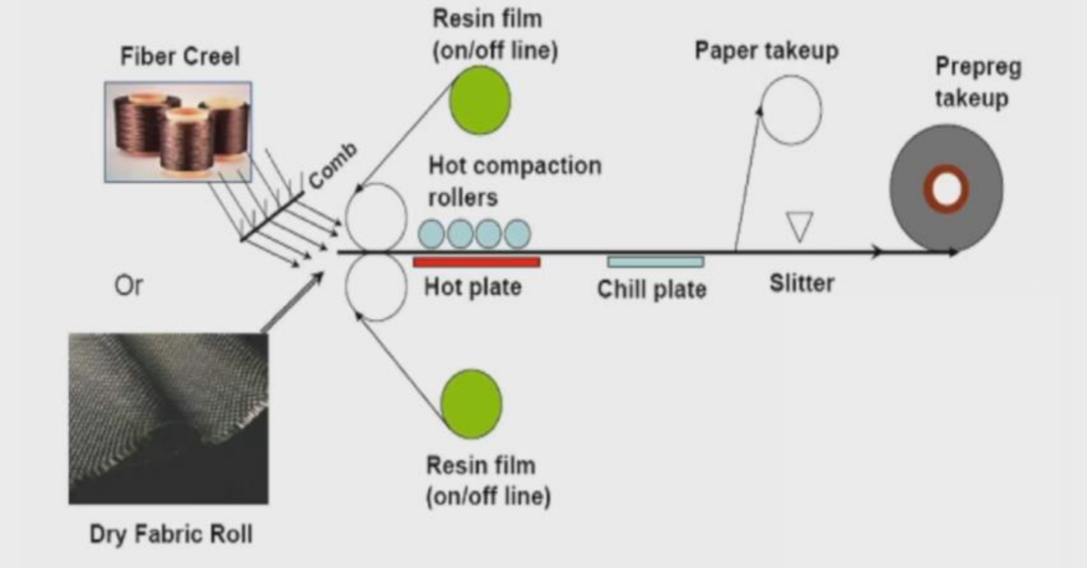

Figure 1.5 – Prepreg manufacturing

1.4.2 Manufacturing of composite structures

There are a lot of methods of composite manufacturing. Basic are:

- Hand layup
- Automated layup

Hand layup

Hand lay-up technique is the simplest method of composite processing. The infrastructural requirement for this method is also minimal. The processing steps are quite simple. First of all, a release gel is sprayed on the mold surface to avoid the sticking of polymer to the surface. Thin plastic sheets are used at the top and bottom of the mold plate to get good surface finish of the product. Reinforcement in the form of woven mats or chopped strand mats are cut as per the mold size and placed at the surface of mold after perspex sheet. Then thermosetting polymer in liquid form is mixed thoroughly in suitable proportion with a prescribed hardner (curing agent) and poured onto the surface of mat already placed in the mold. The polymer is uniformly spread with the help of brush. Second layer of mat is then placed on the polymer surface and a roller is moved with a mild pressure on the mat-polymer layer to remove any air trapped as well as the excess polymer present. The process is repeated for each layer of polymer and mat, till the required layers are stacked [1]. After placing the plastic sheet, release gel is sprayed on the inner surface of the top mold plate which is then kept on the stacked layers and the pressure is applied. After curing either at room temperature or at some specific temperature, mold is opened and the developed composite part is taken out and further processed. The time of curing depends on type of polymer used for composite processing. For example, for epoxy based system, normal curing time at room temperatur is 24-48 hours. This method is mainly suitable for thermosetting polymer based composites. Production rate is less and high volume fraction of reinforcement is difficult to achieve in the processed composites.

Automated layup

- The ply pattern is preprogrammed into the machine (see figure 1.6).
- The head is loaded with a roll of prepreg tape 75mm wide is typical.
- The machine lays the tape onto the mold in the patter that has been programmed.
- The head of the tape placement machine has the capability of following both simple and compound contours.
- All cutting and trimming is done automatically.

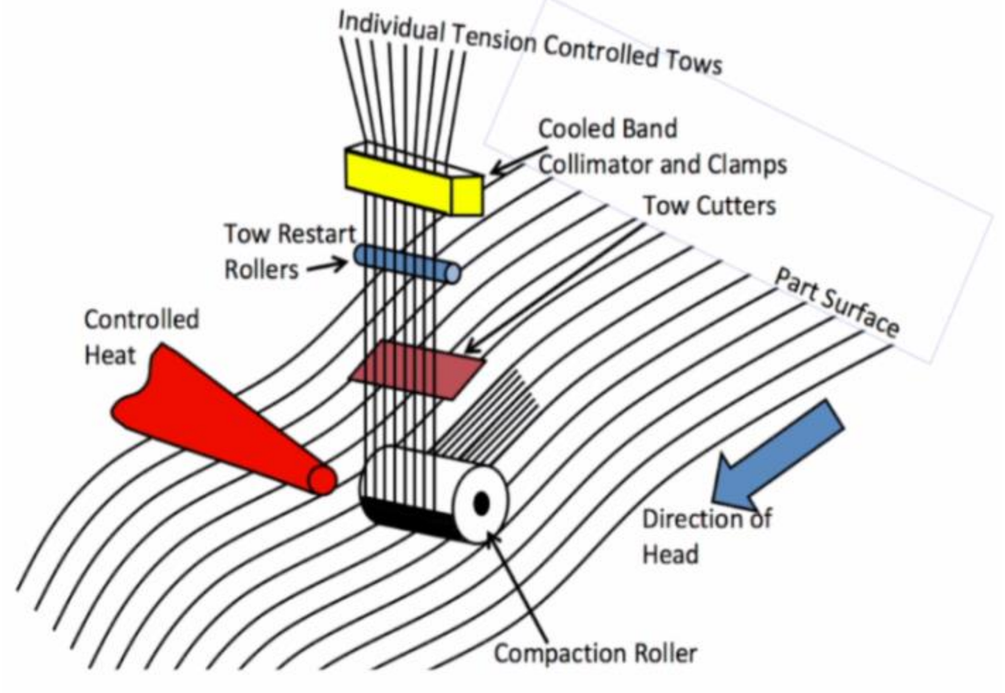

Figure 1.6 – Scheme of Automated layup

1.5 Diagnostic of composite materials

Due to unbelievable characteristics of composite materials popularity of this material had been grown greatly just in few years. As was mentioned composites plays a great role not only in airframe structure of the aircraft but also in the engine structure. High reliable composite fan blades, or blades of HPC and HPT that are made from ceramic matrix composite's, or sandwich construction of the engine surroundings, are the main constituents in reduction of fuel consumption and in reduction of engines weights and all of them could have the same trouble zones during manufacturing. What about service life it differs a little bit.

For example, as fan blades as engine nacelle often can be damaged due to impact or due to environmental effect.

Appropriate to possible damages there are used such types of nondestructive inspections as:

- visual;
- tap;
- ultrasonic;
- thermographic.

Visual inspection

Visual inspection is a primary method for the in-service inspection of composite structures. It is relatively fast and has a large field of view. General visual inspection of the details was performed with the naked eye under conditions of good lighting and surface cleanliness. The sensitivity of inspection was enhanced by using a pocket-torch and by viewing the surfaces also from a low angle. The evaluation showed that visual inspection is capable of detecting impact damages with an initial impact dent depth larger than 0.5 mm (actual impact dent depth larger than 0.3 mm considering relaxation of the dent depth in-service), well below the barely visible impact damage (BVID) value of 1.0 mm. On the other hand, it can not detect delaminations and disbonds and it is not suited for defect sizing and defect depth estimation.

Ultrasound

The most commonly used is ultrasonic inspection, often producing a two-dimensional “C-scan” map of the structure. In composite structures, defects are most often in the form of either disbands or delaminations in the plane of the material, or porosity. The reason for favoring ultrasound inspection is that it is very sensitive to these types of defect commonly found in composites. It is also one of the few methods available for detecting porosity and it can detect most of other defects at the same time [8].

Ultrasound pulses are reflected by interfaces between materials of different properties. In the case of delamination and disbands, this can cause reflection from a particular depth in the material. Such a reflection also results in a loss of transmission through the material.

Porosity does not produce a discrete reflection but scatters the ultrasound in range of directions, also resulting in transmission loss. These transmission losses can be detected by mapping the transmitted signal over the whole structure, known as a though-transmission C-scan. Variations in the transmitted signal can be caused by delaminations, disbands or porosity.

Mapping the time delay to reception of the reflected signals provides information about the depth of the damage and this is known as a depth (or time-of-flight) scan. The information about defect depth can be used to view the ultrasound data as a pseudo-3D image.

For the measurement of porosity levels, it is possible to determine a monotonic relationship between porosity and ultrasonic bulk attenuation at given frequency. A draft European Standard exists to optimize the measurement technique for absolute accuracy in the measurements of bulk attenuation.

Ultrasound offers a good compromise between depth penetration, sensitivity and depth resolution. The inherent attenuation of ultrasound in materials increases with the frequency of the ultrasound, whereas both the sensitivity and depth resolution improve. Thicker materials generally require the use of lower frequency, thus reducing improve. Thicker materials generally require the use of lower frequency, thus reducing the detection capabilities. However, some of this sensitivity can be recovered by using focused beams to reduce the size of the sample volume being inspected.

Ultrasound inspection of sandwich structure

Within the marine industry high-performance materials such as sandwich composites are attractive materials for lightweight constructions. Their increasing applications for especially load-carrying purposes require an extended knowledge of possible hidden flaws incurred after fabrication or in service. Typical and often critical defect types that may effect the strength and durability of sandwich structures are:

- •fiber fracture;
- •matrix cracking;
- •de-lamination and dry areas in the skin laminates;
- •de-bonding between skin and core;
- •core defects like shear cracks and core crushing.

Through-transmission techniques with separate receiver and transmitter transducers on opposite sides of the composite component, is often used for their testing. The great advances of this technique is that the sound has to travel only once in the thickness direction and the inspection evaluation is simply done by comparing amplitude levels of received signals. However, through-transmission techniques are in general not practicable for in-field inspections, where access is often limited to one side of the structure. A more applicable ultrasonic technique for in-field inspections is the Pulse-Echo technique with a single transducer transmitting ultrasonic waves into the component. The same transducer receives the echo, before the next pulse is sent. This method evaluates the signals based on time spent from pulse initiation to the reflected signal is back in the crystal, and on the amplitude level of the reflected signal.

A composite sandwich panel consists of relatively high-density skin laminate materials as GRP and carbon fiber reinforced plastic (CFRP), and a relatively low-density core material as PVC foam and Balsa core materials. For the inspection of the skin laminate it is important to use a wavelength (transducer frequency) where the glass or carbon fibers are as close to being ignored as possible in order to detect real defects. The best frequency choice for skin laminates varies from 15-35 MHz on thin (0.5-1 mm) well-consolidated carbon skins to 0.5-2 MHz on thick hand lay-up glass fiber reinforced plastic (GRP) laminates [8].

Detection of core shear crack in GRP/PVC foam

Within the NDI project several defect types have been simulated in different sandwich test samples. One of the defect types of interest is shear cracks in the core material as indicated in figure 1.7.

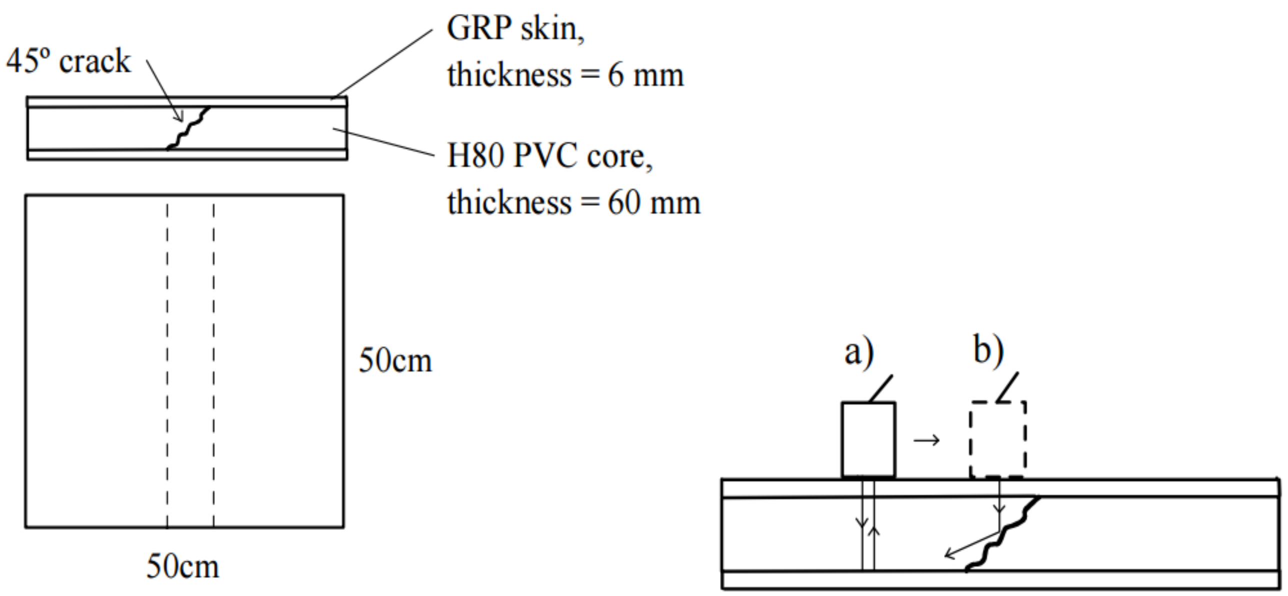

Figure 1.7 – Left: GRP/PVC foam sandwich panel with shear crack. Right: a) ultrasonic transducer transmitting waves into the panel; b) when the transducer is placed upon the shear crack defect the transmitted waves are scattered in other directions and the back-wall echo disappears

The shear crack defect is detected by means of the method indicated in figure 1.7. A scanning result is presented in figure 1.8.

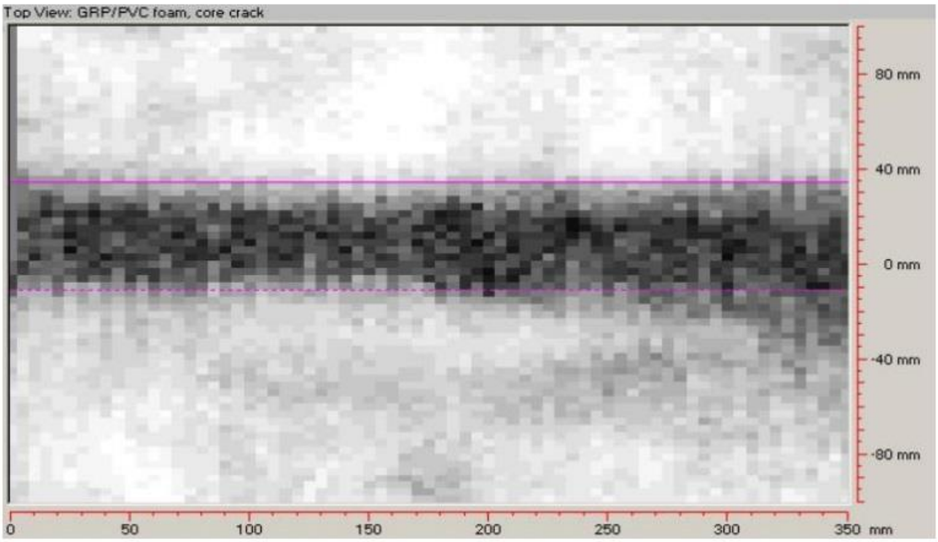

Figure 1.8 – C-scan presentation of a panel with a shear crack in the core

Detection of impact damage in CFRP/PVC foam

Another relevant defect types in sandwich structures are the so-called impact damage, which is characterized by delaminations and cracks in the skin laminate. Depending of the impact energy, the core is often crushed just underneath the damaged skin area in considerable larger areas compared to the damage skin area. Within the NDI project there has been manufactured CFRP-PVC foam sandwich panels with impact damage simulated by means of falling weight tests. One of the test panels has the following specifications:

- CFRP skin thickness: 2 mm;
- PVC foam thickness: 40 mm;
- impactor: 75 mm hemispherical;
- impact energy level: 75 J and 100 J.

The panel has two impact damages, one with impact energy level of 75 J and another with 100 J. The 75 J impact damage are almost invisible on the skin surface, while the 100 J impact damage appears with skin surface indentation in a relatively small area of 30x50 mm [9]. The panel has been inspected by means of automated ultrasonic scanning equipment in Pulse-Echo mode from the damage size with two different methods. The results are presented in figure 1.9 and 1.10 in C-scan mode. The C- scan presented in figure 1.9 is the scanning result from only skin inspection, where no information about possible core damages is obtained. In figure 1.10 the result from full panel inspection is presented.

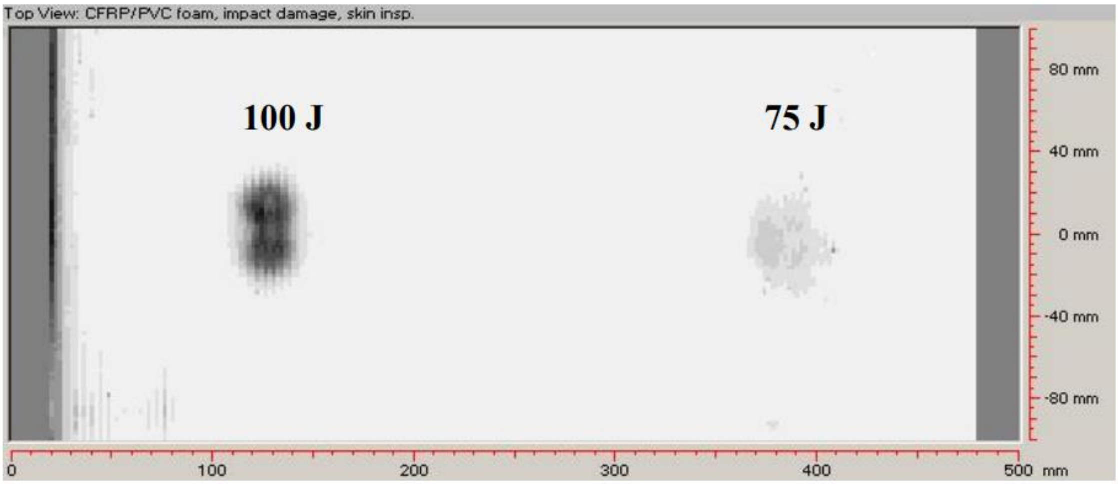

Figure 1.9 – C-scan of panel with impact damages. Damaged area in the skin

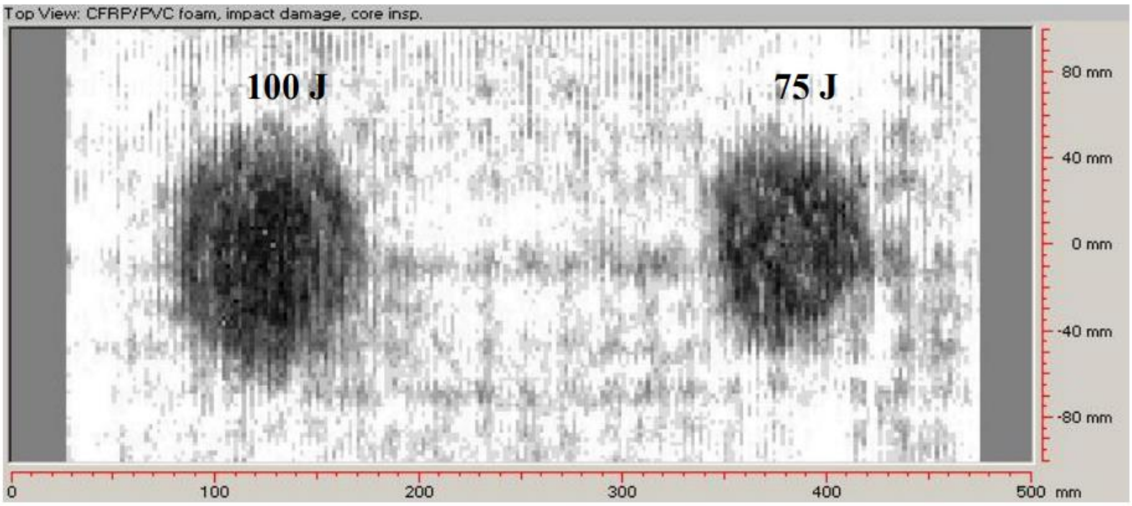

Figure 1.10 – C-scan of panel with impact damages. Damaged area located in the core.

As seen on figure 1.10 the extent of the core damage is clear detected by large amplitude drops on rear side skin-core interface echoes. The defect size is now much larger (about 100x100 mm^2), compared to the indications seen on figure 1.9, which indicates large core crushing damage.

Tap

For inspection of composite structures, the local methods are more appropriate. The simplest of these is tap test where the inspector listens to the sound made when the surface is tapped by anything from a coin to a toffee-hammer. Experiences inspectors can identify defects with a good reliability but the method is highly operator-dependent.

A more sophisticated tapping method involves the use of an instrumented hammer, where the reactive force on the hammer is monitored as a function of time after the impact. Different defect types will cause different changes to the response of the structure.Instrumentation exists for inspecting structures using these transient excitation(tapping) methods or using continuous or swept-frequency excitation.

There is the potential for scanning with these local assessment systems to produce a map of the structure’s response. Some such systems are already used with scanners and the two-dimensional image is extremely helpful in assessing the integrity of the structure.

Thermographic

Thermography has become a useful tool in the inspection of composite structures. Flash Thermography involves quickly applying heat to the surface of a part and viewing it with an infrared camera as the heat moves and dissipates through the part. Areas with defects such as cracks, unbonds, and foreign material (FOD) can be detected, measured for size, and their depth in the part determined. IRT has the advantage of being a completely non-contact test.

Thermography is particularly well suited to evaluating honeycomb sandwich panels and assemblies. Recent developments in thermography technology include using it as a replacement technology for the inspection of jet engine turbine compressor blades, etc [10].

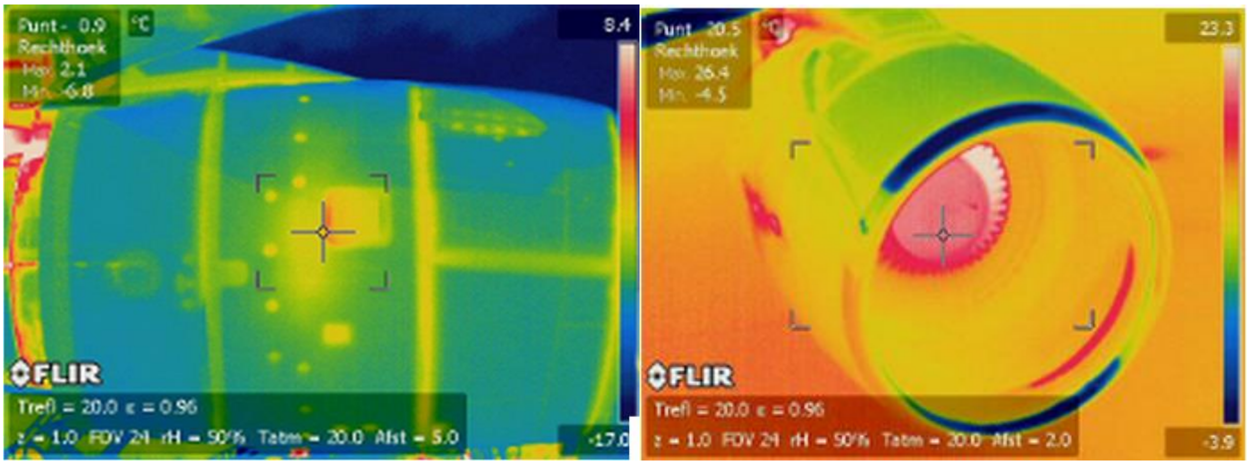

Figure 1.11 – Right image a) an overview (inboard) of an engine, taken from a Boeing 767-300ER; left image b) thermal image of an engine. It takes expertise to "read" the thermal pictures of an airplane as different materials have different emissivity, resulting in different colors in the thermal image.

1.6 Defects in composites

Defects can be produced in composite materials, either during the manufacturing process or in the course of the normal service life of the component.

The manufacturing process has the potential for causing a wide range of defects, the most common of which is “porosity”, the presence of small voids in the matrix. Porosity can be caused by incorrect, or non-optimal, cure parameters such as duration, temperature, pressure, or vacuum bleeding of resin. Porosity levels can be critical, as the will affect mechanical performance parameters, such as inter-laminar shear stress.

Porosity can be described as a large number of microvoids, each of which is too small to be of structural significance or to be detected individually by a realistic inspection technique, but which collectively may reduce the mechanical properties of the components to an unacceptable degree. It is usually produced during the curing cycle from entrapped air, moisture or volatile products. Porosity is most likely following manufacturing by hand lay-up. Single or isolated large air bubbles are referred to as voids [11]. These are large enough to be of structural significance and can also be individually detected and measured by ultrasound. Where large planar voids occur at the interfaces between the plies these are referred to as delaminations. The distinction between discrete voids and porosity is a matter of convenience but for practical purposes, porosity may be thought of as sub-millimeter voids whereas voids of several millimeters dimension would be considered as discrete defects(see figure 1.12). Porosity can act as stress concentrations and will have an effect on some of the mechanical properties i.e. lower transverse and through-thickness tensile, flexural, shear and compression strengths. Void content considered negligible if less than 1-2%.

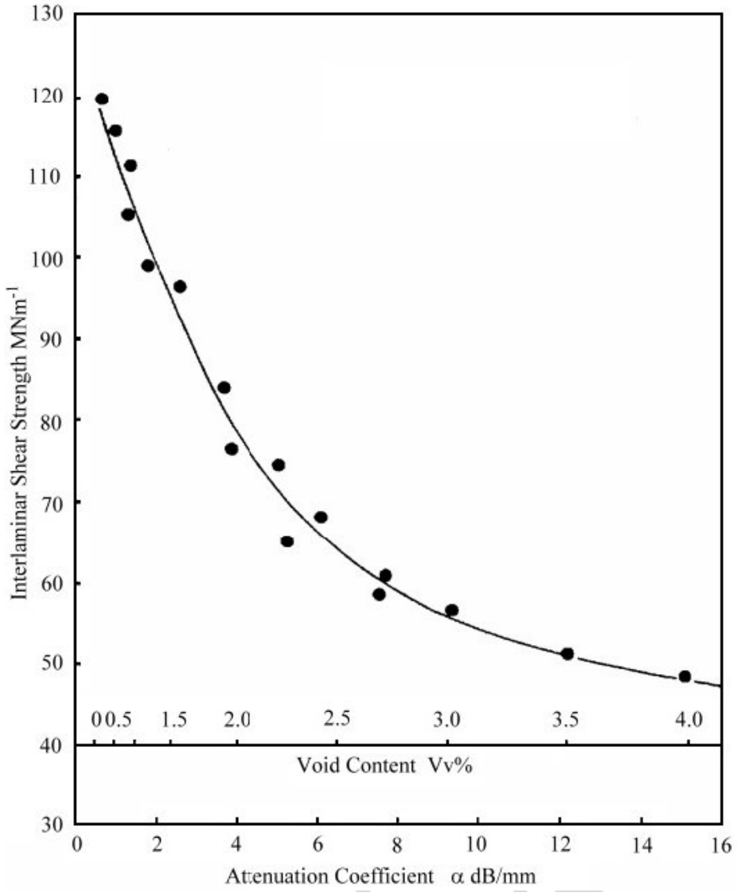

Figure 1.12 – Relationship between interlinear shear strength and porosity (void content) for unidirectional carbon fibers by measurement of ultrasonic attenuation

Also *inclusions* can occur in the manufacture of composites due to foreign matter accidentally included in material during manufacture [11]. Examples include backing paper, peel ply etc. Inclusions can have degrading effect on mechanical properties and may act as sites for initiation of delaminations and are a common cause of disbonds in composites. Inclusions are more likely in hand lay-up processes than in modern processing methods such as resin transfer molding.

Inclusions are detectable by a number of NDE methods including ultrasonic C-scan and X-radiography. Inclusions usually be detected when an assessment of void content is made.

The affect on inclusions on integrity will depend on the location and nature of the inclusion (see figure 1.13). Inclusions are points of weakness and potential initiation sites for more serious defects such as delaminations and disbonding. Laminar inclusions are potentially the most serious. The detectability to NDE methods will depend on how different the inclusion material is to the resin and fiber materials used.

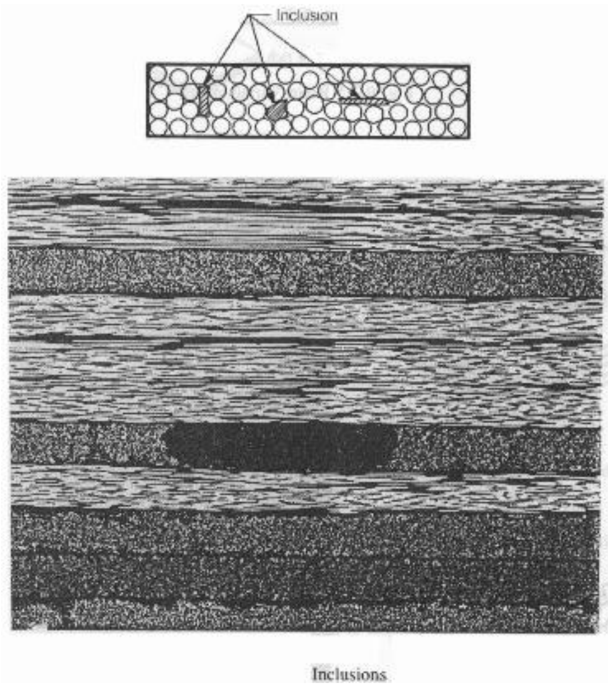

Figure 1.13 – Inclusion in composite material structure

In service damage is most often caused by impacts. In monolithic composites this results in matrix cracking and delaminations of the ply layers. in some cases the surface is punctured, but often this is not the case, despite the internal delamination damage being extensive. Such damage is termed “barely-visible impact damage” (BVID) [2]. Sandwich structures can suffer from the same matrix cracking and delaminations in the skins when impacted, but other types of failure can also occur .

For example, disbanding can be caused at the skin-to-adhesive interface. Fillet-bond failure is where the honeycomb-to-adhesive bond is weakened. Core crushing occurs where the impact energy is absorbed by the core, which distorts and folds, often being returned to its original shape but with greatly reduced compressive strength.

Delamination refers to situations in which failure (or inadequate adhesion) occurs on a plane between adjacent layers within a laminate (see figure 1.14). This type of failure is dominated by the properties of the matrix and since matrix strengths and toughness tend to be relatively low, laminated composites are prone to the development of delamination's. In many types of composite structure delamination's are the most common form of defect/damage. A delamination is defined here as where two layers or plies of a composite material have locally separated [12]. This is distinct from a disbond which is used here to the separation of a bond between two materials, for example a repair patch and the underlying component or an end piece connector and a composite pipe.

Delamination's are very important from an integrity and NDE perspective as they are a precursor to more severe damage such as cracking or catastrophic failure. Delamination's may be formed during manufacture under residual stresses or as a result of the lay-up process or in-service. Impact damage or environmental ingress are common methods for formation of sub-surface delaminations. Edge delaminations are quite common due to environmental ingress.

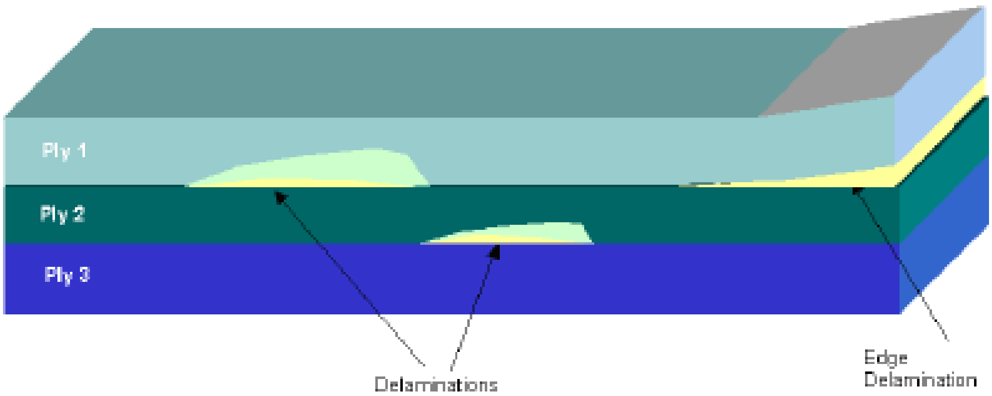

Figure 1.14 – Possible ways of delamination

Cracking, is defined here as a discrete single crack type defect in the composite usually through thickness and normally affecting both matrix and fibers. A crack is distinct from a delamination or disbond which refer to inter-laminar separation of material or de-cohesion of a bond, matrix cracking or transverse cracking which refer to finer scale types of multiple cracking normally occurring in the central ply of composites under service loading, and fiber cracking or breakage.

Cracking has a significant effect on the integrity of the composite, allowing environment ingress and damage to extend under service loading. Cracking is often associated with the final stages of in-service failure (see figure 1.15).

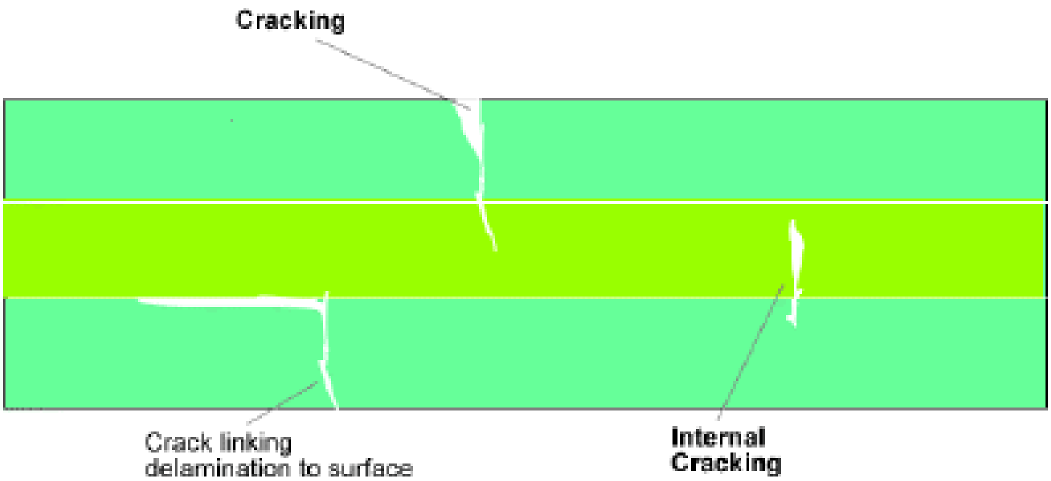

Figure 1.15 – Cracking in a composite layers

Disbond, refers to the situation in composite sandwich structures in an area of a bonded layer (see figure 1.16). This may be the consequence of poor adhesion, service loading or impact damage. The disbond may not be visible externally and if tight or weakly bonded may be difficult to detect using NDE methods. The latter is known as a kissing bond. Disbonding is particularly important to avoid in joins such as end connections. The term disbond here is defined as a separation of the composite material from another material to which it has been adhesively bonded [11]. This is different to a delamination which refers to a similar separation between any plys or layers of the composite. Separation between the skin and core of a composite sandwich structure is separately referred to as a core disbond.

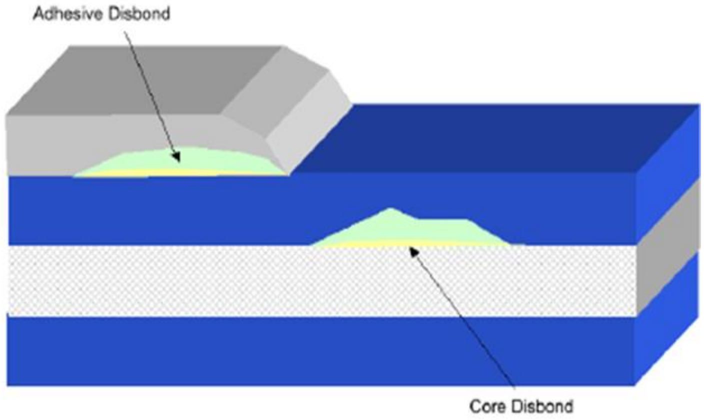

Figure 1.16 – Disbond in a composite structure

Fiber defects. The presence of defects in the fibers themselves is one of the ultimate limiting factors in determining strength of composite materials, and sometimes faulty fibers can be identified as the sites from which damage growth has been initiated(see figure 1.17). These defects are present in fibers as supplied, are always likely to be present and probably must be considered as one of the basic material properties.

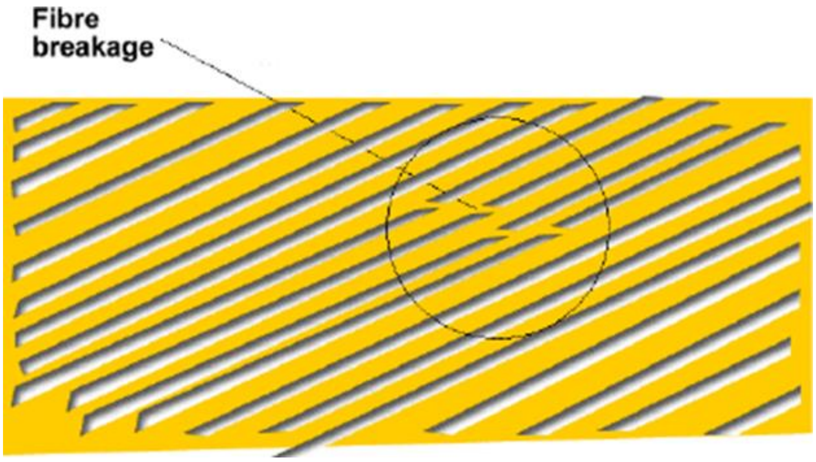

Figure 1.17 – Possible fiber defect

Fiber wrinkling or waviness refers to the in-plane kinking of the fibers in a ply. Waviness or wrinkling of the fibers can seriously affect laminate strength(see figure 1.18).This type of defect is particularly of concern in high integrity aerospace components and investment has been made in NDE methods such as ultrasonic C-scan image processing to characterize the damage [13].

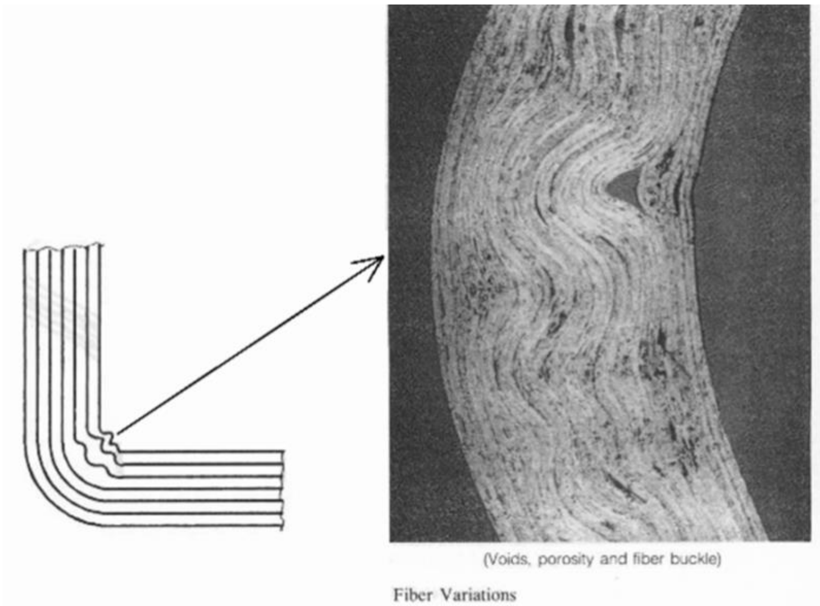

Figure 1.18 – Fiber wrinkling

Fiber misalignment refers to local or more extensive misalignment of fibers in the composite material. This causes local changes in volume fraction by preventing ideal packing of fibers. Ply misalignment refers to the situation where a whole or part of a ply or layer of the composite is misaligned. This is produced as a result of mistakes made in lay-up of the component plies [1]. This alters the overall stiffness and strength of the laminate and may cause bending during cure. The properties of the resulting component will be affected.

Fiber and ply misalignment are potentially disastrous defects but are rarely encountered due to high standards of quality control. Often an off-cut of the material is examined to ensure that the correct ply stacking sequence was used. However the increased use of sub-contractors to produce structural components requires the ability to check the quality of the product on delivery.

Incomplete cure refers to the situation where the matrix has been incompletely cured matrix due to incorrect curing cycle or faulty resin material(see figure 1.19).This may be localized or affect the whole component. The result will be reduced strength and toughness. Incomplete cure is also an issue in adhesive processes using resin based adhesives affecting the integrity of end-fittings and adhesive joints.

Composite materials can be manufactured by a number of techniques which aim to combine the fiber and resin into a well consolidated product. The fiber and resin may be separate before manufacture or, more usually, they may already be combined in the form of prepreg material.

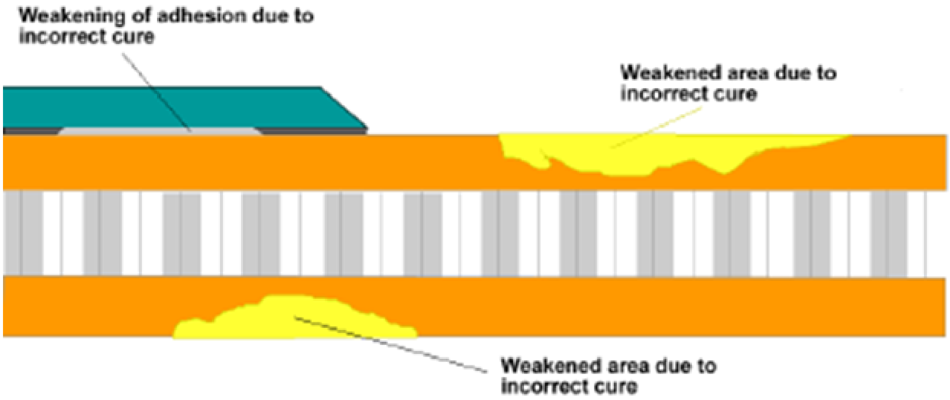

Figure 1.19 – Example of incomplete cure

*Excess Resin***.**During fabrication methods for composites are designed to provide a uniform distribution of fibers in a resin matrix properties depend on the fiber volume fraction. Load transfer across the fiber matrix interfaces are a key feature giving rise to the good strength and ughness characteristics of composites. It is a natural consequence of manufacturing methods that local variations in fiber or resin content will occur. Where the resin content is above design limits this is referred to as excess resin.

Sandwich structure defects. In manufacture of larger composite components such as floor panels using composite sandwich structures it is necessary to splice or join sections of the foam or wood core together to form the overall structure. This is usually undertaken using adhesive bonding and is known as a core splice(see figure 1.20). Any local disbanding of the core splice similarly is likely to grow and lead to failure.

This type of defect is known as a *core splice failure* [9]. Inevitably delamination of the core or cracking of the skin will ensue leading to failure. Core spliced effects need to be avoided in manufacture as they will significantly affect the load bearing capacity of the composite leading to premature failure.

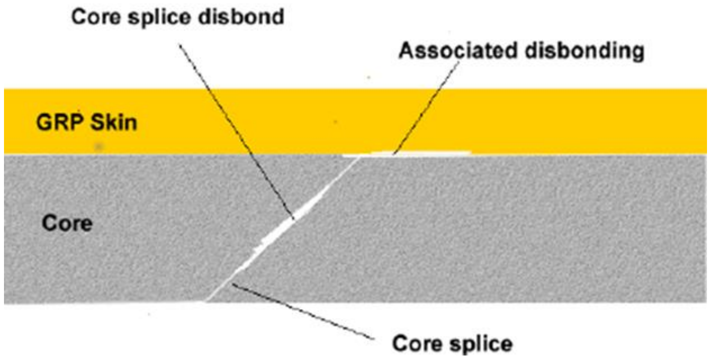

Figure 1.20 – Core splice failure

Such defects may arise under service loading or due to inadequacies in fabrication. Wave loading of marine hulls can significantly test the integrity of core bonding.

Core disbond refers to the situation in composite sandwich structures where the skin of the composite has seperated from the inner core(see figure 1.21).This may be the consequence of poor adhesion, service loading or impact damage. The disbond may not be visible externally and if tight or weakly bonded may be difficult to detect using NDE methods. An example of core disbonding is in marine hulls under the action of wave loading [9]. The term core disbond here is defined as a separation of the composite outer or inner skins from the core. This is different to a delamination which refers to a similar separation between any plies or layers of the composite.

Figure 1.21 – Core disband

The integrity of composite sandwich structures is strongly dependent on good bonding between the skins and the internal core to achieve load transfer. care and cleanliness in bond preparation is paramount. Any disbonding is likely to exacerbate under service loading or environmental ingress eventually leading to partial separation of the skin and failure of the component.

Crushed Core, in composite sandwich structures can use a number of core materials including foam, metal honeycomb and balsa(see figure 1.22).the outer skins are adhesively bonded to the core .Loading by flexing, compression or impact may cause crushing of the core often accompanied by disbonding of the interface. This is known as core-crushing. This damage may not be evident from the surface. Other defects that may occur in the core include: skin to core disbonds, inter-core breakdown and water / ice action breaking cell walls, open core splices. Core crushing is common following accident damage to ship hulls and can occur following service loading in aircraft structures. The integrity of sandwich structures is dependent on good bonding between the core and skins and the integrity of the core structure.

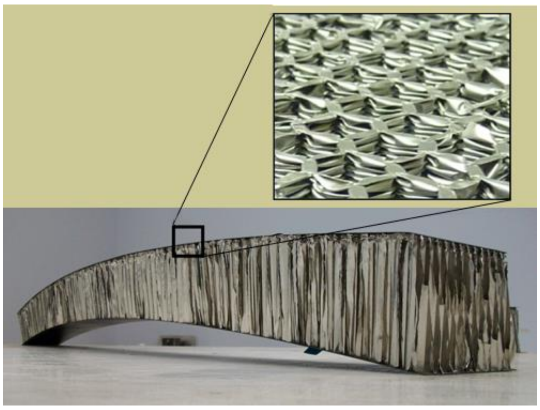

Figure 1.22 – Crushed core defect

Kissing bond(see figure 1.23) refers to the situation where two surfaces have been only partially bonded or are disbonded but touching or in very close proximity. This may be the consequence of poor adhesion, service loading or impact damage. The disbond may not be visible externally and because of it's tightness may be more difficult to detect using NDE methods than a conventional disbond. Disbonding is particularly important to avoid in joins such as end connections.

Kissing bonds can potentially occur anywhere in a composite component where there has been adhesive bonding; including end-fittings, core bonding and with repair patches. Detectability by NDE will depend on location and tightness.

There is as yet no good solution for NDE of kissing bonds, though a number of methods give some capability. For this reason, kissing bonds are best avoided by careful bond preparation procedures.

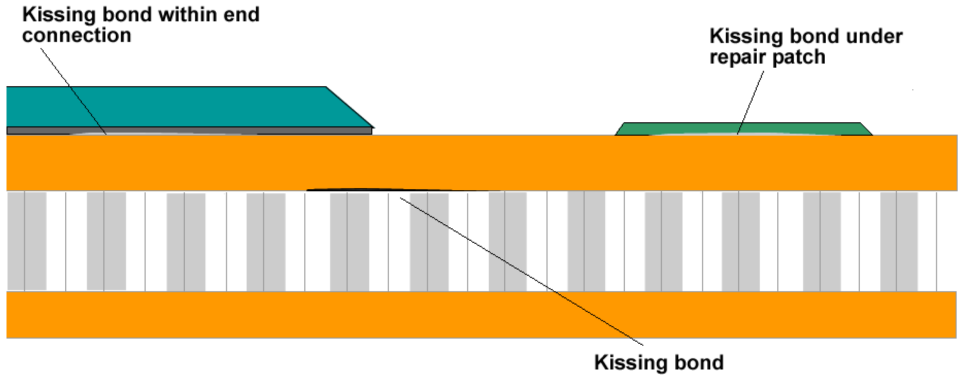

Figure 1.23 – Kissing bond

Composites like any materials can degrade in the environment to which they are exposed. This can give rise to a variety of damage mechanisms and a general reduction in strength and toughness with time. Chemical vessels not protected by an internal polyethylene or polypropylene liner can be particularly affected, or where protective liners have broken down. Erosion or damage to protective gelcoats can also initiate damage to the composite material. The extent of damage will depend on service conditions and the particular resins used. Exposed edges and edges of adhesive bonds are particularly susceptible. Damage can vary from a simple progressive degradation in properties to delamination or disbonding in more severe cases. Interfaces such as the fibre-matrix interfaces, from which much of the properties of the composite material arise, or interfaces between plies can be particularly susceptible.

1.7 Composites repair

Carbon/epoxy composite airframe components are immune to the costly forms of deterioration, notably cracking and corrosion that plague aluminum and most other alloys used in airframe structures. However, these composites are much more easily damaged in service, for example, by mechanical impact. Thus repairability of such damage is an important consideration in the selection of composites for aircraft applications.

- mishandling;
- impact, for example, by dropped tools;
- contact damage in doors, often caused by poor rigging;
- delamination damage, often caused by inadequate shimming during
- component assembly;
- delamination caused during fastener removal or reinstallation;
- local overheating caused by impingement of hot exhaust gases or from
- lightning strike.

Assessment of the repair necessity

Methods of analytical assessment of residual strength in damaged composite components are needed to ensure that only necessary repairs are undertaken. Essentially, one of the following decisions is required:

- no repair action – damage is negligible;
- cosmetic or sealing repair is required to correct minor damage;
- structural repair is required (if feasible) because strength is reduced below ultimate design allowable or has the potential to be reduced in subsequent service;
- repair is not economic and component must be replaced.

When there is penetration damage, the requirement for a structural repair is obvious. The decision is much more difficult for less obvious damage such as cuts, scratches, and barely visible impact damage (BVID). As yet, simple analytical approaches to estimate the strength of damaged composites (similar to fracture mechanics for metals) are unavailable, so empirical methods are generally used. For BVID, quite large areas of damage (typically 25 mm diameter) can be tolerated for older-generation carbon/epoxy systems without failures occurring below the ultimate design strain allowable, generally around 3000-4000 microstrain [14].

Fatigue studies have shown that BVID will not grow under realistic cyclic strain levels for typical carbon/epoxy laminates. This is an important point because BVID will often not be detected until a 100% non-destructive inspection is undertaken. There is also the possibility of damage growth and resultant strength degradation under hygrothermal cycling conditions, but this does not appear to be a serious concern under moderate cycling conditions. However, catastrophic flaw growth is possible under severe hygrothermal cycling. This results from expansion of entrapped moisture due to freezing, or to steam formation on heating during supersonic flight.

Repair Requirements

Generally, the repair scheme used for structural restoration should be the simplest and least intrusive that can restore structural stiffness and strain capability to the required level and be implemented in the repair environment, without compromising other functions of the component or structure. It is usually necessary to restore the capability of the structure to withstand a design's ultimate loads and to maintain this capability (or some high percentage of it) for the full service life. Structural requirements for the repair vary according to the component or structural element. For example, wing skins are strength critical in tension or compression, tail skins and control surfaces are often stiffness-critical (or flutter-critical), whereas spars and (unpressurized) fuselage skins may be stability- or buckling-critical. The functions that must be restored include: aerodynamic shape; balance; clearance of moving parts; resistance to lightning strike.

Important additional requirements are that implementation of the repair should minimize down-time of the aircraft, use readily available and easily storable materials, remove as little sound material as possible, minimize degradation or damage to the surrounding region, require only simple procedures or tooling, produce minimal increases in the weight of the component.

The type of structure and its accessibility are major considerations in determining the repair approach taken. For example, honeycomb structures with thin face skins are relatively easy to repair using core inserts and simple external patches. Highly loaded thick-skin components will usually require elaborate scarf repairs.

Conclusion to composite material analysis

Airlines are under increasing financial and environmental pressure to operate more efficiently with a smaller carbon footprint. Further, the aircraft operator is increasingly subject to scrutiny by surrounding communities interested in reducing noise during take offs and landings while maintaining safety and reliability standards. At the same time, engines, wings and airframes require fewer parts — which means savings in maintenance, repair and overhaul costs that contribute to a 30 percent reduction in cost of ownership. The composites-intensive design of the engines (the heaviest part of the aircraft) will have an approximate 680-kgweight reduction, equivalent to seven additional paying passengers. The design also saves about 2.5 million liters of jet fuel per year, per aircraft.

The speed/cost parameter is often one of the crucial parameters that determine what kind of NDT method that is the most effective as our goal is to achieve less costs with maximum safety. As practice and various experiments had been shown the most reliable, cost and time effecting are

- visual inspection, will always be a primary method for the in-service inspection of composite structures. It is capable of detecting relevant impact damages and other surface irregularities.
- ultrasonic inspection is the primary NDI method for in-service inspection of composite structures, especially regarding its capability for the detection, sizing and depth estimation of defects. UT inspection is relatively fast and reliable.
- thermography inspection are relatively fast, non-contact method that require no coupling or complex scanning equipment. Impact damages are readily detectable but the detectability for delaminations and disbonds is poor to moderate when compared with ultrasonic inspection.

After problem area diagnosis we met another problem, fixing of this trouble zone or damaged area. Talking about the repair requirements, generally it is the same with NDT requirements, speed/cost parameter.

Composite repairs can be quite time-consuming, and require careful attention to lots of picky details. Most of these repairs rely fundamentally on high-quality adhesive bonding. The strength of an adhesive bond cannot be measured without destroying it. Therefore, careful control of the repair process, especially regarding cleanliness, fit of the repair patch, and meticulous surface preparation of the bonding surfaces, becomes crucial. It all goes back to the skill, training, and integrity of the person doing the repair.

All what have been mentioned: fewer parts, 30 percent reduction in costs, high speed/cost parameter became possible due to usage of light weight and high strength composite materials in engine core sections, in wings, airframe and control surfaces structure. Also great leap in engine construction had been produced production from high performance composite materials fan blades of the engine.

Taking into account all mentioned benefits of composite materials usage in aircraft sections we can estimate importance of this material in future and nowadays.

2. WEAR RESISTANCE TEST PROCEDURE

2.1 Impact testing of advanced composites

The advantages of composite materials are numerous and well documented. Composite materials are often used in environments in which they will suffer from impact damage. For example, damage can occur from a hammer being dropped on a composite pipe or from a bullet striking composite armor.

Impact testing fits into two main categories: (a) low velocity impact, and (b) high velocity impact [15]. These two main categories lead to three main types of impact testing. Charpy impact testing and drop weight impact testing fall into the category of low velocity impact testing (here it should be noted that an impact test machine can be used for high velocity impact also) [16]. Ballistics impact testing falls into the category of high velocity impact testing. Technology has increased to the point that there are now sophisticated measuring devices for instrumented impact testing. For all low velocity instrumented impact test devices there are three major components: the dynamic load cell (or tup), the data display system, and the signal conditioning unit [17]. The tup is placed on the impactor used to strike the specimen. Within the tup is a strain gage that measures the change in strain vs. time as the impactor strikes the specimen. The signal conditioning unit removes the noise associated with the signal, and the data display system plots the measured data. An in-depth exploration on the benefits and methods of each type of impact test will be explored more in the following sections.

2.1.1 Charpy Impact Testing

Charpy impact testing has been used for many years to test the impact toughness of various metals. The advent of modern composites brought about materials with properties that depend on their orientation. Consequently, new test methods had to be found to accurately test the directionally dependent impact resistance of composite materials. Sinc Charpy impact testing is both cheap and fast, its use was extended to composites. A Charpy impact test machine is shown in the following picture.


Figure 2.1 – Charpy impact test

Specimen Preparation

The specimen that fits into the Charpy impact tester is rectangular with a notch cut in one side. The notch allows for a predetermined crack initiation location. Many composite Charpy impact tests are performed without the notch cut into the specimen. In these cases it should be noted in the experimental procedure if the notch is not present. A typical Charpy impact specimen is shown in the following figure.

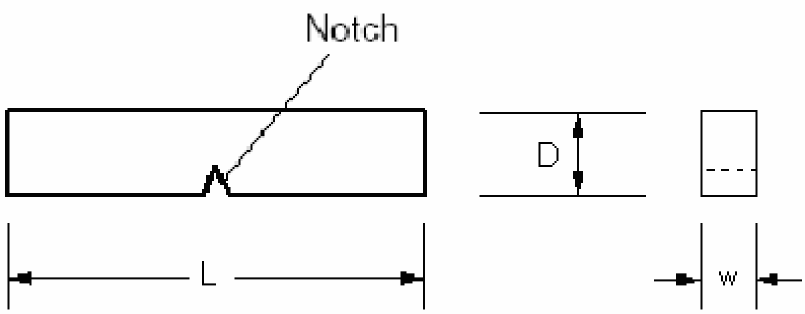

Figure 2.2 – Charpy impact specimen

For a typical fiber reinforced polymer Charpy specimen, L = 126 ± 1 mm, D = 12.7 ± 0.15 mm, and 3.00 mm < w < 12.7 mm [18]. A typical composite Charpy specimen is first made by creating a large panel of laminate oriented in the direction that is dictated by the problem definition. When creating a panel using a wet lay-up or prepreg technique, the wet-out reinforcement plies are stacked in the desired configuration to get a panel that is several layers thick. The specimen is then placed in a vacuum to remove excess resin, and allowed to cure (with or without external pressure and heat). A figure of the final panel lay-up is displayed in the following figure 2.3.

Once the composite specimen has finished curing, the composite specimen is removed from the vacuum bag setup [19]. The resultant plate can then be cut small rectangles which will be used as Charpy impact specimens. The final step is to cut the notch into the specimen.

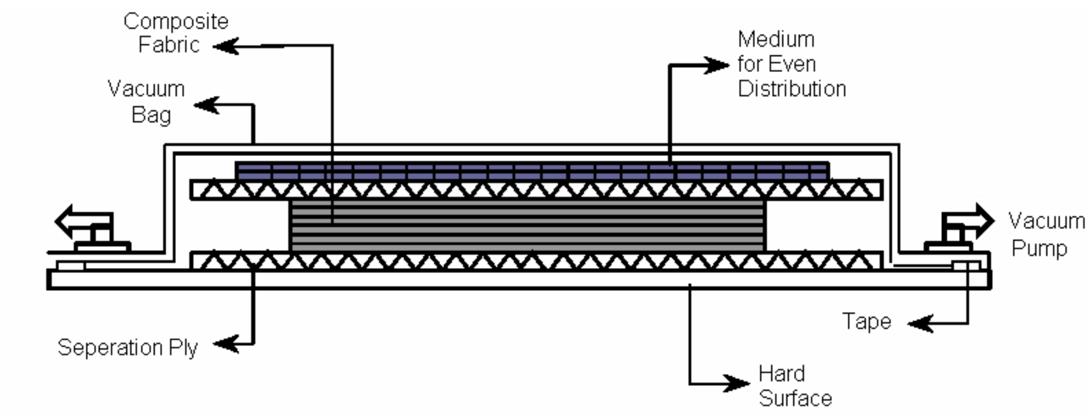

Figure 2.3 – Plate lay-up

Test Setup and Procedure

The Charpy impact test method works by placing a notched specimen (with the notch facing away from the point of contact) into a large machine with a pendulum of a known weight. The pendulum is raised to a known height and allowed to fall. As the pendulum swings, it impacts and breaks the specimen, rising to a measured height. A figure displaying the process is shown below.

The difference in the initial and final heights is directly proportional to the amount of energy lost due to fracturing the specimen.

The total energy of fracture is determined by

$$E_{total} = mg(h_0 - h_f) \quad (2.1)$$

where E_{totd} is the total energy, m is the mass, g is gravitational acceleration, h_0 is the original height, and h_f is the final height. The failure types for composite Charpy impact tests depend on the specimen orientation. Often, specimens exhibit fiber fracture and fiber pull-out, while other times delamination failure is the primary failure mode.

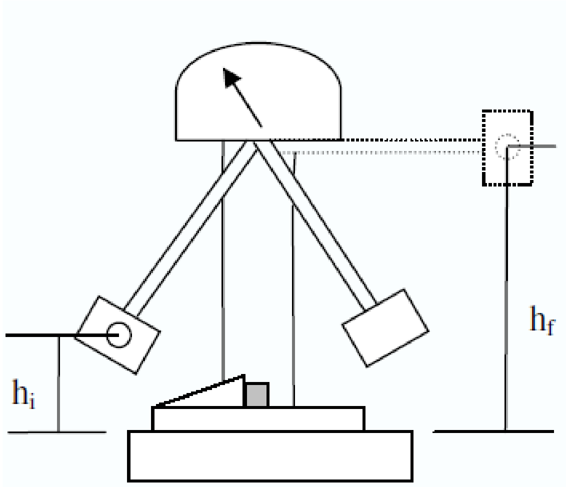

Figure 2.4 – Charpy impact procedure

2.1.2 Drop Weight Impact Testing

Drop weight impact testing is another type of low velocity testing, and it is the most common test for composite materials. Drop weight impact tests are done to test the impact behavior on composite plates, which most closely resemble impact damage in the field. When using a drop weight impact tester, two categories of damage can occur. The first is clearly visible impact damage (CVID), which can easily be seen by the naked eye. The second type of damage is barely visible impact damage (BVID), which can seldom be seen by the naked eye.

In drop weight impact testing, a mass is raised to a known height and released, impacting the specimen. The choice can be made between either an instrumented or non-instrumented test machine. A figure displaying how an instrumented impact machine works is shown below.

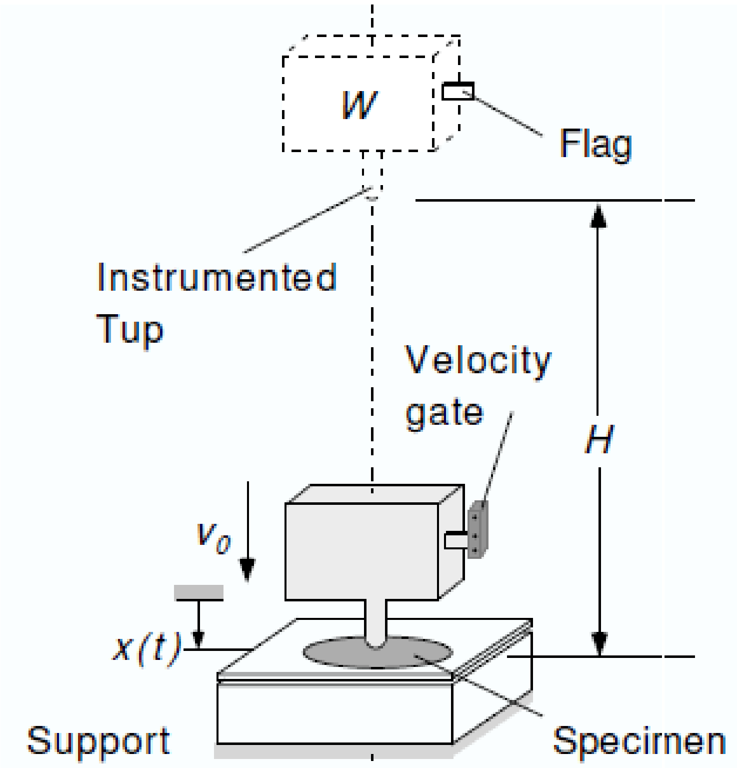

Figure 2.5 – Example of the operation of a drop weight impact test machine

n figure 2.5, *x(t)* is the coordinate system, *H* is the initial drop height, *W* is the impact weight, and v_o is the impact velocity. The tup is a hemispherical impactor that measures the strain during impact [20]. An example of an instrumented impact test fixture is shown in the following figure 2.6.

Specimen Preparation and Test Setup

The specimens used for drop weight testing are flat panel composite specimens. The lay-up and material used is dependent on the desired results of the testing. The flat panel specimen preparation is similar to that of the panels used in the Charpy impact testing shown in figure 2.2.

Following the creation of the panel, specimens are cut to the desired size. This flat specimen is then inserted into the test machine and clamped along its edges. The clamps can be placed in a circumferential configuration or in a rectangular configuration, based on the design and test specifications [20]. Once the test specimen is clamped down, the mass is raised to the desired height, and the mass is locked into place.

Figure 2.6 – Drop weight test device

2.1.3 Ballistics Testing

Ballistics testing is a form of high speed testing that is used to test the ultimate impact strength of composites. High velocity testing is characterized by an impactor traveling in the range of 400-2000 m/s [16]. For high velocity impact conditions, structural response is less important than in a low velocity case, and the damage area is more localized; therefore the geometrical considerations are less important. Ballistics testing consists of firing a high speed projectile at an object and determining after the impact how localized the damage is. This is a good method for testing impact resistance of composites, and has been used for testing products such as composite armor.

Test Setup and Procedure

Ballistics testing is complicated, and care has to be taken during the setup. A typical setup of a conventional ballistics test apparatus is shown in the following figure.

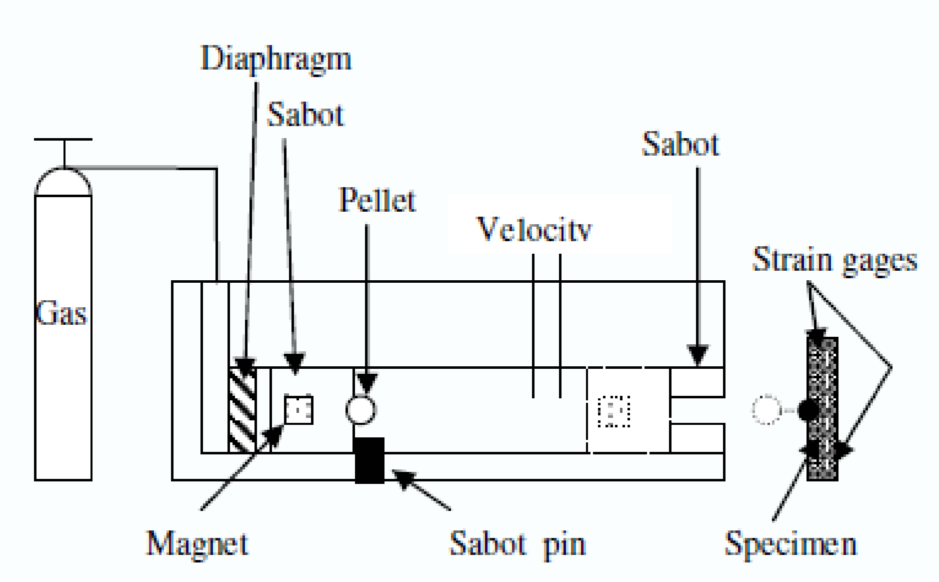

Figure 2.7 – Apparatus for ballistic impact testing

The test apparatus shown in figure 2.7 is typically known as a gas-gun impact test machine. The gas-gun apparatus works by forcing gas into the back of the diaphragm which expands and applies pressure to the sabot. The sabot pin is released, and the sabot is forced along the barrel. The velocity pins measure the time it takes for the front of the sabot to travel the distance between the two pins, and outputs a velocity. The sabot is then blocked by the sabot stops, and the pellet is allowed to proceed to impact the test specimen. The strains can then be measured using strain gages applied to the specimen. The pellet used for testing is usually one with a high hardness, and will be made of a hard steel, or zirconia (for the setup shown in figure 2.7 the pellet would have to be magnetic, as it is held in place by a magnet). An inert gas is used to fill the chamber to cut down on possible accidents.

2.1.4 Comparison of Test Methods

A comparison of the different types of test methods can help in making a decision regarding the correct test to use. Charpy impact testing is easy and fast, which allows the researcher to generate large amounts of data. Charpy impact testing is simple in its scope, and therefore its results are not indepth, nor do they reveal a great amount about the material. The Charpy impact test itself is easily set up, and therefore a great number of specimens and a large amount of data can be collected in a very small amount of time. With the advent of high speed photography, Charpy impact tests are now able to produce results that help to show the propagation of the crack, and instrumentation allows the user to measure the force more accurately. The data, however, may not be suitable for some composite materials due to the anisotropy of the material [15]. For these composites, little value can be gained from the results as to the overall behavior of the material. Due to the simplistic model presented by Charpy impact testing, very few types of post impact test methods are effective.

Drop weight impact testing is a more common “real world” scenario than that of the Charpy impact test, and consequently greater amounts of information can be gathered as to the behavior of the laminate. Drop weight impact testing also allows for different configurations to be used. Therefore, drop weight testing tends to be the preferred method when using low velocity impact testing. Drop weight testing results may also be enhanced from post impact testing.

Ballistics testing cannot be directly compared to the previous two testing techniques, because it is a high velocity test. Ballistics testing can be more complicated. However, often high velocity impact testing is needed, and cannot be avoided. Ballistics testing is highly effective at replicating the behavior of the composite at high speed impact and allows the user to characterize the material by analyzing measured data. It should be noted that it is best to perform a low velocity test when possible, due to simplicity. As is the case with drop weight machine testing, ballistics test results can be enhanced greatly by post-impact testing.

2.2 Methods of testing material and coatings of fretting in accordance with ГОСТ 23.211-80

The research performance on fretting differs with different methods used, the scheme of loading and type of contact, and in the evaluation of surface damage. The method is chosen according to the two basic requirements [26]:

- imitation of fretting in the laboratory should maximally approach the conditions of this type of surface damage in real structures;

- the selected method should be such that you can compare obtained results with data from other works.

The followings requirements are set to test the devices in connection with the specifics of fretting:

- Backlash-free mounting of samples in clamping devices;
- torsional rigidity and low deforming of device;
- availability of vibration skidding movement of controlled frequency and amplitude;
- availability of controlled normal force to create the necessary pressure in contact;
- possibility to supply lubricant or other medium.

The choice of a flat circular contact and swing-rotation movement of contact surfaces is stipulated by the necessity of control of normal load and elimination of edge effect.

The basis of the accepted methods of work contains a comprehensive study of qualitative parameters of friction pares. Scheme of the contact plane-plane type used on installation МФК - 1 (ГОСТ 23.211-80), the general view is shown on figure 2.8.

The main advantages of this method are:

- quick assessment of durability of materials and coatings under fretting;
- satisfactory reproducibility of test results with a minimum number of test samples;
- simplicity of the method and corresponding equipment;
- possibility of smooth control of the frequency and ampliiude of normal load micro shifts;
- tests using plastic and liquid lubricants;
- registration of friction during testing.

Description of the method is that the rolling cylindrical sample (control sample), adjacent by edge with immovable cylindrical sample at a given pressure is driven to swivel-rotary motion with given amplitude and frequency. Measured wear of stationary sample for a given number of cycles is determined by the value of durability of the investigated material. Plant layout is shown on figure 2.9.

Figure 2.8 – General view of installation МФК - 1 for testing the fretting

Installation works as follows: motor 2 transmits rotational motion to eccentric 3 of adjustable eccentricity. Rotational frequency and the number of revolutions are recorded by instrument 1. Eccentric 3 through rod 4 is related to the crank 6 of drive 7 axis 6 of control sample 8swing-rotation motion. Amplitude of control sample 8 displacement and is regulated by an eccentric device 5. Fixed sample 9 is fixed in the centered collet 10 installed on the shaft of the moving stock 11. Samples are loaded by the dynamometer 14 and loading device 15. Size of axial load on the specimens recorded by dynamometer ЗІП 02-79 type ДОСМ-3-0,2 (ГОСТ 2283-79) with the boundary measurements from 0.2 to 2 kN. Friction registration is done by device НО71.5М *13* through amplifier 8-АНЧ-7М *12* with the help of tenzobeam 11. Number of test cycles has to be controlled by the counter located on the front panel of the aggregate.

Vibration amplitude is governed by the change of eccentric eccentricity (roughly) and by change of the length of the horizontal rod length (exactly). Rough amplitude regulation allows changing its size from 10 to 1000 microns, exact -

from 5 to 15 microns. The amplitude of relative displacement is defined as the oscillation difference of movable and fixed samples.

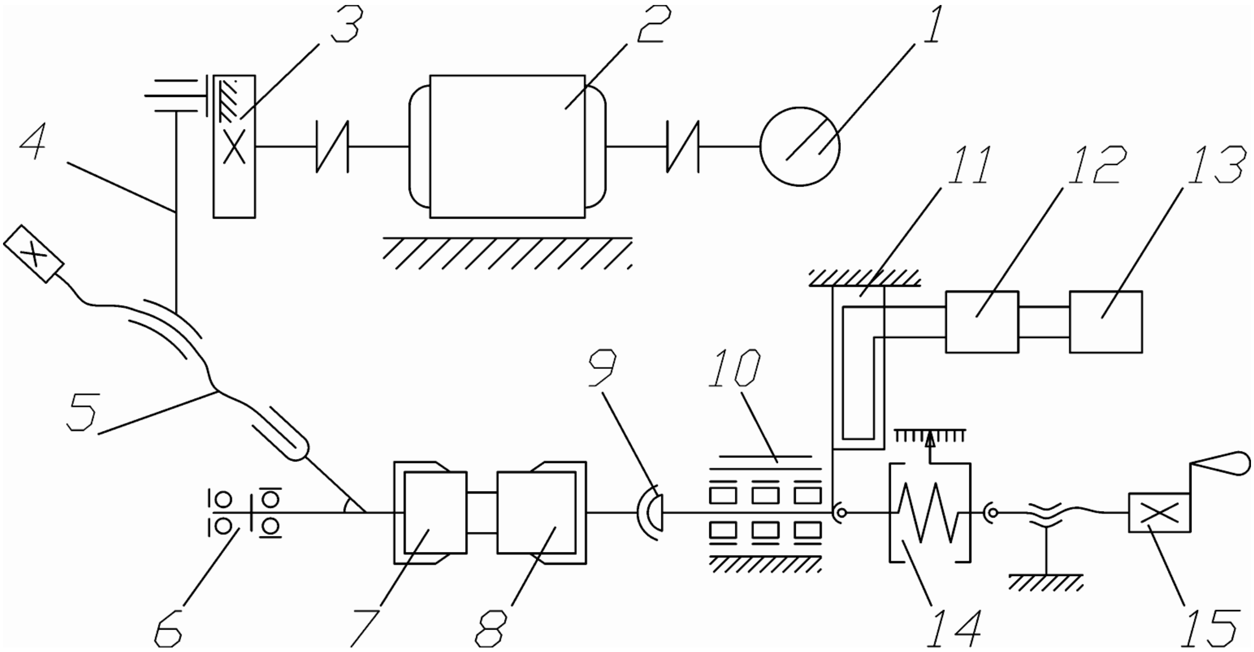

Figure 2.9 – МФК-1 installation layout:

1 - revolution counter, 2 - motor, 3 - eeccentric, 4 - vertical rod, 5 - adjusting device, 6 - horizontal rod, 7 - moving sample, 8 - fixed sample; 9 - self orienting collet, 10 - moving stock of 11 – tenzo beam 12 - amplifier, 13 - registering apparatus 14 - dynamometer, 15 - loading device.

Measuring the amplitude is held directly on the samples using an optical binocular microscope МБС-2 (with an increase in from 8 to 56 times) using strobe effect (stroboscope ТСТ-100).

Samples for testing are shown in Figure 2.10. Contact of test samples is performed on the surface, which is a closed loop with the nominal contact area 0.5 cm^2, 11 mm inner diameter and an outer diameter of 13.6 mm.

Samples should be washed and dried before and after the equipment. For washing are used liquids: gasoline ГОСТ 443-76, acetone ГОСТ 2603-79, ethyl ГОСТ 18300-72. Before the test the measuring and recording equipment should be checked and marked.

Installation allows testing at next parameters [27]:

- loading of samples in axial direction by 200 - 1000 N;

- swivel-rotary motion of control sample to sample with a frequency of 10 - 30 Hz and amplitude 10 - 1000 microns;

- measuring system settings during testing provides continuous registration of number of cycles of control sample swivel-rotation with an error less than 50 cycles.

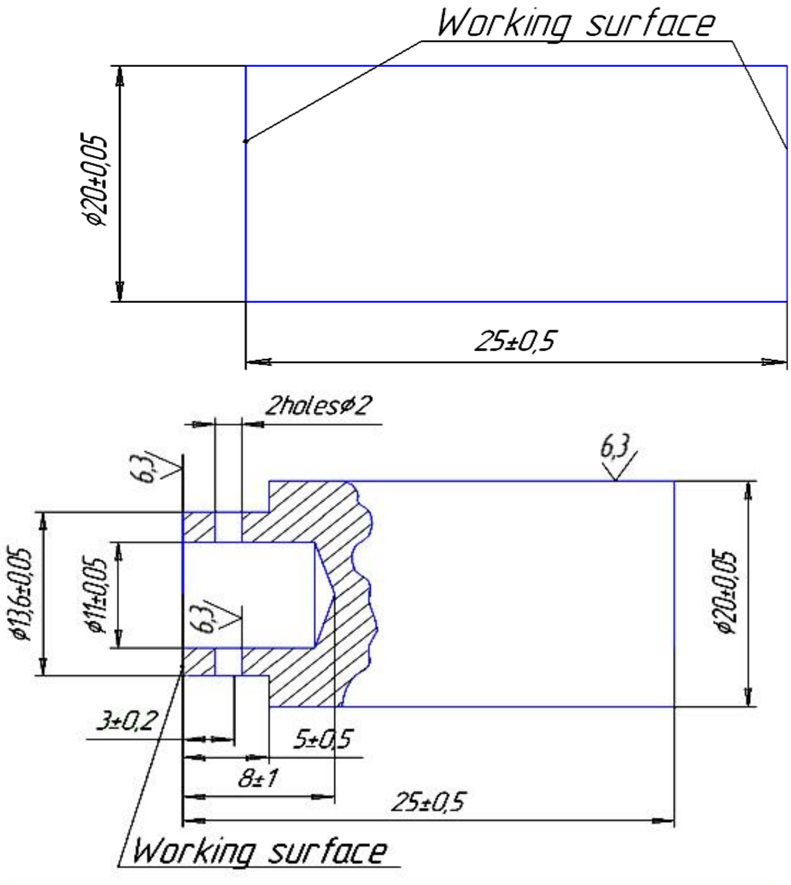

Figure 2.10 - Samples for fretting testing

For the materials testing in liquid environments the special heating chamber is used that provides the possibility of supply and withholding liquid environments in the contact area of the specimens.

The specimens for tests fastened in the unit collets, set in the round openings of chamber, provided with the sealing, manufactured from heat-resistant rubber. The leakage of working environment from a chamber is prevented with a help of sealing regulators.

The control of the temperature of working environment is provided by a thermocouple and pointer of temperature with accuracy ±2 °C, working range of temperatures of chamber 0…200 °C. The set temperature of tests is achieved with the help of a heating element and temperature regulator.

A chamber allows carrying out the experiments in oils and plastic greasings at the temperature from 0 to 200 degrees °C. Heating is carried out by the increase of tension on latra and heating of nichrome coil. The control of temperature of the liquid environment is carried out through the temperature sensor and milliammeter. The impermeability of the chamber internal cavity is carried out with the help of two rubber temperature and oil resistant sealings.

Measuring of the sample and coating wear have carried out using profilometer depth recorder Калібр-201 of model ГОСТ19300–86 up to 10 microns and the vertical type optimeter ІКВ more than 10 microns, by taking profilograms of eight equidistant sections of the working surface of the sample in the radial direction.

Thus, the unique unit for materials wear resistance testing at fretting conditions is developed. The unit enables to carry out the comparative tests of fretting of steels, alloys, coverings and composite materials in different liquid and gas environment. Using the standard specimens for fretting - ГОСТ 23.211-80 the unit allows providing tests in the range of loading from 1 to 40 MPa and in the wide range of sliding speeds.

An important advantage of determining the linear depreciation method [28]

is that the magnitude of wear does not depend on the ratio of material and possible changes in supply patterns.

2.2.1 Metallography

Metallography is study of the structure of metals and alloys, particularly using microscopic (optical and electron) and X-ray diffraction techniques.

Metal surfaces and fractures examined with the unaided eye or with a magnifying glass or metallurgical or binocular microscope at magnifications less than 10 diameters can reveal valuable information as to the crystalline, chemical, and mechanical heterogeneity. Crystalline heterogeneity is known metallographically as grain. Chemical heterogeneity arises from impurities, segregation of chemical elements, and nonmetallic inclusions. Mechanical heterogeneity consists of local deformations of structure, elongation or distortion of nonmetallic inclusions, and regions of chemical segregation, resulting from cold fabrication processes.

Microscopic examination of polished or etched surfaces at magnifications ranging from about 100 to 1500 diameters can reveal such information as size and shape of grains, distribution of structural phases and nonmetallic inclusions, microsegregation, and other structural conditions. Metallographic etching—that is, subjecting the polished surface to the action of a corrosive reagent—can reveal the structure by a selective and controlled solution or can unbuild the metal inwardly from the surface. This successive destruction occurs because of the different rates of dissolution of the structural components under the attack of the etching agent. Polarized light is useful to reveal grain structure, detect preferred orientation, examine oxide surface films, and identify phases of different composition [29].

In electron microscopes a beam of electrons instead of a beam of light is directed onto the specimen; because only a highly energetic electron beam will pass through metal films thicker than about 0.05 micron (1 micron equals 0.001 millimetre), a microscope specimen replica of the surface is ordinarily made. To do this a plastic solution is poured over the etched surface; the hardened solution contains on one side a reverse impression of the surface contours of the specimen. The development of transmission electron microscopes, in which the electrons are accelerated to 100 kiloelectron volts or more, has made it possible to examine internal details of thin foils of metals.

X-ray diffraction techniques involve the impingement of a beam of X-rays on the metal specimen and the subsequent diffraction of the beam from regularly spaced planes of atoms; usually, the diffracted rays are recorded on photographic film. The technique is used to study phenomena related to the grouping of the atoms themselves. By measuring the lines or spots on the diffraction pattern and by analysis of the intensity of the deflected rays, information can be obtained about the positionsof the atoms of the specimen and hence the crystallography of the phases, the presence of internal strains, and the presence of solute atoms in solid solutions.

2.2.2 Fractography

Fractography is the study of fracture surfaces of materials. Fractographic methods are routinely used to determine the cause of failure in engineering structures, especially in product failure and the practice of forensic engineering or failure analysis. In material science research, fractography is used to develop and evaluate theoretical models of crack growth behavior.

One of the aims of fractographic examination is to determine the cause of failure by studying the characteristics of a fracture surface. Different types of crack growth (e.g. fatigue, stress corrosion cracking, hydrogen embrittlement) produce characteristic features on the surface, which can be used to help identify the failure mode. The overall pattern of cracking can be more important than a single crack, however, especially in the case of brittle materials like ceramics and glasses [30].

An important aim of fractography is to establish and examine the origin of cracking, as examination at the origin may reveal the cause of crack initiation. Initial fractographic examination is commonly carried out on a macro scale utilising low power optical microscopy and oblique lighting techniques to identify the extent of cracking, possible modes and likely origins. Optical microscopy or macrophotography are often enough to pinpoint the nature of the failure and the causes of crack initiation and growth if the loading pattern is known.

Common features that may cause crack initiation are inclusions, voids or empty holes in the material, contamination, and stress concentrations. "Hachures", are the lines on fracture surfaces which show crack direction. The broken crankshaft shown at right failed from a surface defect near the bulb at lower centre, the single brittle crack growing up into the bulk material by small steps, a problem known as fatigue. The crankshaft also shows hachures which point back to the origin of the fracture. Some modes of crack growth can leave characteristic marks on the surface that identify the mode of crack growth and origin on a macro scale e.g. beachmarks or striations on fatigue cracks. The areas of the product can also be very revealing, especially if there are traces of sub-critical cracks, or cracks which have not grown to completion. They can indicate that the material was faulty when loaded, or alternatively, that the sample was overloaded at the time of failure.

Fractography is a widely used technique in forensic engineering, forensic materials engineering and fracture mechanics to understand the causes of failures and also to verify theoretical failure predictions with real life failures. It is of use in forensic science for analysing broken products which have been used as weapons, such as broken bottles for example. Thus a defendant might claim that a bottle was faulty and broke accidentally when it impacted a victim of an assault. Fractography could show the allegation to be false, and that considerable force was needed to smash the bottle before using the broken end as a weapon to deliberately attack the victim. Bullet holes in glass windscreens or windows can also indicate the direction of impact and the energy of the projectile. In these cases, the overall pattern of cracking is vital to reconstructing the sequence of events, rather than the specific characteristics of a single crack. Fractography can determine whether a cause of train derailment was a faulty rail, or if a wing of a plane had fatigue cracks before a crash.

Fractography is used also in materials research, since fracture properties can correlate with other properties and with structure of materials [31].

Conclusions to wear resistance test procedure

All the technological operations to which the details are exposed prior to coating application, leave traces on the details surface in the form of pollution. So prior to coating application it is necessary to clean the detail surface. The choice of a surface cleaning method depends on many factors, primarily on the nature of contamination and cleanliness requirements of the surface. In this chapter different methods of preparing metal part before coating application were considered. We have proposed the electric-arc evaporator of metals and ionic gas purification system developed by specialists of the National Science Center "Kharkov Physical-Technical Institute".

The basis of the methods chosen for work contains a study of qualitative parameters of friction pares. Scheme of the contact plane-plane type is used on installation МФК – 1. The main advantages of this method are: quick assessment of durability of materials and coatings under fretting, satisfactory reproducibility of test results with a minimum number of test samples, simplicity of the method and corresponding equipment, possibility of smooth control of the frequency and amplitude of normal load micro shifts, tests using plastic and liquid lubricants, registration of friction during testing.

Currently, the aviation industry widely uses solid chrome plating, primarily to improve the durability and corrosion resistance. With regard to internal surfaces, chrome is often used to increase wear and corrosion resistance of the surface of the hydraulic cylinders of aircraft landing gear. With the above described methods for surface cleaning and deposition of coatings on it coatings of vacuum-arc method can be tight vacuum-arc coating thickness to 200 microns with a hardness of from 170 to 700 kg/mm^2. Different structure of the coatings (both columnar and fine-grained) can be obtained.

With regard to environmentally unsound method of galvanic current the actual is the replacement of chromium electroplating with other refractory coatings applied by environmentally clear methods.

3. COMPOSITE MATERIALS DURABILITY UNDER FRETTING CORROSION IMPACT

3.1 Experimental results

Fretting corrosion test have been performed at the МФК-1 installation by the plane to plane contact scheme in accordance with GOST 23.211-80. Essence of the method is that the rolling cylindrical sample (control sample), adjacent by edge with immovable cylindrical sample at a given pressure is driven to swivel-rotary motion with given amplitude and frequency. With constant load of 10 MPa and samples displacement amplitude of 175 microns research was performed. The number of cycles was $3*10^5$ with the oscillation frequency of 30 Hz.

Materials that are being used:

- carbon fiber tape Элур-П-0.1 (dark-brown color, four layers);
- E-glass fibers with adhesion SR8500 (black color, four layers);
- D-16 alloy as control sample;
- BT22 alloy as control sample.

Materials for control samples were chosen because of their widespread usage in the aviation industry (rivets, bolts, etc.), also because of their strength to weight ratio and average market price.

From the results of the experiment we can say that less damaged is carbon fiber composites Элур-П-0.1. Most damaged is the E-glass fiber composite. It may be explained by several factors, especially due to type of the adhesive that is used as matrix material. Insofar as the carbon composite and glass composite formation temperature differs accordingly to that different type of adhesive are used.

Physical and chemical properties of these adhesives play an important role in the strength to external damages such as scratches, impacts, moisture, etc. Also the reason of such different results (composite material based on carbon fibers approximately on 61.2 % stronger in pair with D16 and on 45.6 % stronger in pair with BT22 comparison to E-glass composite) could be in no presence of matrix defects such as porosity, delamination or incomplete cure of the composite.

Experiment results of such materials as:

- ЭДТ-69Н (4 layers of the E-glass prepreg, adhered with ЭДТ-69Н epoxy);
- 5-211-БН (4 layers of the E-glass prepreg, adhered with 5-211-БН epoxy);

where taken from previously executed experiment on fretting corrosion at the same installation МФК-1, and same amplitude and frequency of specimen movement.

Those results were taken in order to compare efficiency of modern ACM with old one composite materials and make a point of achieved results truthfulness.

Achieved results of fretting corrosion test (see figure 3.1 and 3.2):

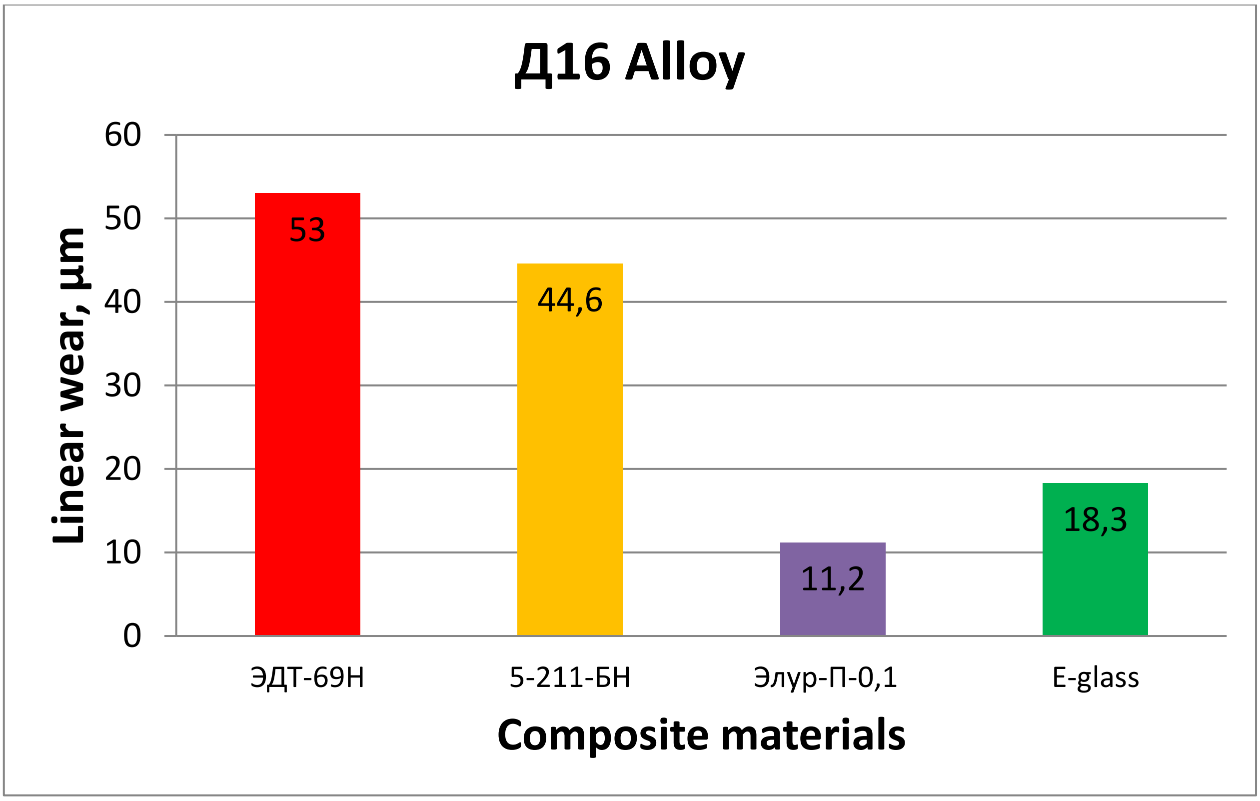

Figure 3.1 – Dependence histogram of linear fretting wear to type of composite materials with counterbody alloy D16

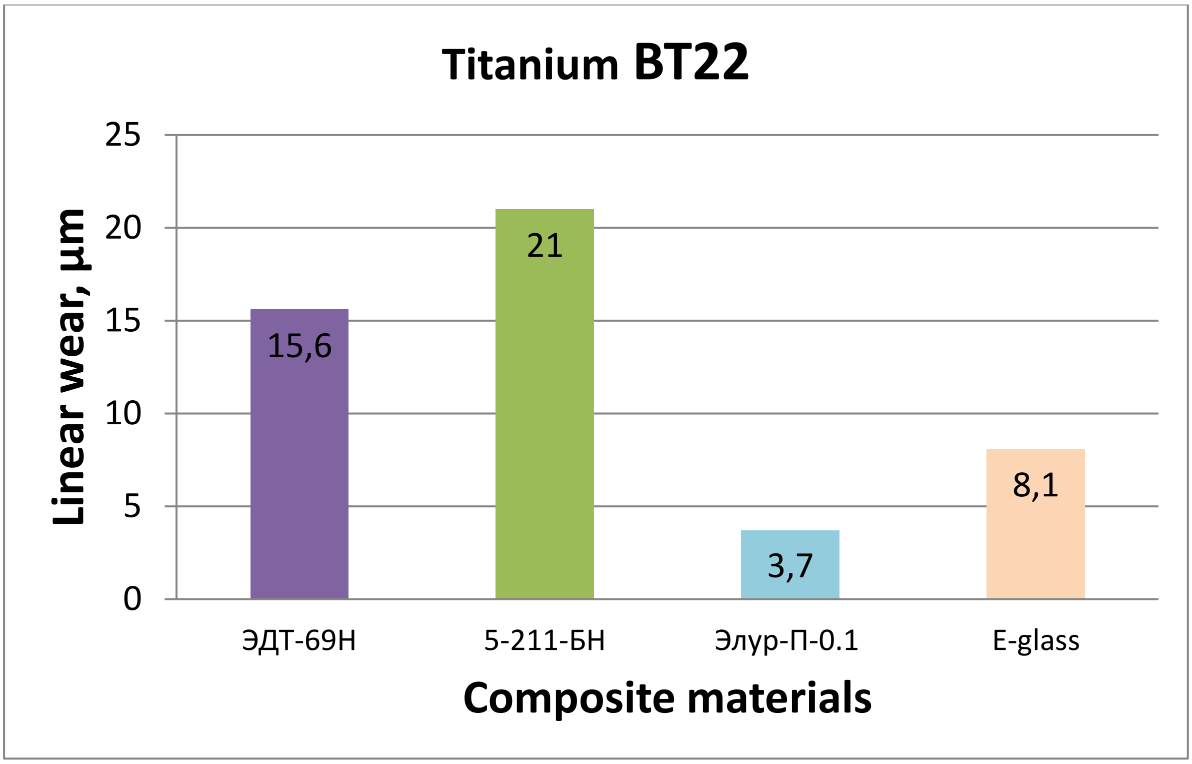

Figure 3.2 – Dependence histogram of linear fretting wear to type of composite materials with counterbody alloy BT22

3.2 Samples fractography

Fractography is defined as the study of the fractured surfaces of materials. It is routinely used to determine the cause of failure in engineering structures by studying the characteristics of a fractured surface. It can also be used in a more fundamental manner to develop and evaluate theoretical models of crack growth behavior. Fractography can be used as a quick and simple procedure to determine the root cause of material failure in plastics.

An important aim of this process is to establish and examine the origin of cracking, as examination at the origin may reveal the cause of crack initiation in metal. Different types of crack growth (e.g. fatigue, stress corrosion cracking, hydrogen embrittlement) produce characteristic features on the surface, which can be used to help identify the failure mode. The overall pattern of cracking can be more important than a single crack, however, especially in the case of brittle materials like ceramics and glasses.

Initial fractographic examination is commonly carried out on a macro scale utilising low power optical microscopy and oblique lighting techniques to identify the extent of cracking, possible modes and likely origins. Optical microscopy or macrophotography are often enough to pinpoint the nature of the failure and the causes of crack initiation and growth if the loading pattern is known.

On the figure 3.3 are shown surface topography of the friction lanes on the tested composite materials with alloys D16 and BT22.

Analyzing the surface of the friction paths we can say that the characteristics of the composites wear in tests with alloy BT22 and alloy D16 almost identical. All surfaces are smooth enough, with a certain roughness. Composites wear have been occurred by the oxidation of the counterbody and destruction during testing of the reinforced E-glass fibers. Abrasive particles generated by friction destroyed surface of the matrix, which explains the increased wear during the tests with aluminum.

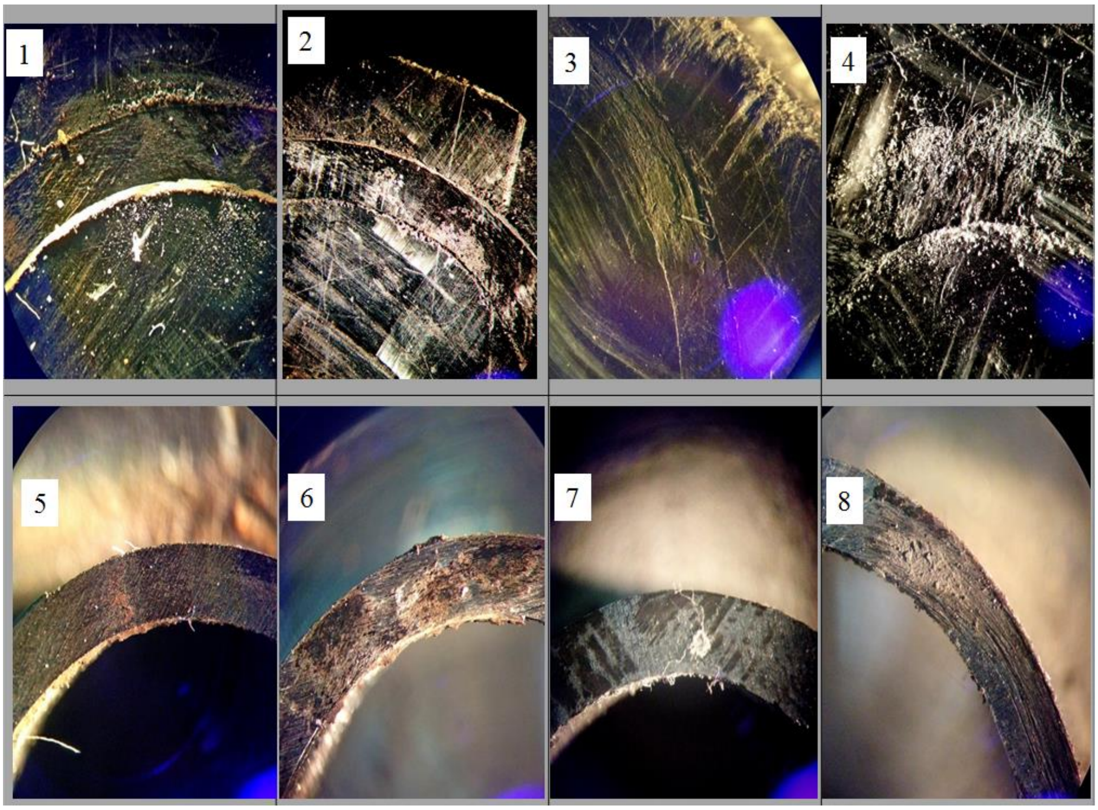

Figure 3.3 – Friction surfaces topography of composite materials in terms of fretting corrosion; 1 – Элур-П-0.1 in pair with BT22; 2 – Элур-П-0.11 in pair with D16; 3 – E-glass with pair BT22; 4 – E-glass 1 in pair with D16; 5,7 –counterbody titanium BT22; 6,8 - counterbody aluminum D16

Conclusion to composite materials

So, fretting corrosion in relation to composite occurs at the places where real movement is not provided of one surface against another; they are riveted and bolted connections, knots, surface control joints of: iron, fairing, composite panels with metal parts, power beams attaching lug. As a result the whole structure became weaker and has lower characteristics of strength and stiffness.

The negative impact of metal rivets on the details of composites, which are connected with metal, is already detected in the process of settling the closing head when there is occurring partial destruction of connecting details.

On the basis of experimental studies on composite materials fretting wear can recommend lock the locking pin, washers preferably from metal side. Locking jam nut, slotted nut, wire from the composites side. Those procedures will reduce relative movement of surfaces among each other. Contact with metals containing aluminum in its structure objectionable for composites as metal oxides that contribute intensive wear process of composites, acting like sandpaper. Thus rivets, bolts and other elements of the connections must be made of titanium because of its oxidation film acts much softer on composite surface.

With composite materials, working in conditions of fretting corrosion, should be chosen carbon fibers Элур-П-0.1 prepreg tape , which showed the best performance in terms of durability fretting corrosion.

During the surface contact of the composite with D16 value of the depreciation in 40 to 60%greater than when dealing with BT22, because of the wear products - aluminum oxide, which actively interacts with the surface than titanium oxide.

Composites fretting corrosion – is a dangerous and hidden type of fracture, which negatively affects the surface of the product, worsening its performance and reliability as a result - resource.

4. ENVIRONMENTAL PROTECTION

4.1 Main factors leading to a negative impact on the environment due to the civil aviation (CA)

Pollution of the air, water and land by substances that are harmful to human health. and the normal development of flora and fauna, is currently the most pressing and urgent problems of environmental protection [32].

Aviation, its activities are among the most highly developed sectors of the economy and industry, and therefore it has a significant impact on the environment. In this section we consider the negative factors associated with the operation and maintenance of aircraft, also take into account the negative effects to the environment caused by accidents and disasters.

Thus, factors impacts of civil aviation on the environment are:

- air pollution;
- water pollution;
- soil contamination;
- the impact of aircraft noise, infrasound, sound shot;
- electromagnetic and ionizing radiation.

It should be noted that the accidents and catastrophes carried out a comprehensive impact of the above factors on the environment, and with much greater intensity and number of casualties than during normal operation of civil aviation.

4.2 Protection of air pollution from ships, aircraft

Air ships emit harmful substances from exhaust gases of aircraft engines [32] in the area of the airport and flight routes, polluting the atmosphere on a global scale.

The composition of the exhaust gas turbine engines includes the following main components that pollute the atmosphere: carbon monoxide, hydrocarbons (methane CH_4, acetylene, C_2H_2, ethane C_2H_6, ethylene C_2H_4, propane C_3H_8, benzene C_6H_6, toluene $C_6H_5CH_3$ etc.), nitrogen oxides, aldehydes (formaldehyde CH_2O, acrolein C_3H_4O, acetaldehyde C_2H_4O et al.), sulfur oxides, carbon black (smoky plume visible for engine inlet), benzo (a) pyrene[33]. Release drained fuel into the atmosphere according to the ICAO standards should be excluded in the process of designing new aircraft engines.

It is obvious that in the area of airport, aircrafts engine emissions depend on the mode of operation and duration of work in this mode. The most time-consuming and environmentally dangerous it is the idle mode. Values of traction in this mode for modern aircraft engines 3% ... 9% of its maximum value R_0.

For a typical modern engine dependence of the emission of harmful substances from its mode of operation is as follows (figure 4.1).

Emission quantitative characteristic of the aircraft engine (AE) is the index of emission (IE), which shows how many grams of any pollutants (harmful substances) emitted during the combustion of 1kg of fuel in the chamber of the engine (measured in [g/kg].

In 1981, the Committee of aircraft engine emissions (ICAO) has developed and adopted the draft regulations on emissions and represented them at the Appendix 16 "Environmental protection".

Standards for emissions is setting limit value of carbon monoxide (CO) gas emissions, of hydrocarbons (CH) and nitrogen oxides (NOx) emission, and also of "Smoke" of the aircraft engines. ICAO standards defining according to emission control parameter $\frac{M_i}{R_0},\left[\frac{g}{kN}\right]$(4.1) which takes in account all regimes of engine operation and its emission indexes. This parameter is characterizing engine degree of harmfulness.

Where: M_i mass of the ejected harmful substances by defined engine operation time; R_0- the takeoff power rate in kN.

ICAO Standards for the aircraft engine emissions control parameter:

$$\frac{M_{CO}}{R_o} = 118\frac{g}{kN};$$

$$\frac{M_{NO_x}}{R_0} = (40\ldots80)\frac{g}{kN};$$

$$\frac{M_{C_xH_y}}{R_0} = 19,6\frac{g}{kN}.$$

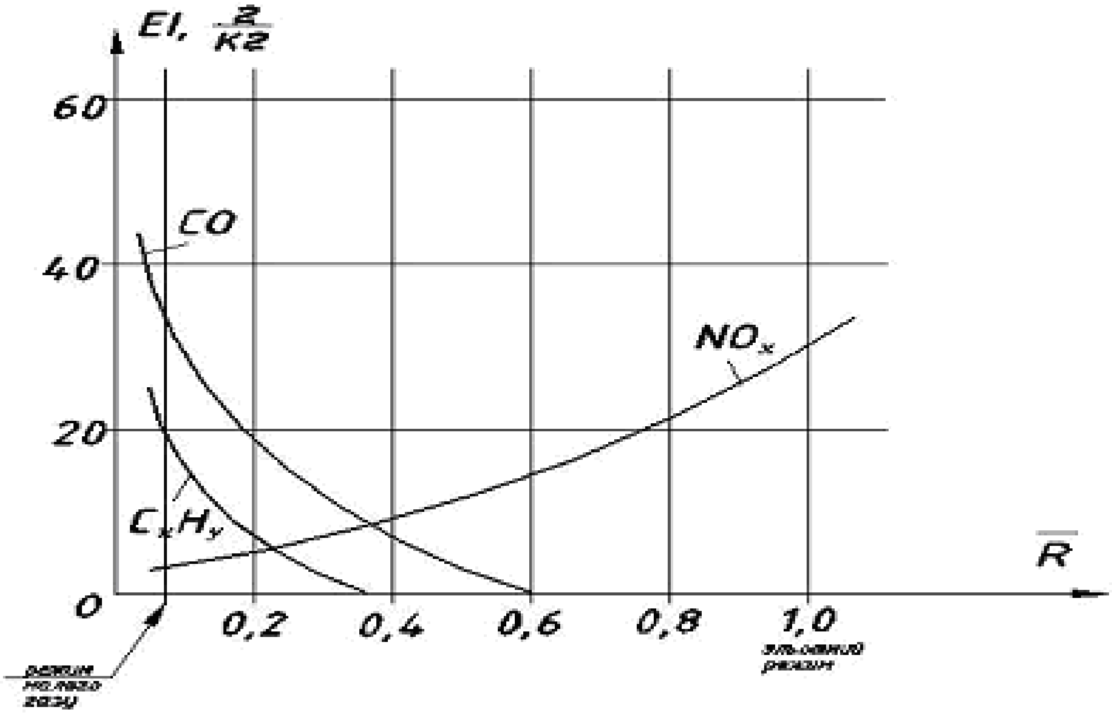

Figure 4.1 – Dependence of the harmful substances emission to the engine mode

Ways to reduce aircraft engine emissions

To reduce the emission of products of incomplete combustion (CO and CH) in the design is necessary to increase combustion efficiency of the fuel, which depends on the emission index EI_{co} and EI_{CH}.

It can be achieved:

- enrichment of the fuel-air mixture in the combustion zone;

- increase the number of zones of combustion in the combustion chamber, allowing you to adjust the engine operation by inclusion or exclusion of the nozzles. These design measures lead to lower specific fuel consumption, improving the efficiency of aircraft engines, and hence reduce the emission indexes of CO and CH.

To reduce emissions of nitrogen oxides NOx aircraft engines can be used the following designs:

- injection of water into the combustion zone;
- the use of two and multi-zone combustion chambers;
- the use of a catalytic combustion inside the combustion chambers at which the gas temperature in the combustion zone is reduced; impoverishment of combustible fuel-air mixture.

Also, when creating new fuels must take into account the degree of pollution during their combustion, AE design excellence, where the fuel will be used.

Operating methods for reducing harmful emissions from aircraft engines based on a shortening and changing modes of the engine in the area of the airport on the stage "start - taxiing - takeoff - taxiing after landing in the parking lot."

Reducing harmful emissions from aircraft engines in the area of the airport can be reached:

- towing aircraft from the parking to the runway;
- taxiing aircraft with a working engine;
- the optimal distribution of aircraft on runways (runway) (if more than one runway) during their takeoff and landing.

Measures to protect the air from pollution and provide for the construction of treatment facilities:

- dust gathering and gas-cleaning plant;
- wet flocculent;
- cyclonic separators;
- special filters (fabric, electrostatic precipitators).

4.3. Water protection from contamination by air transport

The main sources of pollution of the aquatic environment among civil aviation industry - is airports, their infrastructure and equipment assigned to them.

The sources of industrial wastewater at the airports are:

- Buildings and facilities for maintenance of aircraft (aviation base, supporting production and others).

- Buildings and facilities for maintenance of aircraft (aviation base, supporting production and others).

- Buildings and structures ancillary facilities (warehouses, vehicle maintenance, fire station, boilers, etc.).

The main sources of household waste are:

- Terminals, hotels, canteens, board food service.

- Small cities located near the airport.

The main sources of pollution include surface runoff area of the aviation-technical base; of the areas for finishing work, cleaning and handling of aircraft de-icing fluids ("Arctic"); platform and the station square; room service refueling and other.

Airports create such wastewater such as: benzene, acetone, petroleum products, acids, alkalis, dissolved metals (aluminum compounds, beryllium and chromium) and other pollutants, and pesticides.

Wastewater needs cleaning and disposal of the organic and inorganic contaminants. Waste water purification includes the following processes: removal of suspended matters floating, and rough-dispersed colloidal impurities, biological processing and disinfection. Cleaning is the mechanical and biological. During process of the mechanical treatment, liquid separation from solid phases of the wastewater has been occurred by the delaying grates, tanks, septic tanks. With these devices, you can catch up to 30% of the contamination. The principle of the biological treatment consists of destroying the available in the wastewater organic matter remaining after mechanical treatment, due to oxygen provided to the wastewater bacteria’s. Systems to biological wastewater treatment include: autotelic irrigation fields, fields of filtration and biological reservoirs. To clean water from the toxic metals special technology, reagent, electrochemical, ion exchange and combined methods are used.

4.4 Soil protection against contamination by air transport

In terms of air transport intensification processes, the use of chemicals for maintenance of airfields, factories and other enterprises of the CA soil around the airport receiving significant quantities of chemicals. Studies show that the level of soil contamination at airports and factories is high enough. On the ground falls to 200 ... 250 g organic and inorganic chemicals artificial origin. Near the airport soil contaminated with lead, which is formed during the combustion of motor fuels. In the upper layers of the soil near airports lead concentrations of about 0.5 g per kg of soil and above. Also highly contaminated soil due to spillage and dumping fuel. The fate of hydrocarbons in a total volume of pollutants is approximately 75 ... 80%. In addition, the operation of airlines generated solid waste.

The negative effects of pollution. All the above types of pollution have a negative impact on the environment. Organic metal compounds at admission to the environment are a serious threat to the life and health of human and animals, as these compounds are characterized by high volatility, contributing to the spread of pollutants in large areas. Severe soil contamination by petroleum products leads to lower yields or total loss of plants. Solid hazardous waste increase mortality and cause serious disease in the population of the surrounding areas.

Soil protection. In order to protect the soil strict regulations should be developed. To limit the number of used toxic wastes at the territory of airlines and develop measures for their safe storage. Garbage, waste mustn't be dumped (as it does not change their dangerousness) and be recycled. Japan has successfully recycled over 50% of their wastes. Also garbage can be disposed by the biological method (composting). Disposal is due to micro bacterial biochemical decomposition of organic substances. Also very effective method bio thermal (laying in greenhouses, incineration in special plants). The energy released during this, you can let the heating facilities and electricity. It is also necessary to introduce garbage sorting: burn of, some punch, and waste such as resin, plastics, coatings (colors) should be destroyed by high temperature incineration and subsequent storage in special landfills.

4.5 Aircraft noise and ways of protection against it

Sources of noise and infrasound are solid, liquid, gaseous bodies that range. Infrasound emitted during fluctuations bodies with a large mass and low frequency vibrations [34]. Sources have sound strike aircraft moving at supersonic speeds and create a shock wave. Sound pressure level (sound power) for the convenience measured in dB. Sounds that are having the same level but different frequency perceived differently by men. For comparison irritating impact sound waves of different frequencies and levels of noise introduced by perceived noise level (PNL) measured in PNdB.

Also important the duration of the noise, which introduced to account for effective noise effective perceived noise level (EPNL) measured in EPNdB.

ICAO on the basis of experience introduced international standard, according to which the airfield choose three positions (figure 4.2), which measured aircraft noise: Position 1 - takeoff at a distance of 450 meters from the runway axis; item 2 - when typing a height of 500 m at a distance of 6,500 meters from the start of the takeoff; 3 position - at lowering landing at a distance of 2000 meters before the runway.

The negative impact of noise. At the sound pressure level of 140 dB person experiences physical pain in the ears. This so-called "pain threshold", which exceeded 20 dB can cause rupture of the tympanic membrane, and so on - to deafness.

The permissible noise level depends on the take-off weight of the aircraft, engine number, flight path; maximum value should not exceed 108 EPNdB.

Aircraft noise causes adverse effects on flight-technical staff (LTS), which is directly related to the operation of aviation engineering, passengers; Workers enterprise CA; the people living near the airport. Infrasound also affects all living organisms, because under the influence of sound waves of low frequency, internal organs also start to oscillate at a frequency corresponding to the frequency of exciting force, appear discomfort in the abdomen and chest. Impact sound impact can cause human and animal fear, fright, waking from sleep.

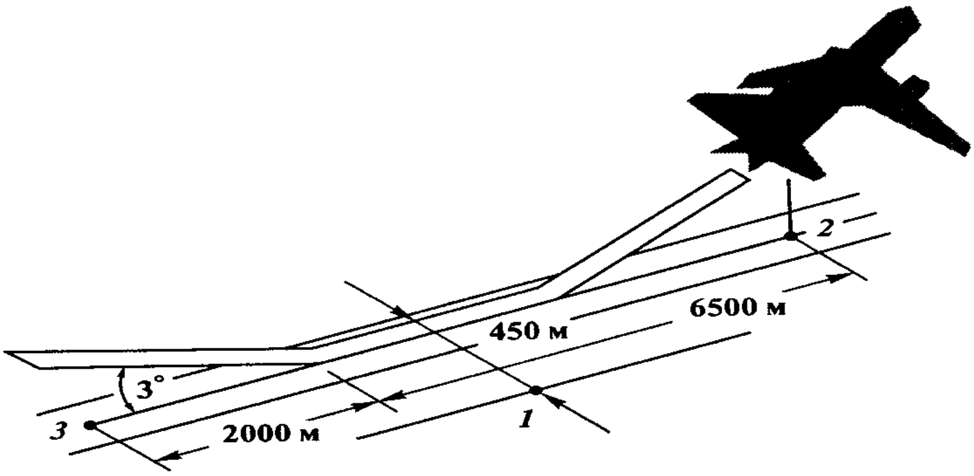

Figure 4.2 – positions on the airfield, due to which measured noise level

Methods to reduce the harmful effects of noise, infrasound and sound impact on the environment.

The main source of noise aircraft is their power units (SU) as the most effective methods of reducing noise pollution associated with the improvement of aircraft engines, their workflow design, the use of noise attenuation. Also note layout engine aircraft.

Measures to reduce noise and infrasound on the airline:

- The refusal of taxiing aircraft with the engine running;
- Organization of special services to control the noise;
- Reducing the total time of the SU;
- Replacement of obsolete aircraft;
- To ensure the rational regime of work and rest of employees;
- The construction of new airports should consider distance to populated areas, the existing route of flight, terrain, weather conditions, the types of aircraft to be serviced;
- Construction of sound proof hangars .
- The use of fixed and mobile airport noise silencers, acoustic screens;

- The use of sound-absorbing and soundproofing materials in the construction of aircraft and the construction of airports (including waiting rooms and office space for more passenger comfort and support staff);

- The application of collective protection (headphones, cotton, clothing, helmets, belts);

- Availability of medical stations to air carriers to provide emergency care, particularly in noise or infrasound damage;

Reduction of impact sound impact can be achieved by:

- Not using supersonic passenger aircraft;

- Acceleration to supersonic speed to only over inhabited areas.

4.6 Protection from exposure of electromagnetic and ionizing radiation

Negative influence. The most negative impact of electromagnetic fields (EMF) suffers a nervous system, in which there are significant changes, discomfiture conditional reflex activity, changes in the electroencephalogram, pathological morphological disturbances in the brain and spinal cord. The changes in the nervous system causing changes in cardiovascular, endocrine and other systems. The impact of EMF also causes cataracts in the eyes. The nature of functional changes depends on the duration of exposure, frequency and parameters fields and on the individual body.

Ionizing radiation is more pernicious, but CA it does not occur as often as electromagnetic. Basically, the aircraft is - special sensors, devices of non-destructive X-ray control. Such radiation can cause leukemia, thyroid cancer, alopecia, violation of any of the loss of immunity, a sharp reduction in life expectancy. Also undergoing radiation contamination of the environment.

Protection and electromagnetic radiation. Protect the environment can be as follows:

- Introduction of stringent norms of radiation devices and equipment used in aviation.

- Determine the limits of radiation doses and the time spent in the area of exposure (especially radiation).

- The territory of the radiation sources (radio centers, radars) must be enclosed themselves sources should be located outside the settlements to the conditions that achieve their assigned a sanitary norms of maximum permissible levels of radiation.

- Reducing power radiation sources through the introduction of new technologies, structural improvements (more precise aiming of the antenna).

- Introduction of border sanitary protection strip, where the electric field of less than 1 kV / m.

- Screening facilities protection.

- The use of warning alarm and personal protective equipment.

- Carrying out regular medical examinations of staff.

4.7 Environmental pollution in accidents and catastrophes

Aviation, its operations are complex, multi-process that requires consideration of many factors and factors of great responsibility, organization, attentiveness. But although CA is a very safe mode of transport, but even here there are accidents, disasters and various other incidents that result in a significant negative impact the environment suffers. This complex is made intense impact, polluted air, water, soil, and possible electromagnetic radiation exposure. But the worst thing is that when such incidents killed many people. Therefore any aviation enterprise for emergency response and disaster preparedness activities necessary to provide emergency services, which include:

- fire and rescue services;
- search and rescue services
- transportation services;
- medical service;
- service special vehicles;

- department of Internal Affairs of the airport;
- services that provide communications;
- service units are engaged in the decontamination area;
- protection Service (to prevent terrorist attacks, illegal entry into the territory of the airport);
- customs service, service control (to prevent ingress of explosives and other dangerous items on board the aircraft).

All the above services should undergo constant training in order to ensure prompt and effective elimination of various incidents that constitute a threat to life and human health and environmental threat.

4.8 The environmental situation at the manufacturing and maintenance of parts made of composite materials

Fillers and polymer binders used in the manufacture of composite materials (CM) are generally classified as hazardous, flammable and explosive substances [35]. Therefore, working with them, you must carefully observe all the special safety instructions, safety and fire prevention.

Production and maintenance of structures made of composite materials is quite harmful and can cause great harm to the environment. To prevent this airline in the territory must be provided waste disposal plant where the waste will be sent to all CM (polluted binder, alcohol-blend, alcohol-acetone, cellophane, cloth, fabric remnants from vacuum bags and other waste). Some waste can be used for manufacturing consumer items, and for unused waste should be the technology of neutralization.

In the production and maintenance of parts of the CM in indoor air is released fiberglass dust; the wet cleaning floor dust fibers can get into the water. To protect water and soil pollution by sewage should predict reversible water system that reduces water consumption to production costs.

4.9 Ukraine environmental legislation

Addressing environmental management, regulation of interaction between society and nature is based on the relevant environmental legislation.

The start of the environmental law in Ukraine can be considered in January 1988, when it was adopted "Regulation of radical restructuring protect the natural environment in Ukraine." The target was to decisively move from administrative to predominantly environmental complex methods of environmental management.

Important to ensure environmental requirements in all areas of human activity is the law of Ukraine "On Environmental Protection" of 25 June 1991. The law determines the priority of environmental safety requirements, mandatory compliance with environmental standards, limits regardless of the scope of management, the need to preserve species diversity and spatial integrity of natural objects and complexes, guarantee environmentally safe environment for life and health, scientifically justified environmental coordination , economic and social interests of society.

Regulatory and legal framework protecting air is passed 16 October 1992 the Law of Ukraine "On Air Protection".

The main requirements of the Act to prevent chemical and biological pollution, as well as the physical and mechanical effects on the atmosphere. Important for the civil aviation enterprises should prevent the problem and reduce noise vehicles.

In case of violation of civil aviation laws on environmental protection, their activities may be suspended or banned from approved by the Ukraine Parliament on October 29, 1992 "Order of restrictions, temporary prohibition (suspension) or termination of enterprises, institutions, organizations and about ' objects. "

Among the regulatory acts aimed at the implementation of environmental requirements exclusively civil aviation enterprises should note approved by the Ukraine Parliament at May 4, 1993 "Air Code of Ukraine", which defines the obligations of the contractor and operator of environmental protection in the exploration, construction, reconstruction and operation of facilities, implementation of new technologies in civil aviation. Air Code defines the general provisions on protection from harmful noise impact of aircraft operations of civil aviation and emissions of pollutants aircraft engines.

Rules of certification of aircraft and noise protection and regulation of aircraft engine emissions defined according to the documents of the International Civil Aviation Organization (ICAO) - Annex 16 "Environmental protection and.

The foundation for the new environmental legislation was the law of Ukraine "On Enterprises" approved by the Ukraine Parliament at March 27, 1991 consolidated law principles of environmental measures now own funds and loans

Legal protection is governed mainly land "Land Code of Ukraine." Land legislation clearly defines the procedure for land use and their removal. Recorded specific legal requirements relating to the organization of land use in civil aviation.

Use of groundwater civil aviation enterprises in accordance with the "Water Code of Ukraine." The water legislation governs the procedure for granting water bodies for public and social water use and determine grounds for termination of the use of water, establishing legal requirements relating to specific types of water, including water transport. "Water Code of Ukraine" provides a set of requirements that define the responsibilities of water users on the rational use of water resources.

In order to ensure nuclear safety and compliance radioactive waste management when working with sources of ionizing radiation , Ukraine Parliament accepted the Law of Ukraine "On Nuclear Energy Use and Radiation Safety" on February 8, 1995 and "On Radioactive Waste Management" on June 30, 1995 year.

Equally important in ensuring environmental safety, environmental protection, rational use and reproduction of natural resources, protection of environmental rights and interests of citizens has passed by the Ukraine Parliament on 9 February 1995 "Law of Ukraine on Environmental Expertise".

Thus, summarizing all the above activities aircraft accompanied by a significant environmental impact. But not only polluted the environment, the most important thing - it is death. You should always remember that: "A person's life and health, honor and dignity, inviolability and security are recognized in Ukraine as the highest social value" (Constitution of Ukraine, Article 3). This rule must be used continuously to implement such measures and activities that would contribute to a comfortable and safe work and rest man. It should take all relevant laws, interact with other states on the protection of human life and the environment. All enterprises, organizations and firms must conduct explanatory work, to make contributions to fund environmental protection funds from which the company would spend at eliminating or preventing the consequences of their negative impact on the environment and health their employees.

Great attention should be paid to the implementation of low-waste production processes, including this:

- Complex processing of raw materials, in which the maximum yield is obtained at each stage of raw materials and minimum waste.
- Application of Microbiological methods of treatment.
- Introduction of closed drainage and water supply systems.
- Consumption waste disposal, which are repeated material resources.
- The creation of territorial-industrial complexes of closed technological cycle of material flows of raw materials and waste.
- New technologies other than a minimum number of process stages and equipment, and high production efficiency.

You'll also need to adopt new standards for environmental management, which set stringent emission standards of pollutants duration of the attendants of threatening life and health of organic and inorganic compounds and others (certification for compliance with ISO 9000, 9001, 9004 and ISO 19011).

We must not forget that nature under its own laws . But, knowing the laws of nature and society and applying them intelligently, it can utilize and improve nature to his benefit. For environmental protection - a protection rights.

Conclusion to environmental protection

Aviation is growing very rapidly and, if left unchecked, will continue to grow at a very high rate. Mid-range forecasts suggest that by 2016 passenger kilometers flown will more than double (compared to 1995), and by 2050 they could grow by 820%.

Even at current levels of activity, aviation generates levels of noise pollution that represent a serious threat to the health of those who live and work near airports. Maximum noise levels recommended by the World Health Organization to protect human health are regularly exceeded in the vicinity of airports. With aviation forecast to continue growing rapidly, the damage to human health is set to become even more serious.

Airports and their aircraft produce large quantities of toxic emissions, all of which are a threat to human health. In particular, they produce very large quantities of nitrogen oxides and volatile organic compounds (VOCs). Research in the USA has linked VOCs generated by Chicago-Midway airport to elevated rates of cancer in its vicinity. The building of a fifth terminal at Heathrow airport to accommodate ever-increasing air traffic would lead to a doubling of nitrogen oxides emissions. It would also mean that Heathrow would remain one of the country’s main producers of VOCs.

Aviation is already a significant source of greenhouse gases, which cause climate change. However, the aviation industry’s very rapid growth means that it is forecast, by 2050, to become one of the single biggest contributors to global climate change. Radiative forcing is a measure of the amount of climate change that results from particular emissions. In the early 1990s aviation contributed 3.5% of total new man-made radiative forcing. Mid-range forecasts suggest that the radiative forcing effect of annual aviation emissions will increase by 700% by 2050. On this basis, 10% of all new man-made radiative forcing would be coming from aviation by 2050. These serious environmental problems point to the need to consider restricting the growth of the aviation industry. It has been argued that restricting aviation growth would have serious effects on economic growth.

However, examination of these arguments shows them to be questionable or flawed, and it seems possible that limiting aviation traffic may deliver positive economic benefits.

The aviation industry is causing serious environmental damage, and is threatening the health of people who live and work near airports. If aviation is allowed to grow unchecked, the scale of the damage will escalate dramatically. This is of particular concern in relation to aviation’s contribution to climate change. These concerns point to the need for a fundamental change in public policy towards the aviation industry

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5. LABOUR PROTECTION

5.1. Hazardous and harmful production factors at work with aircraft technics

According to ГОСТ 12.0.002 - 80 "Terms and definitions":

- harrmful production factor - a production factor whose impact on employed workers in certain circumstances or causes decreased performance;

- hazardous production factor - a production factor what's impact for working in certain circumstances result in injury or sudden deteriorating health.

According to the classification of dangerous and harmful factors (labor safety regulations during maintenance and current repair of aviation equipment ДНАОП 05/01/30 - 1.06 - 98) that affect human health in the production [36], are those:

- the noise, leading to dysfunction of the nervous and cardiovascular systems, loss of hearing acuity, decrease of the response and performance;

- vibration (using pneumatic tools). The impact of production equipment vibration can lead to vibration disease, which is characterized by impaired sensitivity leather, vasospasm hands, and severe pain in the joints and bones;

- exposure moving parts of equipment and machinery. Rotating parts can cause injury and death of a person;

- separation of particles of the material and tools. When handling components on machine stalls, aggravation of the tools on the abrasive discs and during other works possible separation of particles of the material and tools, and this may lead to injury to workers;

- harmful chemicals; this category of hazardous production contains factors due to the formation of toxic substances and gases (fuel impact, solvents);

- use of fire and explosive materials.Explosion and fire danger may occur during manufacturing processes related to use and maintenance of fuel; the possibility of fires and explosions determined by the explosion and fire characteristics of substances (flash and inflammation, lower and upper concentration limits inflammation);

- increased voltage in an electrical circuit, and further short of the circuit which can pass through the human body;

- lack of natural and artificial light increases the visual fatigue[37], a large number of errors of vision loss, decrease productivity and increase the likelihood of injury.

5.2. Technical and organizational measures for reducing exposure to hazardous and harmful production factors

Apply the following measures to reduce the impact of hazardous and harmful factors:

- from exposure to noise, antinoise headphones are used at work on machines and pneumatic tools;

- to reduce the harmful effects of vibration, it is necessary: to arrange tools with special antrivibration handles and ensure workers with special gloves; total impact time on employee should not exceed more than 2/3 of the shift; regularly organize the medical examination of workers; a single continuous impact length of vibrations due to vibration tool should not exceed 15 - 20 minutes;

- moving parts, drive and gear mechanisms should be equipped with protective cover;

- the processing of metal parts for machines, tools exacerbation with abrasive discs and other similar work during what worker must have goggles, remove the hair under the hat, all buttons on overalls must be fastened;

- due to the risk of car movement in the manufactory, layout should be provided; driveways should be closed protective housing; the operation of the crane - beam must comply with the rules and State Committee on health; forbidden to lift cargo weight exceeding permissible load of the machine; workers are not allowed to be under carriers when it moves; to prevent dangerous interactions cabins cars and electric cars be painted in yellow or orange color.

Protection equipment and systems from aerodispersive harmful chemicals[38]:

- removal of harmful and hazardous substances from the air through ventilation;

- the use of respiratory protective (Respirators and other means);

- to protect the skin from falling spray particles which can move with high speed and high temperature;

- the use of eye protection;

- for localization and removing the harmful and hazardous substances from the area of it’s formation, local suction can be implemented.

Measures of protection from high voltage.

According ДНАОП 0.00 - 1.21 - 98 current carrying plants must have fencing with special lock, voltage change when you open the protective parts. Condenser batteries of large capacity should be located in or near the blocking indoors or outdoors in a special steel cabinet. All condenser batteries should always be escaped and provided with means for automatic discharge capacitors during screens removing.

Technical and organizational measures that are used for reducing exposure to hazardous and harmful factors, during work with composite materials. To ensure the safety of health, actions must be complied according with organizational and technical measures. In order to avert the hazardous and harmful factors at the workplace, actions should be done in accordance with the regulations.

Safety measures should be based on the basis of the requirements[39] of the "Regulation on the development of labor protection instructions", approved by the State Committee of Ukraine №9 labor protection from 01.29.1998, in order to ensure safe working conditions while performing work on service of parts made of composite materials [40]. You must also comply with the requirements and provisions of the following interstate standards: ГОСТ 12.1.003 -74 ССБТ ; ГОСТ 12.1.004-91ССБТ ; ГОСТ 12.1.007 - 91 ССБТ ; ГОСТ 12.1.003 -83 ССБТ ;

ГОСТ 12.1.005 -88 ССБТ ; ГОСТ 12.1.019 -79 ССБТ ; ГОСТ 12.4.034 - 85 ССБТ ; ГОСТ 12.4.016 - 83 ССБТ .

Under these conditions developing preventive measures to prevent accidents.

1. It is necessary to organize an orderly traffic in ring industrial areas and on the territory of enterprise. For this floor markings are used. Persons under 18 years of age and those who have passed medical examination, specifically trained and received a certificate to drive electric cars, allowed to drive an electric car.

2. The moving parts of machinery must be closed with casing. It is prohibited to employees be located on cargo or underneath.

3. To work with composite materials permitted the persons over 18 years that have passed medical examination, examined the safety instructions, and are certified for work. Repeated check held at least once a quarter.

4. All workers who work with composite materials must be provided with clothing, footwear and individual protective means coats or overalls, cap or scarf, special gloves, glasses firmly attached to the face frame, respirator ПРБ-5, ПРБ-5МП or "Petals".

5. Production areas where parts made of composite materials, must be equipped with the exchange ventilation system [41], which provides a 6-fold air exchange per hour. Desks should be equipped with local suctions.

6. To prevent the formation of static energy it is necessary to provide ground areas, bridges and working platforms, door handles, handrails, steps and handles devices. To avoid the formation of static electricity in the defatting armature provide input in gasoline antistatic anti-wear additives such as "Syhbol."

7. Adhesives, solvents stored in a hermetically sealed containers of colored metal coated with these data, quantities not exceeding the daily supply.

8. In industrial premises twice per shift do wet cleaning.

9. In the room where served parts made of composite materials, no need to perform welding, also not use open fire, do not clutter up the aisles to the fire equipment.

10. In the event of an injury, you should immediately notify the master or the head unit, keep setting the scene of an accident, if it does not threaten the lives and health of employees and the next must apply to the medical unit to provide first aid and recording of the accident.

11. In the case of the appearance of the workers at theworkplace in the stage of alcohol or drugs, the administration does not allow him to work, sends it to the drug treatment cabinet or makes relevant act. The administration has the right to dismiss an employee from the company for the appearance at the work in progress of intoxication, according to [42] article 40, paragraph 7 of the Code of Ukraine on Labour Protection

12. The employee must [43]:

- know and comply with the requirements of regulations on labor protection rules for handling machinery, machinery, equipment and other means of production in relation to the profession States to benefit of collective and individual protection;

- follow the instructions of labor protection provided by collective agreement and the internal regulations of the enterprise [42] (Article 18 of the Law of Ukraine "On Labour Protection").

13. Violation of laws and other regulations on labor protection, obstruction of officials of state supervision and representatives of trade unions, blame the workers involved in the disciplinary, administrative, financial and criminal liability under the law [42] (Article 49 of the Law of Ukraine "On Protection work ").

5.3. Providing fire and explosion safety in the work division[7]

According to ГОСТ 12.1.004-91 sources of fire are:

- electric discharges when working with hand power tools and light source of the work area;

- sparks from the blows of hand tools when performing technical process of joining components and assemblies;

- shocks in case of an explosion of compressor stations, air ducts;

- kerosene vapor blast during cleaning works. The probability of fire from a single product or technical equipment during its developing and manufacturing should not exceed 10^{-6} per year.

According to the interstate standards ГОСТ 12.1.004-91; ГОСТ 12.1.004 - 85 ССБТ ; ГОСТ 12.1.010 - 76 ССБТ ; ГОСТ 12.1.011 - 78 ССБТ ; ГОСТ 12.1.018 - 76 ССБТ ; ГОСТ 12.1.011 - 86 ССБТ ; ГОСТ 12.1.041 - 83 ССБТ ; ГОСТ 12.1.044 - 84 ССБТ organizational and technical measures for fire and explosion safety include:

- the necessity of setting the fuses in the electricity meter in order to stabilize voltage of the electrical supply;

- use of instruments with protection against sparks, the use of such a tool, which is made of no spark materials or the appropriate fire safe design;

- additional fencing technological process performance areas;

- personnel should work with fire and explosives materials according rules;

- set on equipment that can explode or flash, signs prohibiting use of an open flame;

- need to avoid production operations on faulty equipment, as it may lead to explode or fire, as well as when disconnected control measurement device, which are defining process parameters (temperature, pressure, etc.);

- delivery of an easy flashing and combustible liquids in small quantities in a safe non-combustible containers;

- for the equipment, products or the parts washing and degreasing should be used incombustible detergents and special cleaning methods;

- routine inspection, routine preventive and overhaul of technological equipment with regard to the implementation of measures for fire explosion safety;

- installation of compressor stations in designated areas (cells with reinforced walls and ceilings to protect adjacent premises in case of an explosion, periodic maintenance and control of parameters);

- use of special membranes for air ducts and periodic inspection of cranes and nozzles for the presence of air leakage;

- works to clean exhaust devices should be conducted systematically and be recorded in the log;

- strict compliance with fire safety regulations when handling kerosene and other flammable substances, the use of powerful ventilation equipment. Workplaces should be equipment with sand cases. Stopping of all kinds of instrumental work where cleaning operation are performing.

Also during the design and construction should take into account that the shop belongs to the category A (the degree of use of fire-resistant materials). The shop must install a hard fire control, increase the demands on compliance with fire safety rules by the administration, master mechanic and energy. It is necessary to ensure a safe exit from the aircraft plant, which provides a wide gate. These gates need to be greased, grooves are clean, entrance to the gate should be free.

To prevent static electricity, grounding provided. When using local lighting using voltage 36 V. For cleaning oiled rags there are used special drawers that are removed at the end of the day.

The shop is prohibited:

- use of open fire without permission fire protection [44];

- save flares, fuel and acids at the not established places;

- assembling, soldering outside the special places.

In order to provide fire extinguishing in the early stages there are two fire hydrants attached to the household - the production pipeline. The length of each hose 15 m, capacity - 2.5 l / s. From stationary fire extinguishers should be two balloon extinguisher UP - 2M. To report a fire in convenient locations must install two telephones. To prevent a fire in the absence of people, you need to install an automatic electric fire alarm system. As a foster electrical system fire station, uses a system - СДПУ station - 1 of siren.

In fire protection the fire vehicles АЦ - 30 at the ЗИЛ - 130 should be provided. Access possibility to the fire truck into the shop, through the sliding gate should be provided.

5.4. Calculation of ventilation when working with composite materials

In the calculation we use ГОСТ 12.4.021 - 75 ССБТ .

Since working with composite materials largest number of volatile substances released from the binding, the calculation will spend on it. For example, calculate the air at work with a binder ЭDT-69N. The components included in the binder, their maximum permissible concentration (MPC) are presented in table 5.1.

Table 5.1 – The components that make up resin and their maximum permissible concentration (MPC)

Name of the components that are part of the resin	**MPC of hazardous substances mg/m³**
Oxirane	**1**
Toluene	**50**
Acetone	**200**
Ethyl	**1000**

Frequency rate of the air exchange defined by the formula:

$$n = \frac{Q_{sum}}{V} , \qquad (5.1)$$

Where: Q_{sum} – the total amount of air needed to control and protect against harmful fumes, m^3/h; V – room volume, m^3.

$$V = a \cdot b \cdot c , \qquad (5.2)$$

Where: a – room width; b – room length; c – room height.

$$V=8\cdot 10\cdot 8=640 \ m^3$$

Total amount of air needed to control and protect against harmful fumes defined by the formula:

$$Q_{сум} = \sum_{i=1}^{n} Q_i , \qquad (5.3)$$

Where: Q_i – amount of air needed to protect against harmful fumes of each component in resin .

$$Q_i = \frac{kn_{об}}{(k_1 - k_2)\ 10^{-6}}, \qquad (5.4)$$

Where k=0,1 – the amount of harmful vapors by equipment item within an hour, kg; k_1 – the maximum permissible concentration of harmful substances in the air of the room, mg/m^3; k_2 – the concentration of contaminants in a inflow air, mg/m^3; n_{eq} – the number of equipment units, n=1.

Accepting that $k_2 = 0$, assuming that a inflow air does not contain harmful impurities.

Then:

$$Q_1 = \frac{0,1 \cdot 1}{(1-0) \cdot 10^{-6}} = 100000 m^3,$$

$$Q_2 = \frac{0,1 \cdot 1}{(50-0) \cdot 10^{-6}} = 2000 m^3,$$

$$Q_3 = \frac{0,1 \cdot 1}{(200-0) \cdot 10^{-6}} = 500 m^3,$$

$$Q_4 = \frac{0,1 \cdot 1}{(1000-0) \cdot 10^{-6}} = 100 m^3,$$

Then the total amount of air:

$$Q_{sum} = Q_1 + Q_2 + Q_3 + Q_4 = 102600 \text{ m}^3/\text{h}$$

Define the frequency of air exchange:

$$n = \frac{Q_{sum}}{V} = \frac{102600}{640} \approx 160 \text{ l/h}$$

To implement the mechanical ventilation we will chose centrifugal fan type Ц-50№16, which has the following characteristics:

- productivity: L = 75,000 m^3/h;
- pressure: P=1000 N/m^2;
- efficiency: η =0,8.

Define fan quantity:

$$n_{вен} = \frac{2Q_{сум}}{L} = \frac{2 \cdot 102600}{75000} \approx 2{,}736 \qquad (5.5)$$

Accept the number of fans - three (3). Calculation according to the Staroverov I.G. "Designer's Handbook of industrial, residential and public buildings and facilities: ventilation and air conditioning" according to the table "Recommended accessories of the general purpose centrifugal fans" selecting brand engine A4200L4 with the following characteristics: power N = 45 kW; rotor speed n = 1475 rev/min; m = mass of the engine 2245 kg.

5.5. Manual labor protection when working with composite materials

This instruction is developed based on the requirements of the "Regulations on the development of labor protection instructions", approved by State supervision on health Ukraine №9 of 29 January 1998 to ensure safe working conditions in the performance of composite materials.

1. General requirements:

a) to work with composite materials allowed persons over 18 years old;

b) persons who have passed a medical examination;

c) those who have studied the safety instructions, have been briefing safety, certified for work; second briefing held at least once per quarter;

d) all working with composite materials must be provided clothing, footwear and individual protective means: robe or overalls, cap or scarf, special gloves, glasses tight adjacent to the face frame, respirator ПРБ-5, ПРБ-5МП or "Petals".

2. Safety requirements before starting work:

a) wear and organize clothing and protective clothing received under personal protection industry standards;

b) check availability and serviceability of grounding devices and equipment;

c) enable indoors inflow and exhaust ventilation;

d) prepare required serviceable tool for the job: knife for the Prepreg cutting with serviceable handle and cover;

d) after detection of any faults inform the master. D not begin until fault will be fixed.

3. Requirements security during the performance:

a) perform only the work that the master or shop administration entrusted;

b) the production of polymeric composite materials and their mechanical processing should be done under the hood using a vacuum cleaner;

c) cleaning the surface equipment and facilities from adhesives should be performed with a tools made of non-spark materials that do not form sparks when struck;

d) avoid getting resins and solvents on your hands, face or eyes; adhesives, solvent if it gets on your skin, you should immediately remove it with soft cotton swab, and then wash your hands with hot soapy water and grease with ointment based on vaseline or lanolin; not allowed to wash hands with organic solvents.

d) not to store food, personal items on the site; not to eat at workplaces;

e) not to clutter up workspace on the approaches to it; wastes such as glass fibers, carbon fibers, boric fiber and hybrid fabric, fold napkins trough into the container with a lid. After work wastes should be taken out of the room.

4. Security requirements after work shift:

a) organize the workplace, tools;

b) residues of flammable substances (FS: gasoline, acetone, etc.) bring in a designated space;

c) remove protective clothing and protective equipment, pick them into the individually cabinet;

d) turn off ventilation;

d) the occurrence of any malfunction report to the master;

e) wash your face and hands with warm water and soap to take a shower.

Fillers and binders used in production and maintenance of structures made of composite materials, are usually categorized as hazardous, fire and explosives. Therefore, safety requirements and fire prevention measures instructions at the working area should be followed. We must remember that human life – is the most important and true and true and fair fulfillment of established requirements and regulations will save it.

Conclusion to labour protection

Labour protection is instrumental for achieving decent work and for contributing to social justice and social peace. It is as fundamental today. Labour protection and social security are complementary, and together provide the social protection that workers and their families need. The regulation of working conditions in the areas of wages, working time, occupational safety and health (OSH), and maternity protection is central to effective and inclusive labour protection. Effective systems of social dialogue and collective bargaining contribute to these protections. Taking into account current challenges and looking to the future of work, provide guidance for integrated and innovative approaches to address the needs of both men and women workers with family responsibilities.

All workers should enjoy adequate protection guided by international labour standards, and taking into account different national circumstances. Regulations and institutions that govern labour protection need to keep pace with the transformations in the world of work. In the interests of workers, sustainable enterprises, and societies as a whole, decent working conditions and appropriate protection must be afforded to all workers, without distinction.

GENERAL CONCLUSION

Composite materials usage is rising as manufacturers in different industries increasingly adopt this versatile material. Today composites are used in wind energy, marine, construction, aerospace, military/defense, automotive, sporting goods, pipes, tanks and many more applications. Composites offer several advantages over traditional materials: higher tensile strength, lighter weight, greater corrosion resistance, better surface finish and easy processing. Although they are more expensive than traditional materials, such as aluminum, steel, concrete and wood, composites are making inroads into applications where corrosion resistance, weight savings, fuel savings and other performance benefits are critical.

The advanced composites market accounted for less than $2 billion in 2011, but it is expected to witness double-digit growth through 2017 because of growing demand in the aerospace, defense, transportation and wind energy markets [45].

As aircraft are creatures of economics. Commercial transport planes whisk passengers and cargo around the world in hours, but only if they generate direct profit for the airlines that fly them. Business jets profit commercial enterprises, albeit more indirectly, by doing the same for growth-conscious corporate executives. In order to find the right balance is necessary to improve aircraft life cycle as much as possible. For this idea realization needed to start from the end, from the aircraft necropolis.

The main goal of materials selection is to manage and minimize corrosion influence on aircraft structure and predict it’s further propagation. In general, materials that are inherently corrosion-resistant are more expensive than those that are not. For this reason only after almost decade we will see fully composite aircraft. Until that time comes, aircrafts will be engineered from metals and advanced composites. As this couple are connected to each other usually with joint elements, between them always will occur small relative movement or fretting corrosion. Fretting corrosion practically impossible to indicate, only predict. That's why to improve life cycle of the aircraft with minimum costs and maximum efficiency it is essential to shut off aluminum alloys from composite materials.

Basing on experimental results we can say aluminum oxide that exists on the surface of the aluminium could damage ACM and cause unpredictable delamination, or crack with further catastrophic, in best case expensive repair.

For prognosticating those damages, alteration of aluminum joints on titanium joints are highly recommended.

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