MINISRY OF EDUCATION AND SCIENCE OF UKRAINE

NATIONAL AVIATION UNIVERSITY

Departament of aircraft design

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MASTER THESIS
(EXPLANATORY NOTE)
EDUCATIONAL DEGREE
"MASTER"

THE EDUCATIONAL PROFESSIONAL PROGRAM
«AIRCRAFT EQUIPMENT»

Theme: « Application of crack stoppers in the ramp structure »

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Kyiv 2020

NATIONAL AVIATION UNIVERSITY

Aerospace Faculty
Department of aircraft design
Educational degree «Master»
Specialty 134 «Aviation and space rocket technology»
Educational professional program «Aircraft equipment»

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TASK
for the master thesis

VOSTROKNUTOV MYKYTA

1. Theme: **«** Application of crack stoppers in the ramp structure **»**, approved by Rector's order № 1906/ст from October 5, 2020.
2. Period of work execution: from October 5, 2020 to December 13, 2020.
3. Initial data: statistics of metal characteristics, calculation material on the behavior of fatigue crack growth, literature review of the problem of fatigue of materials and methods of preventing their growth.
4. The content of the explanatory note: the analysis and modeling the crack arrest device for existing problem, maintain the fatigue analysis and compare the results in different designs of it.
5. Required materials: layout of cargo ramp (A1×1), crack arrestor (A2), finite element model (A×1) Graphical materials are performed in Solidworks, Ansys.

6. Thesis schedule

№	Task	Terms	Remarks
1	Analysis of literature on diploma work topics	14.10–24.10 2020	
2	Analysis of ramp loading data	25.10–30.10 2020	
3	Preliminary project of ramp beam, calculation of geometric parameters crack arrestor.	01.11 – 10.11 2020	
4	Design of crack arrestor. Making 3D-models and finite element model.	10.11 – 20.11 2020	
5	Analyzing characteristics of performance of crack arrestor	20.11 –30.11 2020	
6	Performing other parts of the explanatory note	01.12 – 05.12 2020	
7	Explanatory note finalizing	05.12 – 07.12 2020	

7. Special chapters consultants

Chapter	Consultant	Data, signature	
		Task issued	Task received
Labor protection	PhD, associate professor O.V. Konovalova		
Environmental protection	PhD, associate professor L.I. Pavliukh		

8. Date of issue of the task: «__»_______2020

Thesis supervisor __________ M.V. Karuskevych

The task was accepted for execution: __________ M.K. Vostroknutov

ABSTRACT

Explanatory notes to the Master's degree work «Application of crack stoppers in the ramp structure»:

68 pages, 28 pictures, 6 tables, 20 references.

The presented Master's degree work **aimed on** the extension of the early proposed approach to the study of fatigue control of metals. For this purpose, some finite element modeling was performed. In the researchers conducted by the Aircraft Structure Department at National Aviation University the possibility to assess the special fatigue testing machines has been proved.

The object of investigation – fatigue of cyclic loaded beam.

The subject of investigation – the influence of crack stoppers applying to the structure.

The scientific value of the presented work is as follows: prevention of crack propagation in places of restrained access, increasing of structure life time.

The practical value of the work is determined by possibility to use the practical knowledge in further implementation of crack stoppers in material behavior control.

It is recommended to use the results of the master's work in the study of crack propagation control and the crack initiation by means of crack stoppers implementation.

FATIGUE, CRACK STOPPERS, CRACK PROPOGATION, RAMP, TRANSPORT AIRCRAFT, CYCLIC LOADS

ABBREVIATIONS

SIF	-	Stress intensity factor
FEM	-	Finite element method
COD	-	Crack opening displacement
VCE	-	Virtual crack extension
LAT	-	Laser additive technology
HAZ	-	Heat exposure zone
EDM	-	Electro-discharge machining
EB	-	Electron beam
GSE	-	Ground handling equipment
CCD	-	Charge-Coupled Device
ICAO	-	International Civil Aviation Organization
FAA	-	Federal Aviation Administration
EPA	-	Environment Protection Agency
IPCC	-	Intergovernmental Panel on Climate Change

CONTENT

INTRODUCTION

Despite all the precautions, many of these structural elements have cracks. These cracks reduce the rigidity and overall load-bearing capacity of the structure. One of the most important structures of large transport aircraft is rump, where are all loadings and unloading of cargo provided. It is represented by a mechanized hatch located in the tail or nose of the fuselage, capable of descending to the earth's surface. Usually, the ramp is equipped with military transport and cargo aircraft, sometimes the ramp can be found on airliners. Thanks to the ramp, loading can be carried out directly "under the board", that is, the truck drives up to the plane close to and can even enter the cargo compartment. Some cargo, such as heavy armored vehicles, can only be loaded using a ramp. The dimensions of the ramp of the Airbus Beluga aircraft allow loading the fuselage of another aircraft into it. Also, through an open ramp, personnel are dropped with parachutes, which flies on a military transport aircraft.

This paper analyzes the effect of crack stoppers implementation to prevent the destruction of rump after number of cyclic loads. The traditional rump of cargo compartment consists of monocoque structure, usually 2 mm thick plates of floor, stiffeners, frames and stringers, and usually these components are made of aluminum alloy and connected by rivets. The structure of ramp must withstand the stresses while loading and shear loads, longitudinal - for longitudinal tension and compression of loads due to bending.

Usually talk about fatigue of materials is in the context of metals, and here are the reasons. Firstly, metals are prone to fatigue due to their crystalline microstructure and dislocations that are present there, which are the main cause of fatigue. Second, the heavily loaded parts of the structure that are responsible for structural integrity are usually made of metal. Failure of these parts could lead to a worst-case scenario.

Fatigue is a common phenomenon among all metal structures. Due to repeated flight cycles and frequent use, the metal elements of the aircraft weaken over time and will need attention and repair over time.

This weakness is manifested in cracks that are initially microscopic. However, with continued use of aircraft over time, the cracks increase and become noticeable over time. The plane begins to age after the first flight, and the effects of corrosion and fatigue occur almost immediately. Aging becomes a problem when the aircraft can no longer be effectively repaired or maintained on harsh flights.

Signs of fatigue are more pronounced in aging aircraft and become more dangerous because the aircraft is constantly exposed to cyclic loads on structure. Because of this, after a certain number of flight cycles - the number calculated by the manufacturers to ensure safety - the aircraft must be dropped. These regulations are designed to prevent catastrophic failures.

The main aim lay in analysis of fatigue problem in the rump structure of cargo aircraft. Usage of modern analysis technologies and methods of problem solving. Choose of methods research and repair estimation. Improved the life and fatigue prevention of structure by using of crack stoppers method. Was observed of influence on the environment and decreasing of impact because several technologies implementation. Prepared of instruction for employees for save work and non-hazardous conditions providing.

1 THE PROBLEM OF STRUCTURAL DAMAGE EVALUATION

1.1 Analysis of existing problems of fatigue of metals

Material fatigue is one of the most common causes of destruction of machines, mechanisms, structures. Widely used material for aircraft construction - aluminum alloys, and like any metal, they suffer fatigue damage. For aircraft structures, the problem of fatigue is the most relevant and complex. This is primarily due to the fact that the requirements for minimizing the mass of aircraft structures do not allow to provide the required load-bearing capacity in the most common way - by increasing strength reserves.

The main function of the aircraft structure is to withstand and transfer all applied moments and forces, to maintain aerodynamic forms, to protect crew and payload from any environmental conditions. Fatigue loads in a transport plane fuselage are mostly due to forces cycles that occur with each loading or unloading cycle. The most average fatigue crack propagation in a cargo compartment is aw cracks at the carry beams of rump. Loading process of cargo results a local bending moment along fastener lines and corners of L-type cross-section of beam. Ramp construction is mostly planar and this plane under linear tension applying due to the cargo transferring. Cargo loading is the main source of impact on transversal beam crack initiation.

For research was taken the problem appeared at AN-124-100. Along radial transition of rib in wall of the beam was detected a crack. After visual macro analysis of detail, the signs of plastic deformation, defects of mechanical processing or corrosion was not present.

In a process of execution, the crack has been opened for macro fractographic research. In this research discover that cracks in upper part of beam was developed because of material fatigue.

The maximum values of longitudinal tension reaching at the bear connection of two details because of great moments appearing that goes through skin and frames. The transferring of stresses between frames and skin causes really great loads, also combining it with stresses that transferred from the mechanism of connection leads to fatigue crack initiation in the transversal direction of frame.

A great part of the fatigue lifetime is basically spent at the crack growth part. The speed of growth is based on the numbers of cyclic loads, but with taking into account environment, mean stress and overloads the rate of crack growth could be increased. The loads should be small enough and be below a critical limit to stop crack growth.

If the rate of growth becoming too large, on the surface of fracture appears the fatigue striations which shows the location of crack tip and the width of every striation means the crack growing after single loading cycle. As result plasticity at tip of crack produce more striations. The material and manufacturing defects from size 10 μm can initiate grow of fatigue crack.

After exceeding of a critical fracture toughness will occur the unstable rapid fracture by mechanism of microvoid coalescence. In the end we will obtain the number of different zones of rapid fracture and fatigue on the surface of sample scraping.

1.2 Nature of Fatigue

The condition of the material is changing with time because of influence of non-constant external loads. A lot of different parameters such as strain, stress, or energy dissipation can influence on the condition of the point of the material. These parameters mainly control the fatigue process. The time between two peaks in a researching variables named load cycle. Naturally, all cycles have different amplitude magnitude. A cyclic load creates a periodic-cyclic stress application in materials with elastic properties. However, for a cursory discussion, it can be assumed that the state variable that controls fatigue has the same value at the beginning and at the end of each load cycle. In this case it is easy to define the load cycle. It is showed on the picture below when stress is state variable that control fatigue.

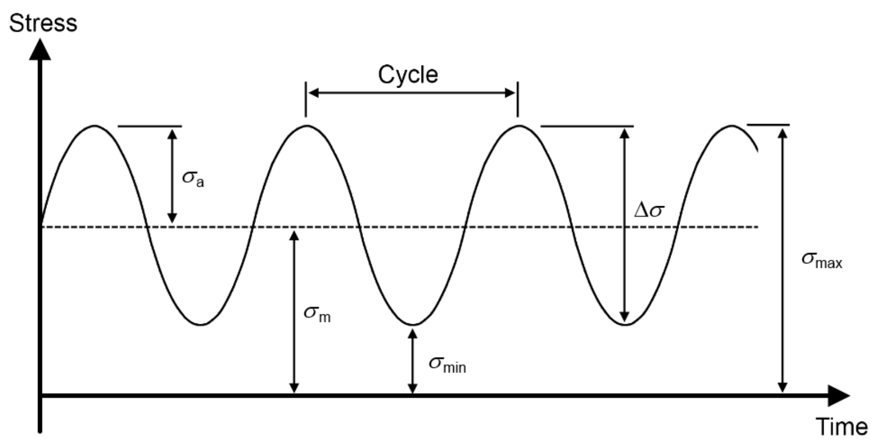

Figure 1.1 - Representation of cyclic loads on stress-time diagram.

For the simulation of metal behavior under fatigue, we need to obtain the parameters of cycles of loading. To get results that is most close to natural conditions we need to combine several cycles with varies in time parameters. It is necessary to make randomly generated by the program strains for loaded part. More simple fatigue analysis applies to part model cyclic loading with constant values.

To describe cyclic loads, we have to input:

- maximum stress σ_{max};
- minimal stress σ_{min};
- stress amplitude $\sigma_a=0.5(\sigma_{max} - \sigma_{min})$;
- mean stress $\sigma_m=0.5(\sigma_{max} + \sigma_{min})$;

- stress range $\Delta\sigma$
- coefficient of cycle asymmetry $R = \sigma_{min}/ \sigma_{max}$;

One of the main goals of the fatigue test is to determine the fatigue curve or the Wheeler curve or the S-N curve. This curve should be plotted on the coordinates, where the horizontal axis shows the number of cycles, and the vertical axis - the amount of load. Then each point of the curve will show how many cycles the test object can withstand without failures under cyclic loading with a certain load. Experimental data would be far from an ideal curve due to the stochastic nature of fatigue. The constructed value represents a condition when the investigated object will not be destroyed with high probability. The fatigue curve can have one shape, shown in Figure 1.3.

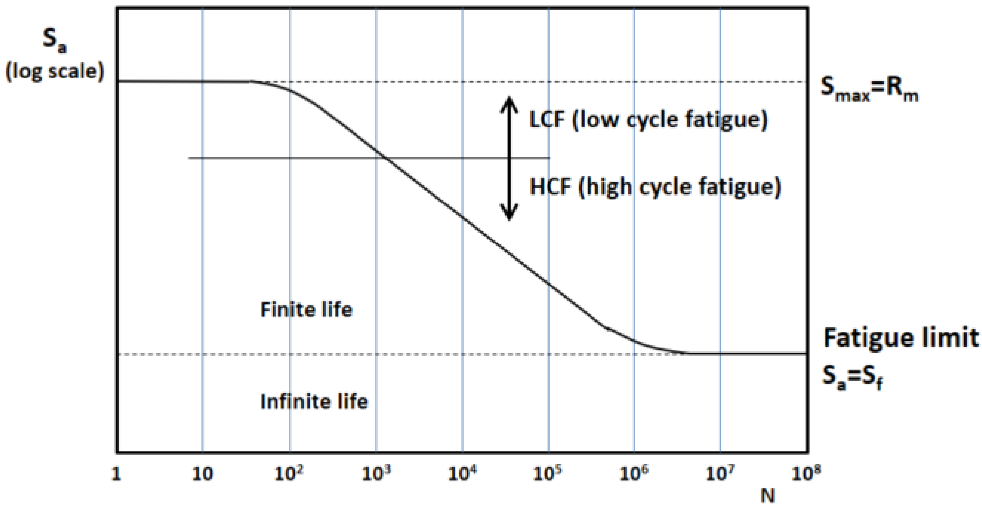

Figure 1.2 - Representation of S-N curve.

Together with fatigue curve, crack initiation and propagation mechanics is also important mark of material fatigue properties. So, while conduct fatigue test it is important not only to measure cycles until specimen broke but also observe what was happened during test. Process of metallic material fatigue failure consist of two stages: crack initiation; crack propagation until failure. During first stage the crack is initiated due to physical effects on micro level. The crystal structure of metal contains defects or dislocation. That mean that there is deviation from ideal structure of crystal, for example in crystal lattice some atom is absent and void present on its place, or oppositely additional atom present in crystal lattice, et cetera. Theoretically, in metal with ideal crystal structure, very high load needed, to move one row of atoms relative to another in metal, which is happened in case of plastic deformation. In ideal crystal metal, to cause plastic deformation, all the atoms in grain parallel to slip plain should overcame interatomic forces.

In 1924, J. Frenkel calculated that the total strength should be several times greater than the actual limit of strength of the material. In the real metal, dislocations are present, and when cyclic loads are applied, this dislocation moves, interacts and new ones appear. Under cyclic loading, the dislocation is gradually organized into a substructure (for example, a cell or tape substructure). When the dislocation density in such a substructure reaches a critical value of approximately 1013 - 1014 m-2, a microcrack occurs at this point. The size of the initial microcrack is usually about 10-4 mm. Three different physical models of how a destructural substructure transforms into a microcrack can be identified.

- models of slow shear near the internal barrier, in which the elementary act of crack initiation is considered as joining the leading dislocations to the basis of a flat dislocation substructure, pulled by shear stress to heavy obstacles of different physical nature (chemical inclusion of grain boundaries and others);
- model of initiation of barrier-free microcracks as a result of interactions of dislocations at the intersection of the existing shear plane or twins;
- initiation of microcracks due to thermal oscillatory processes.

The stage of initiating the microcrack of fatigue can be divided into 3 stages. The first stage is a cyclic micro-output. Here, plastic deformation occurs in the grains, which are favorably oriented and moist in the grains near the metal surface. The second stage is the stage of cyclic harvest. During the third stage, called strain hardening / softening, submicrostructures are formed.

After crack was initiated, it starts to growth until it size become critical and structure fails. Presence of crack in metal cause change in load distribution in loaded part. Crack acts like stress concentrator near it end, load become higher than in areas distant from crack. Stress concentrator factor describe these changes.

$$K = \frac{\sigma_{max}}{\sigma_a}, \qquad (1.1)$$

where σ_{max} – is maximal stress near stress concentrator,

σ_a – applied stress (stress in case if no stress concentrator present)

For elliptical stress concentrator:

$$K = 1 + \left(\frac{2a}{b}\right), \qquad (1.2)$$

Where a – half 0f main elliptical axis,

b – half of lower elliptical axis.

For case of crack it is more convenient to use stress intensity factor:

$$K = \sigma \cdot \sqrt{\pi \cdot l \cdot Y}, \qquad (1.3)$$

where σ – applied stress,

l – length of crack,

Y – coefficient, that depend from specimen size.

Near the crack end the stress could achieve yield limit. Over that limit stress could not grow and maximum stress near crack is limited by yield stress of metal. In area where yield limit of stress achieved the plastic deformation occur. This is shown in figure 1.4.

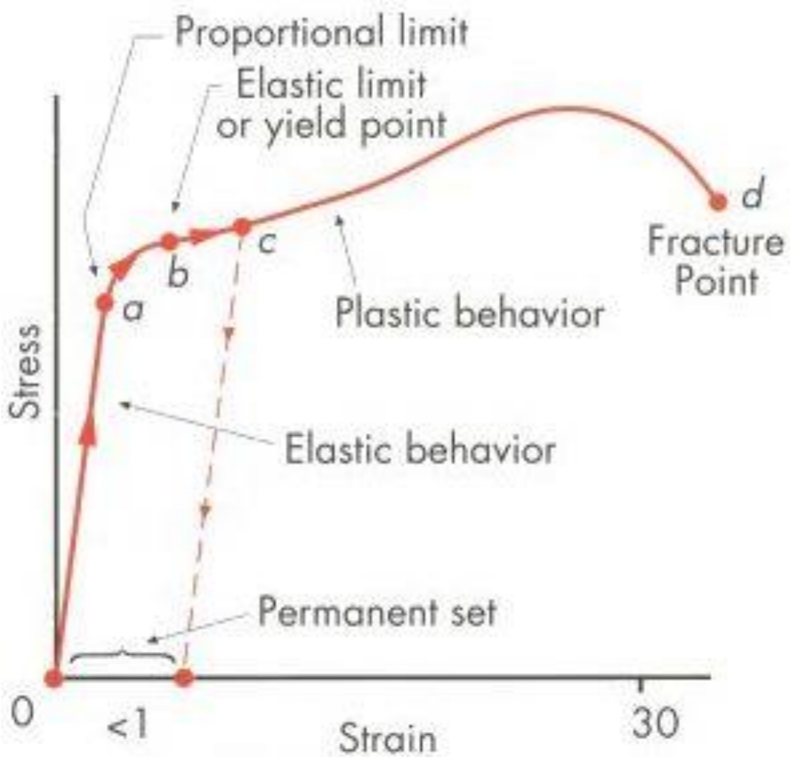

Figure 1.3 – Stress-strain graph for metals

Plastic deformation zone size could approximately be calculated by equation:

$$r_y = 0.033 \cdot \left(\frac{\Delta K}{\sigma_t}\right). \qquad (1.4)$$

For case of cyclic loading it is also possible to use amplitude of stress intensity factor:

$$\Delta K = \Delta\sigma \cdot \sqrt{\pi \cdot l \cdot Y}. \qquad (1.5)$$

The destruction mechanics describe processes of crack growth. Destruction mechanics include few theories:

- linear elastic destruction mechanics describe process of crack propagation for brittle destruction or destruction where plastic deformation zone in crack end is ignorable. In this theory, crack propagation process described in term of energy, which could be released from elastic deformation of material and energy needed for creating free surface of crack;

- nonlinear elastoplastic destruction mechanics which deals with critical disclosure of crack end δc or Jc-integral

There is another effect that should be mentioned because it has influence on process of crack propagation. This is effect of fatigue crack closure, which was firstly found by V.Elber.

According to Elber, fatigue crack closure happens because of plastic deformation. While load is maximum at its cycle, the crack opening is also maximum. While load begin to decrees crack opening begin to decrease as well. But zone of plastic deformation is still there. That's how fatigue crack closure effect occur. This mechanism is characteristic for plastic metals and alloys. Also, there is other mechanisms of fatigue crack closure.

Between stage of crack initiation and crack propagation stages of fatigue damage, the intermediate stage could be distinguished. It is small fatigue crack. This stage is under close look of scientific community, which is confirmed by large amount of publication. Small crack propagation process different from large crack propagation process. After dislocation substructure achieve its critical level, at that place small fatigue crack begin to occur. Small (initial) crack sizes are less than grain size and zone of plastic deformation have order of half crack length. On figure 1.6 the kinetic diagram of fatigue damage is shown for small and large fatigue crack.

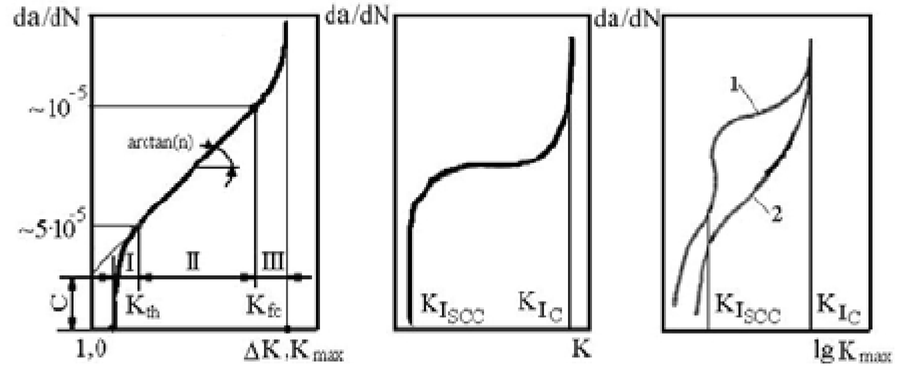

Figure 1.4 - Kinetic diagram of fatigue damage

While approach to grain boundary crack propagation speed could dramatically decrees. In extreme case crack propagation could be blocked in front of obstacle (grain boundary, chemical inclusion or fibers of composite material).

Stage of crack propagation could be divided on 3 regions on kinetic diagram:

- Threshold region with speed of crack propagation v = 10-5-10-6 mm/cycle
- Paris region or region of stable crack propagation. 10-5 – 5· 10-6<v<10-3 mm/cycle
- Stable tearing crack growth region v > 10-3 mm/cycle

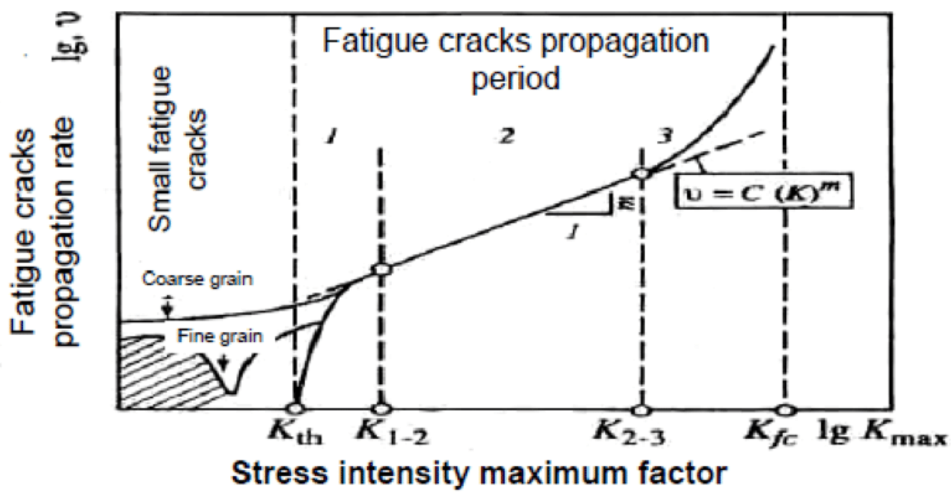

Figure 1.5 - Full kinetic diagram of crack propagation process.

There small crack region is shown in the left part for values of K form 0 to Kth. From value of Kth starts threshold region. The Paris region lay between K_{1-2}

and K_{2-3} . From K_{2-3} to F_{fc} the stable tearing crack growth region take place. K_{fc} is value of stress intensity factor at specimen failure.

1.3 Stress intensity factor

Stress intensity factor (SIF) in using for studying the crack propagation feature. The mechanics of numerical fracture using several methods to evaluate SIF. In the begging of finite element (FE) application for fracture analysis were popular to use the force and crack opening displacement (COD) methodologies. Results accuracy of stress intensity factor can be reached by using of virtual crack extension (VCE) methodology. Just one analysis should be completed to satisfy the virtual crack extension method requirements for calculation SIF. This methods COD and VCE can be used to evaluate the SIF for any of three failure stages. Although, to obtain the results, extra complex numerical manipulation must be applied.

SIF is a basic value that determines the load influence around the tip of crack. It is directly connected with the geometry, crack dimensions and detail stress application conditions. Stress intensity factor value characterize that the stresses are greater at locally around field of the crack tip.

As one of a basement research was taken Tomas Swifts developments of the Fail-safe Design Features of Aircraft Structures. The self-propagating fracture was stopped at the low loaded zone ahead of the crack tip by providing enough peripheral and longitudinal toughness. Along the stiffener the load was redistributed on the wider area that lead to lowering loads at the crack tip. It gives ability to change the degree of damage to a rigid structure. The stringer is not able to prevent longitudinal fractures in the fuselage structures. But the frames proved to be more effective at stopping longitudinal cracks. The radial tensile stress because of pressure changes in the longitudinal compartment of the skin and gets its maximum numbers in the middle between the frames. The transferring of stresses from the skin to the doubler causes a high stress in the anchorage support, which, in combination with radial tensile stress, can cause longitudinal fatigue cracks.

Bending due to the transfer of some load pressure to the frame increases the local axial tension in the flanges of the stringer locally, causing fatigue cracks in the skin, which extend to two adjacent bays of skin. The design included the ability to stop the crack after rapid destruction. For the construction of a pressure fuselage in a transport aircraft, the ability to retain cracks must be demonstrated so that the structure complies with American certification standards (14 CFR 25.271). The accepted practice of demonstrating compliance with the standard is a full-scale ground test in which an explosive charge clogs the blade into the fuselage, creating a longitudinal skin crack approximately one frame long. This configuration maximizes the local flexibility of the destroyed structure and thus provides a conservative test of the ability of the surrounding structure to stop a large fracture caused by damage to foreign objects.

In our case the maximum values of longitudinal tension reaching at the bear connection of two details because of great moments appearing that goes through skin and frames. The transferring of stresses between frames and skin causes really great loads, also combining it with stresses that transferred from the mechanism of connection leads to fatigue crack initiation in the transversal direction of frame.

1.4 Accumulated damage

To calculate residual lifetime on basis of teardown test it is necessary to summarize damage, accumulated during different loading with different amplitude in any sequence.

According to Palmgren-Miner rule it is possible to linear summarize damage from cyclic loading with different cycle parameters. Cycle load history could be simplified to finite number of blocks – n, during which the cycle load parameters (amplitude, mean value) constant. Duration of n_i block would be marked as N_i then:

$$D = \sum \frac{n_i}{N_i}, \qquad (1.6)$$

where D – accumulated damage.

The failure is expected when damage D is achieving 1. But it is well known that real dependence far from linear and damage can occur at values between 0.1 and 10. The rule is owing to the Swedish engineer Palmgren how in 1924 proposed hypothesis of the linear progression of damage. Palmgren was studding fatigue resistance of ball bearings. Hi found that with individual cycle of load, the damage D progressed linearly with load repetition. Furthermore, he notices that damage, produced by load spectra of different amplitude accumulated in linear fashion.

Few years later, in 1937 Langer, who worked with electric power generator, proposed a similar linear rule independently, for steel piped and pressure vessels.

In 1945, Miner, on basis of Langer's work apply linear damage accumulating rule for tension-tension axial fatigue data for aircraft skin metal (aluminum alloy 24S-T ALCLAD). This work was used in Douglass Aircraft, and demonstrated excellent agreement between experiments and prediction of linear damage rule. Now this rule is known as Palmgren-Miner rule and it states that fraction of life used by a series of n_i cycles of equal amplitude S_i is proportional to the correspondent cycle ratio. Schematically Palmgren-Miner rule is shown on figure 1.7.

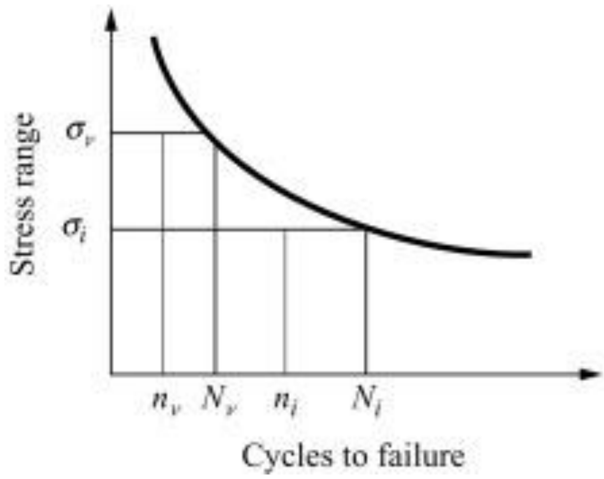

Figure 1.6 - S-N curve diagram described by Palmgren-Miner rule

Significant drawback of Palmgren-miner rule is that it does not take in to account sequence of loads with different amplitude and assume same speed of damage propagation independent from previous history of load. That mean that high load in beginning of exploitation and small loads after that give same damage as low load in beginning, followed by small load.

Conclusion to part 1

Fatigue is a common phenomenon among all metal structures. Due to repeated flight cycles and frequent use, the metal elements of the aircraft weaken over time and will need attention and repair over time.

This weakness is manifested in cracks that are initially microscopic. However, with continued use of aircraft over time, the cracks increase and become noticeable over time. The plane begins to age after the first flight, and the effects of corrosion and fatigue occur almost immediately. Aging becomes a problem when the aircraft can no longer be effectively repaired or maintained on harsh flights.

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The main goals lay in analysis of fatigue problem in the rump structure of cargo aircraft. Usage of modern analysis technologies and methods of problem solving. Choosing of methods research and repair estimation. The observation of influence on the environment and decreasing of impact because several technologies implementation. Preparation of instruction for employees for save work and non-hazardous conditions providing.

2 RESEARCH METHODS AND PROCEDURES

2.1 Introduction

Cracks are surface or subsurface fissures that develop in a material. Propagation energy derived from mechanical, thermal, chemical, and metallurgical effects, or a combination of these may influence crack initiation and growth. Various types of cracks exist in metals and can be categorized as cooling, solidification, centerline, crater, grinding, pickling, heat treatment, machining tears, plating, fatigue, creep, stress corrosion and hydrogen cracks. Cracks can grow and lead to complete fracture of the component posing significant threats to component life and may lead to serious injuries or loss of life. Brittle fracture in metals occurs with little or no visible warning. Discovery of any cracks warrants immediate interventions to arrest the cracks before they propagate to the point of fracture. Several crack detection and repair methods in metals have been developed, characterized and validated through research. This paper reviews the repair techniques of cracks in metals. []

2.2 Basic crack repair technologies in metal

When critical fracture cracks are detected in mechanical components and structures, several methods are used to stop or prevent their further growth or spread. The choice of repair method or combination of them depends on many factors, including the nature of the crack, the position of the crack, the orientation of the crack, the size of the crack, the availability of the crack, the use of components, the expected accuracy of repair, the availability of tools, the type of metal and the required expertise. Commonly used methods will be discussed in this section

In aircraft construction, stressed skin is a form of construction in which the outer covering of the aircraft carries part or all of the main loads. Tight skin is made of high-strength rolled aluminum sheets. Tight skin carries most of the load imposed on the aircraft structure. Various specific areas of the skin are classified as very critical, semi-critical or non-critical. Refer to the appropriate aircraft maintenance manual to determine the specific repair requirements for these areas.[]

Minor damage to the outer skin of the aircraft can be repaired by applying a patch to the inside of the damaged sheet. A filler must be installed in the hole made by removing the damaged area of skin. It closes the hole and forms a smooth outer surface necessary for the aerodynamic smoothness of the aircraft. The size and shape of the patch is determined by the total number of rivets required for repair. Unless otherwise indicated, calculate the required number of rivets using the rivet formula. Make a patch of the same material as the original leather, the same thickness or the next thicker.

2.2.1 Metal crack stitching

Metal crack stitching is a mechanical crack repair technique that uses a combination of connected rows of stitching pins and locks. It is reported that the locks are installed along the entire line of the joint with an interval along the length of the crack. It has been reported that this technique produces gas-tight and liquid welds that restore the metal to its original strength without the subsequent need to weld the welds. The authors agree that the technique offers a number of advantages, including humidification and absorption of compressive stresses, propagation of tensile deformations and load dissipation away from cracks, support of initial leveling of repaired surfaces, on-site repairs with minimal equipment dismantling, minimal downtime, cost-effective and have worldwide recognition. It was further reported that crosslinking of metal cracks is commonly used on cast iron, but is also successfully applied to other machined metals, such as plastic cast iron, steel, aluminum and bronze. It is said that this technique is called "metal lock, metal surgery, cold welding, stitch welding and crack sealing", as its other names [].

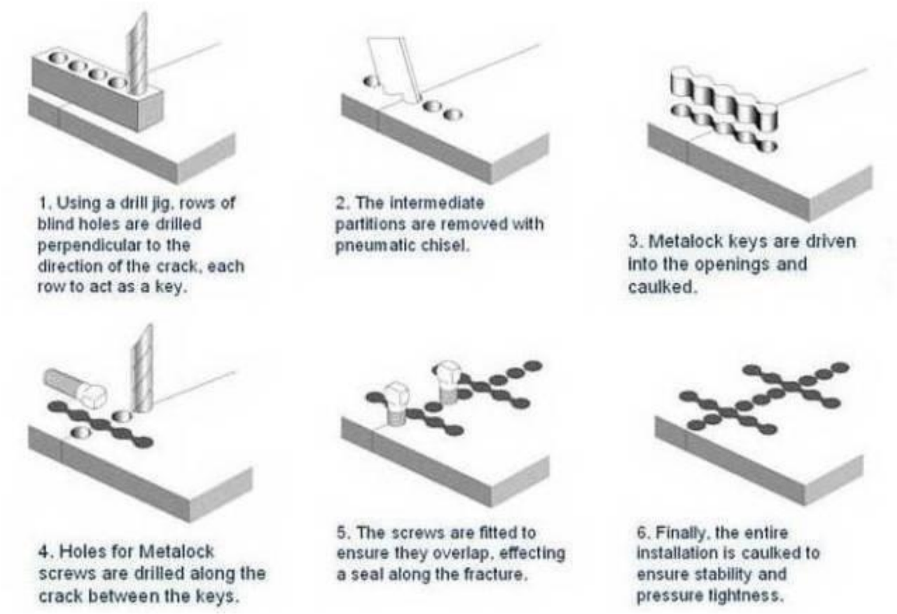

Figure. 2.1 – Repair procedure for metal stitching.

After the crack is detected, the crack is procedurally restored. The main process begins with positioning, readjustment and strong holding of cracked surfaces together with the help of special fasteners and clamps. Then the holes are drilled along the line of destruction to the depth of the casting tool using special devices. Then the locks are installed in the holes to a depth of 80% of the thickness of the casting or metal wall and fixed in a dense state of metal-metal, which become integral with the base metal. Then drill holes along the crack line. Then they are reflected and filled with superimposed pins (seams), as a result of which the joint has a tight strength and original rigidity of casting. Each stitching pin has a breaking groove over its shoulder, which allows the head to twist when it reaches the proper torque []. After that, pneumatic chisels and grinders can be used to smooth the repaired surface. It was reported that the minimum distance between the locks for maximum strength is equal to half the length of the locks used. It has been reported that the use of this technique extends from factories and machines, marine engines, marine gearboxes to power presses and petrochemical plants.

2.2.2 Vee-and-weld method

Vee-and-weld - a method of repairing a weld for long cracks through thickness. After detecting a crack, the material is removed along the length of the crack through three quarters of the thickness of the section, which cracks in the form of V. Then the V-shaped groove is filled with weld metal and the process is repeated on the other side of the section. The best method of removing the material is air arc planning, but grinding also works. The disadvantage of using a disc grinder to remove cracked material is that the crack may blur when more material is removed. This increases the possibility of hiding or masking the crack path and leaving a built-in defect in the repair weld. When destroyed by an air arc, the crack seems to open as the material is removed, which facilitates the laying of the crack path. It is rarely used in aircraft industry.

2.2.3 Stop-hole technique

The stop hole technique is the most commonly used method of repairing fatigue cracks. You need to drill a hole of sufficient diameter at the tip of the crack, completely removing the sharp cut at the tip of the crack to successfully retain the crack. The authors proposed to use larger holes (from 50.8 to 101.6 mm), if it does not threaten the strength and rigidity of the structure or connection and the comfort of the customer. A minimum practical hole diameter of 25.4 mm is also recommended.

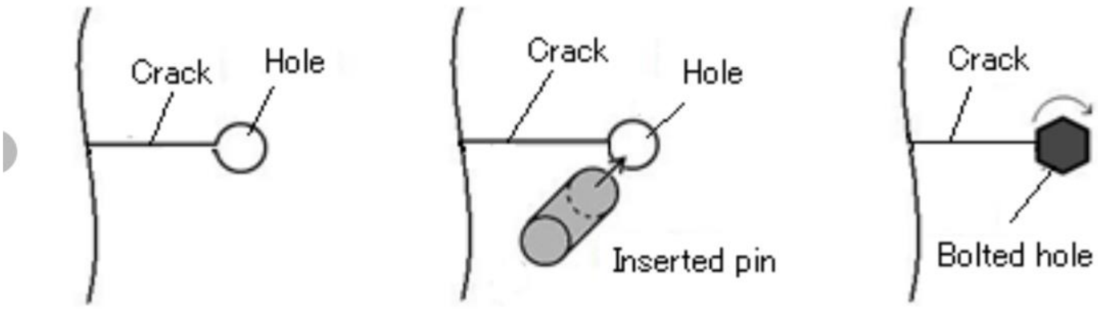

Figure 2.2 - Types of stop-hole, (a) Original stop-hole, (b) Pinned stop-hole, (c) Bolted stop-hole

The procedure was described to begin with by detecting the tip of the crack using the recommended method of detecting cracks and marking it with a central punch. Methods of penetration of magnetic particles and liquids which are the simplest and most widely used detection are offered techniques. The drill may be inclined above the crack tip, or in such a way that its trailing edge touches and removes the crack tip. The authors warned that care should be taken not to miss the tip of the crack to ensure that the crack continues to spread. It was further reported that the hole size to be drilled will be calculated using Equation 1, and in the case of edge cracks, the hole size provided by Equation 1 will be increased by 25%.

$$D = \frac{Sr \cdot \pi \cdot a}{55 \cdot \sigma_y}, \qquad (1)$$

In equation 1

D - hole diameter;

S_r - the nominal stress range where the crack tip is located, a is the half-crack length;

σ_y - the output strength of the material;

It was further reported that bushings or bolts can be inserted into the holes for favorable compressive stresses around the whole hole, an idea that has been criticized by some engineers, claiming that it hides the restoration of cracks during analysis. Cold hole expansion has been reported as another way to introduce useful residual compression, the tension around the hole, hammering the conical mandrel, slightly larger than the hole pushing it through hole, plastically deforming the hole, thus creating a field of compressive stress around it, which will prevent the hole further propagation. The authors concluded that flame-cut holes should never be used to remove cracks tips, because they create a state of the destroyed surface, which can cause new fatigue cracks.

2.2.4 Adding doubler or splice plates

Another method that can be used to repair cracks through thickness is double or splicing plates, hereinafter referred to as double plates or doublers. Double-sided plates add material to either increase the cross-section or ensure continuity in the cracked cross-section. The philosophy of doublers to restore fatigue cracks is to add cross-sectional area, which in turn reduces stress ranges. For example, if a fatigue crack grows to the full depth of the bridge beam, it can be restored in two ways. First, it is possible to determine the repair of the weld and weld, but, as noted in the previous section, the base metal to be restored is likely to have a shorter service life than the original part. To ensure proper fatigue resistance when welding a weld, double plates can be added after repair to reduce the stress range that contributed to the initial cracking, thus protecting the repair.

Figure 2.3 – Illustration of bolted doubler plate repair.

One of the problems of this type of repair is to support the alignment of the two sides of the site with cracks before the repair of the weld. Buckles usually appear on the cracked surface, making it difficult to align. Since in any case, double plates will be required to reduce the stress range, the plates must be designed thicker, assuming that the beam web no longer transmits the load. This technique is especially useful when a deep crack is formed in the bridge beam. In this case, the double plates are designed to restore the full cross-sectional properties of the uncracked beam. The design process is identical to that used to bolt the fields. Doubling can also be used to restore the properties of a highly corroded area.

Doublers or splicing plates can be used to repair cracks through thickness, adding them either to increase the cross section, or to ensure continuity in the cracked cross section, which in turn reduces the stress ranges. However, alignment problems are reported to affect this technique.

Skin patches may be classified as two types:

- Lap or scab patch
- Flush patch

A Lap or Scab Patchis an outer patch where the edges of the patch and the skin overlap. The overlapping part of the patch is riveted to the skin. Colored patches can be used in most areas where aerodynamic smoothness is not important.

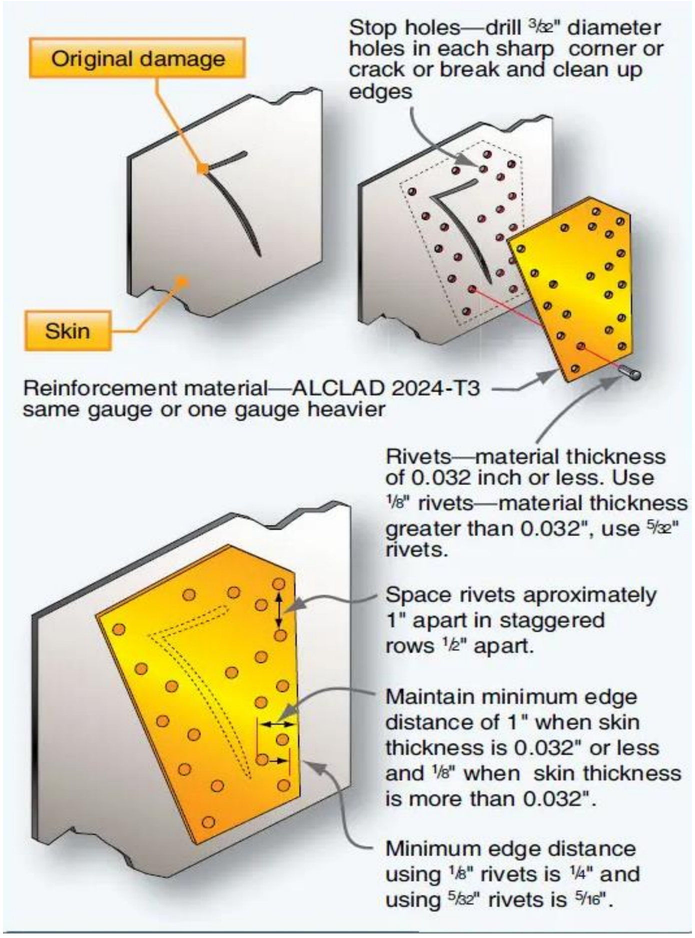

Figure 2.4 - Lap or Scab Patch

When removing cracks or small holes with knee pads or scabs, the damage must be cleaned and smoothed. To repair cracks, apply a small hole at each end and a sharp bend in the crack before applying the patch. These holes relieve stress at these points and prevent the spread of cracks. The patch should be large enough to set the required number of rivets. It can be cut circular, square or rectangular. If it is cut square or rectangular, the corners are rounded to a radius of at least 1⁄4 inch. The edges should be beveled at an angle of 45 ° for the thickness of the material by 1⁄2 the thickness and bent 5 ° above the edge distance to seal the edges. This reduces the likelihood of repairing the air flow above it.

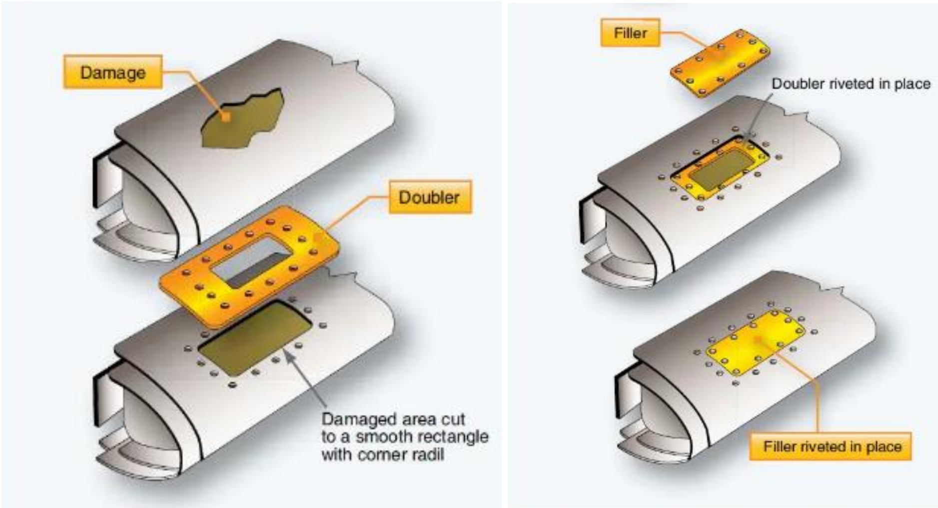

Figure 2.5 - Flash patch

The Flash patch is a filler that is applied to the skin when applied, supported and riveted to the reinforcing plate, which in turn is riveted to the inside of the skin. Figure 2.5 shows a typical patch repair. The doubler is inserted through the hole and rotates until it slides in place under the skin. The filler must be the same size and material as the original leather. The doubler should be made of a material one caliber heavier than leather.

2.2.5 Laser additive technology

Laser additive technology (LAT) uses a laser beam to locally melt the filler powder and the surface of the target material. The parts are constructed in layers, focusing the laser and powder source through the substrate. The powder that protects the gas is fed through an integrated powder supply system, and the heat generated in the melt pool, as well as the laser beam, the powder melts and bonds to the base as it hardens. Compared to its conventional counterparts, LAT offers the advantages of a small heat exposure zone (HAZ) and a small weld dilution zone (WDZ), which protects both the mechanical and metallurgical properties of welded substrates. LAT is widely used for the manufacture of free molds, materials processing, manufacture, maintenance and repair of high-value and important parts. Laser additive crack repair is used in stainless steel and titanium alloys. To compare the obtained results, cracks were removed by milling in V-grooves, U-grooves and U-shaped grooves with an open top with a depth of 10 mm. Cracked areas were cut into three grooves to the root or tip of the crack to remove the crack, and rebuilt with a laser coating.

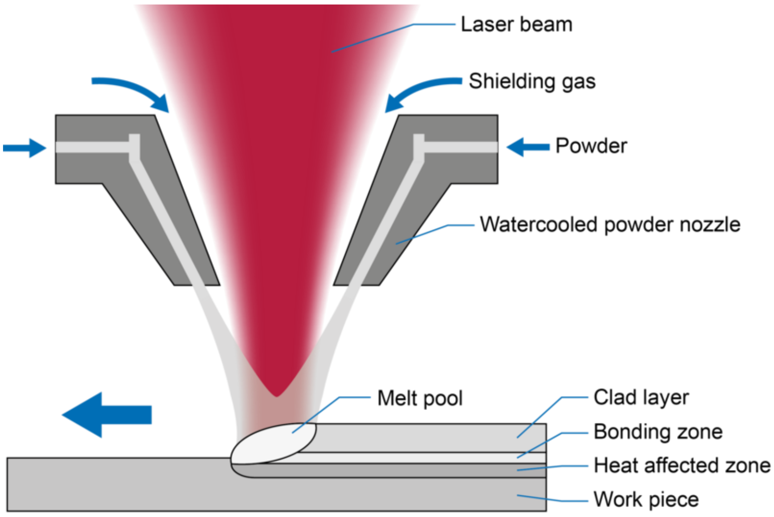

Figure 2.6 – Laser cladding principle

Laser cladding uses the same concept as arc welding methods, except that the laser is used to melt the surface of the substrate and additional material, which may be in the form of wire, powder or strip. Laser veneering is usually performed using CO2, Nd: YAG and, more recently, fiber lasers. Laser veneering usually produces a coating with low dilution, low porosity and good surface uniformity. This method ensures minimal heat consumption on the part, which largely eliminates distortion and requires further processing and avoids the loss of alloying elements or curing of the base material. The coated material undergoes rapid natural hardening upon cooling after precipitation, which leads to a fine-grained microstructure.

The powder used in laser plating is usually metallic in nature and is introduced into the system by coaxial or side nozzles. The interaction of the flux of metal powder and the laser leads to melting, and it is known as a melt. It is applied to the substrate; moving the substrate allows the solid layer of the melt to solidify and thus a track of solid metal is formed. The wire feed is similar to facing with other welding methods, and the wire is located by an external nozzle. The direction and position of the wire feed are essential to achieve good results.

Among the various surface treatments used to improve the corrosion and wear resistance of metallic materials, laser cladding is an attractive alternative to conventional methods due to its own laser radiation properties: high incoming energy, low distortion, avoidance of unwanted phase transformations and minimal dilution. In addition, the advantages of laser cladding include greater processing flexibility and the possibility of selective cladding of small areas. These benefits not only improve product quality, but also provide significant economic benefits

2.2.6 Grinding

Grinding can be used to completely remove parts of the part that contain small cracks, especially cracks at the edges of flanges or other plates. The grinding wheel should be tapered at a slope of 2.5: 1, and the final grinding should be performed in parallel with the applied cyclic stress (ie sparks from the grinding operation should fly in the direction of the primary stress, causing the grinding scratches to be parallel to the primary stress). For example, an edge crack with a depth of inch inches (13 mm) should be removed by grinding along the edge to a total length of at least 2.5 mm (65 mm). It is necessary to consider possible reduction of the area of pure section. In the first execution of the weld on the nose of the weld, small micro cracks are formed when the welding pool is cooled to ambient temperature and compressed. Under cyclic loading, these micro cracks begin to spread and become small fatigue cracks. Studies have shown that the grinding of these micro cracks does not give a significant increase in fatigue strength, possibly because the defects that occur during grinding, compared with the initial micro cracks.

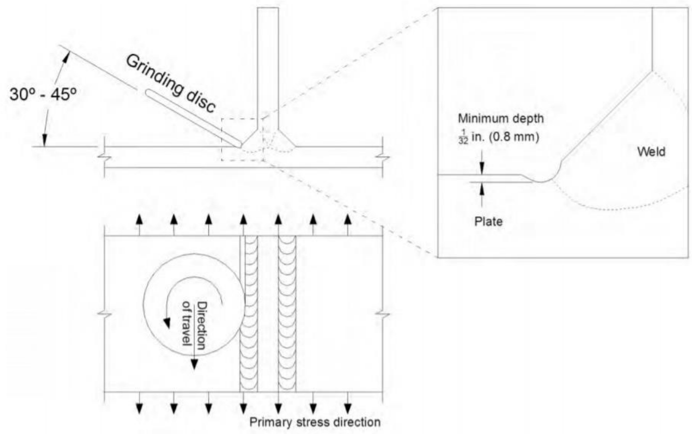

Figure 2.7 – Disc grinding illustration

In offshore designs with tubular joints, where the welds are very large, grinding effectively forms the weld and increases fatigue strength by reducing the corresponding stress concentration factor. It is established that the welds processed by means of the grinding grinder have 50% bigger admissible range of tension in comparison with their untreated analogs. Extensive grinding of welds in the details of cover plates has also proved to be effective. However, such a large grinding is considered excessively expensive as a technique for modernizing bridges. Grinding is also useful as a finishing process for larger repair and upgrade methods, such as hole drilling (burr removal) and welding (toe finishing). Two types of grinding methods - disk grinding and burrs.

2.2.7 Hammer peening

One of the common methods of this peening (stretching) process can be observed in the areas of car repair and custom manufacturing, where manual or machine reinforcement is used to stretch thin sheet metal to create curved surfaces. The manual method uses a hand hammer, which is a hand tool and is a form of processing. There are also machine methods that use a version of the punch to process sheet metal.

Another use of the processing process is the alignment of sheet metal, which is specially used as the main technique of flattening steel strips used in industrial operations of transportation and pressing. In this process, a steel belt having a transverse curvature can be flattened by sheathing the concave surface to stretch it and thereby removing the transverse curvature, aligning the length of the lumbar surface between the previously concave and convex surfaces. Shooting a shot with steel strips is usually achieved with the help of specialized equipment and a special shooting shot.

Shallow surface cracks up to 3 mm deep can be removed with a hammer. The application of this technique to cracks in welds during operation restores the residual service life of fatigue to the initial new weld. It was further reported that with optimal use, these treatments can lead to resistance to fatigue, which is at least one category of fatigue exceeds the original part. It is best used for micron-sized cracks and does not show a significant improvement in fatigue with macro-cracked welds.

2.2.8 Pulsed electron beam irradiation

Restoration of electro-discharge machining (EDM) induced surface cracks by irradiation with a pulsed electron beam (EB). The authors used low-energy irradiation and several shots to study the physical mechanism of crack repair, and the results showed trends in crack reduction and, ultimately, elimination. Under the lowest cathode voltage EB 15 kV and with 5 and 10 shots, partial re-sealing of cracks was detected. According to the authors, the circular nature of the seal provided flow through the crack during the melt, and then compression during rapid quenching, solidifying several joints, where the surface tension of the melt resisted the compressive force.

The cracks induced by the EDM process were completely removed from the surface and to a depth of 4.5 μm of new remelted parts with high voltage of 25 and 35 kV after 20 shots at 25 and 35 kV. Research has shown that pulsed electron beam irradiation has the potential to improve the duration of fatigue and corrosion attacks through the surface crack removal. However, the process seems to be limited by micron-sized cracks

Conclusion

The issue of restoration of cracks in metals was considered and various repair methods are used, which are currently used both with general practical purpose and with high values and critical levels of application. It was noted that computational research plays a key role in improving the understanding of the impact of most crack repair methods on the mechanical properties of repaired components. The recent introduction and use of doubler patch technology for crack repair has also been studied, as it demonstrates significant potential and simplification for crack repair.

4 ENVIRONMENTAL PROTECTION

4.1 Introduction

Air travel plays a significant role in global economic activity, and society relies heavily on the benefits associated with aviation. The aviation industry includes aircraft suppliers and operators, component manufacturers, fuel suppliers, airports and air navigation service providers. Its clients represent every sector of the world economy and every segment of the world population.

Aviation is an integral part of the infrastructure of modern society. It plays an important role in the world economy; it supports both commerce (through business and air travel) and private travel. Aviation also plays an important role in military activities. Thus, aviation affects the lives of citizens in all countries of the world, regardless of whether they fly. The activities of the civil air transport industry have long been limited to issues of public interest, in addition to economic factors. Historically, the most important issues are related to safety and environmental issues related to local noise and air pollution. There are two global environmental problems for which aviation can have potentially important consequences: climate change, including changes in weather conditions (ie rainfall, temperature, etc.), and for supersonic aircraft - stratospheric ozone depletion and the effects of increasing ultraviolet B radiation on the Earth's surface.

It is noteworthy that over the last two decades, significant improvements have been made in aircraft fuel efficiency and other technical improvements to reduce emissions. However, these achievements may be offset in the future by projected growth in airport operations and other aviation activities. As aircraft are only one of several sources of emissions at the airport, it is also important to effectively manage emissions from terminals, maintenance and heating facilities; airport ground handling equipment (GSE); and a variety of land transport that travels around, to and from airports. Optimization of airport design, planning and infrastructure; modification of operational practice to increase efficiency; modernization of the GSE fleet with technologies that do not emit or emit; and promoting the development of other environmentally friendly modes of land transport are some of the modern capabilities of airports, and the rest of the aviation industry can use or apply to help achieve these goals and encourage sustainable development in commercial air transport.

4.2 Evaluation of the CO and NO_x emissions from aircraft engines.

The influence of CO2 on the atmosphere is simple and easy to understand. In the atmosphere itself there are no important processes of formation or destruction. Atmospheric sources and absorbers occur mainly on the Earth's surface and involve exchange with the biosphere and oceans. The impact of CO2 on climate change is direct and depends simply on its atmospheric concentration. CO2 molecules absorb the original infrared radiation emitted by the Earth's surface and lower atmosphere. The observed increase in the concentration of CO2 in the atmosphere by 25-30% over the last 200 years has caused warming of the troposphere and cooling of the stratosphere

Nitrogen oxides are present in the atmosphere. They greatly affect the chemistry of the troposphere and stratosphere, and they are important in the production and destruction of ozone. There are a number of sources (N2O oxidation, lightning, fossil fuel combustion), whose contribution to the NOx concentration in the upper troposphere is insufficiently quantified.

To assess the impact of aircraft on the environment, it is necessary to assess their impact on the environment in the airport area and at high altitudes in the atmosphere. According to modern notions, the area of impact of aircraft engine emissions near the airport is limited to the area of the airport, where ground operations with aircraft, ascent to a height of 1 km after takeoff and descent from a height of 1 km before landing.

So, it is necessary to evaluate the annual impact of engines emissions of CO and NO_x of aircraft at the zone of airport. For consideration was taken related and previously mentioned the strategic airlift, four-engine aircraft the Antonov An-124-100 Ruslan. Last one is equipped with four power plants D-18T, high-bypass turbofan engines. They characterized by 229 kN thrust each, with 0.557 kg/N·hour specific consumption of fuel during regime of low gas.

To use further formulas, we need to know basic parameters of relative thrust at some duration of time during different regimes, that shown in next table:

Table 1

The typical takeoff and landing cycle of aircraft engine power conditions

Number of regime	Characteristics of regimes	Relative thrust $\overline{R}$	Duration of regime ***t***, min
1	Start, idle running before takeoff (regime of low gas)	0,07	15,0
2	Takeoff	1,0	0,7
3	Climb	0,85	2,2
4	Approach landing from a height of 1000 m	0,3	4,0

5	From landing taxiing (regime of low gas)	0,07	7,0

In addition to the small effect of micronutrient reactions, changes in the concentration of the main species in the turbine and the nozzle flow path are caused by the dilution effect of the cooling air. CO_2 changes less than a few tenths of a percent as a result of CO oxidation (the increase in H2O from HO_x recombination is even smaller). This partial increase in CO_2 may increase in the early stages of a high pressure turbine as more advanced cycles are introduced, as associated cycle changes can lead to relatively more CO at the turbine. Current minor changes and probable future changes in the primary exhaust components can be predicted with sufficient accuracy to estimate, however, and all levels are relatively easy to obtain from measurements.

Emissions from aircraft include CO, C_xH hydrocarbons that do not burn completely in the, aldehydes, CO_2, nitrogen oxides NO_x, sulfur oxides, SO_x, benzopyrene the smoke is black. There are about 200 of them in total. But CO, C_xH and NOx are the main gases, because they are the largest. That mean that we should know the weight rate of emissions that producing after full engine cycle in a flight for AN-124. The related parameters are represented in Table 3 for 60 annual flights at several regimes starting from engine ignition.

Table 2

Weight rate of CO and NO_x emissions by different aircraft types

Annual quantity of flights ***N***	Relative thrust $\overline{R}$ of regimes 2, 3, 4 relatively	Weight rate of emissions *W*, kg/hour	
		CO	NO_2
60	1 0,85 0,3	6,0 7,5 18,0	89 61 11

Now we can evaluate the main calculations of annual emissions of CO and NO_x from aircraft engine from formulas:

$$M_{CO} = M_{CO\,GO} + M_{CO\,TLO}\ ,\ kg \qquad (4.1)$$

$$M_{NOx} = M_{NOxGO} + M_{NOx\,TLO}\ ,\ kg \qquad (4.2)$$

Where:

$M_{CO\ GO}$, $M_{NOx\ GO}$ - masses of CO and NO_x, which are emitted during ground operations (start, idle running, from landing taxiing – regimes 1, 5);

$M_{CO\ TLO}$, $M_{NOx\ TLO}$ - masses of CO and NO_x respectively, which are emitted during takeoff and landing operations (takeoff, climb to 1000 m, approach landing from a height of 1000 m – regimes 2, 3, 4).

$$M_{CO\ GO} = K_{CO} \cdot C_{SP\ LG} \cdot R_{LG} \cdot T_{LG}, kg \qquad (4.3)$$

$$M_{NOxGO} = K_{NOx} \cdot C_{SP\ LG} \cdot R_{LG} \cdot T_{LG}, kg \qquad (4.4)$$

Where

K_{CO}, K_{NOx} – emission indexes (kg of detrimental compound per kg of fuel) of CO and NO_x relatively during ground operations;

$C_{SP\ LG}$ – specific consumption of fuel during regime of low gas, kg/N·hour ;

R_{LG} – engine thrust at low gas,

$$R_{LG} = \overline{R} \cdot R_0 , N, \qquad (4.5)$$

$$R_{LG2} = 1 \cdot 229000 = 229000 N,$$

$$R_{LG3} = 0,85 \cdot 229000 = 194650 N,$$

$$R_{LG4} = 0,3 \cdot 229000 = 68700 N,$$

Where:

- – relative thrust (table 2),

R_0 – maximal thrust of engine, N (table 2);

T_{LG} – operating time of engine at low gas for one takeoff and landing cycle (regimes 1,5 at the table 1), hour.

Calculations of CO and NO_x emissions relatively during takeoff and landing operations (regimes 2, 3, 4) are based on formule:

$$M_{CO\ TLO} = W_{CO\ T} \cdot T_T + W_{CO\ C} \cdot T_C + W_{CO\ L} \cdot T_L, kg, \qquad (4.6)$$

$$M_{NOx\ TLO} = W_{NOxT} \cdot T_T + W_{NoxC} \cdot T_C + W_{NoxL} \cdot T_L, kg, \qquad (4.7)$$

Where:

$W_{CO\ T}$, $W_{NOx\ T}$ – weight rate of CO and NO_x emissions relatively during aircraft takeoff, kg/hour (table 3);

$W_{CO\ C}$,$W_{NOx\ C}$ – weight rate of CO and NO_x emissions relatively during climb to 1000 m;

$W_{CO\ L}$, $W_{NOx\ L}$ – weight rate of CO and NO_x emissions relatively during Approach landing from a height of 1000 m;

T_T, T_C, T_L – operating time of engine during takeoff, climb to 1000 m and descent from 1000 m relatively.

After adding the known parameters and quantities to formulas we obtain the emissions parameters M/R_0, g/kN for CO and NO_x at the most effective regimes, and then can compare them with ICAO Control emission parameters.

$$M_{CO\ GO} = 0,0546 \cdot 33.42 \cdot 229000 \cdot 0,7 = 292504.5\ [kg];$$

$$M_{NOxGO} = 0.0054 \cdot 33.42 \cdot 229000 \cdot 0,7 = 28929\ [kg];$$

$$M_{CO\ TLO} = 380 \cdot 0.7 + 450 \cdot 2.2 + 1080 \cdot 4 = 5562 [kg];$$

$$M_{NOx\ TLO} = 5340 \cdot 0.7 + 3660 \cdot 2.2 + 660 \cdot 4 = 14430\ [kg];$$

$$M_{CO} = 292504.5 + 5562 = 298,066.5\ [kg];$$

$$M_{NOx} = 28929 + 14430 = 43,359\ [kg].$$

Calculations of annual emissions of CO and NO_x of aircraft at the zone of airport per year are based on formulas:

$$M_{CO\ AZ} = M_{CO} \cdot N \cdot n, \text{ kg/year}; \qquad (4.8)$$

$$M_{NOx\ AZ} = M_{NOx} \cdot N \cdot n, \text{ kg/year}; \qquad (4.9)$$

$$M_{CO\ AZ} = 298,066.5 \cdot 60 \cdot 4 = 71,535,840\ [kg/year];$$

$$M_{NOx\ AZ} = 43,359 \cdot 60 \cdot 4 = 10,406,160\ [kg/year].$$

Where:

N – annual quantity of takeoff-landing of the aircraft at the airport;

n – quantity of engines of the aircraft.

When determining the emission index, the control parameter of the engine emissions M / R_0, g / kN is determined first of all. This parameter characterized the "damage level" of the engine. ICAO standards are determined according to this emission control parameter.

M – is the mass of a harmful substance over a period of engine operation, g

R_0, – maximum engine thrust, kN.

ICAO standards according to emission control parameters for modern engines:

$$M_{CO} / R_0 = 118 \ g/kN,$$
$$M_{NOx} / R_0 = (40...80) \ g/kN$$

For our calculation:

$$M_{CO} / R_0 = 99.6 \ g/kN,$$
$$M_{NOx} / R_0 = 48 \ g/kN$$

Measures aimed at improving engine efficiency automatically reduce CO and C_xH_y emissions, but this does not reduce NO_x emissions without the application of special measures, which at the same time should not impair the performance of aircraft. One of the effective methods of mass emission control is the optimal choice of fuel residence time in the combustion zone, which allows to rationally balance CO, C_xH and NO_x.

4.3 Regulating aircraft emissions

Emissions from low-altitude operation and ground aviation are governed by engine certification requirements, tailpipe emission standards for clean air law for airport vehicles and off-road ground handling standards. Requirements for the certification of aircraft engines relate to carbon monoxide, hydrocarbons, nitrous oxide and smoke emissions. In 2016, the International Civil Aviation Organization (ICAO) set CO2 emission standards for new aircraft at a two-tier level. One standard applies to new aircraft that are already certified and already in production. A more restrictive performance standard applies to designs that will be certified after 1 January 2020 for commercial jets and 1 January 2023 for business jets, with each category of aircraft put into service approximately four years after certification. The efficiency requirements will apply to all new aircraft deliveries starting from January 1, 2028. The standards are based on aircraft weight and will require an average of four percent reduction in cruise fuel consumption compared to new aircraft delivered in 2015.

New aircraft from Boeing, Airbus and other smaller manufacturers already meet CO2 emission requirements, and by 2020, the average new aircraft will "exceed" the standard by about 10 percent. The EPA issued a finding in August 2016 that GHG emissions to aircraft "cause or contribute to air pollution that is expected to threaten the health and well-being of the population." This allows the agency to set CO2 emission standards for US aircraft in accordance with the Clean Air Act that meet or exceed ICAO requirements. However, the EPA has not yet set CO2 emission standards for US-made aircraft. Without a standard in force in the United States until January 1, 2020, the Federal Aviation Administration (FAA) will not be able to confirm that aircraft manufactured by American companies comply with ICAO regulations. Without this certification, new aircraft cannot be sold internationally. The industry is in favor of adopting the ICAO standard, and the EPA is expected to set the rule this fall.

4.5 Climate change

The Intergovernmental Panel on Climate Change (IPCC) is an international body responsible for assessing science related to climate change. It was established in 1988 by the World Meteorological Organization and the United Nations Environment Program to provide policymakers with regular assessments of the scientific basis of climate change, its effects and future risks, and adaptation and mitigation options. In October 2018, the IPCC published its Special Report. The impact of global warming is 1.5 ° C higher than the pre-industrial level in support of the Paris Agreement process. He concluded that human warming is now estimated to be rising by 0.2 ° C for decades due to past and current emissions. To stabilize warming at 1.5 ° C, total net CO_2 emissions from human activities by 2030 should be reduced to 45% of 2010 levels, reaching zero by 2050. The IPCC considers carbon dioxide (CO_2) as the main greenhouse gas. Aviation accounts for approximately 2 to 3% of total annual global CO_2 emissions from human activities and, in addition to climate change, CO_2 from non-CO_2 emissions (eg NO_X, particulates).

Greenhouse gases and other emissions have a complex impact on the climate. The most common climate effect is an indicator called "radiation exposure", measured in watts per square meter (W / m2). This represents since the pre-industrialization adopted in 1750, the balance between the energy received by the Earth from the Sun has changed and the Earth's energy radiates back into space. RF is used because there is a good relationship between global changes in mean RF frequency and global warming, as changes in overall mean equilibrium surface temperatures are just as easy to calculate as changes in mean global surface temperatures, with positive values indicating warming and negative cooling values.

Since the end of the 19th century, global warming of 0.78oC due to anthropogenic greenhouse gas emissions has led to an overall increase in HF of 2.29 W / m2. A comprehensive assessment of the impact of radio frequencies on aviation was last conducted in 2009. In the base year 2005, the total RF was 0.078 W / m2, which is 4.9% of the total increase in the Russian Federation according to IPCC estimates for the Fourth Assessment Report.

Carbon dioxide (CO_2) emissions from fossil fuel combustion accumulate in the atmosphere and can remain there for hundreds to thousands of years. Thus, the accounting of aviation CO_2 emissions from the beginning of "significant" civil aviation activities, which were usually carried out in 1940, is used to calculate the marginal contribution of aviation to total CO_2 emissions. concentration in the atmosphere. The total aviation of the Russian Federation in 2005 CO_2 was about 40%. The remaining 60% is accounted for by non-CO_2 emissions.

The overall radio frequency effect of aviation emissions of nitrogen oxides (NO_X) at cruising altitude due to atmospheric chemistry has a warming effect on the formation of short-term tropospheric ozone (O_3) and an almost balancing cooling effect on the reduction of the methane atmosphere (CH_4). Less than in 2009, the additional negative effects of radio frequencies (cooling) associated with the decrease in CH4 have been quantified, but the quantified overall balance still remains a warming.

Conclusion to part 4

Aviation is a complex and vital industry serving not only the United States, but the whole world. It delivers huge economic benefits for those countries that support it. Its speed and availability are well suited. to modern society, because globalization, technological development and production are transforming just in time World. In order to maintain its central transport role, aviation must ensure that it can mitigate any restrictions that arise from his operations.

There are features that distinguish aviation from other modes of transport and industries that should be taken into account in environmental strategies. Aviation attaches great importance to safety, which requires the introduction of only proven and technically sound technologies to reduce impact. Aircraft are expensive and have a long service life, requiring a long time for new technologies to be widely included in the fleet. Glider and engine manufacturers as well as airlines will have to invest in the creation and operation of aircraft with new technologies for aviation to realize environmental and operational benefits. Airport infrastructure requires careful planning and construction work, as well as state and financial support

5 LABOUR PROTECTION

5.1 Working conditions analysis

This diploma work is related to providing of material behavior simulation. The research is performed by using specialized literature and personal computer (PC). The subject of this work is an engineer, who works under the modeling and calculation of samples on PC. Main object of the analyzing will be working condition in the scientific laboratory and safety precautions for workers.

In this part the would be analyzed the possible harmful factors and workplace conditions because the main source of diseases and injuries is the labor factors impact on the human body. These factors depend on a presence of unfavorable conditions for human organism including its time of duration and intensity.

The last one can led to trauma, including death and others lead to harm, with additional an increase in presents of all factors.

5.1.1 Workplace organization

Engineer's scientific laboratory is a place for 3-5 same workplaces for other engineers for designing and modeling.

The dimensions of working place is equal to 30 *m* in length, 10 *m* in width and 3,5 *m* in height. After this we obtain the overall amount of laboratory area (S):

$S = length \cdot width\ [m^2],$

$$S = 30\ m \cdot 10\ m = 300\ m^2,$$

Then we should know the volume of given workplace (V):

$$V = S \cdot height\ [m^3],$$

$$V = 300\ m^2 \cdot 3.5\ m = 1050\ m^3.$$

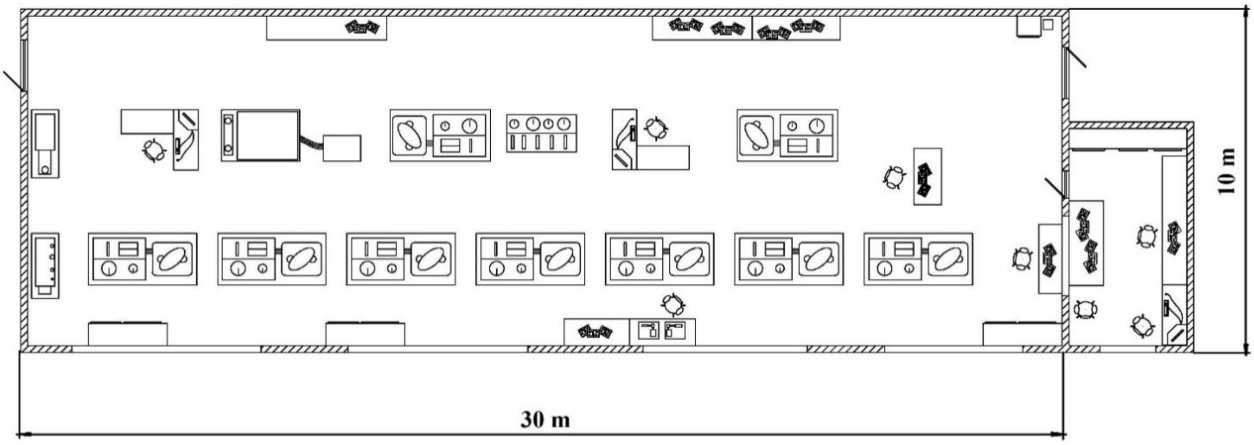

Figure 5.1 - Laboratory facilities layout

Laboratory perimeter is equal to:

$$P = 2 \cdot length + 2 \cdot width\ [m]. \quad (5.1)$$

$P = 2 \cdot 30 + 2 \cdot 10 = 80\ (m).$

Finally, the working area of one person is approximately equal to:

$$A_{person} = \frac{A}{n[m^2]}, \text{w} \quad (5.2)$$

$$A_{person} = \frac{300\ m^2}{4} = 75\ m^2,$$

where n in number of persons.

All shown parameters of construction and works are approved by building code of Ukraine ДБН В.2.2–28–2010 “Administrative buildings”.

In laboratory room mounted 15 ceiling lights and 4 windows from one side. In addition, it equipped two different kinds of sockets (220 V and 360 V supplies)

The workplace microclimate has closely to favorable conditions parameters:

- temperature not exceeding 24°C;
- relative humidity should be 40-60 %;
- velocity of air– 0.2 m/s.

To achieve the preferred values of microclimate are used heater and air ventilation. Presence of noise sources are taken from action of fatigue investigation stress machines, cooling units of machines, volume of noise from hangar compartment and neighbor rooms. In free access it possible to get first aid kit and 5 fire extinguishers in laboratory.

The engineering working process is related to operating with computer. The requirement of document “Про затвердження вимог щодо безпеки та захисту здоров’я працівників під час роботи з екранними пристроями” approved by the order of the Ministry of Health of Ukraine 02.14.2018 №207

5.1.2 The list of harmful and hazardous factors

Based on hygienic standards ГН від 08.04.2014 №248 « Гігієнічна класифікація праці за показниками шкідливості та небезпечності факторів виробничого середовища, важкості та напруженості трудового процесу» we can observe a list of harmful and dangerous factors for our case that could be meet during the working performance:

1. Microclimate: temperature, humidity, air velocity;
2. Production noise, ultrasound, infrasound;
3. Vibration (local, general);

4. Lighting: natural (lack or insufficiency), artificial (insufficient illumination, direct and reflected dazzling glare, etc.);

Characteristics of the labor process, influent on the level of needed energy for high performance, the prevailing load on the cardiovascular, respiratory and other systems. Sensory stress is not defined as harmful in this chapter, but computer work takes up nearly all of work time. In this regard, we will simply mention this point as important.

5.1.3 Analysis of harmful and dangerous production factors

Following to the destination, the designated classes are observed:

- means of the air environment of laboratory and workplaces control (air-conditioning, heating, etc.);
- means of illumination of compartment and workplaces control (light sources and lighting devices.);
- electromagnetic radiation protection;
- noise and vibration protection (sound insulation, vibration isolation, etc.);
- means of electric shock protection (protective earth, grounding, etc.).

There are government regulations on dangerous and hazardous factors that have to be observed. All working conditions must necessarily comply with the requirements of state regulation.

5.1.3.1 Microclimate of the working place

Referred to standards ДСН 3.3.6.042–99 “Санітарні норми мікроклімату виробничих приміщень”, engineer designer’s occupation categorized as light physical work. The optimal values of temperature, relative humidity and air velocity of the working area is compared with actual for better comparison and shown at tables.

Table 3.1 – Optimal values of temperature, relative humidity and air velocity of the working area

Season	Category of works	Air temperature °C	Relative humidity, %	The velocity, м/с
Cold	Easy – 1 b	21...23	40...60	0,1

Warm	Easy – 1 b	22...24	40...60	0,2

Table 3.2 – Actual values of temperature, relative humidity and air velocity of the working area

Season	Category of works	Air temperature, C°	Relative humidity, %	The velocity, м/с
Cold	Easy –1 b	18	58	0,1
Warm	Easy –1 b	24	60	0,15

This table represents that all conditions are in acceptable range except of air temperature. It is obvious that for improving the working conditions it is necessary to increase the number of air heaters on the working place.

It means that in order to improve working conditions for engineer it is necessary to increase the temperature by adding several air heaters in the laboratory.

5.1.3.2 Production noise, ultrasound, infrasound

From medical researches was established that noise negatively effects on various parts of the brain, changing the normal processes of nervous activity. At the same time, visual acuity and sensitivity of color differentiation decrease, the suffering of vestibular apparatus, the functions of the gastrointestinal tract are disrupted, intracranial pressure rises, metabolic processes in the body are broken, etc., while they can create levels that are much higher than the permissible hygienic standards.

The basis of noise normalization is the limitation of sound energy that acts on a person during the work shift to values that are safe for his health and performance. Reduction of vibration can be achieved by changing the technological process with the production of parts made of nylon, rubber, composite epoxy material, timely carrying out of preventive measures and lubricating operations; centering and balancing of parts, reducing gaps in joints and other means and measures.

Normalization of noise is based on the limitation of sound energy acting on a person during a work shift to values that are safer for his organism and performance. Avoiding of the increasing the vibration level can be achieved by changing the technological process of manufacturing parts from nylon, rubber, composite epoxy material, taking preventive measures and lubrication; centering and balancing parts, reducing gaps in joints and other means and measures.

In accordance to ДСН 3.3.6.037-99 "Санітарні норми виробничого шуму, ультразвуку та інфразвуку" the duration of operation with the vibrating instrument should not exceed 65% of the working shift, and the duration of continuous vibration action should be less than 15… 20 minutes. If the vibration of the machine exceeds the permissible value, then the contact time with the work is limited.

5.2 Engineering, technical and organizational solutions to prevent the effects of hazardous and harmful production factors

Collective and individual protection measures are made to avoid accidents and injuries during shift.

Collective means of protection are designed to prevent or reduce the impact on workers of hazardous and harmful production factors, as well as to protect against pollution.

Personal protective equipment is intended for use by an employee to prevent or reduce the effects of harmful and dangerous industrial factors, as well as to protect against pollution. They are used in cases where the safety of work cannot be ensured by the construction of equipment, the organization of production processes and the means of collective protection. Depending on the destination, PPE is divided into the following:

Employee obliged to use personal protective equipment to prevent or reduce exposure to harmful and hazardous industrial factors and to protect against contamination presence in air. They are used in occasion where labor safety cannot be guaranteed by the design of equipment, organization of production processes and collective protective equipment. Depending on the purpose, PPE is divided into:

a) insulating suits (pants, suits);
b) respiratory protection (gas masks, respirators, pneumatic scrap, pneumatic masks);
c) special clothing (overalls, jackets, pants, suits, bathrobes, raincoats, jackets, aprons, vests, armlets);

d) special shoes (boots, boots, boots, shoe covers);
e) hand protection (gloves, gloves);
f) eye protection (goggles);
g) face protection (face masks, face shields);
h) head protection (helmets, helmets, hats, berets);
i) fall protection devices, etc. (safety belts, dielectric rugs, hand grips, manipulators);
j) hearing protection devices (noise helmets, headphones, earbuds);
k) protective dermatological (various washing solutions, pastes, creams, ointments).

Overalls and work shoes must protect the worker and maintain his ability to work. The names of the overalls and work shoes must match the names of the dangerous and harmful factors against which they are protecting. Overalls and work shoes must maintain their hygienic and performance properties for lifetime in the conditions of use and care.

5.3 Fire safety of production facilities

The reasons of fires and fires in training laboratories are very different and are root case to constantly changing due to advances in technology. According to НАПБ А.01.001-2004 “Правила пожежної безпеки в Україні” scientific laboratory refers to category C, as its machinery has a great amount of oil. As mentioned in “Кодекс цивільного захисту України” due to the danger of fire laboratory equipped with 5 fire extinguishers of different types for all possible ignitions, fire alarm and smoke detector system and has place with specialized bucket and sand for extinguishing.

The length of the closest escape way is around 90 m. For immediate evacuation from the laboratory compartment employee need to leave the place from the door with specific label “EXIT”, then turn right and after 60 m to the left. Way scheme is represented on the Figure 4.2. and similar picture is placed in the training laboratory.

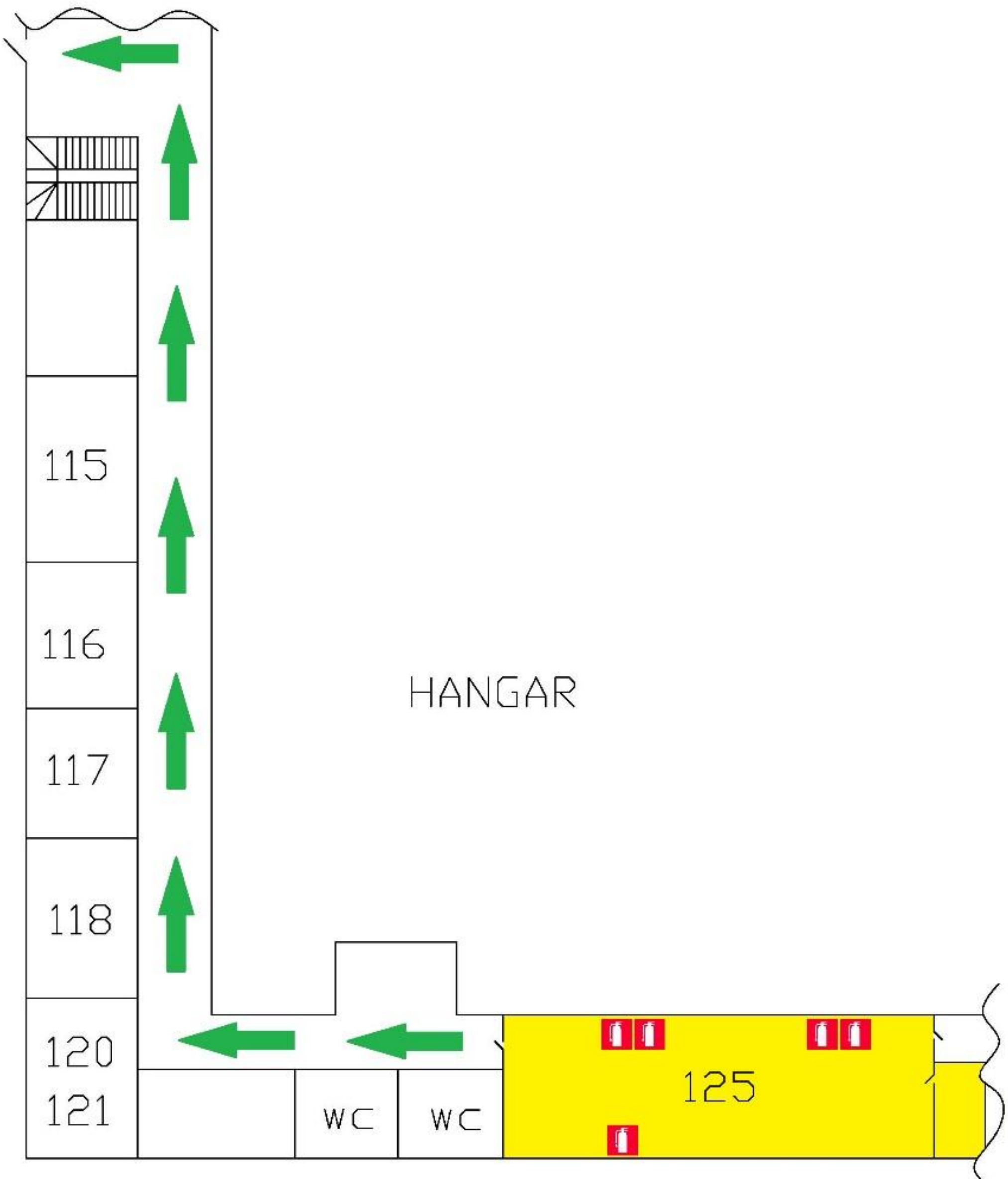

Figure 5.2 - Emergency evacuation scheme

5.4 Artificial lightning calculation

Normal room illumination (E_{min}) depends on the level of visual work performed in this room, which in turn is determined by the minimum size of the object of discrimination. Job Service Engineer IV refers to the OS level visual works. For general lighting engineer at the lowest room illumination by ДБН В.2.5–28–2018 “Природне і штучне освітлення” of at least 400 lx (lux) should be achived. The actual value of light is 200 – 250 lx. Total light output is given by:

$$E_{gen} = \frac{E_n \cdot S \cdot k_1 \cdot k_2}{\mathbf{V}} \qquad (5.3)$$

where E_n – normalized illumination (E_n=*400lx*);

S – area of application;

k

– Coefficient taking into account the aging of lamps and lighting pollution (k_1 =1,2);

k k

– Coefficient taking into account the uneven illumination space (= 1.1);

V – Ratio of luminous flux, defined according to the reflection coefficient of walls, work surfaces, ceilings, room geometry and types of lamps.

Room size up: A = 30 *m*, B = 10 *m*, H = 3.5 *m*.

$$S = A \cdot B = 30 \cdot 10 = 300\ m^2 \quad (5.4)$$

Choose the table using the light flux ratios:

1. Reflection coefficient of whitewashed ceiling ($R_{ceiling}$ = 70%);
2. Index of refraction of white walls (R_{wall} = 55%);
3. Reflection coefficient from the dark hardwood floors (R_{floor}= 10%);
4. Index space ($i = (A \cdot B)/(h_p \cdot (A + B))$.

$$h_p = H - h_n \quad (5.5)$$

where h_n– work surface height over the floor (h_n=0.7 m).

Defining the room rate:

$$h_p = 3.5 - 0.7 = 2.8 m$$

The utilization of light flux:

$$i = \frac{30 \cdot 10}{2.8 \cdot (30 + 10)} \approx 0.26. \quad (5.6)$$

Now we define the value of the total luminous flux: (*V=0.7)*

$$E_{gen} \frac{400 \cdot 300 \cdot 1,2 \cdot 1,1}{0,7} = 22000\ lm \quad (5.7)$$

To ensure total artificial lighting, selected LED bulbs LED–T8SE–180 and replace fluorescent lamps 18W 990 lm. Luminous flux of one lamp LED-T8SE-180 (20W.). Thus, E_l=1650 lm.

Now we define the number of lamps required to illuminate the room:

$$N = \frac{E_{gen}}{E_l} = \frac{22000\mathbf{0}}{1650\mathbf{0}} = 14\ lamps \quad (5.8)$$

Thus, to provide light $E_{gen}=220000\ lm$ output the 14 lamps must be used, lamp instead of 20. Put in 2 rows. Power of 20 fluorescent lamps:

$$W_{gen}=W_N \cdot N=18 \cdot 20 = 360W \quad (5.9)$$

Savings from the use of LED lamps.

$$N = W_{gen} / (N_{LED} \cdot P_{LED})= 360/(14 \cdot 20)= 1.3 \quad (5.10)$$

Conclusion to part 5

It is quite important to maintain the capability of human to perform his work safe for his health and security of his working place and equipment, security of colleagues, working room and building overall. Estimated and found the way of improvement of artificial lightning. The illumination of the training laboratory should be changed to better LED lamps in quantity of 14, that provides enough light for further working with high performance. The most effective solutions to prevent exposure to hazardous factors are to use safety instructions in the laboratory.

Substances used for lubrication of test facilities in the laboratory are flammable, so fire safety must be observed at the work site.

GENERAL CONCLUSION

Repair of cracks in metals was reviewed and various repair methods that are currently in use at both general practical purpose and high value and critical application levels have been discussed. It has been noted that computational studies are playing a key role in improving understanding of the effect of most crack repair techniques on the mechanical performance of repaired components.

Stress analysis of the stiffened panel of transport airplane rump was carried out and maximum tensile stress was identified at the stiffeners and corners of construction. Center longitudinal crack was initiated from corner of part.

Methods of stopping the growth of cracks have been studied. Stopper was mounted on the inner part of corner which connect the floor and transversal beam sections and was attached across initial crack. The main results are as follows:

(1) The fatigue life of a given specimen that has a crack in near the connection with other parts was improved by attaching a crack stopper.

(2) Extension of fatigue was different, depending on method of mounting a fuse crack.

(3) In this study, fatigue was longest when a crack appeared the arrester was mounted on a flat section on the opposite side of the welding site.

(4) When the contact area between the crack fuse and the sample the surface was wider and the crack displacement was reduced, the service life of fatigue becomes longer in the case of a sample with a weld area.

Was observed of influence on the environment and decreasing of impact because several technologies implementation. Prepared of instruction for employees for save work and non-hazardous conditions providing.