MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

NATIONAL AVIATION UNIVERSITY

DEPARTMENT OF AIRCRAFT DESIGN

APPROVED BY
Head of department
Professor, Dr. of Sc.
_________S.R. Ignatovych
«___» _______ 2020.

MASTER THESIS

ON SPECIALTY

“AVIATION AND SPACE ROCKET TECHNOLOGY”

Theme: «Measurement of the thickness of transparent coatings by interferometry»

Prepared by: __________ **V.O.Ogbodo**

Supervisor: PhD, associate professor __________ **V.I. Zakiev**

Labor protection:

Ph.d., associate professor ____________ **O.V. Konovalova**

Environmental protection:

Ph.d., associate professor ______________ **L.I. Pavliukh**

Examined:

Ph.d., associate professor ______________ **S.V. Khiznyak**

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NATIONAL AVIATION UNIVERSITY

Faculty of Aerospace

Department of Aircraft Design

Master's degree

Specialty 134 "Aviation and rocket and space technology"

Specializations "Aircraft Equipment"

APPROVED BY

Head of Department

Dr. Tech. Sciences, Prof.

_ S.R. Ignatovich_

«_____» ___________ 2020

TASK

To perform the thesis of the student

OGBODO VICTOR

1. Topic: "Measurement of the thickness of transparent coatings by interferometry.", Approved by the order of the Rector of October 5, 2020 № 1906 / Art.

2. Term of project implementation: from 5.10.2020. по 13.12.2020р.

3. Initial data for the project: Transparent protective coatings with a thickness of 5-40 microns.

4. Contents of the explanatory note: Examples of application of transparent coatings in modern aircraft and equipment, analysis of modern methods of measuring transparent coatings and substantiation of interferometry, development of methods for measuring protective transparent coatings based on the method of white light interferometry, research different thickness and testing of the proposed method, analysis of harmful and dangerous production factors.5. The list of obligatory graphic (illustrative) material: aviation equipment, basic schemes of methods of measurement of thickness of transparent coverings, the general look of the equipment on which measurements were carried out.

6. Calendar schedule

№	Task	Execution period	Done
1	Task receiving, processing of statistical data.	5.10.2020–8.10.2020	
2	Analysis of modern aviation equipment in which transparent coatings are used.	9.10.2020–15.10.2020	
3	Analysis of modern methods for measuring the thickness of transparent coatings	16.10.202017.10.2020	
4	Substantiation of the interferometry method.	18.10.2020–25.10.2020	
5	Rationale and choice of radiation source.	25.10.2020–29.10.2020	
6	Development of a method for measuring the thickness of transparent coatings.	30.10.2020–5.11.2020	
7	Approbation of the offered technique and experimental researches of samples with the put protective covering.	5.11.2020–20.11.2020	
8	Completion of the explanatory note	21.11.2020–05.12.2020	

7. Consultants of separate sections

Chapter	Consultants	Date, signature	
		Task Issued	Task Received
Labor protection	O.V. Konovalova		
Environmental protection	L.I. Pavliukh		

1. Date:

Supervisor ___________ V.I. Zakiev

Student ___________ V.O. Ogbodo

ABSTRACT

Master degree thesis "Measurement of the thickness of transparent coating by white light interferometry"

87p., 43 fig., 2 table, 1 graph, 1 image, 33 references

Object of study – elements of a system for application of transparent coating and its thickness measurement using white light interformetry.

Subject of study – measurement of the thickness of transparent coating by interferpmetry.

Aim of master thesis – is to develop a new non-destructive methods which can be used in the measurement of the thickness of a transparent coating.

Research and development methods –analysis of the applications of transparent coating on air and space crafts; theoretical research methods: empirical research methods: comparisons analysis. Measurements of coating by white light interformetry and experimental measurement.

Novelty of the results – it is the first time a new method of a non-destructive method is used in the measurements of the thickness of transparent coating which is base on the white light interformetry.

Practical value – its is the improvement in the methods used in measuring the thickness of transparent coating and without causing any form of structural or plastic deformation to the specimen used on, which is one of a very important aspect we consider in aviation run down to non-destructive methods of measuring the thickness by the used of white light interformetry. Also protecting and enhancing the aircraft in its performance and longer service life. Therefore the result of this work can be implemented in air and space industries by the adaptation of a more protective and improve air and space crafts.

AIRCRAFT, TRANSPARENCY, THICKNESS MEASUREMENTS BY WHITE LIGHT INTERFORMETRY, PROTECTION AND IMPROVEMENT TO AIRCRAFT PARTS

CONTENT

ABBREVIATIONS

NVG – Night Vision Google

OPD – Optical Part Difference

SRI – Spectrally Resolved Interformety

LED - Light Emitting Diode

LCI – Low Coherence Interferometry

CCI – Coherence Correlation Interferometry

HIRF – High-Intensity Radiated Fields

UV – Ultraviolet

EM – Electromagnetic

RF - Radio Frequency

PCB – Performance Component Board

EMP – Electromagnetic Pulses

INTRODUCTION

Today air and space crafts are highly sophisticated scientific machine that requires the expertise of hundreds of engineers and scientists working in close harmony to design and produce a successful product. However, a close examination of high performance aircraft reveals that the transparent crew enclosure is frequently inadequate to meet mission requirements, because either the technology was not available or the requirements were not understood.

In this project, I have enclosed the applications of transparent coating in aviation and what they protect against. In order to have a more advanced and life-long service of the aircraft i have mention a few aspect in which transparent coating will be used to enhance the performance of the aircraft, which are the most critical factors contributing to transparency redesign include below:

-Poor optical design for the materials and geometry selected;

-Lack of bird impact protection;

-Poor removal/replacement features (supportability);

-Lack of adequate service life.

A further aspect to look at is the complication which comes with the emergence of new mission requirements, which places an even greater demand on the performance of the aircraft and its transparency system. These emerging requirements may include signature reduction and protection against lasers and chemical environments. Obviously a proactive rather than a reactive approach is needed to integrate all the design requirements in a timely manner to produce a cost effect transparency system for a high performance aircraft. This report also presents a methodology aspect which are to select the materials needed to meet the critical operational and supportability requirements of a generic high performance aircraft. The objective of this report is primarily focused on introducing the application of transparent coating using white light intersparency concepts and material selection Of the transparency system and how they can improve the performance of the aircraft, and what they protect against.

These compounds are designed to enhance equipment reliability/efficiency while providing protection against impact, abrasion, corrosion, erosion, fatigue. Mechanical strength properties are maintained at low/elevated temperatures for properly prepared/primed metal to metal, metal to composite and composite to composite surfaces. This includes aluminum, nickel, titanium stainless steel, which are also employed for airframe and interior components in commercial, military, business, civilian helicopters. They are used for freight haulage, search and rescue operations, inter-city commuting, aerial observation, tourism and medical transport. contribute to improved aerodynamics design, weight reduction, lower fuel consumption and noise, increase payload range/capacity, vibration damping. Advanced non-halogenated, flame retardant systems have been tested for fire, smoke, toxic gas emission and are used in interior cabins. Fast setting, non-sag, gap filling high strength materials reduce general repair expenses and can be easily applied with manual/pneumatic dual cartridge gun applicators. They are resistant to water, salt water, JP-4, hydraulic fluids, have good wetting characteristics and are ideally suited to meet specific requirements depending on part location/geometry. for example. Thin film thickness measurements with sub-nanometre accuracy are important in a range of applications such as thin film optical coatings, displays, semiconductor devices, thin film photovoltaics, thin film transparent conducting oxides .For example, the precise thickness of a single layer anti-reflection coating determines its anti reflective quality and spectral response. The precise thickness of a transparent conducting oxide will determine its transmittance and sheet resistance. Spectroscopic ellipsometryis usually used to make these measurements. Likewise, surface roughness and other surface metrology measurements such as feature width, form, volume and angel on thin films are also important. In optical coatings, surface roughness causes scattering and haze. In display or photovoltaic devices, roughness of the transparent conducting oxide contact can lead to shunting of the devices. These metrology measurements are made using a variety of techniques including stylus profilometry, Atomic Force Microscopy, Scanning Electron Microscopy and Scanning White Light Interferometry (SWLI). Here we report on the use of a variant of SWLI called coherence correlation interferometry (CCI) which is now capable of combining sub-nanometer thin film thickness measurements with quantitative three-dimensional metrology and imaging from the same thin film sample area. The technique provides these measurements quickly and accurately and now has a potentially important role not just in research and development but also in quality control in a manufacturing environment.

CHAPTER 1
APPLICATIONOF TRANSPARENTCOATINGIN AVIATIONANDAEROSPACE

Today air and space craft are manufacturedwith many vulnerable components and technical equipment that needs advance coating to maintain and enhance their performance, out in the world those components are subjected to extremely temperature severe environmental hazard and wear off over time. Which is show in figure 1

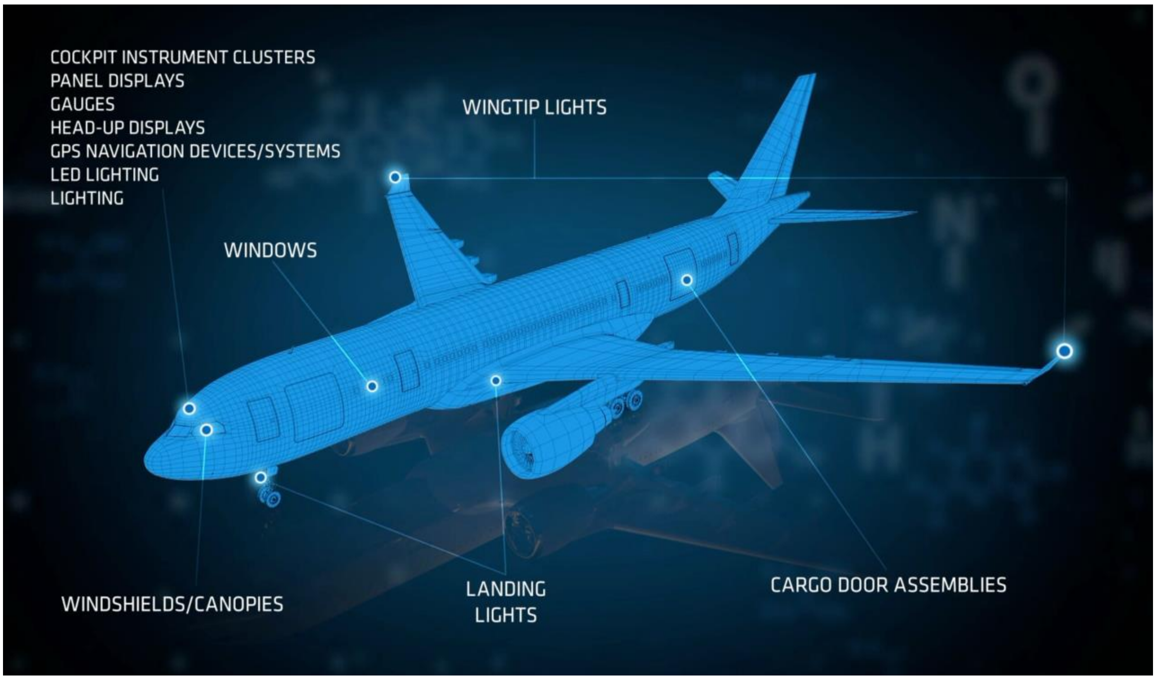


Figure 1 –Show case of the applications of transparent coating

Therefore air and space craft are manufacturedwith many vulnerable components and technical equipment that needs advance coating to maintain and enhance their performance, while because those components are subjected to extremely severe environmental hazard which caand or limit the performance operation or properly function of the air and space craft.

To protect and enhance those components it is then very necessary to produce a product which has resistance to abrasion and damage, from impact, chemical, and uv radiation. Combing optical clarity, with premium weather ability, also resisting scratch on touch screen, fuel efficiency, maximizing speed while resisting optical distortion from chemical hazards such as hydraulic fluids and aviation fluids and maximizing flexibility on the aircraft [1 21] .

1.1 Lens materials for exterior air craft lighting

The aircraft lighting system is of a very important aspect in both air or on the ground, the external lighting on airplanes plays a major role in ensuring flight safety and the safety of ground crews In order to ensure a long lifetime and reliable performance, the lens covers used in aircraft lighting applications must provide consistent transmission of light, with minimal material degradation after exposure to harsh conditions. In this study, abrasion testing was performed on three different jet aircraft lens materials, a heat strengthened borosilicate glass (Kopp 9000), a hard-coated polycarbonate (Makrolon AR), and an aviation grade acrylic (Plexiglas II UVA), to demonstrate suitability for the extreme aerospace environment. Taber abrasion and high-velocity particulate testing results demonstrated a significant abrasion resistance advantage for glass compared to the plastic. Severe transmission loss was observed in the polycarbonate compared to the glass and far exceeded the transmission losses [theorized or deemed acceptable] by industry sources. Abrasion resistance, the ability of exterior lenses to stand up to these harsh environments, must be a high priority during the lighting fixture design and maintenance processes otherwise the potential cost savings of LED technology cannot be achieved in application.

The ability of pilots to see and be seen in poor weather conditions, especially on and near busy airfields, is critical to ensuring the safety of the public. Exterior aircraft lighting is a critical component that helps provide necessary visibility. Aircraft lighting has followed general conventions used in marine applications to help identify positioning between aircraft, and have several individual lighting systems to help this identification process including position and anti-collision lights and in some cases icing, landing, and taxi lights.

LED technology affords some benefits over traditional incandescent. When integrated into a well-designed lighting system with adequate heat sinking and solid-state mounting, LED-based lighting products will easily last more than 50,000 hours of continuous operation, and their lifespan is not reduced by power cycles. LEDs have proven efficiency not available in incandescent bulbs. For instance, the LEDs used in AeroLEDs lighting products have high lumen efficiency ratings, and as a result, they typically use less than a third the power of halogen bulbs. Of importance here is the significant reduction in the electrical load on the airplane's battery and alternator system. Think about what happens in the real world with a typical halogen bulb. With the power back on final approach, low engine rpm reduces alternator output, causing the lamp to produce less than its rated light output at full voltage. LED lights usually maintain full light output, even at lower battery voltages.

Further, the primary driver of halogen bulb filament and Xenon tube lead failures is airframe vibration. The LEDs are solid-state mounted devices that can tolerate high levels of shock and vibration without failing. LED lights are designed to tolerate this high-vibration environment indefinitely [2,3,23] .

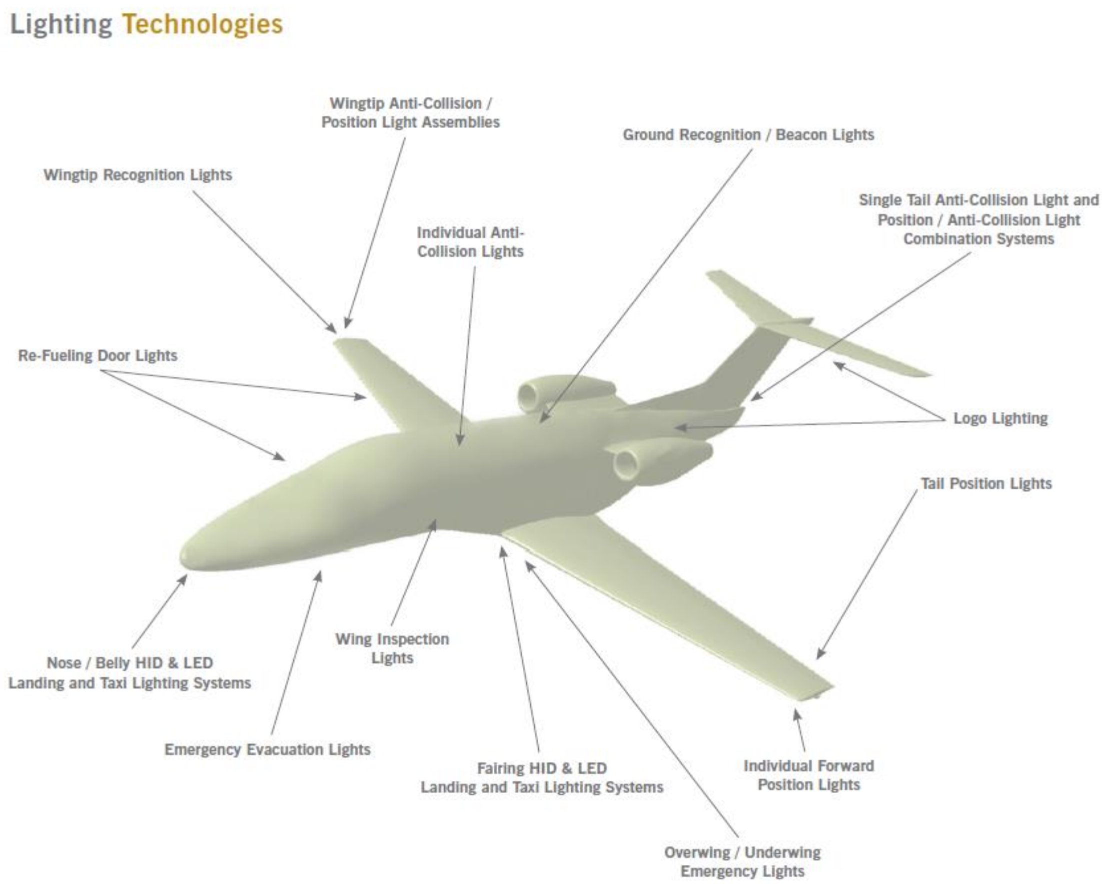


Figure 1.1 – Showcase of lighting technology

in general the aircraft lighting system is one of a very important in which we condsider in aviation, while because it embodies all aspect of visualization and also mode of aircraft operation which is showed in the figure 1.2.

1.2 Len materials

The component of aircraft lighting fixtures uses a transparent lens to cover and protect its light source, with the most common lens materials being used are glass or plastic. Glass lenses are usually made from borosilicate or soda lime silicate compositions and can be provided in annealed or heat strengthened (tempered) states. Plastic lenses are most commonly made of polycarbonate or acrylic, with or without a hard coating applied to improve durability. Table I provides a summary comparison of these three materials.

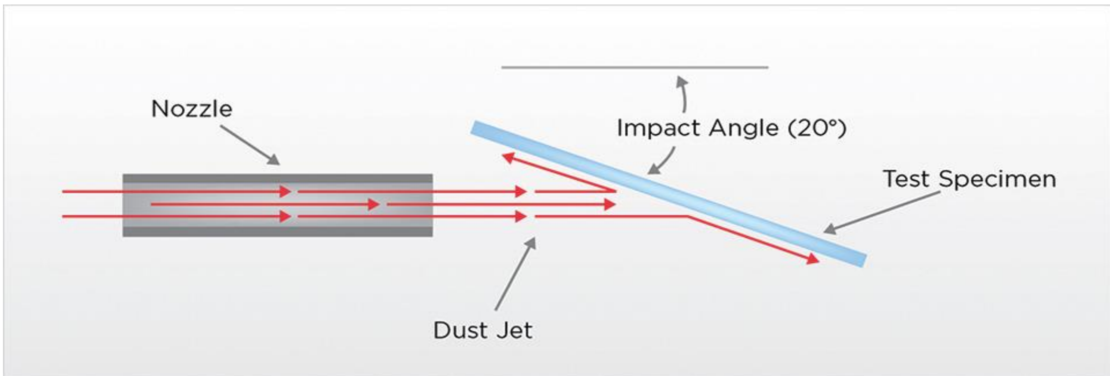


Figure1.2 – Transparent len material For Exterior Aircraft Lighting

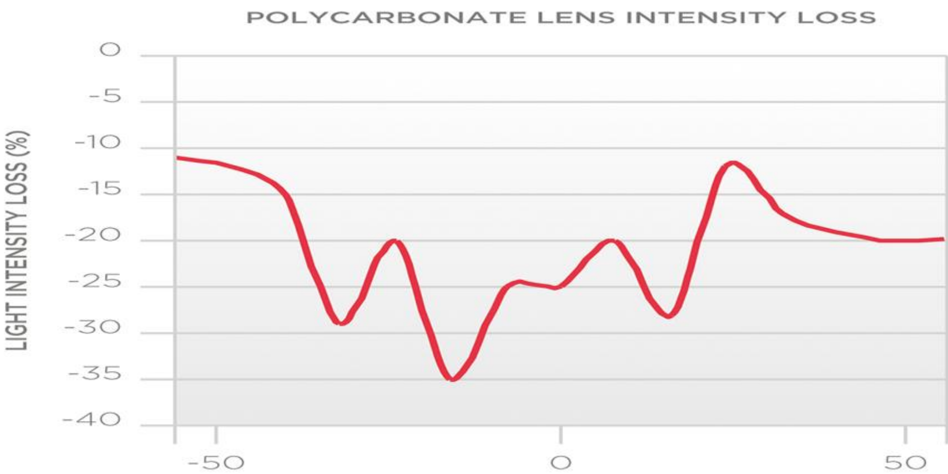


Figure 1.2b – Plastic lens light intensity loss experienced for a sample wingtip exterior light assembly

Data reproduced from

As the need to frequently replace burned-out incandescent bulbs is eliminated, the importance of constructing a reliable exterior lighting system capable of maintaining safe levels of light output despite continual exposure to particulate abrasion, thermal, and chemical stresses is crucial for operators to realize the benefits of LED technology. Lighting fixture manufacturers essentially have two transparent material choices: glass or plastic. The transparent lens material selected to be used in exterior aircraft lighting affects safety, maintenance, and cost.

The two-part investigation uses Taber abrasion and high-velocity particulate impact testing to evaluate the suitability of borosilicate glass, polycarbonate, and aviation grade acrylic in exterior jet aircraft lighting applications. The results conclude that borosilicate glass lenses can withstand the harsh operating environment of aerospace for more significant periods of time than their plastic counterparts, helping to increase the longevity and reliability of LED exterior lighting systems. Abrasion resistant lenses mean reduced maintenance and operating costs over the life of the aircraft. In the harsh, demanding environments experienced by exterior commercial and military jet aircraft lenses, it is necessary to select materials that can provide consistent performance.

In other words we can say The critical functions of lenses used in the exterior aircraft lighting applications is to maintain a consistent transmission of light to ensure the highest level of safety. Taber abrasion and high-velocity particulate impact testing provide an effective means for comparing current aircraft lens materials to determine suitability. At increasing cycles and exposures, the glass continued to maintain significantly higher levels of transmission than plastic. The tests indicate that the abrasion resistance of glass will significantly outperform that of plastic in exterior jet aircraft lighting applications, and as the airframes are pressed into nearly continuous service across varying environments, using materials that can withstand particulate abrasion, thermal, and chemical stresses will reduce the total cost of ownership of an exterior light fixture. When margins of safety, reliability, and maintenance protocols are considered, glass is the superior choice for exterior light fixtures on commercial and military jet aircraft. The testing is clear in showing glass lenses can withstand the harsh operating environment of aerospace for more significant periods of time than their plastic counterparts, helping to provide a consistent, reliable, and safe flying environment [2, 3] .

1.3 Night vision googles enhancement

Nowadays more and more pilots and crews use Night Vision Googles (NVG) for night operations, and Civilian use of night vision goggles (NVG) grows in the area for medical evacuation, search and rescue, security, and border patrol. Normally with a traditional lighting system, the good "reading" of the aircraft (heliport) by the pilot is not guaranteed. The main cause is that the night vision google amplifies residual light at night but doesn't render colors so it is of great importance to have made all of LED and incandescent lights upgradable to be compatible with Night Vision Googles (NVG). in order for the pilot and crew to have clear vision during any night operation and avoid blooming.

This enhanced system enables a more visibility of the pilot and crew and it is composed of a complex LED light engine, for example On helipad lights, the InfraRed and the visible lights can be independently controlled, providing an efficient solution to activate both types of light on a single unit. This system makes flying with Night Vision Googles easier and safer and ensure that pilots flying without Night Vision Googles not to be disturbed.

Figure 1.3 – Enhance Vision System NVG

Night vision devices gather existing ambient light (starlight, moonlight or infra-red light) through the front lens. This light, which is made up of photons goes into a photocathode tube that changes the photons to electrons, the electrons are then amplified to a much greater number through an electrical and chemical process. The electrons are then hurled against a phosphorus screen that changes the amplified electrons back into visible light that you see through the eyepiece. and image will now be a clear green-hued amplified re-creation of the scene you were observing.

There are two different methods used by night vision equipment for visibility in darkness

1) *Thermal imaging.*This method uses the heat emitted by objects to its advantage and shows that to the viewer. The infrared light is detected by infrared-detectors and a detailed temperature pattern is created(Thermogram). The thermogram is converted into electric impulses, these impulses are sent to a signal processing unit, the processed signals are sent to a display and the image is shown.

2) *Light amplification.* This is a more commonly used method. In this method, small amounts of light in the surrounding area are converted into electrical energy. Electrons pass through a thin disk, and are multiplied, these electrons bounce off a phosphor screen which converts them back to light. This light is what the viewer sees and enables the viewer to see in the dark.

Due to the direct influence of night vision equipment availability on the safety of night-time aerial reconnaissance, maintenance needs to be carried out regularly. Unfortunately, some defects are not easy to observe or are not even detectable by human eyes. As a consequence, this study proposed a novel automatic defect detection system for aviators, which is one of the reasons why it's very crucial for coating to enhance this part. night vision imaging systems AN/AVS-6(V1 and AN/AVS-6(V2. An auto-focusing process consisting of a sharpness calculation and a gradient-based variable step search method is applied to achieve an automatic detection system for honeycomb defects. This work also developed a test platform for sharpness measurement. It demonstrates that the honeycomb defects can be precisely recognized and the number of the defects can also be determined automatically during the inspection. Most importantly, the proposed approach significantly reduces the time consumption, as well as human assessment error during the night vision google inspection procedures.

Therefor to have a night as well as a day capability - To carry out low level, high speed penetration - (fighters planes) To attack battlefield targets, especially groups of tanks - To meet these objectives at minimum cost The most effective way to penetrate enemy defences is at low level and survivability would be greatly enhanced with a first pass attack. It is therefore most important that not only must the pilot be able to fly at low level to the target but also he must be able to detect it in sufficient time to complete a successful attack.

The design of the all-day all-weather INVIS Integrated Night Vision surveillance and observation System. The INVIS augments a dynamic three-band false-color night vision image with synthetic 3D imagery in a real-time display. The night vision sensor suite consists of three cameras, respectively sensitive in the visual (400-700 nm), the near-infrared (700-1000 nm) and the longwave infrared (8-14 μm) bands of the electromagnetic spectrum. The optical axes of the three cameras are aligned. Image quality of the fused sensor signals can be enhanced in real-time through Dynamic Noise Reduction, Superresolution, and Local Adaptive Contrast Enhancement. The quality of the longwave infrared image can be enhanced through Scene-Based Non-Uniformity Correction (SBNUC), intelligent clustering and thresholding. The visual and near-infrared signals are used to represent the resulting multiband nightvision image in realistic daytime colors, using the Color-the-Night color remapping principle. Color remapping can also be deployed to enhance the visibility of thermal targets that are camouflaged in the visual and near-infrared range of the spectrum. The dynamic false-color nighttime images can be augmented with corresponding synthetic 3D scene views, generated in real-time using a geometric 3D scene model in combination with position and orientation information supplied by the GPS and inertial sensors of the INVIS system [1, 6,] .

1.4 Scratch resistance protection

In order to avoid scratch on the touch screen used in the aircraft, it is therefore of a very great importance for the touch screen to possess high scratch resistivity. In modern aircraft or automobiles is a grand assemblage of parts made from a variety of materials. Many of these parts have a protective coating applied to improve the appearance or provide additional durability to the substrate.

Abrasion:

• Inorganic based nanoparticles provide improved scratch and abrasion resistance, by increasing alumina or silica content. High concentration is responsible for the improved scratch and wear resistance of the coating.

• Scratch resistance of coating can be improved by using micron sized inorganic fillers, but they cause matt or semi-matt appearance to coating by scattering visible light. However, by using nanoparticles, scattering of light can be reduced significantly. Nano powders of particle size around 40 to 60 nm are effective fillers. Nanoparticles such as ZrO2, AlOOH, SiO2 have been embedded in UV-curable lacquers, resulting in improved abrasion resistance.

• Protective layers based on polymeric or particulate sols applied onto a surface as a sol by simple mechanical coating techniques such as dip and spin coating. The resulting protective layers are purely inorganic, transparent and curable or sinterable even at a low temperature and have a high microhardness in addition to a very good corrosion protection effect. Storage modulus and temperature resistance are increased.

• Highly reactive as they cure in seconds, easy to apply as no special equipment is needed, are environmentally friendly because they contain no solvents, and because of the small particle size, are transparent.

• Ceramic network gives hardness to the coatings and organic components make coatings more flexible and tough.

• The materials are resistant to a large number of chemicals.

• Nanoparticles have been shown to improve the mechanical properties even at low loadings and due to their small particle size; they do not affect the transparency of clear coats. Scratch resistance also improved further due to homogeneous distribution of nanoparticles in polymers. Even a small amount can retain the appearance of surface without any negative impact on coating and its gloss.

In many coating systems the uppermost layer is a clear coating (ranging between Coatings 5–50 μm in thickness), which not only protects the underlying layers or substrate from chemical and UV degradation, but also provides protection from mechanical damage that can result in surface blemishes/scratches. Therefore a touch screen must possess desire permanent, scratch-free finish on all parts The design principle of the four-wire resistive touch screen is to build two transparent coatings in the x-axis and y-axis directions, with the x-plane resistance formed by the x+ and x- ends on the x-axis, and the y+, y-, and the y-plane resistance formed at the end is combined into a switch with more functions using a thin-film key switch. When a certain point of the transparent touch panel is pressed, the contact points of the two-layer resistance at this time are transferred to the electrodes at the four ends. The formed resistance is changed to determine the position, and the electronic controller detects the relative position of the force point or a preset electronic function that should be made. This transparency can be widely used in various control panels to save space occupied by the control keyboard and increase a product's convenience [4] .

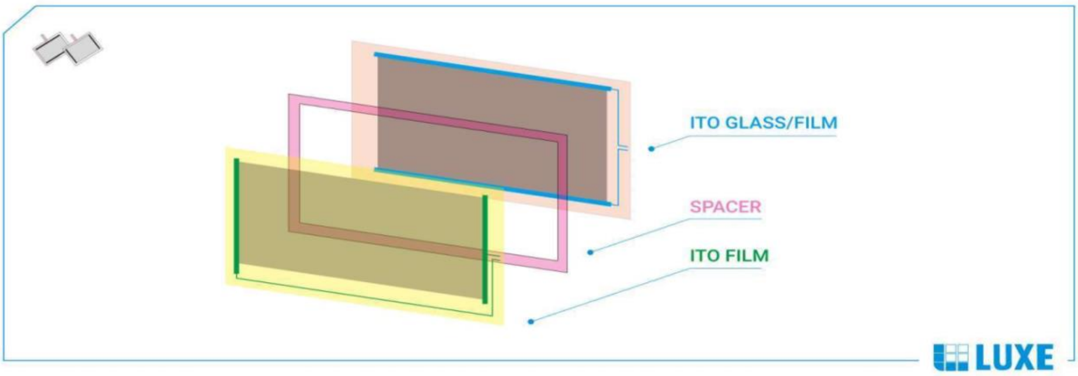


Figure 1.4 – Mode Of Operation Of Touch Screen

The above the figure shows the mode of such scratch resistance operation mechanism and what they consist in a test touch screen specimen[25] .

1.5 Uv light protection air craft mirrors wind screens and pilot vision

Optical radiation can have acute and chronic effects on the tissues of the eye, especially if exposure levels exceed normal repair capabilities, The aircraft's windshield (i.e., windscreen) is the first line of defense for protecting the pilot's ability to see what is happening outside the aircraft. A windscreen must be sturdy enough to deflect the environmental elements (wind, rain, sleet, snow, and hail) and sustain the occasional impact from airborne debris, including bird strikes, while maintaining a high level of transparency over the entire visible spectrum of light. How well a windscreen performs can affect the pilot's ability to maintain proper spatial orientation and avoid obstacles, such as changing terrain, adverse weather conditions, and other aircraft traffic, as well as to safely navigate taxiways around airports.

As the intensity of ultraviolet (UV) radiation increases every year, effective methods to block UV rays to protect pilot skin, plastics, timber and other polymer materials are urgently sought. UV radiation can also cause severe damage in textiles, plastics, paints and timber products in the forms of discoloration, chalking and reduced mechanical properties. Therefore, the development of effective UV-shielding materials is of great importance to our health, society and environment.

The UV-blocking property of a fabric is enhanced when a dye, pigment, delustrant, or ultraviolet absorber finish is present that absorbs ultraviolet radiation and blocks its transmission through a fabric to the skin. Textiles serve as important materials for UV protection in many applications. Nano- TiO2 and ZnOare being applied for UV protection periods. therefore using nanoparticles like titania or zinc oxide improve UV resistance property by not only absorbing but also reflecting those harmful rays. Also, they are not easily destroyed by UV rays and hence can increase the life span and weather resistance of paints.

The effective transmittance of the wind-screen in each of these spectral bands may be determined by calculating the ratio of the total radiant or luminous flux transmitted by the material to the incident flux. A high ratio indicates that incident radiation is transmitted efficiently through the windscreen, while a low ratio denotes substantial attenuation. Optical radiation can also be divided into two general regions with respect to their potential for eye damage: the retinal hazard region and the non-retinal hazard region. The wavelengths of the retinal hazard region include vis-ible light (380-780 nm) and near IR (780-1400 nm), or IR-A radiation. The retinal hazard region identifies those wavelengths that are transmitted through the optical me-dia of the eye (cornea, aqueous humor, crystalline lens, and vitreous humor) and focused onto the retina.

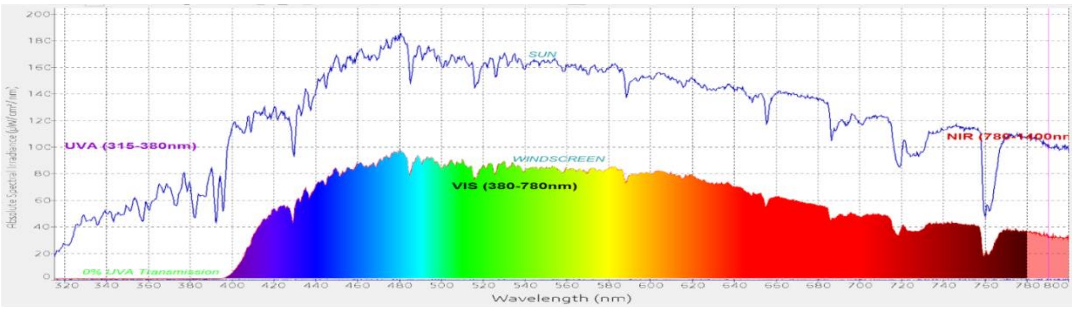


Figure 1.5 – Aircraft Windscreen UV

In another word TiO2, ZnO, SiO2 and Al2O3 particles provide extended protection in semi-transparent stains and provides long-term protection from harmful UV radiation in harsh environments.

In addition, the UV absorbers provide long-term gloss retention and color fastness keeping damaging UV radiation away from the polymer or paint layer that they are protecting and will not impart color change [1, 5, 26] .

1.6 Air craft windows protection aginst hire penetration

The airframe of an aircraft can provide some measure of shielding against high-intensity radiated fields (HIRF), but this is compromised by doors, windows, seams, access panels and components interfaced to the airframe such as antennas used for communication and navigation. Composite materials are increasingly used in aeronautical applications due to their relatively light weight.

Therefore an aircraft should be able to protect its sensitive electronic equipment from the harmful effects of radiated fields having intensity up to some thousands of volts per meter in the range of gigahertz A crucial issue concerns the protection against HIRF penetration through the aircraft windows. The hardening for windows can be accomplished by covering them with metallic meshes or films, which are circumferentially bonded to the aircraft conducting skin with a radio frequency (RF) gasket. Metallic meshes in glass or plastic substrate can provide good electromagnetic (EM) shielding (up to 50-60 dB) in the frequency range in which the wavelength is much longer than the grid dimension, even if the transparency in the visible range is generally limited to 50%. The combination of low sheet resistance and high visible light transmission qualifies films for their use to reduce the impact of electromagnetic interferences. Commonly, metallic parts in a laminated aircraft window are also used as electric heating circuits to facilitate the removal of ice and condensation. Sometimes the multilayer structure of an aircraft window is designed to obtain both high optical transmission and infrared radiation rejection. In fact, infrared radiation is generally responsible for heat buildup and for thermal dispersions in a vehicle.

Aircraft windows are typically laminated assemblies including interlayer material plies interposed between transparent rigid plies, which can be glass or any other well known substitute. The thermoplastic transparent interlayer can be a material such as polyvinyl butyral, silicone, or urethane. The semi-tempered glass of the face-ply is subjected to very strong stresses due to pressure, temperature, high speed, foreign object damages, chemical aggression, and impact with hail. The glass should provide very attractive performances in terms of transparency, durability, and thermal-mechanical characteristics.

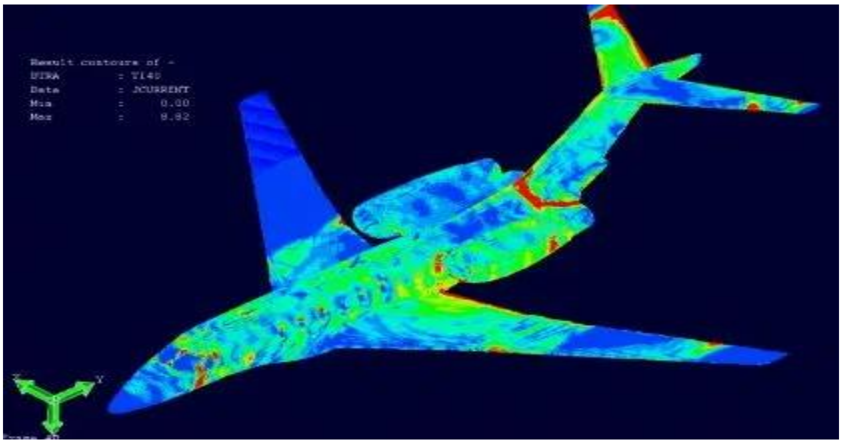


Figure 1.6 – Visual Presentation Of HIRE

The interactions of the HIRF fields with the aircraft can be visualized as color-coded contours, as in this figure. The warmer colors indicate higher field intensities, while cooler colors represent lower field intensities [5, 7] .

1.7 Protective coating for electronic devices

Electronic devices have undergone a revolution in size, performance and portability. From consumer devices like smartphones, tablets and wearables to specialized industrial technology such as automation controls, electronics are everywhere — including in many challenging environments. Without adequate electronic protection, components inside devices can suffer corrosion when exposed to contaminants. This degrades electronic performance and may lead to electrical shorts and device failure. At the same time, smaller, more complex, dense printed circuit boards (PCBs) with high-performance components, LEDs and a variety of miniaturized components are placing higher demands on electronic protection coatings. Coatings offer protection against corrosion for the sensitive internal components of devices and are ultra-thin compared with traditional conformal coatings improving electronic grade coatings to help guard against moisture, water/salt water immersion, sulfur, oils, humidity and pollution. These offer ease of application, reworkability.

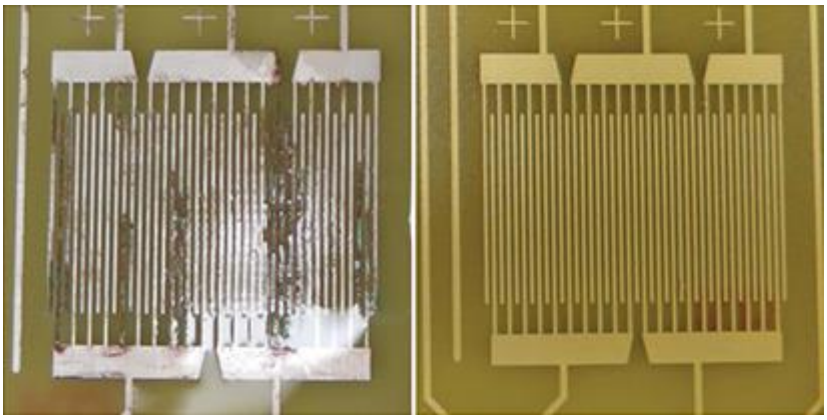


Figure 1.7 – Electronic corrosion protection

Coatingshave been proven effective against corrosion through extensive testing, as seen in these images showing untreated and treated circuitry that has been exposed to salt fog. They provide a uniform oleophobic and hydrophobic layer that helps cover surfaces of a component for exceptional repellency of moisture, oils, dirt, grime, fingerprints and other environmental contaminants. Count on Novec coatings to help provide excellent protection against corrosive agents that devices might encounter, including:

-Moisture;

- Water;

- Salt fog or mist;

- Sulfur.

In order words the spacecraft are subject to a range of environmental electromagnetic effects such as lightning strikes, electromagnetic pulses (EMP) and high-intensity radiated fields (HIRF), which can pose a risk to the safe performance of avionics. Shielding can mitigate these risks and protect electronic systems. However, shielding effectiveness may be compromised by aperture leakage or diffusion, allowing fields to penetrate.

This means that when developing shielding, the aircraft engineer has to balance several contradictory design requirements. In the name of weight reduction, material use should be minimized, but making shields thinner can increase leakage. This is made more complex by the increasing use of lightweight composite materials in the airframe, which have different electromagnetic properties to the conventionally used metals, and by the need to include doors, windows and cables in the aircraft In modern aircraft, flight controls that once were operated manually via cables and hydraulics are increasingly being replaced by digital electronics. Because of weight and maintenance advantages over conventional hydraulic controls, future commercial aircraft are envisioned as "all-electronic." Some aircraft, notably the F-117A Stealth Fighter, are designed near the edge of aerodynamic stability and even depend on computer-assisted controls to stay in the air. In this world of digital fly-by-wire (or light) avionics, computerized controls, smart actuators, and other "black boxes", the potential susceptibility of flight-critical systems to external radio frequency interference is a real concern.

That is why it is very important to protect those devices from HIRF, and develop the techniques and methods for assessing the effects of High Intensity Radiated Fields (HIRF) on the survivability of commercial aircraft digital electronic devices [8, 9] .

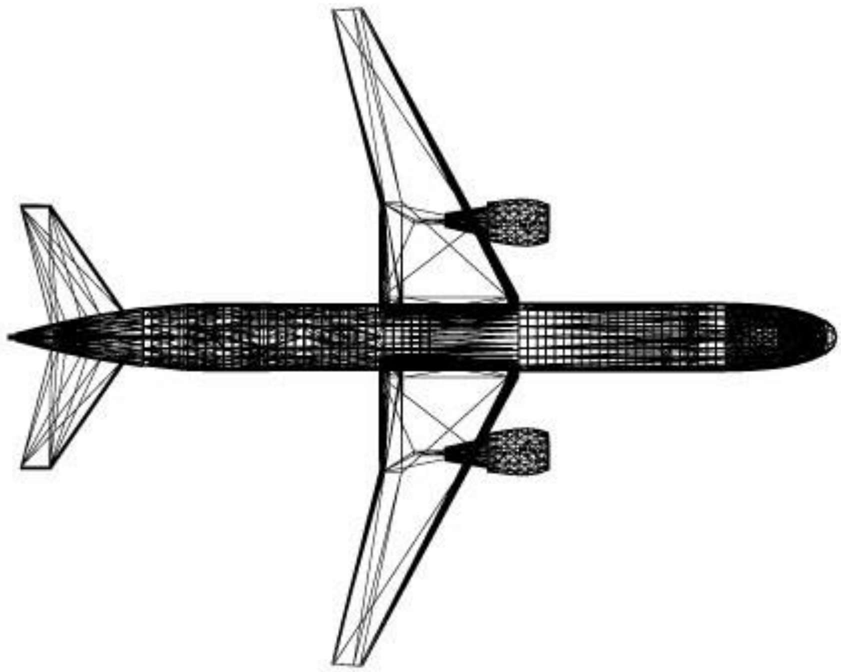


Figure 1.7b – Protective Materials On Aircraft Body

Electronic devices have undergone a revolution in size, performance and portability. From consumer devices like smartphones, tablets and wearables to specialized industrial technology such as automation controls, electronics are everywhere — including in many challenging environments. Without adequate electronic protection, components inside devices can suffer corrosion when exposed to contaminants.[27] .

1.8 Resisting, abrasion damage, for metal corrosion Protection

Landing gear. Landing gear is prone to corrosion when impact or wear therefore applying coating damages the surface over existing surface treatments/coatings to provide extended service, corrosion is triggered by environmental factors, such as oxygen and water, which cannot be eliminated. It is possible, however, to prevent corrosion, and nanocoatingsare important as they can shift the focus of the problem from the protection against corrosion to its prevention.

Protective coatings incorporating nanoparticles have been developed as industrial protective coatings, corrosion protection coatings, thermal resistant, fire retardant coatings, and water based anti-corrosion coatings and fire retardant polymers. Nanocoatings can significantly increase the cost/benefit ratio, providing cost effective solutions and improved performances. Nanoparticles such as nano silica, clay, ZnO, Fe2O3 and TiO2 are typically used in organic coatings for improving corrosion resistance. These nanomaterials have a very high surface area. When this surface is functionalized, it can deliver high loadings of organic corrosion inhibitors. Thus, tailored nanoparticles are the perfect carrier for delivery of the needed level of active corrosion inhibitors. Nanomaterials engineering also extend the possibility of engineering ‘smart’ coatings that can release corrosion inhibitors on demand when the coating is breached, stressed or an electrical or mechanical control signal is applied to the coating.

• Corrosion resistance is essential for metals used in a wide range of applications. Sectors that require the use of anticorrosive coatings include: Oil and Gas, Shipping and Shipyard sector, Energy, Infrastructures, Rolling Stock, Lifting equipment, Port machinery and th Lighting sector

• Current naval ships utilize a protective coating system that consists of separate primer and topcoat films, both individually applied. This practice contributes significantly to the spacecraft constructions, and cost. The affordability of the coating process could be improved if a one-coat, direct-to-metal coating could be used instead.

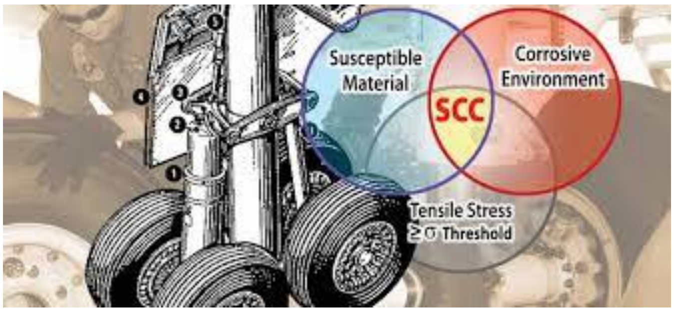


Figure 1.8 – Landing Gear corrosive parts

The figure above show area of the langing gear which is easily exposed to corrosion in volving in different environment forms.

Engines and exhaust system: thermal protection shields, and structures for ultra-high-speed flying objects. Ceramics and ceramic matrix composites that can withstand temperatures as high as 1,600°C are used to manufacture lightweight turbine components that require less cooling air, such as vanes, blades, nozzles, and combustion liners, and parts for the exhaust system that enhance acoustic attenuation and have a long life thanks to their abrasion and corrosion resistance.

Therefore abrasion resistance coating dramatically enhances wear-resistance properties Nanocoatings also significantly improve other properties such as toughness and thermal shock resistance of the intended surface for a variety of conventional materials such as ceramics, composites and metal alloys. Nanocoatings display a lower wear rate than their counterparts of commercial coarse-grained powders.This improvement in wear resistance is attributed to the high hardness and toughness of the nanomaterials, and the change of fracture and material-removal due to ultrafine particle size.multilayer coatings, which consist of alternating layers of materials, further improve the performance of single-layer nanostructured coatings. When properly tailored, nano-multilayer coatings produce super hardness and super modulus effects.

In the engineering point of view composite materials at the nanometer scale it is possible to obtain super hard materials that rival diamond in performance. In machining and wear resistant applications hard coating are essential for enhancing the wear resistance and toughness properties of cutting tools. Conventional coatings do not meet the needs of current machining and manufacturing requirements as well as nanocoatings another principle of such coating is the Nanoscale structuring using nano size grains and nanolayers helps in preventing/pinning dislocations, thereby dramatically enhancing wear-resistance properties, Nano coatings also significantly improve other properties such as toughness and thermal shock resistance of the intended surface for a variety of conventional materials such as ceramics, composites and metal alloys.

Figure 1.8b – Thermal Protection Shield Image

Aircraft canopie: The aircraft canopies must be durable transparent with very low surface energy and excellent abrasion resistance Approach:

-Tailored self assembled surface morphology;

-Surface active components impart low surface energy;

-Tough, flexible, transparent sol gel binder and hail erosion resistance.

Definite measures must be taken to increase the reliability of canopies, especially for large parts with complicated shapes, of maneuverable aircraft. We consider it necessary to state our considerations for some of them, including in terms of the prospects for the application of different parts. So to say the prospects for using organic glasses, including for large transparencies of canopies in existing maneuverable aircraft and aircraft of the near future, are associated with the possibility of developing glasses with the following properties:

– thermal tolerance no lower than Tsoft160°C;

– CLTE <90 10 – 6 K – 1 In the entire range of working temperatures, including above Tsoft ;

– development of means for securing glass blocks in the framework that eliminate bending loads on the edges of the glass blocks. Hence the aircraft canopies from the standpoint of strength under different sources of loading and the possibility of increasing their strength reliability. And in order to achieve this we examine some upgrade of multi-layer parts made from polycarbonate and organic glass as well as multi-layer parts made.(The advantages of organic glass are well-known: low mass, possibility of fabricating large parts with complicated shapes, weak reaction to framework deformation, very low stresses (up to 3 MPa) from excess pressure, and others). from silicate glass, organic triplex and heterogeneous parts as well as the primary sources of loading of parts.

*Aircraft brakes***:** The aircraft break is a very important aspect also and during an emergency operation. The break must be able to function properly and Large aircraft with power brakes require anti-skid systems. It is not possible to immediately ascertain in the flight deck when a wheel stops rotating and begins to skid, especially in aircraft with multiple-wheel main landing gear assemblies. A skid not corrected can quickly lead to a tire blowout, possible damage to the aircraft, and control of the aircraft may be lost.

Over head storage bins and radomes: Durable, high performance adhesives, sealants, coatings offer reliable, cost effective solutions for the assembly/repair of exterior/interior aircraft components. in order to join dissimilar substrates such as thermosetting/thermoplastic composites, titanium, aluminum. This has contributed to designs that save weight, reduce fuel consumption, increase range/payload capacity, lessen noise and enhance safety. For both small and large aircraft this has resulted in improved profitability and for passengers an upgraded flying experience. In terms of fuel linkage the adhesives sealant has a very high in sealing hole and this can be very useful in the aircraft engines.

Protection of life is a very important aspect, we consider in aviation in aircraft door need to be well-seal and fix in order to avoid any form of incident which can lead to accident and then lost of lives and properties, so adhesives sealant coating play a very important role in the sealing of door, and and storage bin, to be in a fix position and well placed and secured lock position.

They can also be applied in Galleys, Lavatories, Landing gear doors Floor panels in order to prevent degradation and wear under high-stress conditions.

Moisture-absorbing: The most phenomenon concerning cold surfaces which are subjected to a warmer, more humid atmosphere is condensation in the form of water droplets (fogging) or even ice crystals (icing). Leaving the transparent mirror and aircraft doors becomes opaque because light is scattered by the droplets or crystals. And it will impair the usability of aircraft mirrors, having an enhanced anti-fogging/icing coating which overcomes the problem of fogging and icing by being able to absorb the condensing water and preventing it from crystallizing. On the aircraft mirrors Fogging or icing of transparent surfaces is undesirable because it results in opacity, preventing light from passing through the material. When a surface that is cooled to temperatures below the melting point of water comes into contact with a warmer, more humid atmosphere, the application of a hydrophilic cross-linked coating can prevent fogging as well as icing. Such a coating, in our case mainly consisting of the hydrophilic polymer PVP, absorbs the condensing water. Therefore, the formation of superficial droplets that cause fogging is inhibited. Ice crystals are prevented from forming as well, owing to interactions between the water molecules and the hydrophilic polymer [1,10, 11 28] .

Conclusion to part 1

Airplane are highly scientific sophisticated machines which requires the expertise of hundreds of engineers and scientists working in close harmony in order design and produce a successful product. However, a close examination of high and performance and the transparencies Coating used in aircraft in order to enhance a more better and durable performance, protections of parts were be analyzied and the areas they may include the few listed below:

-Poor optical design for the materials and geometry selected;

-Lack of bird impact/environmental impact or conditions protection;

-Poor removal/replacement features (supportability)/ poor pilot vision/poor abrasion system on parts.etc.

A crucial issue concerns the protection against HIRF penetration through the aircraft windows, also hardening for windows can be accomplished by covering them with metallic meshes or films, which are circumferentially bonded to the aircraft conducting skin with a radio frequency (RF) gasket. Metallic meshes in glass or plastic substrate can provide good electromagnetic (EM) shielding (up to 50-60 dB),aircraft windows are also used as electric heating circuits to facilitate the removal of ice and condensation. Sometimes the multilayer structure of an aircraft window is designed to obtain both high optical transmission and infrared.

In general we can say that it is of a very big Importance to know the advantage of using transparent coating in aviation and in what area they are used, and what they protect against .

PART 2

METHODS USED IN THE THICKNESS DETERMINATION OF TRANSPARENT COATING

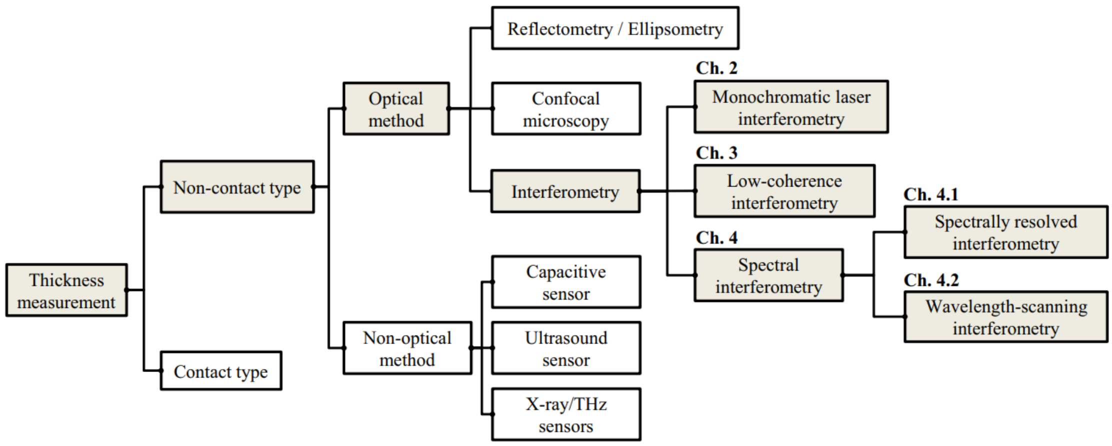
In this section we are going to analyzed how this transparent coating (thickness) used in the advancements and protection of aircraft parts are been measured using different methods of measurement. And before carrying out this or any kind of measurements it is then necessary to know how it can cause structural damage's, change to properties, and other parameter's, to the part it will be used in. paying attention to the type which is more effective without causing any structural damage to the parts when been applied. And not to cause any structural damages to those parts.

When we talk about thickness they are typical parameter related to length, of which measurements are conducted in various fields, such as the aviation, automotive, ship-building, semiconductor, and display industries. Etc Among various measurement techniques, optical interferometry is very attractive in terms of reliability owing to the direct realization of the meter. Moreover, the nature of this non-contact method is such that it does not damage parts used on. In this section, differentmeasurements technique like; optical interferometric methods for measuring thicknesses of thick transparent layers are introduced through a discussion of basic principles and applications. With consideration of optical layouts and analysis methods of interference signals, monochromatic laser interferometry, low coherence interferometry, and spectral interferometry are introduced and will be analyzed.

Due to the increase in the demand for thickness measurements has steadily increased in the semiconductor and display industries. As an example, when fabricating intelligent semiconductor devices, the physical thicknesses of various layers such as substrates and thin films should be monitored and controlled to in other ensure the successful fabrication of structure. In addition, regarding display devices such as organic light-emitting diodes and active-matrix organic light-emitting diodes, the thicknesses of the coating layers should be carefully measured to realize superior image quality levels.Effective and precise to ensure proper function and performance of the coated device.Traditional stylus-based profilomters determine the surface, which may create minor scratches on the delicate and sensitive optical device. Such technique is impossible to measure the thickness of the film that covers the whole coated surface. Surface finish on the both top and bottom surface of the transparent film as well as its thickness and uniformity is critical for produc quality and performace, for instance in CD and DVD Dics production control of the thickness and uniformity of the transparent covers and space layers plays an important role in avoiding focus errors of the laser.to inspection conditions such as the material properties and shapes of samples, the thickness range, and the degree of measurement precision, thickness measurement methods of different types have been proposed and realized to measure thicknesses in different applications. The thickness measurement methods can be simply classified into two types, the contact and non-contact types, as described in

Figure 2

Classification of thickness measurement methods



Different measurement methods have attracted significant amounts of attention due to the practical advantages of non-destructive inspections and damage-free measurements. Non-contact methods are divided into optical methods and non-optical methods. Among optical approaches, reflectometry, ellipsometry , confocal microscopy , and interferometry are representative methods. Both reflectometry and ellipsometry are typical optical means of measuring the thicknesses of thin films below a few µm. But, reflectometry uses the reflectance which is defined as the ratio of the intensity of outgoing wave to the intensity of the incoming wave, while ellipsometry uses changes in the polarization states of reflected light depending on on the optical properties and thicknesses of the thin films. Confocal microscopy, a well-established method, improves vertical and spatial resolutions by detecting only light reflected near the focal point with the help of a pinhole located at the conjugate position of the focal point of the objective lens. By scanning the focal point vertically, the thickness can be determined according to the distance between two peak positions corresponding to interfaces of the sample. In a similar manner, the thickness can also be directly determined by means of the chromatic aberration of the objective lens, as chromatic aberration causes multiple focal points to spread along the optical axis corresponding to the wavelength.

optical methods, non-optical methods such as those involving the use of capacitive sensors ultrasound sensors, and X-ray/THz sensors are useful for optically opaque materials. Capacitive sensors can work only with conductive materials with a thickness range of a few mm to a few tens of mm by detecting capacitancechanges between two electrode plates. For ultrasound sensors, the thickness is determined by detecting the resonance frequency arising when half of the wavelength of an ultrasound wave equals the thickness or by measuring the temporal offset between ultrasound waves reflected from two surfaces of the sample. X-ray and THz sensors can be used for imaging paper, thick metal plates, and ceramics given their unique penetration characteristics.

In order to ensure the reliability of the measured thickness values, measurement methods should be linked to a length standard by a traceability chain and the degree of measurement uncertainty should be discoverable. Unlike the various measurement methods described above, optical interferometry can measure thicknesses with direct traceability to a length standardIn general, optical interferometry methods can be classified according to optical configurations, the characteristics of the light source used, and the methods used to detect interference signals, among other factors [12, 29 30] .

2.1Monochromatic laser interferometry

lightfrom monochromatic light is incident on a transparent plate, an interference signal will be generated by multiple reflections on the front and back surfaces of the platematerilas. A monochromatic laser interferometer measures the thickness value through analysis of this signal Given that the reflectance of a transparent plate is generally low (e.g., the reflectance of uncoated glass is approximately 4%), interference signals for transmissive and reflective configurations can be approximated through simplification via Taylor series approximation, as in Eqs;

$$2I_0T^2 \quad F$$

$$IT \approx (2+F)(1-R)2(1+ 2+F \cos\Phi) \qquad (2.1)$$

Where f is the real function and cos is the angle in fuction and R is variation

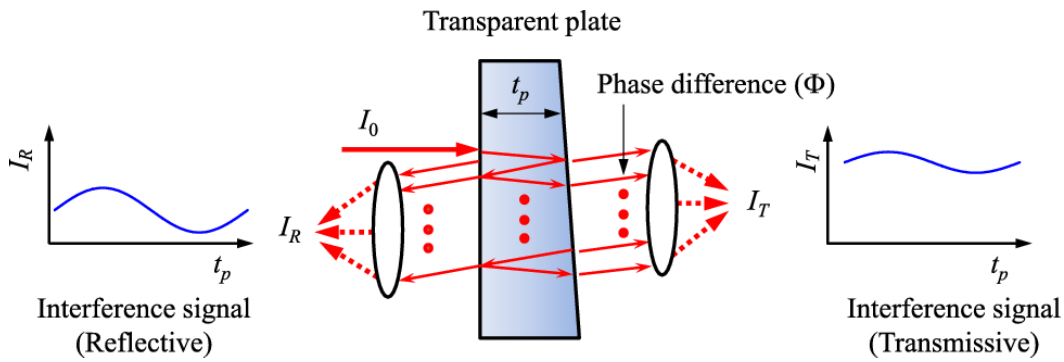


Figure 2.1 – Multiple reflections on both surfaces of a transparent plate generate sinusoidal interference signals of reflected and transmitted beams

The transmissive interference signal usually has a higher offset and lower contrast than the reflected signal=

The nonlinearity error was reduced by applying an elliptical fitting method to these signals in real-time. However, because the phase difference is usually within the ± π range, the variation in the relative thickness could be measured as opposed to the absolute thickness, and the phase value should be unwrapped to restore the accurate thickness variation over the ± π range. Wavelength-scanning lasers and broadband light sources have been used to overcome this limitation.

Multiple-order interference fringes were obtained by rotating a transparent specimen precisely The phase difference Φ(θ) according to the rotation angle θ can be expressed using Eq, and the absolute thickness value can be calculated based on this relationship, where na is the refractive index of air.

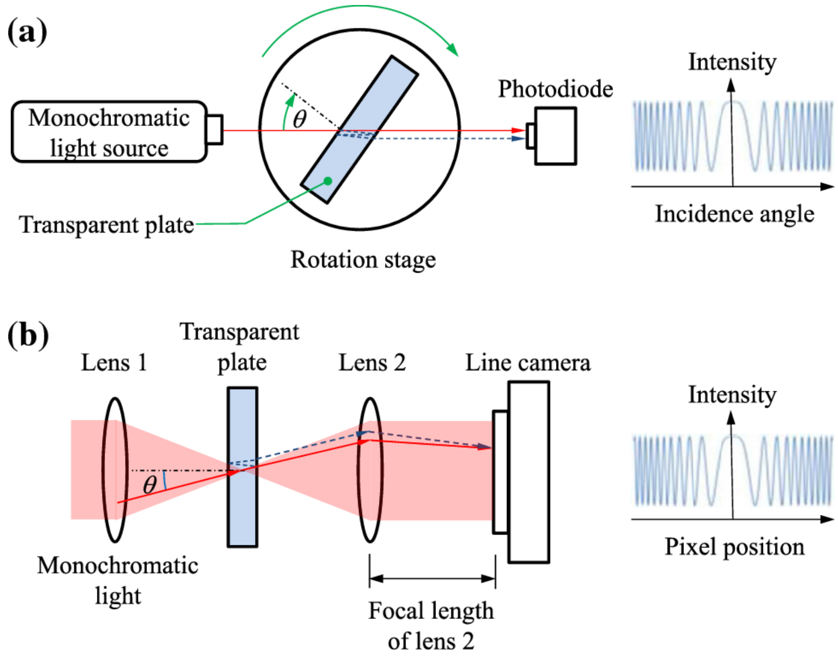


Figure 2.2 – Transmitted intensity variation obtained by rotating a transparent plate and changing the incident angle (a),Haidinger fringe generated by a converging incident beam (b)

2.2 Low coherence interferometry

Low-coherence interferometry (LCI) uses the low temporal coherence characteristics of a light source with a wide spectral bandwidth over a few tens of nm to undertake thickness and surface profile measurements by detecting the peak positions of interference fringes generated only in a localized area. An LCI interference signal can be expressed as the total sum of individual interference signals created at each wavelength from λ1 to λ2 within the wavelength rangeof the light source according to the optical path differenceThe coherence length lc at which the interference signal can be observed is expressed by Eq. (3.2), where c is the speed of light in a vacuum, Δv is the spectral width in the frequency domain, λc is the center wavelength, Δλ is the spectral width in wavelengths [20] .

$$I(z) = \int_{\lambda_1} I_0(\lambda)\left\{1 + \cos\left[\frac{2\pi}{\lambda}z\right]\right\} d\lambda \qquad (2.2)$$

Much research on thickness measurements based on LCI has been performed, ranging from basic studies focused on thickness measurements of optically transparent or opaque materials to advanced studies dealing with simultaneous

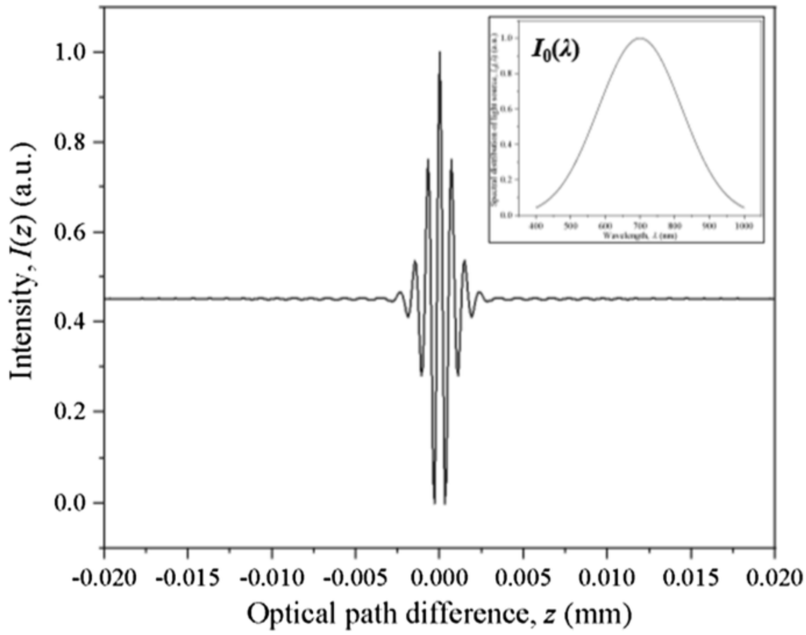


Figure 2.3 – Simulated low-coherence interference signal according to the level of OPD variation

For thickness measurements of opaque materials, a hybrid LCI system combined with another measurement technique has been proposed. Because light cannot penetrate an opaque sample, the thickness measurement must be performed by illuminating both sides of the sample. To do this, a system consisting of a Twyman-Green interferometer and a Sagnac interferometer was proposed, as shown in the below figure First, without a sample, the reference mirror is placed at a certain position which makes the reference arm length L R equal to the test arm length L0, and this position is set as a referenceposition. Second, after inserting the sample into the Sagnac cavity, the interference signals are acquired at two positions, in this case S1, the measurement path length to the front surface, and S2, the measurement path length to the back surface; these are equal to L R while the reference mirror is scanned from the reference position. The physical thickness of the sample can be determined by calculating the difference between the two displacements of D 1 (= L0 − S1) and D2 (= S2 − L0) from the reference position to the interference positions. Similarly, a fiber-based Michelson interferometer was proposed to measure the thickness of an opaque material. The LCI has also been used to measure the refractive index, which is both an optical property of a sample as well as a thickness measurement [21, 22] .

Therefore the LCI measurement system proposed to determine the thickness and refractive index simultaneously

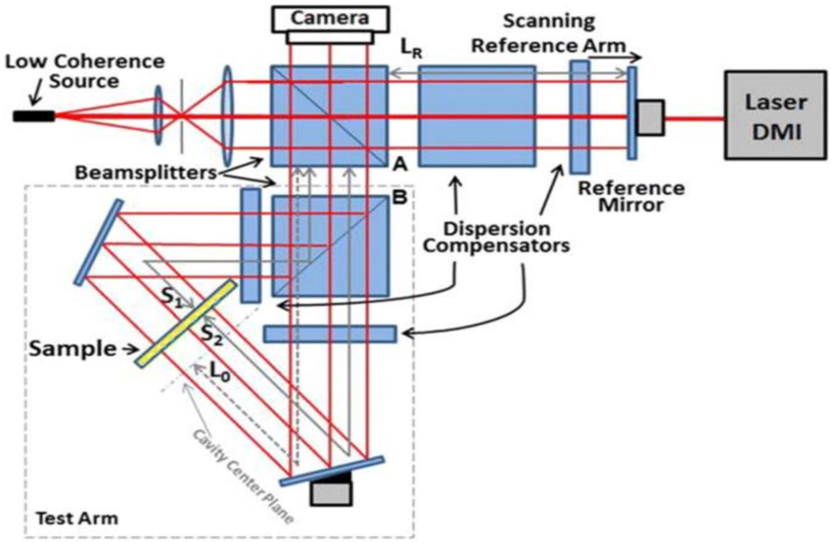


Figure 2.3 – Layout of the low-coherence distance measuring interferometer [Adapted] with permission from [The Optical Society]

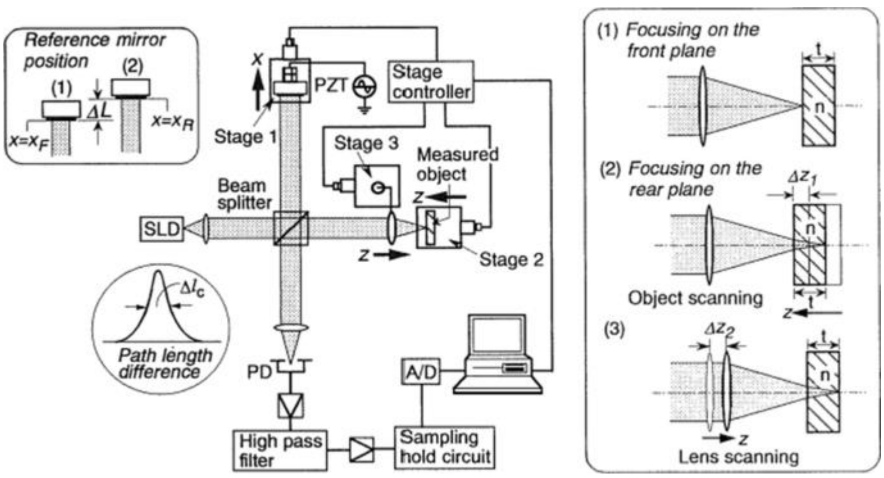


Figure 2.4 –System configuration for simultaneous measurements of the refractive index and thickness of transparent plates. The object and lens scanning methods are schematically shown [Adapted] with permission from [Springer Nature]

The interference signals between a reference beam and two measurement beams reflected from the front and back surfaces through reference mirror scanning, ΔL_1, are measured. Here, Δz_1 can be expressed using the numerical aperture of a focusing lens, ζ, and Snell's law, as indicated in Eq. (3.3), and ΔL_1 is represented by $n{\cdot}t - \Delta z_1$ via the sample displacement, Δz_1, and with the optical thickness of the sample, $n{\cdot}t$. Both t and n can be determined independently through a combination of two equations:

$$\Delta z_1 = \dot{t}\sqrt{\frac{1-\zeta^2}{n^2-\zeta^2}} \tag{2.3}$$

LCI system integrated with a confocal microscope was proposed to measure the thickness and refractive index of individual layers within a multi-layer sample which consists of 13 layers of vertically stacked cover glasses separated by air gaps. In addition, the simultaneous measurement of the phase and group refractive indices realized by placing a sample between two glass plates and using a well-known dispersion formula or polynomial fitting of the refractive index were proposed. As well additionally, an automated thickness measurement system which uses a feedback loopand another system that separates part of the beam path were proposed too. To say that this part of measurement must need An LCI method without a confocal microscope was also proposed for simultaneous measurements of the thickness and group refractive index by detecting shifts of the peak position of the interference signal in the presence of a test material

In Conclusion to this part (LCI) as to expand the measurement range and enhance the thickness measurement resolution. According to Eq. Given adove, a wider spectral bandwidth results in a shorter coherence length but causes a greater dispersion effect due to the long propagation length inside the test material. In other words, an interference signal generated by a measurement beam reflected from the back surface of the sample appears in an asymmetric form due to light propagation in a dispersive medium of it propogation [13 , 31] .

2.3 Spectral interferometry

these Spectral interferometry measures the optical path difference by analyzing an interference spectrum acquired in the wavelength or frequency domainSpectrally resolved interferometry(SRI) measures the OPD by extracting information about the dominant periodic component through the Fourier transform of an interference spectrum acquired within a wide spectral bandwidth. Making SRI is advantageous for high-speed measurements because the OPD can be determined without any additional procedures, unlike conventional monochromatic laser interferometry. Equation is used to determine the intensity I(f) of the interference spectrum at the OPD of L.

Optical interferometry can inherently measure only the optical thickness, which means that the refractive index of the material should be known in advance or measured using another measurement technique to determine the physical thickness. However, in studies of thickness measurements using SRI, various measurement methods have been proposed to measure the thickness and refractive index simultaneously in real time.

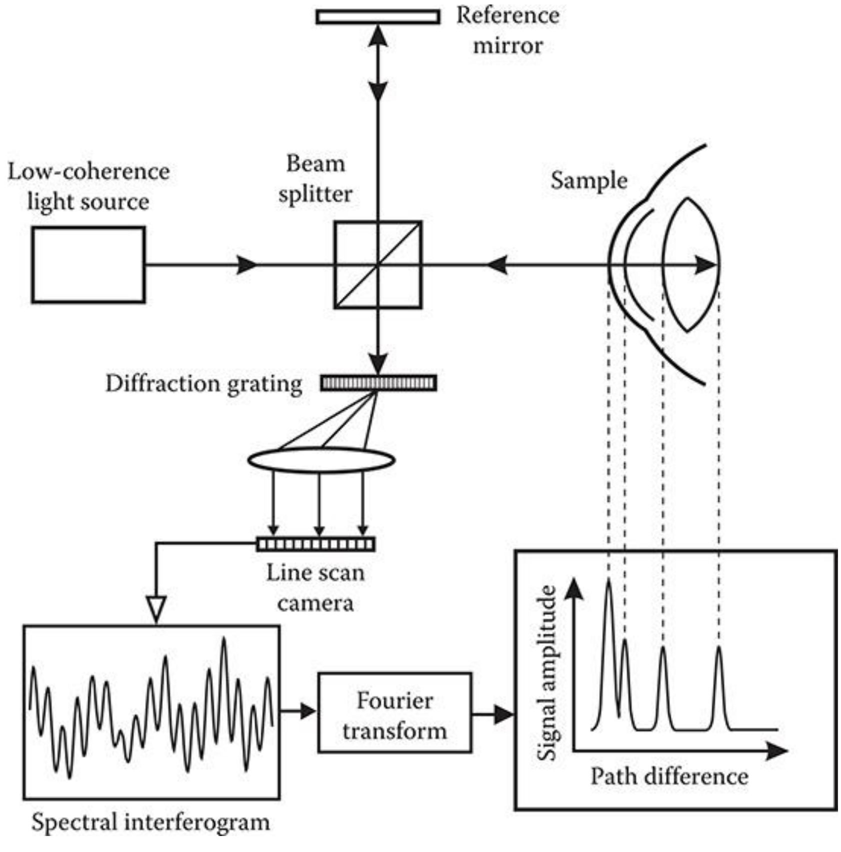


Figure 2.5 –Optical configuration of a Michelson-type spectral-domain interferometer

Now going to analysis the non-optical methods and will compare with the mention optical-methods [12,14] .

2.4 The principle of capacitive sensor

When we talk about capacitor sensorthe main area of it,fuction is the ability produce an electrostatic field instead of an electromagnetic field. Capacitive proximity switches will sense metal as well as nonmetallic materials such as paper, glass, liquids, and clothinother word Capacitive sensors are widely used in industry and science for measuring and control of variety of non-electrical quantities. Their operational principle is based on the sensor's capacitance changes in response to variations of the measuring quantity. These sensors find many different applications spread from moisture and humidity measurement to level, pressure and displacement measurement. They are using different operational and sensing principles to measure different quantities and even it is possible to use variety of principles to measure one and the same quantity.

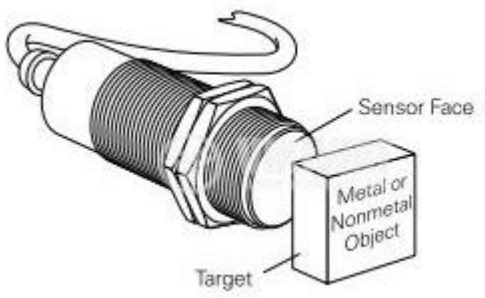


Figure 2.6 – Capacitive proximity switches

Sensing surface of a capacitive sensor is formed by two concentrically shaped metal electrodes of an unwound capacitor. When an object nears the sensing surface it enters the electrostatic field of the electrodes and changes the capacitance in an oscillator circuit. As a result, the oscillator begins oscillating. The trigger circuit reads the oscillator's amplitude and when it reaches a specific level the output state of the sensor changes. As the target moves away from the sensor the oscillator's amplitude decreases, switching the sensor output back to its original state [12, 15] .

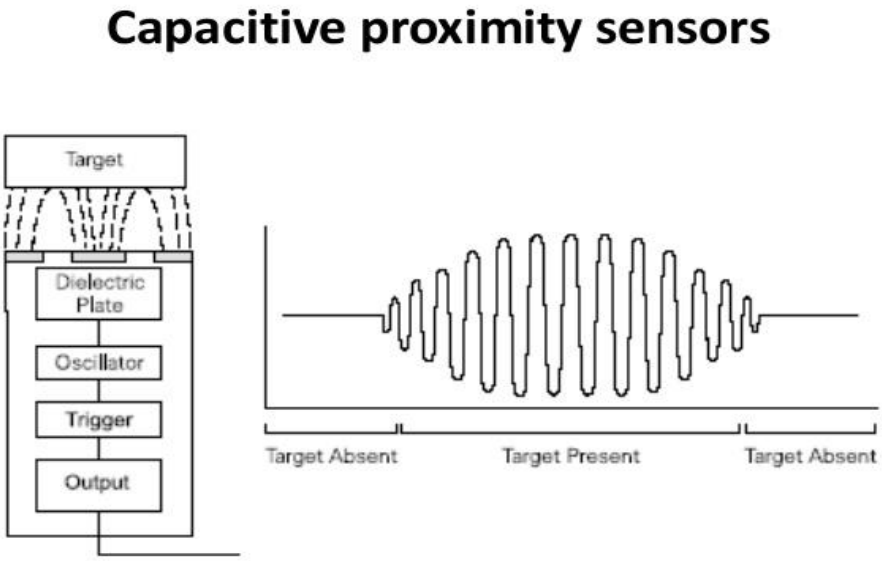


Figure 2.7 – Capacity Proximity Sensors

Standard targets are specified for each capacitive sensor. The standard target is usually defined as metal and/or water. Capacitive sensors depend on the dielectric constant of the target. The larger the dielectric number of a material the easier it is to detect. The following graph shows the relationship of the dielectric constant of a target and the sensor's ability to detect the material based on the rated sensing distance.

Shielded Capacitive sensors will detect conductive material such as copper, aluminum, or conductive fluids, and nonconductive material such as glass, plastic, cloth, and paper. Shielded sensors can be flush-mounted without adversely affecting their sensing characteristics. Care must be taken to ensure that this type of sensor is used in a dry environment. Liquid on the sensing surface could cause the sensor to operate

In other words capacity sensors operational principle is based on the sensor's capacitance changes in response to variations of the measuring quantity. These sensors find many different applications spread from moisture and humidity measurement to level, pressure and displacement measurement. They are using different operational and sensing principles to measure different quantities and even it is possible to use variety of principles to measure one and the same quantity.

Below are some the disadvantages of Capacitive sensor:

➡It is very much sensitive to changes in environmental conditions such as temperature, humidity etc. This will affect the performance.

➡The measurement of capacitance is hard compare to measurement of resistance.

➡Capacitive proximity sensor are not so accurate compare to inductive sensor type.

2.5 Principle of ultrasound sensor

This kind of principle is base on emit short, high-frequency sound pulses at regular intervals. If they strike an object, then they are reflected back as echo signals to the sensor, which itself computes the distance to the target based on the time-span between emitting the signal and receiving the echo. In other word Ultrasonic proximity sensors use a transducer to send and receive high frequency sound signals. When a target enters the beam the sound is reflected back to the switch, causing it to energize or deenergize the output circuit.

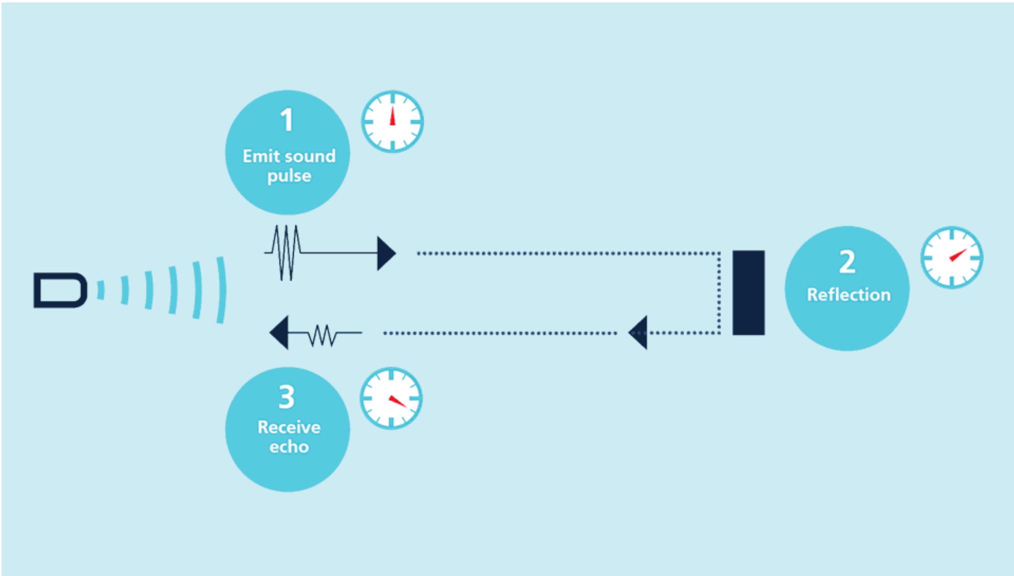


Figure 2.8 –Ultrasonic principle

As the distance to an object is determined by measuring the time of flight and not by the intensity of the sound, ultrasonic sensors are excellent at suppressing background interference.Virtually all materials which reflect sound can be detected, regardless of their colour. Even transparent materials or thin foils represent no problem for an ultrasonic sensor.

A piezoelectric ceramic disk is mounted in the sensor surface. It can transmit and receive high-frequency pulses. A highfrequency voltage is applied to the disk, causing it to vibrate at the same frequency. The vibrating disk produces high-frequency sound waves. When transmitted pulses strike a sound-reflecting object, echoes are produced. The duration of the reflected pulse is evaluated at the transducer. When the target enters the preset operating range, the output of the switch changes state. When the target leaves the preset operating range, the output returns to its original state.

Ultrasonic sensors can see through dust-laden air and ink mists. Even thin deposits on the sensor membrane do not impair its function.

Sensors with a blind zone of only 20 mm and an extremely thin beam spread are making entirely new applications possible today: Fill level measurement in wells of microtiter plates and test tubes, as well as the detection of small bottles in the packaging industry, can be implemented with ease. Even thin wires are reliably detected. Also the ultrasonic sensor can convert electrical energy into acoustic waves and vice versa. The acoustic wave signal is an ultrasonic wave traveling at a frequency above 18kHz. The famous HC SR04 ultrasonic sensor generates ultrasonic waves at 40kHz frequency.

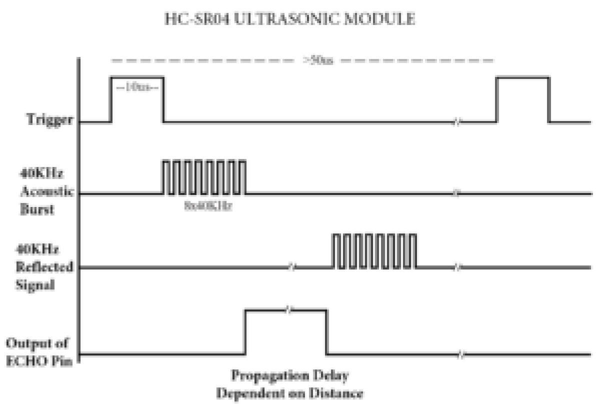


Figure 2.9 – Representation of trigger signal, acoustic bursts, reflected signal and output of echo pin. (Source: HC-SR04 User Guide)

Unmanned aerial vehicles (UAVs)—or drones—commonly use ultrasonic sensors for monitoring any objects in the UAV’s path and distance from the ground

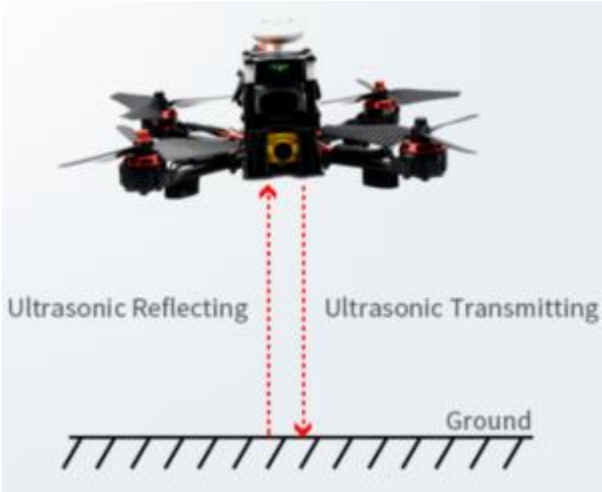


Figure 2.10 – Ultrasonic sensor measuring height during drone’s flight

The autonomous feature of detecting safe distances enables the aircraft to avoid crashing. And as the flight of path changes instantaneously, the ultrasonic detection of distances can prenvent a drone from crashing

Figure 2.11 – Ultrasonic sensor measuring distance from object during drone’s flight

2.6 Limitations of ultrasonic sensors

Below are some of the limitations of this kind of measurement methods:

1. Ultrasonic sensors such as the HC-SR04 can efficiently measure distances up to 400 cm with a slight tolerance of 3 mm. [xiii] However, if a target object is positioned such that the ultrasonic signal is deflected away rather than reflected back to the ultrasonic sensor, the calculated distance can be incorrect. In some cases, the target object is so small that the reflected ultrasonic signal is insufficient for detection, and the distance cannot be measured correctly.

2. Some materials objects like fabric and carpet can absorb acoustic signals. If the signal is absorbed in the target object's end, it cannot reflect back to the sensor, and hence, the distance cannot be measured.

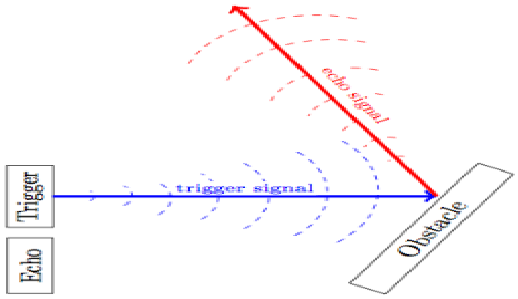


Figure 2.12 – Representation of ultrasonic signal deflected

Intense sensitivity of ultrasonic sensors makes them efficient, but that sensitivity can also cause problems. Ultrasonic sensors can detect false signals coming from the airwaves disturbed by an air conditioning system and a pulse coming from a ceiling fan, for instance

Ultrasonic sensors can detect objects placed within their range, but they cannot distinguish between different shapes and sizes. However, one can overcome this limitation can by using two sensors instead of just one sensor. One can install both sensors a distance away from each other, or they can be adjacent. By observing the overlapped shaded region, one can get a better idea of the shape and size of the target object [12,16] .

Conclusion to the Part 2

In this sections was center on the methods of thickness measurements of a transparent coating materials, on how they can be measured using different methods of measurement. And before carrying out this or any kind of measurements it is then necessary to know how it can cause structural damage's, change to properties, and other parameter's, to the part it will be used in. paying attention to the type which is more effective without causing any structural damage to the parts when been applied. And not to cause any structural damages to those parts.

After a some comparisons between those methods mention listed above and break down of their operational principle and also with some test materials was then chose the best method which is base on white light interferometry, due to the fact the this method has partically no any form of structural damage when been used, and its can also its measurement has no form of limitations in terms of applications and result. The nonlinearity error was reduced by applying an elliptical fitting method to these signals in real-time. However, because the phase difference is usually within the $\pm\ \pi$ range, the variation in the relative thickness could be measured as opposed to the absolute thickness, and the phase value should be unwrapped to restore the accurate thickness variation over the $\pm\ \pi$ range. Wavelength-scanning lasers and broadband light sources have been used to overcome this limitation.

At the end of this section we were able to see the advantage of the principle of white interferometry over other methods of transparent thickness measurements and comparing both the optical and non-optical methods seeing their difference and also in principle of their operation, which differ in such aspect like, accuracy, deforming of part used on, while we made analytical comparsion between both the ultrasonic and capacitive senors, Vertically scanning white light interferometry is a non-contact optical method for 3D-profiles of rough and smooth surfaces

PART 3
EXPERIMENTAL MEASUREMENT OF TRANSPARENT COATING THIKNESS

3.1 Principles of interferometry

Interferometry is based on the wave nature of light. The principle of superposition is realized, ie two waves are superimposed on each other in the same place of space and form a new wave with the combined amplitude. In the presence of interference, light energy is redistributed so that in some parts of the screen the total illuminance is greater than the sum of individual illuminances, and in others - less. The main relations that determine the physical basis of interferometry are as follows.

According to wave theory, the light oscillation s at a point in space with coordinate r is described by the equation:

$$s = a\sin\frac{2\pi}{T}\left(t - \frac{r}{v}\right), \qquad (3.1)$$

where a is the amplitude; T - period of oscillation; t is the time and v is the speed of light propagation..

The phase of oscillation is determined by the ratio:

$$\varphi = 2\pi\frac{t - r/v}{T} = 2\pi\frac{vt - r}{\lambda} = 2\pi\frac{L}{\lambda}, \qquad (3.2)$$

Where λ – wavelength, ie the distance covered by the wave surface during the period T ($\lambda = vT$); L – the optical length of the path that light travels over time t ($L = vt - r$).Initial phase $\varphi_0 = 2\pi t/T$is selected at the origin (r=0).

If a beam with a wavelength λ travels different distances L_1 i L_2, and $\Delta = L_1 - L_2$, there is a phase difference, which, according to formula (3.2), is defined as:

$$\delta = \varphi_1 - \varphi_2 = \frac{2\pi\Delta}{\lambda}, \qquad (3.3)$$

For two light fluxes that have the same circular frequency $\omega = 2\pi/T$ and phase difference δ, taking into account expression (2.4), we write:

$$s_1 = a_1 \sin \omega t; \tag{3.4}$$

$$s_2 = a_2 \sin(\omega t + \delta). \tag{3.5}$$

When adding two equally directed oscillations (3.4) and (3.5) there is a resultant oscillation:

$$s = A \sin(\omega t + \gamma)$$

Where:

$$A^2 = a_1^2 + a_2^2 + 2a_1 a_2 \cos\delta; \tag{3.6}$$

$$tg\gamma = \frac{a_2 \sin\delta}{a_1 + a_2 \cos\delta} \quad ,(3.7)$$

Given that the intensity of oscillation I is equal to the square of the amplitude ($I = a^2$),the intensity of the resulting oscillation I, in accordance with (2.6), will be determined by the ratio:

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\delta \;, \tag{3.8}$$

Formula (3.8) is one of the main in the theory of two-beam interferometers. From formulas (3.8) and (3.3) it follows that when illuminated by a coherent source, the value of I takes the maximum valueI_{max}at$\delta=0;\ \pm 2\pi;\ \pm 4\pi;\ldots$,or at$\Delta=0;\ \Delta=\pm\lambda;\Delta=\pm\ 2\lambda;\ \ldots$, and minimal at$\delta=\pm\ \pi;\ \pm 3\pi;\ldots$, or $\Delta=\lambda/2;\Delta=\pm\ 3\lambda/2;\ldots$.

Usually at different points of the interference field (on the plane), the phase difference δhas different meanings. The geometric location of the points of the field that lie on the same line and in which the valuesδ oidentical, called the interference band, and the distance*b*between the centers of two adjacent strips - the width of the strip. The transition from one lane to the next corresponds to the changeδ, which is equal to 2π (or Δ,which is equal toλ), regardless of the width of the strips.Thus, the intensity of the resulting oscillation at the point of the interference pattern depends on the phase difference or the optical difference of the stroke in the interferometer.

To obtain interference it is necessary that the phase differenceδ wo compound oscillations remained constant during the observation time. Each elementary light source emits a portion ("train") of waves in a short time, and each new "train" has its initial phase of oscillation. Therefore, the phase difference of the oscillations emitted by different light sources changes chaotically with high speed and there is no interference. In interferometers, the beam emitting the light source is separated first, and then they are connected, which maintains a constant phase difference between the two oscillations, ie these oscillations are coherent .Consider in more detail the principle of operation of the Linnik microinterferometer (Fig. 3.1).

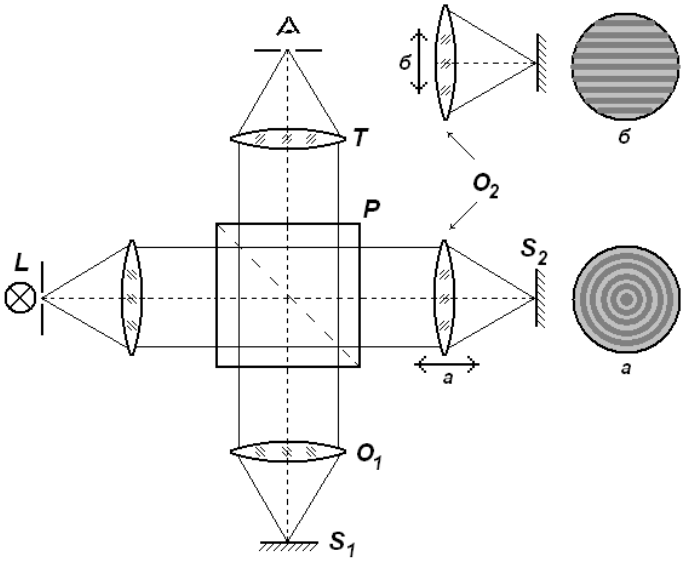


Figure 3.1 – Schematic diagram of Linnik microinterferometer

Object under study S_1 in the form of a mirror and a reference mirror S_2 placed in the focal planes of microobjects O_1 and O_2. In this case, the image of the object and the mirror appear in the focal plane of the telescope T. Mirror S_1 and S_2 perpendicular to the optical axis, the optical lengths of both arms of the interferometer are the same relative to the dividing prism P. At this position of the elements in the interferometer, the stroke difference between any pair of corresponding rays is zero, and in the field of view there is an infinitely wide band of equal slope of zero order (maximum white field). If you move the mirror S_2 along the optical axis, one of the interfering wave fronts will become spherical. In this case, rings of equal thickness (such as Newton's rings) centered about the optical axis will be observed in the field of view of the interferometer (Fig. 3.1a). However, the annular shape of the interference fringes is completely unsuitable for measuring the height of irregularities. To obtain easy-to-measure rectilinear interference fringes, it is necessary to introduce asymmetry into this symmetrical course of the rays, which will not affect the image quality. This is achieved by moving the microlens O_2 perpendicular to the optical axis. Moving does not affect the image quality, as there is a parallel path of rays between the microlens and the telescope. The length of the rays that are parallel to the optical axis will not change either. However, the length of the rays in the inclined beams will change, and between the two corresponding oblique rays there is a difference in the course of light, the magnitude of which will depend on the angle of these rays and the amount of displacement of the microlens. O_2 (Fig. 3.1*б*)

Consider the action of moving the microlens perpendicular to the optical axis of the device (Fig. 3.2). To obtain straight bands of equal inclination, the interferometer must first be calibrated so that the stroke difference for all rays is zero, and an infinitely wide zero-band band is observed in the field of view. The course of the rays in such an interferometer is shown by solid lines in Fig. 3.2

Let's analyze the behavior of rays traveling at an angle$\varphi$to the axis, without shifting the microobject O_2.

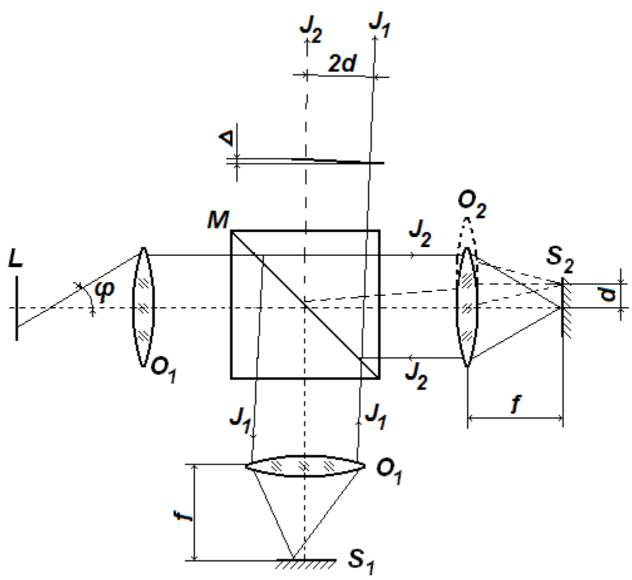


Figure 3.2 – The scheme of the course of the rays when the lens is shifted

From the scheme (Fig.3.2) it is seen that after the separation, the rays J_1 andJ_2converge again on the separator M and no difference between them occurs.The dotted line shows the course of the beam $J_2$when the position of the microobject is shifted$O_2$by magnitude *d*. In this case, the rays J_1, reflected by a mirror S_1,and rays J_2, reflected by a mirror S_2, fter the separator M go parallel to each other at a distance of 2d. They converge in the focal plane of the lens of the telescope T (Fig. 3.1), where they interfere. Since the front of the wave is inclined to the axis of the telescope at an angle φ, the difference between these two rays is equal to:

$$\Delta = 2d\sin\varphi, \tag{3.9}$$

Where d is the amount of displacement of the microlens, φ is the angle of inclination of the rays.

According to formula (3.9), the difference in stroke depends on the amount of displacement of the microlens dand the angle of inclination of the rays φ. When the lens is not offset relative to the axis, ie d = 0, the difference in travel is zero. At constant displacement (*d*=const) the difference in the course of the rays depends only on the angle of incidence φ. Thus, the observed bands are bands of equal slope. The difference in stroke occurs only in the plane of shift of the microlens, so in the field of view there are rectilinear interference fringes oriented perpendicular to the direction of displacement of the microlens. Interference fringes are formed at infinity, the angular size of the interference fringe is equal to $\lambda/2d$.

The number of bands is observed in the field of view of the telescope T (Fig. 3.1) with the angle of view 2a N = 2a/ε. Given that 2a=D/f, where D – diameter of the field of view, and f – focal length of the telescope lens, we obtain the expression for the number of bands:

$$N = \frac{2dD}{\lambda f}, \tag{3.10}$$

From formula (2.10) it follows that the number of bands depends on the amount of shift d microobject and increases with increasing offset. Changing the direction of displacement of microobjects O2 (Fig. 3.2), you can rotate the interference fringes in the desired direction.

In the calibrated interferometer, the interference pattern and the surface of the object under study are observed simultaneously. If there is a bulge or depression on the surface under study, then at this point the difference in stroke changes and the interference fringes are shifted. In interference measurements, the band offset is usually measured visually in fractions of the interval between the bands. It is obvious that the shift of the bands, which is equal to one interval, occurs when the difference in stroke is changed by one wavelength. Let us denote the depth of the depression by H. Then the difference of course ΔH from the depression is equal to ΔH=2H. It gives the placement of interference fringes on p fraction interval. When observed in monochromatic light ΔH = pλObviously, the depth of the depressions H is determined as follows:

$$H = p\frac{\lambda}{2}, \tag{3.11}$$

whereλ – wavelength, p – shift of interference fringes.

The magnitude of the curvature of the interference fringes can be estimated visually. If it is, for example, 10% of the interval between them (p = 0,1), then the smallest height of the inequality, which can be measured visually, is equal to Hmin=0,05λ

If you move the mirror S2 perpendicular to the optical axis on 0,05λ, then the interference fringes will shift relative to the original position by an amount equal to 0.1 of the interval between the bands. Thus, visual observation can determine the depth (height) of the irregularities with an accuracy of approximately 10 nm. However, if the size of the inequality has the same dimensions compared to the width of the strip (1… 5 μm.), Then determine its depth (height) is almost impossible [17] .

3.2 White light as a light source for the interferometer

In the first samples of interference profilometers, monochrome laser light sources were used in surface topography measurements, and interferogram processing methods were based on phase shift algorithms. These methods provide the restoration of the phase of the measuring wave when processing several interferographs obtained by controlled phase shift. Displacement of the reference mirror of the support arm of the interferometer leads to a linear phase shift and displacement of the interference fringes. It is necessary to register the intensity in each pixel of the CCD array with an initial offset, which depends on the surface height. To calculate the phase, it is necessary to measure the intensity in each pixel for at least three different phase steps. To increase the accuracy of measurement, algorithms with more steps are introduced (Table 3.2).

Table 3.2

Algorithms for processing phase-shifted interferograms

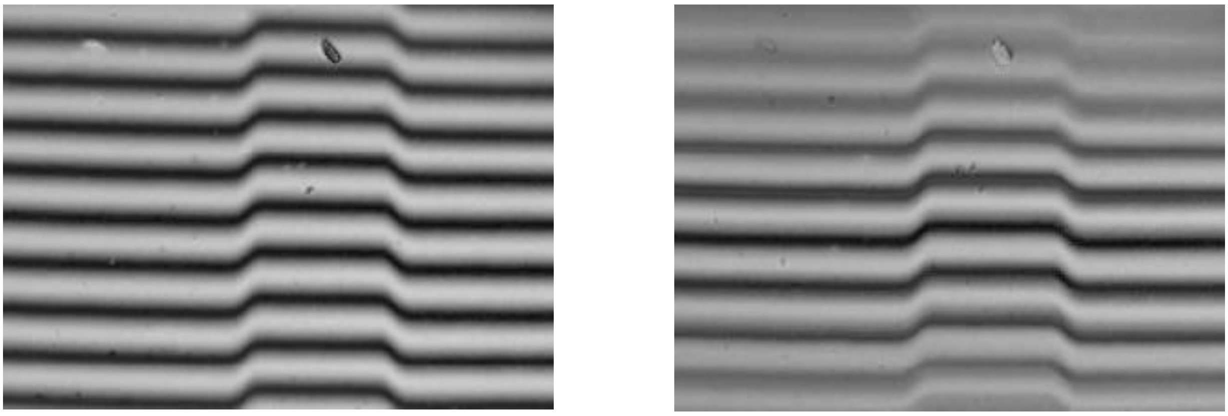
Number of steps	The magnitude of the shift	tg φ
3	π/2	$\frac{I_0 - I_2}{-I_0 + 2I_1 - I_2}$
5	π/2	$\frac{2I_1 - 2I_3}{-I_0 + 2I_2 - I_4}$
7	π/2	$\frac{-I_0 + 7I_2 - 7I_4 + I_6}{-4I_0 + 8I_3 - 4I_5}$

In most algorithms, the transformation is reduced to solving a system of trigonometric equations that relate the intensity of radiation to the value of the phase difference. The signs of the numerator and denominator in the above algorithms are equivalent to the signs of the sine and cosine of the phase sought. That is, analyzing the signs of the numerator and denominator, you can expand the scope of the function from 0 to 2π. Thus, the phase value can be uniquely determined only within 2π and the maximum measured height of the inequality between two adjacent pixels does not exceed the wavelength of the radiation source.

Despite the presence of a large number of phase unfolding algorithms, it can be argued that they are all based on the assumption of no sharp phase differences within the period, ie on the assumption that the wavefront is smooth and the measuring surface has no sharp altitudes.

Thus, the registration of the three-dimensional topography of the surface having height differences above the wavelength of the light source is quite difficult to implement using a laser light source.

When receiving interference in monochrome light, light and dark bands are observed, which do not differ from each other (Fig. 2.4a). When using white light (incandescent lamp or LED) you can see a small number of stripes, one of which (white or black) is easily different from other colored stripes and has a maximum or minimum intensity (Fig. 2.4b).

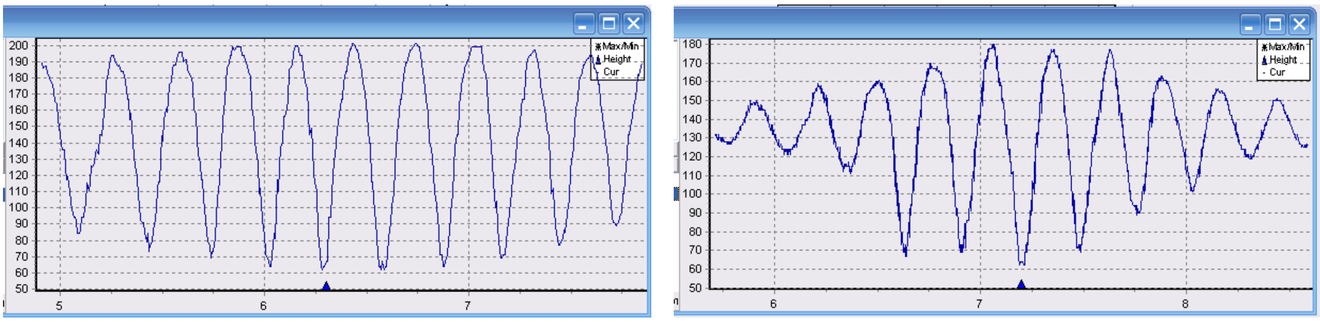


a b

Figure 3.2.16 – Interference pattern in monochromatic (a) and white (b) light

White light is a set of radiation with different wavelengths - from 380 to 750 nm (from purple to red). Each radiation gives its own system of bands that differ in width from the bands of other systems. Thus, in the central achromatic band, the interference order is zero for all wavelengths, and the total zero band is white. The remaining bands have different spectra, which explains the change in color of the border of the bands from red to purple. With the further increase of the difference of the course there is more and more superimposition of strips of different colors on each other, contrast of total strips falls and there is an evenly illuminated site - interference disappears. Thus, on all sides of the central white stripe are symmetrically located two black (almost colorless), and behind them - 4…5 colored stripes of decreasing contrast. Since the coherence length of the white light source is quite small, with a difference of about 3μm, no interference is observed in the white light. This must be taken into account when designing and calibrating the white light interferometer and makes it necessary to equalize the paths of the interfering rays with very high accuracy.

The white light source has low temporal coherence due to the large spectrum width. Therefore, it cannot be considered as a point source. This means that it has low spatial coherence. Thus, when illuminated with white light, the interference fringes are localized in space due to the low spatial and temporal coherence of the illumination. In fig. 2.5 shows the dependences of light intensity on the position of the moving mirror (correlogram), which were registered using a laser source and white light.



a *b*

Figure 3.17 – Interference correlogram in monochromatic (a) and white (b) light

From the presented correlograms it is seen that when using white light on the corelogram there is a point with maximum intensity (Fig. 3.7.5b), which is observed at absolute equality of the interferometer, and when using a laser the signal intensity varies according to sinusoidal law and it is not possible to determine this point (Fig. 3.7.5a)Thus, in white light interferometers, information about the shape of the surface can be determined by scanning the object at depth and determining the maximum intensity, which corresponds to zero difference in light waves and determines the absolute axial position of each point of the surface.The use of a white light source significantly expands the capabilities of the interference profilometer and has the following advantages:

- no noise caused by side, parasitic, interference, as the length of coherence is very short.

- there is no need to determine the order of interference, which significantly expands the possible range of scanning [17] .

3. 3 Experimental measurements

To solve the problem of non-contact measurement of the thickness of the coatings applied to the surface of the glasses, it is proposed to use a non-contact three-dimensional profilometer "Micron-alpha".

Image 3.1 General view of the developed profilometer created based on the microinterferometer

The Micron-alpha profilometer is intended for visualization of a three-dimensional topography of a surface with nanometer resolution on a vertical. The device allows to build the two and three-dimensional image of a surface, to receive quantitative characteristics of a relief of a surface, to calculate parameters of roughness of a surface, to observe interference patterns.The main technical characteristics:

1 Scanning field (X, Y), μm: .1 ..100-2300;

2. Horizontal resolution (X, Y), μm:… .. 0.25;

3. Vertical resolution (Z), nm: ………. (. 5;

4. Maximum measured height (Z), μm: …… 60.

To measure the thickness of the transparent coating, the intensity of the light flux at the selected point is recorded depending on the position of the moving mirror. The first maximum (minimum) of brightness corresponds to the equality of the arms of the interferometer, coinciding with the surface of the coating, and the second, as the mirror moves, with the bottom of the coating. Knowing the sampling step of the moving mirror, you can calculate the distance between the two maxima (minima) and calculate the thickness of the coating. In our case, the sampling step is equal to h = 0.7 nm., We can calculate the distance H between two maxima of intensity H = Nh, where N is the number of mirror steps. This value corresponds to the thickness of the coating

The approbation of the proposed method was performed on protective covers applied to polycarbonate goggles. Measurements were performed on 9 samples. Moreover, in each case, the coatings had a different composition and changes in the application technology. The figure shows some samples

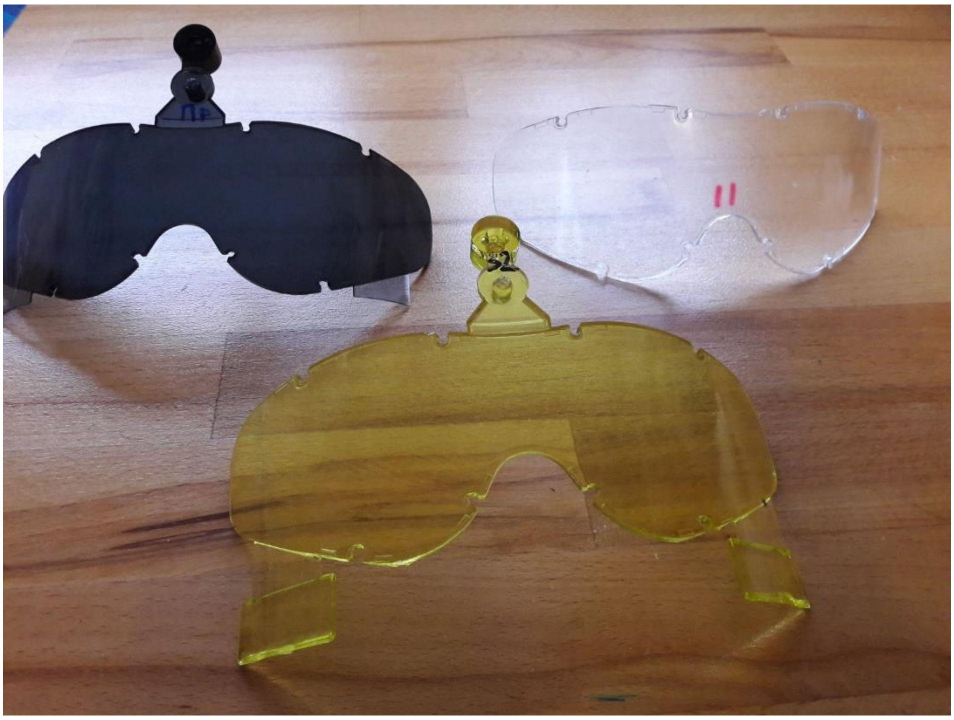


Figure.3.1 Examples of protective transparent coating on military glasses

In figure 3.1 shows a correlogram recorded when measuring the coating applied to the sample №16, the thickness of which is 26 μm.

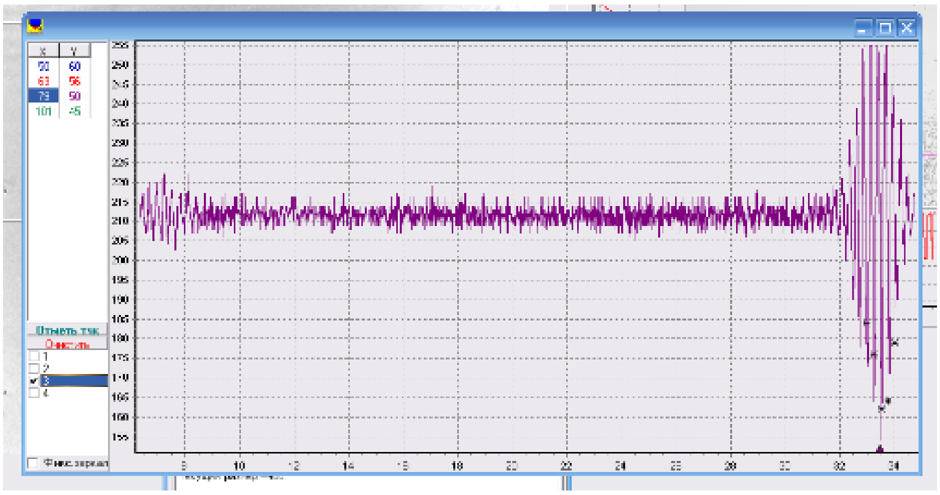


Figure 3.1 Correlogram of the dependence of intensity on the position of the mirror.

In figure 3.1 shows a correlogram recorded when measuring the coating applied to the sample №16, the thickness of which is 26 µm.

Below are the results of measurements of the provided samples, confirming the capabilities of the device.

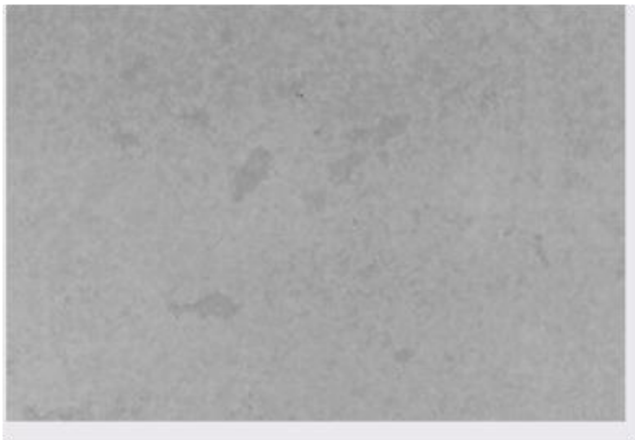
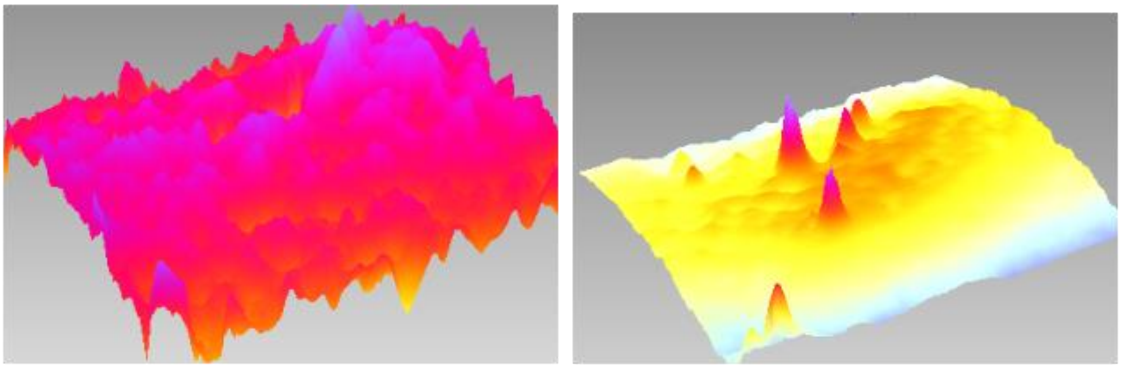
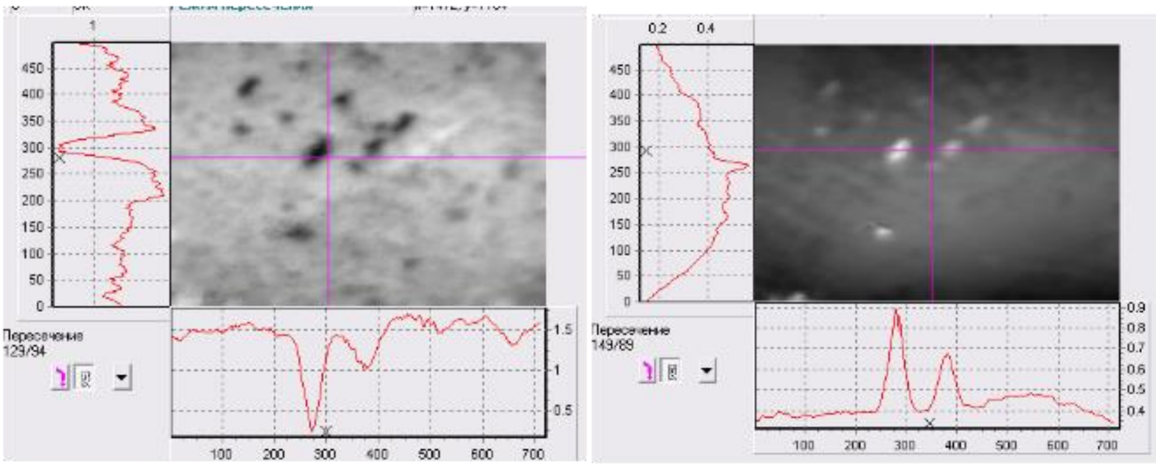


Figure 3.2 Photomicrograph of the surface area with a size of 0.5x0.7 mm sample №16 (spots under the coating).



a) b)

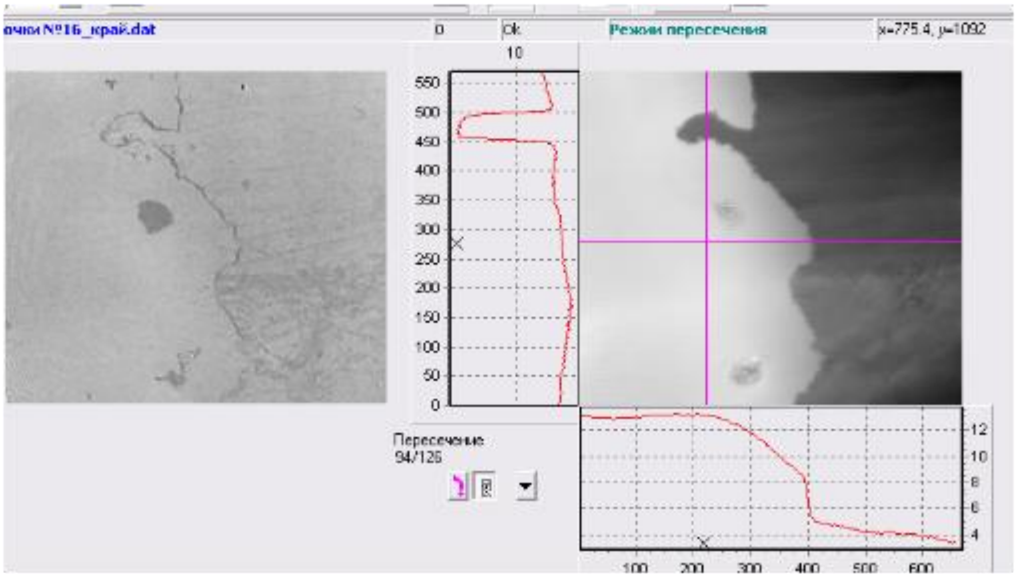
Figure 3.3. 3D surface topography: (a) - under coating (b) - coating surface



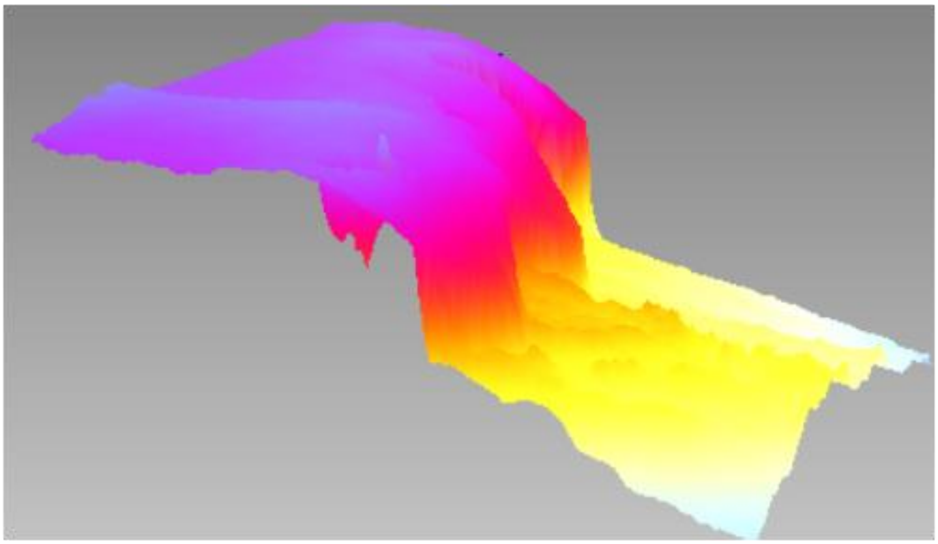
a) b)

Figure 3.4. 2D surface topography: (a) - under coating (b) - coating surface.

In figure. 3.5 shows two-dimensional and three-dimensional topography of the surface area at the boundary of the applied coating (sample №16). The height of the formed step is 10 microns.



a)



b)

Figure 3.5. Topography of the surface at the boundary of the coating: (a) - 2D; (b) - 3D.

The above fugure represent different results of measurements which are provide samples, confirming the capabilities of the device, when been measured.

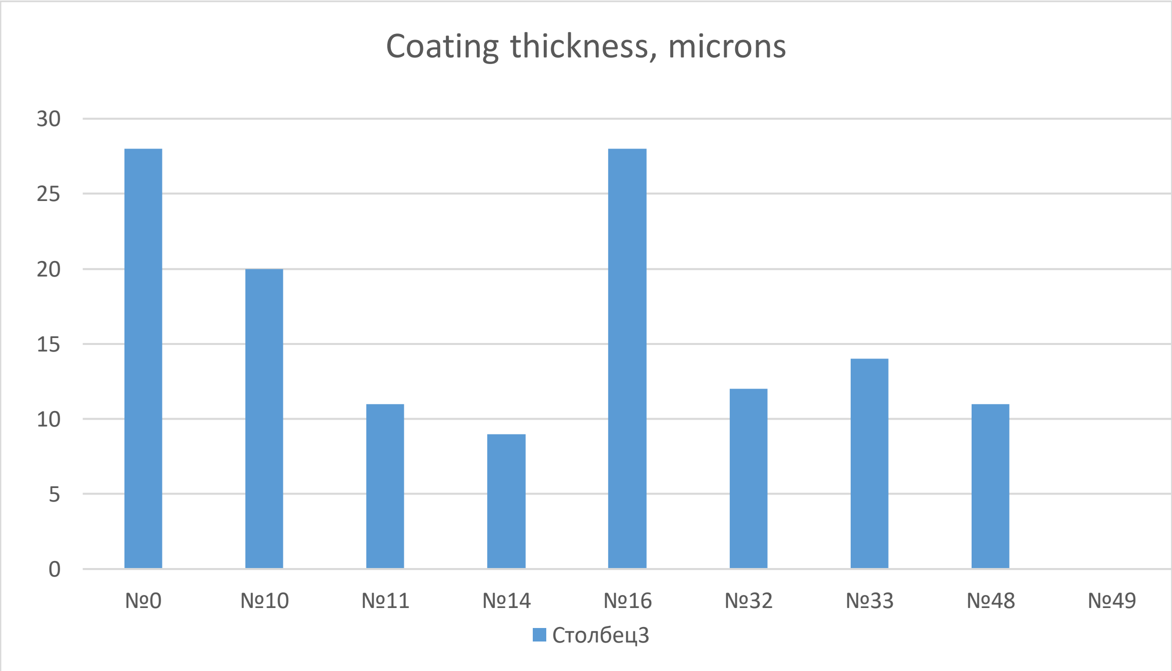
Table 3.3 presents the results of measurements of the coating thickness of the provided samples

Table 3.3

Coating thickness measured at arbitrary points on the surface

№ sample	Coating thickness, microns	№ sample	Coating thickness, мсм	№ sample	Coating thickness, мсм
№ 49	15	№11	11	№ 48	11
№ 32	12	№ 14	9	№ 10	20
№ 33	14	№ 16	28	№ 0	28

The above table show represntetive data of given experimental meaurements



Graph.3.3 measurement of coating sample

As can be seen from the presented results, the non-contact three-dimensional profilometer "Micron-alpha" allows measuring the thickness of transparent coatings. In addition, the device allows you to quantify the geometric characteristics of both coatings and substrates. These measurements will allow you to select the optimal mode of application of protective coatings and output quality control of finished products. And the above graph represent thickness measurement

Conclusion part 3

In this section was center on the analysis of the principle of white light interferometry, light as a source for the interferometer and the experimental thickness measurement. In all of this section was base of the mode of operation of white light interferometer and its advantage base, while is a best choice over other methods of measurement.

When we talk about carry out any form of measurement thickness on parts of the aircraft or any form of application it is then very important to know what kind of deformation can be cause by such method. In order to avoid and form of structural or plastic deformation of the parts place under such measurements methods, we used non-contact method Which run down to the used of white light interferometry as the best form of measurements, while because it's a great accurate results and wont caused any form of structural or plastic deformation to the parts.

Measurement was set by a non-contact method with a three dimensional profilometer on a military glass and a graph showing the ration of our sample and thickness. Therefore the best form of measuring the thickness of any transparent coating ob parts of the aircraft will be the used of white light interferometry, therefore White light interferometry is a widely used technique for measurement of surface topography of objects over large areas. Systems which use this technique can measure areas which are equal to the field of view of the instrument. Interferometric optical topographers are widely used to study surface topography due to the high measurement accuracy, non-contact, rapid data acquisition and analysis. And the Aim of this project is to construct a coherence peak white light interferometer and define its accuracy. To achieve this goal this project includes the design, construction, experiments and validation of the interferometer system.

PART 4

LABOUR PROTECTION

4.1Analysis of harmful and dangerous production factors using Transparent coating (ITO) as an example.

Today air and space craft are manufactured with vulnerable components and technical equipment that needs advanced coating to maintain and enhance their performance. The subject of this work is an engineer, who works with coating tool For analyzing of the work conditions was chosen a laboratory room in one of the office buildings, This technical guideline is prepared for employers and provides recommended actions to prevent the health impairment of workers who are engaged in the production or handling of indium tin oxide (hereinafter called “ITO”) and other indium compounds. (As a coating materials)

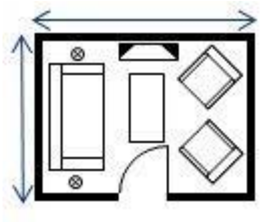
4.1.1 Working condition analysis

The workplace for this investigation is carried out in a small laboratory room in an office that is located in the department of designing aircrafts. The room houses machine tools and other devices and the working space.

The linear size of the room 7m×4m, height – 2.4 m, area – 23 sq. amount of space – 87.6 m3. All dimensions listed are approved by building codes Ukraine ДБН В.2.2-28-2010 “Engineering equipment of buildings and structures. Design of electrical equipment for civilian objects

The most favorable microclimate in the workplace is the temperature no more than 24, relative humidity should be 40-60 % air velocity – 0.2 m/s. To maintain optimal values use microclimate heating, ventilation and air conditioning. Noise sources are machine tools for rolling, computer cooling units, laser printers, air conditioning. The room is a first aid kit, Carbon dioxide fire extinguisher to extinguish the fire. The size of the office room must be proportional to the number of engineers sitting in it. There are plenty of room layouts, but fundamental principles for all of them are the same. It can be an open space zone, where the engineers' workplaces are separated with partitions and it can be an enclosed room, usually called an office unit.

Office room layout may be observed in the figure 4.1.



4.1.2 The list of harmful factors which can impact on workers.

According to the hygienic standards ГОСТ 12.0.003-74« Hygienic classification of labor by indicators of harmfulness and danger of factors of industrial environment, severity and intensity of work process »:

- Increased vibration level (local and general);
- microclimate (temperature, humidity, air velocity, infrared radiation);
- production noise, ultrasound, infrasound;
- ionizing radiation;
- ionization of air;
- microorganisms - producers, living cells and spores of microorganisms, contained in bacterial preparations, pathogenic microorganisms;

4) factors of the labor process:

• heaviness (severity) of labor - a characteristic of the labor process, which reflects the level of total energy consumption, the prevailing load on the support-vehicle, cardiovascular, respiratory and other related systems.

4.2 measures to reduce impact of harmful and dangerous factor production

To prevent workers from indium and other coating exposure in the workplaces of producing or handling ITO, etc, indoors (hereinafter called "handling of ITO, etc.,"), employers are required to implement the following actions and measures.

● measures to be applied in facilities and equipments

Take either of the following measures. Also, refer to a few examples introduced in each measure.

- Install remote control operation or change to automated production and/or handling process.

Example)

▪ Change operational procedure to allow workers to operate from outside of the workplace.

▪ Convert manual operations to mechanized systems.

· Install facilities and equipment which can hermetically seal or segregate source dust.

Example:

▪ Cover the entire area of the source of dust facilities and equipment.

▪ Take a skillful approach in minimizing openings (windows, etc.) of source of dust facilities and equipment jigs and Fixtures.

▪ Change the shape of hoppers and chutes to prevent dust from dispersing.

▪ Cap every kind of container.

▪ Separate and segregate a working place from surrounding areas with installation of vinyl curtains around a source of dust.

▪ Narrow space of working places including the area of the dust source as much as possible.

▪ Locate source of dust facilities and equipment in segregated rooms and enter there only when required.

▪ Install local ventilation equipment.

Example;

▪ Factoring in actual operational conditions and procedures in a workplace, select suitable local ventilation equipment and assess their effectiveness by referring to the following measures.

▪ Minimize the inlet area to the extent as required.

▪ Enhance the ability of dust collection by applying HEPA filters and similar devices.

・Maintain the required inlet wind velocity through openings of local ventilation equipment.

－Carry out daily inspections including detecting the indication of problems in local ventilation facility and check the inlet wind velocity.

- Install push-pull type ventilation equipments - Install facilities to keep the working place humid.

Example:

・ Change working methods to the wet process as much as possible.

・ Moisten and wet jigs and rags, then store them inside covered containers to prevent from drying.

To prevent dust stirred up by exhausted air of cleaners during floor sweeping, centralized-dust collection large outdoor collectors can be one recommendable example to look for.

Also, instruct workers engaged in cleaning ITO, etc., or recovery of sticking designated substance inside of facilities and equipment to wear effective respiratory protective equipment:

Workers must wash their own working uniforms on site. Also use separate lockers for working uniforms and private clothes.

In the case of indoor work places where production and handling of ITO, etc., are carried out (except places where workers usually do not enter thanks to the remote control operation or process automation), measure the concentration of designated substances in air once per less than six months in accordance to methods described

a) Carry out the sealing of facilities and equipment.

b) Enhance the performance capability of local ventilation equipment and dust collectors.

c) Change the work processes and methods, thereby exposure of workers to the designated substance can be Reduced.

Target concentration is a target of current efforts to improve the work environment and it is of different nature from the standard control concentration calculated under the work environment assessment standard.

However, even if the measured value was lower than the targeted value but exceeded the acceptable exposure concentration limit of 3×10^{-4} mg/m3 that is a limit value calculated from the outcome of the test in long-term carcinogenicity studies in animals in this country, it is recommendable to take further actions as required continually to improve work environment and reduce the concentration of indium in air as much as possible.

In a work environment where measurement result exceeds the acceptable exposure concentration limit, workers engaged in handling ITO, etc., are mandated to select effective respiratory protective equipments complying with following guidelines and wear them during handling operations without exceptions

As candidates of effective respiratory protective equipments, there are supplied-air respirators including JIS T8153 compatible air-supply respiratory protective equipment, dust mask capable of capturing higher than 99.9% particle collection efficiency or JIS T8157 compatible respiratory protective equipment equipped with an electric fan capable of collecting particles at higher than 99.9% efficiency. Also use dust masks certified under national standards.)

4.2.1 Calculation for normal ventilation system

Ventilation is an adjustable air exchange, which removes contaminated air from the premises and feeds into a place of fresh air. The main requirement for ventilation systems is the removal of contaminated, wet or heated air from the premises and the supply of clean air to the youth that meets sanitary and hygiene requirements.

By the way of air movement, ventilation is natural, artificial (mechanical) and combined (natural and artificial at the same time). Depending on the purpose - for the supply or removal of air or for both at the same time - the ventilation can be

On plants often arrange combined ventilation systems (common with local, etc.), and in some cases and emergency ventilation, as a rule, it is projected exhaust.Ventilation systems should be fire and explosion-proof, simple in the arrangement not to overcook the premises, do not create excessive noise, be reliable in operation and economical. In addition to the passport for each ventilation installation make a log operation.

According to the standards ДСН(DSN) 3.3.6.042-99 "Sanitary norms of microclimate of industrial premises", performance of fan for the laboratory room:

$$L = k \bullet V \quad (4.1)$$

where L - hourly performance of the fan, m3/h; k - multiplicity of air exchange (for laboratory with machine tool for rolling = 2); V - volume of the room, m3.

The room size is A = 6m, B = 4m, H = 3.3m

$$V = A \cdot B \cdot H = 6 \cdot 4 \cdot 2.4 = 57.6 \text{ m3} \quad (4.2)$$

Then,

$$L = 2 \cdot 79.2 = 115.2 \text{ m3/h (4. 1)} \quad (4.3)$$

Therefore for optimal ventilation of laboratory rooms the performance of ventilation fan must be not less than 115 m3/h.

4.3 Occupational Safety Instruction

General safety requirements. To work as a design engineer are allowed persons who have a higher professional (technical) education in a specialized specialty with or without presentation of requirements for work experience, depending on the category, and also have no medical contraindications.

The design engineer informs his immediate supervisor about any situation that threatens the life and health of people, about every accident that occurs at work, about the deterioration of his health, including the manifestation of signs of an acute illness.

A design engineer must undergo training in labor protection in the form of: introductory briefing, special training in labor protection in the scope of job duties upon admission to work during the first month, then as needed, but at least once every three years. A design engineer who has not timely passed the appropriate instruction on labor protection, an annual examination of knowledge on labor protection, a periodic medical examination, is not allowed to work.

*Safety Requirements before starting work***.** Every engineer should follow the following rules before starting work:

1. Arrive at work in advance to avoid haste and, as a result, falls and injuries.

2. Inspect the workplace and equipment. Remove all unnecessary items.

3. Adjust the seat height. Check the height of the equipment.

4. Check the availability of fire-fighting equipment, first aid kit (its complete set).

5. Check by visual inspection: absence of cracks and chips on the cases of sockets and switches, as well as the absence of bare contacts; reliability of closing all current-carrying devices of the equipment; presence and reliability of grounding connections (absence of breaks, strength of contact between metal non-current-carrying parts of the equipment and the grounding wire); the integrity of the insulation of electrical wires and power cords of electrical appliances, the serviceability of safety devices; sufficiency of lighting of the workplace; absence of foreign objects around the equipment

*Safety Requirements during operation***.** Upon detection of faulty equipment, fixtures, etc., other violations of labor protection requirements that cannot be eliminated on their own, as well as a threat to health, personal or collective safety, the design engineer should inform the employee responsible for eliminating the violations , or to a superior leader.

When working with a PC, an engineer observe the rules for their operation in accordance with the instructions for labor protection:

1. The screen should be 5 degrees below eye level, and be located in a straight plane or tilted towards the operator (15 degrees).

2. The distance from the eyes to the screen should be within 60–80 cm.

3. The local light source in relation to the workplace should be located so as to exclude direct light from entering the eyes, and should provide uniform illumination on a surface of 40 x 40 cm, not create blinding glare on the keyboard and other parts of the console, as well as on the video terminal screen in direction of the eyes.

4. To reduce visual and general fatigue, after each hour of working at the screen, you should use regulated breaks of 5 minutes, during which you can rest.

5. During a work shift, the display screen must be cleaned of dust at least once

When performing work, the design engineer is prohibited from:

1. Touch the rear panel of the system unit (processor) when the power is on.

2. Switch connectors of interface cables of peripheral devices when the power is on.

3. To turn off the power during the execution of an active task.

4. Allow moisture to get on the surface of the system unit (processor), monitor, working surface of the keyboard, disk drives.

5. Perform self-opening and repair of equipment

Safety Requirements after work. Labor protection requirements for the design engineer at the end of work: Inspect the workplace, put things in order. Remove equipment, documentation, etc. to the designated places. When working with electrical equipment, disconnect it from the network [18].

Safety Requirements at emergency situations:

1. Upon detection of malfunctions of equipment, instruments and apparatus, as well as in the event of other conditions that threaten the life and health of workers, the design engineer should stop work and report them to his immediate supervisor and the employee responsible for the implementation of production control.

2. When a fire source appears, the design engineer must: stop working; turn off electrical equipment; organize the evacuation of people; start extinguishing the fire immediately (when electrical equipment catches fire, use only carbon dioxide or dry powder fire extinguishers).

3. If it is impossible to carry out extinguishing on his own, the design engineer should, in accordance with the established procedure, call the fire brigade and inform the immediate supervisor about it.

4. In the event of injury or deterioration of health, the design engineer must stop work, notify the management and seek medical attention.

5. In the event of injury or deterioration in the health of a subordinate employee, remove him from work and send him to the first-aid post, and, if necessary, call the city ambulance [18]

Conclusion to chapter 4

For proper operation working with (ITO) as a form of a coating material the laboratory room must be changed from an old ventilation system to a more advanced and upgraded system which can provide enough air exchange. In the absence of a normally functioning air ventilation system in the laboratory room, the concentration of Indium tin oxide (ITO) titanium carbide and chemical evaporation inhaled by human, as well as many other harmful substances entering the air and adversely affecting the health of a person and significantly impairing its climate comfort, increases significantly. There are such unpleasant sensations as increased drowsiness, loss of interest in work, headache, allergic reactions. Which lead to the calculated optimal performances of the ventilation system and it must be not less than 115 m3/h, so should be installed fan, which meet this parameter. Work in the laboratory must be organized in accordance with the requirements of the current technological documents (norms, instructions, regulations), approved in the prescribed manner

If an employer assigns certain jobs to contractors and if workers other than employees are engage in handling ITO, etc., on site, said employer must provide the contractors with information described in above Item through and request them to take appropriate measures without exceptions to prevent their workers from suffering health problems. Employers are requested to provide workers engaged in handling designated substances with occupational health instructions as listed here based on the information collected from this technical guideline

CHAPTER PART 5

ENVIRONMENTAL PROTECTION

5.1 The influence of using aviation transparent coating to the enviroment

The issue of aviation's impact on the environment and human health has been marginal in the general discussions on environmental issues. Causing a lot of pollution in the air we breathe, in terms of undiluted chemical release from the production of aviation coating materials. And when breath in can cause respiratory tract, organs failure and a lot more. Due the awareness of society about the importance of environmental issues and concerns about how to address them has led governments and private bodies in different countries which has help in the appropriate policy measures to reduce theimpact of pollution on the environment, therefore, environmental issues in the air transport company and industry have attracted so much attention than it was before. There is a drive desire to preserve and enhance the level of quality and a pollution-free atmosphere, seeing the

In this 21th century virtually all issues relating to global civil aviation are decided by the International Civil Aviation Organization (hereinafter referred to as ICAO). ICAO develops the basic requirements for civil aviation, including air certification requirements for environmental impact, and restricts the use of airplanes that do not meet environmental requirements. At the same time, the International Civil Aviation Organization is almost not concerned with compensating environmental damage from the impact of aircraft on the environment, placing these issues at the disposal of each individual state,countries of Europe and other North America have economic mechanisms for compensating for the harmful effects of civil aviation on the environment. Unfortunately, this issue is paid little attention in african, as well as ukraine.

In a general case there is completely no theoretical and methodological approaches to environmental and economic assessment of the impact of civil aviation on the environment. Further the deepening and additions to the theoretical and methodological provisions related to the creation of a mechanism for compensating environmental and economic losses from air transport processes, according to objective estimates, in the near future, the expected increase in volumes of air transportation may amount to 30-40 % per year, and also due to the demands increase or the desired have to produce aircraft with more better performance and protective mechanisms with the help of transparent coating will defiantly increase in the productions of this coating devices on the aircraft parts and lead to increase in the volume of air pollution. Thus, if even quantitative indicators of ecological and economic losses are insignificant, then their substantial growth is possible in the near future.

5.2 Evaluation of the different aircraft pullotion from using transparent coating materilas in the environment

Aircraft pollute the atmosphere due to the emission of harmful substances from it production site and also in service point, for example the production of transparent coating using (indium tin oxide) also the exhaust gases of aviation engines. Due to the increased in demands of upgraded system of the aircraft has led to the increase in the production of transparent coating, which used different chemical oxides. And when the oxides been release will lead to the pollution of the air causing health problem to humans and both living organisms.

Air pollution. this is very important aspect, why because the air is the basic of life, and once polluted lead to loss of life. Aviation has totally very high impact on natural air, due to the productions of different parts which involves the use of different chemicals, and not forgetting the CO from the engines all this has a great impact on our environment. Gases in the atmospheric air throw out nozzles and exhaust pipes of engines. This process is called the emission of aviation engines. The gases generated by the operation of air transport engines account for 87 % of all emissions from civil aviation, which also include emissions from special vehicles and stationary sources, Inhalation of indium tin oxide may cause mild irritation to the respiratory tracts and should be avoided. If exposure is long-term, symptoms may become chronic and result in benign pneumomoconiosis also a new occupational problem called indium lung disease was developed through contact with indium-containing dusts.

Water pollution. Groundwater pollution by oil products occurs near the airports, mainly due to leakage of fuel when refueling aircraft, oil from oil tanks as well as due to technical errors during its transportation and storage of the aircraft. During emergencies, spilled oil products and contaminated soil are removed from the earth's surface. When oil products enter the aquifers, the polluted water is usually pumped out and then purified through appropriate filters. A mixture of dust, fuel combustion products, particles of washable tires and other materials accumulates on the surfaces of airports. Together with rain streams, all this falls into water bodies

Acoustic pollution. Noise (acoustic) pollution is an irritating noise of anthropogenic origin that disrupts the vital activity of living organisms and humans. Irritating noises also exist in nature (abiotic and biotic), but it is incorrect to consider them as pollution, since living organisms have adapted to them in the process of evolution.

Noise pollution has a negative impact on the natural balance in ecosystem. Noise pollution can lead to disorientation in space, communication etc. In this regard, some animals begin to emit louder sounds, which is why they themselves will become secondary sound pollutants, further disturbing the balance in the ecosystem. One of the most famous cases of damage caused by noise pollution to nature is the numerous cases when dolphins and whales were thrown on the beech, losing orientation due to the loud sounds of military sonars that impacts on the animal’s biological locator.

Noise is caused by aircraft engines, auxiliary power units of aircraft, special vehicles for various purposes, cars made on the basis of aircraft engines with thermal and wind turbines that have expired flight life, equipment of stationary objects of the airport infrastructure where maintenance and repair of aircraft is carried out.

Under certain conditions, noise can have a significant impact on human health and behavior. Noise can cause irritation and aggression, hypertension (high blood pressure), tinnitus and hearing loss. The greatest irritation is caused by noise in the frequency range of 3000-5000 Hz. Chronic exposure to noise levels greater than 90 dB can lead to hearing loss. At a noise level of more than 110 dB, a person develops sound intoxication, which in subjective sensations is similar to alcohol or narcotic. At a noise level of 145 dB, a person's eardrums rupture. In addition, the susceptibility to noise also depends on age, temperament, health status, environmental conditions, etc. [19, 20] .

Conclusion to chapter 5

Aviation has a great influence on the Earth's atmosphere. Starting from its production, to service all this process as greatly affected the environment in so many ways. Like the production of coating materials which can involve the use of different chemical oxides, as well as Aircraft gas turbine engines operate on aerosols, the chemical composition of which is somewhat different from automotive gasoline and diesel fuel of better quality with less sulfur and mechanical impurities. However, the main mass of exhaust gases is emitted by aircrafts directly in the airspace at relatively high altitudes, at high speeds and turbulent flow, and only a small proportion - in the vicinity of airports and settlements. The main components that pollute the environment are: carbon monoxide, unburnt hydrocarbons, nitrogen oxides and soot. In idle and when walking on tracks, when approaching the exhaust gases, the content of carbon monoxide and carbohydrates is significantly increased, but the amount of nitrogen oxide is reduced.

therefore in Reducing the amount of harmful emissions can be achieved by increasing production efficiency, and a proper recycling of the chemical product used in coating. also reducing the amount of exhaust gases. The reduction of fuel consumption, and the emission of toxic substances, is also achieved by improving the operation of aircraft, namely: proper recycling of chemical substance, for fuel on increasing the filling capacity of airplanes by useful cargo, reducing the run of airplanes on airplanes under the propulsion of their own engines by towing their tractors to the runway, as well as for due to the location of airports at a considerable distance from the resident buildings.

In conclusion to this part we were able to analyize different aspect which the usage of such coating materils will affect the environment and the eco-system in general and attributing proodures and ways of ensuring the control of such pollutions to the environment while because there is a saying that say that the mother earth is the fundamental of all life, there it is our primary purpose to protect it from any form of destructions

GENERAL CONCLUSION

Since the air and space craft are highly sophisticated machines which require the expertise of hundreds of engineers and scientists working in together in a close harmony in order to develop or design a more protective, long service , and advanced space craft which then lead to the essence of the application of transparent coating in air and space craft. In this project was also made details of analysis of the application of such transparent coating in aviation, and what they protect against, in order words today air and space craft are manufactured with many vulnerable components and technical equipment that needs such advance coating to maintain and to enhance a more effective performance, while because out there in the world those components are subjected to extremely temperature severe environmental hazard and wear off over time.Therefore to protect those component it is then necessary to produce a product which has resistance to abrasion, damage from impact, chemical and uv radiation. Etc, in combing optical clarity.

The main task of this project was center on the methods used in measuring the thickness of such transparent coating in aviation. measurements of a transparent coating materials, on how they can be measured using different methods of measurement. And before carrying out this or any kind of measurements it is then necessary to know how it can cause structural damage's, change to properties, and other parameter's, to the part it will be used on, now paying attention to the type which is more effective without causing any structural damage to the parts when been use, and not to cause any structural damages to those parts. After a some comparisons between those methods mention listed above and break down of their operational principle and also with some test materials was then chose the best method which is base on white light interferometry.

Now a new method of measuring the thickness of transparent coating was then propose to used which is base on the principle of white light interferometry and also this is a non-destructive methods which can be successfully applied in different aviation parts, without causing any deformation to that part. This method in general is base on wave natured of light, when we talk about NDT or methods it also place a very important aspect in the health monitoring of materials, and in this jet age it is what we are mostly concerned about. Having a methods that has high accuracy and can be applied to any parts without causing any structural or plastic deformation, so in general in my project I was able to analysis different methods that can be used, compared their merits, base on different test results, which then runs down to the best methods which is the used of white interferometry. An example of the the measurements of military glass thickness was carry with a developed profilometer based on the microinterferometer.

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