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NATIONAL AVIATION UNIVERSITY
FACULTY OF AIR NAVIGATION, ELECTRONICS AND TELECOMMUNICATIONS
DEPARTMENT OF AVIONICS

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'___'___________2022

# GRADUATION WORK

**(EXPLANATORY NOTES)**

**FOR THE DEGREE OF MASTER**

**SPECIALITY 173 'AVIONICS'**

## Theme: 'Visual examinations and manual checks to determine the condition of an aircraft and its component'

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Kyiv 2022

МІНІСТЕРСТВО ОСВІТИ І АУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
ФАКУЛЬТЕТ АЕРОНАВІГАЦІЇ, ЕЛЕКТРОНІКИ ТА ТЕЛЕКОМУНІКАЦІЙ
КАФЕДРА АВІОНІКИ

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач випускової кафедри
_________Ю.В. Грищенко
«___»___________2022

# ДИПЛОМНА РОБОТА

## (ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ МАГІСТРА
ЗА СПЕЦІАЛЬНІСТЮ 173 «АВІОНІКА»

**Тема:** «Візуальний огляд і ручні перевірки для визначення стану літака та його компонентів»

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Київ 2022

NATIONAL AVIATION UNIVERSITY
Faculty of Air Navigation, Electronics and Telecommunications
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Specialty 173 ‘Avionics’

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‘___’___________2022

## TASK
## for execution graduation work

Helevera Dmytro

1. Theme: ‘Visual examinations and manual checks to determine the condition of an aircraft and its component’, approved by order 1413/ст of the Rector of the National Aviation University of 13 September 2022.

2. Duration of which is from 13 September 2022 to 14 November 2022.

3. Input data of graduation work: Thorough and constant inspections are the basis of flight safety. The obligation of each company or aircraft owner to perform all necessary aircraft maintenance procedures in a timely manner. Throughout the history of aviation, many methods were invented and introduced to make the inspection of the aircraft as effective as possible. High requirements for personnel ensure quality work, but a person can make mistakes. Machine vision can perform an inspection instead of a human and without human flaws.

4. Content of explanatory notes: List of conditional terms and abbreviations, Introduction, Chapter 1, Chapter 2, Chapter 3, Labor protection, Environmental protection, References, Conclusions.

5. The list of mandatory graphic material: figures, tables.

6. Planned schedule

| № | Task | Duration | Signature of supervisor |
|---|---|---|---|
| 1. | Validate the rationale of graduate work theme | 13.09.2022 | |
| 2. | Carry out a literature review | 14.09.2022–22.09.2022 | |
| 3. | Develop the first chapter of diploma | 13.09.2022–28.09.2022 | |
| 4. | Develop the second chapter of diploma | 29.10.2022–09.10.2022 | |
| 5. | Develop the third chapter of diploma | 10.10.2022–25.10.2022 | |
| 6. | Develop the fourth and fifth chapter of diploma | 21.10.2022 – 11.11.2022 | |
| 7. | Tested for anti-plagiarism and obtaining a review of the diploma | 14.11.2022 | |

7. Consultants individual chapters

| Chapter | Consultant (Position, surname, name, patronymic) | Date, signature | |
|---|---|---|---|
| | | Task issued | Task accepted |
| Labor protection | | | |
| Environmental protection | | | |

8. Date of assignment: ‘___ ‘__________ 2022

Supervisor ______________ O.V. Kozhokhina

The task took to perform ______________ Helevera Dmytro

(signature) (surname, name, patronymic)

# ABSTRACT

Explanatory notes to graduation work ‘Visual examinations and manual checks to determine the condition of an aircraft and its component’ contained 115 pages, 58 figures, 4 tables, 38 references.

**Keywords:** AIRCRAFT, MAINTENANCE, INSPECTION, HUMAN FACTOR, ERROR, MACHINE VISION.

**Object of investigation -** is the process of visual examinations and manual checks to determine the condition of an aircraft and its component

**Subject of the research -** Inspection of the aircraft by using different methods of inspection and using a new machine vision method.

**Purpose of graduation work –** implementation machine vision inspection in aircraft maintenance.

**Methods of investigation** – Methods of decision theory, reliability theory, probability theory, statistics theory, information theory, and expert judgment method were used to solve this goal.

**Scientific novelty** – proposed machine vision inspection method during maintenance and its impact on flight safety.

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| AC | Advisory Circulars |
| AC | Alternating Current |
| AMT | Aviation Maintenance Technician |
| AMF | Aircraft Maintenance Facility |
| ATA | Air Transport Association |
| ATC | Air Traffic Control |
| CBT | Computer-Based Training |
| CFR | Code of federal regulations |
| CHIRP | Confidential Human Incident Reporting Programme |
| CRT | Cathode Ray Tube |
| EMI | Electromagnetic Interference |
| EMR | Electromagnetic Radiation |
| FOD | Foreign Object Damage |
| HF | Human Factor |
| IFR | Instrument Flight Rules |
| IR | Infrared |
| LCD | liquid Crystal Display |
| MEDA | Maintenance Error Decision Aid |
| MEMS | Maintenance Error Management System |
| MOR | Mandatory Occurrence Reporting |
| NDI | Non-destructive inspection |
| NDT | Non-destructive testing |
| PCB | Printed Circuit Board |
| PIC | Pilot in Command |
| POH | Pilot's Operations Manual |
| R&D | Research and development |
| RFI | Radio Frequency Interference |
| SB | Service Bulletin |

# INTRODUCTION

**Actuality.** Under the influence of the growth of competition in the segment of aviation equipment, certain quantitative and qualitative changes in its production and restoration are constantly taking place. The degree of automation and computerization of the production process is constantly increasing due to the wider use of automatic lines, manipulators and installations, complex and high-precision equipment, and the introduction of regulation of technological processes with the help of computers. The importance of maintenance and repair processes to maintain the operational condition of aircraft is increasing, since its downtime due to a malfunction significantly worsens the economic indicators of operation.

Aviation companies cannot underestimate the importance of aircraft maintenance. Regardless of the size of the aircraft, maintenance activities should be carried out regularly. These activities include aircraft inspection, restoration work, and aircraft repair. Different aircraft will require maintenance at different intervals.

Safety is the highest priority for everyone involved in aviation. Over 80% (plus) of accidents are caused by human error. These human errors are not made on purpose. Many of these mistakes are made by the best and most conscientious employees. Thus, something had to interfere with the work and/or judgment of that "person" for the error to occur.

Safety for everyone is the most obvious reason for airline service. Airplanes are made up of different parts and it's very complicated.  Therefore, maintenance, repair, and overhaul/operation are critical to the safety of people and aircraft.

Aircraft maintenance can extend the life of the aircraft. A comprehensive approach to maintenance minimizes maintenance time over the life of the aircraft. It provides an overview of the cycles required to create a robust aircraft maintenance program that ensures improved performance and benefits aircraft management. In order to take effective preventive measures, the aircraft must undergo various levels of inspection according to the aircraft maintenance schedule. Maintenance is performed after the aircraft has been inspected, after which it must be decided whether it needs condition-based monitoring or not. All these measures extend the life of the assets.

Correct timing is essential to know when you should bring your aircraft in for inspection. While routine inspections on the calendar are very valuable to the well-being of your aircraft, it is also important to keep track of flight hours so that your aircraft's time-critical maintenance inspections are done in the right order and at the right time.

The aircraft must be fully inspected every 100 hours. The more you fly the plane, the more often you will need to service it. Therefore, manufacturers usually specify flight hours rather than time frames for service and maintenance checks. It is important to know when you should take your aircraft in for inspection. In addition, additional requirements for better reliability and additional safety margin are definitely recommended. Aircraft owners should never underestimate the importance of aircraft maintenance.

Visual inspection is usually the most economical and fastest way to get an early assessment of the condition of the aircraft and its components. Most defects found on aircraft are found by visual inspection. Due to an unremoved plug on one of the many sensors of the plane, problems arise that can lead to unpredictable consequences, in the best case it is an emergency landing and in the worst a plane crash. A large number of plane crashes could have been prevented thanks to a careful inspection of the plane before takeoff. A visual inspection of the aircraft is not only an inspection of the exterior of the aircraft but also an inspection of the internal components of the aircraft. A cracked tube or broken wire can shut down an important aircraft system and lead to dire consequences. Therefore, the improvement of the visual inspection system will always be relevant and constantly modernized.

There are many parts in an airplane that do not need to be replaced until they finally fail. However, sometimes it is better to replace certain parts preventively for greater safety and to eliminate any unforeseen possibilities.

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# CHAPTER 1

# INSPECTION CONCEPTS AND TECHNIQUES

## 1.1. Basic Inspection

Inspections are visual inspections and manual checks to determine the condition of the aircraft and its components. An aircraft inspection can take a different form, from a simple visual inspection to complete disassembly of the unit and checking all components using complex equipment. The inspection system consists of several processes, such as reports written by the mechanic, pilot, or crew and regular inspections of the aircraft. Regular and comprehensive inspections are required to ensure the aircraft is in the best possible condition. Irregular or poor-quality inspections can lead to catastrophic consequences. Any small malfunction eventually turns into a big problem with painful consequences. Therefore, detecting wear or damage to a component at an early stage saves a lot of money and time compared to repairing an already damaged part of the aircraft. Repairing a malfunctioning component cost company, a lot of money. A routine pre-flight inspection of an aircraft may reveal signs of improper maintenance or operation. For example, the plug is not removed from the pressure receiving tube, or the pin is not removed from the aircraft chassis. Such a seemingly imperceptible detail will cause unpredictable consequences. It is impossible to overestimate how important constant inspections of the aircraft and its components are. To service the aircraft in advance and schedule inspections, information on flight hours or a calendar system of inspections is used. Using the calendar system of checks, the corresponding check is carried out after the specified number of calendar weeks. An aircraft in which technical maintenance is carried out according to the flight hours system is checked after accumulating the planned number of flight hours.

### Techniques/Practices

Before starting the inspection, you need to make sure that all doors, hoods, fairings, and covers are removed or open. It is a good idea to inspect all surfaces for any traces of oil or other fluids from the aircraft system. This is one of the earliest signs of malfunction or damage to an aircraft component that can be seen without the use of inspection equipment.

### Preparation

Verification of any complexity requires access to technical documentation and reference information. You should also consult the aircraft's logbook for background information and the aircraft's maintenance history. It is necessary to use checklists to control every detail during the inspection and not to forget or miss anything during the inspection process. In addition to all the above, many additional publications should be used, both in electronic form and in print. These additional publications may contain information provided by aircraft and engine manufacturers, instrument manufacturers, parts suppliers, and the Federal Aviation Administration (FAA).

### Checklists

Always use a checklist when inspecting. The checklist can be developed by you, provided by the manufacturer of the equipment being tested, or obtained from another source. The checklist should include the following:

1. Fuselage and Hull Group
    - Fabric and skin—for deterioration, distortion, other evidence of failure, and defective or insecure attachment of fittings.
    - Systems and components—for proper installation, apparent defects, and satisfactory operation.
    - Envelope gas bags, ballast tanks, and related parts—for condition.
2. Cabin and Cockpit Group
    - General—for cleanliness and loose equipment that needs to be secured.
    - Seats and safety belts—for condition and security.
    - Windows and windshields—for deterioration and breakage.
    - Instruments—for condition, mounting, marking, and (where practicable) for proper operation.
    - Flight and engine control—for proper installation and operation.
    - Batteries—for proper installation and charge.

- All systems—for proper installation, general condition, apparent defects, and security of attachment.

3. Engine and Nacelle Group

- Engine section—for visual evidence of excessive oil, fuel, hydraulic leaks, and sources of such leaks.
- Studs and nuts—for proper torquing and obvious defects.
- Internal engine—for cylinder compression and metal particles or foreign matter on screens and sump drain plugs. If cylinder compression is weak, check for improper internal conditions and improper internal tolerances.
- Engine mount—for cracks and looseness of mounting.
- Flexible vibration dampeners—for condition and deterioration.
- Engine controls—for defects, proper travel, and proper safetying.
- Lines, hoses, and clamps—for leaks, condition, and looseness.
- Exhaust stacks—for cracks, defects, and proper attachment.
- Accessories—for apparent defects in the security of mounting.
- All systems—for proper installation, general condition defects, and secure attachment.
- Cowling—for cracks and defects.
- A ground run-up and functional check—check all powerplant controls and systems for a correct response, and all instruments for proper operation and indication.

4. Landing Gear Group

- All units—for condition and security of attachment.
- Shock absorbing devices—for proper oleo fluid level.
- Linkage, trusses, and members—for undue or excessive wear, fatigue, and distortion.
- Retracting and locking mechanism—for proper operation.
- Hydraulic lines—for leakage.
- Electrical system—for chafing and proper operation of switches.
- Wheels—for cracks, defects, and condition of bearings.
- Tires—for wear and cuts.

- Brakes—for proper adjustment.
- Floats and skis—for the security of attachment and obvious defects.

5. Wing and Center Section
    - All components—for condition and security.
    - Fabric and skin—for deterioration, distortion, other evidence of failure, and security of attachment.
    - Internal structure (spars, ribs, compression members)—for cracks, bends, and security.
    - Movable surfaces—for damage or obvious defects, unsatisfactory fabric or skin attachment, and proper travel.
    - Control mechanism—for freedom of movement, alignment, and security.
    - Control cables—for proper tension, fraying, wear, and proper routing through fairleads and pulleys.
6. Empennage Group
    - Fixed surfaces—for damage or obvious defects, loose fasteners, and security of attachment.
    - Movable control surfaces—for damage or obvious defects, loose fasteners, loose fabric, or skin distortion.
    - Fabric or skin—for abrasion, tears, cuts, defects, distortion, and deterioration.
7. Propeller Group
    - Propeller assembly—for cracks, nicks, bends, and oil leakage.
    - Bolts—for proper torquing and safe tying.
    - Anti-icing devices—for proper operation and obvious defects.
    - Control mechanisms—for proper operation, secure mounting, and travel.
8. Communication and Navigation Group
    - Radio and electronic equipment—for proper installation and secure mounting.
    - Wiring and conduits—for proper routing, secure mounting, and obvious defects.
    - Bonding and shielding—for proper installation and condition.
    - Antennas—for condition, secure mounting, and proper operation.

9. Miscellaneous

- Emergency and first aid equipment—for general condition and proper stowage.
- Parachutes, life rafts, flares, and so forth—inspect following the manufacturer's recommendations.
- Autopilot system—for general condition, security of attachment, and proper operation.

### Publications

For the correct maintenance and operation of the aircraft, you need to rely on a source of information, and aeronautical publications are such a source. These include SBs, manufacturers' manuals, catalogues; FAA regulations; advertisements; advisory circulars (AC); and aircraft, engine, and propeller characteristics.

## 1.2. Routine/Required Inspections

To determine their general condition, 14 CFR requires that all civil aircraft be inspected at certain intervals, depending on the type of flights in which they are engaged. The pilot in command of a civil aircraft (PIC) is responsible for determining whether that aircraft is in a condition for safe flight. Therefore, the aircraft must be checked before each flight. More detailed inspections must be carried out by Aviation Maintenance Technicians (AMT) at least once every 12 calendar months, while an inspection is required for others after every 100 flight hours. In other cases, the aircraft may be inspected according to the established system to ensure a general inspection of the aircraft during calendar or flight period These include staged type inspections.

### Preflight/Postflight Inspections

When operating an aircraft, pilots must follow a checklist found in the Pilot's Operations Manual (POH). The first section of the checklist is called "Pre-Flight Check". The pre-flight inspection checklist includes a go-around section listing items that the pilot should visually inspect for general condition as he or she goes around the aircraft. In addition, the pilot must ensure that the fuel, oil and other items necessary for flight are at the correct level and are not contaminated. In addition, the pilot is required to review the aircraft's maintenance records and other necessary documents to ensure that the aircraft is indeed airworthy. After each flight, it is recommended that the pilot or mechanic perform a post-flight inspection to identify any problems that may require repair or maintenance before the next flight.

**Annual and 100-hour inspections**

Each person performing an annual or 100-hour inspection must use the checklist during the inspection. The checklist may be developed by the individual, provided by the manufacturer of the equipment being tested, or obtained from another source.

Each person approving a reciprocating engine for return to service after an annual or 100-hour inspection shall, before such approval, run the engine or engines to determine satisfactory performance following the manufacturer's recommendations:

1. Power output (static speed and idle speed);
2. Magnets;
3. Fuel and oil pressure;
4. Cylinder and oil temperature.

Each person approving a turbine engine for return to service after an annual, 100-hour, or incremental inspection shall, before such approval, run the aircraft engine or engines to determine satisfactory performance following the manufacturer's recommendations.

**Progressive inspection**

Each person performing a step-by-step inspection shall, at the beginning of the step-by-step inspection system, perform a complete inspection of the aircraft. This initial inspection shall be followed by routine and detailed inspections as specified in the inspection schedule. Routine checks consist of a visual inspection or inspection of the instruments, aircraft and its components and systems, as far as practicable, without disassembly. Detailed checks consist of a thorough inspection of the instruments, the aircraft, its components, and systems, with disassembly if necessary. For this subparagraph, an overhaul of a component or system is considered a detailed inspection.

If the aircraft is located far from a station where inspections are normally carried out, an appropriately qualified mechanic, certified repair station or aircraft manufacturer may inspect following the procedures and using the forms of the person who would otherwise carry out the inspection.

**Continuous Inspections**

Continuous inspection programs are like progressive inspection programs, except that they apply to larger or turbine aircraft and are therefore more complex. Like progressive inspection programs, they require FAA administrator approval. Approvals may be obtained based on the type of operation and the CFR parts under which the aircraft is operated. The maintenance program for commercially operated aircraft shall be detailed in the commercial certificate holder's approved operational specifications (OpSpec).

Airlines operate an ongoing maintenance program that includes both routine and detailed inspections. However, detailed inspections may involve different levels of detail. Inspections A, B, C, and D, often referred to as "inspections," involve increased levels of detail. A-checks are the least complex and occur frequently. D-inspections, on the other hand, are extremely comprehensive, involving extensive disassembly, disassembly, overhaul, and inspection of systems and components. They may occur only three to six times during the life of the aircraft.

**Altimeter and Transponder Inspections**

Airplanes operating in controlled airspace under instrument flight rules (IFR) must have each altimeter and static system checked within the preceding 24 calendar months. Aircraft that have an air traffic control (ATC) transponder must also test each transponder within the previous 24 months. All these checks must be carried out by suitably certified persons.

### 1.3. Airlines for America iSpec 2200

To standardize the format in which maintenance information is presented in aircraft maintenance manuals, American Airlines (formerly the Air Transport Association) issued specifications for manufacturer technical data. The original specification was called ATA Spec 100. Spec 100 has been constantly revised and updated over the years. After all, ATA Spec 2100 was designed for electronic records. These two specifications have evolved into a single document called ATA iSpec 2200. As a result of this standardization, maintenance technicians can always find information for a specific system in one section of the aircraft maintenance manual, regardless of manufacturer. For example, if the information is needed about the electrical system of any aircraft, this information can always be found in section (chapter) 24.

A4A iSPec 2200 divides the aircraft into systems such as air conditioning, which cover the basic air conditioning system (A4A 21). The numbering of each main system makes it possible to divide the system into several subsystems. Late model aircraft, both over and under the 12,500 lb designation, have parts manuals and maintenance manuals organized according to the A4Acoded system. Be aware that not all aircraft have all these systems. Small and simple aircraft have fewer systems than larger and more complex aircraft.

## 1.4. Special Inspections

During the life of the aircraft, there may be occasions when something unusual in the maintenance and use of the aircraft may affect its airworthiness. When these situations occur, special inspection procedures, also called conditional inspections, are performed to determine if structural damage to the aircraft has occurred. The procedures described on the following pages are general in nature and are intended to familiarize the aircraft mechanic with the areas to be inspected. As such, they are not all-inclusive. Always follow the detailed procedures in the aircraft maintenance manual when performing any of these special checks. In situations where the manual does not fit the situation, seek advice from other service technicians who have extensive experience with them.

### Check when landing with hard or excessive weight

The structural stress caused by landing depends not only on the total weight at that moment but also on the severity of the impact. The hard landing check is for hard landings at or below the maximum design landing limits. An overweight landing check must be performed when the aircraft lands at a weight greater than the maximum design landing weight. However, due to the difficulty in estimating the vertical velocity at the time of contact, it is difficult to judge whether the impact was severe enough to cause structural damage. For this reason, a special check is performed after landing at a weight that is known to exceed the design landing weight, or after a rough landing, even though the latter may have occurred when the airplane did not exceed the design landing weight.

Wrinkled skin on the wings is the easiest sign of excessive stress during landing. Another sign that is easy to detect is fuel leakage along the riveted seams. Other possible areas of damage are spars, bulkheads, nacelle skins and mounts, firewall skins, and wing and fuselage stringers. If none of these areas is adversely affected, it is reasonable to assume that no serious damage has occurred. If damage is found, a more thorough inspection and alignment check may be necessary.

### High Turbulence/Above "G" Check

When an aircraft encounters gust conditions, the air load on the wings exceeds the normal load on the wing supporting the weight of the aircraft. Gust tends to accelerate the aircraft, while its inertia opposes this change. If the combination of gust speed and air velocity is too severe, the induced stress can cause structural damage.

A special check is carried out after the flight due to strong turbulence. The focus is on inspecting the upper and lower surfaces of the wing for excessive buckles or wrinkles with the constant set. Where wrinkles have occurred, remove a few rivets and examine the rivet shanks to determine if the rivets have sheared off or been heavily loaded during shearing.

Through inspection doors and other accessible openings, inspect all spar webs from the fuselage to the end. Check for bends, wrinkles and cut elements. Inspect the area around the nacelles and the nacelle skin, especially on the leading edge of the wing, for distortion. Check for fuel leaks. Any significant fuel leakage is an indication that the area may have received overloads that broke the seal and exposed the seams.

If the landing gear has been lowered in severe turbulence, carefully inspect the surrounding surfaces for loose rivets, cracks, or bends. The inner part of the wheel can give additional signs of excessive gusts. Inspect the upper and lower fuselage skins. The excessive bending moment can leave diagonal wrinkles in these areas.

Inspect the surface of the plumage for wrinkles, bends, or cuts. Also, inspect the area where the tail is attached to the fuselage. These checks cover critical areas. If excessive damage is noted in any of these areas, the inspection should continue until all damage is found.

### Lightning strike

Although lightning strikes on aircraft are extremely rare, if a strike does occur, the aircraft is thoroughly inspected to determine the extent of any damage that may have occurred. When lightning strikes an aircraft, the electrical current must pass through the structure and be able to discharge or dissipate in controlled locations. Such controlled locations are primarily aircraft static discharge pits or, on more sophisticated aircraft, zero-field dischargers. When high voltage surges travel through good electrical conductors such as aluminum or steel, the damage is likely to be minimal or absent. When high voltage surges travel through non-metallic structures such as a fibreglass fairing, hood or engine cowling, a glass or plastic window, or a composite structure that has no built-in electrical connection, fires and more serious structural damage can occur. A visual inspection of the structure is required. Look for evidence of composite resin degradation, burning, or erosion on all affected structures, electrical bonding tapes, static discharge wicks, and zero-field arresters.

### Bird Strike

When an aircraft collides with birds during flight, the external areas of the aircraft are inspected in the general area of collision with birds. If the initial inspection shows structural damage, then the internal structure of the aircraft must also be inspected. Also check the hydraulic, pneumatic and any other systems around contact with the birds.

### Fire damage

Inspection of aircraft structures that have been exposed to fire or high temperatures can be relatively simple if there is visible damage. Visible damage requires repair or replacement. If there is no visible damage, the structural integrity of the aircraft may still be compromised. Since most aircraft structural metal components have undergone some form of heat treatment during manufacture, exposure to high temperatures not encountered during normal operations can seriously degrade the design strength of the structure. The strength and airworthiness of an aluminium structure that has passed visual inspection but is still suspect can be further determined with an electrical conductivity tester. This is a device that uses eddy currents and is discussed later in this section. Since the strength of metals is related to hardness, possible damage to steel structures can be determined using a hardness tester, such as a Rockwell C hardness tester.

### Flood damage

Like fire-damaged aircraft, water-damaged aircraft can range from minor to serious. This depends on the level of the flood water, whether it was fresh or salt water, and the time that elapsed between the flood and the start of the repair. Any parts that have been completely submerged in water are completely disassembled, thoroughly cleaned, dried, and treated with a corrosion inhibitor. Many parts may need to be replaced, including the interior carpet, seats, side panels, and instruments. Because water serves as an electrolyte that promotes corrosion, all traces of water and salt must be removed before the aircraft is considered airworthy again.

### Seaplanes

Because they operate in a corrosion-accelerating environment, seaplanes must be thoroughly inspected for corrosion and corrosion-promoting conditions. Inspect bilge areas for used hydraulic fluids, water, dirt, chips, and other debris. In addition, since seaplanes are often subjected to excessive stress from the impact of rushing water at high speeds, check that rivets and other fasteners are not secured; stretched, bent, or cracked hides; damage to the float attachment and general wear and tear of the entire structure.

### Aircraft of aerial use

The two main factors that differentiate the inspection of these aircraft from other aircraft are the corrosive nature of some of the chemicals used and the typical flight profile. The harmful effects of corrosion can be detected in a much shorter period than in conventional aircraft. Chemicals can soften the fabric or weaken the fabric tapes of fabric-covered aircraft. Metal aircraft may require annual paint stripping, cleaning, repainting, and anti-corrosion treatment. The leading edges of the fenders and other areas may require a protective coating or tape. Equipment may require more frequent replacement.

During peak use, these aircraft may perform up to 50 cycles (takeoffs and landings) or more per day, most likely from an undeveloped or grass runway. This can significantly accelerate the failure of elements subject to normal fatigue. The chassis and associated items require frequent inspections. Because these aircraft operate almost continuously at very low altitudes, the air filters tend to clog more quickly.

## 1.5. Special Flight Permits

An aircraft that is not currently airworthy due to an overdue inspection, damage, expiration of time-limited replacement parts, or other reasons, but is capable of safe flight, may be issued a special permit to fly. Special flight permits, often called ferry permits, are issued for the following purposes:

- Flying the aircraft to a base where repairs, alterations, or maintenance are to be performed or to a point of storage
- Delivering or exporting the aircraft
- Production flight testing of new production aircraft
- Evacuating aircraft from areas of impending danger
- Conducting customer demonstration flights in new production aircraft that have satisfactorily completed production flight tests

## 1.6. Nondestructive Inspection/Testing

Non-destructive testing (NDT) or Non-destructive inspection (NDI) is a testing and analysis method used in industry to evaluate the properties of a material, component, structure or system for characteristic differences or weld defects and tears without damaging the original part.

### Training, Qualification, and Certification

The product manufacturer or the FAA usually specifies the specific NDI method and procedure to be used during the inspection. These NDI requirements are specified in the manufacturer's inspection, maintenance, or overhaul manual, FAA announcements, supplemental design verification documents

The success of any R&D method and procedure depends on the knowledge, skills, and experience of the R&D personnel involved. Persons responsible for the detection and interpretation of indicators such as eddy currents, X-rays, or ultrasonic NRIs must be qualified and certified following certain FAA or other acceptable government or industry standards, such as MIL-STD-410, nondestructive Personnel Qualification and Certification, conducting the test, or A4A iSPec 2200, Recommendations for the training and qualification of personnel in non-destructive testing methods. The person must be familiar with the test method, know the potential types of breaks characteristic of the material, and be aware of their effect on the structural integrity of the part.

### Advantages and disadvantages of NDI methods

Table 1.1 shows the advantages and disadvantages of common R&D methods. This table can be used as a guide to evaluating the most appropriate NDI method if the manufacturer or the FAA has not specified a specific NDI method to be used.

**Table 1.1.** Advantages and disadvantages of NDI methods

| Method | Advantages | Disadvantages |
|---|---|---|
| Visual | • Inexpensive<br>• Highly portable<br>• Immediate results<br>• Minimum training<br>• Minimum part preparation | • Surface discontinuities only<br>• Generally, only large discontinuities<br>• Misinterpretation of scratches |
| Penetrant Dye | • Portable<br>• Inexpensive<br>• Sensitive to very small discontinuities<br>• 30 minutes or less to accomplish<br>• Minimum skill required | • Locate surface defects only<br>• Rough or porous surfaces interfere with the test<br>• Part preparation required (removal of knishes and sealant, etc.)<br>• High degree of cleanliness required<br>• Direct visual detection of results required |
| Magnetic Particle | • Can be portable<br>• Inexpensive<br>• Sensitive to small discontinuities<br>• Immediate results<br>• Moderate skill required<br>• Detects surface and subsurface discontinuities<br>• Relatively fast | • Surface must be accessible<br>• Rough surfaces interfere with the test<br>• Part preparation required (removal of knishes and sealant, etc.)<br>• Semi-directional requiring general orientation of held to discontinuity<br>• Ferro-magnetic materials only<br>• Part must be demagnetized after |

| | | |
|---|---|---|
| | | the test |
| Eddy Current | • Portable<br>• Detects surface and subsurface discontinuities<br>• Moderate speed<br>• Immediate results<br>• Sensitive to small discontinuities<br>• Thickness sensitive<br>• Can detect many variables | • Surface must be accessible to probe<br>• Rough surfaces interfere with the test<br>• Electrically conductive materials<br>• Skill and training required<br>• Time-consuming for large areas |
| Ultrasonic | • Portable<br>• Inexpensive<br>• Sensitive to very small discontinuities<br>• Immediate results<br>• Little part preparation<br>• Wide range of materials and thicknesses can be inspected | • Surface must be accessible to probe<br>• Rough surfaces interfere with the test<br>• Highly sensitive to sound beam discontinuity orientation<br>• High degree of skill and experience required for exposure and interpretation<br>• Depth of discontinuity not indicated |
| X-Ray Radiography | • Detects surface and internal flaws<br>• Can inspect hidden areas<br>• Permanent test record obtained<br>• Minimum part preparation | • Safety hazard<br>• Very expensive (slow process)<br>• Highly directional, sensitive to raw orientation<br>• High degree of skill and experience required for exposure and interpretation<br>• Depth of discontinuity not indicated |
| Isotope Radiography | • Portable<br>• Less inexpensive than x-ray<br>• Detects surface and internal flaws<br>• Can inspect hidden areas<br>• Permanent test record obtained<br>• Minimum part preparation | • Safety hazard<br>• Must conform to federal and state regulations for handling and use<br>• Highly directional, sensitive to ˜aw orientation<br>• High degree of skill and experience required for exposure and interpretation<br>• Depth of discontinuity not indicated |

### General Techniques

Before conducting an NDI, preparatory steps must be taken according to the procedures specific to this type of inspection. Generally, parts or areas must be thoroughly cleaned. Some parts must be removed from the aircraft or engine. Others may require the removal of paint or protective coating. Thorough knowledge of equipment and procedures is essential, and calibration and verification of equipment should be current, if necessary.

### 1.6.1. Visual Inspection

Visual inspection can be improved by looking at the suspicious area with a bright light, magnifying glass, and mirror. Some defects may be so obvious that additional inspection methods are not required. The absence of visible defects does not necessarily mean that further inspection is unnecessary. Some defects may lie beneath the surface or be so small that the human eye, even with a magnifying glass, cannot detect them.

### Surface Cracks

When searching for surface cracks with the help of a flashlight, direct the beam of light at an angle of 5 to 45 degrees to the inspection surface in the direction of the end. [Figure 1.1] Do not direct the light beam at such an angle that the reflected light beam is directed into the eyes. Keep your eyes above the reflected light beam when examining. Determine the size of any cracks found by shining a light beam at right angles to the crack and tracing its length. Use a 10x magnifying glass to confirm the presence of a suspected crack. If this is not sufficient, use other NDI methods such as penetrant, magnetic particles, or eddy current for crack inspection.

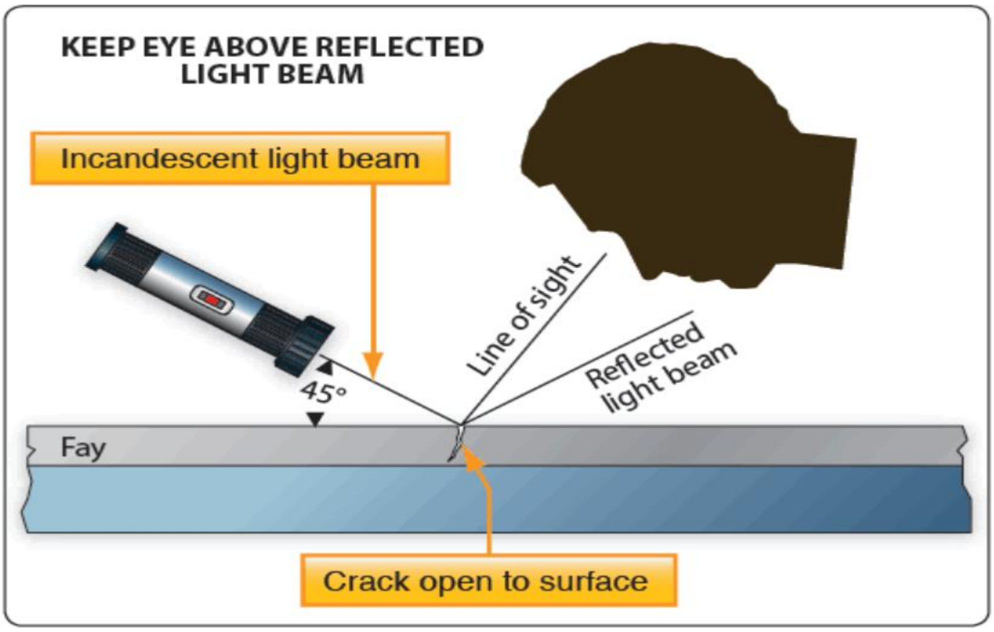


Figure 1.1 Using a flashlight to inspect for cracks

**Borescope**

A borescope inspection is essentially a visual inspection. A borescope is a device that allows an inspector to see internal areas that otherwise could not be inspected without disassembly. Borescopes are used in aircraft and engine maintenance programs to reduce or eliminate the need for expensive disassembly. Aircraft turbine engines have access holes that are specially designed for borescopes. Borescopes are also widely used in a variety of aviation maintenance programs to determine the airworthiness of hard-to-reach components. Borescopes are typically used to inspect the interior of hydraulic cylinders and valves for pitting, scratches, porosity, and tool marks; search for cracked cylinders in aviation piston engines; check turbine blades and combustion chambers of turbojet engines; check the correct placement and fit of seals, fasteners, gaskets, and assemblies in hard-to-reach places; and assess Foreign Object Damage (FOD) in the aircraft, airframe and propulsion systems. Borescopes can also be used to locate and remove foreign objects in aircraft engines and fuselages.

Borescopes are available in two basic configurations. The simplest of these is a rigid telescope of small diameter with a tiny mirror on the end that allows the user to see around corners. Another type uses fibre optics for greater flexibility. [Figure 1.2] Many borescopes provide images that can be displayed on a computer or video monitor to better interpret what is being viewed and to record images for future use. Most borescopes also include a light to illuminate the area being examined.

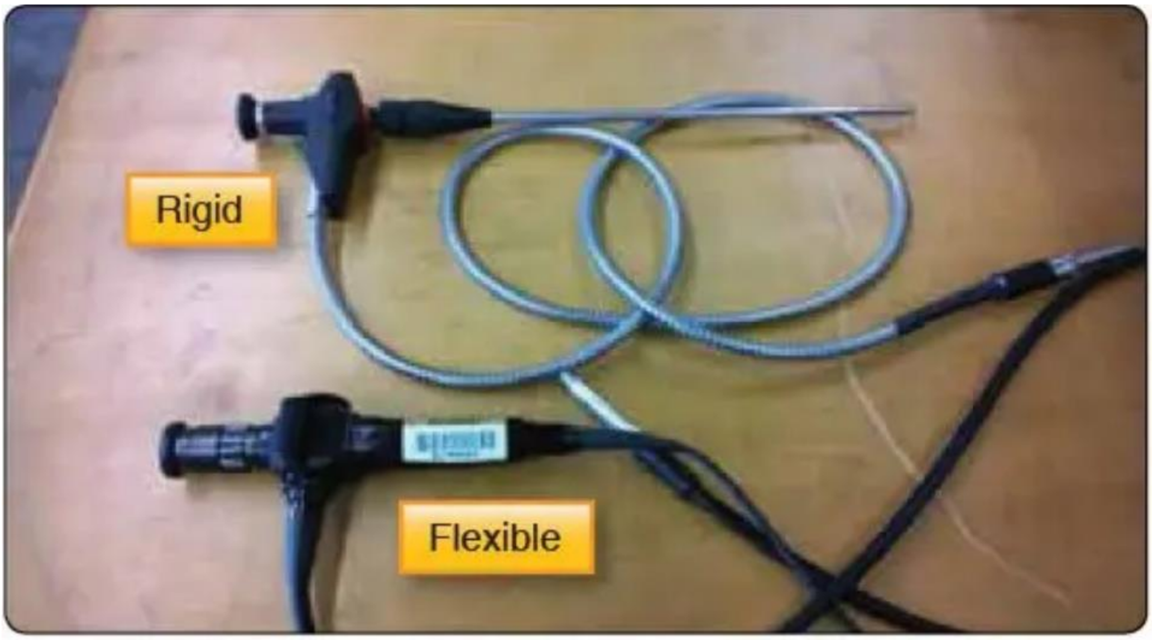


Figure 1.2 Rigid and flexible borescopes

### 1.6.2. Liquid Penetrant Inspection

Penetrant testing is the non-destructive testing of surface-exposed defects in parts made of any non-porous material. It is used with equal success on such metals as aluminium, magnesium, brass, copper, cast iron, stainless steel, and titanium. It can also be used on ceramics, plastics, moulded rubber, and glass.

Penetrant inspection detects defects such as surface cracks or porosity. These defects can be caused by fatigue cracks, shrinkage cracks, shrinkage porosity, cold closure, grinding and heat treatment cracks, seams, laps, and tears. Penetrant testing also indicates no bond between the joined metals. The main disadvantage of penetrant testing is that the defect must be open to the surface for the penetrant to penetrate the defect. For this reason, if the part in question is made of magnetic material, the use of magnetic powder inspection is usually recommended.

Penetration uses a penetrating fluid that enters a surface hole and remains there, making it visible to the inspector. It requires a visual inspection of the part after it has been machined to increase the visibility of the defect so that it can be detected. The visibility of the penetrating material is increased by adding one or two types of dye: visible or fluorescent.

The visible penetrant kit consists of a dye penetrant, a dye removal emulsifier, and a developer. The fluorescent penetrant inspection kit includes a black light unit, as well as cans of penetrant, cleaner, and developer. The lighting unit consists of a power transformer, a flexible power cable and a hand lamp. Thanks to its size, the lamp can be used in almost any position and place.

The stages of penetration are as follows:

1. Thoroughly clean the metal surface.
2. Apply penetrant.
3. Remove penetration with an emulsifier or cleaning.
4. Dry the part.
5. Apply a manner.
6. Examine and interpret the results.

**Interpretation of Results**

The success and reliability of the penetrating verification depend on the care of the workpiece. Several basic principles apply to penetration testing:

1. The penetrant must enter the defect to form an indication. It is important to allow enough time for the penetrant to fill the defect. The defect should be clean and free from polluting materials so that the penetrant can penetrate freely.
2. If all the penetrant is washed out of the defect, no indication can be formed. During surgery, washing or washing, the penetrant may be removed from the inside of the defect, as well as from the surface.
3. Clean cracks are usually easy to spot. Surface openings that are not contaminated, no matter how small they are, it is rare to detect with penetrating control.
4. The smaller the defect, the longer the penetration time. Small crack holes require more penetration than defects, such as pores.
5. If the item is to be verified from a material susceptible to magnetism, it should be checked by magnetic control, if such equipment is available.

6. A visible developer of the penetrating type, applied to the surface of the part, dries to a smooth white coating. As the developer dries, bright red spots appear on surface defects. If red signs do not appear, there are no surface defects.

7. When tested with a fluorescent penetrant, defects appear (under a black light) as a brilliant yellow-green colour, and sound zones appear a deep blue-violet.

8. It is possible to study the signs of the defect and determine its cause, as well as its degree. Such an estimate can be made if something is known about the manufacturing processes to which the part was subjected.

The size of the indication or accumulation of penetrant shows the extent of the defect, and the gloss is a measure of its depth. Deep cracks penetrate better, are wider, and are shiny. Very small holes may hold only small amounts of penetrants and appear as fine lines. [Figure 1.3]

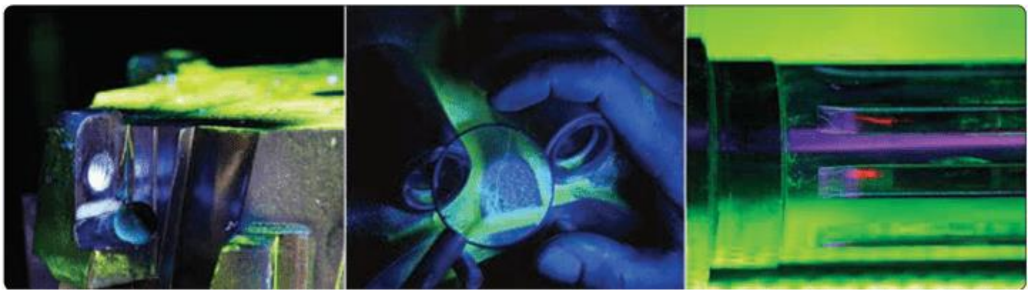


Figure 1.3 Dye penetrant inspection

**False Indications**

With penetrating control, there are no false readings in the sense that they occur during magnetic powder control. However, two conditions can cause penetrant build-up that is sometimes confused with true surface cracks and tears.

The first condition involves signs caused by poor-quality washing. If all of the surface penetrants are not removed during the washing or rinsing operation after the penetrant dwell time, the unremoved penetrant will be visible. Evidence of incomplete flushing is usually easy to identify because the penetrant is in broad areas rather than the sharp patterns found with true signs. If an accumulation of unwashed penetrants is detected on the part, the part must be completely treated. Degreasing is recommended to remove all traces of penetrant.

False marks can also be created if parts are pressed together. If the wheel is pressed against the shaft, the penetrant shows a mark on the landing line. This is quite normal as the two parts are not meant to be welded. Signs of this type are easy to identify because they have a regular shape and form.

### 1.6.3. Eddy Current Inspection

The electromagnetic analysis is a term that describes a wide range of electronic testing techniques involving the intersection of magnetic fields and circulating currents. The most common method is eddy current. Eddy currents consist of free electrons under the influence of an induced electromagnetic field, which "drift" through the metal. Eddy current is used to detect surface cracks, pits, subsurface cracks, and corrosion on internal surfaces, as well as to determine alloy and heat treatment conditions.

Eddy currents are used in aircraft maintenance to check jet engine turbine shafts and blades, wing fairings, wheels, bolt holes, and spark plug holes for cracks, heat, or frame damage. Eddy currents can also be used to repair aluminium aircraft damaged by fire or excessive heat. Different meter readings are visible when the same metal has a different state of hardness. Readings in the affected area are compared with identical materials in known unaffected areas for comparison. The difference in readings indicates a difference in the hardness of the affected area. In aircraft factories, eddy current is used to inspect castings, stampings, machine parts, forgings, and extrusions. Figure 1.4 shows a technician performing an eddy current inspection of a fan blade.

Figure 1.4 Eddy's current inspection

**Basic Principles**

When alternating current (AC) is passed through the coil, it creates a magnetic field around the coil, which in turn induces a voltage of opposite polarity in the coil and opposes the flow of the original current. If this coil is placed in such a way that the magnetic field passes through the conductive sample, then eddy currents are induced in the sample. Eddy currents create their field, which reverses the opposition of the original field to the flow of the output current. The susceptibility of the sample to eddy currents determines the current flowing through the coil.

The magnitude and phase of this counter field depend mainly on the resistance and permeability of the sample under consideration and allow qualitative determination of various physical properties of the material under study. The interaction of the eddy current field with the initial field results in a power change that can be measured using an electronic circuit like a Wheatstone bridge.

**Principles of Operations**

Eddy currents are induced in the test product when an alternating current is applied to the test coil (probe). The alternating current in the coil creates an alternating magnetic field in the product, causing eddy currents to flow through the product. [Figure 1.5]

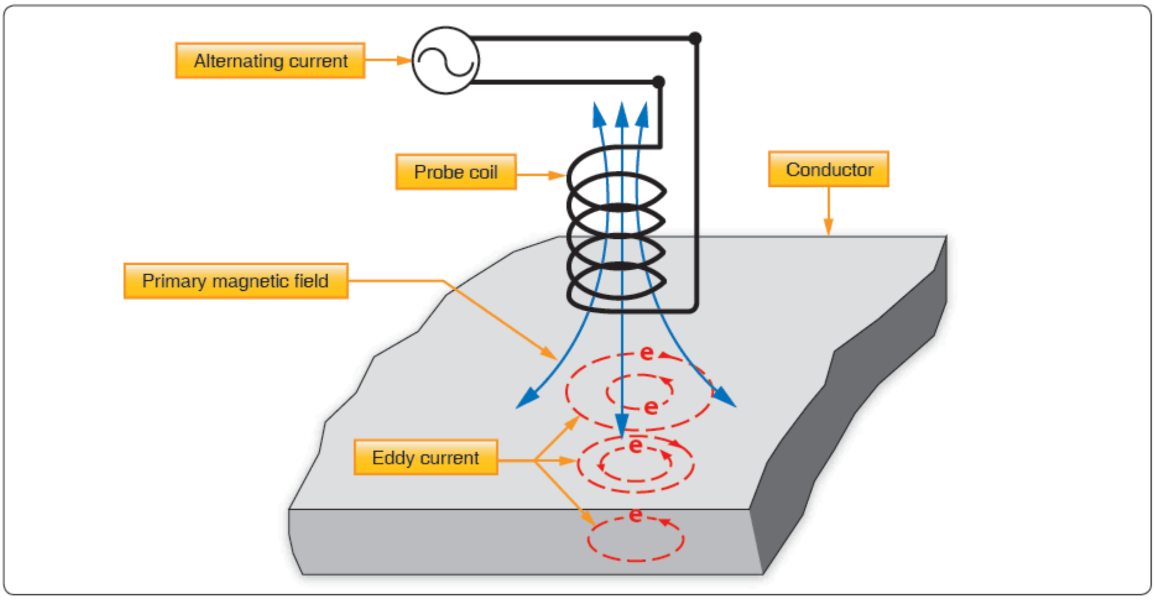
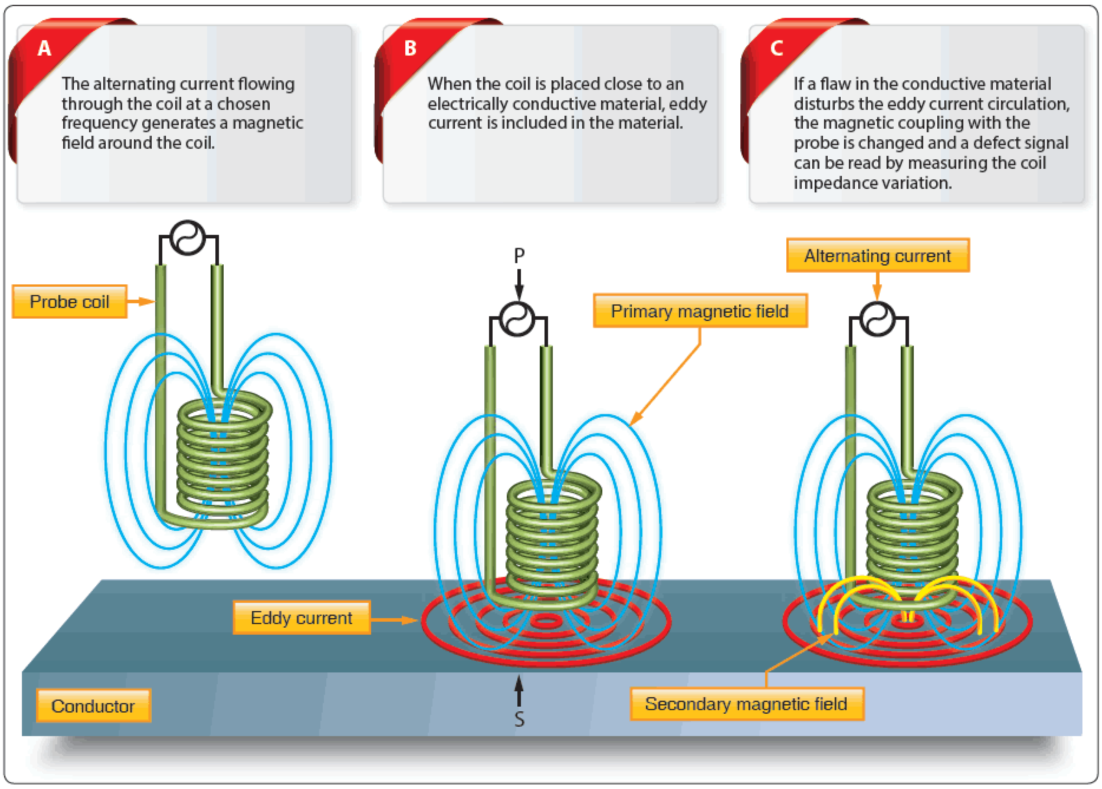


Figure 1.5 Generating an eddy current

Defects or changes in the thickness of the test specimen affect the flow of eddy currents and accordingly change the impedance of the coil. [Figure 1.6] The instruments display changes in impedance either by plots of the impedance plane or by arrow deflection. [Figure 1.7]



A The alternating current flowing through the coil at a chosen frequency generates a magnetic field around the coil.

B When the coil is placed close to an electrically conductive material, eddy current is included in the material.

C If a flaw in the conductive material disturbs the eddy current circulation, the magnetic coupling with the probe is changed and a defect signal can be read by measuring the coil impedance variation.

Figure 1.6 Detecting an eddy current

Figure 1.7 Impedance plane test

A sample is placed or passed through the field of an electromagnetic induction coil, and its effect on the resistance of the coil or the output voltage of one or more coils is observed. The process, which involves electric fields created to probe a sample under various conditions, involves the transfer of energy through the sample, like the transfer of X-rays, heat, or ultrasound.

Eddy current inspection can often be performed without removing surface coatings such as primer, paint, and anodized films. It can be effective in detecting surface and subsurface corrosion, and heat treatment conditions.

**Eddy Current Instruments**

A wide selection of eddy current measurement devices is available. The device for measuring eddy currents performs three main functions: generation, reception, and display. The generating part of the unit provides an alternating current for the test coil. The receiving section processes the signal from the test coil to the required shape and amplitude for display. Instrument outputs or displays consist of a variety of visual, audio, memory, or transmission methods using counters, video displays, chart recorders, alarms, magnetic tape, computers, and electrical or electronic relays.

A reference standard is necessary for the calibration of eddy current measuring equipment. The reference standard is made of the same material as the product under test. The reference standard contains known defects or cracks and may include features such as a notch in the flat surface, a fastener head, a fastener hole, or a countersink hole. Figures 1.8, 1.9, and 1.10 show typical surface cracks, subsurface cracks, and structural corrosion that can be detected using eddy current techniques.

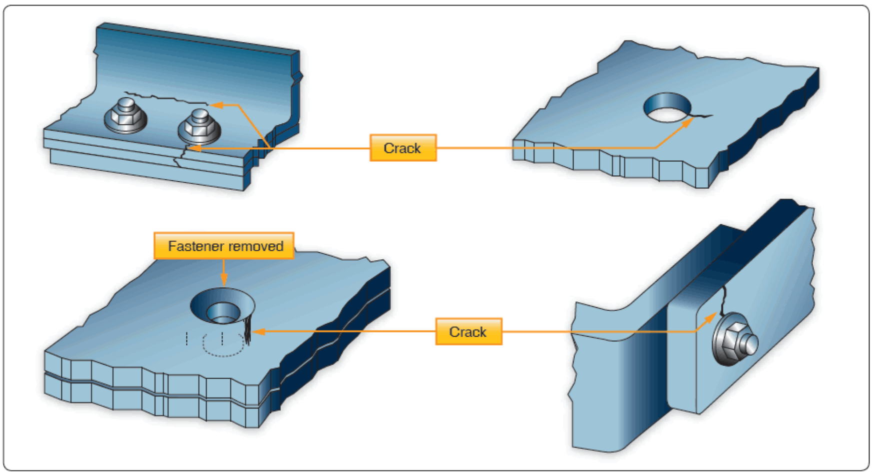


Figure 1.8 Typical subsurface cracks

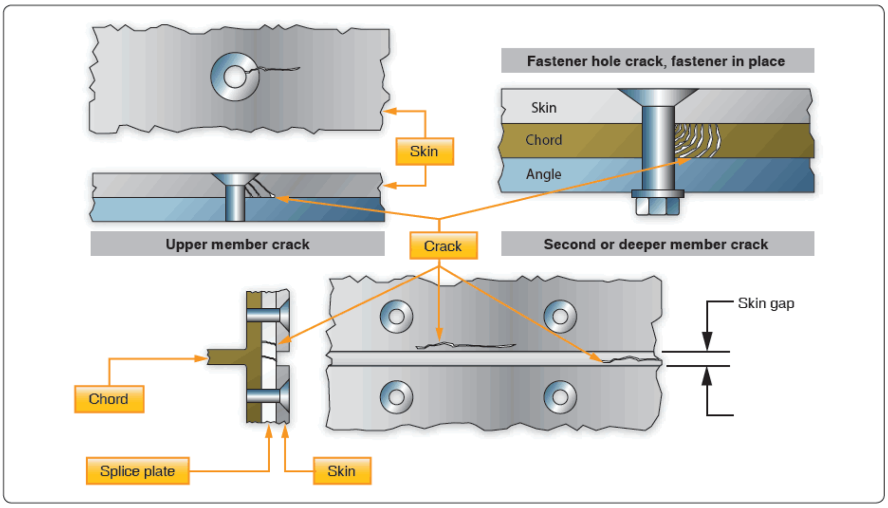


Figure 1.9 Typical surface cracks

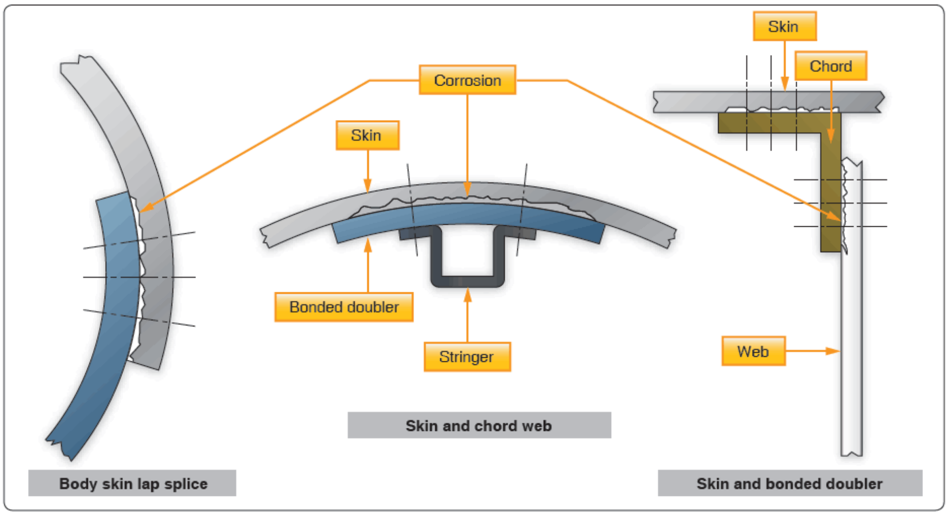


Figure 1.10 Typical structural corrosion

### 1.6.4. Ultrasonic Inspection

Ultrasonic inspection is an NDI method that uses sound energy travelling through a test specimen to detect defects. Sound energy passing through the sample is displayed on a cathode ray tube (CRT), liquid crystal display (LCD) data computer program, or video/camera media. Front and back surface readings and indoor/outdoor conditions appear as vertical signals on the CRT screen or data nodes in the computer test program. [Figure 1.11] There are three types of display patterns: "A" scan, "B" scan and "C" scan. Each scan provides a different image or view of the sample being examined. [Figure 1.12]

Figure 1.11 Ultrasonic inspection

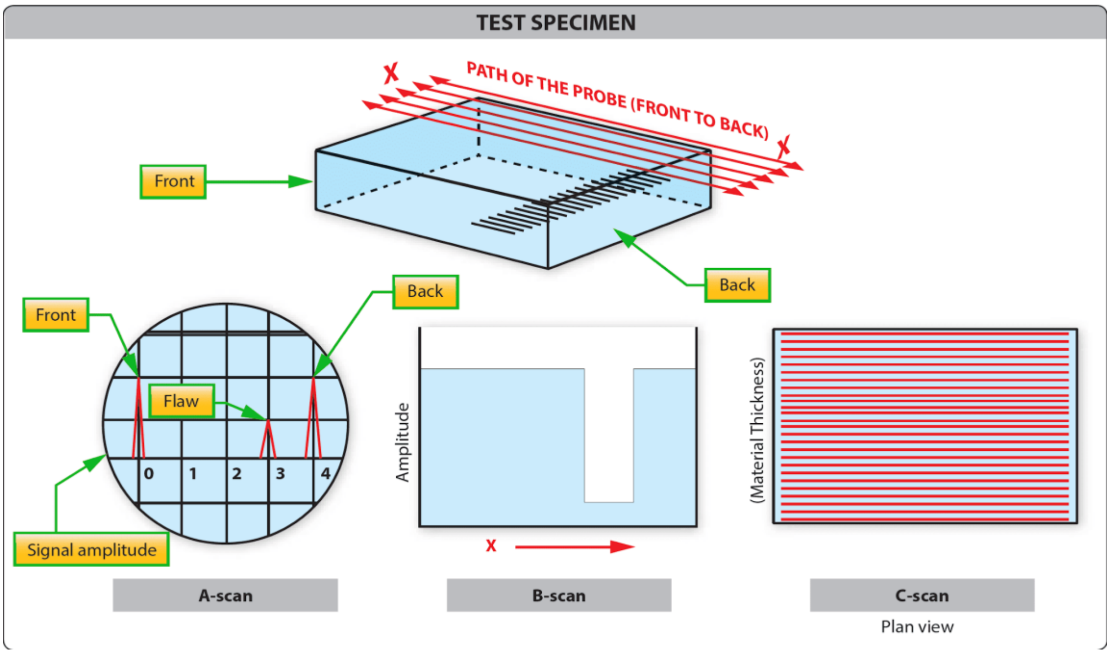


Figure 1.12 Typical structural corrosion

Ultrasonic detection equipment makes it possible to locate defects in all types of materials. Minute cracks, checks, and voids too small to be seen by x-ray can be located by ultrasonic inspection. An ultrasonic test instrument requires access to only one surface of the material to be inspected and can be used with either straight line or angle beam testing techniques.

Two basic methods are used for ultrasonic inspection. The first of these methods is immersion testing. In this method of inspection, the part under examination and the search unit is completely immersed in a liquid couplant, such as water or other suitable fluids.

The second method is called contact testing. It is readily adapted to field use and is the method discussed. In this method, the part under examination and the search unit is coupled with a viscous material, liquid, or paste that wets both the face of the search unit and the material under examination.

There are three basic ultrasonic inspection methods: pulse echo, transmission, and resonance. Through transmission and pulse-echo are shown in Figure 1.13

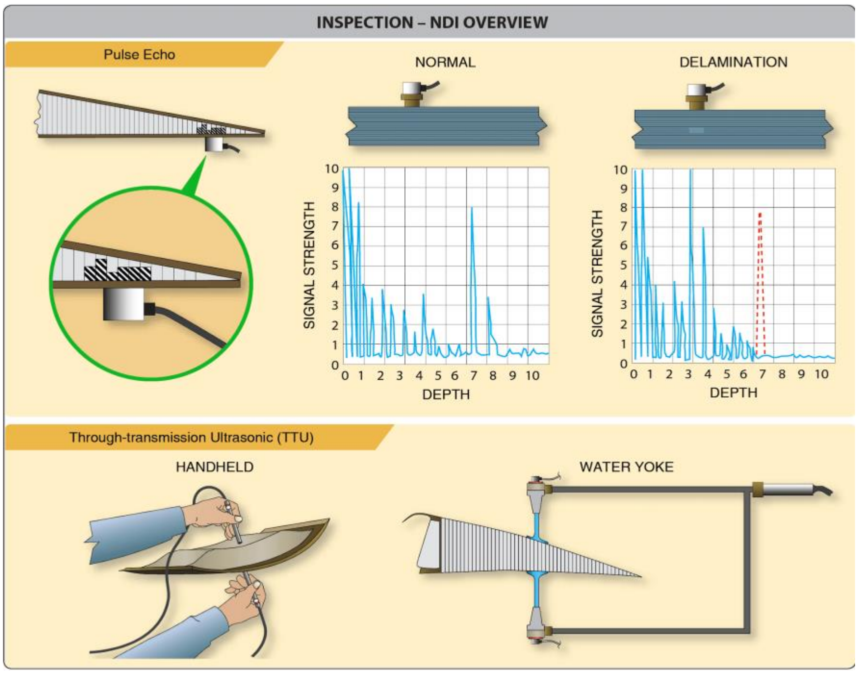


Figure 1.13 Through-transmission and pulse echo indications

## Pulse Echo

Flaws are detected by measuring the amplitude of signals reflected and the time required for these signals to travel between specific surfaces and the discontinuity. [Figure 1.14]

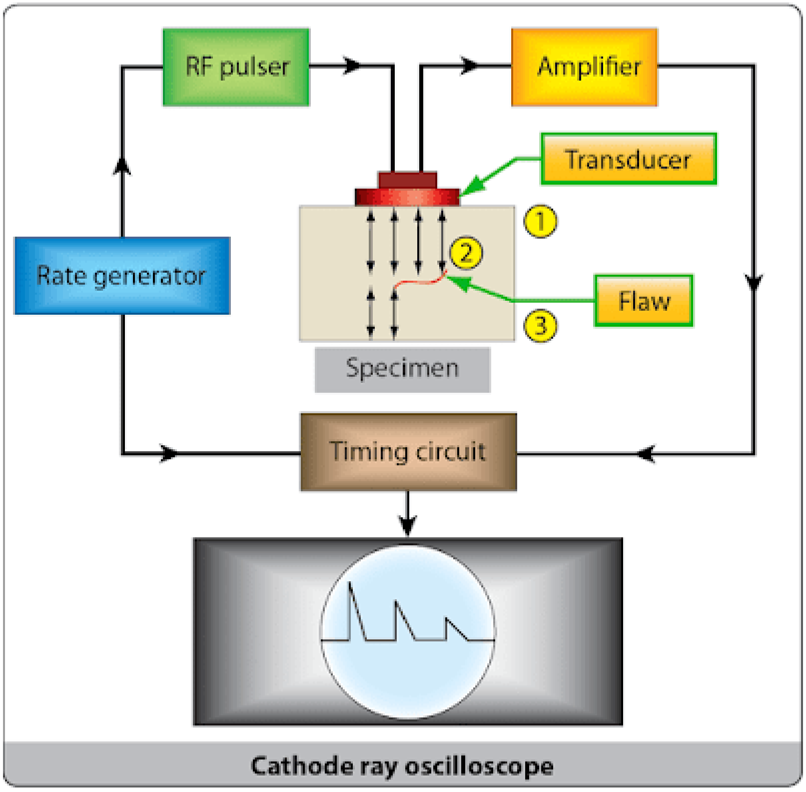


Figure 1.14 Block diagram of a basic pulse-echo system

A time base triggered simultaneously with each transmit pulse, causes the spot to run across the screen of the CRT or LCD monitor. The spot moves from left to right across the sight surface at a rate of 50 to 5,000 times per second, or faster if necessary for high-speed automatic scanning. Due to the speed of the transmit and receive cycle, the image on the oscilloscope appears stationary.

A few microseconds after the start of the sweep, the velocity generator electrically excites the pulsator, which in turn emits an electrical pulse. The transducer converts this pulse into a short series of ultrasonic waves. If the interface between the sensor and the sample is properly oriented, the ultrasound is reflected in the transducer when it reaches the internal defect and the opposite surface of the sample. The time interval between the transmission of the initial pulse and the reception of signals from the sample is measured by timing circuits. The reflected pulse received by the transducer is amplified, transmitted, and displayed on the device screen. The pulse is displayed in the same relation to the front and back pulses as the defect is to the front and back surfaces of the sample. [Figure 1.15]

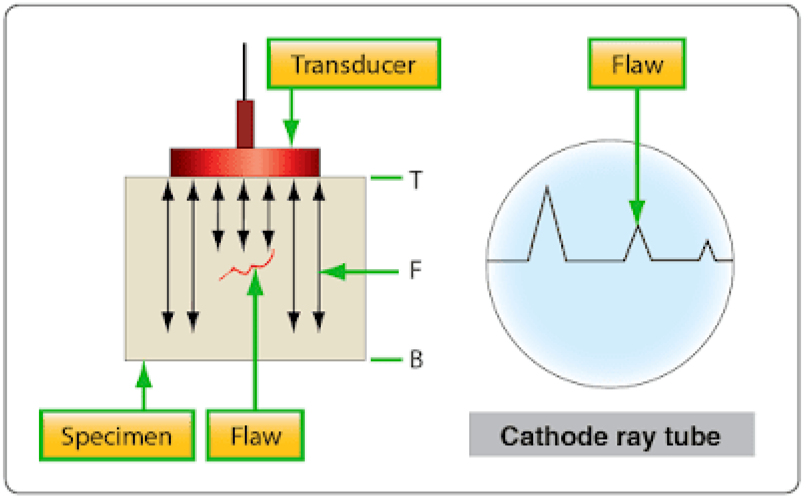


Figure 1.15 Pulse-echo display in relationship to flaw detection

Pulse-echo instruments can also be used to detect defects not directly below the probe using the angled beam test method. Angled beam testing differs from direct beam testing only in how the ultrasonic waves pass through the material being tested. As shown in Figure 1.16, the beam is projected into the material at an acute angle to the surface using a crystal cut at an angle and mounted in plastic. The beam or part of it is successively reflected from the surfaces of the material or any other discontinuity, including the edge of the piece. In direct beam testing, the horizontal distance on the screen between the initial pulse and the first return reflection represents the thickness of the piece, while in corner beam testing this distance represents the width of the material between the search block and the opposite edge of the piece.

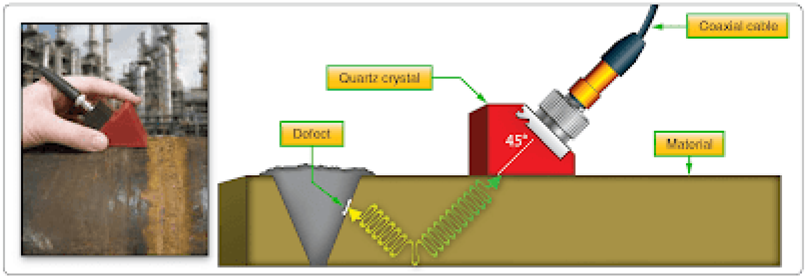


Figure 1.16 Pulse-echo angle beam testing

## Through Transmission

Transmission testing uses two transducers, one to generate the pulse and the other placed on the opposite surface to receive it. Violation of the sound path indicates a defect and is displayed on the device screen. Through transmission is less sensitive to small defects than the pulse-echo method.

**Resonance**

This system differs from the pulse method in that the frequency of transmission may be continuously varied. The resonance method is used principally for thickness measurements when the two sides of the material being tested are smooth and parallel and the back side is inaccessible. The point where the frequency matches the resonance point of the material being tested is the thickness-determining factor. It is necessary that the frequency of the ultrasonic waves corresponding to a particular dial setting be accurately known. Checks are made with standard test blocks to guard against the possible drift of frequency.

If the frequency of an ultrasonic wave is such that its wavelength is twice the thickness of a specimen (fundamental frequency), then the reflected wave arrives back at the transducer in the same phase as the original transmission so that strengthening of the signal occurs. This results from constructive interference or resonance and is shown as a high amplitude value on the indicating screen. If the frequency is increased such that three times the wavelength equals four times the thickness, the reflected signal returns completely out of phase with the transmitted signal and cancellation occurs. Further increase of the frequency causes the wavelength to be equal to the thickness again and gives a reflected signal in phase with the transmitted signal and a resonance once more. By starting at the fundamental frequency and gradually increasing the frequency, successive cancellations and resonances can be noted, and the readings used to check the fundamental frequency reading. [Figure 1.17]

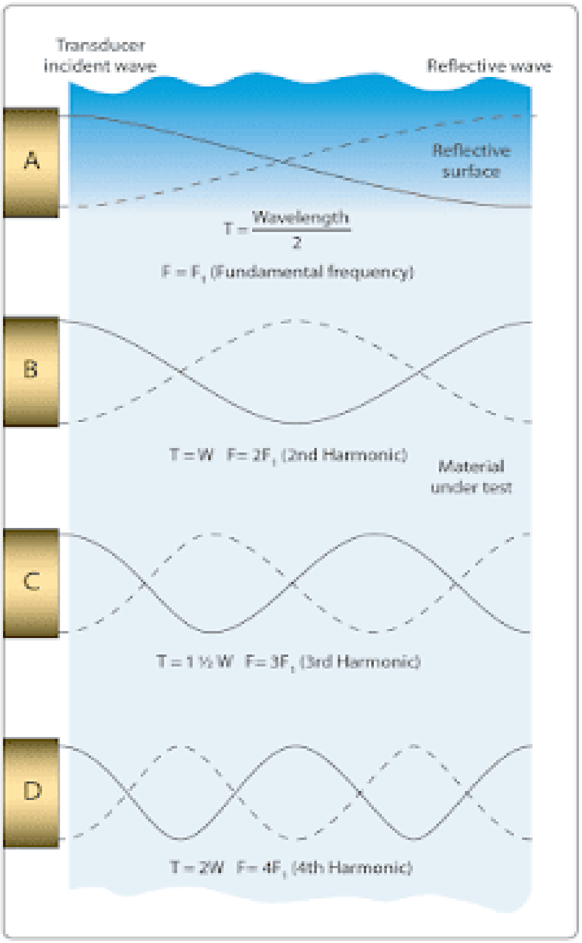


Figure 1.17. Conditions of ultrasonic resonance in a metal plate

In some appliances, the generator circuit contains a motor-driven capacitor that changes the frequency of the generator. [Figure 1.18] In other devices, the frequency is changed by electronic means. The frequency change is synchronized with the horizontal sweep of the CRT. The horizontal axis represents the frequency range. If the frequency range contains resonances, the circuit is arranged to feed them vertically. Calibrated transparent scales are then placed in front of the tube and the thickness can be read directly. Instruments typically operate from 0.25 mill cycle (ms) to 10 ms in four or five ranges.

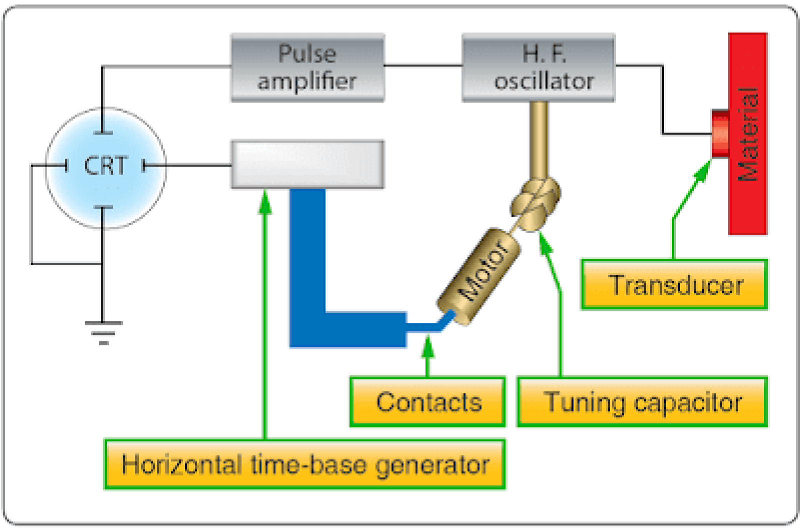


Figure 1.18 Block diagram of resonance thickness measuring system

A resonant thickness gauge can be used to check the thickness of metals such as steel, cast iron, brass, nickel, copper, silver, lead, aluminium and magnesium. In addition, areas of corrosion or wear on tanks, pipes, aircraft wing skins, and other structures or products can be identified and evaluated. Dial-operated direct-reading instruments are available that measure thicknesses from 0.025 in. to 3 in. with an accuracy of better than ±1 percent. Ultrasonic inspection requires a skilled operator who is familiar with the equipment being used as well as the inspection method for the many different parts being inspected. [Figure 1.19]

Figure 1.19 Ultrasonic inspection of a composite structure

### Ultrasonic Instruments

A portable, battery-powered ultrasound device is used for field inspection of aircraft structures. The device generates an ultrasound pulse, detects and amplifies the returning echo signal, and displays the detected signal on a CRT or similar display. Piezoelectric transducers produce longitudinal or transverse waves, which are most commonly used for aircraft structural testing.

### Reference Standards

Reference standards are used to calibrate the ultrasonic instrument. Reference standards serve two purposes: to provide an ultrasonic response pattern that is related to the part being inspected and to establish the required inspection sensitivity. To obtain a representative response pattern, the reference standard configuration is the same as that of the test structure or is a configuration that provides an ultrasonic response pattern representative of the test structure. The reference standard contains a simulated defect (notch) that is positioned to provide a calibration signal representative of the expected defect. The notch size is chosen to establish inspection sensitivity (response to the expected defect size). The inspection procedure gives a detailed description of the required reference standard.

### Complaints

Ultrasonic testing is limited to the part in contact with the sensor. A layer of contact material is required to connect the transducer to the test specimen because ultrasonic energy does not propagate through air. Some typical binders used are water, glycerin, motor oils and grease.

## 1.7. Inspection of Aircraft Bonded Structures

Ultrasonic control is increasingly used in the construction and repair of aircraft. Many configurations and types of bonded structures are used in aircraft. All these varieties complicate the application of ultrasonic control. An inspection method that works well on one part or one area of a part may not apply to different parts or areas of the same part. Below are some variables of bound structure types:

- The upper cladding is made of different materials and thicknesses

- Adhesives of various types and thicknesses are used in glued constructions
- Basic structures include differences in the core material, cell size, thickness, height, back skin material and thickness, doublers (material and thickness), closure fasteners, foam adhesive, shell grades, internal ribs and laminate (number of layers, layer thickness and material layer)
- Only the upper or upper and lower shells of a bonded structure may be available

**Types of Defects**

Defects can be divided into five general types to represent different regions of bonded and laminated structures as follows:

- Type I — separations or voids at the outer interface between the skin and the adhesive.
- Type II — separation or voids at the interface of the adhesive with the core.
- Type III — voids between laminate layers.
- Type IV — voids in the foam adhesive or separation between the adhesive and the closure element where the core joins the closure element.
- Type V — water in the core.

### 1.7.1. Acoustic Emission Inspection

Acoustic emission is an NDI method that involves placing acoustic emission sensors at various locations on the aircraft structure and then applying a load or voltage. Materials emit sound waves and voltage waves, which take the form of ultrasonic pulses. Cracks and areas of corrosion in the airframe's stressed structure emit sound waves that are registered by sensors. These bursts of acoustic radiation can be used to detect defects and estimate their growth rate as a function of the applied load. Acoustic emission testing has an advantage over other NDI methods because it can detect and locate all activated defects in a structure in a single test. Due to the complexity of aircraft designs, the application of acoustic emission testing to aircraft required a new level of sophistication in test techniques and data interpretation.

### 1.7.2. Magnetic Particle Inspection

Magnetic particle inspection is a method of detecting invisible cracks and other defects in ferromagnetic materials such as iron and steel. This does not apply to non-magnetic materials. In rapidly rotating, reciprocating, vibrating, and other highly stressed aircraft parts, small defects often develop to the extent that they lead to the complete failure of the part. Magnetic powder inspection has proven to be extremely reliable in quickly identifying such defects located on or near the surface. With this inspection method, the location of the defect is indicated and the approximate size and shape are outlined.

The inspection process consists of magnetizing the part and applying ferromagnetic particles to the surface to be inspected. Ferromagnetic particles (indicator medium) can be held in suspension in a liquid that is washed over the part; the part can be immersed in a suspension liquid, or particles in the form of a dry powder can be sprinkled on the surface of the part. The wet process is more often used when inspecting aircraft parts.

If a discontinuity is present, the magnetic field lines are disrupted and opposite poles exist on either side of the discontinuity. Thus, the magnetized particles form a pattern in the magnetic field between opposite poles. This template, known as an "indication", provides an approximate shape for the projection of the rupture surface. A break can be defined as an interruption of the normal physical structure or configuration of a part, such as a crack, overlap, seam, inclusion, porosity, etc. A tear may or may not affect the usefulness of the part.

#### Development of Indications

When a discontinuity in a magnetized material is exposed to the surface and the magnetic substance (indicator medium) is available at the surface, flux leakage across the discontinuity tends to form the tracer medium in the path of higher permeability. (Permeability is a term used to refer to the ease with which magnetic flux can be established in a given magnetic circuit.) Because of the magnetism in the part and the adhesion of the magnetic particles to each other, an indication remains on the surface of the part in the form of an approximate outline of the break just below it. The same action occurs when the break is not exposed to the surface, but because the amount of flux leakage is less, fewer particles are held in place and a weaker and less clear indication is obtained.

If the rupture is very far from the surface, there may be no flow leakage and surface indications. Flow leakage at a transverse discontinuity is shown in Figure 1.20

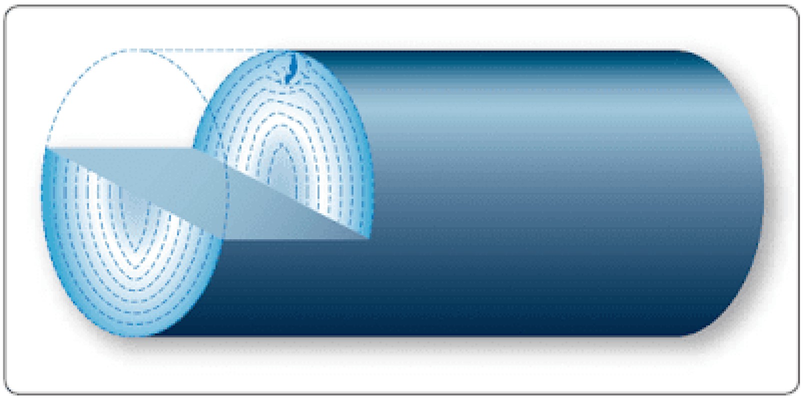


Figure 1.20 Flux leakage at the transverse discontinuity

The flux leakage at a longitudinal discontinuity is shown in Figure 1.21

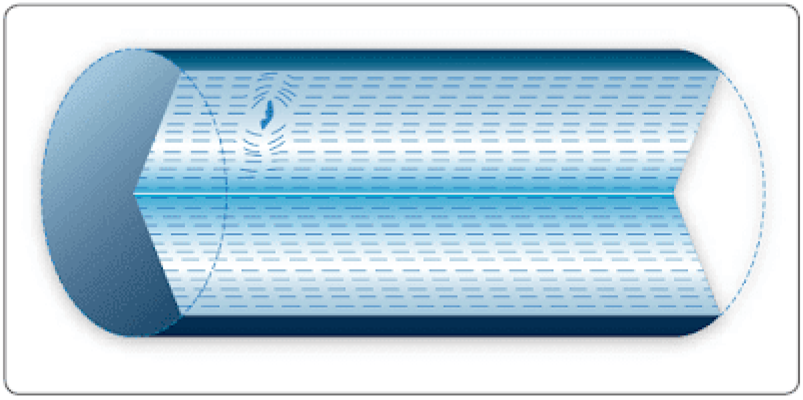


Figure 1.21 Flux leakage at the longitudinal discontinuity

### Types of Discontinuities Disclosed

The following fracture types are commonly detected by the magnetic powder test: cracks, flyaways, seams, cold seals, inclusions, splits, tears, pipes, and voids. All this can affect the reliability of parts in operation.

Cracks, splits, breaks, tears, seams, voids and pipes are formed by the actual separation or rupture of solid metal. Cold shutters and overlaps are folds that have formed in the metal, which breaks its integrity.

Inclusions are extraneous materials formed by impurities in the metal during the stages of metal processing. They can consist, for example, of furnace lining fragments collected during the melting of the base metal or other extraneous components. Inclusions disrupt the continuity of the metal because they prevent the joining or welding of adjacent metal surfaces.

### Preparation of Parts for Testing

Grease, oil and dirt must be cleaned from all parts before they are tested. Cleaning is very important because any grease or other foreign material present can cause minor marks due to magnetic particles adhering to the foreign material as the slurry drains from the part.

Sufficient amounts of oil or foreign material on the tear may also interfere with the formation of the tear pattern. It is not recommended to rely on a suspension of magnetic particles to clean the part. Slurry cleaning is not thorough, and any foreign material thus removed from the part contaminates the slurry, thereby reducing its effectiveness.

With a dry procedure, thorough cleaning is necessary. Grease or other foreign material holds the magnetic powder, which leads to irrelevant indications and makes it impossible to evenly distribute the indicator medium on the surface of the part. All small holes and oil holes leading to internal channels or cavities must be sealed with paraffin or other suitable non-abrasive material.

Coatings of cadmium, copper, tin, and zinc do not interfere with the satisfactory operation of magnetic powder inspection, except where the coatings are extremely heavy or the discontinuities to be detected are extremely small.

Chromium and nickel plating usually do not prevent signs of cracks open to the surface of the base metal, but they do prevent signs of small cracks such as inclusions. Because it is a stronger magnet, nickel plating is more effective than chrome plating at preventing indicia.

### Effect of Flux Direction

To find a defect in a part, the magnetic field lines must run approximately perpendicular to the defect. Thus, it is necessary to induce magnetic flux in more than one direction because defects can exist at any angle to the major axis of the part. This requires two separate magnetization operations called circular magnetization and longitudinal magnetization. The effect of flow direction is shown in Figure 1.22

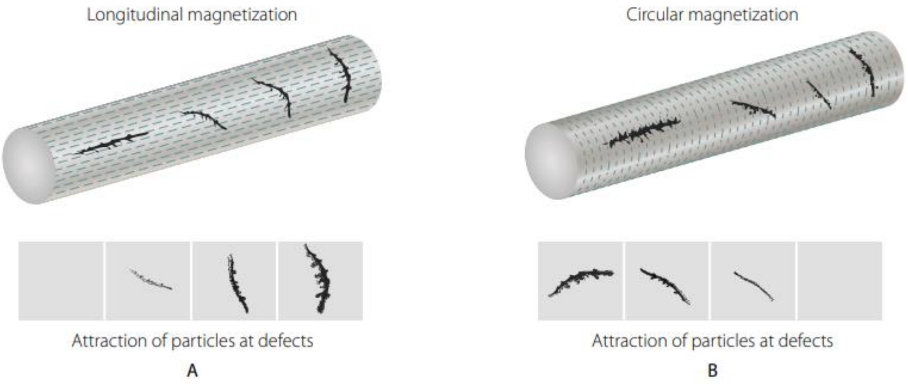


Figure 1.22 Effect of flux direction on strength of indication

Circular magnetization is the induction of a magnetic field consisting of concentric circles of the force around and within the part. This is achieved by passing an electric current through the part, localizing defects located approximately parallel to the axis of the part. Figure 1.23 illustrates the circular magnetization of the crankshaft. With longitudinal magnetization, the magnetic field is created in a direction parallel to the long axis of the part. This is achieved by placing the part in a solenoid that is excited by an electric current. The metal part then becomes the core of the electromagnet and is magnetized by the induction of the magnetic field created in the solenoid.

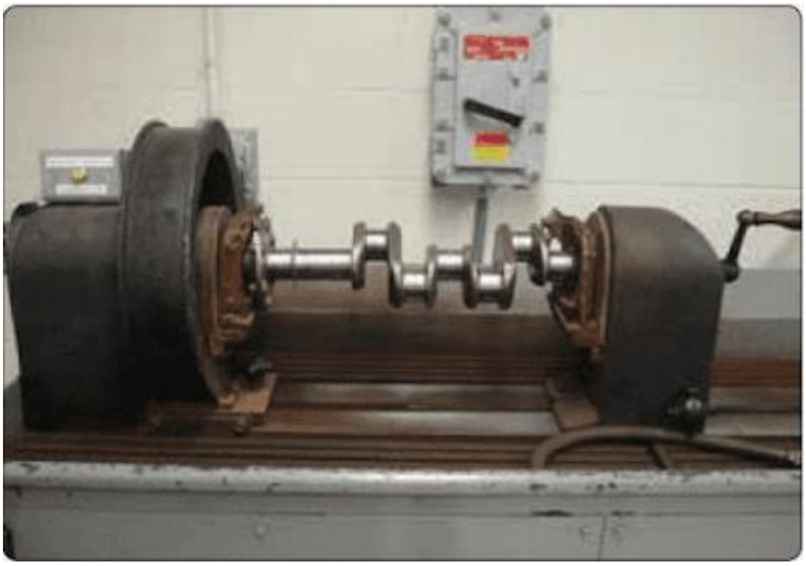


Figure 1.23 Circular magnetization of a crankshaft

When longitudinally magnetizing long parts, the solenoid must be moved along the part to magnetize it. [Figure 1.24] This is necessary to ensure proper field strength along the entire length of the part.

Figure 1.24 Longitudinal magnetization of camshaft (solenoid method)

The solenoids produce an effective magnetization approximately 12 inches from each end of the coil, thus accommodating parts or sections approximately 30 inches in length. A longitudinal magnetization equivalent to that produced by a solenoid can be achieved by rotating a flexible electrical conductor around the part. Although this method is not as convenient, it has the advantage that the coils conform more closely to the shape of the part, creating a slightly more uniform magnetization. The flexible coil method is also useful for large or irregularly shaped parts when standard solenoids are not available.

**Effect of Flux Density**

The effectiveness of magnetic powder control also depends on the flux density or field strength on the surface of the part when using an indicator medium. As the flux density in the part increases, the sensitivity of the test increases due to greater flux leakage at gaps and, as a result, improved formation of the magnetic particle structure.

Excessively high flux density can form irrelevant features such as grain flow patterns in the material. These features make it difficult to identify patterns that are the result of significant gaps. Therefore, it is necessary to use a field strength high enough to detect all possible harmful discontinuities, but not strong enough to create confusing irrelevant features.

## Magnetizing Methods

When a part is magnetized, the field strength in the part increases to a maximum for a particular magnetizing force and remains at that maximum as long as the magnetizing force is maintained.

When the magnetizing force ceases, the field strength decreases to a smaller residual value depending on the magnetic properties of the material and the shape of the part. These magnetic characteristics determine whether a continuous or residual method is used to magnetize the part.

In the continuous control method, the part is magnetized and the tracer medium is applied while the magnetizing force is maintained. Thus, the available flux density in the part is maximum. The maximum value of the flux directly depends on the strength of magnetization and the permeability of the material from which the part is made.

The continuous method can be used in almost all circular and longitudinal magnetization procedures. The continuous procedure provides greater sensitivity than the residual procedure, especially when detecting subsurface tears. The highly critical nature of aircraft parts and assemblies and the need for underground inspection in many applications has led to the more widespread use of the continuous method. Because the continuous procedure detects more minor discontinuities than the residual procedure, careful and judicious interpretation and evaluation of the discontinuities detected by this procedure is necessary.

The residual test procedure involves magnetizing the part and applying an indicator medium after removing the magnetizing force. This procedure is based on the residual or permanent magnetism in the part and is more practical than the continuous procedure where the magnetization is carried out by flexible coils wound around the part. In general, the residual procedure is used only for steels that have been heating treated for stress applications.

## Identification of Indications

Correct assessment of the nature of the readings is extremely important, but sometimes difficult to do based on observation of the readings alone. The main distinguishing features of the indications are the shape, growth, width and clarity of the contour. These characteristics are more valuable for distinguishing types of ruptures than for determining their severity. Careful observation of the nature of the magnetic particle pattern should always be included in a full assessment of the significance of a specified discontinuity.

The easiest signs to distinguish are those formed through cracks open to the surface. These cracks include fatigue cracks, heat treatment cracks, shrinkage cracks in welds and castings, and grinding cracks. An example of a fatigue crack is shown in Figure 1.25.

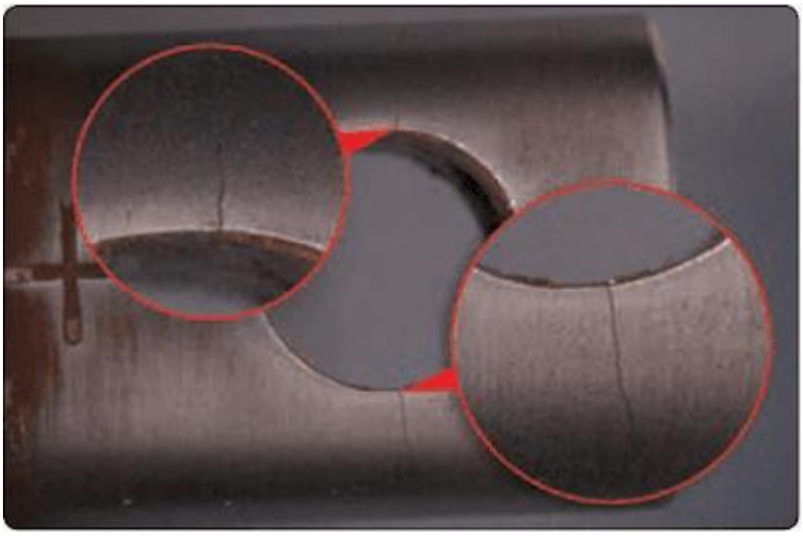


Figure 1.25 Fatigue crack on the bottom end fitting of a Hydrosorb shock absorber

## 1.8. Inspection of Composites

Composite structures are checked for delamination (separation of different layers), separation of the shell from the core, as well as signs of moisture and corrosion. As recommended by the aircraft manufacturer, the methods previously discussed may be used, including ultrasonic, acoustic, and radiographic inspections. The simplest method used in testing composite structures is the tapping test. New techniques such as thermography have been developed to inspect composite structures.

### Tap Testing

Tap testing also called the ring or coin test is widely used as a quick assessment of any accessible surface to detect the presence of delamination or delamination. [Figure 1.26]

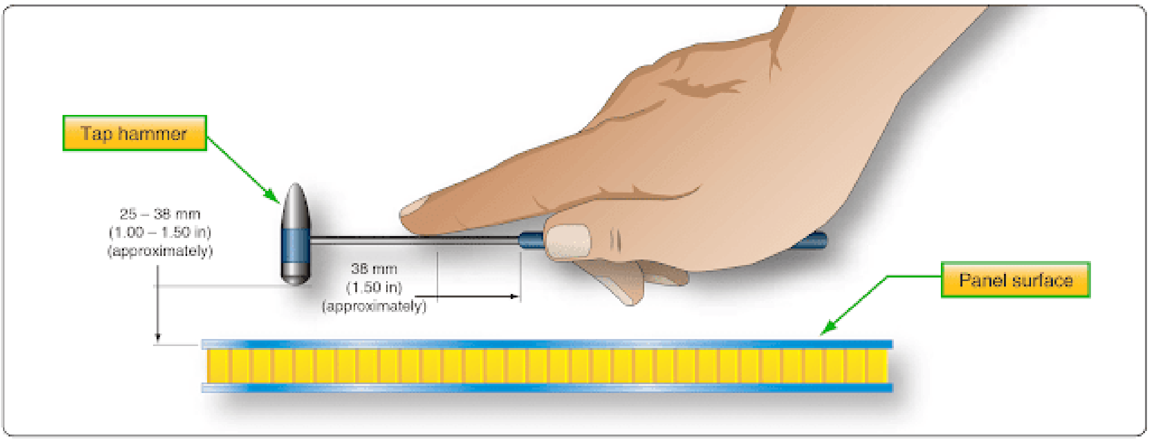


Figure 1.26 Tap testing using a hammer

The testing procedure involves lightly tapping the surface with a light hammer (maximum weight 2 ounces), coin, or another suitable device. The acoustic response or "ring" is compared to a known good area. A "flat" or "dead" response indicates an area of concern. The tap test is limited to detecting defects in relatively thin shells less than 0.080 inches thick. On cellular structures, it is necessary to check both sides. A tapping test on one side only will not reveal a tear on the opposite side.

### Electrical Conductivity

Composite structures are not electrically conductive by nature. Some aircraft do not suffer from electrical problems due to their relatively low speed and type of use.

Manufacturers of other aircraft, such as high-speed, high-performance jets, must use different methods of incorporating aluminium or copper into their designs to make them conductive. Aluminium or copper (aluminium is used with fibreglass and Kevlar, while copper is used with carbon fibre) is placed in the overlay layers as a fine wire mesh, screen, foil, or spray. During the repair of damaged areas of the structure, it is necessary to ensure that the conductive path is restored. Not only must the conductive material be included in the repair, but the continuity of the electrical path from the original conductive material to the replacement conductor and back to the original must be maintained. Electrical conductivity can be checked using an ohmmeter. It is necessary to carefully follow the instructions of the manufacturer.

### Thermography

Thermography is an NDI technique often used for thin composite structures that uses radiant electromagnetic thermal energy to detect defects. The most common sources of heat are heat lamps or heaters. The basic principle of thermal monitoring is to measure or map surface temperatures as heat flows from, to, or through the test object. All thermographic methods are based on differences in thermal conductivity between normal defect-free areas and areas with defects. Typically, a heat source is used to increase the temperature of the test product while observing surface heating effects. Since areas without defects conduct heat more efficiently than areas with defects, the amount of heat that is absorbed or reflected indicates the quality of the joint. Defect types that affect thermal properties include debonding, cracks, impact damage, panel thinning, and water intrusion into the composite materials and honeycomb core. Thermal methods are most effective for thin laminates or defects near the surface.

The most common method of thermographic control uses an infrared (IR) system to measure the temperature distribution. This type of inspection can provide fast, one-way, non-contact scanning of surfaces, components or assemblies. The heat source can be as simple as a heat lamp, provided that adequate thermal energy is applied to the viewing surface. The induced temperature increase is several degrees and quickly dissipates after the heat input is removed. The IR camera records infrared patterns. The resulting temperature data is processed to obtain more quantitative information. The operator analyzes the screen and determines whether a defect has been detected. Since IR thermography is a radiometric measurement, it can be performed without physical contact. Depending on the spatial resolution of the IR camera and the size of the expected damage, each image may have a relatively large area. Additionally, because composite materials do not radiate heat nearly as much as aluminium and have a higher emissivity, thermography can provide better damage detection with less heat input. Understanding the structural arrangement is imperative to ensure that the substructure is not mistaken for defects or damage.

## 1.9. Inspection of Aircraft Welds

The discussion of welds in this publication is limited to assessing the quality of completed welds by visual means. While the appearance of the finished weld is not a positive indicator of quality, it does give a good indication of how carefully it was made. A properly designed weld is stronger than the base metal it joins. The characteristics of a properly welded joint are discussed in the following paragraphs.

A good weld has the same width; the ripples are uniform and well located in the base metal and show no overheating burns. [Figure 1.27]

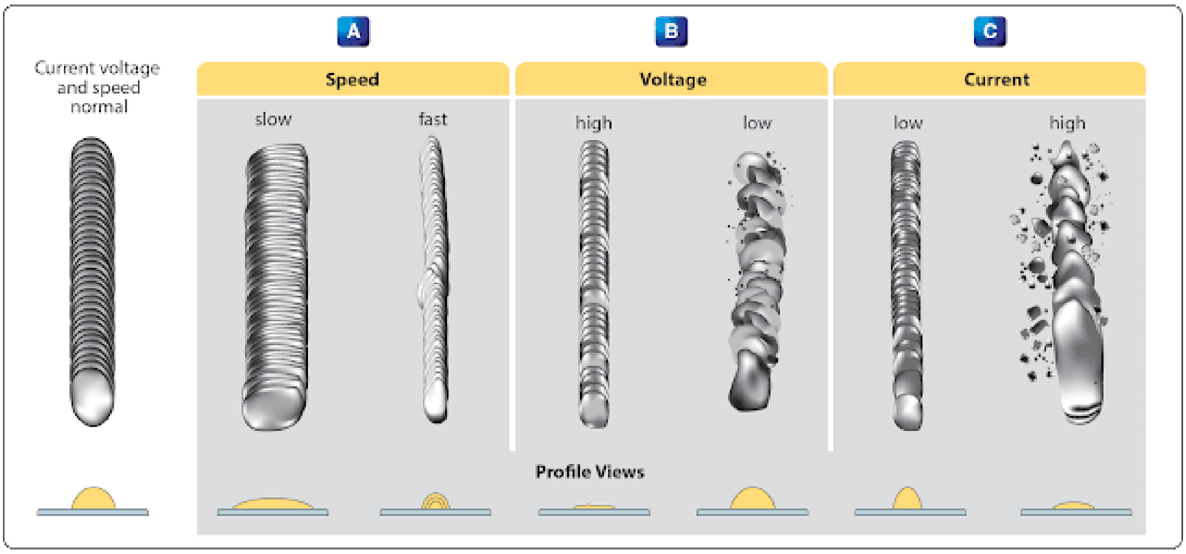


Figure 1.27 Examples of poor welds: too rapidly (A), improper penetration and cold laps (B), and irregular edges and considerable variation (C)

The weld has good penetration and does not contain gas pockets, porosity or inclusions. The edges of the roll are not straight, but the weld is good because the penetration is excellent.

Penetration is the depth of penetration of the weld. Thorough penetration is the most important characteristic that contributes to a strong weld. Penetration is affected by the thickness of the material being joined, the size of the filler and the way it is added. In a butt weld, the penetration should be 100 % of the base metal thickness. For a fillet weld, the penetration requirements are 25 to 50 % of the thickness of the base metal. The width and depth of the roll for butt and fillet welding are shown in Figure 1.28.

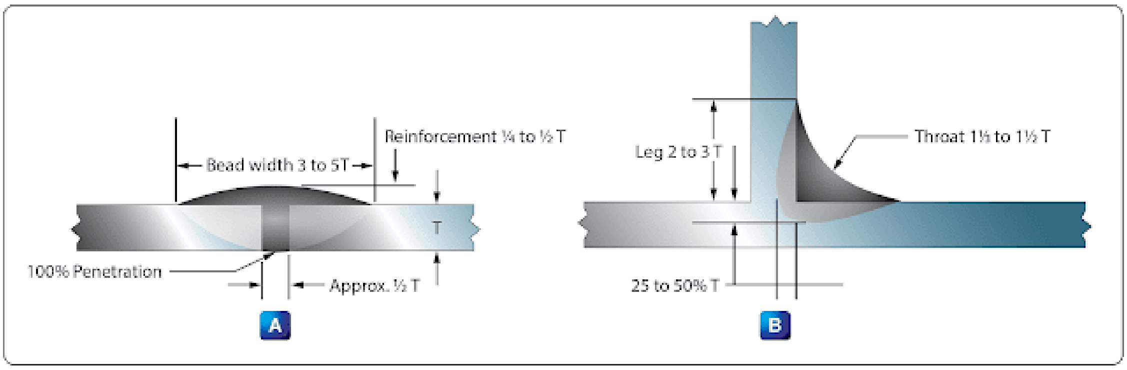


Figure 1.28 Butt weld (A) and fillet weld (B), showing the width and depth of the bead

To further assist in determining weld quality, the following paragraphs discuss several examples of improper welds.

The weld in Figure 1-A was made too quickly. The long and pointed appearance of the ripples was caused by excessive heat or oxidizing flames. If the weld were cross-sectioned, it would likely reveal gas pockets, porosity, and slag inclusions.

Figure 1-B shows a weld with improper penetration and cold laps caused by insufficient heating. It looks rough and uneven, and its edges do not cut into the base metal. During welding, the puddle boils if excessive amounts of acetylene are used. This often leaves small bumps in the centre and craters at the end of the weld. Cross-checks are obvious if the weld body is healthy. If the weld is cross-sectioned, pockets and porosity are visible. [Figure 1-C]

A bad weld has uneven edges and significant variations in penetration depth. Often has the appearance of cold welding.

## Conclusion to chapter 1

An aircraft consists of many components and all of them required maintenance. By today involved a lot of inspection methods for testing every part of the aircraft. Inspection can be simple as a walk-around of a plane or using equipment like ultrasonic inspection or Eddy Current Inspection. Visual examination of aircraft by humans remains the cheapest and fast way to determine the condition of aircraft but has some exceptions and problems. Only regular and thorough inspections maintain aircraft in the best possible condition.

# CHAPTER 2

# AIRCRAFT MAINTENANCE INCIDENT ANALYSIS

## 2.1. Global focus on maintenance failure

Maintenance failure continues to be one of the most obvious threats to safety in terms of engineering or airworthiness. Over the years, the evolution of aircraft design methods, the use of new materials and the use of the experience gained from incidents and accidents have led to improvements in the design of aircraft systems and the reliability of components. Although accidents due to airworthiness problems do occur, they are relatively rare.

However, despite these improvements, the maintenance delivery system remains vulnerable to human-related issues. Humans are prone to error, so mistakes and mistakes will happen. It is through proper training and competency assessment regimes and the creation of a culture that promotes good engineering practice that the likelihood of error will be reduced. The organization must also create an environment where engineers can focus on the task at hand without external pressures that would compromise the quality and integrity of the work by pressuring individuals to cut corners. It is these violations of processes and procedures that cause accidents and incidents both for the individual and for the organization.

Training is essential because engineering skills and good practice do not happen in a vacuum. Everyone involved in aircraft maintenance must possess the necessary competence, including the necessary behaviour and attitude to work. A procedural control is important because there is a reason why maintenance must be done in a certain sequence. The quality of work and the thoroughness with which functional tests are performed confirm the adequacy of the work performed. It is a continuum from start to finish and having multiple participants in the overall process requires coordination and attention to detail. Investigating maintenance incidents is a valuable tool to improve safety. This allows us to see what went wrong and why. The contributing factors to any incident are important so that we can identify interventions that will prevent or at least minimize the likelihood of it happening again. Human errors depend on a person's circumstances, mood, and approach to work.

Many reasons lead to a simple lapse in concentration that leads to a mistake or an error. Therefore, it is important to pay attention to corrective actions that will help both the individual and the maintenance system.

Self-study is not a solution to the problem. There is clear evidence that training is not an entirely effective way of eradicating errors. The underlying culture and approach to security matters. This needs to be facilitated through the organization's values and strategic direction. A person must recognize that he is part of a team and that everyone has a role and standards to uphold. The unlicensed mechanic plays a vital role as it is at the point of 'doing' that many mistakes are made, so organizations need to focus on all staff members to ensure they have the tools, training, procedures/processes, and competence required to consistently complete the task at hand at the proper level. This does not mean that supervision is unnecessary. It is the overall integration of a specific task and its impact on other tasks that are performed in parallel that makes the role of the manager vital. It is the supervisor who manages workload, task allocation and planning while protecting people from outside pressure and influence. Top management plays an important role in creating the right environment and system for people to work in. This includes providing sufficient resources, and effective procedures, building an appropriate safety culture and a shared vision for managing external pressures and providing the right tools and equipment. Without a human risk management system, service errors will continue to occur.

Following a series of significant maintenance failures in the early 1990s, considerable work was undertaken to examine the issue of human factors (HF) and human performance in aircraft maintenance. It was found that the increasing complexity of aviation technology, the prevalence of night maintenance and the impact of increased pressure on the commercial needs of operations all potentially created an environment where the potential for error could exist. Within this HF focus, there was some support for the need to inform engineering staff of the potential pitfalls associated with human error and performance. The concept of bug investigation has taken hold, and several frameworks and basic investigative tools have emerged. However, identifying the root cause is one thing, but knowing how to solve it is quite another. This led to the introduction of HF training requirements for all maintenance personnel at both entry-level and continuing education levels.

## 2.2. The analysis of incident data

The CAA MOR (Mandatory Occurrence Reporting) data set analyzed by Confidential Human Incident Reporting Programme (CHIRP) included 2,733 maintenance incident reports spanning the period from January 2005 to December 2011. This data set contained 2,399 reports involving large aircraft, 85 involving large helicopters, and 249 involving small aircraft (less than 5,700 kg). It is not known what proportion of the actual number of incidents across the industry this represents, as this is entirely dependent on the reports sent to the CAA, despite the reporting of such incidents being mandated by the MOR scheme.

The following information for each CAA occurrence report was provided to CHIRP for analysis:

- type of aircraft;
- entry number;
- Classification of the degree of occurrence;
- Date of occurrence;
- Operator/maintainer;
- Aircraft manufacturer;
- Event descriptor;
- Pre-heading;
- Information about the event and investigation;
- ATA Department.

Although this data set is slightly different from those used in studies under previous CAA documents, key elements were still present, so it is believed that the methodology of data analysis and therefore the results obtained. There were notable differences between the data in the CHIRP-MEMS (Maintenance Error Management System) database and the data provided to CAA from the MOR system of records. In many cases, the reporting organization provided the CAA with basic incident information to ensure MOR compliance, but then provided more detailed information to CHIRP for their MEMS database and further analysis at the end of the investigation.

There is a significant amount of public literature on human error in the public domain, and many of the papers published in recent years have focused more on aircraft maintenance. This reflects the growing interest in engineering incidents.

The resulting data set for the period covered 2,733 events that were analysed. The breakdown by category of aircraft is shown in Figure 2.1

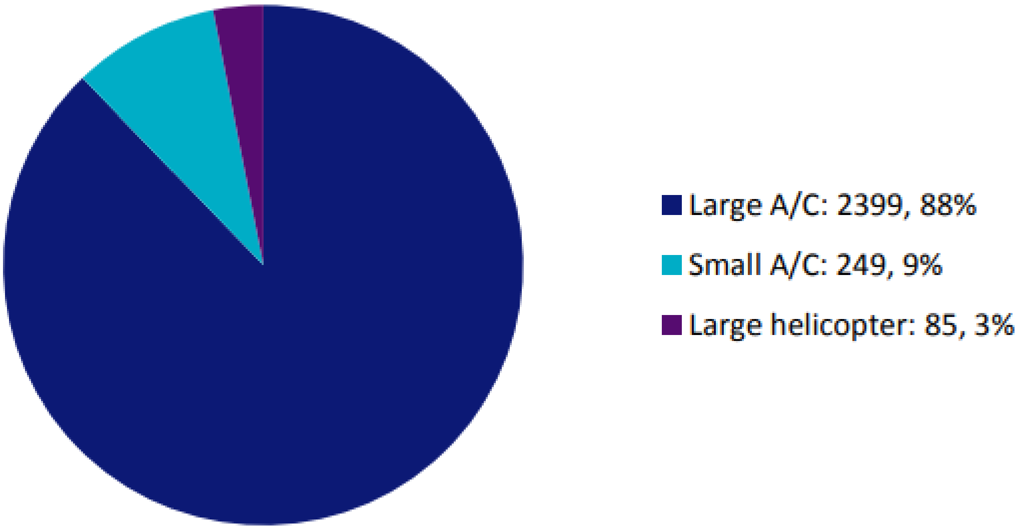


Figure 2.1: Overall breakdown of the analysis

The 88% largest share of events involves large aircraft. This is not surprising as the 'mandatory' elements of the MOR scheme apply to these aircraft and not to smaller, more general aviation-oriented aircraft.

Incident reports involving small aircraft, both airplanes and helicopters, accounted for only 9% of the total. It should be noted that many small aviation events are not mandatory to report, so there are likely to be additional events that are not captured in the MOR data held by the CAA. Therefore, the focus of this review is understandably mainly related to large aircraft and aircraft used for commercial air transport. The data set is split into Part M events - maintenance management issues and maintenance error events. The analysis is shown in Figure 2.2. Despite small variations in the balance between the two classes of events, the proportion was relatively stable for all aircraft categories. What is significant is the slightly higher proportion of Part M - maintenance management issues reported for large helicopters. Since these are mainly related to maintenance cost overruns for life-limited components, this is not surprising given the much longer inspection and overhaul periods assigned to such aircraft. It can also be due to errors that occurred when data was migrated to new computer systems.

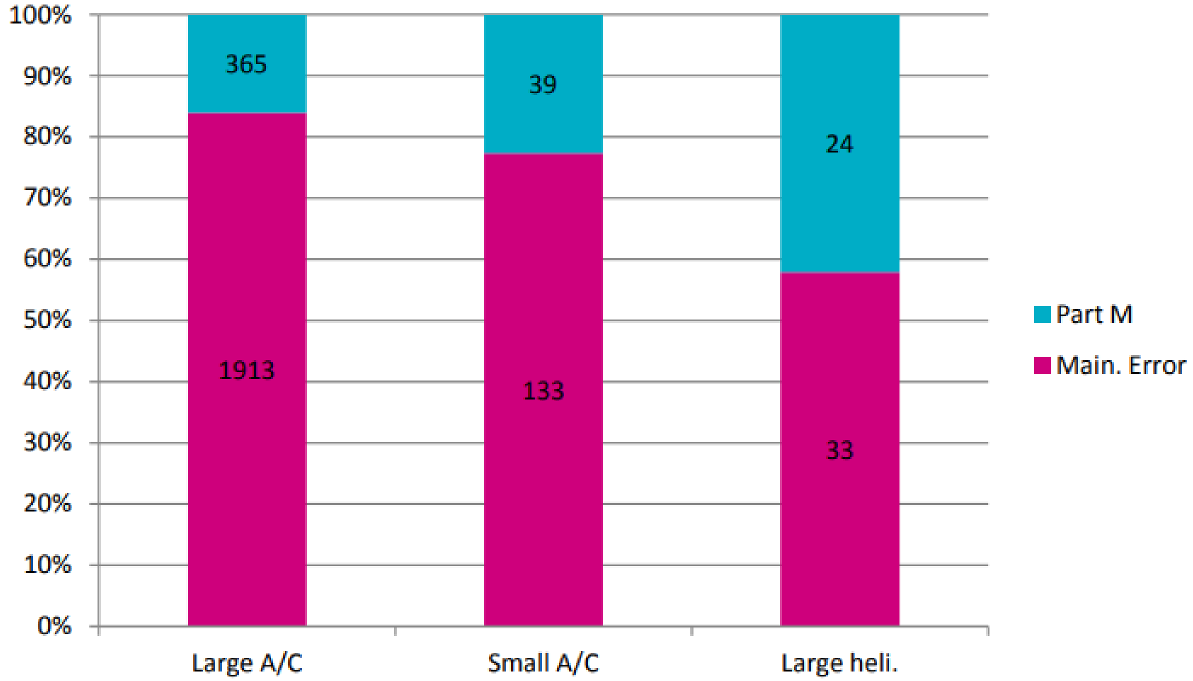


Figure 2.2: Breakdown of events, Part M vs maintenance error

Maintenance error cases can be further analysed at a high level to show a correlation with the CAA MOR classification obtained by the CAA. This is shown in Figure 2.3. The most significant MORs, usually related to accidents, are classified as Category A and smaller reports, which are usually closed after receiving a CAA, as Category D.

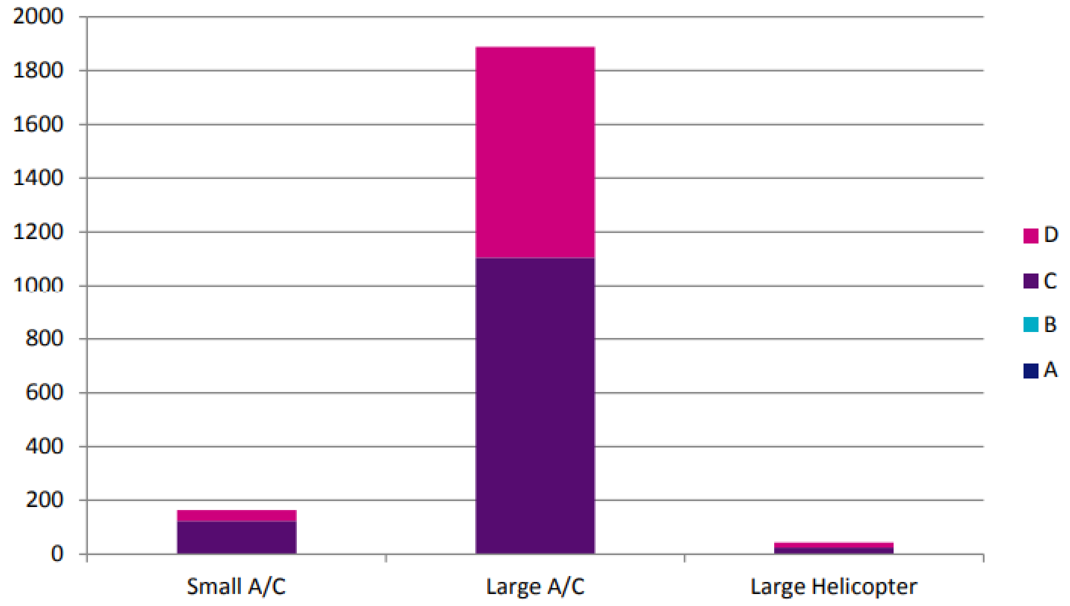


Figure 2.3: Maintenance error-risk distribution, all categories 2005-2011

This shows that the CAA classifies most MORs related to maintenance as Category C. This does not mean that they are minor, and may require the CAA to investigate the circumstances surrounding the MOR. There are two reasons for this. First, make sure the operator or maintenance organization is responding appropriately to the event. This will initially be aimed at fixing the problem to return the aircraft to service. The secondary function will be to further analyse the event and determine the root cause to implement corrective measures to prevent a recurrence. In comparison, further analysis of the high error rate associated with part M yields the results shown in Figure 2.4.

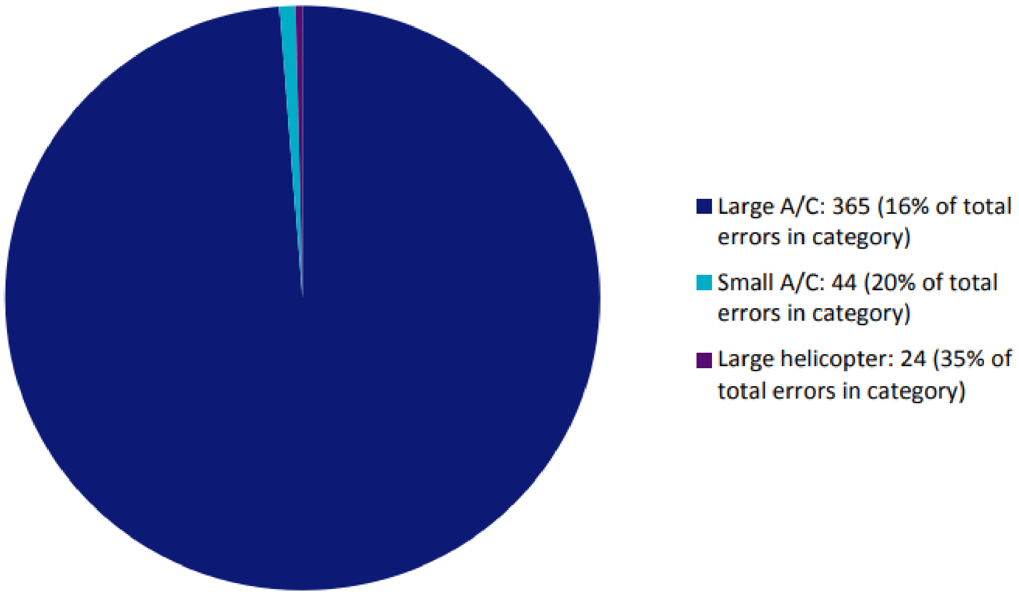


Figure 2.4: Distributions of Part M errors reported 2005-2011

Figure 2.4 shows that 433 Part M errors were reported. Of these, 303 (70%) were related to overhauling life-expiration, airworthiness directives, or maintenance checks called for as part of an approved maintenance program. approximately 40 reports indicated non-compliance with the Airworthiness Directive. This is often a reflection of poor maintenance planning, where proper maintenance is not performed and rescheduled within a reasonable timeframe. In some cases, the overrun is due to data entry issues. A closer analysis of the contributing factors also shows that there may be some evidence of a conflict between the performance of the job and the commercial pressure to continue operating the aircraft. The other 130 (30%) reports primarily highlight errors in data setup. These errors are often simple transcription errors between paper post-maintenance documentation and the electronic database used to manage the planning function. For example, entering data on the service life of components after they are installed on an aircraft and predicting the next tasks. Such errors can lead to overruns if not detected by other intermediate means, such as unplanned component replacement or detailed database auditing. The last basic or high-level category is the number of reports related to production and overhaul, see Fig. 2.5.

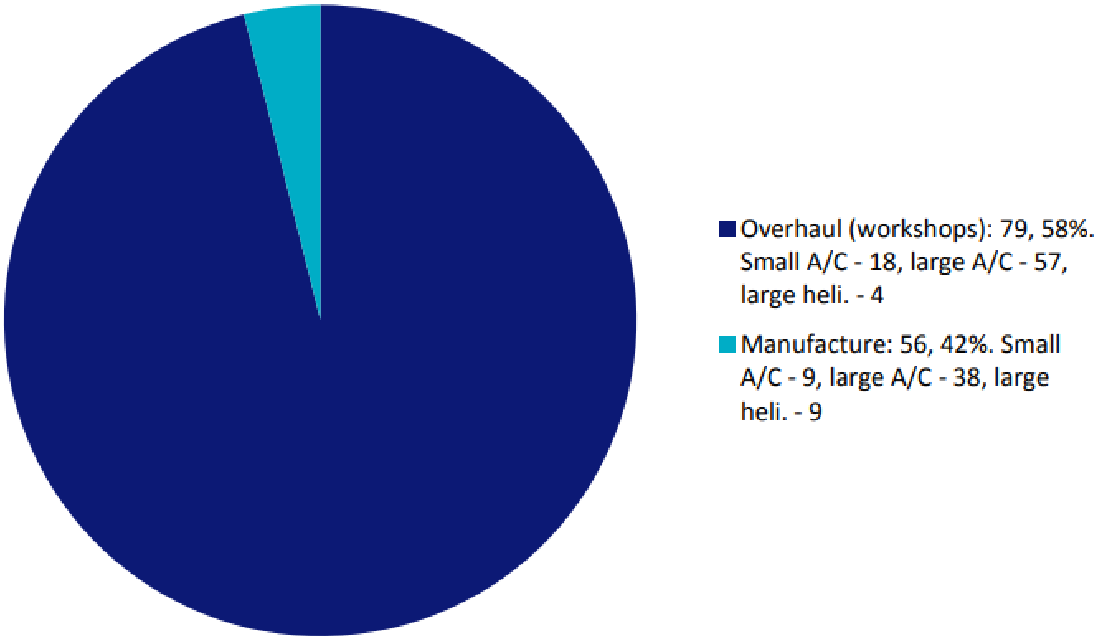


Figure 2.5: Distribution of events considered as the manufacturer or overhaul errors, data 2005-2011

These are events that, after an analysis of the underlying circumstances, are problems rooted in a manufacturing error or attributed to a major repair agency, rather than a direct error in the operator's system. Both failures could be caused by human error, but the fact that they occurred at third-party organizations clouds the available data and the ability to analyse the data and find root causes. Manufacturing errors must be recorded in the production and inspection system. Any deviations should be the subject of a design concession, but the assembly of complex components is no different from a maintenance activity that can ultimately lead to a maintenance error, e.g., disassembly, installation of incorrect parts, etc. Logically, such errors should be given as much attention, but the current requirements under Part 21 do not require error management or recording systems in the same way as Part 145. Perhaps this is something that EASA should consider for future amendments to Part 21. Production events and major repairs together account for 135 events or approximately 4.9% of the total number of reported MORs. It is interesting to note that not all production events are reduced to a physical error. Many of these are due to technical authorship errors in approved data. The distribution for the period from 2005 to 2011 is shown in Figure 2.6.

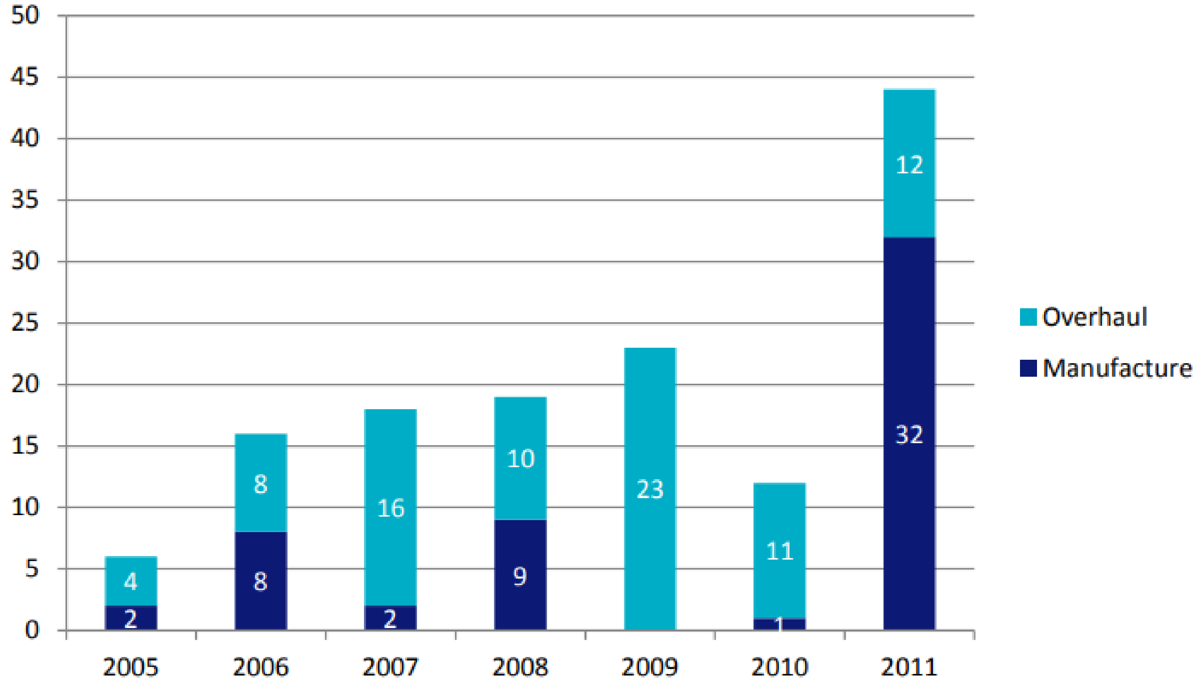


Figure 2.6: Error reports attributable to manufacture or overhaul

The inclusion of production or production events in the data indicates that these activities should indeed also be considered in the context of applying an error management system. The potential for an incident or accident is just as significant as for maintenance. The number of maintenance-related MORs received each year is shown in Figure 2.7. The overall reporting levels are consistent. It is not possible to explain the apparent decrease in reporting in 2010, although it is recognized that the overall level of industrial activity in the operation of aircraft has decreased because of the global financial crisis. The increase in the number of reports for 2011 may reflect increased "commercial" pressures and the result of a reduced workforce, which increases the risk of error. The upward trend reported in Part M reflects the introduction of Part M requirements in 2005 and the learning curve involved in transitioning to the new structure. See the following sections for more information on common error causes

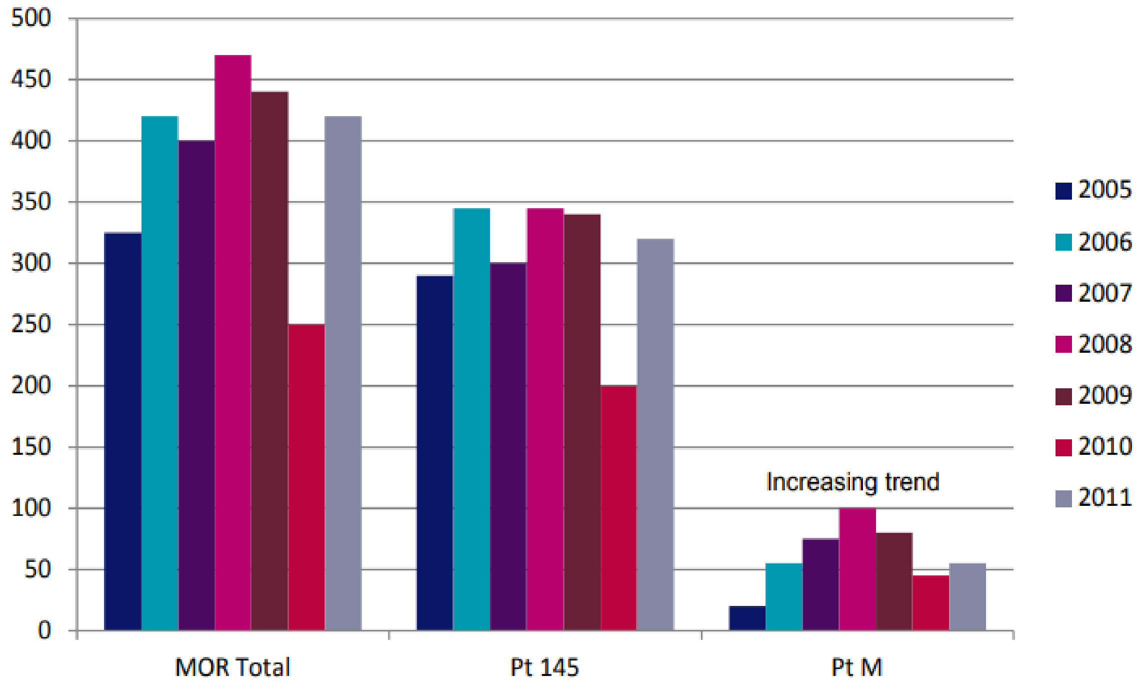


Figure 2.7: Maintenance MOR reporting levels 2005-2011

A high-level analysis allowed the identification of service errors by ATA partition, represented graphically in Figure 2.8.

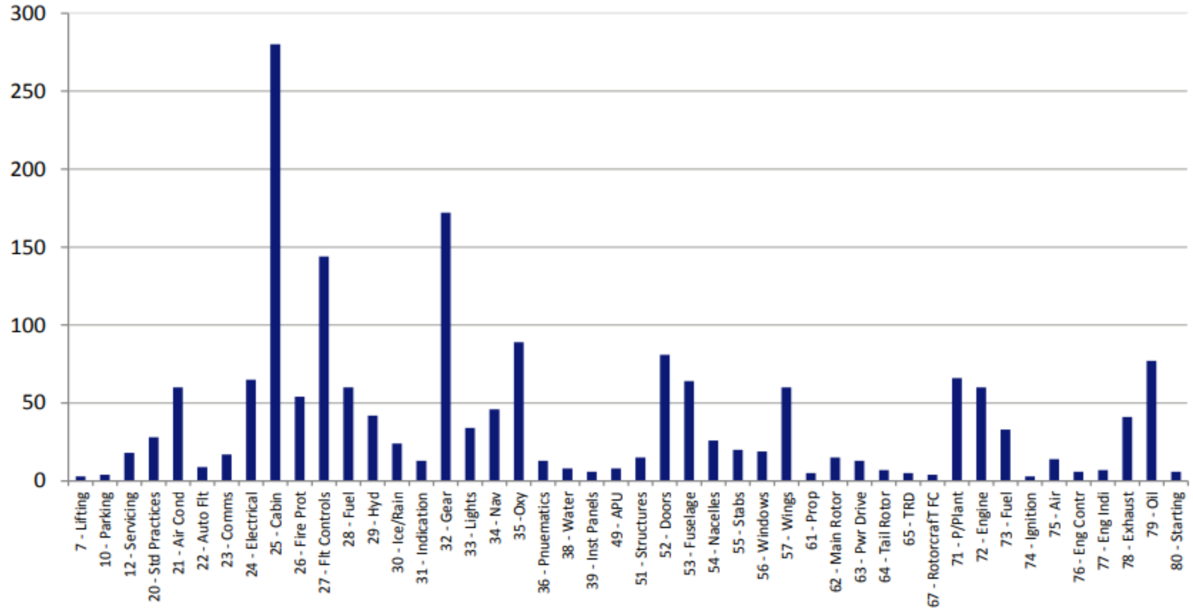


Figure 2.8: Global maintenance error events by ATA chapter

From this it can be seen that the main ATA Chapters that appear to attract a maintenance error event are:

- ATA 25 cabin/safety equipment 11%
- ATA 32 landing gear/undercarriage 8%
- ATA 27 flight controls 6%
- ATA 35 oxygen 4% ATA 52 doors 3%
- ATA 79 engine oil 3%

This does not mean that errors do not occur in other areas of maintenance. Most ATA units have experienced some error cases. It is interesting to note that Chapter 25 covers a variety of maintenance tasks, from the installation and condition of seats to the installation of safety equipment. There is a significant difference in the potential safety hazard if an error is made in installing the wrong style of cushion and if the emergency slide is not properly installed on the door. Figure 9 shows changes in reporting trends over the analysed period. Despite some variation from year to year, the overall numbers for these ATA divisions are consistent, except for ATA Chapter 25, Cabin/Safety Equipment. There is no obvious explanation in the MOR data for the apparent decrease in incidents for ATA 25. One can only conclude that incidents are not being reported as they should be, or tasks are not being read as often.

Figure 2.9 shows changes in reporting trends during the analysed period. Despite some variation from year to year, the overall numbers for these ATA sections are consistent, except ATA Chapter 25, Cabin/Safety Equipment. There is no obvious explanation in the MOR data for the apparent decrease in incidents for ATA 25. One can only conclude that incidents are not being reported as they should be, or tasks are not being read as often.

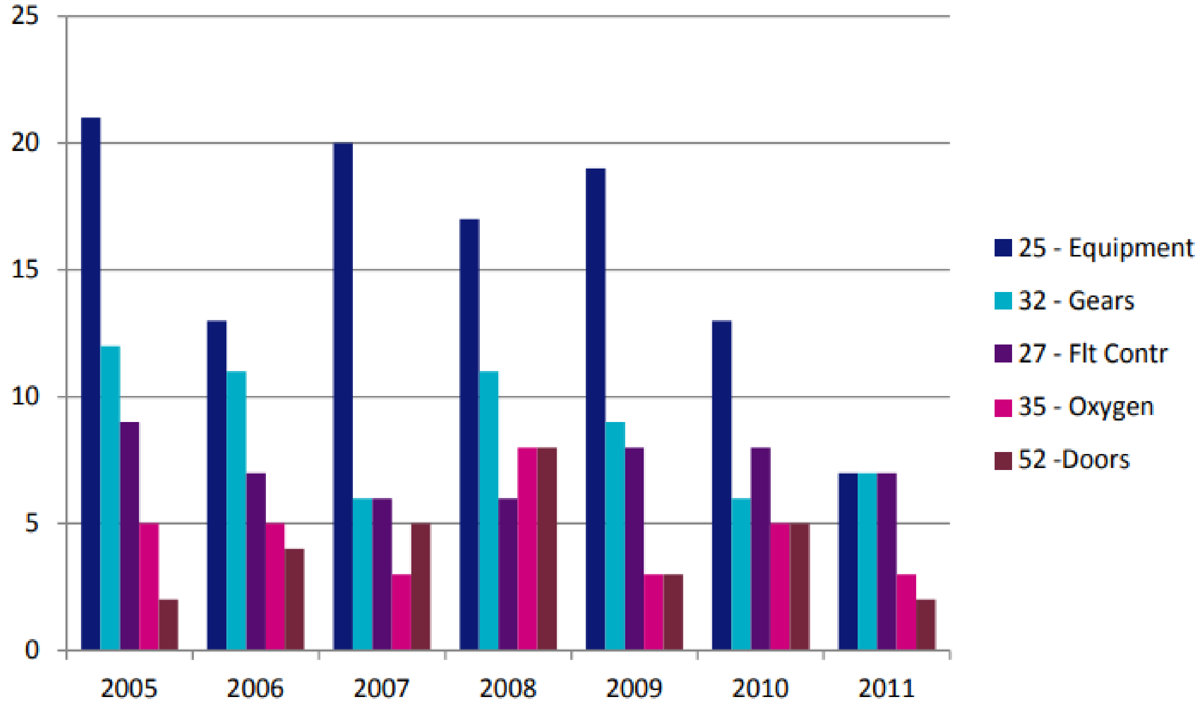


Figure 2.9: Reporting trends primary ATA chapters as % of total yearly maintenance error MOR

It is also possible to conduct a more detailed analysis of the root cause of events. This is shown in Figure 2.10 for the global dataset. The 100% figure represents 2,108 MORs overall, 1,890 for large aircraft, 174 for small aircraft and 44 for large helicopters.

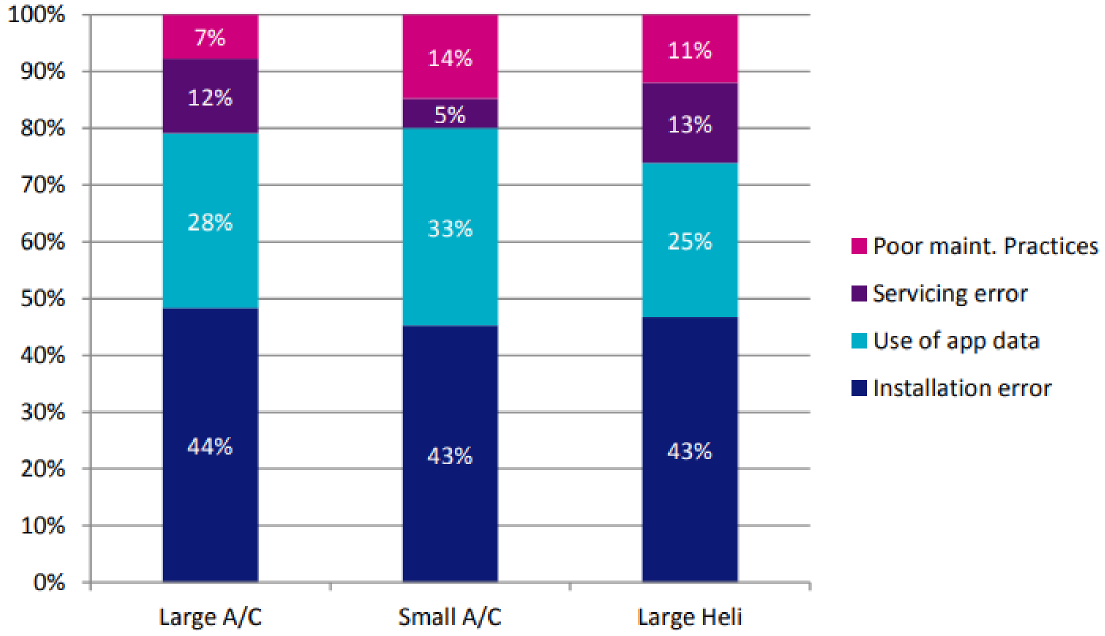


Figure 2.10: Maintenance error distribution comparison, common categories 2005-2011

From these figures, the most likely type of error is "incorrect installation". The next place is occupied using confirmed data, or rather the probable lack thereof. Improper installation includes mismatching all required components (such as gaskets or gaskets), improper routing of electrical cables, and improperly applied torque. "Use of approved data" includes proper use of approved data such as maintenance instructions, service information or repair drawings. Again, Figure 2.11 shows changes in reported trends for types of maintenance errors over the period analysed. While there is some variation from year to year, the overall numbers for these ATA divisions are also consistent, except for "Installation Errors."

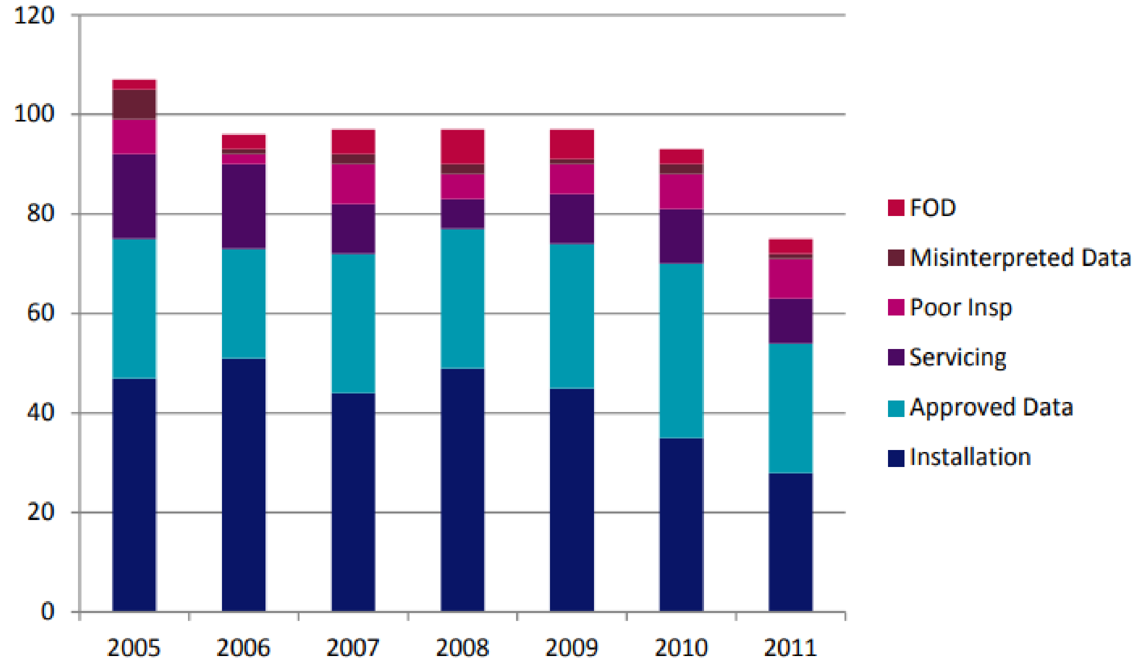


Figure 2.11: Key maintenance error types as % of total each year, all aircraft categories

There is no apparent explanation in the MOR data for the apparent decrease in installation error cases, other than the possibility that internal inspection detects the error before commissioning. This would mean that events are still occurring but, despite being caught, are not being reported following the requirements of the CAA MOR and the European Event Reporting Directive.

## 2.3. Large aircraft global statistics

Figure 2.12 represents the MOR total of 1890. Those 1890 MORs can be broken down by ATA Chapters

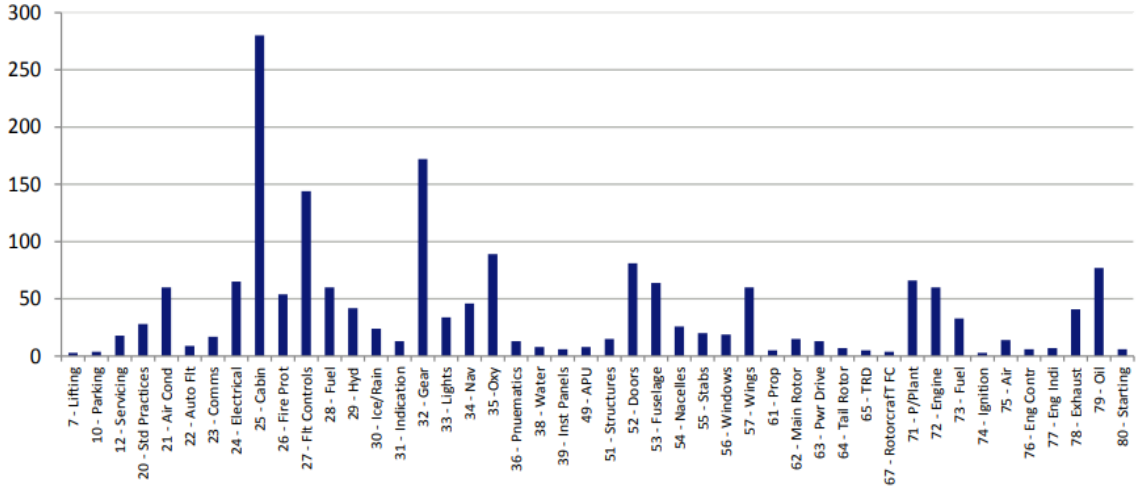


Figure 2.12: Breakdown of maintenance error MORs by ATA chapter, 2005-2011

Once again, the top six ATA Chapters can be identified and the percentage of MORs shown against the total maintenance error number. These are:

- ATA 25 cabin/safety equipment 14%
- ATA 32 landing gear/undercarriage 8%
- ATA 27 flight controls 7%
- ATA 35 oxygen 5%
- ATA 52 doors 4%
- ATA 79 engine oil 3%

In many cases, the number of examples of incorrect installation confirms the belief that this is the biggest risk of error. While the consequences of errors in flight control systems are more readily apparent to the flight crew, this is not the case for items such as door slides that are improperly installed. The consequences of a malfunctioning door during an emergency evacuation are just as worrisome as the in-flight problems that mistakes can cause.

### 2.4. Large aircraft maintenance error types

It is clear from the supporting data reports that in many cases the engineer concerned did not use the latest available manuals or approved data to complete the task. This highlights a cultural problem where, because information may not be available, the engineer reverts to basic engineering skills. However, this does not apply to critical dimensions or tasks during rigging, etc. Figure 2.13 illustrates the types of MOR maintenance errors from 2005 to 2011. This is generally self-explanatory.

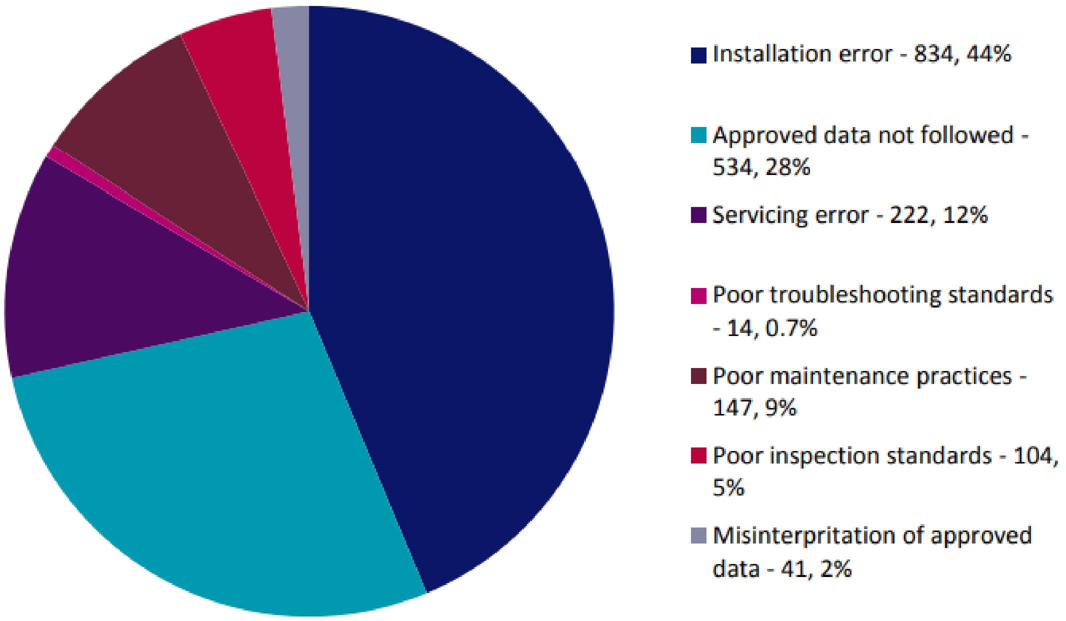


Figure 2.13: MOR maintenance error types 2005-2011

This clearly shows that installation errors and non-adherence to approved data together account for about 72% of reported events. Failure to use approved data is, of course, a key causative factor in an incorrect installation.

## 2.5. Small aircraft global statistics

Figure 2.14 shows global data for the small aircraft category. A total of 174 events involving a variety of fixed-wing aircraft such as the DHC-1 Chipmunk to the BN-2 Islander and smaller rotorcraft such as the Robinson R22 to the Sikorsky S76 were analysed. The fixed wing was responsible for 98 of these events (about 56%), with the remaining 76 events (44%) involving rotorcraft. However, there are proportionally many more small aircraft than rotorcraft, so this reinforces the belief that there are fewer reports of large helicopters than there should be.

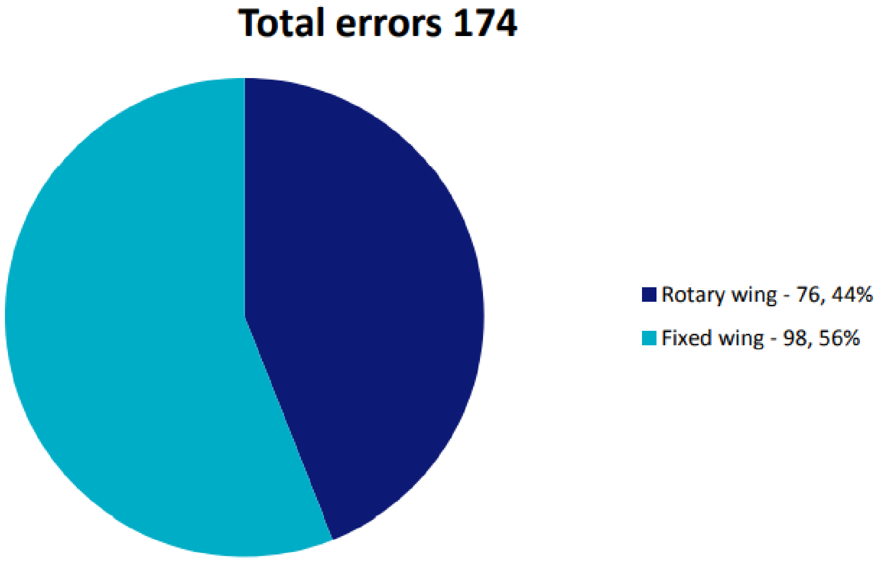


Figure 2.14: Global MOR data for maintenance error, small aircraft

Small aircraft are not as complex as their larger counterparts. Systems tend to be simpler in design with less redundancy and system protection. This means that they may be more susceptible to the consequences of service errors. Figure 2.15 shows the breakdown by chapter of the ATA. It should be noted that not all small aircraft manufacturers use the ATA Chapter system for identifying and coding maintenance. When analysing the data, CHIRP assigned the appropriate ATA codes to the report to provide some consistency in the analysis and to provide comparisons to larger aircraft if anyone is interested.

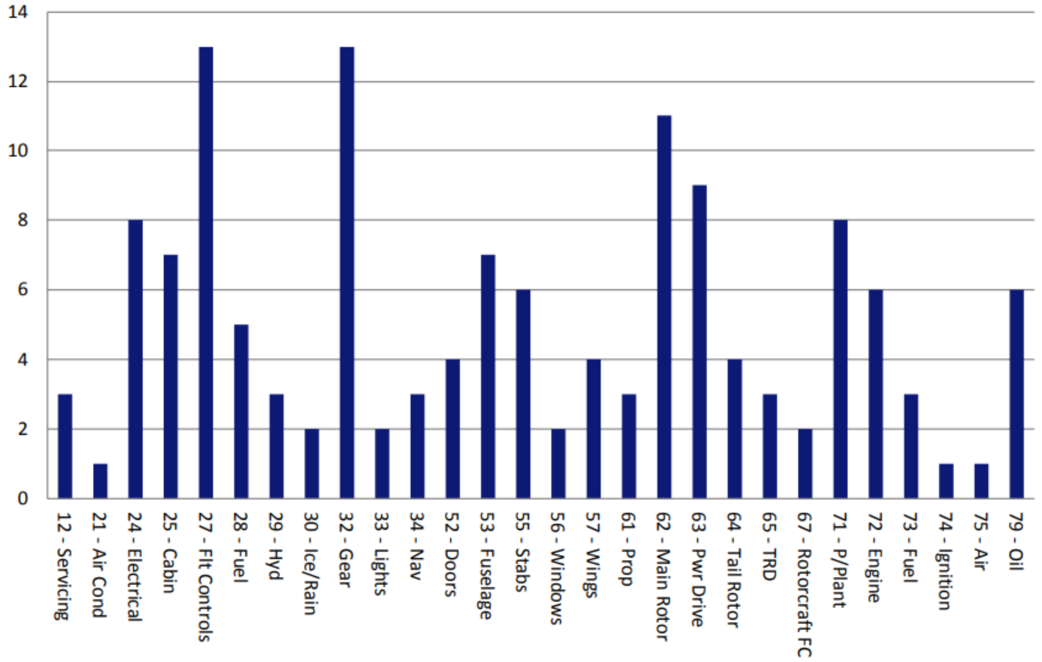


Figure 2.15: Breakdown by ATA chapter, small aircraft

The 6 top ATA Chapters can be shown as a percentage of the total reports as follows:

- Chapter 32 – Landing Gear 7% (13 events)
- Chapter 27 – Flying Controls 7% (13 events)
- Chapter 62 – Main Rotor 6% (11 events)
- Chapter 63 – Power Drive 5% (9 events)
- Chapter 71 – Powerplant 4% (7 events)
- Chapter 24 – Electrics 4% (7 events)

## 2.6. Small aircraft maintenance error types

Like the analysis of maintenance error types for large aircraft, Figure 2.16 presents information for the small aircraft category.

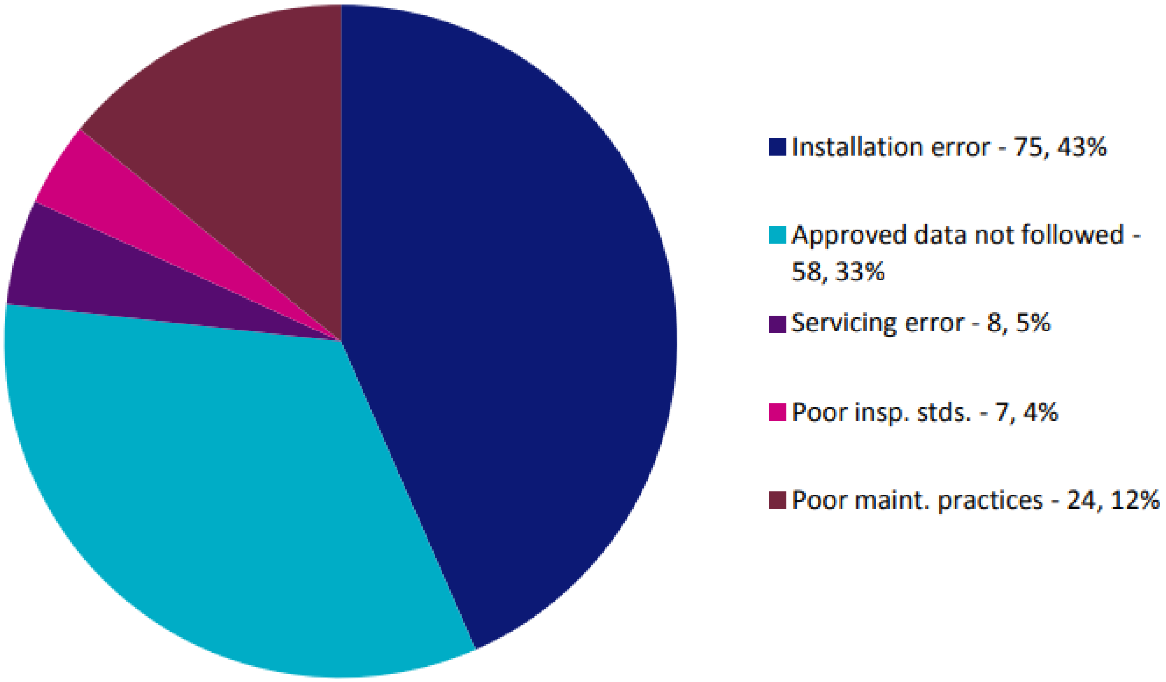


Figure 2.16: MOR maintenance error types 2005-2011, small aircraft

Although based on the limited data available, installation error was similar for larger aircraft, the percentage of non-compliance with approved data (33% vs. 28%) and poor maintenance practices (14% vs. 9%) was higher for small aircraft than for large aircraft. planes This may well reflect the small aircraft maintenance culture, the organization's lack of focus on quality control, and the lack of training for new entrants.

However, without conducting a separate reassessment of each MOR, the actual causes cannot be determined.

## 2.7. Examples of maintenance error

### Example 1

Date 08/2010 ATA Chapter 78 – Exhaust

Event Description: During a walk-around inspection the flight crew noticed an anomaly in the bypass duct of the right-hand engine. With the C duct, open damage was found to the heat shield, apparently caused by a borescope plug being missing

Implications: The missing plug meant that hot engine gases were not contained as designed and had the potential to escape and cause heat damage to components on the engine. Up to the time the issue was noted, the engine's overheat warning system and/or fire warning system did not activate.

Investigation: The borescope plug was missing and therefore allowed gases to escape. Further engineering investigation revealed that the heat shield was missing. Hot gases had impinged upon the thrust reverser structure causing some heat damage and distortion. The investigation found that the aircraft had been subject to a borescope inspection some three days earlier by a contracted maintenance organisation. The maintenance organisation carried out a MEDA (Maintenance Error Decision Aid) investigation and found that, due to other commitments, the primary contracted organisation could not accomplish the work. The task was therefore contracted by the operator to another borescope inspection organisation. This led to some management issues with check planning and calling out of the work. Planned access to the proposed hangar was not possible due to another aircraft check overrunning so gaining access to an alternate hangar resulted in the check commencement being delayed, significantly reducing the available period for the task to be completed. This also meant that the usual facilities and support were not available. The work pack, as supplied by the operator was incomplete and this required the check supervisor to spend additional time sorting out the issue. Staged inspection sheets were not provided and as the plug removal and fitment were carried out by two different mechanics the opportunity to ensure that all disturbed plugs were refitted was compromised.

Corrective actions: There were several actions proposed following the investigation into this event. These included improvement in check planning by the operator, the interface with the contracted maintenance organisation, management and operator/third party interface issues, the need for stage inspection sheets and improved supervision of third-party work.

**Example 2**

Date 10/2011 ATA Chapter 29 – Hydraulic systems

Event Description: On selecting flap 1, the left hydraulic system pressure warning is illuminated followed by the left hand quantity warning. The crew declared PAN call and following some further checks approached and landed safely.

Implications: Loss of hydraulic fluid, loss of pressure and potential compromise of certain system operations.

Investigation: On investigation after landing, a split in a hydraulic flexible hose was found in the left-hand main landing gear wheel well. This pipe ran from the left system filter/case drain module and the relief valve assembly. It was noted that the hose was poorly supported with a single 'P' clip and was free to move. A temporary repair was carried out using flexible hoses and the left system was replenished. An ADD was raised to include re-inspection at each daily check.

Corrective action: Noting the temporary repair carried out the aircraft was returned to service. The MOR record notes that the operator’s quality assurance department appears to have authorised for replacement of the pipe not to exceed the next A check. Further investigation into the replacement pipe showed that a rigid pipe should have been installed.

**Example 3**

Date 11/2011 ATA Chapter 73 – Fuel Control

Event Description: Following an FCU replacement, on starting during the engine post-task function checks the right-hand engine did not control and continued to accelerate past normal idle. The engine shut down to prevent Overspeed.

Investigation: The maintenance organisation had changed the FCU on both left- and right-hand engines on the night shift. During the following day shift, the organisation carried out the post-task function checks. The left engine started and operated normally. The right-hand engine continued to accelerate beyond idle and, showing no signs of stopping, was shut down when around 80% was achieved. The rigging of the FC was checked and found satisfactory. A second start attempt was made with the same fault present. The FCU was removed and inspected whereupon a small plastic drive shaft was found to be missing. The driveshaft was found still attached to the old FCU and was transferred. Subsequent engine runs were carried out without a problem.

Corrective action: The fact that the ground run was carried out and found the defect is some mitigation against the failure to transfer the driveshaft during the replacement of the FCU. The AMM procedure was clear about the shaft in place. However, a simple comparison between the unit being removed would also have highlighted the anomaly. The issue was followed up with the relevant staff.

## Conclusion to chapter 2

The above information from the analysis of MORs associated with CAA maintenance errors clearly indicates potential areas for consideration. This is useful information for any engineering organization or operator who wants to consider potential security risks and develop security strategies to address them.

The following examples are a snapshot of some of the MORs, which include additional details and an indication of what the investigation found. It is clear from the examples that the MOR system does not always have much information about the actions taken or what the company could have done to try to prevent a recurrence.

# CHAPTER 3

# USING MACHINE VISION FOR VISUAL INSPECTION OF AN AIRCRAFT AND ITS COMPONENTS

## 3.1. Tasks of Visual Control

Visual inspection is critical in many maintenance, repair and overhaul operations and is often the primary defense against premature failure caused by unresolved surface defects. Traditionally, visual inspection is performed by human operators, which is a time-consuming and subjective process. Recent advances in deep learning have the potential to accurately detect defects, resulting in reduced inspection times.

Visual inspection means inspection by looking. On the one hand, visual inspection is supposed to provide specific quality characteristics of intermediate or final products, and on the other hand, it can be used to identify and analyze deviations in the maintenance process.

Individual tasks of visual control can be divided into the following review categories:

Completeness: Recognition of known objects, regularities

- for example, on the assembly site: are all the components assembled?
- for example, charging: is the package filled?
- for example, in PCB assembly: are all components located?

Correct position and orientation

- for example, on the assembly site: are all the components in the right place and correctly oriented?

Consistency of dimensions, shape and angles of parts and tools

- size determination
- have all necessary specifications and tolerance agreements been met?

Surface condition, the texture

- does the condition of the surface meet expectations?
- is the surface uniform and does it meet the established tolerance limits?

Optical properties

- colour
- reflective behaviour

Identification of materials

- for example, automated sorting of various synthetic materials
- for example, detection and removal of impurities from flows of bulk goods (food, synthetic granulate, etc.)

Defects: both aesthetic and technical defects:

- for example, the detection of traces of varnish on a varnished surface (aesthetic defect)
- for example, the detection of scratches on optical components (technical defects)

Although the human visual system, consisting of the eyes and the brain, has many amazing capabilities that cannot be provided by a competitive machine today, the visual inspection performed by humans has some serious drawbacks.

Among other things, a manual visual inspection is:

- monotonous,
- laborious,
- gruelling,
- subjective,
- lack of good reproducibility,
- costly to document in detail,
- in many cases too slow,
- expensive.

## 3.2. Human vision problem

Human vision is without a doubt one of the most important of the five senses that humans possess that we depend on above all other senses. Human vision is the special and complicated sense of sight that revolves around light. It’s fascinating how the human visual system perceives and interprets things. We see things as they are – cars on the road, items on grocery store shelves, leaves on trees, widgets in a factory, and clouds in the sky.

No obvious deductions are needed or extra effort is required to interpret each object or scene.

All these things depend on the eyes and how they detect light patterns and coordinate with the brain to translate light into images that we then see. The human eye is such a complex optical system, very much like a camera; the light bounces off a particular object that you're looking at and enters the eyes through the cornera. Next, the light passes through the pupil and the iris, which together control the amount of light entering the eyes. When all of them work together, they focus light on the back of the eye called the retina [Figure 3.1**].** When light hits the retina, the minuscule cells contained within the retina turn it into electrical signals.

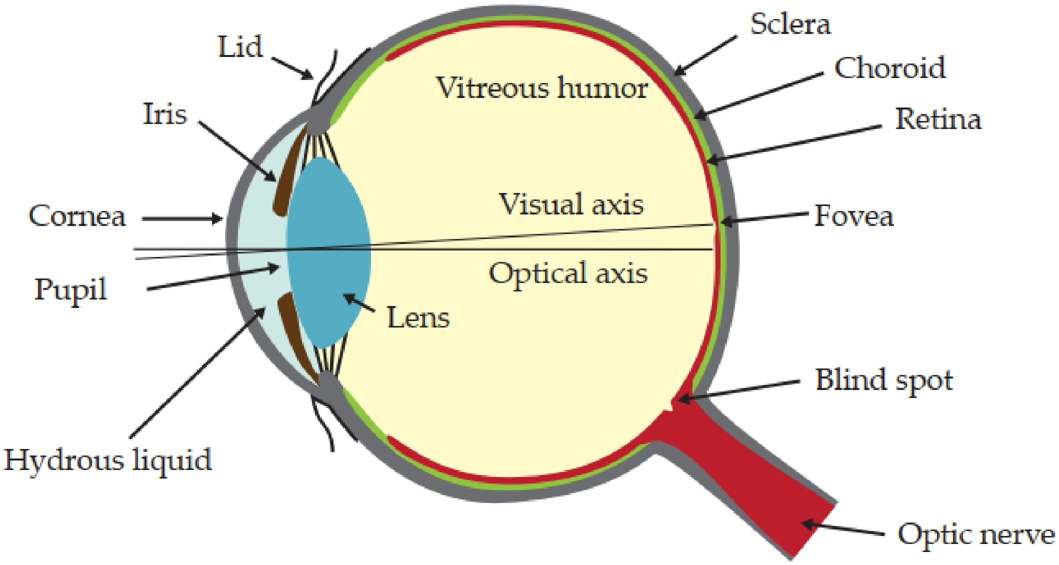


Figure 3.1. Sketch of the human eye

But, as with any other human sensor, human eyes have some problems which influence the quality of the visual inspection.

The most serious of them:

**Visual acuity**

Visual acuity refers to the ability to distinguish the shapes and details of things that a person sees (or simply "the ability to distinguish small details"). This is one of the factors of the overall vision.

### Color vision

The spectrum, obtained by refracting light through a prism, shows some characteristic regions of colour—red, orange, yellow, green, blue, indigo, and violet. These regions represent large numbers of individual wavelengths Figure 3.2.

Subjects with colour-defective vision are those whose wavelength discrimination apparatus is not as good as that of the majority of people. They see many colours as identical that people with normal vision see as different. About 1% of males and a much smaller percentage of females are dichromats; that is, they can mix all the colours of the spectrum, as they see them, with only two primaries instead of three. Colour vision is possible due to photoreceptors in the retina of the eye known as cones. These cones have light-sensitive pigments that enable us to recognize colour.

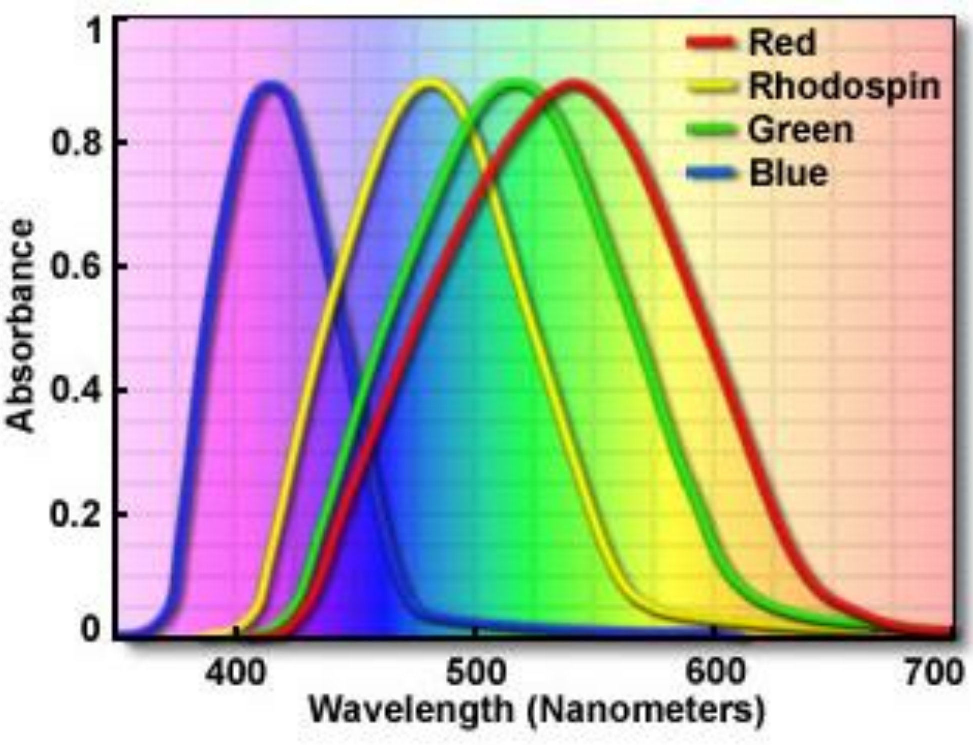


Figure 3.2. Absorption spectra of the four human visual pigments

### Optical illusion

In contrast to technical visual inspection systems, the human visual system can easily be fooled when viewing optical illusions, which shows directly that the two systems work quite differently

Humans see optical illusions when the visual system (eyes and brain) attempts to interpret an image that evokes a perception that deviates from reality. Your brain displays an image that makes the most “sense,” but it is not always what is actually in front of our eyes. The following example, (Figure 3.3) which goes back to Adelson, shows the difficulties of humans in absolutely capturing two colours, here, two shades of grey, square "A" looks darker than square "B" to our eyes, but they are the same shade of grey.

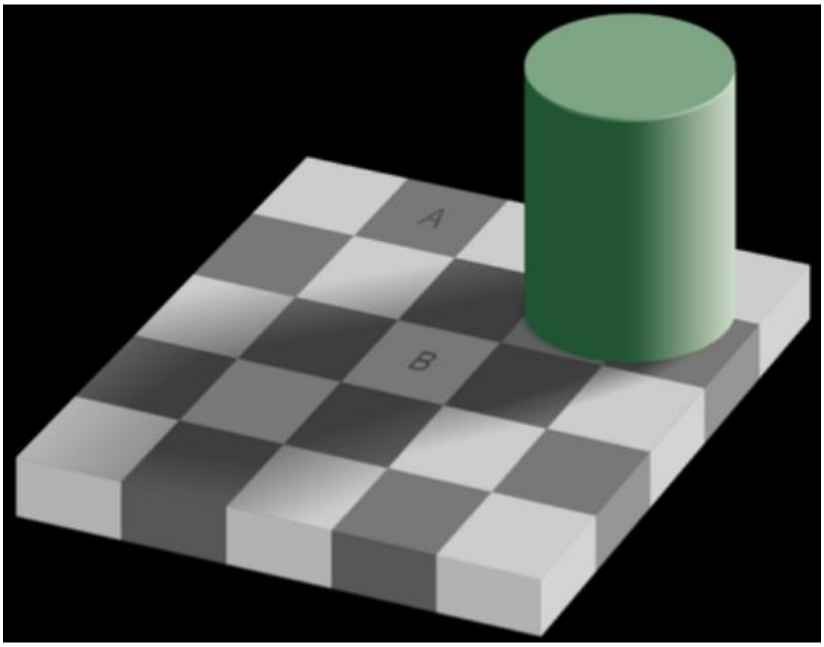


Figure 3.3. Checker Shadow Illusion

Optical illusions have their limits, however—they can't always fool us. There are tricks to letting our brain interpret the image correctly. In this case, if you directly compare the two squares with a grey bar, you can see that they are the same colour, as shown in Figure 3.4

The checkerboard’s digital image is represented by a matrix of grey values. A technical visual system would just compare the values corresponding to the two zones, notice their equality, and would not be fooled.

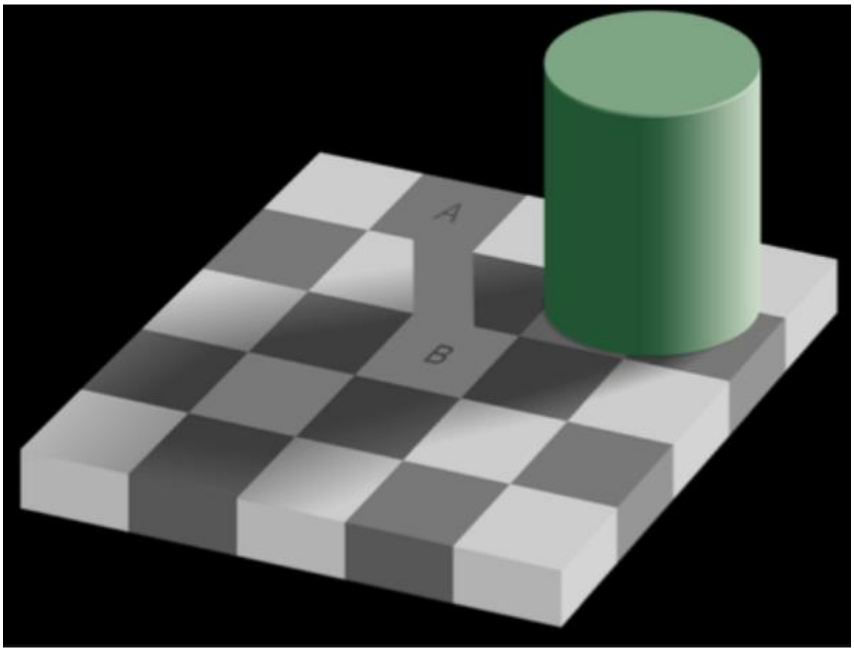


Figure 3.4 Squares “A” and “B” are the same shade of grey.

### 3.3. Human Factor problem

When thinking about the risks of potential failure of inspection to detect all critical defects, it is impossible not to mention the notion of human error.

Several studies have identified the most common, immediate effects of human error in aviation maintenance. A major airline shows the distribution of 122 maintenance errors over a period of three years to be: omissions (56%), incorrect installations (30%), wrong parts (8%), and others (6%). A three-year study by the Civilian Aviation Authority (CAA) found the eight most common maintenance errors to be: incorrect installation of components, electrical wiring discrepancies (including cross-connections), loose objects (tools, etc.) left in the aircraft, inadequate lubrication, cowlings, access panels and fairings not secured, fuel caps and refuel panels not secured, and landing gear ground lock pins not removed before departure

Whereas cognitive psychologists are concerned with the internal psychological or cognitive mechanisms of the mind that are assumed to explain the action, practitioners look at human error mainly as an exacerbating feature. Considering human error as a cause and as a symptom not only constitute only two different views, but also two different eras in the approach towards human error—a difference that is still sometimes blurry to the managers of complex systems

With that respect, science has dealt with human error and thanks to undertakings in cognitive psychology and accident analyses we are today closer to understanding human error and its underlying mechanisms. But it is still a problem nowadays.

Furthermore, humans do not have a ‘photographic memory’ for hues and colour intensities. For example, if one wants to do a mending job and thus needs to buy the same colour in which the object to be repaired is painted, one will certainly fail and buy the wrong colour if one only uses one’s memory of the desired colour. With a technical system, hues and colour intensities can be quantitatively compared without any difficulty if the corresponding images have been acquired under the same conditions.

Those examples clearly show that a human solves certain visual tasks quickly and without any problems. However, a human does not know how it is being done. Humans are not conscious of the underlying process: they are not aware of their algorithms. For the development of technical visual inspection systems, usually, a particular coding is necessary. A common misconception in the practical field of automated visual inspection is the idea that if a problem is easy to solve for a human, it has to be particularly easy to create equivalent automated programs. Recent approaches try to avoid the explicit formulation of algorithms by employing machine-learning methods

A human inspects actively. If one believes that one is not able to see well enough what one is being looked for while examining a test object, a human will more or less specifically vary their 'image acquisition' by changing the perspective and/or the illumination to optimize their view of the current task or will use other optical means (mirrors, magnifiers, etc.). The technical emulation of this process is called 'active vision' or 'active visual inspection' in terms of this book. Important examples include robot-based visual inspection systems that make use of a robot to systematically change the image acquisition of the test object, the illumination, and the camera.

### 3.4. The automation of visual inspection

The automation of visual inspection promises relief. An adequate automated system works without fatigue, yields impartial and reproducible results, and allows complete and detailed documentation. It is not always reasonable to aim for a fully automated solution. Many successfully implemented visual inspection systems have technically solved the part of the task that can well be automated. Everything else, particularly what can be done especially well by a human, will be done manually and thus, a human-computer system is established, combining the strengths of technology with those of a human in a symbiotic way. Possible examples are automated visual inspection systems detecting defects which are configured to be relatively sensitive, to ensure a high detection rate (i.e., the count of detected defects concerning the actual amount of occurring defects) so that as few defects as possible remain undetected. Such a high detection sensitivity will inevitably lead to a high rate of false alarms (i.e., the detection of defects which are not present), which would lead to many discarded test objects. If those test objects that were potentially affected by a defect later undergo manual visual inspection by a human, a hybrid visual inspection system with different advantages has been created. On the one hand, the number of test objects which have to be inspected by a human is significantly reduced by employing the automated pre-test, which will save labour costs. On the other hand, such a two-step procedure and the complementary strengths of technology and humans usually lead to a significantly increased quality of the inspection. Table 3.1 compares humans and technical visual inspection systems concerning their sensor systems and data processing .

**Table 3.1.** Comparison of humans and machines concerning their special abilities concerning visual inspection.

| | **Human visual system (eyes and brain)** | **Technical visual inspection system (image device and computer)** |
|---|---|---|
| **Sensors:** | • Low optical resolution;<br>• Intensity values and dimensions cannot be captured absolutely as there is no geometric or radiometric standard;<br>• Limited to visible light; | • High optical resolution;<br>• Absolute intensity values and dimensions can be captured;<br>• The light outside of the visible part of the spectrum |

| | | |
|---|---|---|
| | • Spectral perception with three channels. | can be used;<br>• The multichannel spectral resolution is possible. |
| **Image processing and analysis:** | • Huge amount of parallel, highly interconnected, and slow neurons;<br>• ‘Programmed’ by learning from examples | • One or more powerful processors;<br>• Algorithms usually need to be explicitly designed. |
| **Special abilities:** | • Experience and background knowledge;<br>• Adaptability and learning aptitude;<br>• Active vision by immediately varying the inspection setup (visual control loop);<br>• Enormous cognitive capabilities;<br>• Intuition | • Precise calculations;<br>• High processing speed;<br>• Lossless saving of large amounts of data (‘photographic memory’). |

### Optical capturing of test objects

Of course, when using automated visual inspection, only those object properties can be inspected that can be optically acquired. Such properties can be divided into different classes. In addition, light has various parameters, which are altered by the test object characteristically, so that they can be used to conclude the object's properties. This section will sketch which of a test object's properties can be acquired using which optical method. This topic will be thoroughly covered in later chapters, as soon as the required terms and formalisms have been introduced.

Light, emitted by a light source, illuminates the test object. Because of the interaction with the test object, the irradiated light will be partly absorbed, partly altered, partly reflected, and partly dispersed. By receiving a part of the light sent off by the test object with an optical observing instrument (e.g., a camera), data can be acquired that contains information about the test object (Fig. 3.5). The following image processing methods try to regain that information.

In terms of information technology, the light emitted by a light source can be seen as a carrier signal that gets modulated by placing the test object in its path. Thus, the modulated light contains information about the test object. This modulation of the information can be based on various physical phenomena. This is why the light may encode the information about the test object in different ways.

Those physical phenomena create diverse optical information channels:

1. Distribution of the light intensity for position and orientation;
2. Spectrum (distribution of the intensity for the wavelength);
3. Polarization (the distribution of the directions of the electric field vectors perpendicular to the direction of propagation of the light);
4. Coherence (the light wave’s temporal and spatial relations);
5. Phase (the current state of the oscillation in the direction of propagation);
6. Time dependence (the dependence of the value of the intensity and other parameters on time).

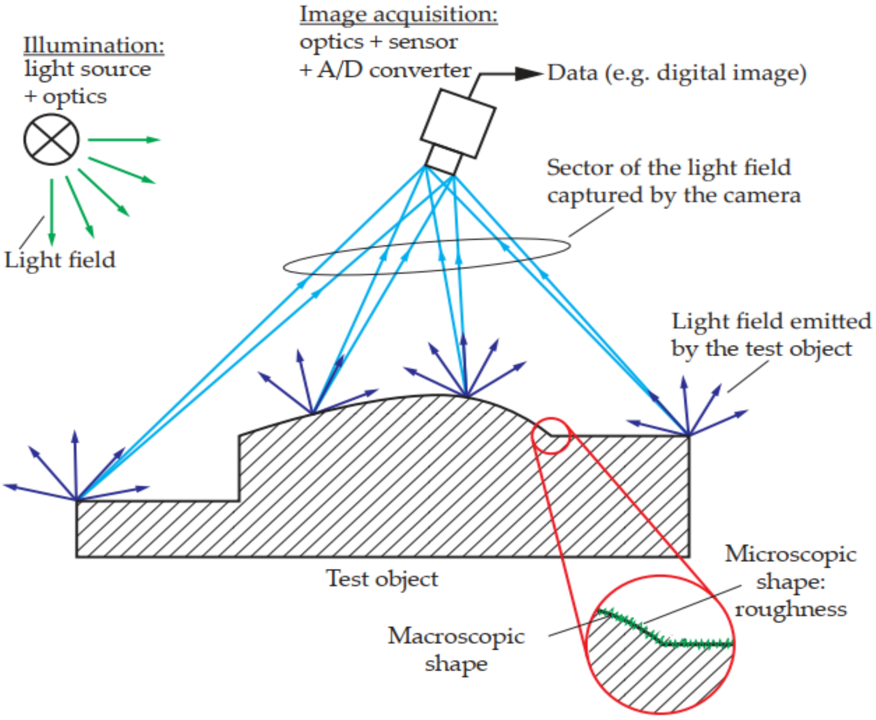


Figure 3.5. Optically acquiring information about a test object.

The irradiated light is influenced by the spatial shape and effective optical material properties of the test object. This is why one can only expect to get information about the test object’s shape and optical properties by evaluating the observed light. When testing transparent or partially transparent objects, which are permeable to light, the interaction not only takes place on the surface of the object but also inside the object.

However, opaque objects, which are not transparent and where the interaction with the light mainly takes place on the object’s surface, play an important role in automated visual inspection. The interaction of the test object and the irradiated light can pragmatically be described by a suitable reflection function, which can cover more or less the physical properties concerning the relevant phenomena. The irradiated light is multiplicatively related to the reflection function. The result is a description of the emission of the modified light into the surrounding space. Depending on the definition of such a reflection function, only optical material properties or additional shape-based effects, like dispersion of the light caused by the surface's roughness, are captured.

## 3.5. Machine vision

Typical machine vision systems consist of the structure shown in Fig. 3.6, which is to be read bottom-up. This figure is deliberately shaped like a pyramid based on the process of image acquisition.

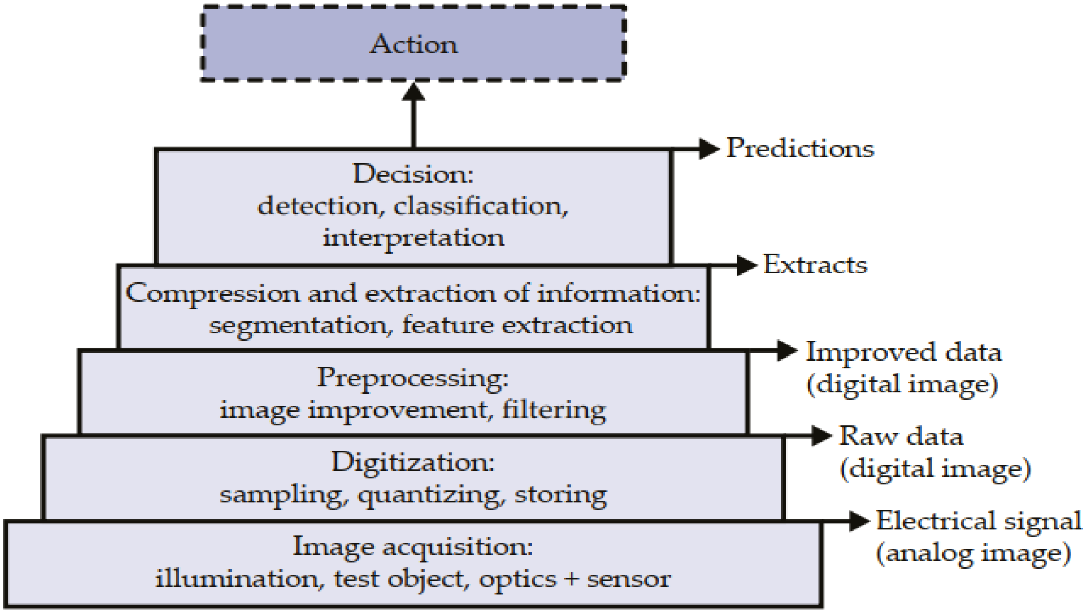


Figure 3.6 The processing chain of machine vision systems

The suitability and quality of this level are crucial for the whole chain of visual inspection tasks.

The amount and quality of information that is contained in the acquired image data depend entirely on the step of image acquisition. Information that is not acquired during this step can be recovered only with difficulty, or even not at all, by subsequent image processing steps, regardless of how much effort is spent on them. Many visual inspection systems failing in practice did not adhere to this simple rule.

The light that is emitted by the light source interacts with the test object, passes through the imaging optics, and finally reaches the sensor, where it is transformed into an electrical signal. This analogue signal, which is usually an electrical voltage, is discretized and limited concerning space and amplitude. In such a representation, it can be saved as a digital image and processed by a computer. But besides the information relevant for visual inspection, this raw data usually contains disturbing and irrelevant components, such as noise, inhomogeneities, and so on. The subsequent image restoration process tries to retain the relevant information and compensate for the irrelevant signal components. As a result, improved image data is obtained, which is separated into meaningful regions and/or processed to extract the parameters relevant to the task (features). Finally, decisions can be made based on this condensed information: such decisions can be detection (e.g., of a defect), classification (e.g., of different objects) or interpretation (e.g., inference of production parameters), depending on the visual inspection task.

A subsequent action can then be taken, depending on and adapted to that decision, such as discarding or keeping the test object, or selectively altering production parameters, for example.

It cannot be stressed sufficiently often that a well-considered image acquisition system can have an enormous impact on the capabilities of an automated visual inspection system. The huge amount of optical and geometrical degrees of freedom of the image acquisition setup (light source, test object, optics, and sensors) offers a huge design space whose opportunities, however, can only be systematically exploited with the necessary knowledge and a concept adequately adjusted to the problem at hand. Efforts spent at this stage usually turns out to be a good investment in the final capabilities of the visual inspection system. For some tasks, it is even possible to obtain images during the image acquisition phase that are so expressive and easily interpretable, that the subsequent image-processing steps are nearly trivial. The following examples will illustrate this.

**Example 1**

Any aircraft has a lot of mounts and attachments with screws. Accounted huge aircraft's size, some of these screws could have been missed, due to different causes, but each of them is very important.

Checking the correct installation of every screw takes lots of time. This time could be used for other work or save on labour payments. This inspection task can be automated very well. In this example, a method is employed that yields an extremely high-contrast image that can be used to simultaneously check whether all screws are wrenched. This is achieved by attaching a camera to a drone. The Drone can fly above an aircraft and looks at the surface of the aircraft or any other hard-to-reach places. Figures 3.7 and 3.8 represent a typical mistake made by human error, but machine vision does not make any problem identifying it.

Figure 3.7 Example of a loose and tight screw

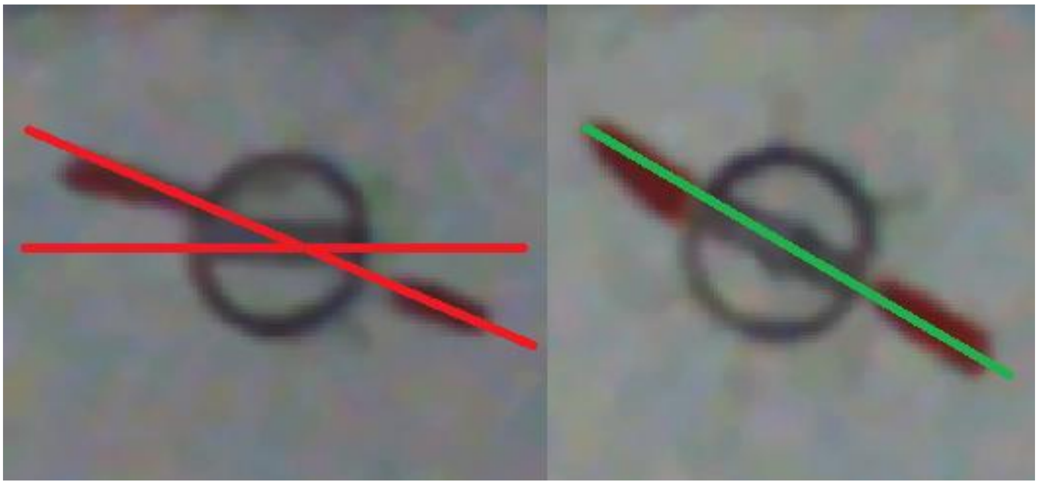


Figure 3.8 Example of a loose and tight screw

**Example 2**

Cracks are local breaks in the material in the frame or structure of the machine. Cracks may develop later during service or cyclic loading when the aircraft experiences various types of fatigue loads. Vibration is a major source of fatigue cracking in aircraft, arising from atmospheric turbulence, as well as many factors associated with engines, both piston and turbofan. Such structures must be inspected non-destructively to detect hidden damage, such as fatigue cracks before they reach a critical length and be repaired before they lead to catastrophic failure. Periodic inspections by machine vision will minimize the damage of this kind. Therefore, it is necessary to regularly apply accurate and reliable methods to detect such defects in aircraft. As you can see in the figure, the machine vision accurately detected the location of the crack (Figure 3.9).

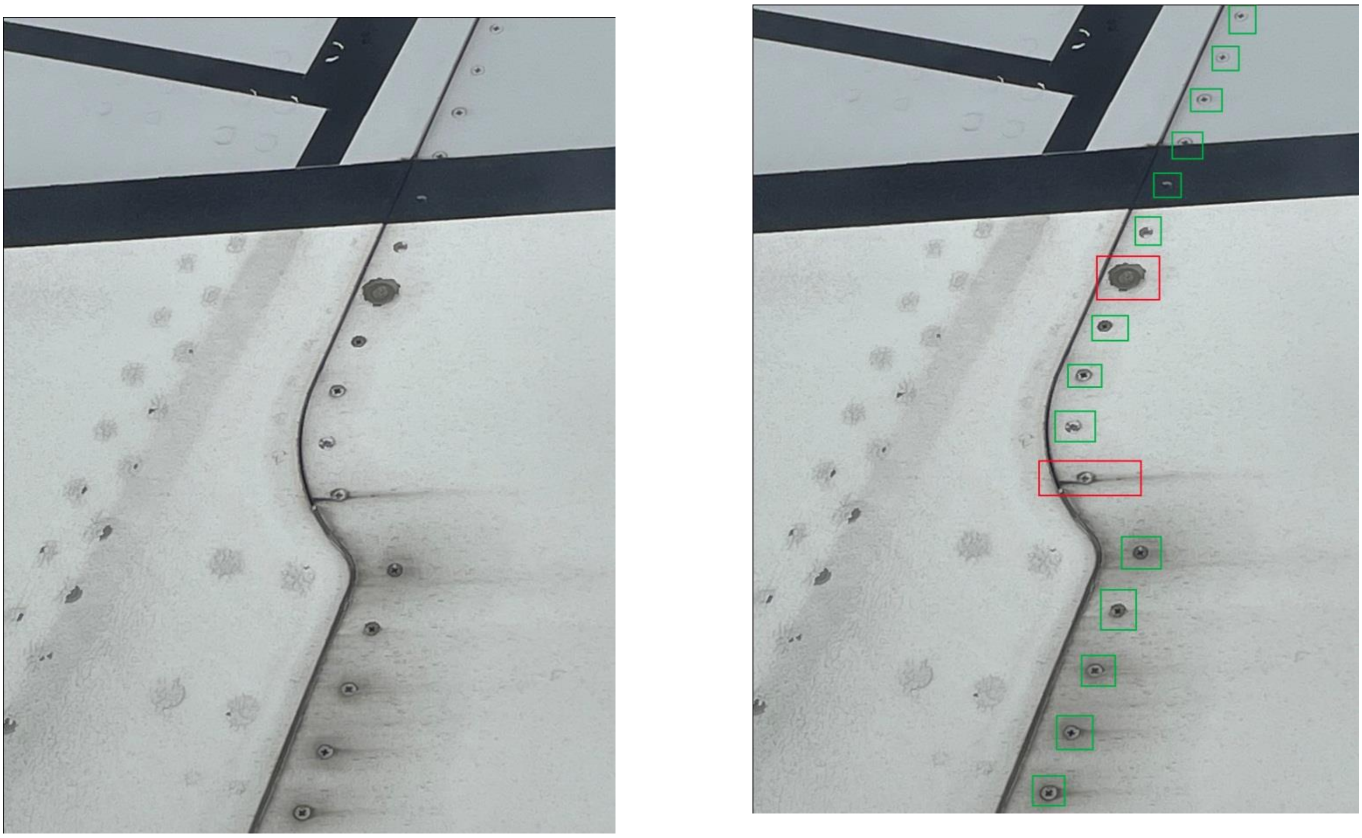


Figure 3.9 Example of a crack of surface

## Conclusion to chapter 3

A human has shortcomings due to which he or she cannot perform the inspection perfectly. It can be visual defects or the human factor or both of them. The human factor has been learned for many years, but there are no clear solutions to the problems of the human factor. In today's realities, it is possible to replace a person with a machine. Machine vision can inspect an aircraft or its component in the same way as a person can, completely excluding human defects. Also, each inspection can be saved for future use, for example for staff training.

# CHAPTER 4

# ENVIRONMENTAL PROTECTION

## 4.1.Description of Electromagnetic interference

The last two decades have seen enormous changes in how human health affected by electromagnetic interference (EMI), especially during maintenance of any aviation system. It is so essential that studying the effect of EMI is necessary for all aviation engineers following the requirements EASA PART 66 and is described in Module 5 topic 5.1 Electromagnetic Environment [2].

In Ukraine companies that maintenance aviation equipment such as ‘MAU technique’ minimum safety and health requirements for staff during using personal protective equipment at the workplace followed by [7]. Moreover, regulated by Order No. 1804 of 11/29/2018 is valid from 01/15/2019 published by Ministry of Social Policy of Ukraine. On approval of the Minimum Safety and Health Requirements when employees use personal protective equipment at the workplace. [8].

EMI is the disturbance generated by an external source that affects an electrical circuit by electromagnetic induction, electrostatic coupling, or conduction (Fig. 4.1).

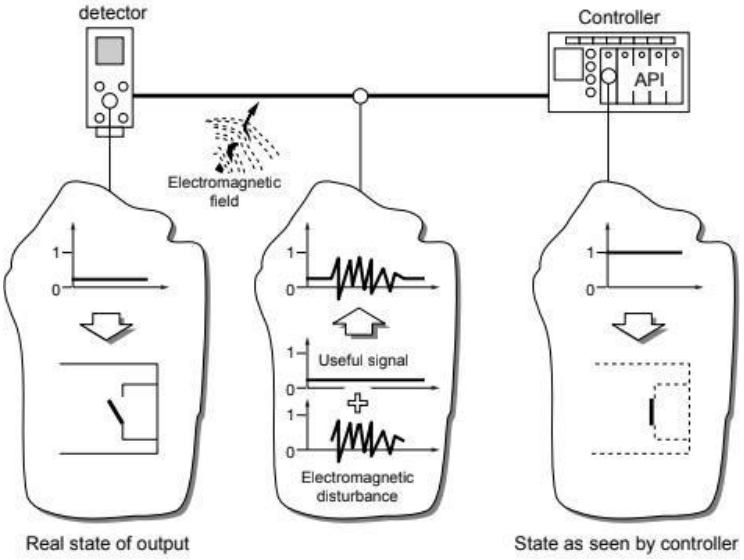


Fig.4.1. Example of EMI

Electromagnetic fields harm the health of maintenance staff. Low frequency, radio frequency and microwave frequency may cause a flow of current through the human body. This flow of current generates heat and produce thermal injury. Natural low frequency fields are static electric fields between the ionosphere and Earth, and static electromagnetic pulses due to lightning. These fields have been keeping living beings in an invisible cage of EM wave and pulses. The health effects that might originate from EM radiations are almost certainly the most complicated and difficult to understand of all the effects of EM radiations.

This graduated work is concerned with of influence human factors on operation and maintenance of remotely piloted aircraft systems. In addition, should be pointed out that EMI problem is tightly connected with one of the most popular models of human factors, which is the SHEL model.

E. Edwards first introduced the SHEL model (Fig 4.2.), and then in 1975 supplemented by the Hawkins diagram illustrating it, and adopted by ICAO as a conceptual model for explaining the role of the human factor in aviation [1].

The constituent blocks of the SHEL model (this abbreviation is formed from the initial letters of the names of the model blocks: Software - software, Hardware - object, Environment - environment, Liveware - subject) clearly emphasize the need for their mutual correspondence.

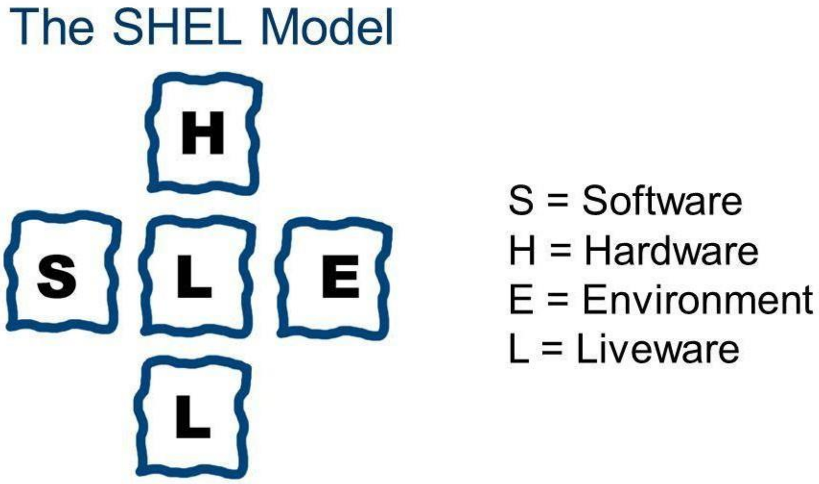


Fig. 4.2. The interrelationship between human factors and aviation environment

This chapter is devoted to the issues related to the influence of electromagnetic radiation on the environment and humans. Using modern technology, some measures to reduce harmful emissions can significantly reduce the negative impact on maintenance staff and the environment.

## 4.2. Electromagnetic interference during maintenance

It should be noted that the increased concern of EMI (Fig. 4.3.) during maintenance in recent years because it occurs due to the following and regulated by 3.3.6.096-2002 ‘On Approval of State Sanitary Rules and Regulations when working with Electromagnetic Field Sources’ [15]:

1. Greater dependence on electrical and electronic systems for continued safe flight.
2. Reduced electromagnetic shielding due to greater use of composite materials.
3. Increased susceptibility of electrical and electronic systems to HIRF due to increased data bus and processor operating speeds, higher-density integrated circuits and cards, and greater sensitivities of electronic equipment;
4. Expanded frequency usage, especially above 1 gigahertz (GHz);
5. Increased severity of the HIRF environment because of an increase in the numberand radiated power of radio frequency (RF) transmitters; and
6. Adverse effects experienced by some aircraft when exposed to HIRF.

There are the following sources of external interferences in aircraft (Fig. 4.4.):

Two forms of interference

- Conducted interference
- Radiated interference

Sources of interferences

- External Electrical Systems
- Engines system – ignition system
- Inadequate bonding
- Faulty static discharger/wicks.

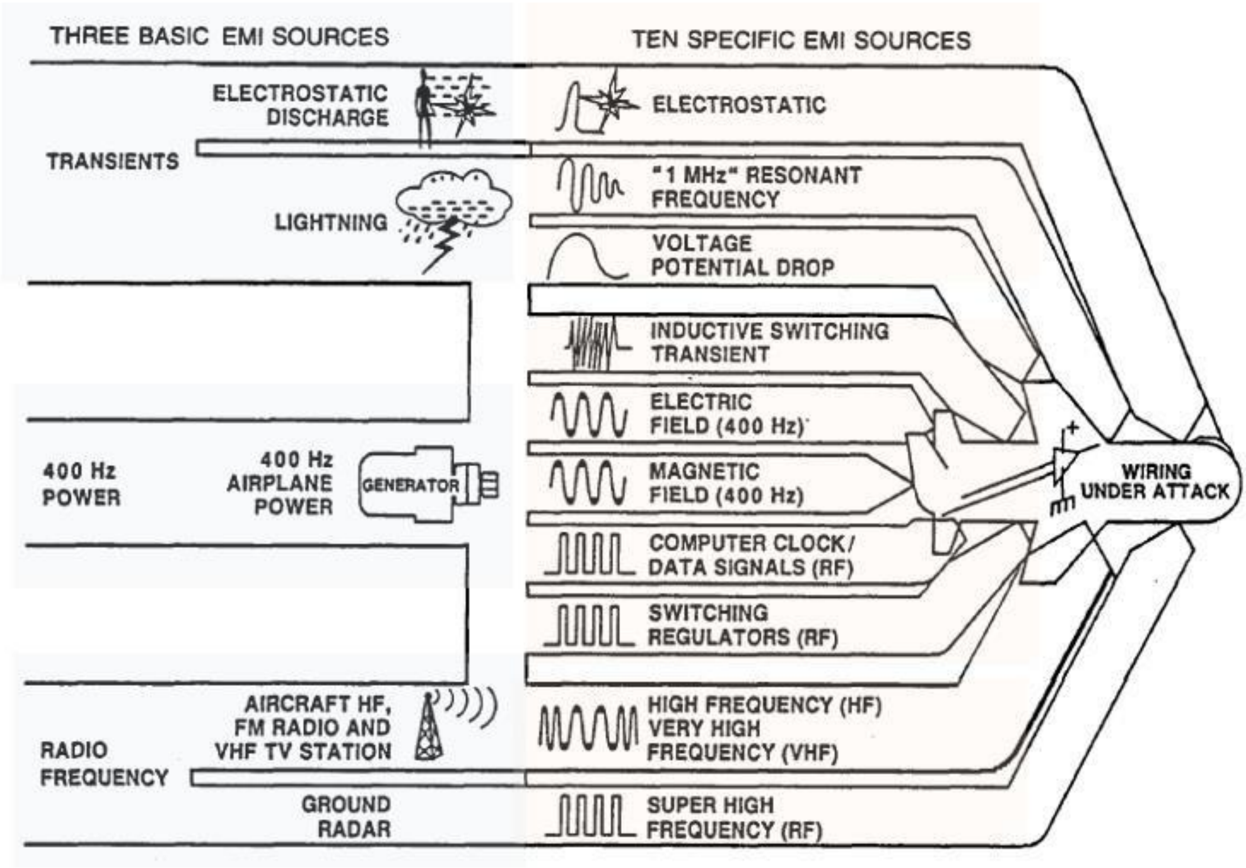


Fig. 4.3. Representative EMI sources

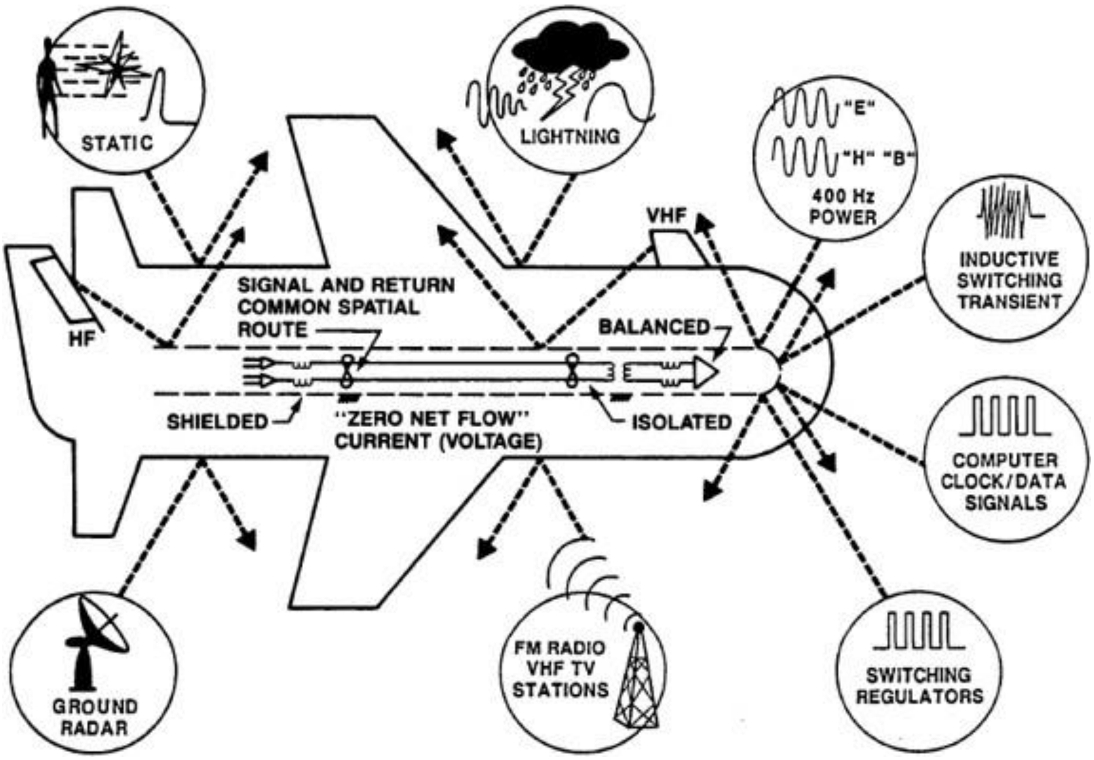


Fig. 4.4. EMI Environment in aircraft

The following can control EMI on aircraft:

- Well Located aerials – the interference to the comm/nav systems like ADF and VHF (Very high frequency).
- Electronic equipment to be grounded and the related wires to be shielded and grounded.
- The lighting current flows through the outer skin and discharge to the extremity.
- Bonding – all equipment to be bonded together, min R = 0.05 ohms.
- Static Discharger – provide the resistance path to the atmosphere.

There are also worries about suspected electromagnetic interference with aircraft systems. It was reported many aviation incidents connected, for example:

- June 07, 1997. B737-300: *Verify position* was indicated on the CDU. Both the IRS and radio position was correct. The flight management system (FMC) position was not. The difference rapidly increased to 8 nautical miles. After switching a GSM in the cabin from STBY to OFF, the FMC updated normally. FMC was correct for the remainder of the flight and on the return flight.
- April 30, 1997. B737-400: During the level cruise, the AP pitched up and down with ROC/ROD of 400 fpm indicated. Another AP has selected no change. The cabin was checked for PC's and other electronic devices: nothing was found. Requested passengers to verify that their mobile phone (GSM) was switched OFF. Soon after this request, all pitch oscillations stopped.

Therefore, it can be easily seen that EMI affect not only maintenance staff but also all aviation systems and can lead to aviation incidents and accidents.

### 4.3. The impact of EMI from avionics the environment

Today, the new age avionic system is equipped with tons of micro and micro-computers, electro- and radio devices. Without them, it is no longer possible to imagine the modern aircraft, moreover the cockpit.

One of the most harmful computer hardware for the human body is the displays and generators of clock frequencies of processors and coprocessors.

Displays, designed based on cathode ray tubes, are the sources of electrostatic field, soft X-ray, ultraviolet, and infrared and visible frequency spectrum and form high-frequency electromagnetic radiation (EMR) due to the high charged-particle accelerators.

The influence of the EMR complex or its species on the occurrence of various diseases began to be studied from the moment of their use. At the end of the 1950s, the first norms limiting radio frequency influence were introduced in the USSR. Inthe late 60s, Soviet scientists found the influence of electromagnetic fields, even feeble, on the human nervous system. In the 70s, this problem became the subject of broad discussions and studies, which are relevant by these days.

The sources of EMC are power supply (frequency 50 Hz), linear scan system (2-400 kHz), and cursor beam modulation unit (5-10 MHz).

It was found that low frequency radiation, in the first place, negatively affects the central nervous system, causing headaches, dizziness, nausea, depression, insomnia, lack of appetite, the emergence of stress syndrome, and the nervous system responds even to short duration effects relative to the weak Frequency fields: changesin the hormonal state of the body, broken biocrasses of the brain. All this is reflected in the learning and memorizing processes.

The low-frequency electromagnetic field can cause skin diseases (acne, eczema, pink lichen, and other), diseases of the cardiovascular system and the intestinal-gastrointestinal tract; it affects the white blood cells, which leads to the appearance of tumours, including malignant [3].

Noting that a flight crewmember may have exceeded that limit before confir- mation of pregnancy, operators should have effective provisions in place to ensure that the flight crewmember does not exceed a dose of radiation after declaration of pregnancy.

The standards for video display terminals in the cockpit are as follows:

— to ensure protection and achieve normalized levels of computer radiation, it is necessary to use preshrink filters and other protective equipment that has been tested in accredited laboratories and have an annual hygienic certificate;

— the screen should be located at an optimum distance from the pilot's eyes, taking into account the size of the letters and digits and symbols - 600 – 700 mm.- place the keyboard on the table surface at a distance of 100 - 300 mm from the edge closer to the user;

- when performing the main work, the noise level in the cockpit should not exceed 50 dB [4].

The basis of such considerations lies in the fact that laptops use screens based on liquid crystals that do not generate harmful radio frequencies, typical of ordinary monitors with an electron-beam tube.

However, the results of research conducted in research centres showed that the electromagnetic radiation of notebook computers far exceeds the environmental standards due to the peculiarities of the formation of an electrostatic field for the organization of the required level for the polarization of liquid crystals. The frequency of clock generators reaches tens and hundreds of MHz, which also generates a hazardous EMR.

### 4.4. Methods of protection against electromagnetic radiation

If the characteristics of the EMR exceed the requirements of normative acts, different means and methods of flight crewmembers protection are used.

The following methods of protection against EMR were the most widespread:

1. Reducing radiation power in the source. Reducing the radiation parameters directly in the source itself is achieved by the rational choice of the generator, the use of coordinated loads and special devices – absorbents of power (equivalent to the antenna and load). The latter is used as generator loads instead of open emitters. Power absorbents are coaxial and wave guidelines, partly filled with absorbent materials.

2. Distance protection system unit and monitor should be as far away as possible from the user. If it is impossible to reduce the intensity of irradiation by these methods, use protection distance and its increase. Distance protection is provided by the mechanization and automation of production processes, the use of remote control and special manipulators, and the rational placement of equipment in the workplace.

3. Screening of radiation sources and workplaces. Screening is one of the most effective and most frequently used protective devices from the EMR.

4. Use of a liquid crystal monitor, since its optical radiation, is much smaller than other types of monitors. This option is also widely used on-board of modern aircraft.

5. To protect against radiation and health, it takes much time to spend in the fresh

air and to protect from a sedentary seat behind the computer you need to interrupt the work for physical exercises and rest for the eyes.

6. It is also necessary to take care of the eyes, for example, to use glasses with appropriate light filters [3].

## Conclusion to chapter 4

Electromagnetic pollution of the environment is one of the most pressing problems of humanity in our time.

Widespread use of a variety of electrical appliances, including personal computers, aircraft systems, leads to an unceasing increase in electromagnetic background. It has already been proved that the action of electromagnetic waves on a human body has a disastrous nature.

EMI can cause avionic equipment performance to degrade or even malfunction. EMI can affect cockpit radios and radar signals, interfering with communication between pilot and control tower. Airborne devices that can cause interference include laptop computers, electronic games, cell phones, and electronic toys, and all have been suspected of causing events such as autopilot disconnection, erratic flight deck indications, and airplanes turning off course.

EMI effects from lightning, solar flares, electrostatic discharge, and HIRF fromradar and various kinds of transmitters or communications equipment – have all resulted in numerous aviation incidents throughout the years. As a result, EMI effects are now considered in all aspects of avionics design and certification.

Generators of electromagnetic interference to an aircraft can come from several sources, for example:

- Transmitters of radio frequencies that may be installed on the aircraft itself, such as high-frequency (HF) or VHF communication links, or high-energy sources located on the ground such as our everyday frequency modulated (FM) radio or HF-VHF-UHF broadcast HIRF;
- The aircraft power line 400-Hz electric and magnetic fields;
- The computer and avionics microprocessor timing and control clock signal circuits that generate radio frequencies of one MHz or higher;

- The aircraft power switching regulators which are used to convert from one level of power to another;
- Electrical switching transients sparked by the turn on and off of aircraft lights, fans, and engines or by the operation of control surfaces, ailerons slats, and flaps ;
- Electrostatic discharges including lightning.

The conductive paths of electrical wiring provide an avenue to usher electromagnetic interference directly to airplane avionics and signal inputs. Eliminate wiring, and electromagnetic interference almost vanishes. Wiring is the most important factor in electromagnetic interference and electromagnetic compatibility.

In order to prevent or reduce the negative impact of EMI, workers must comply with the norms of electromagnetic radiation and the peculiarities of working with it. It is also worth to make sure of compliance with sanitary standards for electronics and high-tech optical technology.

Since electromagnetic radiation on the aircraft at least meets international norms and standards, but has a negative impact on human health, it therefore needs to take recommended measures to protect against EMF in the radio frequency range and optical range.

# CHAPTER 5

# LABOUR PROTECTION

## 5.1. List of hazardous and harmful production factors

Labour protection is necessary during maintenance of aviation equipment. Everyone who involved in this process, from the employer to the newest worker, has different but essential duties to keep the workplace safe. Because employers have the most authority in the workplace, they have the most significant responsibility. However, it is crucial for maintenance staff to own safety that you understand everyone’s health and safety duties, including they own.

Knowledge of all hazardous and harmful production factors are obligated to preventing injuries and illnesses at work.

In Ukraine, companies that maintenance aviation equipment, for example, ‘MAU technique’, minimum safety and health requirements for staff during using personal protective equipment at the workplace followed by [7]. Moreover, regulated by Order No. 1804 of 11/29/2018 is valid from 01/15/2019 published by the Ministry of Social Policy of Ukraine ‘On approval of the Minimum Safety and Health Re- quirements when employees use personal protective equipment at the workplace’ [8]. In addition, Law of 10/14/1992 No. 2694-XII ‘About labour protection’ from the Verkhovna Rada of Ukraine [9].

An understanding of the importance of labour protection of aircraft maintenance engineering is essential to anyone considering a career as a licensed aircraft engineer. Labour protection impinges on everything an engineer does in the course of their job in one way or another. Knowledge of this subject has a significant impact on the safety standards expected of the aircraft maintenance engineer.

Various factors impinge upon the engineer’s physical working environment it include:workplace layout and the cleanliness and general tidiness of the workplace (e.g. storage facilities for tools, manuals and information, a means of checking that all tools have been retrieved from the aircraft and other);

- the proper provision and use of safety equipment and signage (such as non-slip surfaces, safety harnesses and other);
- the storage and use of toxic chemical and fluids (as distinct from fumes) (e.g.

avoid- ing confusion between similar looking canisters and containers by clear labelling or storage in different locations, and other).

To some extent, some or all of the factors associated with the engineer’s workplace may affect his ability to work safely and efficiently. JAR 145.25(c) - Facility Requirements states:

- ‘The working environment must be appropriate for the task carried out and in particular special requirements observed. Unless otherwise dictated by the particular task environment, the working environment must be such that the effectiveness of personnel is not impaired.’

The **working environment** comprises the physical environment componentsof the working environment interact (Fig. 5.1.), for example:

- engineers are trained to perform various tasks;
- successful task execution requires a suitable physical environment;
- an unsuitable or unpleasant physical environment is likely to be de-motivating.

The specific design of buildings and structures of the aircraft maintenance facility (AMF) may be adjusted in accordance with the adopted scheme for organizing the maintenance of the aircraft, which should be reflected in the design task.

The plot of AMF should be of a size that ensures the placement of all buildings and structures for maintenance of the aircraft, taking into account the sanitary and fire requirements set forth in Construction Regulation Standards Building Code "General plans of industrial enterprises. Design standards". In determining the size of the plots, the future development of the AMF complex should be taken into account. For this purpose, certain areas are reserved, adjacent to the buildings and facilities planned forexpansion [3].

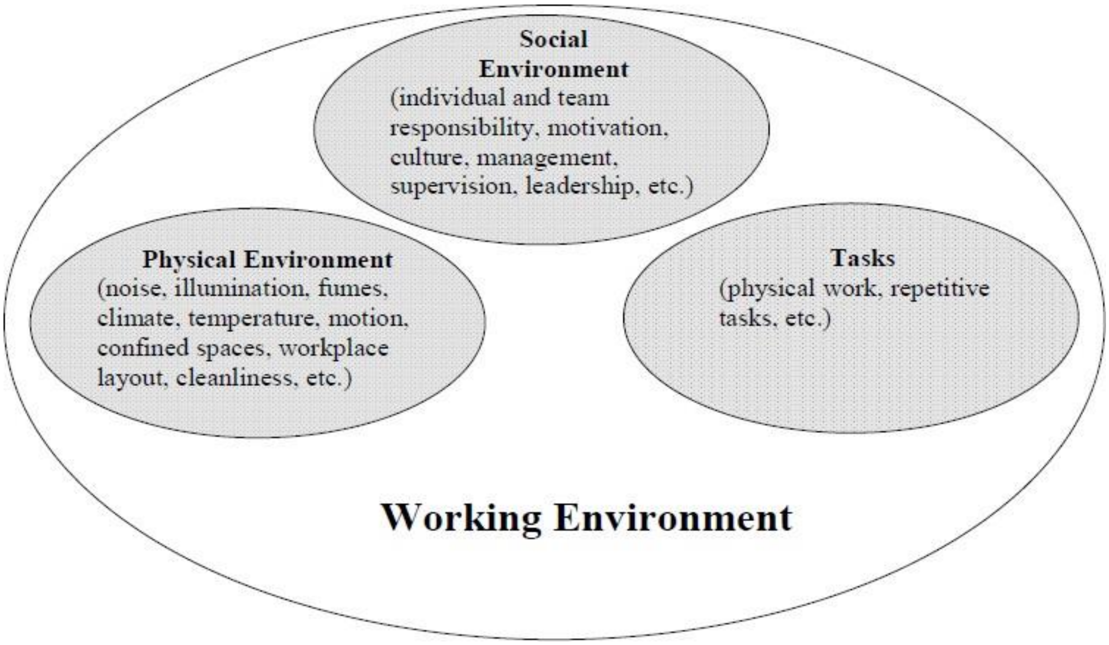


Fig. 5.1. Components of the 'Working environment'

Modern hangar construction is characterized by a large variety of planning and design schemes, while some are used for one type of aircraft; others suggest the content of different types of aircraft and helicopters. Nowadays, almost all commercial and military hangars have dozens of engineers and technicians who carry out repair and service around the clock. To protect the life and safety of the airplanes as well as buildings, it is necessary to install high-performance fire detection and fire extinguishing systems.

Aircraft hangar is an area of the fire hazard difficult detection due to a large area, the presence of fuel, solvents, accumulation of vapours, radar and electrical interference.

Although the crew is trying to spend as much fuel (jet fuel or aviation gasoline) as possible before the aircraft enters the hangar, but many hangars take just tucked aircraft as well.

Explosive materials may be also stored on the maintenance plot. In addition, staining occurs accumulation of vapours, which may cause fire [1].

Some flame detectors can be activated (triggered by an alarm) due to interference caused by radar, bundle, and X-rays. An effective practice is to use detection devices with Electromagnetic interference (EMI) / Radio Frequency Interference (RFI) protection. EMI and RFI protection are the subjects of study in my thesis work.

## 5.2. Technical and organizational measures that intensify or minimize the impact of hazardous and harmful factors on maintenance stuff

The noise environment in which the aircraft maintenance engineer works can vary considerably. For instance, the airport ramp or apron area is clearly noisy, due to running aircraft engines or auxiliary power units (APUs), moving vehicles and so on. It is not unusual for this to exceed 85 dB - 90 dB that can cause hearing damage if the time of exposure is prolonged. The hangar area can also be noisy, usually due to the use of various tools during aircraft maintenance. Short periods of intense noise are not uncommon here and can cause temporary hearing loss. Engineers may move to and from these noisy areas into the relative quiet of rest rooms, aircraft cabins, stores and offices.

For work with hazardous and hazardous working conditions, such as high noise levels, workers are given free of charge special elements according to the established standards, which are an obligatory minimum for the employer to issue personal protective equipment free of charge, defining the protective properties of the personal protective equipment and the terms of their use. This was approved by the Order of the State Committee of Ukraine for Industrial Safety, Labour Protection and Mining Supervision No. 62 of April 16, 2009, registered with the Ministry of Justice of Ukraine on May 12, 2009 under No. 424/16440 [10].

It is very important that aircraft maintenance engineers remain aware of the ex-tent of the noise around them. It is likely that some form of hearing protection should be carried with them at all times and, as a rule of thumb, used when remaining in an area where normal speech cannot be heard clearly at 2 meters.

Old jet and turbo-jet engines can produce noise levels that exceed 115 dB. Auxiliary power units, ground power units, condensed air equipment, tugs, fuel trucks and loading and unloading equipment also increase the level of background noise. Levels of noise in the runway and in aircraft parking areas are rarely lowered to 80 decibels. Protective equipment should provide effective noise reduction, be convenient in terms of ergonomics and does not hinder communications between the staff. Dual systems (headphones and earplugs) provide better protection and allow adjustment at different noise levels.

In order for the flights to be conducted strictly according to the schedule and satisfy all the requirements of the passenger, ground equipment is moving at high speeds, aircraft parking, runways and runways but is often poorly lit [2].

Workers are at risk of being tightened up in turbines of jet engines or can be hitby a propeller or by a jet exhaust.

Limited visibility at night and unfavourable weather increases the risk of attacking ground stuff by moving equipment and operating mechanisms.

The strict control over the procedure of stuff in dangerous proximity to fuel storage facilities should be included in the general program of labour protection.

Compliance with the rules and cleanliness is important to sequence the orderon the airfield. It is necessary to carefully remove spilled and spent liquids. The fulfilment of these requirements is also important in carrying out the basic repair [1].

When setting standards for noise limitation, as a rule, they are not from the optimal (comfortable), but from the permissible conditions under which the harmful effects of noise on a person are not detected, or insignificant.

Noting that Regulation (EC) No 216/2008 [11] provides for the involvement of European countries not Members of the European Union with the objective of ensur- ing a proper pan-European dimension, in order to facilitate the improvement of civil aviation safety throughout Europe. Considering that Ukraine and the European Union and its Member States have initialed a Common Aviation Area Agreement (CAA Agreement) [12] which provides for Ukraine's participation in the relevant parts of the EASA system. So permissible limits for aircraft noise are defined in 'CertificationSpecifications for Aircraft Noise CS-36', 3 April 2007 by EASA [13].

Industrial noise permissible limits defined in DSN 3.3.6.037-99 'Sanitary standards of industrial noise, ultrasound and infrasound' [14]. Rated (normalized) parameters of permanent or intermittent production (transport) noise are the levels of sound pressure in the octave frequency bands (the boundary spectra measured in dB, the designation of the spectrum corresponds to the sound level in the 1 kHz band), and the sound levels corrected on the scale 'A' of the standard noise meter (dBA).

Permanent noise is considered, the levels of which over time vary by no more than 5 dB. Non-constant noise is considered, the level of which over time varies by more than 5 dB. Intermittent noise is interrupted by pauses lasting for several hours, minutes or seconds.

$$Itkb\ \ (a) = 10 \lg lg \left( \frac{1}{100} \sum_{i=1}^{n} t_1 * 10^{0.11} \right)$$

Where: L - average class i, dB; t - time of the impact of noise class i from the total control time, %.

Calculated values of Lkb (A) are compared to rated (normalized) sound levels (dBA).

For discrete and pulsed noise, the permissible levels are reduced by 5 dB.

The normalization of noise in facilities and on the territory of residential buildings. In [14] made adjustments to the nature of the noise (for tonal or pulse -5 dB), the time of day (for day time - +10 dB), the location of the object (for the resort area -5 dB) and the total time of exposure to noise.

The normalized values have the following meanings: at a geometric frequency of 1/3 octane band 12.5 kHz - 75 dB, at 16 kHz - 85 dB and at frequencies above 20 kHz - 110 dB.

Exposure levels and duration - professional noise exposure must be monitored in such a way that the exposed person does not suffer from excessive exposure, which is determined by the level and duration of the sound per person. The values of the acceptable combination of level L and duration T are given in Table 5.1, or they are calculated by the formula, min.

The corresponding values of the dose exposure of noise are given in the table.

1.2., where TWA is the eight-hour time-weighted average sound level: TWA = 10 lg (£>/100) + 85, and D - dose of noise.

The choice of the exposure limit depends on the definitions of two parameters:

1) the maximum acceptable threshold level of hearing (TLH), above which there is a deterioration of the hearing and below which it is believed that the hearing is normal;

2) the proportion of exposed population noise, which is protected from hearing impairment.

There are no restrictions on infrasound level yet. It is recommended to use as an indicative maximum permissible level of infrasound of 95 dB, if the time of exposure to ultrasound is more than four hours.

**Table 5.1.**

The dependence of the permissible sound level on the duration of its action

| I, dBL | t | | |
|---|---|---|---|
| | Hour | Min | Sec. |
| 80 | 25 | 24 | |
| 90 | 2 | 31 | |
| 100 | | 15 | |
| 110 | | 1 | 29 |
| 120 | | | 9 |

**Table 5.2**

Dependence of the average level of sound from the dose of noise

| D % | TWA |
|---|---|
| 50 | 82.0 |
| 100 | 85.0 |
| 1000 | 95.0 |
| 10000 | 105.0 |
| 100000 | 115.0 |
| 1000000 | 125.0 |

The fires in the paint areas usually begin with the explosion of the steamair mixture, which is accompanied by the destruction of the protective element, and are characterized by high average volume temperature, dense smoke of the air, the danger of the transition of fire into other hangar rooms, the structural elements of the building are destroyed in the absence or non-development skidding designs. Parameters of the system of surround fire extinguishing with the distribution network and the weight of the fire extinguisher in a tank of 150 kg and more. Minimum mass of fire extinguisher, kg, required to protect this space, calculated by the formula:

$M_{min} = M1+M2+M3$

where: M1 – main mass of the fire extinguisher, proportional to the amount of protected space, kg;

M2 - additional weight of the fire extinguisher to compensate for the attribution of the powder part through openings, the each area of which $S_{p1}$ is less than 5%of the total area of the building envelope structures – $S_{1G}$, with the total area of such openings greater than 1% but less than 15% of $S_{0G}$, kg;

M3 - is an additional weight of the fire extinguisher to compensate for the transfer of powder through the openings, the area of each of which $S_{r2}$ is more than 5% of 8, and the total area of such openings does not exceed 15% of $S_{0G}$, kg. The total area of openings that are not closed during the submission of the fire extinguisher from the system $S_{p1}$ and $S_{r2}$, should not exceed 15% of $8_{0G}$.

The M1 and M2 weights should be evenly distributed in the protected volume during feeding. The weight of M3 shall be fed along the corresponding slot in proportion to its area $S_{p2}$.

$M1 = q_{v0} \cdot V_3 M2 = 2{,}5\Sigma S_{n1} M3 = 5{,}0\Sigma S_{n2}$

- where $q_{v0}$ - the rate of supply fire extinguisher for bulk extinction, kg*m$^3$; $V_3$ - the volume of protected space, m$^3$; $S_{n1}$ - the area of openings, which is less or equal than 5% of the total area of the enclosing structures, m$^2$; $S_{n2}$ - area of openings, the area of which is more than 5% of the total area of the enclosing structures, m$^2$; 2.5 - the rate of supply of additional mass of the fire extinguisher to compensate for its assignment through the slots in the area of $8_{n1}$, kg * m$^2$; 5,0 - the rate of supply of additional mass of the fire extinguisher to compensate for its assignment through the slots area $8_{nl}$, kg*m$^2$.

The rate of supply of extinguishing powder from the system is accepted like: $q_{v0}$ = 0,6 kg*m$^3$.

The minimum expense of the fire extinguisher, kg*s, which must be provided by the system, is determined by the formula:

$$G_{min} = \frac{M\,min}{30}$$

In this case, the intensity of the supply of the fire extinguisher should be: $I_{vo} \geq 0{,}02$ kg*s*m$^3$

The minimum duration of the outflow fire extinguisher, $t_{min}$ in a volumetric manner with a distribution network is determined by the formula:

$$t_{min} = 0,67 q_{v0} * I_{v0}^{-1}$$

However, it should not be less than 5 seconds.

For other combustible materials and grades, the specified delivery rules may be clarified because of fire test results.

## 5.3. Providing fire and explosive safety in hangars

When designing a fire-extinguishing unit for aircraft hangars, the following moments should be taken into account: the rapid development of the fire due to the large amount of solid combustible materials, aviation fuel and other combustible liquids, a low degree of fire resistance of the partitions.

Typically, aircraft are housed in aircraft hangars without aviation fuel in tanks, but there is still some fuel in the fuel system. Moreover, many technical fluids in an aircraft are also combustible. These substances affect the nervous system, the organs of sight and breathing of the person (immediately there is a deterioration of vision, tearing, choking, vomiting, and convulsions).

The main aluminium alloys of the wing and airplane shells have a low critical temperature (about 250 ° C) and a low melting point (≥ 520 ° C for the D16 alloy),

due to which, if there is a burning of fluid and rubber, there may be a loss or drop in mechanical the strength of these alloys and their rapid destruction [2].

Given the high reaction temperature (~ 3000 ° C), the combustion zone of magnesium alloys stands out in a brightly lit spot against the background of "low temperature" flames of other substances and materials. This will bring new sources of fire. The combustion area is increased until covers the entire surface of the structure. Requirements for automatic foam fire extinguishing systems are contained in the following normative documents: НАПБ А.01.001-2014 ‘On approval of the Fire Safety Rules in Ukraine’ [16], ДСТУ EN 60079-0:2017 (EN 60079-0:2012, IDT)
’Explosive environments. Part 0. Equipment. General requirements’ [17].

When choosing a method of extinguishing a fire in a hangar and the type of foam generator, the following facts should be taken into account:

- a fire may occur both inside and outside of the aircraft;
- in aircraft there is a mixed fire load, which includes polymer materials, fuel, rubber goods;
- the rate of development of a fire in the hangar is high due to the probable opening of all hatches and doors;
- before the placement of aircraft in aircraft hangars, fuel is usually drained, but part of it still remains in the fuel system. In American fire safety stand-ards, the aircraft is charged if it contains more than 0.5% of the fuel (A1.3.1.1.1 ETL 02-15).

American standards (including ETL 02-15) provide a volumetric method of extinguishing a fire, but in its formulations, there are a number of differences from the ones adopted in the annex to [16].

The requirements for a surface fire extinguishing method in an air hangar are given in the NPA 2018-15 ‘Rescue and firefighting services at aerodromes’ by EASA [18]. The main provisions in this document are:

- the calculated area of the fire section is determined by the ratio of the hangar area to the maximum number of aircraft in it;
- the estimated fire duration is 10 minutes;
- fire extinguishing unit should ensure the simultaneous and uniform supply of air-mechanical foam on top of the plane and to not cover them the floor area of the fire department, as well as the bottom of the lower surfaces of the aircraft;
- from above it is recommended to submit foam of average multiplicity, below
- of low multiplicity;
- moment of inertia detector response to the flow cell foam - no more than 30 seconds.

## 5.4. Fire and explosion safety instructions

According to [16], at a meeting of gas turbine engine aircraft or helicopter, a person who encounters should be in sight of the commander of the aircraft at a distance of at least 25 m from it; and for aircraft with piston engines - at a distance of atleast 10 m.

The movement of aviation personnel, special transport, self-propelled machin- ery and other mechanisms before a controlling aircraft is prohibited.

After installing the aircraft to the parking lot, shutting down the motors and stopping the airspeed, the aircraft must be immediately grounded with a special device and the thrust pads must be fitted under the wheels of the main supports.

Responsible for the issue of aircraft, must make sure that there are no obstacles and the security is provided. He should be standing left to the aircraft to be in visual communication with the commander of the aircraft.

Control of the aircraft at night or with limited visibility, should be carried out with the inclusion of aeronautical lights and headlights.

The brigade of not less than three people carries out Works in the middle of fuel cistern-tanks. The direct executor works in the middle of the caisson tank, is provided with the necessary overalls, special footwear, rescue belts and hose gas masks.

When checking the aircraft fuselage for leakproofness - the area around it should be fenced off at a distance of 13 m, install a sign with the inscription: Caution! Possible spreading of the glider parts". Before starting the test, check the opera-tion of the device for emergency reduction of air pressure in the fuselage. Persons who are not participating in the test are taken out of the danger zone beyond the boundaries of the aircraft. The noise level at the parking lot, during the leakproofnesstest, shall not exceed 50 dB.

Treatment of aircraft with antifluid liquids should be carried out at special places of parking in accordance with technological instructions for the performance of work on aviation engineering.

## Conclusion to chapter 5

Careful handling of labour protection in the maintenance environment should serve to minimize risks. However, should health and safety problems occur, all personnel should know as far as reasonably practical how to deal with emergencies, which may include:

- An injury to oneself or to a colleague;

A situation that is inherently dangerous, which has the potential to cause injury(such as the escape of a noxious substance, or a fire).

The organization should also provide procedures and facilities for dealing with emergencies and these must be adequately communicated to all personnel. Maintenance organizations should appoint and train one or more first aiders.

Compliance with the requirements of regulatory documents is necessary to ensure a safe and high-performance working process in the production and operation of technical systems. In aviation hangars, it is recommended to pay particular attentionto noise and fire safety issues. After all, in the first place, the violation of these requirements leads to the most serious consequences for both technical personnel and the property of the enterprise.

# CONCLUSION

Machine vision is the automatic extraction of information from digital images for process or quality control. Most manufacturers use automated machine vision instead of inspectors because it is better suited for repetitive inspection tasks. It is faster, more objective and works constantly. Machine vision can inspect hundreds or even thousands of parts per minute and provides more consistent and reliable inspection results 24/7. Measuring, counting, locating, and decoding are some of the most common applications of machine vision in manufacturing today. By reducing defects, increasing productivity, promoting compliance and tracking parts with machine vision, airlines can save money and increase profitability.

In addition, with machine vision inspection, defects are detected early in the maintenance process and components can be rejected or corrected before final component assembly, saving both money and time.

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