МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
АЕРОКОСМІЧНИЙ ФАКУЛЬТЕТ
КАФЕДРА ПІДТРИМАННЯ ЛЬОТНОЇ ПРИДАТНОСТІ ПОВІТРЯНИХ СУДЕН

ДОПУСТИТИ ДО ЗАХИСТУ
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«_____»_____________ 2022 р.

ДИПЛОМНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ МАГІСТРА

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

Тема: «Методологічні основи технологій неруйнівного контролю елементів повітряних суден.»

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Київ 2022

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

ADMIT TO DEFENCE
Head of Department
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«____» ___________ 2022

MASTER DEGREE THESIS
(EXPLANATORY NOTE)

GRADUATE OF EDUCATIONAL DEGREE "MASTER"

FOR EDUCATIONAL AND PROFESSIONAL PROGRAMS "MAINTENANCE AND REPAIR OF AIRCRAFT AND AIRCRAFT ENGINES»

Topic: "Methodological bases of aircraft elements non-destructive control technologies"

Fulfilled by: ____________________ **Haohao Hu**

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Kyiv 2022

NATIONAL AVIATION UNIVERSITY

Airspace Faculty
Aircraft Airworthiness Retaining Department
Educational Degree "Master"
Speciality 272 “Aviation Transport”
Educational and Professional Programs: “Maintenance and repair of aircrafts and aircraft engines”

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“___” _________2022 p.

Graduation Project Assignment

Haohao Hu

1. **Topic**: “Methodological bases of aircraft elements non-destructive control technologies”approved by the Rector’s order of “_03_”_09 2022_ № _2021/CT_.

2. The Graduation Project to be performed between:___03.09.2022___and_ 24.11.2022

3. Initial data for the project:analysis of methodological bases of aircraft elements non-destructive control technologies

4. The content of the explanatory note: introduction, analytical part, structural analysis and description of aircraft turbine blade, labour precaution, environment precaution, conclusions.

5. The list of mandatory graphic materials:Non-destructive testing technology and aircraft turbine blades

6. Time and work schedule

№	Stages of Graduation Project Completion	Stage Completion Dates	Remarks
1	Task receiving, selection of material	03.09.2022-30.09.2022	
2	Analytical part, detailed analysis of Non-destructive testing technology	30.09.2022-10.10.2022	
3	Project part	10.10.2022-01.11.2022	
4	Labour precautions	01.11.2022-05.11.2022	
5	Environment Protection	05.11.2022-11.11.2022	
6	Arrangement of explanatory note	11.11.2022-14.11.2022	
7	Preparing for project defend	14.11.2022-24.11.2022	

7. Advisers on individual section of the project:

Section	Adviser	Date, Signature	
		Assignment delivered	Assignment accepted
Labor protection	Ph.D., associate professor Kazhan K.I.		
Environment protection	Ph.D., associate professor Pavlyuh L.I.		

8. Assignment issue date:“_____”___________ 2022.

Degree work supervisor ___________________Rugain O.V.
(signature)

Assignment is accepted for fulfillment _________________Haohao Hu
(signature)

ABSTRACT

The explanatory note to the diploma work "Methodological bases of aircraft elements non-destructive control technologies"

76 p., 40fig., 20 references

NON-DESTRUCTIVE TESTING EDDY CURRENT TESTING TURBINE BLADE APPLICATION

The importance and role of NDT in the aviation industry:

(1) For the design of aviation products

(2) Characterization and evaluation of material and process defects

(3) For structural manufacturing and process control

(4) For safety assessment and life prediction monitoring of aviation products

In scheduled maintenance, it is difficult to detect defects quickly because the maintenance of the aircraft must be completed within the scheduled time and released in time for commercial operation. NDT is the most economical way to perform inspections and the only way to find defects. Aircraft structures and different components are made of a variety of materials, and it takes a long time to break the aircraft into pieces and inspect each component And it takes a lot of human, material and financial resources, so economical and effective non-destructive testing methods are used in aviation inspection and maintenance.

Challenges of NDT in the Aviation Industry:

Changes in aircraft materials can also affect its NDT requirements. Aluminium, once the most commonly used aircraft material in the world, is now used in far less than a decade ago. In contrast, more carbon fiber composite materials are used in aircraft manufacturing, which brings new

requirements and challenges to non-destructive testing. Because composite structures are more complex, consisting of multiple layers and multiple elements, thickness variations and buckling are common in the resulting parts, and such parts are prone to failure.

CONTENT

LIST OF ACRONYMS

NDT - Nondestructive testing

VT-Visual Testing

PT- Penetrant Testing

RT- Radiographic Testing

UT - Ultrasonic Testing

MT- Magnetic Particle Testing

IR - Infrared Testing

ET - Eddy current testing

ECT - Eddy current testing

CNC - Computerized Numerical Control

EDM - Electrical Discharge Machining

INTRODUCTION

In this day and age, aircraft generally have a life expectancy of a few dozen years. To ensure such a long life of the aircraft, it is inseparable from the full efforts of the people behind the aircraft maintenance, repair and overhaul, it is with their full protection, the aircraft can maintain a long period of normal flight. The key to this work is speed and efficiency. After all, the longer an aircraft stays in the maintenance facility, the higher the cost to the operator.

In this context non-destructive testing (NDT) is the most economical way to carry out inspections. The structure and different components of an aircraft are made of various materials, and it takes a long time and costs a lot of money to break the aircraft into pieces and inspect each component, so cost effective NDT methods are used in aviation inspection and maintenance. Changes in aircraft materials can also affect the requirements for NDT. Aluminum was once the most common material used in aircraft manufacturing, but now more carbon fiber composites are being used in aircraft manufacturing, bringing new requirements and challenges to NDT. Because composites are more complex, the parts made are subject to a variety of shape changes, and such parts are highly susceptible to failure.

Among the various NDT techniques, eddy current inspection is widely used in the aerospace industry because of its advantages such as no contact with the workpiece, fast detection speed and high detection sensitivity.

Chapter 1: ANALYSIS OF Nondestructive testing (NDT) technology and turbine blade

1.1 Overview of Eddy Current Testing

1.1.1 Overview of common non-destructive testing techniques

Nondestructive testing (NDT) technology refers to the technology that can be used to complete the inspection work without causing damage to the object under test, because of its non-invasive characteristics, so it has become a high degree of precision, high structural integrity requirements of the main inspection means of parts, now commonly used non-destructive testing methods are visual inspection, penetration testing, magnetic particle testing, etc. These methods all have their unique advantages and disadvantages, for the inspection of the turbine blades of aero-engine, some of these methods can only be inspected after the blades have been disassembled, which is time-consuming and difficult to carry out effective in-situ monitoring of the blades that have been assembled on the engine; some of them are difficult to achieve high accuracy for turbine blades with complex curved surfaces, and are prone to miss inspection. Some of them are difficult to detect with high precision for turbine blades with complex curved surfaces, and are easy to miss. The following is a brief description of these common NDT methods.

Visual Testing (VT) (Figure1.1) is based on the detection of flaws visible to the naked eye and is the most widely used NDT technology in various industries. In the production and maintenance process, rapid control of product quality can be achieved.Of all the NDT techniques, this method is the most convenient and economical and is a mandatory step before and after all testing operations. This method has the advantage of being simple, fast and widely available. The main disadvantage is that only the surface of the part can be inspected, and the surface may need to be cleaned, decontaminated or sandblasted before inspection.

Figure1.1 Visual Testing

Penetrant Testing(PT)(Figure1.2) is a method for non-destructive testing of surface defects that are invisible to the naked eye. It does this by exploiting the capillary properties of the fluid (that is, through the capillary penetration of a specific indicator in the defect). The method creates an indicator pattern on the surface of the measurement object, thereby revealing defects. The optical contrast of these modes is high (brightness and color), the width of which exceeds the width of the defect hole.Penetrant testing has the advantages of ease of use, high resolution and no requirements for the material to be tested, but it requires a high degree of surface roughness, contamination and the experience and quality of the inspector.

Figure1.2 Penetrant Testing

Radiographic Testing (RT or X-ray or Gamma ray)(Figure1.3) is a non-destructive test (NDT) that examines the sample volume. X-rays use X-rays and gamma rays to produce X-ray images of your sample, showing variations in thickness, defects (inside and out), and assembly details, ensuring your work is of the highest quality.The advantages of the radiographic testing include the visualisation of the results, the availability of dimensional information on the defects, the long-term storage of the results and the detection of internal defects in the specimen, as well as the fact that there are no special requirements for the material and surface condition of the object to be inspected. The main disadvantages of this method are: the radioactive rays are usually harmful to the human body and therefore the method has some safety problems; the inspection equipment is usually expensive and requires a high level of skills and qualifications of the inspector.

Figure1.3 Radiographic Testing

Ultrasonic Testing(UT)(Figure1.4) is a technique for detecting the geometry, quality and mechanics of an object by studying the reflection and scattering of ultrasound waves from the object to be measured. The main advantages of ultrasonic testing are: a wide range of thicknesses, up to 2m thick metal parts, but also 1 ~ 2mm thin-walled metal parts; high sensitivity, can detect very small defects within the material; can accurately determine the depth of defects; harmless to humans and the environment. The main disadvantages of ultrasonic testing are: the need to use coupling agents for inspection and the poor detection of objects with complex shapes and structures.

Figure1.4 Ultrasonic Testing

Magnetic Particle Testing(MT)(Figure1.5), is a technique used for most ferromagnetic materials, including iron, nickel, and cobalt, as well as some of their alloys, are detected by MT. In comparison to other nondestructive testing methods, MT requires less surface preparation, making it a relatively fast and straightforward process. As a result, it has become one of the more widely used NDT methods.Magnetic particle testing has the advantages of intuitive display, high detection sensitivity, good adaptability and low cost. Due to the limitations of this method, it can only be used on or near ferromagnetic surfaces, and the determination of magnetic traces requires a certain degree of experience, so the results can be influenced to some extent by the inspector. In addition, to ensure the accuracy of the test results, the test piece needs to be demagnetised before and after the test.

Figure1.5 Magnetic Particle Testing

Infrared Testing (IR)(Figure1.6) is a technique based on Planck's law of thermal radiation. According to this law, the higher the temperature of an object, the stronger the radiation. When there is a temperature difference between the object and its surroundings, heat flow occurs inside the object and defects can affect the flow process and cause uneven temperature distribution inside the object. Therefore, the basic principle of infrared inspection is to determine the presence of defects by observing and analysing the temperature changes on the surface of the object under test using infrared radiation measurement and analysis. Infrared inspection methods have the advantages of being fast, efficient, non-contact and intuitive. The main disadvantages are that the equipment is expensive, it is difficult to automate the inspection and the sensitivity decreases as the depth of the defect increases.

Figure1.6 Infrared testing

Eddy current testing(ET)(Figure1.7) is a non-contact method for detecting metal parts. On one or more detectors, an alternating magnetic field is formed when alternating current is passed through one or more coils. By connecting the probe to the part under test, the alternating magnetic field induces eddy currents within the part under test. Discontinuities or changes in characteristics of the test element cause the flow of electrical current, which is detected by the detector, allowing the thickness of the material to be measured, or cracks and corrosion to be found.The advantages of eddy current testing technology are its high sensitivity, its speed and efficiency, and the fact that eddy current sensors output electrical signals directly, which makes it easy to process and transmit the results. The main disadvantages are that the eddy current sensor can only detect defects on or near the surface of the specimen because of the shallow penetration of eddy currents in the test piece due to the skin effect and that it can only detect defects in conductors because it is based on the law of electromagnetic induction.

Figure1.7 Eddy current testing

1.1.2 Basic principles and characteristics of eddy current testing

Eddy current detection is a physical phenomenon based on electromagnetic fields. As can be seen from Figure 1.8, in an eddy-current probe, alternating current is passed through the coil, creating a vibrating magnetic field. When the detector and its magnetic field are in close proximity to a conductive substance such as a metal sample, a circulating electron current called an eddy current moves through the metal like a vortex in a water current. The vortices flowing in the metal in turn form their own magnetic fields and interact with the coil and its magnetic field.

Thickness or defects in the metal, such as proximal cracks, can change the amplitude and shape of the vortices, which can lead to the generation of magnetic fields. This in turn affects the movement of electrons within the coil, changing the impedance of the coil. An operator can identify changes in the test piece by plotting changes in amplitude and phase angle of the eddy current instrument.

The section of the test with the highest resolution is where the eddy current density is greatest, which is close to the part's surface. The test frequency, as well as the magnetic permeability and conductivity of the test material, can be used to compute the standard depth of penetration, which is the depth at which the eddy current density is 37% of its surface value. As a result, changes in test sensitivity, resolution, and penetration are influenced by changes in the test material's conductivity, magnetic permeability, frequency of the AC pulses driving the coil, and coil geometry.

The abilities of an eddy current inspection might be impacted by a variety of things. Higher conductivity materials are more susceptible to surface flaws, but they also have less penetration into the material, with penetration also being influenced by test frequency. While lower test frequencies increase penetration, higher test frequencies improve near-surface resolution at the expense of penetration depth. Since the magnetic field goes deeper into the test item with larger coils, a larger volume of material may be examined from any given point, whereas smaller coils are more sensitive to minute flaws. Because of the larger background changes, noise generated by variations in a material's permeability might reduce the resolution of flaws.

While the operator has no influence over the test material's conductivity and permeability, they can choose the test frequency, coil type, and coil size based on the test's needs. Resolution in a test is controlled by the type of probe, whereas detection ability is governed by the properties of the substance and the testing apparatus. Some inspections entail using a variety of frequencies to maximize the results or a number of probes to achieve the best resolution and penetration needed to find every potential problem. For each application, choosing the appropriate probe is crucial to maximizing test performance.

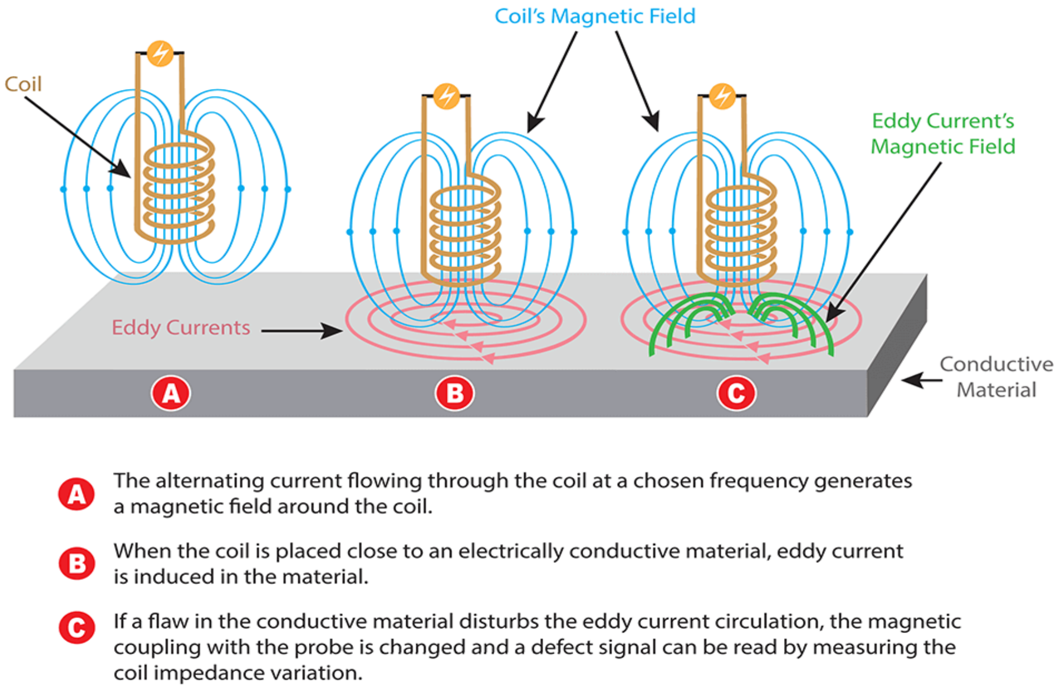


Figure1.8 Schematic diagram of eddy current testing

1.1.3 The advantages of eddy current testing technology in blade defect detection

In the field of non-destructive testing, the non-destructive testing of curved parts has always been a challenge, and several of the common non-destructive testing methods mentioned above have their own limitations. For the blade surface defects of interest in this paper, the detection methods are usually penetrant testing, magnetic particle testing or visual testing with an endoscope, of which the first two have high resolution but must be disassembled from the engine, making them time-consuming and costly. When the crack is small, it is easy to miss the detection. In addition, both methods are difficult to automate, and they are highly dependent on the inspector, who needs to have a certain level of experience and quality.

Eddy current testing technology as a convenient and efficient means of detection, the use of its blade defects detection has the following advantages. Eddy current testing technology can directly obtain the electrical signal containing the surface quality information of the object to be measured, which is easy to use various algorithms to de-noise, analyse and judge the signal and therefore easier to achieve automatic detection; through the reasonable design of the coil structure and circuit parameters, the eddy current testing sensor can have a high resolution, so that it has a better detection effect on small cracks; eddy current testing does not require the object to be measured The eddy current testing does not require pre-processing of the object to be measured and the probe size can be made small enough to be used in small spaces, making it easier to achieve in-situ detection of leaves. In summary, eddy current testing has unique advantages and broad application prospects in the detection of crack defects in complex curved structures such as blades, and is worthy of further study.

1.1.4 Current status and development of eddy current testing

A variety of businesses utilize eddy current inspection to look for flaws and take measurements. When the nature of the problem is well known, one of the main applications of eddy current testing is for defect detection. The technique is often used to inspect a small area, and the probe design and test parameters must be created with a clear understanding of the problem that is to be found. Eddy currents can only be utilized to identify surface and near-surface defects since they tend to cluster at a material's surface.

Eddy currents can be used to gauge the thickness of thin materials like tubing and sheet stock. As a result, eddy current is a helpful tool for identifying corrosion damage and other damage that results in material thinning. Measurements of corrosion thinning are made using this method in systems like heat exchangers and on the skin of airplanes. Paint and other coatings' thicknesses are also measured using eddy current testing.

The electrical conductivity and magnetic permeability of materials also have an impact on eddy currents. As a result, eddy current measurements can be used to sort materials and determine whether a material has been subjected to high temperatures or heat treatment, which alters some materials' conductivity.

One can purchase eddy current tools and probes in a wide range of setups. For simple transportation, eddy scopes and a conductivity tester are supplied in extremely compact, battery-operated systems. There are other computer-based solutions available that give the laboratory simple data manipulation features. Software for signal processing has also been created to remove trends, erase backgrounds, and reduce noise. Additionally, impedance analyzers are occasionally employed to enable more accurate quantitative eddy current measurements. To create photographs of the scan zones, certain facilities offer multidimensional scanning capabilities. For specific uses, such as scanning certain areas of aircraft fuselages, a few portable scanning devices are also available.

In 1820, Oersted first discovered that an electrically energised conductor could generate a magnetic field. By 1831, Faraday had discovered and described in detail the phenomenon of electromagnetic induction through several experiments; in 1873, Maxwell put Faraday's concept into a complete mathematical equation and established a systematic and rigorous theory of electromagnetic fields; in 1879, Hughes succeeded in identifying different metallic materials with the help of pulsating currents; in 1920, Kranz invented the eddy current thickness gauge, which enabled him to use eddy currents to measure the thickness of metal pipe walls; Farrow invented the eddy current thickness gauge in 1930. In 1950, Dr. Forster of Germany perfected the eddy current testing technique in theory and practice. In 1955, Dr Forster founded a research institute and was the first to develop and produce practical eddy current testing instruments and equipment on a large scale, and to transfer the relevant eddy current testing technology and patents to foreign research institutes and manufacturers, which greatly contributed to the development of eddy current testing technology". Since then, eddy current testing has become a key research area in the field of non-destructive testing and new techniques have been proposed, such as multi-frequency eddy current, pulsed eddy current, far-field eddy current and low-frequency eddy current techniques. Eddy current testing technology was introduced to China in the 1960s and began to be used in the metallurgical industry in large numbers in the late 1970s. By now, eddy current testing technology has been widely used in China, for example, through the eddy current testing equipment has become aerospace, nuclear energy, petroleum and other industries in the tube, wire testing indispensable means, rotary probe eddy current testing equipment has also been widely used in polished bars, bearings, ball testing.

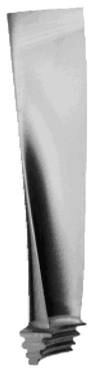
In recent years, a large number of research institutions at home and abroad have explored the application and innovation of eddy current testing technology and have achieved fruitful research results. For example, the US FAA Airworthiness Assurance Center has successfully applied single-frequency eddy current testing technology and dual-frequency eddy current testing technology to the corrosion inspection of Bell helicopter fuselage structures; Boeing and the US Air Force Research Laboratory have cooperated to apply array eddy current testing technology to the detection of hidden defects in fuselage structures and achieved good results; Guiyun Tian from Newcastle University and Binfeng Yang from the Air Force Engineering University in the UK have used eddy current testing technology for the remote inspection of flat specimens. Guiyun Tian from the University of Newcastle and Binfeng Yang from the Air Force Engineering University have conducted research on the use of far-field eddy current testing technology for flat specimens and have achieved significant results; Fei-Lu Luo from the National University of Defence Technology and Xiang-Lin Chen from Tsinghua University have conducted more systematic and in-depth research on array eddy current testing technology and flexible eddy current testing technology.

1.2 Overview of aircraft engine blade defect detection

1.2.1 The importance of blade defect detection

Aircraft are made up of several subsystems and tens of thousands of components, of which the engine is undoubtedly the most important part, considered the "heart" of the aircraft and the diamond in the industrial crown. Aircraft engines often operate in very harsh environments and as a result, flight accidents due to engine failure are commonplace.

In the working process of aircraft engines, the key process of compressing the air in the engine is completed by the turbine blades(Figure 1.9), so the quality of the blades has an important impact on the efficiency, reliability and safety of the engine. The high speed rotation of the engine makes the blade bear the load is very complex, and the blade's work in the high temperature environment, easy to appear high temperature oxidation and thermal corrosion and other problems, these factors lead to the blade become the engine failure rate of the higher parts. And because of the special working environment of the blade, make the blade in even a very minor fault is likely to quickly expand and deteriorate, and then serious accidents and cause great harm to people and property. For example, in a flight in 1999, a WP13 engine blade of a fighter aircraft broke under complex loads, resulting in a second-class aircraft accident. Therefore, in order to ensure flight safety, both before the blade is put into service to do systematic testing, but also during the blade service, according to the blade failure law regularly to test the blade, in order to ensure that the blade in good working condition.



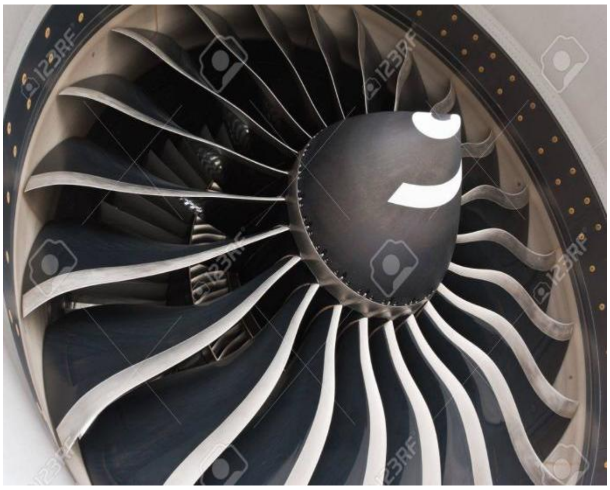


Figure 1.9 Aero-engine turbine blades

According to the relevant theory, blade defects can be divided into porosity, inclusions and other types, certain defects have certain acceptance standards. For example, the aero-engine non-destructive testing ASTME192 acceptance standard clearly points out that the critical size of the pore class defects for 0.508mm, that is, only when the size of the hole class defects is greater than 0.508mm to determine the blade for failure, and for crack defects, once the blade exists crack defects, that is, failed products, because if the crack in the region for stable expansion area, even if its size Even if the size of the crack is very small, it will expand rapidly at an exponential rate into a larger crack, which will eventually lead to blade breakage. The proportion of flight accidents caused by crack defects is high, around 40%, of all flight accidents. Therefore, this paper takes the detection of crack defects as the main object of research, and the following theoretical analysis, simulation experiments and inspection experiments are all based on the detection of crack defects.

1.2.2 Causes and areas of blade defects

Blade flaws are frequently brought on by the occurrence of several various types of damage mechanisms, including fatigue, creep, corrosion, erosion, sulfidation, damage from external objects, and vibration. For instance, the impact of a foreign object, such a bird, might result in a nick that interrupts the flow of the material and concentrates stresses, which starts the development of a crack. The crack may cause a considerable portion of the blade to break off or lift up in the material. Environmental conditions, fuel quality, operational settings, cyclic loads, and engine and maintenance history are just a few of the variables that can speed up and aggravate this chain of defect development. Hail may be the catalyst for the breaking of blade material, while vibrations and salty air are significant elements in the case of crack formation. Simple lists are unable to capture this kind of defect development.The generation mechanism of turbine blade defects mainly includes high-cycle fatigue, low- cycle fatigue and thermal fatigue.

High-cycle fatigue refers to fatigue where the cyclic stress is relatively low but the number of cycles is high. The lower the load, the longer the life of the blade, i.e. failure will only occur if the number of cycles is high enough. Low-cycle fatigue refers to fatigue where the cyclic stress is high but the number of cycles is low. The strain in low cycle fatigue is usually a plastic strain, generally cyclic low frequency large load easily lead to low cycle fatigue, load loading material plastic deformation, the greater the load, the shorter the life of the blade, that is, the number of cycles will occur when the failure. Low-period fatigue is the main cause of turbine blade failure, in general, low perimeter fatigue sources appear in the lower part of the blade body, the edge plate, the root part and other stress concentration area, these areas due to centrifugal load caused by the stress, very easy to produce micro-cracking. Thermal fatigue refers to the fatigue damage caused by the uneven temperature distribution in the blade and the inability of all parts of the blade to expand freely. Turbine guide blades are susceptible to thermal fatigue, and the resulting cracks mostly occur in the blade body near the inlet and exhaust edges of the press.

According to the above analysis, the common parts of the aero-engine turbine blade defects are the lower part of the blade body, the edge plate, the blade root, the blade inlet side, the exhaust side and so on. Therefore, during the service of the turbine blade, these parts should be inspected and tested.

1.2.3 Research status of blade defect detection technology

As the turbine blades of aero-engines are prone to crack damage during production, assembly and use, and the damage can seriously affect the normal operation of the engine, a number of research institutes at home and abroad have conducted long-term and unremitting research on the detection of defects in turbine blades. At present, the main techniques commonly used for turbine blade defect detection are radiographic testing, ultrasonic testing, penetration testing, magnetic particle testing and visual testing. Among them, ray testing is generally used to detect the internal defects of cast blades, such as air holes, sand holes, etc.; ultrasonic testing is generally used to detect the internal quality of forged blade blanks; infiltration testing and magnetic particle testing are mainly used to detect the surface crack defects of blades; visual testing is usually used to detect the surface quality of blades with the help of endoscopes, hole detectors, microscopes and other equipment. The internal space of the engine, so with their help can achieve the blade surface quality of in-situ inspection. In recent years, the use of eddy current testing technology has been proposed for the detection of blade surface defects, in order to take advantage of its high sensitivity and ease of automation to finally achieve automated in-situ detection of small defects on the blade surface.

Foreign research on aero-engine blade defect detection technology has been carried out earlier, and many companies have now developed various commercial blade defect detection products. For example, the US company SONOSCAN developed an ultrasonic detection sensor for blade defect detection in the early 1980s; NUCON inspection equipment company launched the NIPSCAN system for detecting the integrity of large aircraft engine blades and internal crack defects; the US company WELEH ALLYN developed a fibre-optic endoscope that can be used for in-situ detection of blade surface defects The imaging system VIDEO PROBE2000.

1.3 Conclusion

NDT is a branch of materials science that assesses material defects, structural defects, physical and mechanical properties, composition, etc., without altering or damaging the state and properties of materials and workpieces. NDT technology is mainly used in manufacturing stage inspection, finished product inspection and in-service inspection. For our airlines, it is mainly in-service inspection, which is used to check the changes in the structure or condition of aircraft parts during operation to ensure the safe and reliable operation of aircraft. Non-destructive testing (NDT), as an important means to check the structural damage of aircraft, is gaining more and more attention as the maintenance force of each airline increases.

In order to ensure the flight safety of aircraft, eddy current inspection technology has been widely used to inspect metal components in the aerospace field, and it is necessary to conduct regular in-service inspections of related components. Eddy current technology is commonly used to detect surface and sub-surface defects, such as multi-layer structures of aircraft, cracks in aero-engine blades, cracks in bolt and screw holes, landing gear, wheels and aluminum skins, and also for detecting defects in wing joint welds. Interference signals caused by probe shake and material inhomogeneity can be effectively suppressed during the inspection process. Metal memory inspection technology can be used to diagnose early damage or stress concentrations in the above components.

Chapter 2: Structure of Eddy current testing system

2.1 Components of an Eddy Current System.

The following elements make up an eddy current inspection system in its most basic form:

- A coil assembly
- An oscillator
- A bridge circuit
- Signal processing circuits

• An output display

Below is a block diagram of an inspection system with a coil attached to a test part. Systems can be built for general use or for more specialized tasks. Instruments made specifically for a task, like those that measure coating thickness or electrical conductivity, are typically simpler to calibrate and use than general-purpose instruments, but they are also restricted to the task for which they were made. -Oscillator. The oscillator feeds the test coil an alternating current at one or more frequencies. The purpose of the inspection and the material being inspected dictate the frequency employed.

-Coil Assembly (Probe). Eddy currents are introduced into the part being examined by the coil assembly, which also monitors variations in eddy current flow. One coil may serve both purposes in some instances. In an assembly, numerous coils are used more frequently. A typical setup uses one coil to induce the eddy current flow and two additional coils as detectors. Another configuration uses a single coil on the test part to serve as both an inducer and a detector.

-Bridge Circuit. Changes in eddy current magnitude and distribution are converted by the bridge circuit into signals that are later processed and displayed. A typical mode of operation is to set the bridge's output to zero in "good" or "non-flaw" conditions. When a flaw or "other-than-good" condition is present, the bridge becomes unbalanced and produces a signal that is relatively weak. Subsequent circuits use this signal as an input.

-Signal Processing Circuits. The signal from the bridge circuit is processed differently depending on the type of information to be displayed. Simple eddy current devices that detect and amplify the signal or convert it to digital format can be built. More sophisticated systems can decode the complex electromagnetic signal and convert it to amplitude and phase, as well as provide filtering to eliminate unwanted signals. .

-Output Display. Data from eddy current tests can be presented in either analog or digital format. Meter readout, a strip chart, an X-Y recorder plot, an oscilloscope display, or a video screen presentation are all examples of common output devices. Meters are appropriate for performing specific types of tests that only require the measurement of signal amplitude. Signal amplitude can be displayed and correlated with other parameters such as time or position using strip charts, X-Y recorders, and digital storage. Eddy current instruments with a two-dimensional graphical display are used when both the amplitude and phase of an eddy current signal must be measured. These are the most common instruments available and give the inspector the most flexibility in interpreting results.

2.2 Design of eddy current sensors

2.2.1 Description of eddy current sensors

Eddy current sensors detect displacement using the eddy current formation principle. These sensors have been used for many years to measure shaft displacement in rotating machinery because they provide manufacturers with high linearity, high-speed measurements, and high resolution. When a moving or changing magnetic field intersects a conductor or vice versa, eddy currents form. Within the conductor, the relative motion creates a circulating flow of electrons, or currents. These current eddies generate electromagnets with magnet fields that counteract the effect of the applied magnetic field. The greater the applied magnetic field, or the greater the conductor's electrical conductivity, or the greater the relative velocity of motion, the greater the currents developed and the greater the opposing field. This formation of eddy currents is detected by eddy current probes.Eddy current probes detect the formation of secondary fields in order to determine the distance between the probe and the target material.

2.2.2 The probe

2.2.2.1 Design of probe

The main function of the eddy current sensor probe is to act as a coil holder, creating a stable working environment and protecting the coil from external shocks. In view of the application scenario for eddy current sensors, the following requirements need to be taken into account when designing the probe. As eddy current testing is usually carried out by hand or by clamping the probe in a fixture, the shape of the probe is required to make it easy to hold and clamp, and the surface of the probe should not be too smooth to prevent slippage. As the coil wire needs to be connected to the external circuit and the length of the coil wire is short, it is not possible to transmit the signal over long distances, so it is necessary to design an interface on the probe to connect the coil wire to the sensor circuit and to transmit the excitation signal and the detection signal over long distances. In order to reduce the lifting effect caused by the complex curved shape of the blade, the probe end face in contact with the blade should be as small as possible and a non-metallic wear layer should be bonded to the probe end face to reduce the wear of the probe end face during the inspection process.

2.2.2.2 Classification of Eddy Current Probes

The method of application can also be used to classify eddy current probes. The most common application is a contact or surface probe used on a part's flat or relatively flat surfaces. Encircling coils are eddy current probes that are used to encircle a part. ID coils or bobbin coils are eddy current probes that are completely encircled by the part.As shown in Figure 2.1.

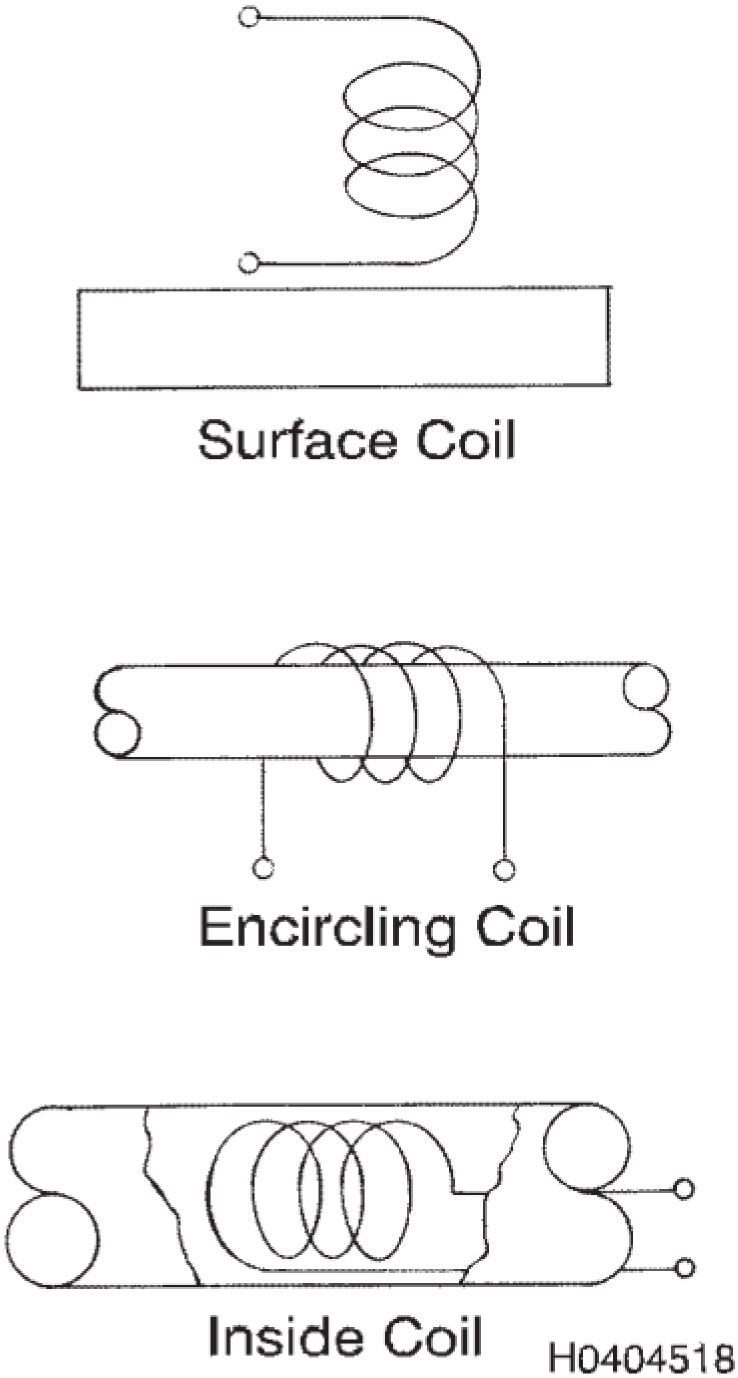


Figure 2.1 Basic Coil Configurations

According to the mode of operation we have two main types of probes.

Fixed Sliding Probes(Figure 2.2) In comparison to adjustable probes, these probes are typically used for thinner material. Maximum penetration is approximately 1/8 inch. Fixed sliding probes are ideal for detecting longitudinal surface or subsurface cracks, such as those found in lap joints. The typical frequency range is 100 Hz to 100 kHz.

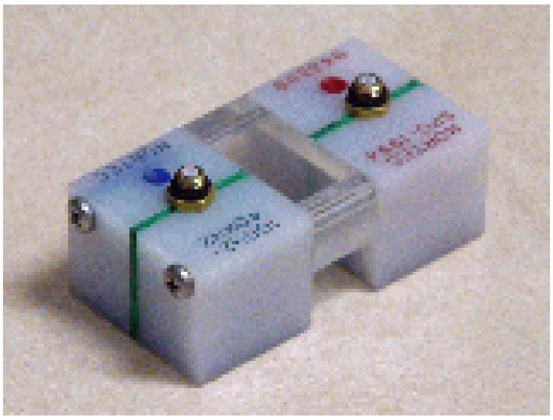


Figure 2.2 Fixed Sliding Probe

Adjustable Sliding Probes(Figure 2.3) These probes are ideal for detecting subsurface cracks in thick multi-layer structures such as wing skins. The maximum penetration is approximately 3/4 inch. Adjustable sliding probes have a frequency range of 100 Hz to 40 kHz.

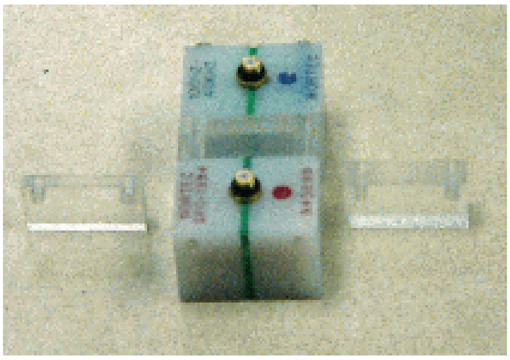


Figure 2.3 Adjustable Sliding Probe

Adjustable probes, as the name suggests, are adjustable by using spacers to change the penetration capabilities. The thickness of the spacer between the coils is normally adjusted for optimal detection. A thinner spacer is frequently used for tangential scans or 90 degree scanning with an offset from the center.

The spacer thickness ranges from 0 (no spacer) for surface inspections and small fastener heads to a maximum of about 0.3 inch for deep penetration with large heads in larger probe types. As the sensitive area expands, a wider spacer provides more tolerance to probe deviation, but the instrument requires more gain. Sliding probes typically penetrate thicker materials than donut probes.According to the application, we will have more variety by subdivision.

Some probes that are commonly used for ECT are listed below with a description of the flaw types they target and parts they are usually used to inspect.

Surface probes(Figure 2.4): which are used to detect flaws on and beneath metal surfaces, typically have a large diameter to accommodate lower frequencies for deeper penetration or scanning larger areas.

Figure 2.4 Surface probe

Pencil probes(Figure 2.5): Smaller diameter probes with high-frequency coils for high resolution of near-surface flaws.

Figure 2.5 Pencil probes

Bolt hole probes(Figure 2.6): These probes are designed to inspect the inside of a bolt hole and can be rotated manually or automatically using a rotary scanner.

Figure 2.6 Bolt hole probes

Donut probes(Figure 2.7): Designed for inspecting aircraft fastener holes while the fasteners are still in place.

Figure 2.7 Donut probe

Sliding probes(Figure 2.8):which are also used to test aircraft fastener holes, provide faster scan rates than donut probes.

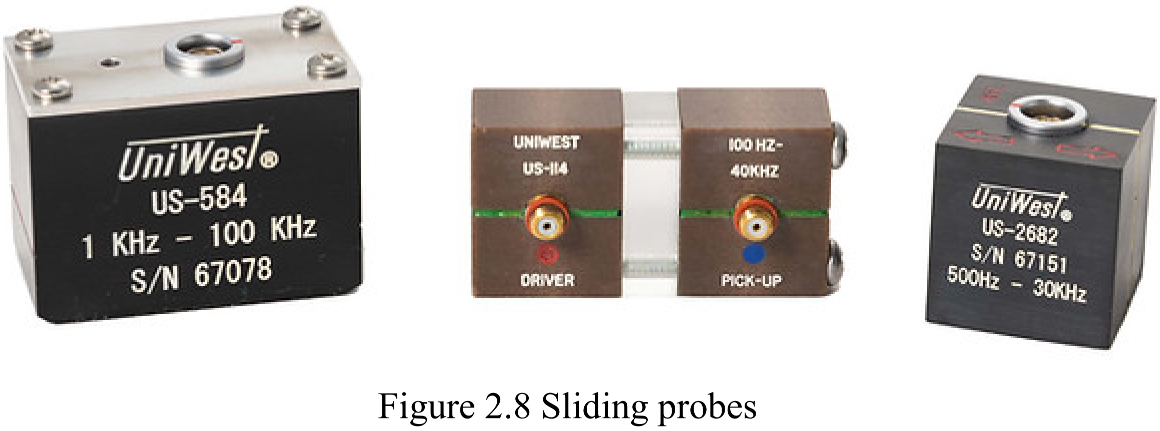


Figure 2.8 Sliding probes

ID probes(Figure 2.9): Internal diameter (ID) probes come in a variety of sizes and are used to inspect heat exchangers and similar metal tubing from the inside.

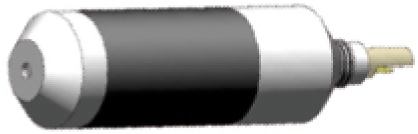


Figure 2.9 ID probe

OD probes(Figure 2.10): The test piece is passed through the coil to inspect metal tubing and bars from the outside.

Figure 2.10 OD probe

2.2.3 The coil

2.2.3.1 Design of coil

The way eddy currents are induced and detected in the material under test is the most important aspect of eddy current testing. This is determined by the probe's design. As previously discussed, probes can have one or more coils, a core, and shielding. All have an impact on the probe, but the coil requires the most design thought.

A coil is made up of a length of wire wound helical around the length of a former. The primary function of the former is to provide enough rigidity in the coil to prevent distortion. Formers used for coils with diameters greater than a few millimeters are typically made of dielectric tubes or rings. Coils with small diameters are typically wound directly onto a solid former.

The region inside the former is known as the core, and it can be made of solid material or just air. When the core is made of air or another nonconductive material, the probe is known as an air-core probe. Some coils are wound around a ferrite core, which concentrates the magnetic field of the coil into a smaller area. These coils are known as "loaded" coils.

To avoid magnetic hysteresis effects, the wire in an eddy current probe is typically made of copper or another nonferrous metal. The winding is usually multi-layered to increase the value of inductance for a given length of coil. At a given frequency, the greater the inductance (L) of a coil, the greater the sensitivity of eddy current testing.

The coil must have the least amount of current flowing through it at all times.

A coil may expand due to a rise in temperature, which raises the value of L.

A coil may also experience magnetic hysteresis, which is slight but observable when a ferrite core is utilized.The value of L is given by:

$$L = Kn^2 \cdot \frac{\pi[(r_0^2 - r_c^2) - \mu_r r_c^2]}{l} \cdot \mu_0 l$$

r_o is the mean radius of the coil.

r_c is the radius of the core.

l is the length of the coil.

n is the number of turns.

μ_r is the relative magnetic permeability of the core.

μ_o is the permeability of free space.

K is a dimensionless constant characteristic of the length and the external and internal radii.

2.2.3.2 Coil Impedance

The voltages IR and $I\omega L$ (L contains both self- and mutual-inductance) are produced when an alternating current I is given to a coil. The current passes through the coil's resistance as well as its inductive reactance. Figure 2.11 shows that the voltage across L is 90 degrees ahead of the voltage across R. Consequently, the circuit's overall voltage, E is

$$E = I\sqrt{\omega^2 L^2 + R^2}$$

Ohm's Law states that the coil's overall impedance is

$$Z = \frac{E}{I} = \sqrt{\omega^2 L^2 + R^2}$$

and the phase θ can be derived by

$$tan\theta = I\omega L \ / \ IR = \omega L \ / \ R = 2\pi f L \ / \ R$$

As a result, the exciting current lags the total circuit voltage by and the voltage on the inductance by 90 degrees. Given that an instrument can detect impedance, as shown in Figure 2.11, resistance and inductance can be accomplished by

$$X_R = |Z| \, cos\theta$$

$$X_L = |Z| sin\theta$$

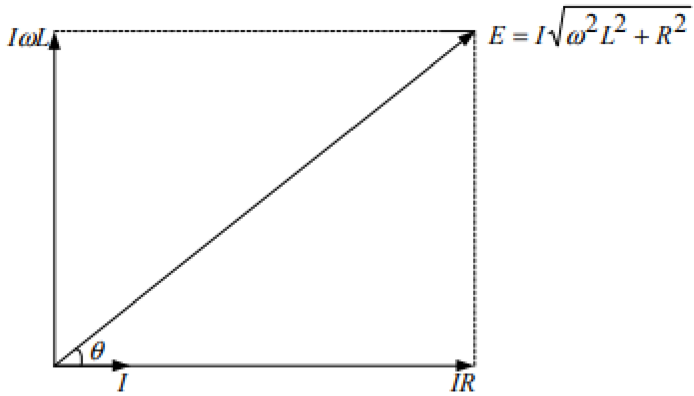


Figure 2.11 Diagram of impedance for coil

Coil capacitance must be taken into account in order to obtain a more accurate result, especially when using long cables. The capacitive inductance X_C is defined as follows:

$$X_C = 1 \ / \ \omega C = 1/2 \ \pi f C$$

where C is the stray capacitance of the coil in farads. Additionally, the capacitive reactance generates a voltage across in that lags the exciting current by 90 degrees. Figure 2.12 illustrates a parallel RLC circuit using a resistor in series with an inductance to determine the overall coil impedance.

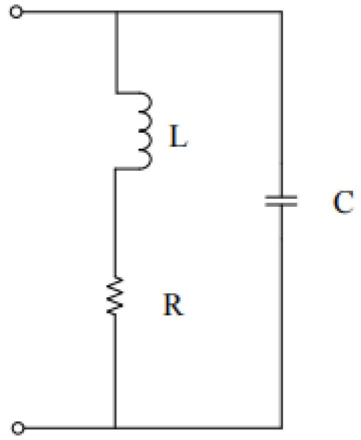


Figure 2.12 RLC circuit indicating coil impedance

Due to the circuit's combination of resistance, inductance, and capacitance, its overall impedance is

$$Z = \sqrt{\frac{R^2 + (\omega L)^2}{(1 - \omega^2 LC)^2 + (\omega CR)^2}}$$

and the phase angle is

$$tan\theta = \frac{\omega L - \omega C[R^2 + (\omega L)^2]}{R}$$

When

$$\omega = \omega_0 = \sqrt{\frac{1}{LC} - (\frac{R}{L})^2}$$

Resonance occurs when the total impedance reaches its maximum value, with ω_0 being the resonance frequency. This circumstance is advantageous for many circuits. The frequency response of the coil impedance is depicted in Figure 2.13. The circuit is resistive when the frequency is near to zero because the total impedance is equal to the resistance in the system. The circuit impedance reaches its highest value when the frequency is tuned to its resonance frequency. X_L, the inductive reactance, controls the impedance primarily on the left half of the curve, whereas X_C, the capacitive reactance, controls the impedance on the right half.

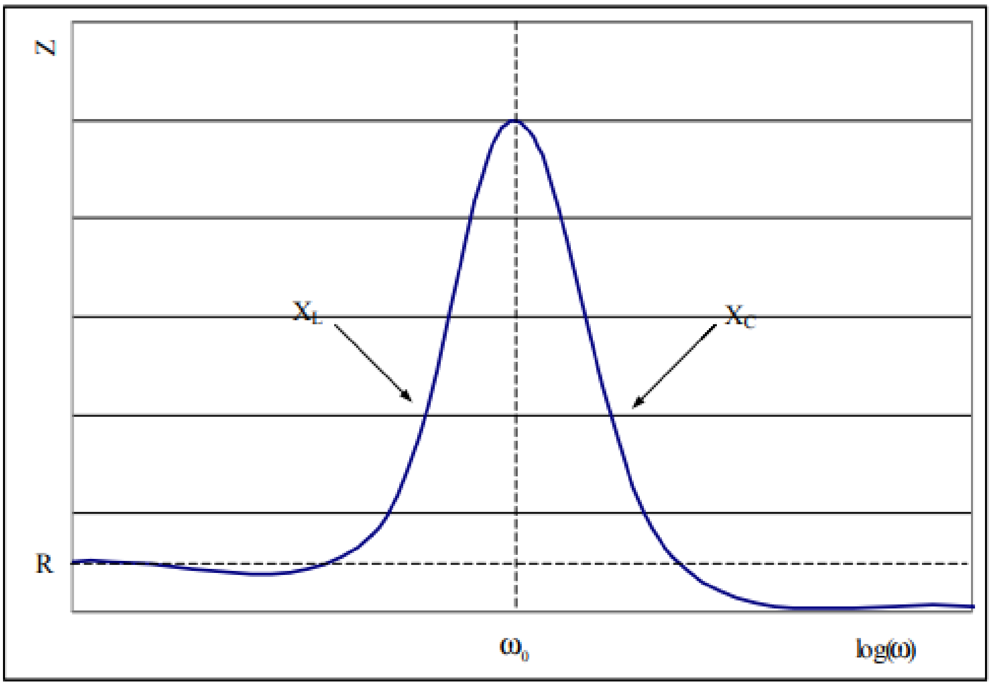


Figure 2.13 Frequency response of coil impedance

2.3 Overview of Signal Detection, Processing, and Display

Signal Sources. By monitoring the alternating current in the coil (single coil arrangement) or by utilizing a separate sensor coil to monitor the resulting electromagnetic field, material changes can be identified when using an eddy current approach. These signals can be examined for data pertinent to the current inspection. The coil that serves as the receiver produces an electrical current that either precedes or follows the oscillator current of the instrument, which is a crucial point to remember. The phase angle determines whether the signal is "leading" or "lagging," respectively.

Signal Detection. Use of a bridge circuit, as shown in Figure2.14, is a straightforward but efficient signal detection technique . The variable impedance Z_1 can be adjusted such that no current flows through the amplifier when the test coil is powered up and placed on a flaw-free or reference area. The bridge is either "balanced" or "nulled" after this adjustment. The coil "unbalances" the bridge and current flows through the amplifier when it is placed on a deficient or damaged area because of the shift in current via the coil. The indication for inspection is this current. The frequency of the signal matches that of the current flowing through the coil. The circumstance that led to the bridge's unbalance is revealed by the phase and amplitude of this signal.

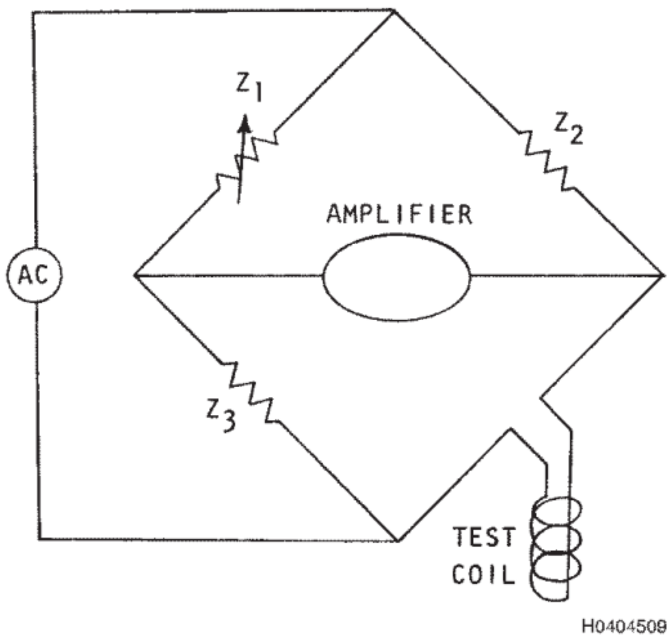


Figure 2.14. Simplified Bridge Circuit

Signal Analysis. The simplest form of instrumentation relies on sensing changes in the amplitude of the current flowing through the bridge to analyze the signal. Alternating current changes in strength are amplified and changed to direct current for display or readout. Accurate measurements of amplitude and phase are made with more advanced instrumentation.

Displays. The type of information needed and the complexity of the instrumentation determine how eddy current signals are displayed. Meters, warning signals, or recorders are frequently employed when simply signal amplitude needs to be determined. A two-dimensional display device is typically utilized when both amplitude and phase information need to be presented.

Impedance Changes. When a coil is positioned next to an electrically conductive or ferromagnetic component, its impedance seems to alter. The induced eddy current in the component generates a secondary electromagnetic field that opposes the primary electromagnetic field. Additionally, this opposing field causes the coil's principal current to flow in the opposite direction. If the component is not ferromagnetic, both the primary and secondary magnetic fields' combined net magnetic field strength and the coil's current flow are reduced. This has the same effect as lowering the coil's inductance while raising its resistance. If the component is ferromagnetic, the relative magnetic permeability's magnifying impact causes the net magnetic field to grow, but the opposing action of the secondary magnetic field from the induced eddy currents causes the current flow in the coil to decrease. This is the same as raising the coil's inductance and resistance. This results in a change in the apparent impedance of the test coil when changes in a part impact either the strength of the magnetic field at the part's surface or the strength and distribution of the eddy currents in the part (s). Eddy current test results can be used to detect, amplify, display, and analyze these variations in current flow, both in phase and amplitude. Signal amplitude and phase variations can be connected to modifications in the items being examined.

Inductive Reactance. Inductive reactance is the measurement of the amount of resistance or opposition to the flow of alternating current caused by inductance in a coil. The amount of the coil's inductance and the frequency of the alternating current affect inductive reactance. As the inductance or frequency rises, the inductive reactance rises as well.

This can be stated by the following equation:

$$X_L = 2\pi fL$$

Where:

X_L = Inductive reactance (Ohms)

π = 3.141596

f = frequency (Hertz)

L = Inductance (Henrys).

Combining Out of Phase Quantities. Along with the inductive reactance, a real coil also features a resistive impedance component. The net impedance can be described using both of them. Coils can be viewed as resistors connected in series with inductors. When an alternating current is applied to this series circuit, two voltages will result: one across the resistor and the other across the inductor. The two voltages will combine to form the net voltage across the resistor and inductor (or, in this case, across a genuine coil). The voltage across the resistor will be 90 degrees out of phase with the current, while the voltage across the inductor will be in phase with the current. As shown in Figure 2.15, the two voltages combined produce a voltage that is out of phase with the current, but not by a full 90 degrees.

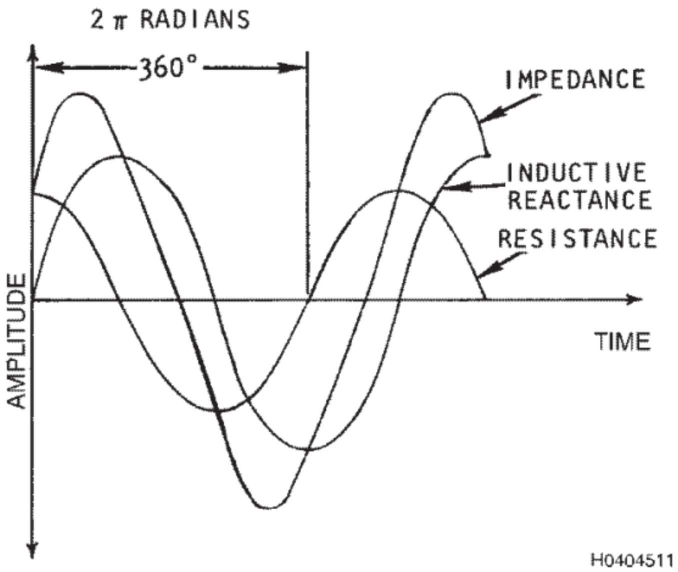


Figure 2.15 Combining of Out-of-Phase Voltages

2.4 Eddy Current Testing Instrument

Eddy current instruments come in a wide range of setups that can be purchased. Instruments are accessible in both analog and digital formats. Typically, the type of display used to deliver the data is used to categorize instruments. The typical display types are impedance plane, analog meter, digital readout, and time versus signal amplitude. Some equipment can display data in a variety of display formats.

The most fundamental eddy current testing device (Figure 2.16) is made up of an alternating current source, a coil of wire linked to it, and a voltmeter to gauge the voltage variation across the coil. Instead of using a voltmeter, an ammeter might be used to gauge the circuit's current variation.

While some forms of faults might actually be detectable using this kind of technology, the majority of eddy current devices are a little more advanced.

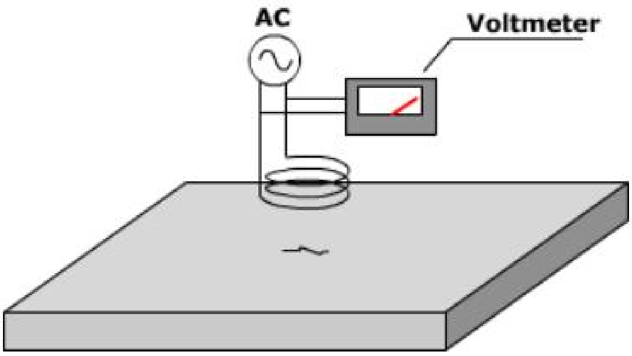


Figure 2.16 basic eddy current testing instrument

Common used eddy current testing instruments

1.Handheld Eddy Current Testing Instrument

Figure 2.17 Handheld eddy current testing instruments

Inspectors have more field flexibility thanks to handheld eddy current testing instruments(Figure 2.17) that give them access to a portable ECT data recording device.

2.Eddy current testing instrument

Figure 2.18 Larger eddy current testing instrument

Larger eddy current testing devices (Figure 2.18), which assist inspectors in logging ECT data, are also useful. Both surface array and tube versions are available for these sensors.

3.Modular Eddy Current Testing Unit

Figure 2.19 Modular Eddy Current Testing Unit

An instrument-only modular ECT unit (Figure 2.19) is a smaller, more portable eddy current testing device. Condensers and steam generators are inspected using these equipment, which are solely intended for usage at power plants.

Depending on the kind of probe being used, eddy current testing equipment can conduct a wide range of tests. The performance of the tests can be improved by selecting probes carefully.

2.5 Conclusion

Eddy current testing system design is a very complex matter, according to the physical and chemical characteristics of the object to be detected to select the appropriate probe, as well as according to the actual detection characteristics of the design to meet the requirements of the coil, both to provide a stable output input signal, but also to maintain a certain level of sensitivity.The coil must reasonably match the electrical impedance specifications of the linked device. The signal-to-noise ratio increases with the impedance match. In order to determine the size of the fault, the coils must also be designed. Minor coils are needed for smaller defects. Surface probes are the most common method used in the field for eddy current testing. The surface probe is utilized in holes, on plates, sheets, and parts with irregular shapes. The coil diameter and the existence of coil shielding regulate the size of the area that the probe will test.

Chapter 3: Practical application of eddy current testing in turbine blade detection

3.1 Principles of electromagnetic field finite element analysis

Maxwell's system of equations summarizes the laws of the electromagnetic field in a systematic， its differential form is given by

Ampere's law of loops：

$$\nabla \times H = J + \frac{\partial D}{\partial t} \tag{1}$$

Faraday's Law of Electromagnetic Induction:

$$\nabla \times E = -\frac{\partial B}{\partial t} \tag{2}$$

Gauss's Law of Electric Flux:

$$\nabla \cdot D = \rho \tag{3}$$

Gauss's law of magnetic flux:

$$\nabla \times B = 0 \tag{4}$$

where: H is the magnetic field strength, *A/m*; J is the conduction current density, *A/m2*; E is the electric field strength, *V/m*; *B* is the magnetic induction strength, *T*; *D* is the flux density *C/m2*; ρ is the density of the freely charged body, *C/m3*

In engineering practice, it is often not possible to obtain an exact analytical solution to a problem directly, but rather to find a numerical solution using numerical methods, of which the finite element method is one of the most effective. In practical finite element calculations, auxiliary quantities such as vector magnetic potential A and scalar potential Φ are usually introduced to convert Maxwell's equations into second order equations for finite element calculations.The vector magnetic potential and scalar potential are defined as follows:

$$B = \nabla \times A \tag{5}$$

$$E =- \nabla \times \Phi \tag{6}$$

The vector magnetic potential and scalar potential defined in Eqs. (5) and (6) can be derived from Eqs. (1) and (3) to obtain the partial differential equation for the magnetic field (7) and the partial differential equation for the electric field (8), respectively:

$$\nabla^2 A - \mu \in \frac{\partial^2 A}{\partial t^2} =- \mu J \tag{7}$$

$$\nabla^2 \Phi - \mu\varepsilon \frac{\partial^2 A}{\partial t^2} =- \frac{\rho}{\varepsilon} \tag{8}$$

By solving the above partial differential equation, we can now obtain the exact analytical solution.

3.2 Establishment of a three-dimensional simulation model of a turbine blade

As the experimental study was conducted only for the eddy current testing of cracks in the blade body of the turbine blade, the finite element model was built only for the blade body part and ignored the mortise part of the blade. The blade body has a large twist, a complex shape and a large degree of spatial freedom, and the vortex probe is always perpendicular to the part of the blade that the probe touches during the sweep. The 3D blade model was established by ANSYS finite element simulation software, as shown in Figure 3.1.Depending on the properties of each part of the model, different model cells were used and the nodal degrees of freedom of the cells were set to change the properties of the cells according to the choice of modelling cells.

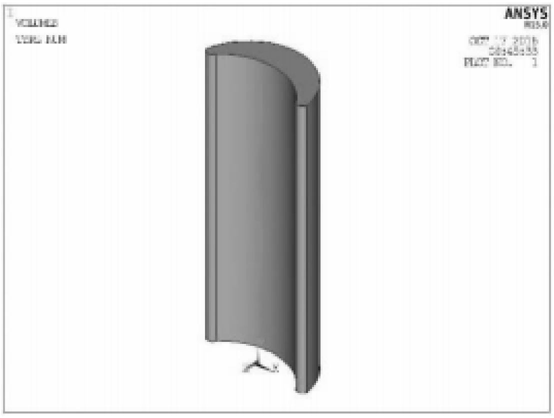


figure3.1 Finite element model of blade body

The turbine blade eddy current testing simulation model parameters are: blade length 50 mm, relative permeability 1, conductivity 0. 75 *Ms/m*; coil is cylindrical, default inner diameter 1.0*mm*, outer diameter 4.0*mm*, height 1.5 mm, number of turns 50, two coil centres 5.0*mm* apart, lift-off 1.0*mm*; sine wave excitation voltage 10V, excitation frequency default 500*kHz*; crack length, width and depth 2.0*mm*×0.5*mm*×0.5*mm*. The crack length, width and depth are 2.0*mm*×0.5*mm*×0.5*mm*.In order to improve the efficiency and accuracy of the calculation In order to improve the efficiency and accuracy of the calculation, a mixture of tetrahedral and hexahedral meshing is used to divide the simulation model, with the largest mesh density at the defects, followed by the excitation and detection coils, as shown in Figure 3.2. The near-field and far-field air layers are wrapped around the outer layer of the model and the near-field and far-field air layers are divided freely. Finally, flux-parallel boundary conditions are applied outside the far-field model according to the distribution of the coils. The magnetic field distribution near the defect and the induced electric potential of the coil are obtained by solving and post-processing. The magnetic field distribution in the vicinity of the defect and the induced electric potential of the coil are obtained by solving and post-processing. In order to guide the development of the probe, the excitation frequency is investigated separately. The excitation frequency, the excitation signal voltage, the average coil radius and the number of turns of the coil are investigated separately in this paper. The effects of excitation frequency, excitation signal voltage, mean coil radius and number of turns on the induction electromotive force of the detection coil are investigated.

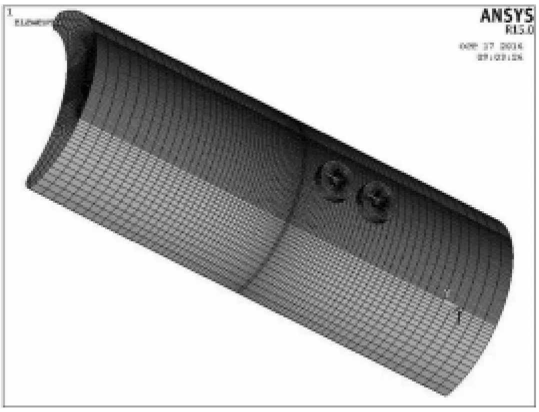
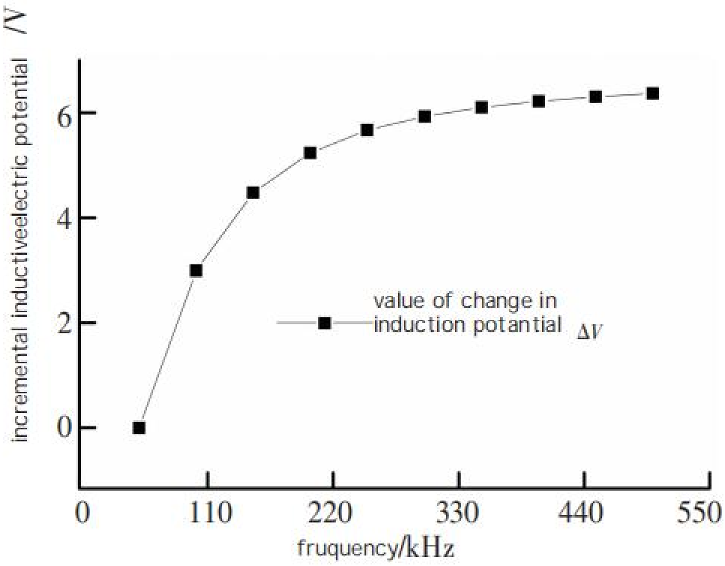


Figure 3.2 Meshing of finite element model of blade body and coil

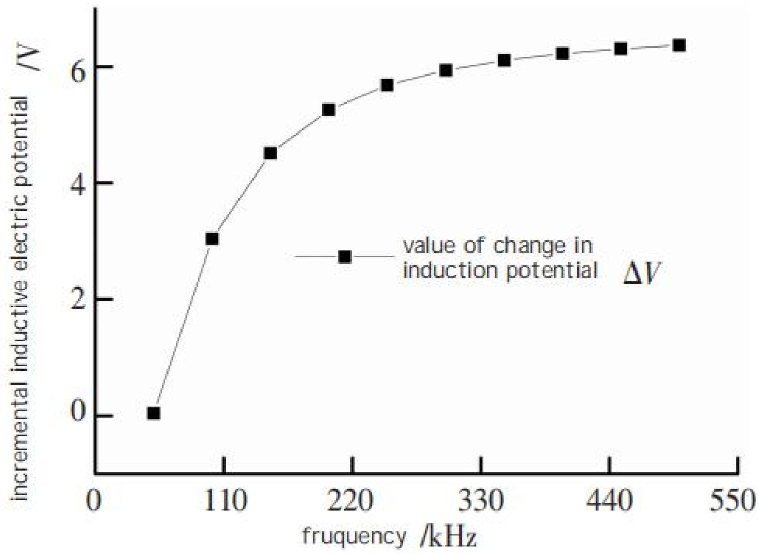
3.3 Finite element simulation results and analysis

3.3.1 Effect of excitation frequency on the induction potential of the detection coil

By increasing the coil excitation frequency from 50*kHz* to 500*kHz* and keeping the other simulation model parameters unchanged, the curve of the coil induction electromotive force is shown in Figure 3.3. As can be seen in Figure 3.3, similar characteristics are observed when the coil is located on the concave or convex side of the leaf body, with the voltage of the excitation signal gradually increasing, the amplitude of the induction potential of the detection coil increases linearly, decreasing and levelling off as it reaches nearly 300*kHz*. Considering the induction potential amplitude and the skin depth of the eddy currents and the detection requirements, a coil excitation frequency of 300*kHz* or more is chosen for the actual detection.



(a)Concave

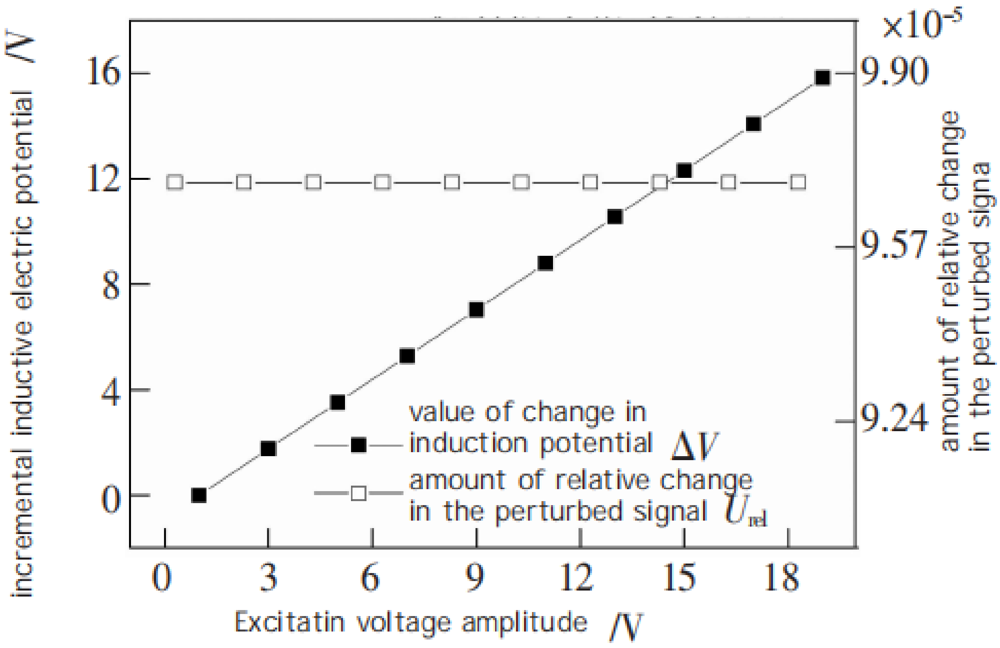


(b)convex

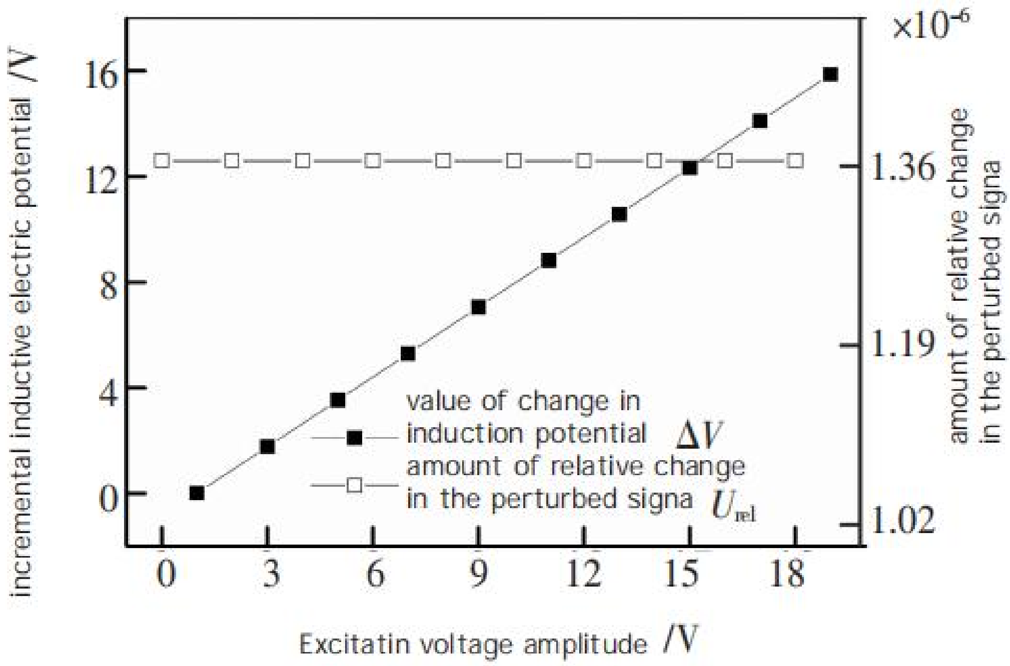
Figure 3.3 Variation curve of inductive electric potential amplitude with excitation frequency

3.3.2 The influence of the excitation signal voltage on the induction potential of the detection coil

By increasing the voltage of the excitation signal of the coil from 1*V* to 19 V, the relative change curve of the induction electromotive force of the detection coil and the defect disturbance signal is obtained, as shown in Figure 3.4, the relative change in the amplitude of the defect disturbance signal Urel = (U- U_0)/ U_0, where U, U_0 are the magnitude of the induced electric potential of the coil with and without defects, respectively. As can be seen from the graph, the coil is located under different curved surfaces of the leaf body and has the same pattern, i.e. as the excitation voltage of the excitation coil is gradually increased, the magnitude of the induction potential of the detection coil shows a linear increase, while the relative change in the defect disturbance curve is a straight line approximately parallel to the horizontal axis and its magnitude remains almost constant.It can therefore be concluded that the magnitude of the induced electric potential of the detection coil increases as the excitation signal of the excitation coil voltage of the excitation coil increases, while the relative amount of change in the defect disturbance signal is is not affected by the change in excitation signal voltage.



(a)Concave

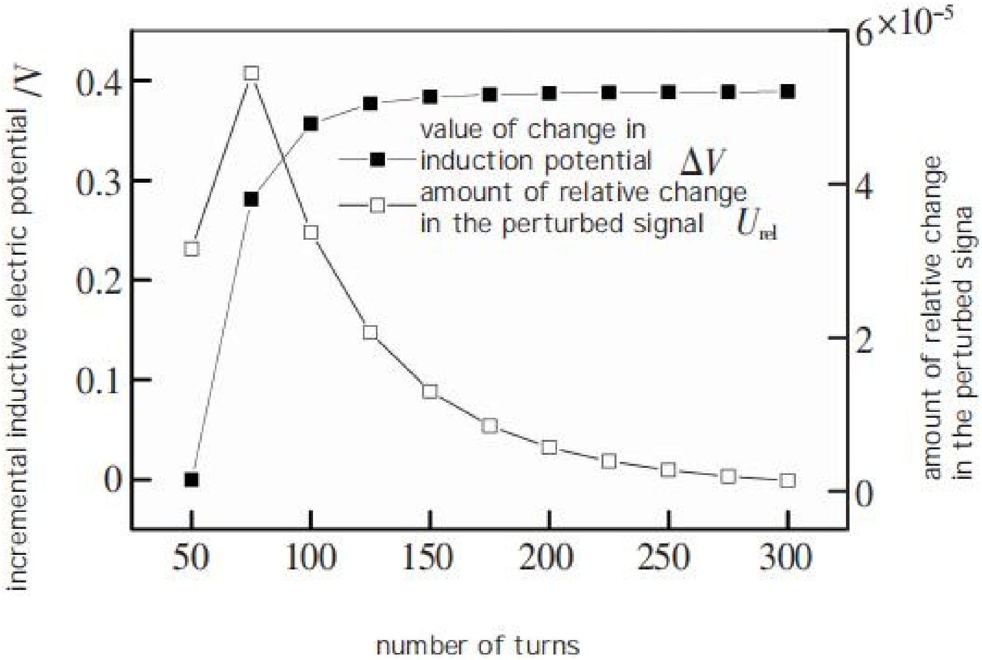


(b)convex

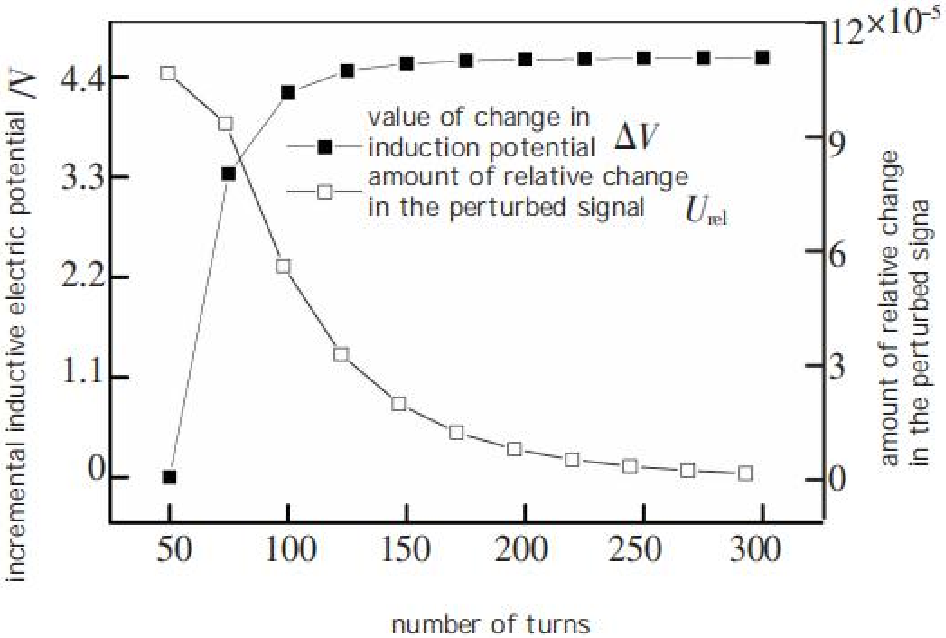
Figure 3.4 Variation of induction potential and Urel amplitude with excitation voltage

3.3.3 Influence of the number of turns on the induction potential of the test coil

The effect of the number of turns on the detection of l-turn induction electromotive force Increase the number of turns of the coil while ensuring that the density of turns does not change. The relative change in the amplitude of the induction potential and the disturbance of the defect is obtained. The relative change curve is shown in Figure 3.5. The coils are located on different surfaces of the leaf body. As the number of turns of the coil increases, the amplitude of the induction potential increases rapidly and then levels off at about 100 turns, unlike the trend of U_{rel}, which increases gradually with the number of turns of the coil, there is a small increase in U_{rel} when detecting defects and then a rapid decrease, leveling off at 200 turns. At this point the U_{rel} remains almost constant.



(a)Concave



(b)convex

Figure 3.5 Variation of induced electric potential and Urel amplitude with the number of turns of l-turn

3.4 Turbine blade crack defect detection test

The eddy current testing probe was developed based on the simulation results, taking into account the fact that the curvature of the turbine blade changes during the inspection process and that the contact surface between the probe and the blade must be small in order to reduce the interference caused by the change in curvature. Among the sensor types differential The differential sensor uses the principle of offsetting the same signal and superimposing different signals. The differential sensor uses the principle of offsetting the same signal and superimposing different signals to effectively suppress common mode interference signals such as temperature variations, lifting effects and surface conditions of the workpiece, thus improving sensitivity. Therefore, taking into account the above factors and the results of the reference simulation, the number of turns of the receiver coil is 100 and the average radius is $1.2mm$. $25\mu m$ enamelled wire is wound around a core with a radius of $0.5mm$. The two receiver coils are connected in opposite directions and fixed to form a differential receiver coil set, then 50 turns of $50\mu m$ enamelled wire are wound around the outside of the differential receiver coil set. The front end of the differential eddy current sensor is $4mm$ after gluing and encapsulating; at the same time, in order to protect the probe and eliminate the lift-off, an elastomeric device is designed and processed to compress the probe from 0 to 4 mm, as shown in Figure 3.6. The five-axis automated eddy current The five-axis automated eddy current inspection system was developed as a turbine blade inspection system. The system mainly consists of The system consists mainly of a five-axis coupled sweeping system and a near-field eddy current detector, in which the five-axis coupled sweeping system can freely adjust the sweeping speed of the probe up to a maximum of $80mm/s$. The system is capable of freely adjusting the probe sweep speed to a maximum of $80mm/s$ and can be programmed with a C language containing the sweep path, sweep C code generated by the UG numerical control programming module containing the sweep path, sweep range and sweep direction of the turbine blade can be loaded to control the sweep of the turbine blade. The five-axis sweep system is shown in

Figure 3.7 and the UG CNC programming module is shown in Figure 3.8. The UG programming module is shown in Figure 3.8.

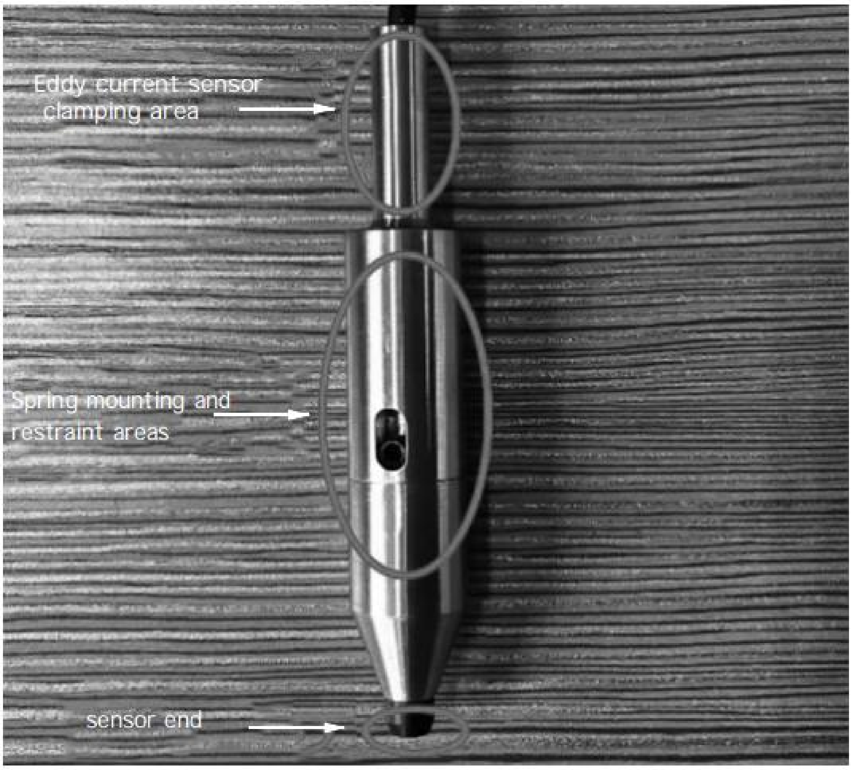


Figure 3.6 Differential Eddy Current Sensor Physical Drawing

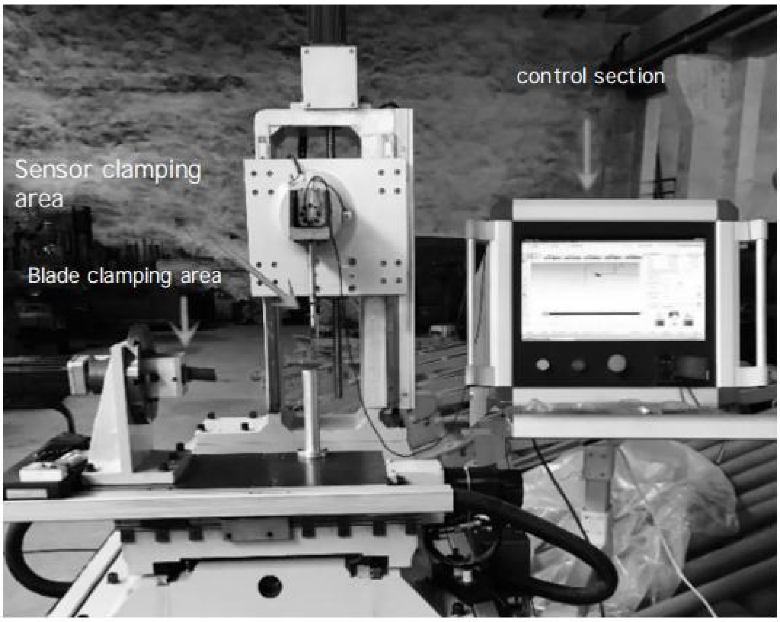


Figure 3.7 Five-axis joint sweeping system

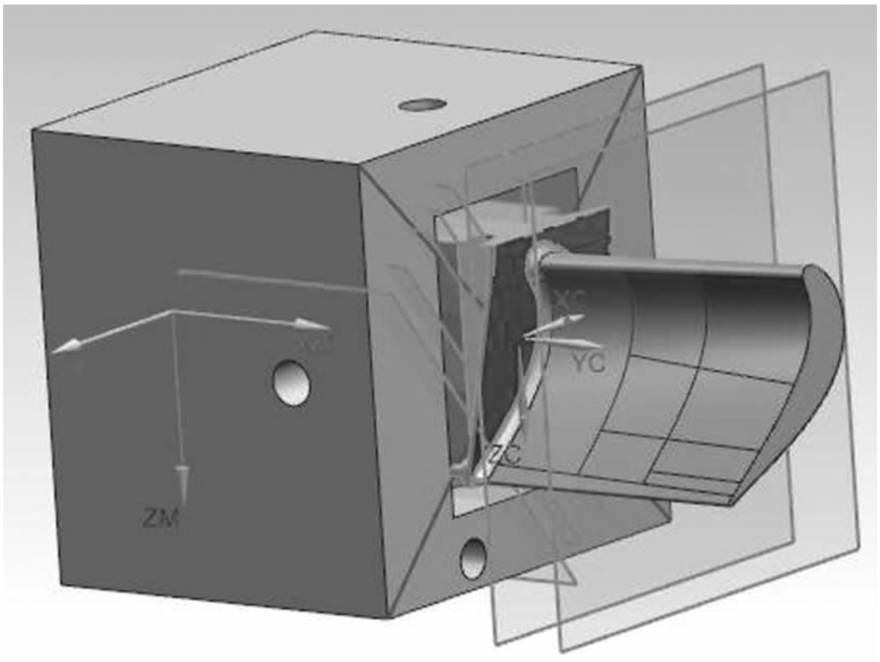
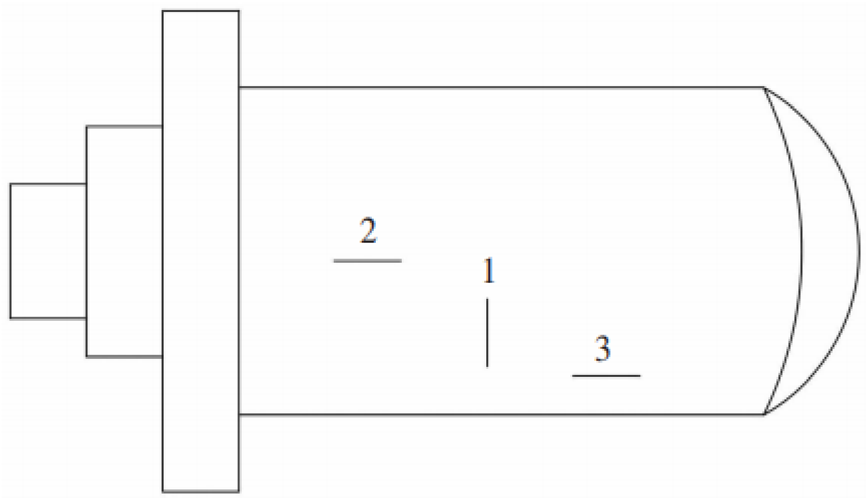
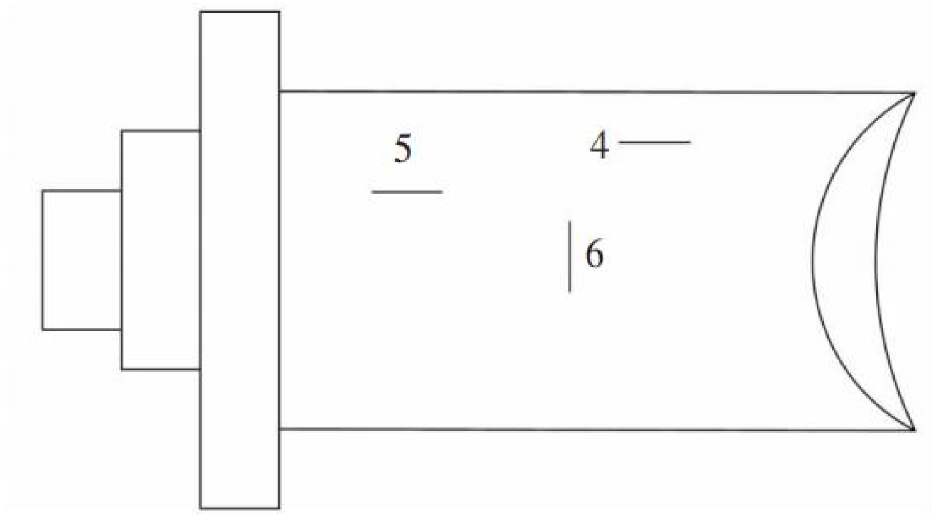


Figure 3.8 UG CNC Programming Module

Different parts of the upper blade body of the turbine blade specimen of nickel-based high-temperature alloy were prefabricated by EDM. The parts were prefabricated by EDM with microcracks of $5mm\times0.13mm\times0.2mm$ in length, width and depth, and the defect distribution is shown in Figure 3.9.



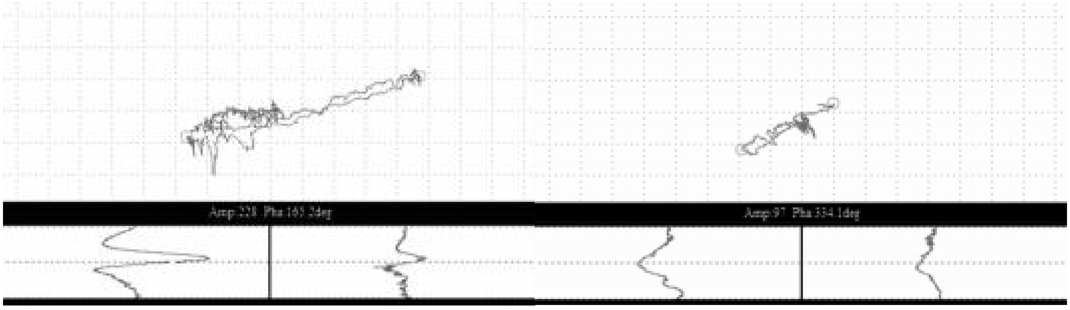
(a)concave



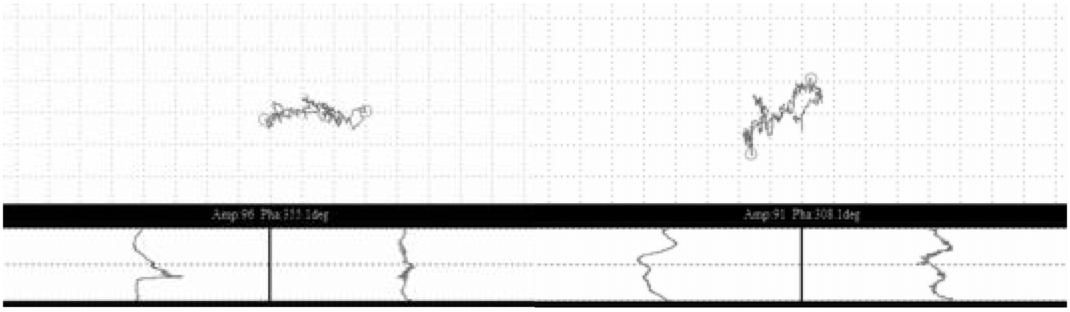
(b)convex

Figure 3.9 turbine blade defect distribution

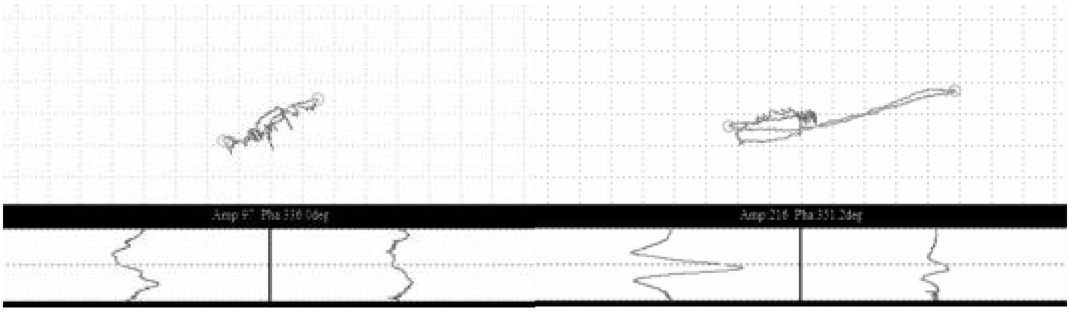
The excitation frequency shouldn't be too low in order to prevent extensive vortex penetration and damage because the real turbine blade is a hollow chamber with heat dissipation inside of it. In order to prevent the vortex from penetrating too deeply and being impacted by the internal cavity structure, the excitation frequency should not be too low. Combined with the simulation results, the excitation frequency of 500kHz sine wave is chosen as the excitation signal, and the excitation signal voltage is 8V. The maximum output voltage of the eddy current testing system is 8V. According to the different distributions of defects, the UG programming module is used to set the following defects in the blade (b) No. 1 and No. 6 defects in the middle part of the blade are swept by the differential eddy current sensor in the vertical direction of defect extension; No. 3, No. 4 and No. 5 defects near the edge of the blade are swept in the parallel direction of defect extension to avoid edge effect; No. 2 defects in the large curvature of the blade are swept by the differential eddy current sensor in the vertical direction of defect extension. No. 2 defects in the curvature of the leaf body is relatively large in the same way to sweep parallel sweeping; sweeping results are shown in Figure 3.10.



Defect No. 1 Defect No. 2



Defect No. 3 Defect No. 4



Defect No. 5 Defect No. 6

Figure 3.10 Turbine blade defect detection results

According to Figure 3.9, the scanning direction of the probe has a great influence on the detection signal of the defects, and the best impedance maps are presented for defects No. 1 and No. 6 when the scanning method is perpendicular to the extension direction of the defects, while the impedance maps for defects No. 2, No. 3, No. 4 and No. 5 are quite poor when the scanning method is parallel to the extension direction of the defects. However, due to the large curvature of the defect distribution area or susceptible to edge effects, only the sweeping method parallel to the defect extension direction can be used, and in time, under the influence of this detection method, the real part of the defect signals of No. 2, No. 3, No. 4 and No. 5 can still clearly observe the jump caused by the defects, and there is a phase difference between the defect signals and the noise signals, which can effectively identify the defects.

3.5 Conclusion

The simulation and test results are consistent, and the designed eddy current testing probe has a high sensitivity, and the small size of the front end of the sensor can ensure that the sensor fits effectively on the surface of the blade with a certain curvature. It can effectively detect and identify the cracks on the turbine blade in each direction of extension of the turbine blade.

Chapter 4: Labour protection

4.1 Electrical laboratory notes

1.the laboratory to do strong electrical experiments, you must be more than two people to carry out experiments. In the experimental platform to have a warning sign (there is a danger of electricity) or warning line. Experiment process to ensure that someone is watching, the experiment is completed in time to power off.
2. the power has been suspended on the switchgear must be hung "no closing, someone working" warning sign.
3. set up around the power distribution room, "high-voltage danger, do not approach" warning signs, and mark the voltage level.
4.electrical equipment in the absence of electricity, all think there is electricity, can not blindly touch.
5.need to operate with electricity, must bring insulated gloves or wear insulated boots.
6. Do not plug, unplug or connect electrical lines with electricity.
7.power out of the line terminals when not in use should be wrapped with insulating tape to prevent accidental electric shock.
8.in the electronic circuit board soldering process after cutting the foot, cut the foot surface should be back away from the body, especially the face, to prevent the pin from being cut off the bullet injury.

9.high voltage capacitors, after the end of the experiment or idle, should be connected in series with a suitable resistor for discharge.

10. in the need for charged operation of low-voltage circuit experiments, one-handed operation is safer than two-handed operation.

11. the use of capacitors should pay attention to the polarity of capacitors and voltage, when the capacitor voltage is higher than the capacitor voltage, causing capacitor burst and injury to people.

12. Electrostatic Protection

Static electricity can cause damage to the high-performance components of large instruments, endangering the safety of the instrument, but also due to the discharge of the instantaneous inrush current on the human body caused by injury. Although not life-threatening because of the current, but in serious cases can make people fall, electronic devices discharge cremation caused by flammable gas combustion or explosion, so it must be protected. The main measures to prevent static electricity are as follows:

① anti-static zone do not use plastic, rubber flooring, carpets and other good insulating ground materials. Can be laid conductive flooring.

② in flammable and explosive places, should wear conductive fibers and materials made of anti-static work clothes, anti-static shoes, gloves, etc.. Do not wear chemical fabrics, rubber shoes and insulating soles shoes.

③ High-voltage charged body should be shielded to prevent human induction of static electricity.

④ Before entering the laboratory prone to static electricity, you should first touch the metal grounding list, to eliminate the body from the outdoor static electricity. Sitting work occasions, can be grounded on the wrist with a wristband.

4.2 Major security hazards at the workplace

4.2.1 Electricity safety

1. the laboratory instruments, equipment should be firmly grounded protection; laboratory power supply load is not allowed to increase at will, the size of the fuse should be consistent with the current allowed by the electric gate.
2.the laboratory circuit is not allowed to change at will, such as instruments or equipment found to be faulty, do not disassemble themselves, need to be reported by the Director of the Laboratory Center for School Affairs agreed before repair.
3.the electric heating equipment can not be placed on the wooden table operation, otherwise, the equipment should be placed under the insulating material to prevent radiation heat to make the table on fire.
4.the equipment found in the operation of abnormalities, should immediately stop running, timely repair.
5.do not allow the use of electric stove heating, hot meals.
6.all metal parts of the wire, should be insulating tape sticky, to prevent electrocution accidents.
7.found someone electrocuted to immediately pull the switch, while protecting the safety of the electrocuted, do not pull the switch to pull people, when far from the lock, the application of wooden sticks to strike the power connector.
8.electrical appliances running, can not leave people, people go to stop running appliances.
9.every day when you leave the laboratory, you should check whether the power is disconnected, people go lights off.

4.2.2 Heavy Equipment Safety

As eddy current testing mainly detects aircraft engine blades, in order to ensure the effectiveness of the experiment, usually directly to the blade detection, so we need to use a large fixture equipment, once the improper operation is very likely to cause injuries to the inspector.

Notes on the use of commonly used special equipment

1.select the production license and inspection of qualified special equipment, prohibit the use of special equipment that has been explicitly eliminated and scrapped by the state.
2.special equipment installation, renovation, repair must be completed by a qualified unit.
3.special equipment in the installation and commissioning of the completion of 30 days to the quality supervision department for registration before officially put into use.
4.special equipment shall be regularly tested for safety performance and energy efficiency tests. Without regular inspection or failed inspection shall not continue to use.
5.the establishment of safety technology files.
① equipment and parts of the factory random technical documents.
② installation, maintenance, overhaul, transformation of the contract and technical information.
③ registration card, special equipment use registration certificate, inspection report, safe use of operating procedures.
④ Operation records, daily inspection records.
⑤ fault and accident records, emergency rescue plan.
⑥Operator registration.

4.2.3 Laboratory personnel qualification safety

All employees who use specialized equipment, conduct tests and/or calibrations, analyze results, and sign test reports and calibration certificates must be competent, according to laboratory managers. When using staff who are under training, proper supervision must be set up. Specific job-related personnel must be qualified based on the necessary education, training, experience, and/or verifiable skills.

NDT requires that personnel performing certain tasks hold individual credentials, and it is the responsibility of the laboratory to meet the requirements for those designated personnel to be licensed. The need for people certification may be mandated by law, specified in a standard for a certain technical field, or requested by the client.

In addition to possessing the necessary credentials, training, experience, and understanding of the tests carried out, individuals who are in charge of providing opinions and interpretations in test reports are expected to have: - Knowledge of the technology used to manufacture the article, material, product, etc. being tested, knowledge of the methods used or intended to be used, and knowledge of defects or downgrades that may occur in the course of use knowledge of defects or degradation, etc.; - knowledge of the general requirements set forth in regulations and standards; - understanding the consequences of deviations from the intended usage of materials, products, and other things.

4.2.4 Electromagnetic radiation safety

Eddy current testing is a testing technique involving electromagnetic detection, and the electromagnetic radiation generated during the experiment is to some extent hazardous to humans.

Hazards of microwave to living organisms

Microwave is a high frequency electromagnetic wave, the frequency of about $300MHz$~$300GHz$ electromagnetic wave called microwave, corresponding to the wavelength range of 1 meter to a millimeter. A certain dose of microwaves can produce a thermogenic effect on the organism, which brings corresponding effects to different parts of the organism.

The effect of microwaves on the nervous system is related to the mode of exposure and the dose of exposure. Short-time, small-dose irradiation can strengthen the excitatory process of the cerebral cortex; long-time, high-dose irradiation can strengthen the inhibitory process, especially the most obvious effect on the head. The effect of high-dose microwave can affect the mediation function of autonomic nerves, causing changes in blood circulation, respiratory rate and changes in the skin and rectum.

Large amounts of microwave radiation can result in severe pulmonary edema and bleeding, dramatic blood vessel dilation, alveolar epithelium loss, and an inflow of blood into the alveolar cavity through the capillaries. These effects can be fatal. Microwaves do, however, have a therapeutic effect on lung inflammation when used in tiny dosages.

Women who are often exposed to microwaves can have irregular menstruation and lactation deficiency during lactation. For men, when the microwave radiation to testicular temperature rise above 35 ℃, the production of sperm is significantly reduced or stopped.

For the human eye, when the power density of microwaves is greater than 10mW□ cm^{2}, less than 300mW· cm^{2}, the eye crystal can produce recoverable damage. When the power density is greater than 300mW□ cm^{2} produce irreversible damage.

Large doses of repeated microwave radiation skin will appear coagulative necrosis, muscle fibers and transverse lines blurred. Skin and muscle do not have significant histological changes under the radiation of small doses of microwaves.

4.2.5 Fire safety

The main causes of laboratory fires

1. laboratory flammable and explosive hazardous materials caused by fire

In the laboratory, the use of a variety of chemical hazardous materials is extremely common, a wide variety. These items are lively in nature, poor stability; some flammable, some explosive, some spontaneous combustion, some of the nature of mutual contact that can occur on fire or explosion, in storage and use, the slightest carelessness, it may lead to fire accidents.

2.open flame heating equipment caused by fire

Electric oven if running for a long time, prone to control system failure, heat generation, temperature rise, resulting in the baked material or combustible materials near the oven spontaneous combustion.

Such as a laboratory power outage due to the use of electric oven, did not cut off the power, call after the oven continuous power up to several hours without management. Combined with the failure of temperature control equipment, baking combustible materials near the oven caused a major fire accident.

Heating electric furnace fire is the cause: the overflow of combustible vapors from the heated material contacting the hot resistance wire; or the container rupture after the combustible material fell on the resistance wire; or insulation damage, moisture after the line short circuit or poor contact, resulting in electrical sparks, causing combustible material on fire. Among them, the heat source of high-temperature electric furnace is very easy to ignite the surrounding combustibles.

3.electrical equipment caused by fire

One of the major causes of fire is electrical failure. Electrical equipment of many different types is frequently used in chemical laboratories. Electrical heat and electric sparks will be produced by electrical equipment overload, short circuit, broken wires, loose joints, poor contact, insulation down, and other faults, igniting the nearby combustible materials.

4.violation of operating procedures caused by fire

Laboratory often distillation, reflux, extraction, recrystallization, chemical reactions and other typical operations, are dangerous as an important feature. If the operator is inexperienced, no preparation before work, unskilled operation or violation of operating rules, do not listen to the dissuasion or guidance of unauthorized operation, etc., are prone to induce fire and explosion accidents.

Precautionary requirements

-Fire prevention requirements for the use of electrical equipment

All electrical equipment in the lab should be strictly controlled, and the installation, protection, and upkeep of electrical equipment should all be properly governed by the applicable national standards.

When operating some electrical devices, care should be taken to avoid overloading the system. It is appropriate to utilize a separate power supply line, and the wiring, switches, and insulation all need to fulfill the necessary standards.

The overall explosion-proof specifications should be met by the electrical infrastructure of laboratories that often use flammable and explosive gases and liquids. To prevent operation with concealed threats, electrical equipment and wiring should be inspected and updated as soon as possible.

-Strengthen fire safety management

When performing an operation, any combustible material that gets on the body surface should be immediately rinsed off and kept away from a fire. Clothing that has been soiled by an oxidizer should be removed as well; otherwise, a little heat can easily catch fire.

4.3 Basic methods to improve laboratory safety

4.3.1 Strengthen the management of the use of old instruments

Whether the old instruments are properly maintained and cared for not only affects the life of the instruments, but also relates to whether the research work can be carried out smoothly. Strengthening the The use management of old instruments can be improved without affecting the stable operation of the instruments. The use management of the old instruments can be improved without affecting the stable operation of the instruments, to enhance their reliability and prolong their The use management of old instruments can be strengthened, without affecting the stable operation of the instruments. The frequency of instrument maintenance can be increased appropriately from the properties of the instruments and the specific use of the instruments. Instrument administrators and engineering The instrument managers and engineering technicians should communicate with the instrument manufacturers more about the design of the instruments. The instrument managers and engineering technicians should communicate and exchange with the instrument manufacturers on the design of the instruments, and design a set of emergency mechanism for the instruments as far as possible. In this way, the In case of instrument failure and possible accidents, the emergency mechanism can interrupt the process in a timely manner so as to In this way, the emergency mechanism can interrupt the process in time when the instrument fails and may cause an accident, thus minimizing the damage as much as possible.

4.3.2 Further strengthen laboratory safety education

Laboratory safety education should be further strengthened to improve laboratory personnel safety awareness. Among them, teachers, as the first safety responsibility of the laboratory As the first person responsible for laboratory safety, teachers have the important responsibility of ensuring laboratory safety and guiding students' research. Therefore, teachers themselves should participate in laboratory safety education and integrate their professional knowledge into the content of safety education. Therefore, teachers themselves should participate in laboratory safety education, integrate their professional knowledge into the content of safety education, enhance the level of safety education, and make safety education and scientific research Therefore, teachers themselves should participate in laboratory safety education, integrate their professional knowledge into the content of safety education, raise the level of safety education, and make safety education and scientific research work more closely together. At the same time, teachers' attention to safety work can also serve as an example for other laboratory personnel and lead the laboratory to form a research-oriented environment. The teachers' attention to safety can also serve as an example for other laboratory personnel and lead the laboratory to form a good atmosphere of attention to research safety. Engineers and technicians are indispensable for the normal operation of the laboratory. They are an important guarantee for the smooth development of research work. Therefore, laboratory safety education also requires the participation of engineers and technicians. In addition to completing their own work, engineers and technicians should attend various training and academic meetings related to laboratory safety. safety-related training and academic conferences to increase their knowledge base in this area and apply it to laboratory safety education. and apply them to the practice of laboratory safety education and management, so as to To continuously improve the level of laboratory safety education and management.

4.4 Conclusion

All nations operate under the principle of safety first, prevention first, and those of us who frequently work in laboratories must constantly raise our level of awareness of safety. Accidents can be avoided by learning a great deal about safety, adhering rigorously to operational guidelines, rules, and regulations, and remaining aware at all times. Damage can be reduced if safety precautions are effective and accidents are handled correctly after they happen.
Specific laboratory safety rules include the following aspects:
Types of laboratory safety accidents, laboratory safety management, first aid treatment, fire, fire prevention and suppression, fire evacuation and escape, chemical hazard Safety of hazardous materials, the use of gas cylinders and pressure vessels safety, types of radiation, hazards and protection and other safety issues.

Safety management points.

1. to adhere to the "safety first, prevention-oriented" policy.
2.strengthen the construction of safety systems - safety management responsibility system, safety education system, campus safety information reporting system hidden danger rectification and management methods, serious, large-scale safety accident emergency plans, emergency plans for public emergencies, laboratory safety objectives management reward and punishment system.
3. Seriously do the investigation and rectification work of safety hazards.

Chapter 5: Environment protection

5.1 Impact of environmental pollution

The human body is exchanging substances with the environment through metabolism. Under normal conditions, the substances in the environment and the human body maintain a dynamic balance, allowing the body to grow, develop and be dynamic.

Environmental pollution is a condition that occurs when human activity causes the environment's quality to decline, jeopardizing both human and other animals' ability to develop normally. The function of the human body will be impacted, toxic responses will occur, and in severe circumstances, life may even be put in risk when the environment is contaminated and the amount of waste water, waste gas, waste residue, noise, radioactive chemicals, etc. in the environment reaches a specific level.There are three kinds of factors that cause environmental pollution: chemical, physical and biological. The harm of environmental pollution to human body can be divided into acute, chronic and long term from time to time, and some environmental pollution will not only harm ourselves but also affect the next generation.It is the duty of every citizen to prevent and control pollution and protect the environment.

The common environmental pollution in non-destructive testing

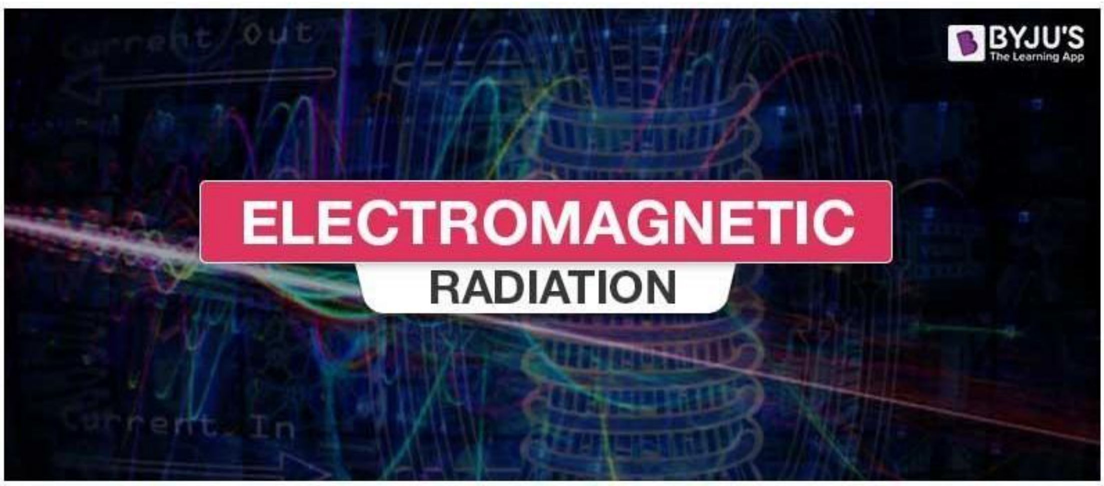
In NDT work, for example, radiation hazards caused by radioactive on human health, laser testing is harmful to the human eye, ultraviolet radiation used in fluorescence flaw detection has harmful effects on human eyes and skin, magnetic powder in flaw detection, the magnetic field has an impact on iron molecules in the blood, the electric field through the skin may cause eczema and other skin diseases, are well known and are mentioned in the corresponding NDT personnel training materials and include protective measures.

5.2 Electromagnetic radiation in non-destructive testing

5.2.1 Definition of electromagnetic pollution

Electromagnetic radiation refers to the phenomenon of energy propagation through space in the form of electromagnetic waves.

Alternating current in its surroundings are to form alternating electric field, alternating electric field and produce alternating magnetic field, alternating magnetic field and produce alternating electric field, this alternating electric field and alternating magnetic field perpendicular to each other, to the source as the center to the surrounding space alternately produced and propagated at a certain speed, that is, electromagnetic waves. Electromagnetic radiation reaches a certain level when the formation of electromagnetic pollution. We work and live in a very high degree of automation of the factory, workshop, is a changing electromagnetic environment. Electromagnetic radiation is in the form of electromagnetic waves spread in the space environment, it is a material in motion, there is no static mass. Unlike buildings, machinery and equipment, production of raw materials can be stationary in a space, with its fixed volume and weight. Electromagnetic waves are invisible, inaudible and untouchable, but they do exist and can be detected with instruments. It is electromagnetic waves have no exclusive space, there is no space physical shape mutually exclusive this special property, so that we are in the production space electromagnetic environment is complex, may form obvious or serious electromagnetic radiation pollution.



5.2.2 Characteristics of electromagnetic radiation pollution

-Hazardous

The harmfulness of electromagnetic radiation is mainly manifested in the interference of electrical equipment and electronic devices within the electromagnetic environment. To the surrounding The health of the surrounding personnel damage in two aspects.

-Latent

Electromagnetic radiation pollution is energy flow pollution, this pollution is difficult to be perceived, part of the danger of electromagnetic radiation pollution The harmfulness of some electromagnetic radiation pollution is still not recognized by people, therefore, its harmfulness or electromagnetic radiation pollution characteristics of the existence of harm The latent nature of electromagnetic radiation pollution.

The impact of electromagnetic pollution on the environment

Electromagnetic pollution of the environment produces electromagnetic interference, after scientific experiments and production practice proved that it can make electrical equipment, electrical Electronic equipment control devices and process measurement devices performance degradation, abnormal work or failure. High-level electromagnetic induction and radiation can cause flammable and explosive substances, volatile liquids or gas explosive media accidental explosion or combustion. Electromagnetic radiation is also harmful to the ecological environment.

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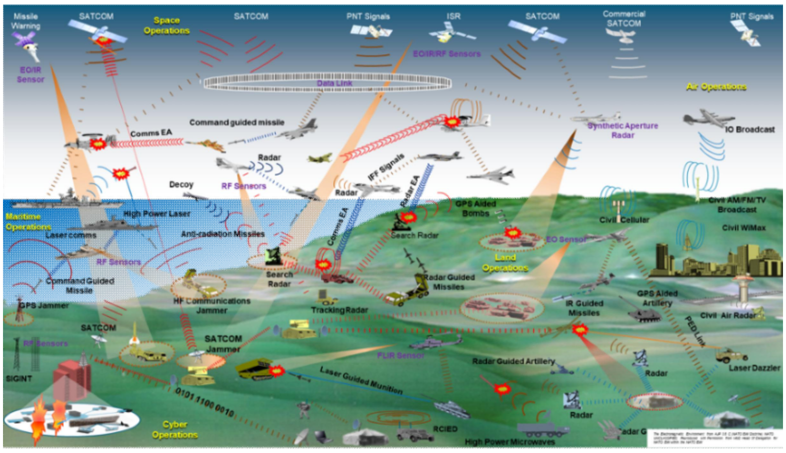
Electromagnetic pollution of the environment produces electromagnetic interference, after scientific experiments and production practice proved that it can make electrical equipment, electrical Electronic equipment control devices and process measurement devices performance degradation, abnormal work or failure. High-level electromagnetic induction and radiation can cause flammable and explosive substances, volatile liquids or gas explosive media accidental explosion or combustion. Electromagnetic radiation is also harmful to the ecological environment.



Electromagnetic radiation is harmful to the human body mechanism is mainly thermal effect, non-thermal effect and cumulative effect, etc..

1 thermal effect: more than 70% of the body is water, water molecules by electromagnetic radiation friction, causing the body to heat up, thus affecting the normal work of the body organs.

2. non-thermal effect: human organs and tissues are weak electromagnetic field, they are stable and orderly, once disturbed by external strong electromagnetic field, in a balanced state of weak electromagnetic field is about to be destroyed, the body will also suffer damage.

3. cumulative effect: thermal and non-thermal effects on the human body after the action, the damage to the human body has not had time to self-repair before (the body itself has a certain tolerance a (internal resistance), again by electromagnetic radiation, its degree of injury will occur cumulative, long will become permanent pathology, life-threatening. For long-term exposure to electromagnetic radiation groups, even if the power is very small, the frequency is very low, the weaker electromagnetic field, a long time will also produce radiation accumulation, may also induce unexpected lesions, which should cause alarm.

5.2.4 The main protection measures of electromagnetic radiation

1. Seriously do a good job of simulation prediction and hazard analysis

Whether electronic, electrical equipment, or transmitting devices, before the product leaves the factory, should be electromagnetic radiation and leakage state prediction and analysis, the implementation of the national mandatory product certification system. Large and medium-sized systems in use before, should also be the surrounding environment electromagnetic field distribution simulation prediction, in order to analyze the pollution hazards

2. Implementation of shielding

As the shielding of the equipment is not perfect, such as the past equipment, some shielding body is not a good conductor, or the lack of good electrical contact; some equipment structure is not tight, the gap is too large; some equipment panels are non-shielded materials, thus causing leakage field strength is very large, sometimes local heat or spitting fire phenomenon. Due to the unreasonable structural design of the shielding body, there are some equipment main radiation unit shielding shell with angular protruding design, easy to cause tip radiation. So the correct and reasonable shielding is to prevent electromagnetic radiation and leakage of electronic and electrical equipment, the basic means and key to achieve electromagnetic compatibility.

3. Absorption protection

Absorption protection is based on the matching principle and resonance principle of the manufacture of absorption materials, placed in the electromagnetic field, the absorbed wave energy can be converted into heat or other energy, so as to achieve the purpose of protection. The use of absorption materials for high frequency band of electromagnetic radiation, especially microwave radiation and leakage suppression, the effect is good. Absorbing materials are mostly used for testing parameters of equipment and systems. Prevent equipment leakage of energy through gaps and holes, can also be used for personal protection.

4. The use of mechanized and automated operations, the implementation of distance protection

Theoretically, the induction electromagnetic field is inversely proportional to the square of the distance, and the radiation electromagnetic field is inversely proportional to the distance.

Therefore, it is known that the greater the shielding distance, the greater the attenuation of electromagnetic field strength. Therefore, increase the operating distance can improve the shielding effect.

5.3 Conclusion

General non-destructive testing techniques are associated with electromagnetic, ray, electromagnetic radiation generated during the detection process have more or less impact on the human body, for some high-frequency electromagnetic radiation will also affect our normal industry, when the aircraft in the air, if the communication and navigation system is electromagnetic interference, it will lose contact with the base, which may cause flight accidents; when the ship used in communication, navigation or distress call for help Some electromagnetic waves will also interfere with wired electrical facilities and cause the failure of railroad signals, traffic lights out of control, computer errors and automated plant operations malfunction. Not only that, electromagnetic will also affect the survival of plants, in the long-term existence of electromagnetic radiation in the region, such as microwave transmission stations facing the slopes, may cause the death of large areas of plants.How to effectively prevent is a problem that we need to think about and solve.

General conclusion

With the development of modern industry, there are higher requirements for product quality and structural safety, reliability of use, etc. Since NDT does not damage the specimen and its high sensitivity, it has become more and more widely used in many industries and sectors in various countries. Metallurgy, machinery, oil and gas, chemical industry, shipping, nuclear industry, aerospace and so on are widely used in non-destructive testing technology.

Among many inspection techniques, eddy current inspection is more recognized and accepted because of its many advantages, such as fast detection speed, non-contact detection, high sensitivity, detection of metal and non-metal coating thickness, and the detection signal can be digitized, especially the aerospace industry is more dependent on it.

This paper explains the importance of NDT in modern industry and describes in detail the application of eddy current inspection in aircraft turbine blade inspection, which fully reflects the superiority of eddy current inspection technology in aircraft turbine blades and directly reflects the important position of eddy current inspection technology in aerospace industry.

With the development of science and technology, our nondestructive testing technology will be more and more widely used, the technology will become more and more mature, the variety will be more and more rich, I believe that in the near future all of this will be achieved.

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