International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 11 | Nov - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

A Review Paper on Non-Destructive Teston Marine and Aeronautical Structure

Mr.T T V S R.Krishna Kumar[*M.Tech,M.Ba,(Phd)]*, K.Dinesh Kumar, G.Durga Prasad,
N.Hima Sai Kiran, and Praharaju V N S B Sudhakar.

Department of Mechanical Engineering
Nadimpalli Satyanarayana Raju Institute of Technology
Sontyam ,Pendurthi-Anandapuram Highway, Visakhapatnam-531173

Krishnakumar.me@nsrit.edu.in

***Abstract* - Non-destructive testing (NDT) is a significant variousness in the guarantee of the structural integrity and reliability of critical components in the marine and the aeronauticalindustries. Owing to extremely harsh working environments and high-stressed conditions of these very industries inspected and assessed for defects, cracks, and corrosion are highly rigorous. Their approach allows assessment of material properties, geometric configurations, and possible modes of failure without damage to nor modification of the component itself.**

Different techniques such as ultrasonic testing, radiography, eddy current testing, acoustic emission testing, magnetic particle testing, and liquid penetrant testing are employed to detect surface and subsurface anomalies.

***Keywords* - Non-destructive testing, marine, aeronautical, ultrasonic testing, radiography,eddy current testing**

INTRODUCTION

Non-destructive testing are methods to evaluate material integrity for surface or internal flaws or metallurgical condition without interfering in any way with the destruction of the material or its suitability for service. There are varieties of methods to evaluate materials and components as per their state of application The field of Non-Destructive Evaluation (NDE) or Non- Destructive Testing (NDT) involves the identification and characterization of damages or defect on the surface and interior of materials without cutting apart or otherwise altering the material.In other words, NDT refers to the assessment or evaluation and inspection process of materials or components for characterization or finding defects and flaws in comparison with some standards without altering the original attributes or harming the object being tested. NDT techniques make available or provide a cost effective Testing means of a sample for individual investigation and examination or can be applied on the whole material For checking in a production quality control system. In many cases, the approach to finding a defect requires more than use of a single NDT test method. It may require a combination of methods and also exploratory, invasive openings. A better understanding of the background, advantages and limitation of each NDT method is essential in ensuring the success of the evaluation.

Understanding one NDT method alone may not be enough to ensure the success in solving theproblem at hand. A wide variety of non-destructive testing methods plays most important roles in testing of composite materials. The applications of composite NDT may include in many places such as in manufacturing, pipe and tube manufacturing, storage tanks, aerospace, military and defence, nuclear industry, and composite defects characterization. Damage in composite materials can occur during material processing, manufacture of the component or in- service operations among which cracks, porosity and delamination are the most prevailing defects. Many techniques applied in the composite NDT area include radiographic testing, visual testing(VT) or visual inspection, ultrasonic testing, thermographic testing, infrared thermography testing, Acoustic ultrasonic testing, Acoustic emission testing, Liquid penetrant testing, Electro-magnetic testing, Magnetic particle testing, Shearography testing, Optical and Optical testing. This report discusses several NDTs techniques for material and composite defectidentification and characterization while finding the most efficient approach.

Non-Destructive Testing Methods

There is wide variety of nondestructive techniques or methods. These methods can be performed on metals, plastics, ceramics, composites, cermets, and coatings in order to identify cracks, internal voids, surface cavities, delamination, incomplete defective welds and any type of flaw which would lead to premature failure. Commonly used NDT test methods can be seen in *table I*

1)Visual Inspection- Visual inspection is effective, especially in detecting the large macroscopic flaws including that of poor welds. Many welding defects are macroscopic such as crater cracking, undercutting, slag inclusion, incomplete penetration welds, and the like. Likewise, isalso suitably used for detecting flaws in composite structures and piping of all types. Bad welds or joints, missing fasteners or components, poor fits, wrong dimensions, improper surface finish,large cracks, cavities, dents, inadequate size, wrong parts, lack of codeapproval stamps and similar proofs of testing.

TABLE I
(COMMONLY USED NDT TECHNIQUES)

Technique	Capabilities	Limitation
Visual Inspection	Macroscopic surface flaws	Small flaws are difficult to detect, subsurface flaws.
Microscopy	Small surface flaws	Not applicable to larger structures; subsurface flaws
Radiography	Subsurface flaws	Smallest defect detectable is 2% of t thickness; radiation protection. ! subsurface flaws not for porous materials
Dye penetrate	Surface flaws	No subsurface flaws not for poro materials
Ultrasonic	Subsurface flaws	Material must be good conductor sound.
Magnetic Particle	Surface / near surface and layer flaws	Limited subsurface capability, only f ferromagnetic materials.
Eddy Current for metals	Surface and near surface flaws	Difficult to interpret in sor applications; only for metals
Acoustic emission	Can analyze entire structure	Difficult to interpret, expensi equipments

2)Radiography- Radiography technique has a benefit or advantages over some of the other NDT methods in that the radiography provides a permanent reference for the internal soundness of the object that is radiographed. The x-ray emitted from a source has an ability to penetrate metals as a function of the accelerating voltage in the x-ray emitting\tube. If any defect or irregularities such as void present in the object are radiographed, more x-rays will pass in that\ area and the film under the part in turn will have more exposure or spot light than in the non- void areas. The Sensitivity of x rays is nominally 2% of the materials thickness. Thus for a piece of steel having a thickness of 25mm, the smallest void that could be detected from this x ray would be 0.5mm in dimension. For this reason, parts are often radiographed in different planes.A thin crack does not show up unless the x-rays ran parallel to the plane the crack. We also find out that Gamma radiography is identical or equivalent to x-ray radiography in operation.

This technique is not popular due to its disadvantages; hazard involved during handling radioactive materials. This technique is useful for detection of internal defects or defects in ferrous and non-ferrous metals and other materials. X-rays produced electrically and Gamma rays produced by radio-active isotopes are penetrating radiation which is differentially absorbedby the material through which it passes; the greater the thickness, the greater the absorption.

3)Dye Penetrate Testing- This technique is based on the ability of a liquid to be drawn into a "clean" surface breaking flaw by capillary action. Materials that are commonly inspected using DPT or LPI include metals (aluminium, steel, titanium, copper, etc.), glass, many ceramic materials, rubber, plastics. The penetrant which is used in dye penetrate testing may be appliedon all non-ferrous material and ferrous material and we also know that magnetic-particle inspection is largely used for ferrous elements instead of DPT on account of its subsurface- detection capability. DPT is used to detect any defects in casting, forging, and welding surface defect such as hairline crack or surface porosity and cracks in new products and fatigue in service or in operating element. LPI is founded upon capillary action, where as low surface tension fluid penetrates into clean and dry surface-breaking discontinuities. Penetrant may be applied to the test component or specimen by dipping, spraying, or brushing. After adequate penetration time has been allowed, the excess penetrant is removed and a developer is applied.The main advantage One of the advantages of using a developer in DPT is that it makes penetrant to come out from the flaw so that a hidden or invisible indication becomes visible to the inspector. Inspection is performed under ultraviolet or white light, depending on the type ofdye used fluorescent or non-fluorescent (visible).

4)Ultrasonic Testing- The ultrasonic method is applied for the flaw detection inside sound conducting materials. The principle of an ultrasonic test is comparable in some ways to a principle of echo sounding: a short pulse of the ultrasound is produced by introducing an electriccharge into piezoelectric crystal vibration for a very short period at a frequency associated with the thickness of the crystal. In flaw detection this frequency is generally between 1 MHz and 6 MHz Vibration or sound waves of this frequency travel many miles in homogeneous elastic material, including most metals without much dissipation For instance the velocity in steel is 5900 meters per second, and in water 1400 meters per second. Ultrasonic testing utilizes an extremely wide range of techniques depending on the means of producing and detecting mechanical vibrations or waves within test articles. Cathode ray tube is the traditional technique of displaying information in ultrasonic testing, in which horizontal movement of the spot from left to right represents time elapsed. The rate at which the spotmoves is such that it gives the appearance of a horizontal line on the screen.

5)Magnetic Particle Inspection- This method uses magnetic fields and small magnetic particles, such as iron filings to detect flaws in components. The only requirement from an inspect ability standpoint is that the component being must be of ferromagnetic material like iron, nickel, cobalt, or one of their alloys since those are materials that can be magnetized to such a level that it is possible to perform an inspection. In the simplest use, an electromagnet yoke is put on the surface of the item to be inspected, and a kerosene-iron filling Sandeep Kumar Dwivedi et al.suspension is poured on the surface and the electromagnet is energized. If there is a discontinuity such as a crack or a flaw on the surface of the part, magnetic flux will be broken from that place and a new south and north pole will form at each edge of the discontinuity. Then just like if iron particles are scattered on a cracked magnet, the particles will be attractedto and cluster at the pole ends of the magnet, the iron particles will also be attracted at the edges of the crack behaving poles of the magnet. This cluster of particles is much easier to see than the actual crack and this is the basis for magnetic particle inspection. This method is suitable for the detection of surface and near surface discontinuities in magnetic material, mainly ferrite steel and iron.

6)Eddy Current Testing- Eddy currents are created through a process called electromagnetic induction. When alternating current is applied to the conductor, for example as in copper wire, amagnetic field develops in and around the conductor. During the process this magnetic field expands as the alternating current rises to maximum and collapses when the current is set to zero. If a new or secondary electrical conductor is placed within the close proximity to this changing magnetic field, current will be induced in the second conductor. These currents depend on the characteristics of the material; for example, voids, cracks, variations in grain size, as well as the physical distance. between coil and material. These currents form impedance on a secondcoil which is used to as a sensor. In practice the surface of the part is to be inspected or examined by placing a probe above the surface, and electronic equipment monitors the eddy current in the work piece through the same probe. Eddy currents testing can be used to find out quantity of items such as in crack detection, material thickness measurement, coating thickness measurement, heat damage detection, case depth measurement, material identification by measuring the conductive ability of a sample and control monitoring through heat treatment.

7)Acoustic Emission Testing- Acoustic Emission is a process generated when any material experiences some sort of internal transformation, which might have caused by an outside pressure, such as any mechanical in operation. loading generating sources of elastic waves. Thisis the result of a small surface displacement of a material created due to stress waves generated when the energy in a material or on its surface is released rapidly. The wave which is developed by the source is of practical interest in techniques applied to induce and capture AE in a controlled fashion, for study and/or use in inspection, examination, quality control, system feedback, process monitoring and others. The very important thing is that the acoustic emissions are detected with sensors consisting of piezoelectric ceramic elements. This method is particularly effective for continuous surveillance of load-bearing structures.

THEORETICAL ANALYSIS

Visual method based on processing images of the surface of the turbine blades in visible lightVisual method is commonly used in a non-destructive examination of technical objects.

In the case of the use of optical instruments,and in particular a videoscope, it is possible to inspect the object without necessity of disassembling it. The acquisition and development of information that could be useful for the diagnosis of machine parts, is a complex process thatrequires multiple treatments. In general this process can be summarized as follows:

- illumination of the diagnosed object located in the background with white light,
- acquisition of the test object image,
- digital analysis of the image,
- presentation of information on the image.

Illuminated surface of the blade can be recognized by a light-sensitive detector (CCD matrix with an optical system–optoelectronic system) through a secondary source of light from its surface. CCD matrix counts incident photons ,energy of the light rays incident on each pixel. In the case of a computer vision system the image is obtained from ambient by means of an optoelectronic device – videoscope (Fig. 1). This enables indirect method of diagnosis of the object through the processing and analysis of data collected in the form of digital images.

Fig. 1 Optoelectronic device-videoscope

For one-dimensional model and homogeneous material,the expression of the temperaturechange during the cooling of the surface heated by short thermal pulse, is as follows:

$$T(t)-T(0) \sim Q\alpha^{-\frac{1}{2}}t^{-\frac{1}{2}}$$

where:

Q - is the heat pulse energy per unit of area,t - surface cooling time,

T(0) - is the temperature at a selected point or area of theheated surface, just after extinguishing the pulse,

T(t) - the temperature in the cooling process at any time

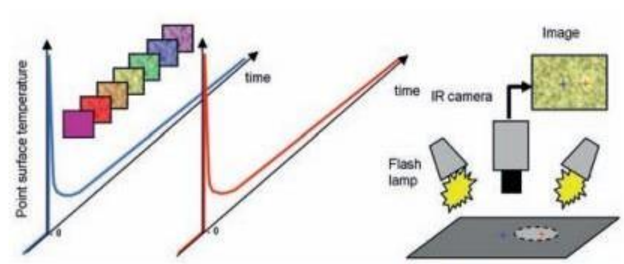

Fig. 2 Diagram to explain the application of pulse thermography

The occurrence of defects in the material reduces the diffusion rate which means that temperature of the surface area above the defect will be different from the temperature of the region under which there are no defects – and therefore, the aspect of the above relationship changes. This method (as well as others), has limitations, due to rapidly fading with depth the temperature contrast it only allows for the detection of subsurface flaws. Thermographic examinations covered the turbine blades made of alloy EL-867WD, classified into various categories: new, used - fit and damaged during turbine engine operation. The obtained results confirmed changes of parameter dependence of thermal response of the examined blade materials to stimulating heat pulse (Fig. 4).

Fig. 3

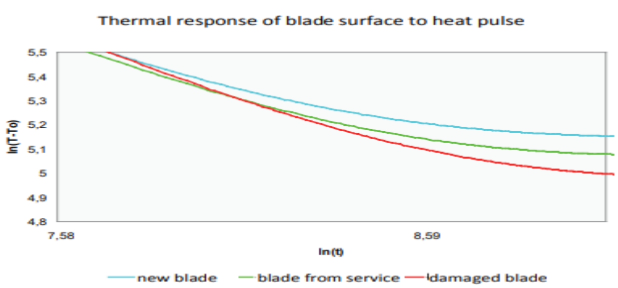

Fig. 4 Blades thermograph and changes of dependence of the parameter IN(T-To) of the thermographic signal at selected points of the blade surfaces

Subsequently, by means of active pulsed thermography examinations of operated gas turbineblades were performed.The research was carried on the rim steering blades of gas turbine aircraft jet engine made of an alloy ŻS–6K. Based on visual criteria of assessment, the blades were classified into various groups according to their degree of overheating (category I to V). The result of research affirmed that the thermal response of the blades material considered as “able” (category I) is uniform over the entire surface (Fig. 8). While on the basis of the analysis of the response to the heat pulse of the blade material classified as “unfit” it was possible to determine clearly deviating from the average value of the zone. These areas coincide with areas visually assessed as overheated which, togetherwith the results of the tests conducted on samples (Fig. 5) gives rise to the inference of superheated material structure.

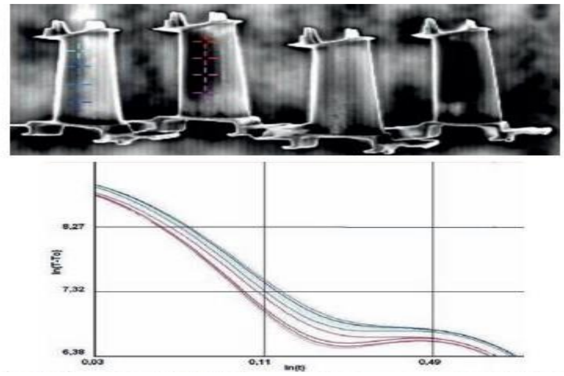

Fig. 5 view of exploited blades I and V categories and chart of their material response for the heat pulse

Features of digital images allow to determine their histogram, i.e. the frequency chart of successive values of pixels in the image. The histogram shows how numerous are points in the image with different brightness values lk [1, 6].It is assumed that the first element of the histogram has the number 0, and the last is equal to the number of levels of image brightness. Ifthe image contains mxn points and is saved using P levels of gray (for monochrome image):

pm ={0,1,21, ,lk, , 254,255} and for the RGB color image: pR ={0,1,21, ,lk, , 254,255}, pG ={0,1,21, ,lk, , 254,255}, pB ={0,1,21, ,lk, , 254,255}, then the usual result is mxn/p that

have a certain level of gray or shades of colour component in the case of colour images. Thehistogram is represented as a vector of length corresponding to the number of brightness levels, it can be written as follows [24, 25]:

$$h(l_k) = \sum_{m=1}^{M} \sum_{n=1}^{N} p(l_k, (m,n)) \, ,$$

where:

h(lk) - the sum of points, that level of gray equals lk and(2) Disruptions that occur in all stages ofthe process of acquiring and analyzing information impinge on the reduction of the efficiency ofdata acquisition in the form of digital images. The following assumptions for research are

being assumed:

- acquisition of images in the same conditions and the same resolution,

- illumination – diffuse white light,
- no light interference – reflected from other surfaces,
- acquisition of images using a videoscope of the same

resolution at the same magnification.

Representative areas (averaged ROI areas – regions of interest) are selected to describe the tested surfaces unequivocally. By means of the Matlab software (ImageProcessing Toolbox)image of the blade surface is transformedinto the RGB colour image or grayscale image.

Typically, thetest of image histogram is carried out in order to determine whether the “black-white” information is sufficient to describe the change of the colour caused by the action of high temperature (superheat).Parametric description of histograms is to determine the position of the maximum value of the amplitude, i.e. the number of pixels (ordinate axis) for thevalues of saturation of grayscale or RGB (abscissa axis) – Fig. 4. In order to extract diagnostic information the examined waveforms of the changes of the maximum amplitude values in the function of temperature are approximated by polynomials.Acquisition by videoscope and computer analysis of images of the surface samples of the blades made of superalloy EI-867WD were performed before and after heating in a furnace in realistic conditions. Studies of the first order statistics (parametric description of histograms) of images of blades surfaces showed a monotonic decrease of values of the amplitude of grayscale saturation (Fig. 5).

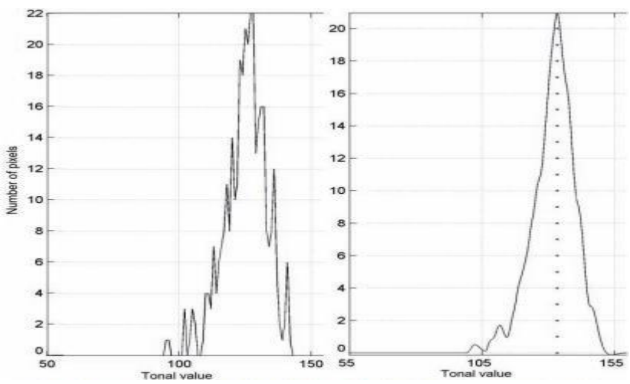

Fig. 6 Exemplary spectral analysis of the image of blade surface

i)X-ray computer tomography

Tomography is the collective name for the diagnosticmethods aimed at obtaining a spatial image of the machine element. In the technical diagnosis, a method of computed tomography (called CT) has been widely applied [10]. It is a kind of X-ray tomography allowing for obtaining spatial images (3D) from the radiograph scanning of the object performed from different directions (Fig. 9). By using the tomograph and a computer implemented program, an object tomogram is obtained. CT is now widely used in industrial production quality control process as a non-destructive method. In the computer tomography radiation source is X-ray tube. The X-ray detectors used in computer tomography are mainly ionization chambers and scintillators.

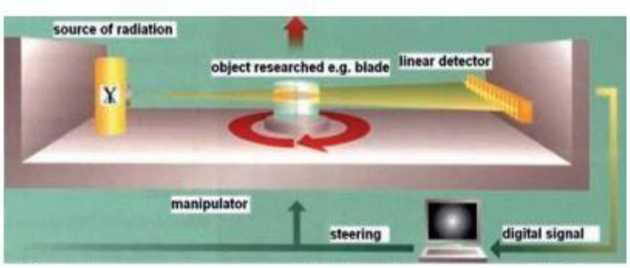

Fig. 7 Example of a tomography investigation with use of a linear detector

X-ray source there are performed a series of radiographies with a beam of X-rays. The data stream from the detectors contains information about the absorption (scattering) of radiation through the various components of the test object. These data are stored in computer memory and digitally analyzed in order to obtain monochrome images. Each cross section of X-rays through object of study is divided into small parts – voxels. For each voxel there is assigned a numerical value proportional to the degree to which it absorbs radiation. To determine this value for n voxels there is a need of at least n of equations describing the absorption in a given layer. N different cross-layer projections are needed. The more projections,the better image accuracy is achieved. The most commonly used image reproducing methods are analytical methods. They are able to yield the best results, but require large computing power. Two-dimensional Fourier analysis method uses fast Fourier transform to describe obtained absorption profiles. Transformation is subjected to each of the projection, and thus the absorption coefficient in each of the voxels is obtained. The absorption coefficients are converted to CT numbers, also called HU Hounsfield units [8]:

$$IHU = K\frac{\mu_p - \mu_w}{\mu_w}$$

where:
K - constant image enhancement (individual for eachtomography)
μp – pixel absorption coefficient
μw – the coefficient of water absorption (reference value).

In order to obtain high accuracy of projection the internal

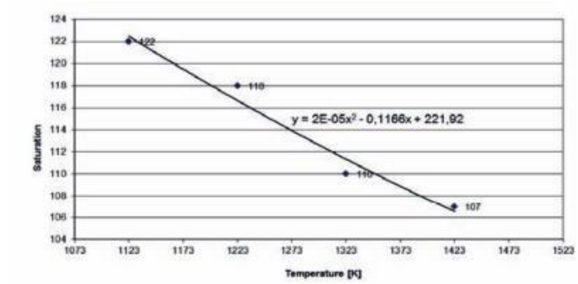

Fig. 8 The values of the position of the maximum amplitude of grayscale saturation of blade surfaces annealed in conditions similar to realistic

structure of machine element, theradiation beam is limited by the diaphragm to a flat beam and a digital linear detector is used (one series of sensors). After rotating the element by 360° a flat X-ray image of slice isobtained. In order to obtain a spatial image of the entire element, the element is shifted in a vertical plane, and at each step a full turn is made. A 3D image is obtained after processing of all collected data. Computer radiography applied to turbine blades allows the observation of actual thickness of the inner, invisible walls [8]. An image of the object can berepresented in the colours and the shape of the inner wall can be determinedin the appropriate scale, e.g., the size and location of the defect. Also, the geometry of the internal components can be accurately measured and the tolerance of their actual dimensions be assessed. Thus, CTscan allows to verify the correctness of realization of the component with a very high degree of accuracy and diagnose internal damages, for example, cracks, blade canalsblockage, etc. (Fig. 9).

SUMMARY

Various types of damage to the components of gas turbines occur in the process of their operation. Of all parts of the turbine, the most vulnerable to damage are blades, whose condition has a significant impact on the reliability and durability of the entire engine andassembly, in which it is embedded. The main causes of damage to the blades of the
gas turbine are their overheating and thermal fatigue. The destruction of the gas turbine blades usually starts with the destruction of the protective coating and, as a result, the blade base material is exposed to direct aggressive impact of exhaust gases. This situation leads directly to overheating of the material, seen as unfavorable changes in the microstructure.
As a result, the surface roughness changes, and in particular the colour of the blade surface. Thecolor of the surface is therefore a diagnostic signal, which is used in the visual method. Using computer analysis of image recognition, one can objectively evaluate change in the blade state, such as overheating based on the analysis of the colour changes in its surface. Visual method thus enables diagnosis of the status of the blades without necessity to disassemble the turbine. Results of the study on gas turbine blades, the new and the used ones, after using an active thermography showed the existence of dependencies and relationships between operational heat load and signals changes of the material thermal response. These dependencies and relationships are used to assess the state of overheating of the gas turbine blade material. Although this method is more sensitive and reliable. however, it can be used after disassembling the blades from the turbine Computer tomography allows achieving spatialimages of the test objects state in a relatively short period of time. It is characterized by high credibility and reliability. Like the previous method it can be used after disassembling the blades from the turbine. In addition, costly X-ray CT scanner is required for the research. The use of presented non-invasive methods, especially in a complex manner, significantly increase the probability of detecting condition changes of the blades, which will increase the reliability and safety of operation of gas turbines.

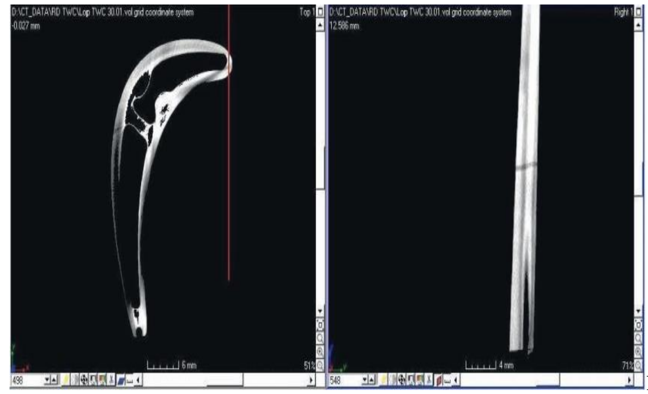

Fig. 9

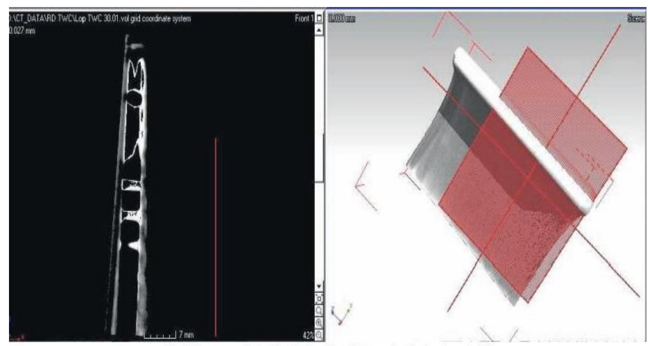

Fig. 10 Tomogram of a turbine blade with a visible crack at the leading edge

CONCLUSION

Various types of damage to the components of gas turbines occur in the process of their operation. Of all parts of the turbine, the most vulnerable to damage are blades, whose condition has a significant impact on the reliability and durability of the entire engine and assembly, in which it is embedded. The main causes ofdamage to the blades of the gas turbine are their overheating and thermal fatigue. The
destruction of the gas turbine blades usually starts with the destruction of the protective coatingand, as a result, the blade base material is exposed to direct aggressive impact of exhaust gases. This situation leads directly to overheating of the material, seen as unfavorable changes in the microstructure. As a result, the surface roughness changes, and in particular the colour of the blade surface. The color of the surface is therefore a diagnostic signal, which is used in the visual method. Using computer analysis of image recognition, one can objectively evaluate change in the blade state, such as overheating based on the analysis of the colour changes in its surface. Visual method thus enables diagnosis of the status of the blades withoutnecessity to disassemble the turbine. Results of the study on gas turbine blades, the new and the used ones, after using an active thermography showed the existence of dependencies and relationships between operational heat load and signals changes of the material
thermal response. These dependencies and relationships are used

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 11 | Nov - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

to assess the state of overheating of the gas turbine blade material. Although this method is more sensitive andreliable, however, it can be used after disassembling the blades from the turbine.

Fig. 11 Ultrasonic Testing

Fig. 12 Eddy current testing

Fig. 13 Magnetic particle testing

Fig. 14 Acoustic Emission Testing

Fig. 15 Liquid penetrant testing

REFERENCES

[1] Advances and researches on non destructive testing: A review
SK Dwivedi, M Vishwakarma, A Soni - Materials Today: Proceedings, 2018 – Elsevier
[2] Non-destructive inspection of marine composite structures
M Battley, A Skeates, R Simpkin… - Proceedings of the High …, 2002 - researchgate.net
[3] Nondestructive materials characterization: With applications to aerospace materials
NGH Meyendorf, PB Nagy, SI Rokhlin - 2013 - books.google.com
[4] A Review on Non-Destructive Testing (NDT) Techniques: Advances, Researches and Applicability
R Patel, D Patel, D Meshram -
… Journal of Current Science Research and …, 2022 - ijcsrr.org
[5] Marine composites non-destructive evaluation
E Greene - Ship Structure, 2014
[6] Advances in Non-Destructive Testing Methods
G Perun - 2024 - europepmc.org
[7] A Review of Common Aerospace Composite Defects Detection Methodologies
L Gebrehiwet, A Chimido, W Melaku… - Int. J. Res. Publ …, 2023 - researchgate.net
[8] Nondestructive testing of defects in polymer–matrix composite materials for marine applications using terahertz waves
ME Ibrahim, D Headlang of Nondestructive …, 2021 – Springer
[9] Nondestructive testing method for welding quality in key parts of ocean-going ships
FTang,YYu-Journalofcoastalresearch2020 -meridian.allenpress.com
[10] Advances and researches on non destructive testing: Areview
SK Dwivedi,MVishwakarma,ASoni-Materials Today: Proceedings, 2018 - Elsevier