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Jawaharlal Nehru
“Step Out From the Old to the New”

Indian Standard

RECOMMENDED PRACTICE FOR
MAGNETIC PARTICLE EXAMINATION OF
STEAM TURBINE ROTOR BLADES

ICS 27.040; 77.040.20
FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Non-destructive Testing Sectional Committee had been approved by the Metallurgical Engineering Division Council.

Magnetic particle flaw detection is used to locate cracks, discontinuities at or just below the surface of ferromagnetic turbine rotor blades.

This standard does not prescribe any acceptance criterion for turbine rotor blades, however, that after indications have been produced, they must be interpreted or classified and then evaluated according to the specific requirement.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical value (revised)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.
IS 15539 : 2004

Indian Standard

RECOMMENDED PRACTICE FOR MAGNETIC PARTICLE EXAMINATION OF STEAM TURBINE ROTOR BLADES

1 SCOPE

This standard describes the general procedures for wet fluorescent magnetic particle examination, a non-destructive test method for detecting surface and near surface cracks and other discontinuities in ferromagnetic turbine rotor blades. This recommended practice would produce repeatable results and also precise enough to use as a basis for the preparation of specific procedure to suit the individual type of turbine blades.

This standard does not indicate, suggest, or specify acceptance standards for turbine rotor blades inspected. It should be pointed out, however, that after indications have been produced, they must be interpreted or classified and then evaluated according to the specific requirement. For this purpose, there should be a separate standard to define the type, size, location, area of concentration and orientation of indications that are unacceptable in each type of turbine blade.

2 SUMMARY OF METHOD

The magnetic particle test method is based on the principle that magnetic lines of force when present in a ferromagnetic material will be distorted by a change in material continuity, such as sharp dimensional change or a discontinuity. If the discontinuity is open or near to the surface of magnetized material, flux lines will be distorted at the surface, a condition termed flux leakage. When fine magnetic particles are distributed over the area of the discontinuity while the flux leakage exists, they will be held in place and the accumulation of particles will be visible under proper lighting conditions.

3 EQUIPMENT

3.1 Types

There are various types of magnetic particle equipment available such as yokes, portable units, mobile units, stationary units, etc. Selection of a specific type of equipment should depend on the intended application, the type and magnitude of the magnetizing current required and the desired speed of inspection.

Various control test given in the Annex A are recommended for ensuring the reliable magnetic particle testing.

4 MAGNETIC PARTICLE MATERIALS

4.0 For the inspection of turbine rotor blades, very fine service induced discontinuities such as tight fatigue cracks open to surface are expected, wet magnetic particle examination shall be employed. Wet magnetic particle examination technique uses fine ferromagnetic particles which have been treated to impart colour (fluorescent and non-fluorescent) in order to make them highly visible against the background of the surfaces being examined. The magnetic particles generally have high permeability to allow ease of magnetization and low retentivity so that they will not be attracted to each other. Wet magnetic particles are designed to be suspended in a vehicle such as water or oil at a given concentration for application to the test surface by flowing, spraying or pouring. The wet particles are available in both fluorescent and non-fluorescent concentrates. The liquid vehicles should not be used under the extreme environmental conditions such as temperature above 135 °C. Some sort of mixing equipment is usually required to keep wet particles in suspension (desirable properties of a suspension vehicle are given in Annex A). The wet fluorescent method usually is performed indoors or in areas where shelter and proper application equipment are available. Fluorescent wet particles glow with a bright yellow-green colour when viewed under black light. Non-fluorescent particles are usually black or reddish brown, although particles with other colours are available. The colour often chosen for any given examination should be one that contrasts maximum with the blade surface.

4.1 Particle Concentration

For fluorescent particles, the recommended settling volume is from 0.1 to 0.5 ml in a 100 ml bath sample and from 1.2 to 2.4 ml per 100 ml of vehicle for non-fluorescent particles unless otherwise specified by the particle manufacturer.

5 PART PREPARATION

The surface of the rotor blades to be examined should
be essentially clean, dry and free of contaminates such as oil, grease, loose rust, loose scale, etc. Cleaning of the test surface may be accomplished by detergents, organic solvents or mechanical means.

6 SEQUENCE OF OPERATION

The sequence of operation in magnetic particle examination is related to the application of particles and magnetizing current. In practice, it involves bathing the blade with the inspection medium to provide an abundant source of suspended particles on the surface of the test surface and terminating the bath application simultaneously with the initiation of the magnetizing current flowing. The duration of the magnetizing current is typically of the order of 0.5s.

The three basic types of current used in magnetic particle examination to establish magnetization are alternating current a.c., single phase half wave rectified alternating current (HW) and three phase full wave rectified alternating current (FWRC). The inductance associated with a.c. results in a skin effect that confines the magnetic field to the surface of a part. Hence a.c. can be advantageously used for the detection of surface breaking defects such as fatigue cracks. In contrast, both HW and FWRC produce a magnetic field having maximum penetrating capabilities and are used when near surface discontinuities are of concern.

7 MAGNETIZATION TECHNIQUES

A set of turbine blades or a single blade can be magnetized either directly or indirectly. For direct magnetization, the magnetizing current is passed directly into the part creating a circular magnetic field in the part. With indirect magnetization techniques, a magnetic field is induced in the blade which can create a circular, longitudinal or multi-directional magnetic field in the blade.

For the inspection of turbine blades, indirect method of magnetization using coils and cables should be used to avoid any possible arcing that can happen as in the direct method of magnetization. In the coil or cable wrap technique, the magnetic field strength is proportional to the current and inversely proportional to the thickness of the blade section being inspected.

Alternating current electromagnetic yokes provide effective means of magnetization of a confined region of interest that is the root region of the blade, for the detection of surface discontinuities. This method is very sensitive for the detection of service induced fatigue type discontinuities. Half wave rectified direct current electromagnetic yokes, however, provide an effective means for near surface discontinuities as well.

8 DIRECTION OF MAGNETIC FIELDS

Since indications are not normally obtained when discontinuities are parallel to the magnetic field, and since discontinuities may occur in various or unknown directions in a blade each blade must be magnetized at least in two directions approximately at right angles to each other.

9 MAGNETIC FIELD STRENGTH

9.1 To produce satisfactory indications, the magnetic field in the turbine rotor blade must have sufficient strength. For the indications to be consistent, the field strength must be controlled within reasonable limits, usually 25 percent. Factors that affect the strength of the field are size, shape and material of the blade and the technique of the magnetization. Since these factors vary widely, it is difficult to establish rigid rules for field strength for different geometries. For new geometries it is best to experiment with a blade having known discontinuities and by determining the actual requirements. In general, the field indicator can be effectively used for finding the direction and adequacy of magnetic field for detection of discontinuities of all possible orientations.

9.2 Overall Magnetization

Overall magnetization in the longitudinal direction is produced by passing a current through a multi turn coil encircling (wrapping) the rotor shaft. This produces a magnetic field on all blades of the rotor stage(s) covered and also the surfaces of rotor and rotor to blade root region. The direction of the magnetic field produced is parallel to the axis of the coil. The unit of measurement is ampere turns (NI). The effective field extends on either side of the coil to a distance approximately equal to the radius of the coil being employed. Turbine rotors with many stages should be examined, examination shall be carried out in a shot of a few stages at a time. The basic formula employed for determining the ampere turns when cable wrap technique is used to produce overall magnetization is:

\[ NI = \frac{K}{(L/D) + 2} \]

where

- \( I \) = coil current, ampere;
- \( N \) = number of turns in the coil or cable wrap;
- \( D \) = part diameter, mm;
- \( L \) = part length, mm;
- \( K \) = 35 000 ampere turns; and
- \( NI \) = ampere turns.

For magnetizing the blades in the circumferential
direction, cable loop in the form of a garland shall be used. Yoke may also be used for establishing field at any required direction by properly positioning the yoke. The field strength of yokes can be empirically determined by measuring its lifting power.

10 APPLICATION OF WET MAGNETIC PARTICLES

Wet fluorescent magnetic particles suspended in a vehicle at a recommended concentration may be applied either by spraying or flowing over the areas to be inspected during the application of the magnetizing field current (continuous technique) or after turning off the current (residual technique). Since fine or weakly held indications on highly finished or polished surfaces may be washed away, care must be taken to prevent high-velocity flow over critical surfaces and to cut-off the bath application before removing the magnetic field. Since a residual field has a lower magnetic flux intensity, for sensitive defect detection, continuous method shall be used rather then residual method of magnetization.

11 INTERPRETATION OF INDICATIONS

Indications formed as a result of magnetic flux leakage fields may be relevant or non-relevant indications caused by particles being held by reasons other than leakage fields are false.

Relevant indications are produced by flux leakage fields which are the result of discontinuities that may or may not be acceptable. Relevant indications should be evaluated with regard to the acceptable limits as applicable.

Non-relevant indications can occur singly or in patterns as a result of flux leakage fields created by conditions such as changes in section, inherent material properties, etc.

12 RECORDING OF INDICATIONS

When required, permanent record of the indications may be made by one or more of the following means.

12.1 Sketching the Indication(s)

Indications are recorded by hand.

12.2 Covering the Indication(s)

a) With transport adhesive-backed tape, removing the tape with the magnetic particle indication(s) adhering to it, and placing it on paper or other appropriate background material, and

b) With a spray-on strippable film that fixes the indication(s) in place. When the film is stripped from the part, the magnetic particle indication(s) will adhere to it.

12.3 Photographing

The indications themselves, the tape, or the strippable film reproductions of the indications is photographed. Discontinuities along with relative locations on the component are indicated in the photograph.

12.4 Recording the Location, Length and Number of Indications

A record of the parameters listed below and as applicable should accompany the inspection results:

a) Magnetic particle technique,
b) Magnetizing process,
c) Magnetizing current,
d) Magnetic current strength, and
e) Direction of magnetic field.

13 DEMAGNETIZATION

13.1 All ferromagnetic materials will retain some residual magnetism, the strength of which is dependent on the retentivity of the turbine blade material. A residual field may permit chips to adhere to the surface affecting subsequent cleaning process. When required, an acceptable level of residual magnetization and its measurement method shall also be specified. In general demagnetization is accompanied by subjecting the turbine blade to a field equal to or greater than that used to magnetize, then continuously reversing the field direction while gradually decreasing it to zero.

13.2 Decreasing Alternating Current

In this technique, the turbine blade is subjected to the field and gradually reducing its strength to a desired level.

13.3 Reversing Direct Current

In this technique, the blade is subjected to consecutive steps of reversed and reduced direct current magnetization to a desired level. This technique requires special equipment for reversing the current while simultaneously reducing it in small increments.

Effectiveness of the demagnetizing operation can be indicated by the use of appropriate magnetic field strength indicators. For complete demagnetization, it is advisable to carry out circular magnetization before longitudinal magnetization.

14 POST-INSPECTION CLEANING

Post-inspection cleaning is necessary where magnetic particle materials could interfere with subsequent processing or with service requirements. Typical post-cleaning techniques employed are:
a) Drying of wet particles and subsequent removal by brushing or compressed air, and
b) Removal of wet particles by flushing with solvent.

15 ACCEPTANCE STANDARDS
The acceptability of the turbine rotor blades examined by this method is not specified herein. Acceptance standard shall be determined taking in to account the design requirements.

ANNEX A
(Clause 3.1)

VARIOUS CONTROL TEST FOR RELIABLE MAGNETIC PARTICLE TESTING

A-1 PERFORMANCE TESTING OF MAGNETIC PARTICLE TESTING EQUIPMENT
The following tests are recommended for ensuring the reliable performance of the magnetizing equipment and accessories.

A-1.1 Ammeter Accuracy Tests
The equipment meter readings should be verified with those of a control test meter incorporating a shunt or current transformer connected to monitor the output current. The equipment reading shall not deviate by more than ± 10 percent of the current values as shown by the test meter.

A-1.2 Equipment Current Output Check
To assure the continued accuracy of the equipment, ammeter readings at each transformer tap should be made with a calibrated ammeter shunt combination. Variations exceeding ± 10 percent from the equipment ammeter readings indicate the necessity for its service or repair.

A-1.3 Internal Short Circuiting Check
Magnetic practice equipment should be checked periodically for internal short-circuiting. With the equipment set for maximum amperage output, any deflection of the ammeter when the current is activated with no conductor between the contacts is an indication of an internal short circuit.

A-1.4 Electromagnetic Yoke Lifting Force
The magnetizing force of a yoke can be tested by determining its lifting power on a steel plate. The lifting force relates to the electromagnetic strength of the yoke. Alternating current electromagnetic yokes should have a lifting force of at least 4.5 kg and for dc yokes it shall be 18 kg at the maximum pole spacing where they will be used.

A-1.5 Black Light Intensity Control Test
The black light intensity at the examination surface (380 mm from the face of the light lens filter) should not be less than 800 μ W/sq cm when measured with a suitable blacklight meter.

A-1.6 Maintenance and Calibration of Equipment
The magnetic particle equipment employed should be maintained in proper working order at all times. The frequency of calibration, usually once a year or whenever a malfunction is suspected should be specified in the general procedures of the testing facility. Calibration tests should be conducted in accordance with any specification that may be applicable.

A-2 DESIRABLE PROPERTIES OF SUSPENSION VEHICLE
Generally the particles are suspended in a low viscosity oil or conditioned water. Low viscosity, kerosine petroleum hydrocarbon vehicles are ideal for suspending both fluorescent and non-fluorescent magnetic particles and are commonly employed.

Two significant advantages for the use of oil vehicles are:

a) magnetic particles are suspended and dispersed in oil vehicles without the use of conditioning agent, and
b) oil vehicles provide a measure of corrosion protection to turbine blades.

Oil vehicles to be used in wet magnetic particle examination should possess the following:

a) Low viscosity in order not to impede particle mobility;
b) Minimum flash point of 135°C in order to minimize fire hazards;
c) Odourless, not objectionable to user;
d) Low inherent fluorescence, if used with fluorescent particles; that is, it should not interfere significantly with the fluorescent particle indications; and
e) Non-reactive, that is it should not degrade suspended particles.

Water may be used as a vehicle for wet magnetic particles provided suitable conditioning agents are added which provide proper particle dispersion, in addition to corrosion protection for the turbine blade being tested and the equipment in use.
A-3 LOW VISCOSITY
The conditioned water should not exceed a maximum viscosity of 45 cSt at 90°C.

A-4 NON-FLUORESCENT
The conditioned water should not be fluorescent if intended for use with fluorescent particles.

A-5 NON-REACTIVE
The conditioned water should not cause deterioration of the suspended magnetic particles.

A-6 ALKALINITY
The alkalinity of the conditioned water should not exceed a pH of 10.5.
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