RESEARCH OF NDT EXAMINATION OF THE TURBINE COMPONENTS USING LIQUID PENETRANT INSPECTION

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Abstract: *This paper discusses about the results of NDT examination research of the turbine components using liquid penetrant inspection. Study is performed by a leading company on the power generation domain.NDT is part of technological activities in order to meet the full requirements of the tehnical project.*

The objectives are identification the control key points in the manufacturing of turbines parts, because they require thermally, mechanically and high pressure (e.g. 500-600°C ; 3000-5000 rpm; 150atm)[1]. Because of these operating conditions, any defect in the material structure, welding can affect the proper functioning. This study should be applied for the inspection of raw, semi-finished and finished materials, for the being in service and welded parts, inspection of the heat treatment or its missing. This study describes the requirement for the liquid penetrant inspection specified for the materials used for the manufacturing of steam turbines, or other parts and components.

Keywords: *industry, turbine components, NDT, liquid penetrant inspection*

1. Introduction

Through this work aims to conduct studies and research on the occurrence of nonconformities in the manufacturing process, in one of the market leading companies in the production of equipment for thermal power plants using classic fuel (coal, oil, gas) or nuclear and power equipment that works with renewable resources (waste). This article aims to identify and rank the types of defects occurring in the blanks used in the manufacture of turbine components based on liquid penetrant inspection. The study is conducted under examination NDT bulletins, recorded in the previous two years. The study was conducted in order to establish the importance of this type of control as early identification of nonconformities in order to lower the number of rejected parts finite phase.

2. Method

The NDT (nondestructive test) assumes:

- nondestructive analysis related documentation;
- selecting the appropriate examination revealing possible discontinuities;
- establishing the optimal technique and hence the necessary equipment;
- setting accessories and supplies;
- calibration system in relation to type examination and examination requirements;
- parametric method specific examination;
- the actual conduct of the investigation;
- interpretation of discontinuity indications and completion of the examination report;

Liquid penetrant inspection (LPI) or penetrant testing (PT), is a widely applied and low-cost inspection method used to locate surface-breaking defects in all non-porous materials (metals, plastics, or ceramics)[2]. The penetrant may be applied to all non-ferrous materials and ferrous materials. LPI is used to detect casting, forging and welding surface defects such as hairline cracks,

surface porosity, leaks in new products, and fatigue cracks on in-service components.

This methods should be applied for the inspection of raw, semi-finished and finished materials, the parts being in service and welded parts, irrespective of the heat treatment or its missing[3].

Discontinuity- a physical interruption of sudden non-uniformity in the microstructure of the material.

Liquid penetrant indication- evidence of liquid penetrant, blotted out by the developer, on atested part.

Relevant incation- an indication that derives from a discontinuity in the material and recuires evaluation according to the codes and standards for that part.

Non-relevant indication- an indication that doesn't derive from a discontinuity in the material and that will not have a negative effect in the function of the part.

False indication- an indication created by an improper technique of examination.

Liquid penetrant- a colored, visible or fluorescent liquid able to penetrate the discontinuities opened to the surfaces through capillarity phenomenon.

Emulsifier- a liquid the inteacts with oily substances to make them water washable.

Developer- a material that is applied on the test surface for contrast assurance and indication notice.

Developing time- the elapsed time between the aplication of the developer and the exemination part beginning.

Emulsifying time- the time when an emulsifier is permitted to remain on the part surface for entering in combination with the liquid penetrant prior to its removal.

Dwell (penetration) time- the total time when the liquid penetrant is in contact with the part surface, including the required time for aplication and removal.

The following type of indications shall be used:

- liniar indications: indications whose length is equal to or greater than three times its width;

- rounded indications: indications whose lenght is less than three times its width;

- relevant indications: indications resulted from the existent discontinuites on the parts surface.

When the used techinique is not specified, be taken into consideration the following:

-the type of discontinuities thal shall be detected;

-the size, the shape and the condition of inspected part surface and material.

The temperature of the part surfaces and materials shall be within 16÷520C range during the testing.

If an inspection divided per areas in necessary, the inspection of the next area shall be resumed with a 10% surfaces over the previously inspected area.

2.1 Inspection methods:

2.1.1 Method A: Fluorescent penetrant inspection:

-water- washable (for example fluorescent penetrant and dry powder developer or non-aqueous developer solvent base);

-post-emulsification (for example fluorescent penetrant, hydrophilic emulsifier and dry powder developer or non-aqueous developer).

2.1.2 Method B: Liquid penetrant inspection in terms of contrast- color:

-water- washable (for example colored penetrant with non-aqueous developer);

-solvent- removable (colored penetrant, removal agent and non-aqueous developer).

Technical restrictions:

-fluorescent penetrant inspection shall not follow a colored penetrant inspection.

-the matters' mixing from different sets is not allowed (different producers).

Penetrant examination can be applied to surfaces of parts and semi-products, regardless of their position in space. It will prefer the horizontal position, with access from top to bottom, and technological reasons, slightly inclined to allow surface. For the absolute sensitivity liquid penetrant examination method sees Figure.1.

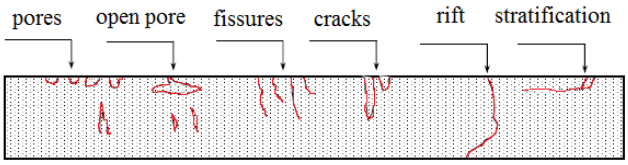

Figure 1: *Types of defects*

In the most favorable conditions , minimum detectable discontinuity is opening about: 1 ... 3 µm .Liquid penetrant examination can be applied to surfaces of parts and blanks, regardless of their position in space. It will prefer the horizontal position, with access from top to bottom and technological reasons, slightly inclined to allow leakage area .

The liquid penetrant in discontinuities fine depends on:

-surface tension of the penetrant liquid;

-discontinuities form;

-surface temperature and liquid penetrant, which influences the viscosity and surface tension;

-pressure;

-mechanical factors: the inner surface roughness of discontinuity and mechanical occlusion of capillaries section, which causes increased contact angle θ;

-chemical factors: oxide layers which have higher surface energy than metal and reduces the contact angle , thus favoring the penetration of the liquid;

-penetration of liquids other discontinuities, which produces increasing the angle θ , specific surface tension penetrating mixture-liquid parasite, reducing capillary;

-dust and colloidal particles which increase and decrease capillary angle θ;

-organics (oils, greases, paints) closes the gaps, adversely alter the surface tension, viscosity enhancers penetrant, reduce contrast and affect negatively the process of emulsification penetrants for use with postemulsionare.

2.2 Steps of liquid penetrant inspection

Steps of liquid penetrant inspection see Figure 2:

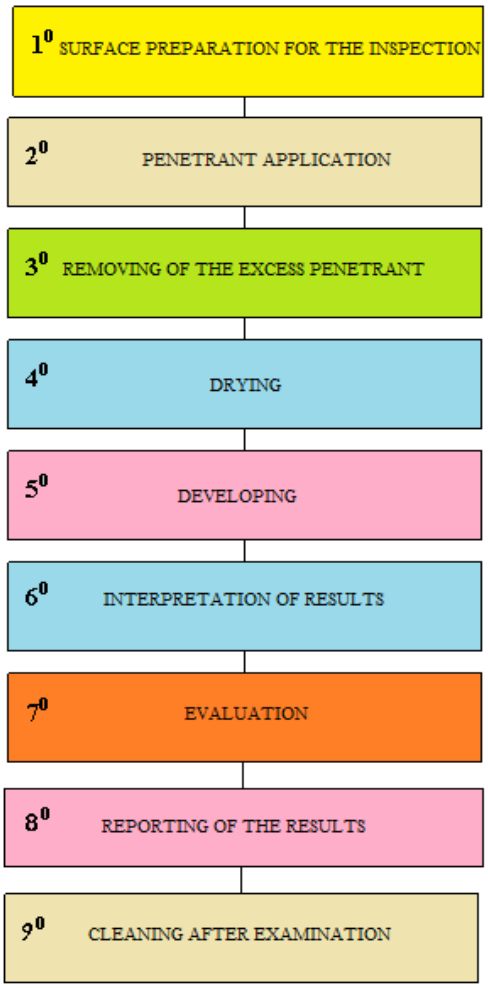

Figure 2: *Steps of liquid penetrant inspection*

2.2.1 Surface preparation for the inspection

Satisfactory results can be obtained on surfaces resulted from welding, casting forging, rolling, etc. In any case, the surface preparation by polish or matching is necessary when the surfaces irregularities may mask the indication from unacceptable discontinuities or when they can affect the examination efficiency. Is not allowed an testing surface any foreing materials (paint, grease, corosion, oxid) Before the inspection performance, the parts and the materials shall be cleaned by one of the following methods: detergent cleaning; solvent cleaning; degreasing in solvent under vapor- phase; alkali cleaning; cleaning in ultrasonic- stirred solvent bath; cleaning by paint removel agents; mechanical cleaning and surfaces conditioning; chemical attack. Regardless of the cleaning methods previously

to the liquid penetrant inspection specifid in the manufacturing technology, before the penetrant aplication, the exeminated surface and a minimum 25 mm adjacent area will be cleanid by a solvent to remove any trace of impurities: dust, lint and greases during hand ling and transportation.

Surface drying after cleaning: Drying after degreasing is binding absolut and it shall be performed by natural evaporation or by filtered and dry compressed air blast. Minimum drying time: 5 minutes.

2.2.2 Penetrant application

The penetrant shall be applied by imersion (the case of small components), brushing with a pig hair brush or spraying shall be performed by filtred compresed air with a filter to exclude the contamination with oil, wather, greases or other impurities, which may be in the compressed air unit. Spraying, aerosol may also be used. Adequate ventilation shall be provided at the inspection place and shall be use the adequate protection equipment.

The penetration time is critical. It shall range within 10÷30 minutes. If the penetration time is exceeded and there is a risk that the liquid penetrant to dry on the surface, it's compulsory to moisture again the surface with penetrant (anyhow, this must be avoided as much as possible).

2.2.3 Removing of the excess penetrant

After the penetration time expires, any trace of penetrant of the surfaces shall be removed so that such penetrant should not be also removed from the posible discontinuities.

2.2.4 Drying

When water- washable penetrant are used after removing of the excess penetrant the drying surface follows. This can be done using the absorbent materials or warm air. For warm air using the temperature should not be greater than 520C. When solvent- removable penetrants are used, the drying shall be performed by natural evaporation or wiping with absorbents material.

2.2.5. Developing

The deveoper shall be applied as much as possible imediately after the excess penetrant removing and drying.

The following types of developers shall be used:

-for the water- washable shall be used watery developer or solvent developer;

-for the solvent- removable shall be used wet solvent developer;

-for the fluorescent penetrant shall be used powder developer or wet solvent developer. The developing time is minimum 7 min and maximum 30 minutes regardless of the used developer type.

2.2.6. Interpretation of results

The real size and the type of discontinuities are hard to evaluated if the penetrant diffuses excessively into the developer. Consequently, the examinated surface should be noticed during the aplication of the developer by the opertor to determine the nature and the shape of the discontinuites. The final interpretation shoud be made ay intervals of 7÷30 minutes for developing. Longer periods of interpretation are also, allowed on condition that the diffusion of the penetrant should not influence the result interpretation. If big surfaces are examinated, an examination diveded into portions shall be carried out to meet the time prescribed. The fluorescent penetrant examination shall be performed under UV light.

2.2.7. Evaluation

All the indication occurred after the examination should be evaluated according to the acceptance standards mentioned in the manufacturing technological documentation. Irregularities of the surfaces caused by machining or other surfaces interventions may produce non-relevant indications. Non-relevant or false indications are subject to the re-examination to establish if these are real or not. Re-examination may be precedent by a surface reconditioning.

Non-relevant, false indications or the picmented areas, which may mask defects, are not allowed.

2.2.8. Reporting of the results

The result of the examnation shall be reported on the test report.

2.2.9. Cleaning after examination

After examination of the results, the examinated surface shall be cleaned according to the provisions of the liquid penetrant supplier. In Figure 3, we have a set controls materials and a disk, which has been liquid penetrant examination.

Figure 3: *Set controls materials and a examined piece*

3 Results

Through this method has controlled parts of the turbine. During the technological process of production and finally, in some situations and after installation . Most often subjected to this type of control has the rotor shaft parts, disc blades and bandages .

An analysis of this type of control, for the past two years, is shown in the charts below , see Figure 4:

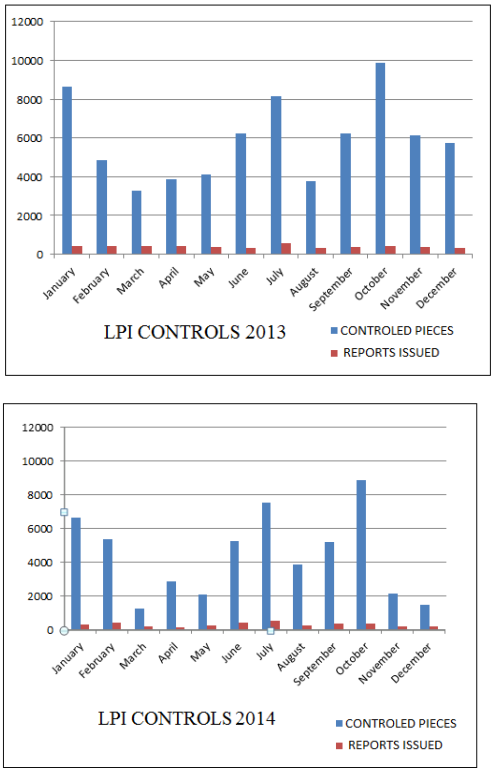

Figure 4: *Variation in the number of controls LPI*

A newsletter is control NDT is issued for a song (e.g. shaft, rotor assembly, etc.) or for a lot of pieces of the same type (e.g. rotor blades, bandages, etc). Very often, when records are required to control quality documentation, it is done without being issued a ballot but behind him control; the exception is when it finds a deviation from creiteriul control. In this case a bulletin is issued mandatory control, as the basis of non-compliance report will be issued.[4]

In the graphs above reveals a decrease in the number of parts controlled in 2014 compared to 2013 due to lower number of orders, the number of pieces made by default.

Another analysis performed consist in comparing the number of parts contained inside the rotor assemblies tutbina controlled by the usual methods of NDT: magnetic particles test, liquid penetrant test and ultrasonic test.That comparison, conducted in the last two years is shown in the charts below, see Figure 5:

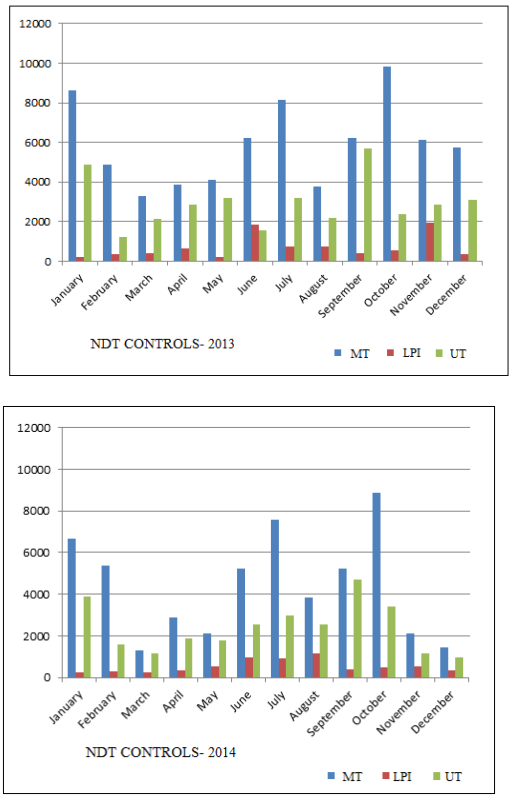

Figure 5: *Variation controls NDT*

This method is economical, versatile, and requires minimal training when compared to

other NDE methods. Liquid penetrant exams check for material flaws open to the surface by flowing very thin liquid into the flaw and then drawing the liquid out with a chalk-like developer. Welds are the most common item inspected, but plate, bars, pipes, castings, and forgings are also commonly inspected using liquid penetrant examination.[5]

4 Conclusions

Advantages:

High sensitivity to small surface discontinuities of the turbines parts;

Easy inspection of parts with complex shapes;

Quick and inexpensive inspection of large areas and large volumes of parts/materials;

Few material limitations (metallic and nonmetallic, magnetic and nonmagnetic, and conductive and nonconductive can all be inspected);

A visual representation of the flaw are indicated directly on the part surface;

Aerosol spray cans make the process portable, convenient, and inexpensive;

Indications can reveal relative size, shape, and depth of the flaw;

It is easy and requires minimal amount of training.

Disadvantages:

Detects flaws only open to the surface;

Materials with porous surfaces cannot be examined using this process;

Only clean, smooth surfaces can be inspected. (Rust, dirt, paint, oil and grease must be removed.);

Metal smearing from power wire brushing, shot blasting, or grit blasting must be removed prior to liquid penetrant examination;

Examiner must have direct access to surface being examined;

Surface finish and roughness can affect examination sensitivity. (It may be necessary to grind surfaces before PT.);

Multiple process steps must be performed and controlled;

Post cleaning of parts and material is required, especially if welding is to be performed;

Proper handling and disposal of chemicals is required;

Fumes can be hazardous and flammable without proper ventilation.

5 References

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