# Dye Penetrant Inspection of Turbine Blade Root Attachment

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***Abstract-*** **Non Destructive Evaluation of mechanical component like blade of rotating machine like turbine ensures the reliability of performance based on in-service degradation of component under operating condition and pre-service quality of component. Critical rotating components of Steam Turbine of power plants like Turbine blade are subjected to various stresses during operation, start–up and shut-down condition. These cause the components to undergoes cracks in the turbine blade at maximum concentration area. Hence the Non-Destructive Inspection is carried out periodically for the prevention of failures of turbine blade due to probable cracks. These Fractures, cracks are generally reveled using Dye Penetrant Inspection Technique.**

***Index terms-*** **Non Destructive Evaluation, Dye Penetrant Test, Cracks, Fractures, Stresses**

## I.INTRODUCTION

Dye penetrant inspection (DPI), also called liquid penetrate inspection (LPI) or penetrant testing (PT), is a widely applied and low-cost inspection method used to check surface-breaking defects in all non-porous materials (metals, plastics, or ceramics). The penetrant may be applied to all non-ferrous materials and ferrous materials, although for ferrous components magnetic-particle inspection is often used instead for its subsurface detection capability. 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.

DPI is based upon capillary action, where surface tension fluid low penetrates into clean and dry surface-breaking discontinuities. Penetrant may be applied to the test component by dipping, spraying, or brushing. After adequate penetration time has been allowed, the excess penetrant is removed and a developer is applied. The developer helps to draw penetrant out of the flaw so that an invisible indication becomes visible to the inspector. Inspection is performed under ultraviolet or white light, depending on the type of dye used - fluorescent or non-fluorescent (visible).

In the Power Generation Plants, Steam Turbine is an essential rotating component in which the aerodynamic shaped blades are mounted in the rotating shaft with the help of grooves provided with rim or directly in the rotating shaft. The blade root is mounted in this groove. These grooves are consisting of different types of shapes and sizes same shape and size is provided at the root of the blade. These shape and geometry provided for the attachment is called as Root Attachment.

Fig. Straddle type Root Attachment

In Residual Life Assessment or Remaining Life Assessment (RLA) of Steam Turbine the inspection of rotating blades is very essential because it undergoes various types of cyclic stresses during start-up, operation and shut-down of steam turbine. In the case of rotating blade, the root attachment area is subjected to maximum stress concentration. So that Dye Penetrant Inspection test is performed to detect the probable cracks and fractures.

## II. TEST PROCEDURE

### A. Visual Examination

The Steam turbine is consisting of three stages which are High Pressure (HP) stage, Intermediate Pressure (IP) stage, Low Pressure (LP) stage which consists of blades of different sizes with different size of root attachment. These blades are unmounted from the rotor disc and visually examined to see if the blade surface to be tested is appropriate for the performance of dye penetrant test.

B. Pre-Cleaning

The test surface is cleaned to remove any dirt, paint, oil, grease or any loose scale that could either keep penetrant out of a defect, or cause irrelevant or false indications. Cleaning methods may include solvents, alkaline cleaning steps, vapor degreasing, or media blasting. The end goal of this step is a clean surface where any defects present are open to the surface, dry, and free of contamination. Note that if media blasting is used, it may "work over" small discontinuities in the part, and an etching bath is recommended as a post-blasting treatment.

C. Application of Penetrant

The penetrant is then applied to the surface of the item being tested. The penetrant is usually a brilliant colored mobile fluid with high wetting capability. The penetrant is allowed "dwell time" to soak into any flaws (generally 5 to 30 minutes). The dwell time mainly depends upon the penetrant being used, material being tested and the size of flaws sought. As expected, smaller flaws require a longer penetration time. Due to their incompatible nature one must be careful not to apply solvent-based penetrant to a surface which is to be inspected with a water-washable penetrant.

D. Excess Penetrant Removal

The excess penetrant is then removed from the surface. The removal method is controlled by the type of penetrant used. Water-washable, solvent-removable, lipophilic post-emulsifiable, or hydrophilic post-emulsifiable are the common choices. Emulsifiers represent the highest sensitivity level, and chemically interact with the oily penetrant to make it removable with a water spray. When using solvent remover and lint-free cloth it is important to not spray the solvent on the test surface directly, because this can remove the penetrant from the flaws. If excess penetrant is not properly removed, once the developer is applied, it may leave a background in the developed area that can mask indications or defects. In addition, this may also produce false indications severely hindering the ability to do a proper inspection. Also, the removal of excessive penetrant is done towards one direction either vertically or horizontally as the case may be.

E. Application of Developer

After excess penetrant has been removed, a white developer is applied to the sample. Several developer types are available, including: non-aqueous wet developer, dry powder, water-suspendable, and water-soluble. Choice of developer is governed by penetrant compatibility (one can't use water-soluble or suspendable developer with water-washable penetrant), and by inspection conditions. When using non-aqueous wet developer (NAWD) or dry powder, the sample must be dried prior to application, while soluble and suspendable developers are applied with the part still wet from the previous step. NAWD is commercially available in aerosol spray cans, and may employ acetone, isopropyl alcohol, or a propellant that is a combination of the two. Developer should form a semi-transparent, even coating on the surface.

The developer draws penetrant from defects out onto the surface to form a visible indication, commonly known as bleed-out. Any areas that bleed out can indicate the location, orientation and possible types of defects on the surface. Interpreting the results and characterizing defects from the indications found may require some training and/or experience [the indication size is not the actual size of the defect].

F. Inspection

The inspector will use visible light with adequate intensity (100 foot-candles or 1100 lux is typical) for visible dye penetrant. Ultraviolet (UV-A) radiation of adequate intensity (1,000 micro-watts per centimeter squared is common), along with low ambient light levels (less than 2 foot-candles) for fluorescent penetrant examinations. Inspection of the test surface should take place after 10- to 30-minute development time, and is dependent on the penetrant and developer used. This time delay allows the blotting action to occur. The inspector may observe the sample for indication formation when using visible dye. It is also good practice to observe indications as they form because the characteristics of the bleed out are a significant part of interpretation characterization of flaws.

G. Post Cleaning

The test surface is often cleaned after inspection and recording of defects, especially if post-inspection coating processes are scheduled.

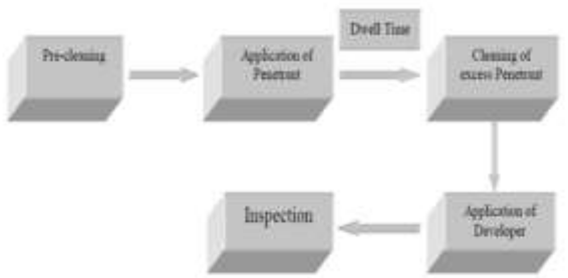


Fig. Flow Chart of Dye Penetrant Test Procedure

Fig. Liquid Penetrant test (Fluorescent Penetrant Inspection)

## III. ADVANTAGES AND DISADVANTAGES

The main advantages of DPI are the speed of the test and the low cost. Disadvantages include the detection of only surface flaws, skin irritation, and the inspection should be on a smooth clean surface where excessive penetrant can be removed prior to being developed. Conducting the test on rough surfaces, such as "as-welded" welds, will make it difficult to remove any excessive penetrant and could result in false indications. Water-washable penetrant should be considered here if no other option is available. Also, on certain surfaces a great enough color contrast cannot be achieved or the dye will stain the work piece.

Limited training is required for the operator although experience is quite valuable. Proper cleaning is necessary to assure that surface contaminants have been removed and any defects present are clean and dry. Some cleaning methods have been shown to be detrimental to test sensitivity, so acid etching to remove metal smearing and re-open the defect may be necessary.

## IV. CONCLUSION

In the Non-Destructive Evaluation the test procedure of Dye Penetrant Inspection studied is able to detect all the suspected cracks on the surface and fractured parts of the root attachment area of steam turbine rotor blade in unmounted condition. The method was also able to reveal the discontinuities that were open to the surface and also can detect wide spectrum of flaws regardless of the configuration and the orientation of the work piece.

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