Penetrant Testing: A Non Destructive Testing Method In Jeopardy !

Patrick DUBOSC, sherwin/babb co, Plaisir, France

Abstract. Penetrant Testing, this « old NDT method », shows invaluable performance in detecting discontinuities opened to the surface. Unfortunately, it uses chemicals, is based on a physical effect (capillarity) not well understood by users, is time-consuming, needs a lot of space, of man-hours, of water, and inspection itself uses eyes + brain, which are known to be obsolete !
Current trends :
inadequate surface preparation (for instance, using alkaline cleaners containing too much silicates)
speeding up of the entire process
badly designed automatic washing stations
etc…
lead to a question : will Penetrant Testing survive as a reliable, impossible-to-replace NDT method !

Introduction

In 1970, in an American technical journal, a paper stated that before 2000, Penetrant Testing would be forgotten, replaced by non contact, electronic methods.
Fortunately for Babb Co and others, year 2000 was the best ever till then; 2001, 2002, 2003, were even better, with a plateau in 2004.
Sales are again on the rise.

1. History

1.1 From the origins

It could be said that during the century from 1880 (Penetrant Testing begins ca 1880 using warm oil and calcium carbonate) to 1980, a lot of technological improvements were made (better products, better viewing conditions, better reliability).

1.2 The last 25 years

From ca 1980, a new way of doing appeared : “project managers”, logistics specialists, more focus on “immediate financial rewarding”, etc….
Then, environment, health and safety concerns have been more and more in mind, but they are sometimes poorly understood :

- Chlorinated solvents ? No, thank you !
- Aromatics ? No, thank you !

Further, in a time when everything is speeding up, to see that 30 to 60 minutes are required to process a part is unacceptable !

What ? Nobody was ever able to make the process faster ? “We, as specialists of management, of “product line” installations, of automation, of artificial vision, we will delete use of chlorinated solvents, in fact of any solvent (so we’ll be more environment friendly), we will improve penetrant testing, speed it up, make it use less manhours, less surface, be far cheaper !”

“Well, old chaps (“fuddy-duddies”, they think, but they have still a thin layer of politeness), go away, you’ll see what we are able to do !”

2. How to make Penetrant Testing an efficient, non-polluting, far cheaper, technologically at-the-top, machine ?

2.1 What are Penetrant Testing drawbacks ?

- Parts preparation
- Penetration time
- Washing time
- Drying time
- Developing
- Visual inspection by human beings
- Interpretation
- After inspection part’s cleaning (post cleaning)
- Waste water treatment

There are many lost times between every step (as an example : to let parts cool down after drying).

Further, somewhat peculiar chemicals are used. Effluents should not be discarded off in the atmosphere or in sewers.

In short, only problems, on top of operators who decide whether a part is OK or not, instead of machines !

2.2 Parts preparation

The basics of penetrant testing is that, if penetrant is to enter a discontinuity so that it may become detectable :

- Discontinuity shall be opened to the surface
- Part’s surface and discontinuity shall be free of any pollutant (paint, oxides, grease, oils, moisture, combustion residues, etc…)
- Part’s preparation itself shall leave no residue whatsoever

2.2.1 Process used till end of '70s

For decades, adequate physicochemical processes have been carried out to remove paints, protective layers, oxides, oils, grease, etc… : paint removers, metal layers removers, deoxidisers, and, as a final step, volatile solvents to remove residues left by these means, as well as to remove oils and grease which may still be on the part.

2.2.2 New times, new ideas

All of this shall be done step by step, along many hours, and requires a lot of energy (some processes require warm or hot liquids).

When time has come for energy conservation, when using less chemicals is required, etc…, some "answers" appeared :

- For instance, for aircraft parts under maintenance, as a prerequisite of the Penetrant Testing Procedure of a well-known prime, the following advice is written in capitals :

  DO NOT REMOVE PAINT OR METALLIC LAYER before applying penetrant.

- Volatile and flammable solvents are changed for solvents with no "FLAMMABLE" label, though they are not chlorinated. These "non flammable" solvents have a very low vapour pressure and they do not evaporate.

2.2.3 VOC mistake

"Oh, sorry, they are classified as VOC (Volatile Organic Chemicals) : so, they are volatile, and then fit degreasing needs previous to penetrant testing".

Sorry, NO !

VOC labelling comes for any organic chemical whose vapour pressure (its evaporation "ability") is above 10 Pa (i.e. 1/10 000 th of the atmospheric pressure) at 20°C. So, yes, a "degreaser" with a vapour pressure of 1 mm mercury (i.e. 132 Pa) at 20°C is VOC ; with a flash point over +60°C (140°F), is not flammable, but, yes…. It will need several days to evaporate from the narrow discontinuity it has entered !

2.2.4 Alkaline degreasers : the ultimate answer ?

Another type of degreaser is alkaline degreasers.

Quite often they are not as efficient as solvent in vapour degreasing installations, they need a huge amount of calories, and they give vast quantities of effluents.
Further, penetrant testing has-once again-specific requirements, hence two major drawbacks !

- insufficient rinsing which, after water evaporation, leaves organic or mineral residues in discontinuities.
- too a high silicates content : silicates are cheap, allow for a high pH, and ease dissolving or suspension of many dirts. Only advantages, it seems !

BUT, when content is high (the “high” is > 0,5 % !), parts at ambient temperature come in contact with the hot degreaser and this leads to a thin layer of silicate all over the part ; this hard, impossible to dissolve layer makes any discontinuity non detectable : parts are always OK !

2.3 Penetration time

What a wasted time ! Thirty minutes for high criticity parts, when it could be easily shown that within 2 to 3 minutes, capillary effect (and the correlative pressure) makes 90 % of the penetrant which will finally enter, enter the crack !

Check for the mistake ! In fact, there is a huge difference between the glass capillary tube, very clean, opened at both ends, and the discontinuity, with a lot of hidden recesses which retain pollutants, and closed at one end.

Experience, for many years, has definitely proved that it is better to let time be an important parameter.

2.4 Washing

Well known specialists prefer a gentle wash, maybe in two or three steps.

“But, wait a minute, specs state, for instance, 1 bar (14 psi) max. for air and 1 bar (14 psi) max. for water. So, first, set the equipment at the max figures allowed. Then use high flow guns or hoses ; so rinsing will be more efficient within a shorter time, and background, so detrimental to interpretation, will be let at a minimum”.

That’s the way of doing in automatic wash stations.

But results are far better when there is a relative movement between hoses/guns and parts : for instance, an “up-and-down” or a rotational movements. Well, but then machines are more complex and expensive !

2.5 Drying

Once again, so many time and calories used / lost ! So, even on complex-shaped parts, with dead-holes, threadings, drying time will be shortened.

Hence, moisture may be left on some areas when developer is applied.

2.6 Development

Not only this step is critical (a very thin layer of developer shall be applied) but waiting is required : during development time, square meters are unproductive !

2.7 Visual inspection and interpretation

The “top of the eccentricity” ! Human beings who inspect parts with their eyes, and use their brains to make decisions !

Penetrant Testing is indeed technically obsolete !

So many systems of artificial vision and decision making are in use in the industry : why, by the hell, this cannot be used to inspect parts ?

Be aware that for the last 30 years, ANY attempt has FAILED, for reasons which could be orally given.

2.8 Post cleaning

When numerous NDT methods let parts really intact (Eddy Currents, Infra red Testing, acoustic emission, etc…), Penetrant Testing is more like cooking or painting. And post cleaning is not the easiest step of the process : taking away traces of developer and especially traces of penetrants is more complex than guessed.

2.9 Waste water treatment

To rinse parts of 1 liter of penetrant, between 800 and 4000 liters of water are needed, or a lot of rags.

Further, don't forget waste coming from parts' preparation.

So, not only one has to spend money to buy products, but one has also to pay to get rid of them !

3. You now understand why it is so urgent to get rid of this NDT method !

And more !

3.1 European regulation

As anyone should know, European regulations dealing with chemicals are harsher and harsher, year after year.

3.2 Users' diktats

And, as if it is not enough, users issue their own, more stringent requirements !

Take as an example a major aircraft-engine manufacturer and a surfactant "family" called alkylphenol ethoxylates (APEs)

The European Directive targets cleaning, degreasing products, for industry or domestic use (except if chemicals are recycled), or products for "metal working", except if waste water is recycled or burnt.

This Directive deals only with Nonylphenol and the nonylphenol ethoxylates (which belong to APEs ; but all the APEs are not nonylphenol ethoxylates).

This manufacturer has issued a document stating that all the chemicals used in its plants shall contain less than 0,1 % APEs ; this manufacturer, by its own, has spread the application range of this Directive to products which were not targeted and, due to this, in fact has forbidden use of an entire family of chemicals whose only some few members should have been.

Penetrants and emulsifiers should not be thrown away after rinsing : they are generally treated (on activated carbon, or through other processes), water is then thrown away-or, better, recycled.

Therefore this manufacturer played a role nobody asked it to have, about products which are not targeted by the Directive, due to either their formulation, or the process they come in, or both.

Conclusion

Yes, Penetrant Testing is in a bad situation, not because of some technical obsolescence (no other method is able to detect, on thousands of turbine blades per day , discontinuities 1 µm wide, 10/15 µm deep, on leading edges, tailing edges, blade roots, in only one process), but because :

- more and more often, people who carry out PT (including parts' preparation) are not an independent entity (as are : Quality Assurance, Metrology department). They are now full part of the production department. This is detrimental to quality.

- of a poor understanding of how it "works", of its specific requirements, by a whole "generation of people" who rely exclusively upon computer, electronics, automation, decision making by machines.

P.T. being a major NDT method for aerospace industry, nuclear industry, and so many other industries, it is a big concern to see how P.T. processes have been degraded along these last 20/30 years.

Safety is impaired as tiny cracks, or even, not so tiny discontinuities, could go undetected. Brand new blades or blisks (just to take a major example in aerospace industry), or similar parts after maintenance, could be put in place on aircraft, with undetected critical cracks.

This, in turn, could lead to spectacular, dramatic accidents, even on aircrafts with very few flying-hours.

Knowledge in physics, chemistry, biology (to better understand problems coming from waste water treatment) of new "leaders", "persons in charge", is too low. And those who have this knowledge either are to retire or are not in a position to enforce rules for a thorough Penetrant Testing.