Reliability of Surface Inspection Techniques for Pressurized Components

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ABSTRACT

In the Nordtest NDT-programme (1984 - 1988) the detection of flaws by surface inspection methods has been studied. In the round-robin exercise, 133 test pieces have been inspected by 32 inspectors in Denmark, Finland, Norway and Sweden. From the results, the detectability of defects by magnetic particle and liquid-penetrant testing and the influence of materials and techniques used are evaluated.

1 INTRODUCTION

The reliability of safety assessment of pressurized components is a product of the reliability of stress analysis, material properties and nondestructive examination techniques. The reliability of stress analysis has lately been greatly improved due to increased computing power. This fact emphasizes the role of the reliability of the material properties and the NDE techniques. The reliability of material properties still leave a lot to be desired and the reliability of ultrasonic and radiographic NDE has been studied in several international projects.

Liquid penetrant and magnetic particle testing are widely used to detect service induced surface defects in the pressurized components of nuclear plants. The access to the inspection item seldom causes any difficulties and the radiation dose of the inspection personnel remains low due to the short time necessary for the work.

In order to evaluate the reliability of surface inspection methods a round-robin exercise was carried out in the Nordic countries. In the round-robin exercise 133 test pieces containing 635 surface flaws were inspected by 31 companies in participating countries (Denmark, Finland, Norway and Sweden).

1.1 Test specimens

The test specimens used in the round-robin exercise were mainly collected from industry and contained natural surface defects. Additionally some cracks had been produced through fatigue in a few samples. Number of test specimens in magnetic particle and penetrant inspection are shown in table 1.

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Table 1. Test specimens for magnetic particle (MT) and penetrant (PT) testing

	MT	PT		
Material	Fe	Fe	Al	Ss
Number of specimens	67	6	33	33
Number of defects	294	31	151	190
Total number of inspections	977	83	505	499

The number of specimens was 67 in ferritic steel, 33 in austenitic steel and 33 in aluminum. The number of welded specimens was 16 in ferritic steel, 16 in aluminum and 19 in stainless steel. The total number of defects in the specimens was 635.

1.2 Inspection teams and procedures

In the round-robin exercise each specimen was inspected by 14 - 16 different teams. The test procedures (including reporting levels and drawings) for magnetic particle and liquid penetrant testing were given by the organizers of the project, though it was also acceptable to use the participants' own procedures. Test procedures were general allowing participants to choose test equipment and techniques. The choice of inspection chemicals and techniques was made by the participants. Participants used both fluoresence and coloured penetrants and powders delivered by different manufacturers. Only wet method was used in magnetic particle inspection. The reporting level for indications was determined in the procedure to be 1 mm.

1.3 Evaluation of results

When the round-robin tests were completed, the test specimens were inspected in the laboratory and all the locations where teams had reported indications were thoroughly analyzed by penetrant and/or magnetic particle inspection methods. On the basis of this analysis, the indications were classified in different flaw size (depth and length) and type (round or linear) categories or were judged to be non-relevant. The depths of the flaws were measured either with eddy-current or potential-drop techniques. Destructive analysis was not carried out.

The results presented in this paper are based on the evaluation of all 133 test pieces or on the evaluation of welded specimens. In the curves presenting the probability of detection (POD), the flaws have been collected in groups according to the length / depth of the flaws. In each group the number of flaws is approximately the same and sufficient for analysis although the number of very long / deep flaws is lower.

2 RESULTS

2.1 The effect of the size and type of flaw on the probability of detection

The probability of detection (POD) against the depth of the flaw in the specimens is presented in Fig. 1 for magnetic particle (MT) and liquid penetrant (PT) testing. According to these curves where both linear and round defects are included the detection probability of small (short and low) defects is higher with PT than with MT. In Fig. 2 the detection probabilities for flaws in 6 test specimens inspected both with MT and PT are presented. These specimens contained linear defects (small cracks) and in this case the POD for MT is higher.

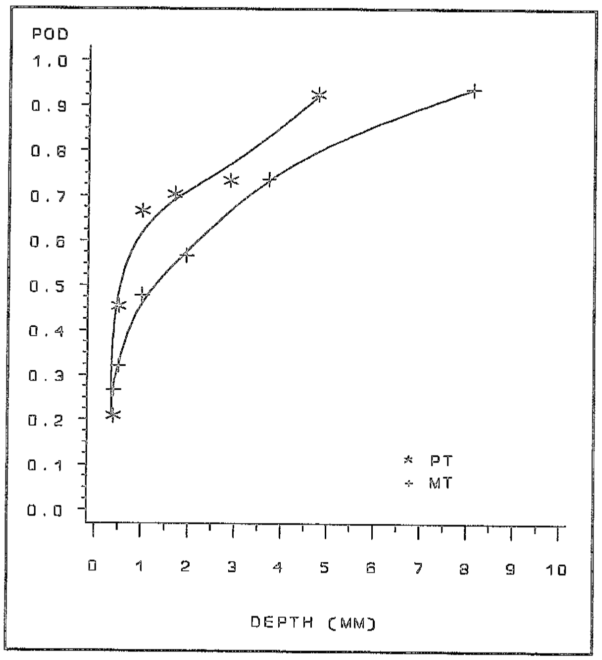

Fig. 1. The probability of detection for flaws of different depths with magnetic particle and liquid penetrant testing (all test samples).

The detection probabilities for defects in welded specimens are presented in Fig. 3. The detection probability for weld defects is higher with PT than with MT, but it has to be noticed that test specimens are not the same. Weld defects have been detected both with PT and with MT better than all types of defects (Fig. 1).

The test samples contained mainly defects the length of which was less than 75 mm. The scatter of the probabilities of detection for short defects is very large and the probabilities of detection for long defects lower than expected (Fig. 4). In both liquid-penetrant and magnetic particle testing the probability of detection increases very slowly or remains the same when the length has exceeded a few millimeters. It is, however, necessary to keep in mind that the number of long defects is relatively low and these defects are cracks.

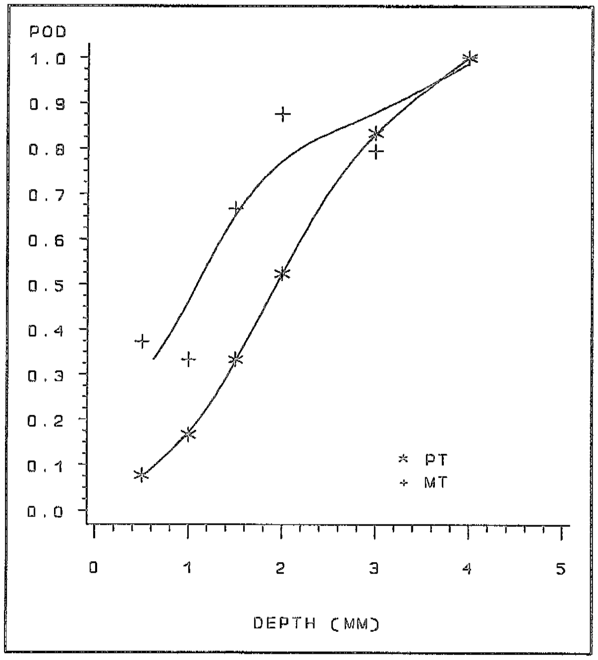

Fig. 2. The probability of detection for flaws of different depths with magnetic particle and liquid penetrant testing (6 samples inspected both with PT and MT).

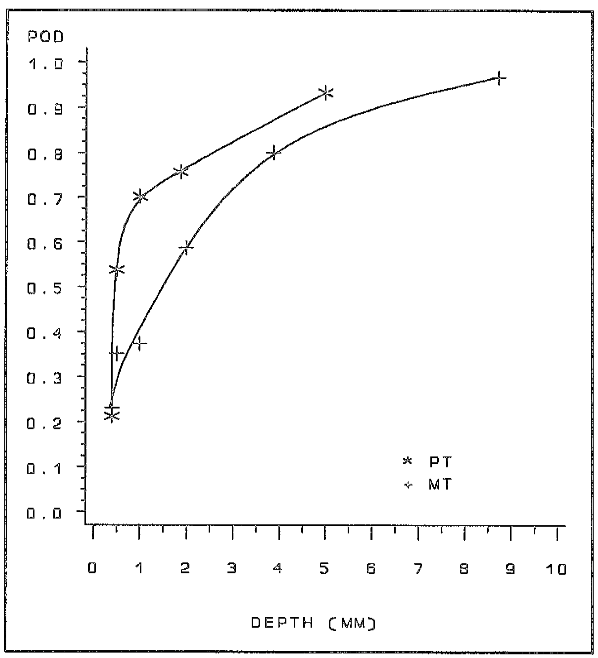

Fig. 3. The probability of detection of flaws in welded samples with magnetic particle and liquid penetrant testing.

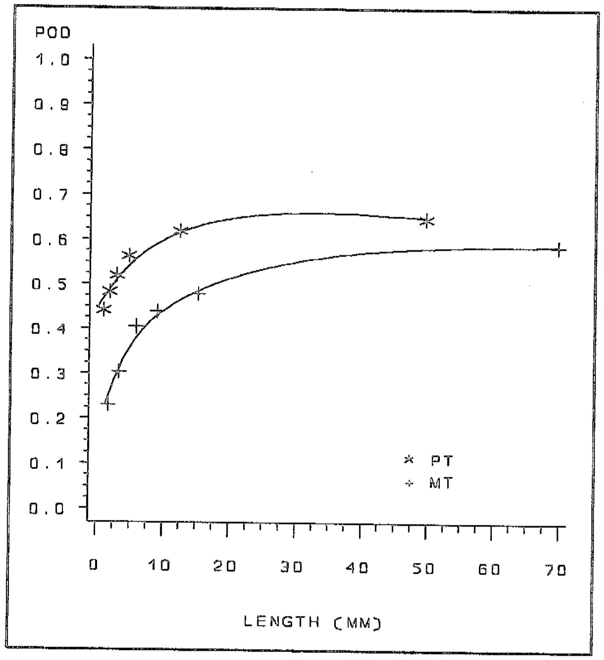

Fig. 4. The probability of detection for flaws of different lengths with magnetic-particle and liquid-penetrant testing.

2.2 The effect of inspection chemicals and techniques on probability of detection

When the effect of using fluorescent or coloured chemicals was studied, it could be seen that the detection probability of small defects is slightly lower with fluorescent penetrants than with coloured ones The reasons for this are probably the insufficient cleaning of the surface and the surface roughness.

There seems to be no major difference between the results when AC or DC magnetization is used. The detection probability of small defects is slightly better with AC magnetization. The highest POD has been measured for bench magnetization and the lowest for prod magnetization. The differences are relatively small.

2.3 The effect of operators competence

The highest individual POD-curve was achieved by a certified operator and the lowest by a non-certified operator. On average, the difference between all certified and non-certified operators was not very large, though the small defects were clearly better detected by certified operators. Also the scatter of results was smaller for certified operators.

3 CONCLUSIONS

Based on the results of the round-robin exercise carried out in the Nordic countries, the following conclusions can be drawn.

Liquid-penetrant testing with coloured chemicals gives the most reliable results when all types of surface flaws have to be detected. Especially for round defects this technique is very sensitive. The probability of detection is higher and the number of false indications recorded lower than with other techniques.

Magnetic-particle testing can reliably reveal cracks and linear discontinuities. For the detection of shallow cracks alternating current should be used. If the quality of the surface is not exceptionally good even here coloured chemicals have to be used.

Only certified operators should be used for inspection of critical components. The probabilities of detection of certified operators for small defects were in this study clearly higher than those of non-certified operators.

The detection probability of flaws with liquid penetrant and magnetic particle testing is high compared with other NDT-methods.

Minimum size of detectable flaws depends e.g. on surface roughness.

The critical defect size of a construction is normally large enough to achieve high detection probability.

The reliability of inspection can be improved by repeating the inspection.

Intervals of inservice inspections should be carefully planned in order to assure that defects can be detected with high probability before they grow critical.

Reliability of surface inspection methods can be increased by

- using certified operators
- using proper test procedures
- repeating inspections
- applying suitable surface treatment
- taking into consideration probable defects and their locations
- increasing reporting requirements
- using proper equipments, inspection chemicals and magnetizing method
- using equipment and methods which the operators are familiar with.

REFERENCES

KAUPPINEN, P. and SILLANPÄÄ, J. Reliability of surface inspection methods. Proceedings of the 12th World Conference on NDT, Amsterdam, 23. - 28.4.1989. Elsevier Science Publishers, Amsterdam, The Netherlands, pp. 1723 - 1728.