The Use of Permanent Magnets for Magnetic Particle Inspection

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Abstract. One of the basic requirements of magnetic particle inspection, and certainly one of the most considerable factors, is that the part undergoing inspection shall be properly magnetized so that leakage fields created by discontinuities are strong enough to attract the magnetic particles.

This paper refers specifically to the use and acceptability of permanent magnetic yokes/probes to generate magnetic fields in critical in-service and newly fabricated components. Often, permanent magnets are used where no electrical supply is nearby or available at all, and in some environments that demand that all equipment to be used therein, to be intrinsically safe.

The intent of this paper is to enable users of the specific permanent magnet equipment to become au fait with the capabilities and limitations of such equipment as well as how probability of detection (POD) is influenced during certain applications.

1. OUTLINE

This presentation is a condensed description of the research that has been undertaken so far in order to determine the correct use of permanent magnets (PM’s) that generate magnetic fields in critical in-service and newly fabricated components.

This paper will cover:

- The resources that were used,
- What activities were carried out,
- Presentation of the results,
- Conclusions incorporating recommendations and future work.
2. RESOURCES

2.1 Equipment

Regarding the resources that were required, specific equipment and test specimens had to be sourced.

Two types of PM’s were found – the cable and horseshoe type. These were also models from different manufacturers. See Figure 1 and 2 for images of the PM’s that were used.

Four commonly known types of field indicators were used, the ‘Berthold Spoon’, ‘ASME Pie Gauge’, ‘Ely strips’ and a QQI.

When it came to measuring field strength, a Hall Effect meter was used and for measuring residual field, a Gauss meter was used.

For process control, a 20kg cast iron Barbell was utilised to ensure that each PM possessed sufficient lifting force prior to use.

![Permanent Magnets](image1)

**Figure 1.**

![Permanent Magnets](image2)

**Figure 2.**

2.2 Test Specimens

It was planned initially to use a broad range of test specimens that included weldments, forgings and castings. Due to time constraints, welded plates were selected only.
Plates of two thicknesses were inspected, the types of discontinuities were classified and whether they fell under the fatigue or fabricated variety was also established. See Figure 3 below for examples of some of the plates that were used for the research.

![Test Specimens](image)

Figure 3.

3. ACTIVITIES

3.1 Field Strength Measurements

Field strength measurements were taken at various areas around and between the magnets’ poles as well as on a flat steel surface at specific distances.

Figure 4 below shows some of the positions where the hall-effect probe was held.

![Magnetic Field Strength Measurements (Hall Gauge)](image)

Figure 4.

3.2 Field Indicators

With the field indicators, all four were utilised on the plates of various thicknesses as well as on the handle of some of the magnets.

For clarification purposes, a coin was also used to determine the height/length of the individual magnets within their respective housings.

For a visual representation of the magnetic field generated by the poles, a rough magnetograph was created. See Figure 5 for images of two of the field indicators, a typical magnetograph and the location of the coin between two poles.
3.3 Inspection

During the inspection activities, three plates with fabricated discontinuities were selected.

For the exercise, the plates were placed in two positions (flat and vertical) and were inspected with the specific PM’s used for the research.

4. RESULTS

4.1 Field Indicators

The results proved to be quite interesting.

With the field indicators, the lines produced varied between the respective indicators, material thicknesses and pole spacing’s.

It was also noted that the taller the specific magnets with possible spacers added, resulted in a stronger field emanating from each pole.

The closed loop type magnets with handles also produced lines on the indicators as well when placed on the center of the handle.

4.2 Inspection

Varying degrees of success was achieved when it came to confirming the presence of discontinuities. On the first plate (see Figure 6), the following was noted:

- On the left, the two indications were produced by two magnets with the plate in the flat position.
- The indications on the right were produced by the same two magnets but with the plate being in a vertical position.
On the second plate (see Figure 7), the images show the different results from four of the PM’s with the plate being in the vertical position.

With the third plate (Figure 8), 3T than the previous two:

- The images show the different results from three of the magnets with the plate being in the vertical position.
- The bottom right image is one that was taken of the indications that were acquired with an AC electromagnet.

Table 1 provides an overview of the results as discussed in Para. 4.2.
# Table 1.

<table>
<thead>
<tr>
<th>Magnet A</th>
<th>Plate Position &amp; % Indication visible</th>
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<tbody>
<tr>
<td></td>
<td>Flat</td>
</tr>
<tr>
<td>P1</td>
<td>100</td>
</tr>
<tr>
<td>P2</td>
<td>N/I</td>
</tr>
<tr>
<td>P3</td>
<td>0</td>
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<tr>
<th>Magnet B</th>
<th>Plate Position &amp; % Indication visible</th>
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<tr>
<td></td>
<td>Flat</td>
</tr>
<tr>
<td>P1</td>
<td>100</td>
</tr>
<tr>
<td>P2</td>
<td>N/I</td>
</tr>
<tr>
<td>P3</td>
<td>&lt;10</td>
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<th>Magnet C</th>
<th>Plate Position &amp; % Indication visible</th>
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<tr>
<td></td>
<td>Flat</td>
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<tr>
<td>P1</td>
<td>100</td>
</tr>
<tr>
<td>P2</td>
<td>N/I</td>
</tr>
<tr>
<td>P3</td>
<td>0</td>
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<table>
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<th>Magnet D</th>
<th>Plate Position &amp; % Indication visible</th>
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<tr>
<td></td>
<td>Flat</td>
</tr>
<tr>
<td>P1</td>
<td>100</td>
</tr>
<tr>
<td>P2</td>
<td>N/I</td>
</tr>
<tr>
<td>P3</td>
<td>&lt;10</td>
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<table>
<thead>
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<th>Magnet E</th>
<th>Plate Position &amp; % Indication visible</th>
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<tbody>
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<tr>
<td>P1</td>
<td>100</td>
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<tr>
<td>P2</td>
<td>N/I</td>
</tr>
<tr>
<td>P3</td>
<td>&lt;60</td>
</tr>
</tbody>
</table>

**Legend:**
- Plate 1 (P1) = 10mmT
- Plate 2 (P2) = 10mmT
- Plate 3 (P3) = 30mmT
- N/I = Not inspected

**Notes:**
- A. Poles were approx. 150mm apart (edge to edge)
- B. P1 and P3 each had an artificial indication that was situated close to the junction between the parent material and the HAZ of the weld.
- C. P2 had an artificial indication that was situated adjacent to the root of the weld.
- D. An AC Electromagnet was used to produce the baseline indications.
- E. % Indication visible is an estimate only.
- F. The indication depths and widths were undetermined.
- G. The magnets were removed from the surface after 60 seconds.
5. CONCLUSIONS

5.1 Summary

Thinner materials produced clearer indications - due to the concentration of magnetic field within the material and not all PM’s that were used provided similar indications on the same test specimen.

The orientation of the inspection surface, effective particle application as well as sufficient magnetising times proved to be of importance and the differences in material permeability definitely have an effect on the results.

Such uncertainty when using PM’s can be viewed as being the main reason for the minimum information being made available in Codes and Standards.

A lot more research is required in order to gather sufficient data with which, guidance on the best practice for the effective use of PM’s can be established and/or whether a probability of detection (POD) demonstration process should be implemented. If it is unfeasible to conduct a proper POD demonstration on a series of specimens, it cannot be expected for a validated application of this technique to be implemented in the field.

5.2 Recommendations

When contemplating on using a PM, it is recommended that:

- The Code requirements (if any) are known especially where sufficient field strength verification is concerned;
- Express permission is acquired in writing prior to using such equipment;
- The customer is informed of all of the limitations of the inspection especially that that accurate sizing is not really possible;
- A qualified/validated and approved works instruction/technique be used, that at least stipulates the minimum and maximum pole distance and minimum magnetising time;
- The material thickness is predetermined;
- The magnet should be of the type that that forms a closed loop and has a cast handle constructed of low retentive/high permeability material;
- The opposite magnet pole polarity is to be verified first;
- Effective particle application techniques are utilised with the sufficient agitation of such particles on the surface;
- No residual magnetism is present within the material prior to inspection.

5.3 Future Work

Test specimens (critical components) with varying material thickness containing actual service induced discontinuities must be sourced. The location of the discontinuities must also be preferably unknown to the researchers. This can be the same for test specimens that comprise of forged or cast material.

The expansion of the parametric study with regards to the variances in pole spacing (or as stipulated in some codes), the parallel placement of more than one PM over the area of interest and the use of stronger PM’s should be pursued.
At the moment, preliminary findings regarding the effectiveness of DC electromagnets are inconclusive but warrant additional investigation.

6. ACKNOWLEDGEMENTS

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References