Ryszard Krawczyk, Piotr Wojtas, Karolina Poch

Comparative assessment of selected welding imperfections in VT, PT and MT methods

Abstract: The issues connected with assessment of sensitivity in selected NDT methods are considered. In particular, the attention has been paid to the tests which make it possible to detect any imperfection of surface, i.e. visual testing, liquid-penetrant and magnetic-powder method. The aim of the studies was to reveal the analogy and differences between results obtained from series of tests (VT, PT and MT).

Keywords: non-destructive testing, magnetic particle inspection (MT), penetration testing (PT)

Introduction

The non-destructive testing of welding materials and welded joints is classified into two categories. The first category, comprising tests enabling the detection of surface imperfections is comprised of three methods, i.e. visual testing (VT), penetration testing (PT) and magnetic particle testing (MT). The second category, comprising non-destructive tests enabling the detection of internal imperfections, often referred to as volumetric imperfections, producing no superficial symptoms or indications, includes two methods, i.e. ultrasonic testing (UT) and radiographic testing (RT). The testing and assessment of surface imperfections of welding materials and welded joints are a very important element of technological and operating processes. Conducting tests makes it possible to verify that materials or structural elements being tested do not contain surface imperfections directly compromising the safety of operation and the possibility of further use of an element being tested.

Importance of surface NDT

The visual test of welded joints is a basic test which must be carried out irrespective of what other tests will follow. The visual test consists of a thorough inspection of te element being tested in order to assess the state of its surface. The conditions which must be satisfied during VT are specified in detail in standard PN-EN ISO 17637:2011 ”Non-Destructive Testing of Welds – Visual Testing of Fusion-Welded Joints”.

Penetration testing is based on the phenomenon of capillarity, i.e. water penetrating narrow spaces and rising within them despite inversely directed gravitational force. This process makes it possible to detect even the smallest discontinuities present inside a material and coming up to its surface. In turn, the essence of magnetic particle testing is focused on two aspects, the first of which involves introducing a magnetic field to the object being tested, whereas the other refers to the manner of interpreting revealed indications. Both elements are interdependent as in order to assess the effectiveness of the

dr inż. Ryszard Krawczyk (Ph.D. Eng), mgr inż. Piotr Wojtas (M.Sc. Eng), mgr inż. Karolina Poch (M.Sc. Eng) - Częstochowa University of Technology, Zakład Spawalnictwa /Welding Technology Department /

magnetic field introduction it is necessary to apply one of the methods used to identify any detected imperfections. Each of these testing methods (VT, PT and MT) is based on different phenomena and is characterised by different testing sensitivity. It is assumed that VT is characterised by the lowest, PT by higher and MT by the highest testing sensitivity. Having taken this into account, an attempt aimed at comparing detection sensitivity of the aforesaid testing methods, particularly PT and MT, was undertaken.

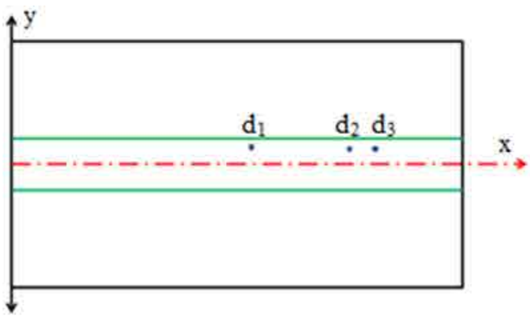
Fig. 1. Testing station prepared for tests

Tests – preparation of sample and testing station

The objective of the conducted experiments was to reveal differences and relations between the results of visual, penetration and magnetic particle testing methods carried out on the same object, i.e. the same imperfections. To this end, it was necessary to make test V-preparation butt joints of 10mm-thick S355 steel plates. During MAG welding the arc energy was significantly reduced, resulting in the lack of side fusion on both fusion lines. The external surfaces of the sample were subjected to grinding, by means of which weld face reinforcement and weld root were removed. Afterwards, the sample underwent etching. The processing of the sample aimed to decrease the effect of weld reinforcements and significant roughness of the element, which could significantly deteriorate testing accuracy. The sizes of the sample used in tests were 220×130×8 mm.

In order to carry out non-destructive testing (VT, PT and MT) it was necessary to prepare a testing station provided with measuring equipment following related standards (PN-EN 13927: 2009, PN-EN ISO 3452-4: 2006 and PN-EN ISO 9934-3: 2003). The testing station was equipped with the following devices and materials:

- set of reagents for penetration testing: Diffu-Therm penetrant, remover and developer,
- device for magnetising an object being tested – contour probe DA400S made by the Parker company,
- set of reagents for magnetic particle testing: Diffu-Therm ferromagnetic coloured and fluorescent powder, priming paint and remover,
- set of measuring instruments and additional devices:
  - instrument for measuring tangent and residual areas,
  - instrument for measuring the intensity of ultraviolet and visible light,
  - Berthold magnetic field indicator,
  - reference samples,
  - ultraviolet lamp,
  - straightedge, slide caliper,
  - magnifying glass.



VT TESTING			
No.	x [mm]	y [mm]	d [mm]
1	124	4	1
2	173	4	0,3
3	188	4	0,4

Fig. 2. Characteristics of imperfections revealed during VT

The equipment and measuring devices used in the tests were provided with check certificates and the reagents had confirmed use-by dates. In order to verify the suitability of reagents, their sensitivity was additionally tested on standards appropriate for a given method. The prepared testing station is presented in Figure 1.

The experimental tests (VT, PT and MT) were carried out according to a specified sequence. The first was a visual test consisting of a thorough inspection of the test surface both by the naked eye and using a magnifying glass 3x. The visual testing did not reveal any linear imperfections on the surface of the sample, yet it revealed three blowholes which due to weld face grinding are visible as pores with the following diameters d_1=1 mm, d_2=0.3 mm and d_3=0.4 mm. The characteristics of point imperfections are presented in Figure 2.

The second stage consisted of penetration testing by means of the dye penetrant method. The results of the test are presented in Figure 3 showing the sample following the test, the sample sketch with plotted indications and a table with full dimensional characteristics.

The penetration testing revealed the presence of twenty one linear indications, the total length of which was 192 mm as well as identified three non-linear indications with the diameters of d_{10} =2.2 mm, d_{15} =0.8 mm and d_{17} =1.0 mm respectively.

At the next stage fluorescent magnetic particle tests (MT-F) were carried out. The results of the tests are presented in Figure 4 showing the sample after the test, the sample sketch with plotted indications and a table with full dimensional characteristics.

The magnetic particle testing revealed the presence of twenty linear indications, the total length of which was 270 mm.

At the final stage, magnetic particle testing using the dye penetrant technique was carried out. The test revealed that the priming paint

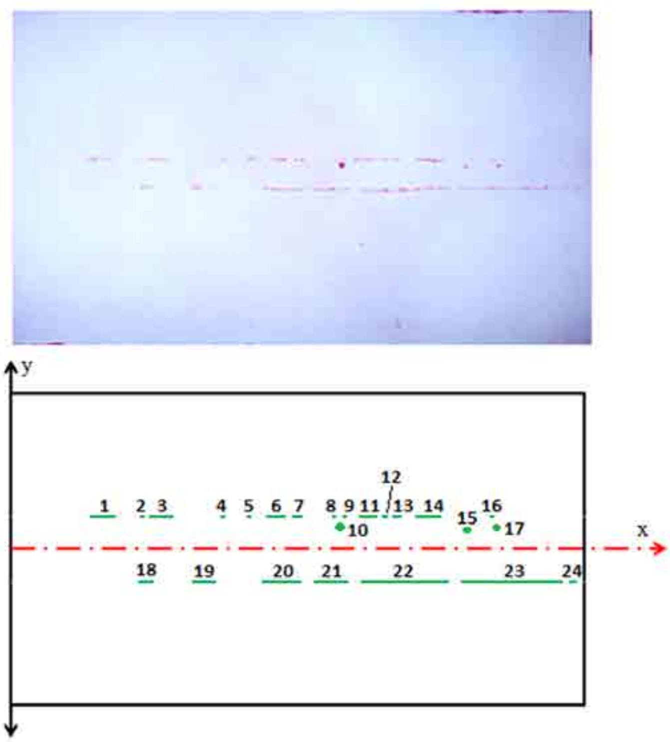


Fig. 3. View of the sample after PT, sketch of the sample with plotted indications and table with full dimensional characteristics

PT: dye penetrant method				
No.	x [mm]	y [mm]	l [mm]	d [mm]
1	24	5	12	---
2	44	5	2	---
3	48	5	10	---
4	78	5	2	---
5	87	5	2	---
6	98	5	6	---
7	106	5	5	---
8	120	5	2	---
9	124	5	2	---
10	123	3	---	2,2
11	130	5	9	---
12	141	5	2	---
13	144	5	2	---
14	152	5	13	---
15	172	4	---	0,8
16	180	5	2	---
17	187	4	---	1,0
18	44	-5	4	---
19	66	-5	4	---
20	92	-5	18	---
21	112	-5	16	---
22	130	-5	36	---
23	170	-5	40	---
24	213	-5	3	---

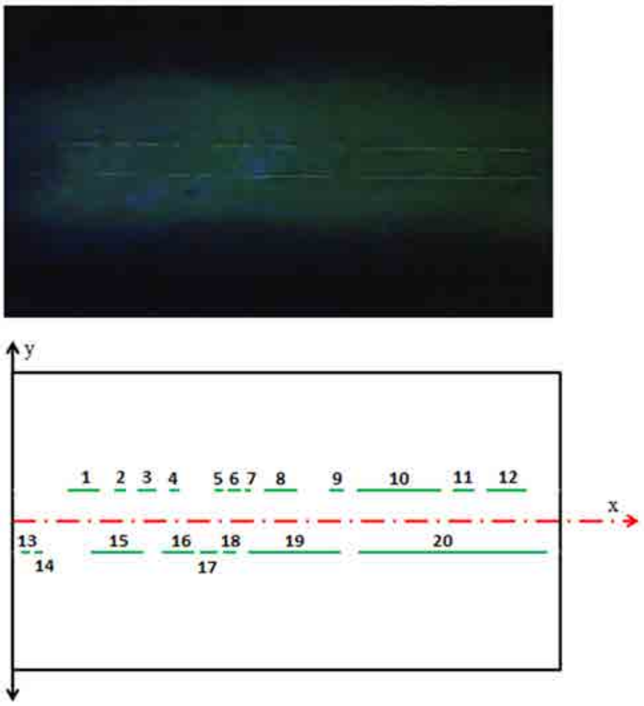


Fig. 4. View of the sample after MT-F, sketch of the sample with plotted indications and table with full dimensional characteristics

MT -F				
No.	x [mm]	y [mm]	l [mm]	d [mm]
1	21	5	16	---
2	48	5	4	---
3	56	5	6	---
4	68	5	4	---
5	86	5	3	---
6	92	5	2	---
7	98	5	3	---
8	110	5	10	---
9	134	5	5	---
10	142	5	32	---
11	176	5	7	---
12	185	5	25	---
13	8	-5	4,5	---
14	14	-5	4,5	---
15	40	-5	16	---
16	66	-5	11	---
17	90	-5	5	---
18	96	-5	2	---
19	102	-5	34	---
20	142	-5	76	---

can close the outlet of irregularities preventing subsequent, e.g. penetration, tests. Figure 5 presents the results of the test.

The penetration testing revealed the presence of thirty eight linear indications, the total length of which was 247 mm, and also identified three non-linear indications having the diameters of d_{10} = 1.2 mm, d_{15} = 0.4 mm and d_{17} = 0.5 mm respectively.

Analysis of results and summary

The analysis involved the comparative assessment of welding imperfections detected during the following tests:

- penetration testing with the dye penetrant technique (PT-D),
- magnetic particle testing with the fluorescent technique MT-F,
- magnetic particle testing with the dye penetrant technique (MT-D).

The comparison of the presented test results reveals that detected imperfections and their detections differ in basic dimensions. Following the general assessment of the test sample area it is possible to draw a conclusion that MT-F was characterised by the best detectability of linear imperfections. In this testing the total length of indications amounted to 270 mm, in MT-D 247 mm, and in the penetration method (PT-D) 192 mm. The best result obtained in MT-F is approximately 9% more advantageous than that obtained in MT-B, and 40% better than the result obtained in PT-D. It is largely due to the fact that penetration testing enables the detection of open imperfections which at the same time are present on the surface whilst in magnetic particle testing such requirements do not have to be satisfied.

Only MT-F failed to uncover non-linear imperfections. The failure to detect these discontinuities is strictly related to the following factors:

- shape of the imperfection – a small oval shape of the discontinuity does not cause sufficiently great interference in the magnetic field,
- intensity – a small number of point discontinuities do not cause sufficiently great interference in the magnetic field either.

The other two testing methods, in addition to detecting linear indications, also made it

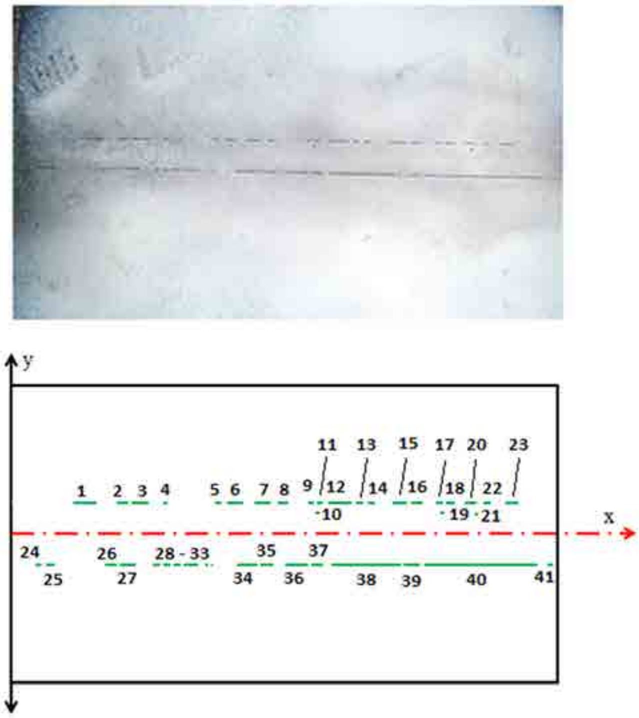


Fig. 5. View of the sample after MT-D, sketch of the sample with plotted indications and table with full dimensional characteristics

MT-D				
No.	x [mm]	y [mm]	l [mm]	d [mm]
1	28	5	10	---
2	44	5	5	---
3	51	5	8	---
4	64	5	2	---
5	82	5	3	---
6	88	5	6	---
7	96	5	4	---
8	102	5	4	---
9	120	5	2	---
10	124	4	---	1,2
11	126	5	2	---
12	130	5	8	---
13	140	5	4	---
14	146	5	3	---
15	154	5	7	---
16	164	5	5	---
17	172	5	3	---
18	177	5	4	---
19	173	3,5	---	0,4
20	186	5	4	---
21	188	4	---	0,5
22	193	5	3	---
23	198	5	6	---
24	10	-5	4	---
25	16	-5	4	---
26	38	-5	8	---
27	48	-5	7	---
28	58	-5	2	---
29	62	-5	3	---
30	67	-5	4	---
31	73	-5	5	---
32	79	-5	1,5	---
33	81	-5	1,5	---
34	92	-5	8	---
35	102	-5	8	---
36	112	-5	12	---
37	125	-5	6	---
38	132	-5	30	---
39	164	-5	6	---
40	172	-5	38	---
41	212	-5	6	---

possible to uncover non-linear indications. In PT-D the diameter of obtained indications is, on the average, 130% greater in relation to actual imperfections detected in visual tests, whereas the indications in MT-D are on the average 25% greater than those observed in VT. This leads to the conclusion that indications detected by means of penetration testing do not present the real dimensions of imperfections but rather the indications obtained by the penetrant spread around imperfections on the developer surface. Comparing PT-D and MT-D, in which both types of indications were detected, it is possible to state that magnetic particle testing is characterised by better detectability and that its sensitivity is better by approximately 30%.

In conclusion it is possible to state that testing techniques analysed in this study (VT, PT and MT) significantly differ as to the detectability of linear and non-linear imperfections. Therefore it is advisable to always use at least two surface testing methods. The best configuration includes visual testing followed by magnetic particle testing with the use of the dye penetrant method.

References

1. Czuchryj, J., and Sikora, S. (2007). Podstawy badań penetracyjnych wyrobów przemysłowych. *Wydawnictwo Instytutu Spawalnictwa w Gliwicach*, Gliwice, Poland.
2. Czuchryj, J., Drop, M., Sikora, S., and Szymański, A. (2011). Podstawy badań magnetyczno–proszkowych wyrobów przemysłowych. *Wydawnictwo Instytutu Spawalnictwa w Gliwicach*, Gliwice, Poland.
3. Krawczyk, R., Poch, K. (2011). Assessment of sensitivity of selected techniques for magnetic particle inspection. *Biuletyn Instytutu Spawalnictwa w Gliwicach*, 55 (4), pp. 33-39.