Janusz Czuchryj, Sławomir Sikora

Visual Tests of Welded Joints Made of Thermoplastics

Abstract: The article describes visual tests of joints having varied thicknesses, made of thermoplastics and welded using a manual extruder. The research-related tests were performed following the principles specified in PN-EN 13100-1. Welding imperfections detected during the tests and the regulations of the PN-EN 16296 standard were used to identify the quality levels of the test joints.

Keywords: non-destructive tests of joints, NDT, visual tests, thermoplastics, welding imperfections

DOI: *10.17729/ebis.2017.3/3*

Introduction

Polymers also known as plastics are organic materials made of carbon, hydrogen silicon, nitrogen, oxygen, sulphur, phosphorus and chlorine. Polymers also include additions of dyes or pigments, catalytic agents, fillers, softeners, oxidation inhibitors and other substances. Polymers are synthetic materials usually made of oil products [1].

In the global economy, products of all shapes and dimensions made of polymers increasingly often replace metals. In many cases, such products must be joined using welding techniques. For instance, welded joints made of thermoplastics are used when making gas and cold water pipelines, flue gas desulphurisation plants, ventilating ducts, sewage treatment plants etc. [1, 2]. Similar to tests involving welded joints made of metals, the primary method used when assessing the quality of welded joints made of thermoplastics is visual testing. The fact that the above-named issue is relatively new inspired work aimed to make NDT personnel familiar with principles regulating this area.

Principles of Visual Tests

The principles governing visual tests of welded joints made of thermoplastics are presented in PN-EN 13100-1. According to the above-named requirements, it is required that the illumination on the joint surface be a minimum of 350 lx, yet its recommended value amounts to 500 lx. The test surface should be made accessible in a manner enabling the direct observation along the entire weld at a distance not longer than 600 mm.

Remote tests involving the use of optical equipment for the inspection of openings using the fibre optic technique or cameras should be treated as additional requirements established in the product-related standard (standard concerned with application) or agreed between concerned parties. If it is necessary to obtain high contrast and to highlight joint properties in relation to the base, an additional source of white light can be used. In accordance with PN-EN 13100-1, assessing personnel should know related standards, specification and the welding technique applied when making a given joint as well as have good vision

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tested in accordance with the requirements of PN-EN ISO 9712. Visual tests of welded joints made of thermoplastics are usually performed after the completion of welding (Fig. 1).

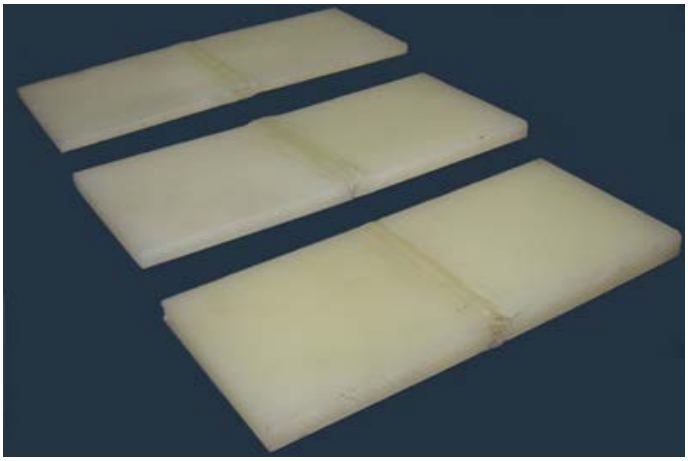


Fig. 1. Exemplary welded joints made of thermoplastics prepared for a visual test [2]

Exceptionally, e.g. if required by a product-related standard or agreement between concerned parties, tests can be conducted during other phases of the production process. The scope of tests should be specified before their performance. The assessing person should be provided with necessary inspection and production-related documentation. The visual assessment of elements prepared for welding (if necessary) should also involve the verification whether the shape and dimensions of elements satisfy requirements specified in related standards (e.g. in PN-EN 13067). If need be, a joint could be subjected to assessment during the process of welding. Ready-made joints should be assessed each time after the performance of surface treatment. The assessment should focus on whether requirements specified in agreed acceptance criteria (e.g. quality levels) have been satisfied. Imperfections in welded joints made of thermoplastics and detected using visual tests are presented in Table 1 (developed on the basis of classification provided in PN-EN 14728).

The test joints were made using hot gas welding or extrusion welding in relation to the following group of materials PVC-C, PVC-U (including PVC-Ni, PVC-RL, PVC-HL), PP (including PP-B, PP-H, PP-R), PE, PVDF, ECTFE, FEP and PFA.

Individual Research

The above-presented principles underlay research work involving the performance of visual tests of test butt joints made of polypropylene plates having various thicknesses.

Test Joints

The test joints were made of natural polypropylene PP-H (manufactured by Denoplast) characterised by a density of 0.92 g/cm^3, fusibility coefficient of 0.6 g/10 min (according to MFR 190/5), tensile strength 30 MPa, Shore hardness 68, elongation of min. 8%, coefficient of longitudinal elasticity amounting to min. 950 MPa and a toughness of 11 mJ/mm^2.

The polypropylene plates were used to make test joints being 10, 15 and 20 mm thick (each). The edges of the 10 mm thick plates were scarfed in a manner enabling the obtainment of a V-shaped weld groove having an angle of 70°, whereas the edges of the 15 mm and 20 mm thick plates were scarfed in a manner enabling the obtainment of an X-shaped weld groove having an angle of 60°. The plate edges were smoothed using a scratcher and a scraper. The smoothed surfaces were subjected to degreasing. The process of continuous welding performed by means of the manual extruder was conducted using a bead thickness of up to 15 mm, a plasticised mass temperature of 230°C, a hot air temperature of 300°C and a hot air flow rate of min. 300 l/min. The filler material used in the tests was a TIPPLEN H890 rod having a diameter of 4 mm and was characterised by a tensile strength of 38 MPa, elongation of 13%, toughness of 11 mJ/mm^2 and by the coefficient of longitudinal elasticity amounting to 1300 MPa. The joints subjected to the visual tests are presented in Figure 2.

Visual Tests and Results

Ready-made joints should be assessed in accordance with adopted (agreed requirements),

Table 1. Imperfections (detected using VT) present in welded joints of thermoplastics according to PN-EN 14728

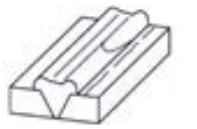
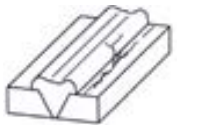
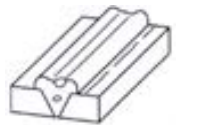
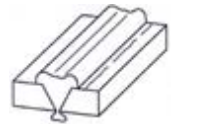
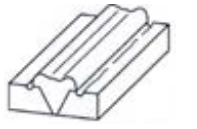
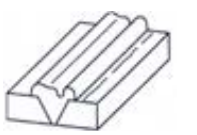
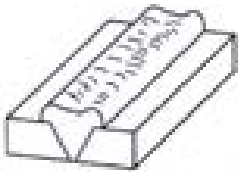
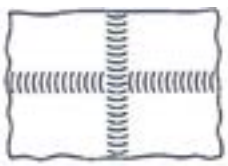
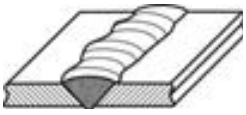
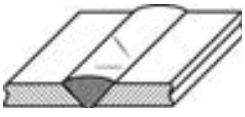
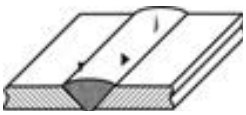
No.	Reference number	Imperfection name	Description	Sketch
1	1AAAA	Crack	Gap in the continuity of weld material or base material	
2	1AAAK	Crack at the beginning/end of a run	Crack between the beginning and the end of the weld run	
3	1AAJA	Group of unconnected cracks	Set of variously directed unconnected cracks	
4	1ABAA	Longitudinal crack	Crack, the primary direction of which is close to the longitudinal axis of the weld	
5	1ACAA	Transverse crack	Crack, the direction of which is more or less perpendicular to the longitudinal axis of the weld	
6	1AFAA	Branched crack	Group of interconnected branched cracks	
7	2AAAA	Gas cavity	Open or closed space	
8	2BAMF	Pores	Small gas pores reaching the surface	
9	2DAAA	Microcracks	Cracks constituting an area of microrough material, caused by stresses and/or a chemical, leading to the (local) formation of a white fracture; visible only under the microscope	-
10	4CAAG	Lack of penetration	In hot gas welding or extrusion welding – penetration of the weld material in the joint below a specific value	
11	4DAAG	Excessive penetration	Excess material in the weld root	
12	4EAAF	Undercut	Lack of material on weld edges	
13	4QBAF	Groove in upset material or excess weld material	Excessive depth of the groove in the run or in the weld, parallel to the longitudinal axis of the run/weld	

Table 1. (continuation)

No.	Reference number	Imperfection name	Description	Sketch
14	4QCJB	Groove in upset material or excess weld material	Transverse groove in the weld run, in the axis of the weld of an element formed by spatter	
15	5AAAA	Defective shape	Deviation from required weld geometry	-
16	5DAAA	Weld overlap	Excess weld on the surface of the base material, without connecting with the base material	
17	5EJAA	Linear misalignment	Deviation from specified tolerances concerning the displacement of planes between two elements being welded	
18	5EKAA	Angular misalignment	Deviation from a specified angle between two elements being welded	
19	5GAAA	Irregular width	Excessive fluctuations in the width of weld or run	
20	5HAAA	Irregular weld surface (great roughness)	Excessive change in weld surface (roughness, corrugation)	
21	6AAAA	Improper weld dimensions	Deviations from required weld dimensions	-
22	6BAAA	Excess molten material	Excessive height of excess weld material	
23	6FAAA	Incompletely filled groove	Local or continuous lack of weld material	
24	7GAAA	Improperly restarted weld	Local surface irregularities in the area of weld restart	
25	7TAAA	Intersecting welds	Intersecting weld layers in hot gas welding and extrusion welding	
26	8TCGF	Transverse weld scales	Excess surface scales (waves) in extrusion welding	
27	9AAAA	Mechanical damage	Local damage	
28	9CAAA	Tool imprint	Local damage caused by the tool	

e.g. such as Guidelines by Office of Technical Inspection no. UDT-ST-1/00 entitled *Fusion and Pressure Welding of Thermoplastics*. The individual research and research-related tests utilised the recommendations specified in PN-EN 16296. The definitions of adopted requirements are presented in Table 2.

The test results in the form of visual test reports are presented in Figure 3. The visual test reports revealed that, in accordance with the

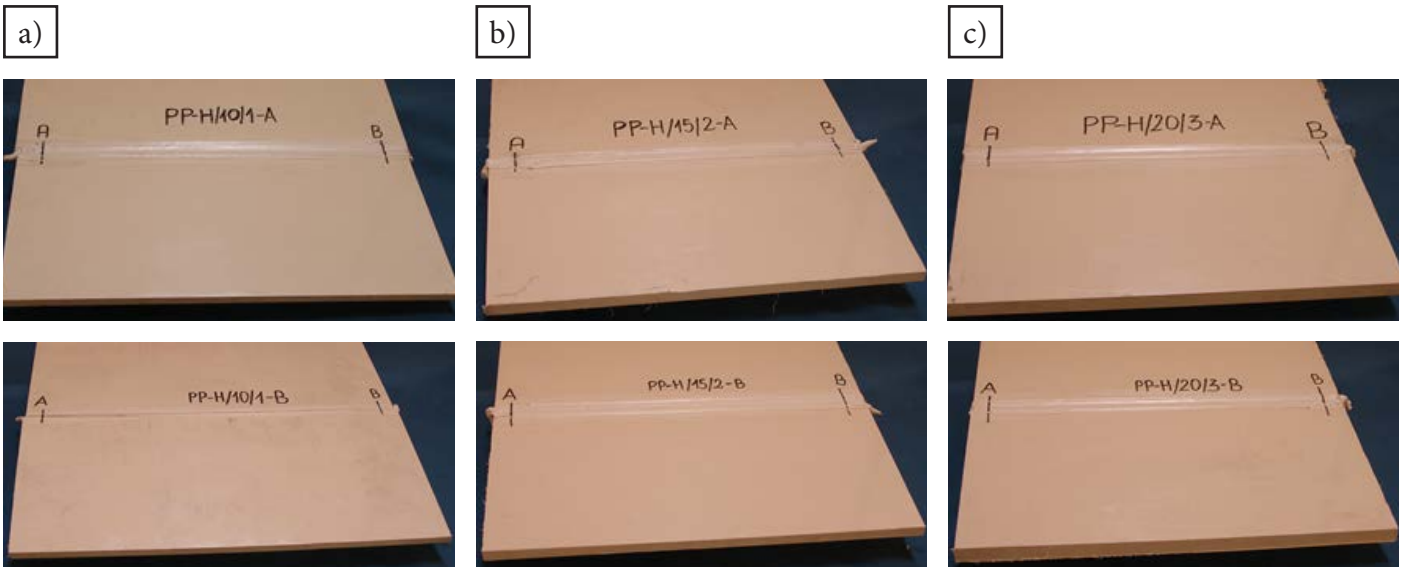


Fig. 2. Face and root-side view of a) 10 mm, b) 15 mm and c) 20 mm thick joints made of polypropylene and subjected to visual tests

Table 2. Requirements of quality levels related to joints made of thermoplastics welded using a manual extruder and subjected to visual tests

No.	Designation	Name	Quality level B	Quality level C	Quality level D
1	1AAAA	Cracks	Unacceptable	Unacceptable	Unacceptable
2	2DAAA	Microcracks	Unacceptable	Unacceptable	Unacceptable
3	4BAAA	Incomplete fusion	Unacceptable	Unacceptable	Unacceptable
4	4CAAG	Lack of penetration	Unacceptable	Unacceptable	Acceptable only if the difference between actual and required penetration is less than 10% of the material wall thickness, yet not greater than 1 mm
5	4DAAG	Excessive penetration	Acceptable (only in PE and PP) if its size is restricted within the range of 10% to 25% of the material wall thickness	Acceptable (only in PE and PP) if its size is restricted within the range of 5% to 30% of the material wall thickness	Acceptable (only in PE and PP) if its size is restricted within the range of 0% to 40% of the material wall thickness
6	4EAAA	Undercuts	Acceptable locally if the toe angle is gentle and if they do not exceed 10% the material wall thickness, yet not more than 1 mm	Acceptable locally if the toe angle is gentle and if they do not exceed 10% the material wall thickness, yet not more than 2 mm	Acceptable locally if the toe angle is gentle and if they do not exceed 20% the material wall thickness, yet not more than 3 mm

Table 2. (continuation)

No.	Designation	Name	Quality level B	Quality level C	Quality level D
7	4QAAA	Groove in upset material or in excess weld material	Acceptable locally if the groove bottom is located above the surface of the material being welded	Acceptable locally if the groove bottom is located above the surface of the material being welded	Acceptable locally if the groove bottom is located above the surface of the material being welded
8	5AAAA	Defective shape	Recommended mechanical testing of welded joints specimens	Recommended mechanical testing of welded joints specimens	Recommended mechanical testing of welded joints specimens
9	5DAAA	Weld overlap	Unacceptable	Acceptable locally if the length of the unjoined weld overlap is shorter than 5 mm	Acceptable locally if the length of the unjoined weld overlap is shorter than 10 mm
10	5EJAA	Linear misalignment	Acceptable if not exceeding 10% of the material wall thickness	Acceptable if not exceeding 20% of the material wall thickness	Acceptable if not exceeding 30% of the material wall thickness
11	5EKAA	Angular misalignment	Acceptable if not exceeding 0.6o	Acceptable if not exceeding 1.0o	Acceptable if not exceeding 1.5°
12	5GAAA	Irregular width	Acceptable if present in single segments	Acceptable	Acceptable
13	5HAAA	Irregular weld surface (great roughness)	Unacceptable	Unacceptable	Unacceptable
14	6BAAA	Excess molten material	Acceptable if the height of excess weld material is restricted within the range of 10% to 30% of the material wall thickness, yet not more than 6 mm	Acceptable if the height of excess weld material is restricted within the range of 5% to 40% of the material wall thickness, yet not more than 8 mm	Acceptable if the height of excess weld material is restricted within the range of 0% to 50% of the material wall thickness, yet not more than 10 mm
15	6FAAA	Incompletely filled groove	Unacceptable	Unacceptable	Unacceptable
16	7GAAA	Improperly restarted weld	Unacceptable	Acceptable small cross-sectional reductions and the lack of steep toe angle	Acceptable small cross-sectional reductions and the lack of steep toe angle
17	7VAAA	Intersecting welds	Unacceptable	Unacceptable	Unacceptable
18	8VAAA	Transverse waviness	Acceptable if present in single segments	Acceptable	Acceptable
19	9CAAA	Tool imprint	Acceptable locally if the imprint bottom is not sharp and its depth is shallower than 10% of the material wall thickness, yet not exceeding 0.5 mm	Acceptable locally if the imprint bottom is not sharp and its depth is shallower than 10% of the material wall thickness, yet not exceeding 1.0 mm	Acceptable locally if the imprint bottom is not sharp and its depth is shallower than 15% of the material wall thickness, yet not exceeding 2.0 mm

LABORATORIUM BADAN NIENISZCZĄCYCH

PROTOKÓŁ BADAŃ WIZUALNYCH

SEKTOR WYROBU W | Strona: 1/2 | Data: 02.03.2017

WARUNKI PRZEPROWADZENIA BADAŃ WIZUALNYCH

1. Norma/Procedura badawcza: **PN-EN 13100-1**
2. Nr identyfikacyjny: **PP-H/10/1**
3. Przedmiot badań: **Złącze doczołowe płyt z tworzywa termoplastycznego**
4. Zakres badań: **100% spoiny + SWC (10 mm z każdej strony spoiny) w zakresie od A do B – badanie od strony lica i grani**
5. Informacje dotyczące obiektu badań:
   a) gatunek materiału podstawowego i jego grubość: **PP-H – 10mm**
   b) gatunek materiału dodatkowego do spawania: **TIPPLEN H890**
   c) metoda spawania: **Ekstruder ręczny**
   d) rodzaj złącza spawanego i sposób jego ukosowania: **BW/V**
   e) opis stanu powierzchni: **po spawaniu – oczyszczona**
6. Informacje dotyczące kryterium odbioru: **wymagania PN-EN 16296**
7. Informacje dotyczące warunków prowadzenia badań:
   a) natężenie oświetlenia : **870 lx**
   b) odległość pomiędzy okiem a powierzchnią badaną: **max 600 mm**
   c) kąt patrzenia: **min 30°**
8. Wyposażenie badawcze do badań wizualnych:
   a) **suwmiarka zwykła nr IK154**
   b) **spoinomierz typu SPA40**
   c) **szkło powiększające 3x**
   d) **luksomierz LX52**
   e) **kątomierz**
   f) **przymiar liniowy**
9. Ocena wg: **PN EN 16296**
10. Odstępstwa od procedury: **Brak**
11. Uwagi: Wyniki badań - verte

Wykonujący badania: mgr inż. Sławomir Sikora

Kierownik Badań: mgr inż. Janusz Czuchryj

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5. Informacje dotyczące obiektu badań:
   a) gatunek materiału podstawowego i jego grubość: **PP-H – 15mm**
   b) gatunek materiału dodatkowego do spawania: **TIPPLEN H890**
   c) metoda spawania: **Ekstruder ręczny**
   d) rodzaj złącza spawanego i sposób jego ukosowania: **BW/X**
   e) opis stanu powierzchni: **po spawaniu – oczyszczona**
6. Informacje dotyczące kryterium odbioru: **wymagania PN-EN 16296**
7. Informacje dotyczące warunków prowadzenia badań:
   a) natężenie oświetlenia : **870 lx**
   b) odległość pomiędzy okiem a powierzchnią badaną: **max 600 mm**
   c) kąt patrzenia: **min 30°**
8. Wyposażenie badawcze do badań wizualnych:
   a) **suwmiarka zwykła nr IK154**
   b) **spoinomierz typu SPA40**
   c) **szkło powiększające 3x**
   d) **luksomierz LX52**
   e) **kątomierz**
   f) **przymiar liniowy**
9. Ocena wg: **PN EN 16296**
10. Odstępstwa od procedury: **Brak**
11. Uwagi: Wyniki badań - verte

Wykonujący badania: mgr inż. Sławomir Sikora

Kierownik Badań: mgr inż. Janusz Czuchryj

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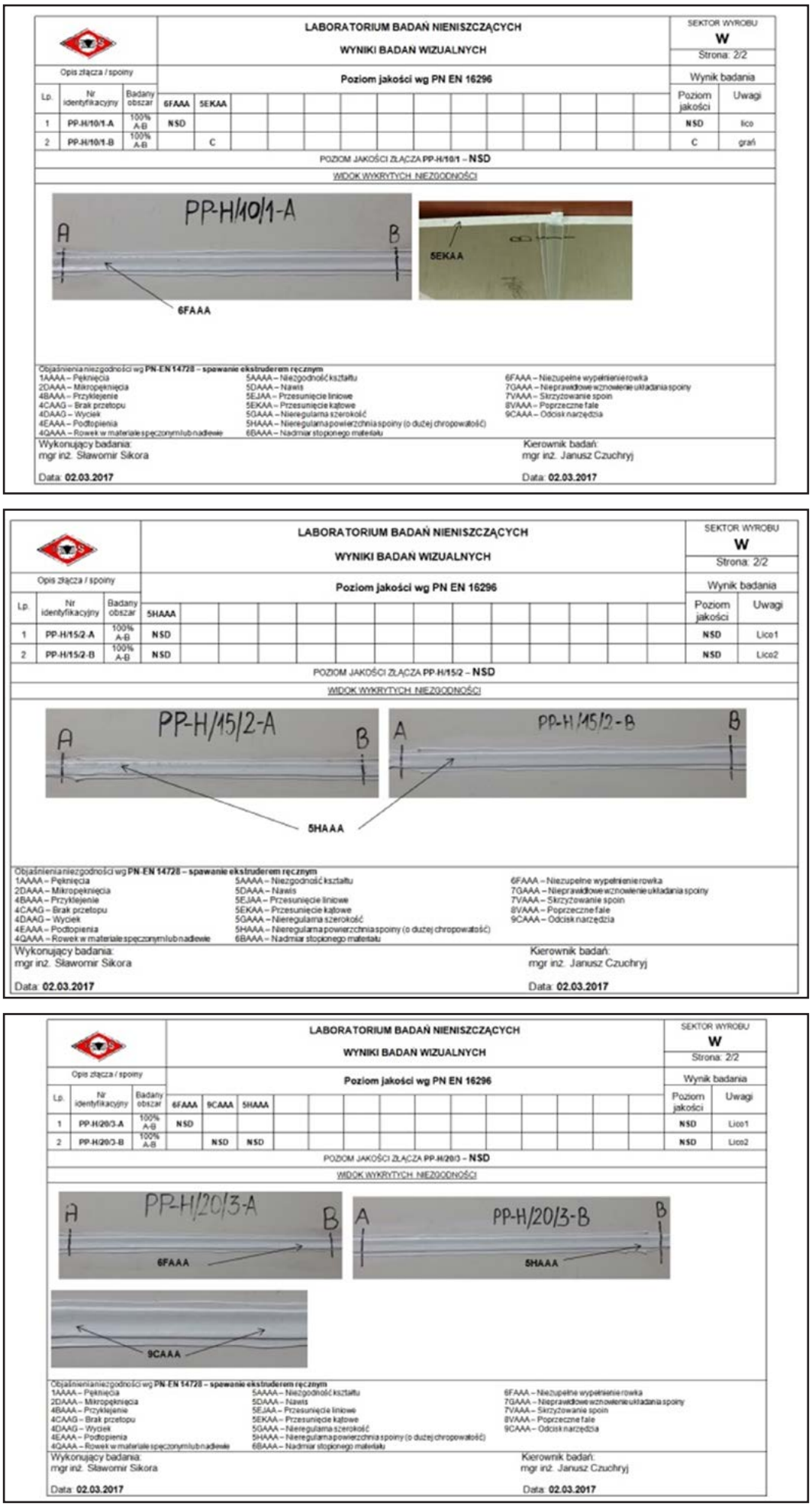
1. Norma/Procedura badawcza: **PN-EN 13100-1**
2. Nr identyfikacyjny: **PP-H/20/3**
3. Przedmiot badań: **Złącze doczołowe płyt z tworzywa termoplastycznego**
4. Zakres badań: **100% spoiny + SWC (10 mm z każdej strony spoiny) w zakresie od A do B – badanie od strony lica i grani**
5. Informacje dotyczące obiektu badań:
   a) gatunek materiału podstawowego i jego grubość: **PP-H – 20mm**
   b) gatunek materiału dodatkowego do spawania: **TIPPLEN H890**
   c) metoda spawania: **Ekstruder ręczny**
   d) rodzaj złącza spawanego i sposób jego ukosowania: **BW/X**
   e) opis stanu powierzchni: **po spawaniu – oczyszczona**
6. Informacje dotyczące kryterium odbioru: **wymagania PN-EN 16296**
7. Informacje dotyczące warunków prowadzenia badań:
   a) natężenie oświetlenia : **870 lx**
   b) odległość pomiędzy okiem a powierzchnią badaną: **max 600 mm**
   c) kąt patrzenia: **min 30°**
8. Wyposażenie badawcze do badań wizualnych:
   a) **suwmiarka zwykła nr IK154**
   b) **spoinomierz typu SPA40**
   c) **szkło powiększające 3x**
   d) **luksomierz LX52**
   e) **kątomierz**
   f) **przymiar liniowy**
9. Ocena wg: **PN EN 16296**
10. Odstępstwa od procedury: **Brak**
11. Uwagi: Wyniki badań - verte

Wykonujący badania: mgr inż. Sławomir Sikora

Kierownik Badań: mgr inż. Janusz Czuchryj

Fig. 3a. Visual test reports concerning the welded joints made of 10, 15 and 20 mm thick thermoplastic plates (grade PP-H): test conditions



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SEKTOR WYROBU W

Strona: 2/2

Poziom jakości wg PN EN 16296

Lp.	Nr identyfikacyjny	Badany obszar	6FAAA	5EKAA	Wynik badania: Poziom jakości	Uwagi
1	PP-H/10/1-A	100% A-B	NSD		NSD	lico
2	PP-H/10/1-B	100% A-B		C	C	grań

POZIOM JAKOŚCI ZŁĄCZA PP-H/10/1 – NSD

WIDOK WYKRYTYCH NIEZGODNOŚCI

Objaśnienia niezgodności wg PN-EN 14728 – spawanie ekstruderem ręcznym

1AAAA – Pęknięcia
2DAAA – Mikropęknięcia
4BAAA – Przyklejenie
4CAAG – Brak przetopu
4DAAG – Wyciek
4EAAA – Podtopienia
4QAAA – Rowek w materiale spęczonym lub nadlewie
5AAAA – Niezgodność kształtu
5DAAA – Nawis
5EJAA – Przesunięcie liniowe
5EKAA – Przesunięcie kątowe
5GAAA – Nieregularna szerokość
5HAAA – Nieregularna powierzchnia spoiny (o dużej chropowatości)
6BAAA – Nadmiar stopionego materiału
6FAAA – Niezupełne wypełnienie rowka
7GAAA – Nieprawidłowe wznowienie układania spoiny
7VAAA – Skrzyżowanie spoin
8VAAA – Poprzeczne fale
9CAAA – Odcisk narzędzia

Wykonujący badania: mgr inż. Sławomir Sikora — Data: 02.03.2017

Kierownik badań: mgr inż. Janusz Czuchryj — Data: 02.03.2017

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Strona: 2/2

Poziom jakości wg PN EN 16296

Lp.	Nr identyfikacyjny	Badany obszar	5HAAA	Wynik badania: Poziom jakości	Uwagi
1	PP-H/15/2-A	100% A-B	NSD	NSD	Lico1
2	PP-H/15/2-B	100% A-B	NSD	NSD	Lico2

POZIOM JAKOŚCI ZŁĄCZA PP-H/15/2 – NSD

WIDOK WYKRYTYCH NIEZGODNOŚCI

Objaśnienia niezgodności wg PN-EN 14728 – spawanie ekstruderem ręcznym

1AAAA – Pęknięcia
2DAAA – Mikropęknięcia
4BAAA – Przyklejenie
4CAAG – Brak przetopu
4DAAG – Wyciek
4EAAA – Podtopienia
4QAAA – Rowek w materiale spęczonym lub nadlewie
5AAAA – Niezgodność kształtu
5DAAA – Nawis
5EJAA – Przesunięcie liniowe
5EKAA – Przesunięcie kątowe
5GAAA – Nieregularna szerokość
5HAAA – Nieregularna powierzchnia spoiny (o dużej chropowatości)
6BAAA – Nadmiar stopionego materiału
6FAAA – Niezupełne wypełnienie rowka
7GAAA – Nieprawidłowe wznowienie układania spoiny
7VAAA – Skrzyżowanie spoin
8VAAA – Poprzeczne fale
9CAAA – Odcisk narzędzia

Wykonujący badania: mgr inż. Sławomir Sikora — Data: 02.03.2017

Kierownik badań: mgr inż. Janusz Czuchryj — Data: 02.03.2017

LABORATORIUM BADAŃ NIENISZCZĄCYCH

WYNIKI BADAŃ WIZUALNYCH

SEKTOR WYROBU W

Strona: 2/2

Poziom jakości wg PN EN 16296

Lp.	Nr identyfikacyjny	Badany obszar	6FAAA	9CAAA	5HAAA	Wynik badania: Poziom jakości	Uwagi
1	PP-H/20/3-A	100% A-B	NSD			NSD	Lico1
2	PP-H/20/3-B	100% A-B		NSD	NSD	NSD	Lico2

POZIOM JAKOŚCI ZŁĄCZA PP-H/20/3 – NSD

WIDOK WYKRYTYCH NIEZGODNOŚCI

Objaśnienia niezgodności wg PN-EN 14728 – spawanie ekstruderem ręcznym

1AAAA – Pęknięcia
2DAAA – Mikropęknięcia
4BAAA – Przyklejenie
4CAAG – Brak przetopu
4DAAG – Wyciek
4EAAA – Podtopienia
4QAAA – Rowek w materiale spęczonym lub nadlewie
5AAAA – Niezgodność kształtu
5DAAA – Nawis
5EJAA – Przesunięcie liniowe
5EKAA – Przesunięcie kątowe
5GAAA – Nieregularna szerokość
5HAAA – Nieregularna powierzchnia spoiny (o dużej chropowatości)
6BAAA – Nadmiar stopionego materiału
6FAAA – Niezupełne wypełnienie rowka
7GAAA – Nieprawidłowe wznowienie układania spoiny
7VAAA – Skrzyżowanie spoin
8VAAA – Poprzeczne fale
9CAAA – Odcisk narzędzia

Wykonujący badania: mgr inż. Sławomir Sikora — Data: 02.03.2017

Kierownik badań: mgr inż. Janusz Czuchryj — Data: 02.03.2017

Fig. 3b. Visual test reports concerning the welded joints made of 10, 15 and 20 mm thick thermoplastic plates (grade PP-H): test results

PN-EN 16296 standard, all of the test joints made in thermoplastic PP-H were classified as failing to meet quality level D, customarily designated as NSD.

Analysis of Test Results

The analysis of the visual test reports (Fig. 3) revealed that the 10 mm thick joint (identification number PP-H/10/1-A representing the weld face and PP-H/10/1-B representing the weld root) was, over its entire surface, characterised by the presence of welding imperfections in the form of the incompletely filled groove and angular misalignment. Because the lack of the completely filled weld groove, the joint was classified as failing to meet the requirements of quality level D (lowest). In turn, the above-named angular misalignment classified the joint as meeting the requirements of quality level C (intermediate). The imperfections present in the joint could be attributed to the improper pre-weld preparation of the joint as well as to the inaccurately performed welding process, which in turn, demonstrated the insufficient training of the welder as well as the lack of professional supervision over welding works.

The 15 mm thick double-sided butt joint (identification numbers PP-H/15/2-A and PP-H/15/2-B) was also classified as failing to meet the requirements of quality level D (NSD). The reason for the above-named assessment was the irregular weld surface (welding imperfection) visible on the excess weld material of the test joint. The weld surface areas recorded in the test report were characterised by excessive, i.e. unacceptable, roughness.

The surface of the 20 mm thick joint (identification numbers PP-H/20/3-A and PP-H/20/3-B) contained unacceptable welding imperfections including an incompletely filled groove, irregular weld surface and a tool imprint. Each of the above-presented imperfections classified the joint as failing to meet the requirements of quality level D (NSD). In addition to the previously provided reasons behind the formation of imperfections, in the case under discussion the imperfections could also be ascribed to the improper use of workshop tools resulting in damage to welded surfaces and the formation of the imperfection unacceptable in terms of joint operationality. The foregoing also revealed the low technical culture demonstrated by the production process personnel.

Summary and Conclusions

Non-destructive tests involving joints made of thermoplastics constitute a relatively new issue in the area of technical diagnostics. This fact inspired work aimed to introduce to NDT personnel principles governing this area. The research-related tests focused on visual testing, i.e. a primarily recommended method when verifying the quality of all welded joints.

The visual tests of the test butt joints made of polypropylene plates having various thicknesses were performed in accordance with the requirements of PN-EN 13100-1. The acceptance criterion was based on the requirements of PN-EN 16296 concerned with the limit values of welding imperfections present in welded joints made of thermoplastics in relation to quality levels B, C and D as well as taking into consideration the joining technique involving the welding process performed using a manual extruder. Similar to PN-EN ISO 5817, quality level B represents the highest, quality level D the lowest, whereas quality level C represents the intermediate requirements.

The visual tests of the test joints revealed that all of the joints were characterised by low workmanship. The lack of sufficient experience of the welding of thermoplastics, the inadequate training provided to the welder and the improper use of production tools led to the formation of unacceptable surface welding imperfections in the test joints. As a result, all of the joints were classified below the requirements of quality level D. The acceptance of the joints for operation would require the removal of the imperfections. After the repair, the joints

should be subjected to visual tests maintaining the acceptance criteria related to ready-made joints. The performed tests demonstrated that the visual inspection of welded joints made of thermoplastics is a highly problematic issue.

The practice applied when assessing welded joints made in metals cannot be directly used when evaluating welded joints made of plastics. It can be concluded that training aimed to prepare a competent VT operator should also include issues related to the joining of thermoplastics by means of welding methods and that the above-named problems should be reflected in training programmes prepared for NDT personnel.

The tests justified the formulation of the following conclusions:

- The quality of the welded joints made of polypropylene and subjected to visual tests was classified as "NSD", which demonstrated the low workmanship of the joints.
- Visual tests of welded joints made of thermoplastics are highly difficult.
- Training provided to VT operators should include knowledge concerning the joining of thermoplastics using welding methods.
- Information concerning technologies used in the joining of thermoplastics should be included in training programmes for VT operators.

References:

[1] Dobrzański L. A.: *Podstawy nauki o materiałach i metaloznawstwo*. Materiały inżynierskie z podstawami projektowania materiałowego. WNT, Gliwice, Warszawa, 2002

[2] Czuchryj J., Sikora S.: *Metody i techniki badań nieniszczących złączy spawanych*. Wydanie I, Wydawnictwo Instytutu Spawalnictwa. Gliwice, 2014

Reference and related standards

- PN-EN ISO 9712: *Non-destructive testing – Qualification and certification of NDT personnel*
- PN-EN 13067: *Plastics welding personnel. Qualification testing of welders. Thermoplastics welded assemblies*
- PN-EN 14728 – *Imperfections in thermoplastic welds - Classification*
- PN-EN 13100-1: *Non-destructive testing of welded joints of thermoplastics semi- finished products. Part 1: visual examination*
- PN-EN 16296: *Imperfections in thermoplastics welded joints. Quality levels*
- PN-EN ISO 5817: *Welding – Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) – Quality levels for imperfections*