RESEARCH ON WELDING OF PLASTIC MATERIALS

Constantin PETRICEANU[1], Corneliu RONTESCU[2], Dumitru-Titi CICIC[3], Oana-Roxana CHIVU[4], Maria-Cristina DIJMĂRESCU[5]

Following the welding of plastic materials nonconformities may occur in the joint area, which may lead to the failure of the welded product during operation. This paper presents the results obtained following the ultrasonic nondestructive testing of the welded joint of plastic materials. After the ultrasonic testing, the welded samples were cut and subjected to visual and penetrating liquid testing. When the results obtained following the destructive and nondestructive tests were analyzed, it was observed that the ultrasonic nondestructive testing method is an efficient way to determine the conformity of welded joints of plastic materials.

Keywords: welding, polypropylene, ultrasonic test, welding parameters

1. Introduction

In the past, the sanitary hot/cold water installations were made of materials such as steel, galvanized steel or even worse, of lead alloys, but these materials have adverse effects on the user's health. As years passed by, these materials started to fail due to the strong corrosion effect of water, as it often has in its structure a series of impurities that act as promoters/catalysts of the process. A solution adopted until approximately 10 years ago was to replace those installations with pipes made of pexal, but they too have a major disadvantage, namely they do no last very long due to the ageing of the materials – they mostly crack in the bend area.

Modern materials used for manufacturing the products that replace the existing pipes are copper, polypropylene (PPR) or polyvinyl chloride (PVC). The use of such materials is based on the fact that the lifetime of PPR pipes is 3 up to 5 times higher as compared to the other existing solutions.

[1] Lecturer., Dept. of Materials Technology and Welding, University POLITEHNICA of Bucharest, Romania, e-mail: petristef@upb.com
[2] Lecturer., Dept. of Materials Technology and Welding, University POLITEHNICA of Bucharest, Romania, e-mail: corneliu.rontescu@upb.ro.com
[3] Lecturer., Dept. of Materials Technology and Welding, University POLITEHNICA of Bucharest, Romania, e-mail:dumitru.cicic@gmail.com
[4] Lecturer., Dept. of Materials Technology and Welding, University POLITEHNICA of Bucharest, Romania, e-mail: virlan_oana@yahoo.co.uk
[5] PhD. Student, Dept. of Materials Technology and Welding, University POLITEHNICA of Bucharest, Romania, e-mail: cristina_dijmarescu@yahoo.com

The PPR pipes may be used for sanitary installations, tanks, distribution systems, supply pipes for heaters, piping systems, but also for manufacturing green buildings [1].

The welding process is considered a special process as it is a production process that generates outputs that cannot be measured, monitored, or verified until it's too late, meaning after the resulted products have been used. In order to prevent output deficiencies, these special processes must be validated so as to prove that they can generate planned results [2].

A nondestructive method for discovering nonconformities that may occur in the welded joint area is the ultrasonic testing. The process of ultrasonic nondestructive testing determines the existence of flaws, discontinuities, leaks, contamination, thermal anomalies, or imperfections in materials, components or assemblies without impairing the integrity or function of the inspected component [3,4,5]. The process can be also utilized for real-time monitoring during manufacturing, measurement of physical properties such as hardness and internal stress, inspection of assemblies for tolerances, alignment, and periodic in-service monitoring of flaw/damage growth in order to determine the maintenance requirements and to assure the reliability and continued safe operation of the part [6].

2. Experimental procedure

When welding PPR parts, the essential welding parameters are: nature of the base material, temperature of the base material subject to joining, heating time and value of the pressure.

The main purpose of the experimental procedure was the analysis of the nondestructive testing possibility of welded PPR parts as well as the validation of the testing method for the studied case.

A series of 12 welded samples were performed in order to validate the welding process and the ultrasonic nondestructive testing method of PPR welded joints. The components used for the tests had the following dimensions: cylindrical bushing - $\phi_{ext} = 28{,}70 \pm 0{,}01$, $\phi_{int} = 19{,}20 \pm 0{,}01$, pipe - $\phi_{ext} = 20{,}20 \pm 0{,}01$, $\phi_{int} = 13{,}20 \pm 0{,}01$. The values of the welding parameters used for the samples are presented in table 1.

For the experimental procedure we used a thermostat fuser with the possibility to vary the heating temperature. After the target temperature was reached (200^0C, 250^0C, 300^0C), the parts were brought into contact with the thermostat fuser and kept like this for a certain period of time (8s, and 12s) so that they could be brought to the plastic state. After the heating time the parts were assembled and pressed with a certain pressure force (30N and 50N) that was sufficient to make the welded joint [7].

The resulted welded samples are presented in Fig. 1.

Table 1

Values of the welding parameters

No.	Temperature [^oC]	Heating time [s]	Pressure force [N]	No.	Temperature [^oC]	Heating time [s]	Pressure force [N]
1.	200	8	30	7.	250	12	30
2.	200	8	50	8.	250	12	50
3.	200	12	30	9.	300	8	30
4.	200	12	50	10.	300	8	50
5.	250	8	30	11.	300	12	30
6.	250	8	50	12.	300	12	50

After the samples were obtained, they were initially subjected to visual testing followed by an ultrasonic nondestructive test. In order to make the process more efficient, the testing was conducted on a semi-automated ultrasonic nondestructive stand.

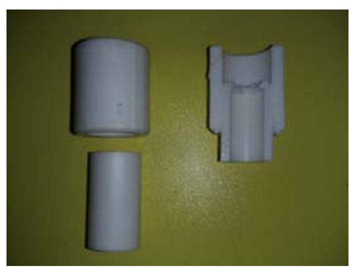


Fig. 1. Sample welded according to the welding parameters presented in Table 1.

The ultrasonic testing was conducted by using two testing methods:

- the "A – scan" method is a visualization method of the ultrasonic material testing results where the x-axis represents the time (microseconds) and the y-axis represents the amplitude of the reflection i.e. how strongly the sound is reflected). A-scan presentation displays the amount of received ultrasonic energy as a function of time. A-scan is a spot-by-spot testing method.
- the "B – scan" method is the display method during which the measurement of the acoustic parameters is carried out after a line on the surface of the sample, and the results are presented in coordinates – normal cross-section through the specimen on the testing direction wave amplitude.

For the validation of the results obtained following the ultrasonic testing, the samples were cut on cross direction, in the area of the ultrasonic testing lines.

After cutting, the samples were subjected to a visual testing and penetrating liquid testing process of the interest areas in order to make a comparison to the results obtained following the nondestructive testing process.

3. Results and discussions

Following the analysis of the results obtained by applying the visual testing method we noticed that a mould mark occurred at the inner limit between the pipe and the socket pipe. The dimensional size of the mould mark depends on the values of the welding parameters.

After measuring the core diameter of the samples we discovered that for sample no. 12, starting from the diameter of Ø14±0.01mm (sample 6), the cross section got smaller due to the excessive occurrence of the mould mark up to a core diameter of Ø9.22±0.01mm (Fig. 2). For sample no. 12, the high temperature value and the long heating time led to the excessive melting of the material in the contact area of the parts. When the pressure force was applied, the excess material was extruded inside the parts, which led to the occurrence of the mould mark (Fig. 2.a). This type of nonconformity may lead to the defective operation of the installation and to the increase in the work pressure in the respective area. Furthermore, the change in the fluid flowing process may lead to the corrosion of the joint area and finally to the failure of the weld during operation. For samples 1-4 the temperature of the parts did not ensure the joining of the parts on a sufficient length.

a) b)

Fig. 2. Welded samples: a – sample with proper flow area, b – sample with improper flow area.

The results obtained following the ultrasonic testing are presented in figure 3 (A-scan testing method) and figure 4 (B-scan testing method).

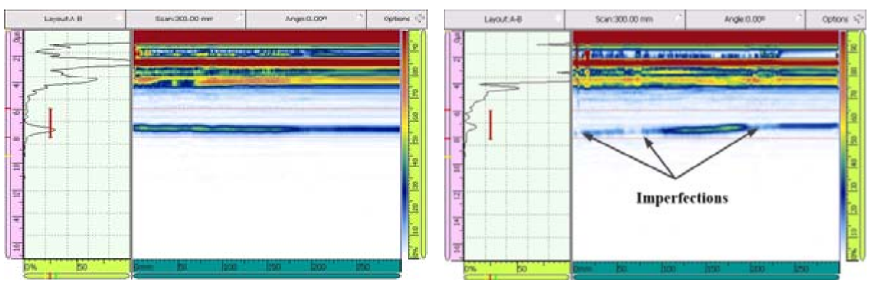
From the analysis of figures 3.a and 3.b we could observe that the echo height differs depending on the analyzed sample. For sample number 6, the echo height is significantly higher in comparison to the height resulted for sample no. 12. The decrease in the echo height may be caused by the occurrence of discontinuities in the connection area between the two welded parts. This causes a part of the energy of the supersonic waves to be reflected in the new separation zone, thus leading to a decrease in the height.

Following the analysis of figures 4.a and 4.b, in case of B-scan testing we discovered that the occurred discontinuities are distributed on the entire circumference of the welded sample.

For the validation of the ultrasonic testing method, the welded samples were subjected to the destructive testing so as to allow access to the welded joint areas. The welded parts were cut up on the circular line, in the ultrasonic testing areas.

a) b)

Fig. 3. Results obtained following the A-scan testing method: a – conforming sample, b – nonconforming sample



a) b)

Fig. 4. Results obtained following the B-scan testing method: conforming sample, b – nonconforming sample

a) b)

Fig. 5. Results obtained following the penetrating liquid testing method: a – conforming sample, b – nonconforming sample

After cutting, the parts were subjected to penetrating liquid testing (Fig. 5). Following the analysis of the samples presented in figure 5, we discovered that for sample no. 12 (Fig. 5.a) no conformities occurred. For sample no. 6 (Fig. 5.b) we noticed that the joined parts did not mix, so that nonconformities like no melting, pores and cracks occurred in the connection area between the parts.

4. Conclusions

Following the analysis of the obtained results we can draw the following conclusions:

- the quality of the welded joints of the PPR parts depends to a great extent on the welding parameters, as well as on the preparation of the parts for welding;
- following the welding process, nonconformities such as no melting, pores, cracks or thermal degradation of the polymer molecule at temperatures above 250 degrees may occur in the welded joint area;
- the use of the ultrasonic testing method may help to discover the nonconformities occurred during the welding process;
- the results obtained following the destructive testing revealed the nonconformities discovered when the ultrasonic testing was applied;
- the analysis of the results presented in the paper led to the validation of the ultrasonic testing method concerning the welding of PPR parts.

Acknowledgement

The work has been funded by the Sectoral Operational Programme Human Resources Development 2007-2013 of the Ministry of European Funds through the Financial Agreement POSDRU/159/1.5/S/132397.

R E F E R E N C E S

[1]. *I. Mitelea, N. Varzaru, I. Bordeasu, M. Popescu*, The high frequency welding aptitude of thermoplastic polymers, Materiale Plastice, 46, Nr. 1, 2009

[2]. *EN ISO 9000:2015*, Quality management systems - Fundamentals and Vocabulary

[3]. *Gh. Amza, D. Dobrotă*, Ultrasound effect on the mechanical properties of parts loaded by welding, Metalurgija 52 (2013) 1, 83-86

[4]. *F. Hagglund, , M. A. Spicer, M.J. Troughton*, Phased array ultrasonic testing of welded joints in plastic (PE) pipes, 6th Middle East Nondestructive Testing Conference, 7-10 October 2012, Kingdom of Bahrain

[5]. *L. Mazeika, R. Sliteris and A. Vladisauskas*, Measurement of Velocity and Attenuation for Ultrasonic Longitudinal Waves in the Polyethylene Samples, Ultragarsas, vol. 65, 2010.

[6]. *Gh. Amza, C. Petriceanu*, Mathematical modeling of the ultrasonic nondestructive control, Revue Roumaine des Sciences Techniques, série de Mécanique Appliquée, Tome 54, No 3, P. 143–258, Bucharest, 2009

[7]. *Fl. Dumitrache, G. Iacobescu, R. Iova*, Sudarea prin presiune (Welding pressure), vol. 2, Ed. UPB, 1985