EXPERIENCE IN APPLICATION OF THE EUROPEAN STANDARDS FOR QUALIFICATION OF SURFACING PROCEDURES

E. TURYK[1] and **I.A. RYBTSEV**[2]
[1]Institute of Welding
16–18 B. Czeslaw Str., 44100, Gliwice, Poland. E-mail: eugeniusz.turyk@glivice.pl
[2]E.O. Paton Electric Welding Institute, NASU
11 Bozhenko Str., 03680, Kiev, Ukraine. E-mail: office@paton.kiev.ua

The experience of application of qualification of surfacing procedure in accordance with the European standards is described. Main terminology, used in standards, is given and explained. Qualification of welding (surfacing) works at the enterprise is carried out by the outside independent expert body with an accredited test laboratory of non-destructive and destructive testing. During qualification the testing of procedures of surfacing on standard test specimens in the form of plates or pipes is carried out preliminary. As an exception the qualification of surfacing procedures is allowed on non-standard test specimens simulating the part being surfaced. The quality of deposited test specimens is checked firstly by using the non-destructive methods of testing. At the positive results of these methods of testing the specimens are subjected to the destructive methods of testing. If after testing the inadmissible defects were not revealed, then the expert body makes a protocol about qualification of surfacing procedure WPQR. 5 Ref., 2 Tables, 8 Figures.

Keywords: *surfacing procedure, qualification, European standard, reference specimen, non-destructive testing, destructive testing*

The need in qualification of procedures of welding (surfacing) appeared due to introducing of the International and European standards of the Quality Management System, in which welding is considered as a special process, i.e. process «in which the confirmation of conformity of the final products is difficult» (ISO 9000:2000). It is written in requirements of standard ISO 9001:2008: «Organization should confirm all the processes of production and maintenance, the results of which cannot be checked by successive monitoring or measurements, due to which their drawbacks become evident only after beginning of products use or after rendering the services». Similar requirements to the quality of welding (surfacing) are specified by the series of standards ISO 3834 on quality assurance in welding production.

To have the better understanding of problems of qualification of procedures of welding (surfacing), it is necessary to get acquainted with terminology, used in these standards. In accordance with GOST R ISO 15607–2009 «Technical requirements and qualification of procedures of welding of metallic materials» the following terminology is introduced:

- **welding procedure**: specified sequence of actions for welding fulfillment, including the recommendations for the process(es) of welding, equipment, base materials and welding consumables, preparation for welding, preheating (when necessary), method and control of welding, postweld heat treatment (when necessary);
- **welding process**: processes of welding are used in standard, the list and definition of which are given in ISO 857-1, and system of numeration of welding processes according to EN ISO 4063;
- **preliminary welding procedure specifications** (pWPS): document, containing the values of parameters of welding procedure, which should be qualified;
- **welding procedure specification** (WPS): document which was qualified by one of methods and which contains the values of parameters of welding procedure, providing repetition of their fulfillment in production;
- **work instruction**: document, containing the simplified WSP, suitable for applying in the shop;
- **welding procedure qualification record** (WPQR): protocol containing all the necessary data for qualification of pWPS.

In principle, all this terminology can be referred to surfacing as a process related to welding process, changing the term «welding» for term «surfacing».

To fulfill the standard requirements to the quality of welding (surfacing) works the manu-

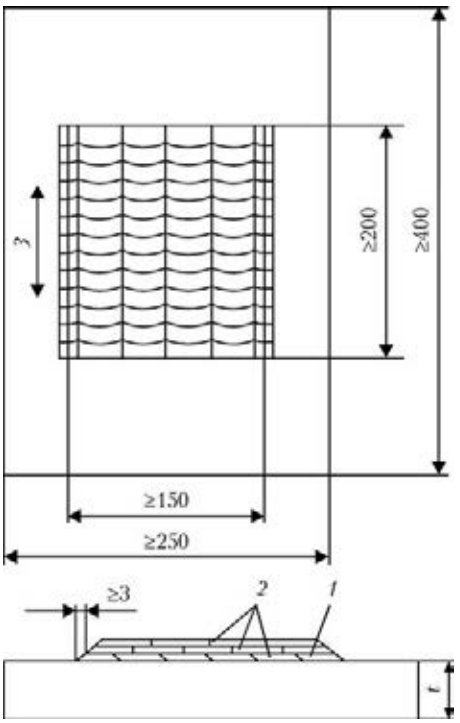

Figure 1. Surfaced test specimen (plate): *1* — buffer layer (sublayer, deposited when necessary); *2* — numbers of layers according to pWPS or total thickness of deposited layer; *3* — direction of surfacing; *t* — thickness of base metal [1]

facturer should apply the qualified technologies, and method of qualification should correspond to standards for product or technical specifications. The presence of qualified technologies (procedures) of surfacing is the proof of the fact that the industrial technologies are in a complete compliance with the set requirements. Qualification should be made before the fulfillment of welding (surfacing) works at the production facility. It is recommended to carry out qualification of welding (surfacing) works by outside independent expert body with an accredited test laboratory for non-destructive and destructive testing.

Test samples. The obligatory requirement of standard ISO 15614-7 [1] is the conducting of preliminary optimizing of surfacing procedures on standard test specimens in the form of plates or pipes (Figures 1 and 2).

In ISO 15614-7 a regulatory reference to standard ISO 15613 [2] is given, which admits the carrying out of tests of deposited non-standard test specimen, simulating the industrial parts in shape and sizes in that case when their geometry, specific boundary conditions, heat removal, etc. cannot be reproduced by standard specimens. In this case, during qualification, based on the so-called pre-industrial testing, it is necessary to coordinate the details of preparation of non-standard test specimens, scope of tests and requirements to test results with the expert body. The surfacing of test specimens is performed in accordance with pWPS developed by manufacturer in the presence of expert appointed by the expert body.

Volume of tests and evaluation of results. The tests include the non-destructive and de-

Table 1. Types of tests for surfaced tests specimens [1]

Specimen	Type of test	Volume of control	Notes
All types of surfacing, except wear-resistant one	Visual inspection	100 %	–
	Ultrasonic flaw detection	100 %	*a*
	Detection of surface cracks	100 %	*b*
	Lateral bending	2 specimens	*c*
	Examination of macrostructure	1 specimen	–
	Examination of microstructure	Same	*d*
	Chemical analysis	»	–
	Content of delta-ferrite/ferrite number (FN)	»	*a*
	Hardness measurement	1 measurement	*d*
Wear-resistant surfacing	Visual inspection	100 %	–
	Detection of surface cracks	100 %	*b*
	Examination of macrostructure	1 specimen	–
	Hardness measurement	1 measurement	–
	Examination of microstructure	1 specimen	*d*

a — if required by appropriate standards;
b — dye penetrant or magnetic powder flaw detection;
c — bending in transverse direction can be replaced by ultrasonic flaw detection, plus two additional examinations of macrostructure;
d — not required for metal of group 1 acc. to ISO 15608 [3].

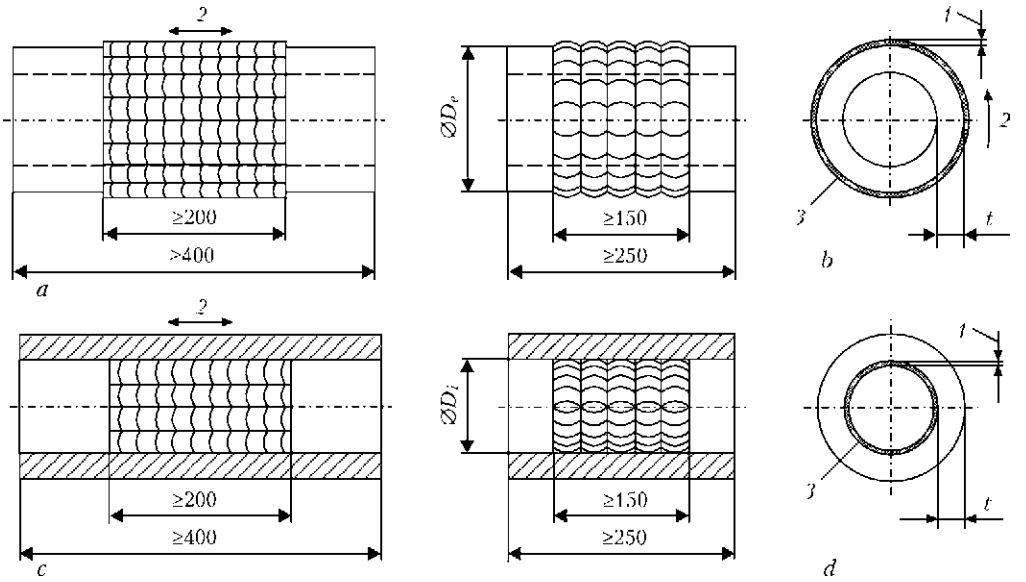

Figure 2. Surfaced test specimen (pipe): *a* — longitudinal surfacing of external surface; *b* — circumferential surfacing of external surface; *c* — longitudinal surfacing of inner surface; *d* — circumferential surfacing of inner surface; *1* — buffer layer (sublayer, deposited when necessary); *2* — direction of surfacing; *3* — numbers of layers according to pWPS or total thickness of deposited layer; D_e — external diameter of pipe; D_i — inner diameter of pipe; t — thickness of base metal [1]

structive methods in accordance with requirements (Table 1). NDT of test specimens should be made before cutting of specimens for tests. Heat treatment after surfacing, which is preset by the technical specifications, should be carried before the NDT.

If the test specimen satisfies the requirements of visual inspection (cracks and other similar plane defects are inadmissible) and NDT, then the specimens for destructive testing are cut out from it (Figures 3 and 4).

Specimens for examination of macro- and microstructure should be prepared and etched on one side so that to reveal clearly the fusion line, HAZ and deposited layers. Specimens for examination of macrostructure should include a base metal, not touched by a heat effect of surfacing.

Hardness is measured by Vickers method at load $HV10$ or $HV5$. Hardness of deposited layer should be measured under angle of about 15° to the edge surface (Figure 5). In case of wear-resistant surfacing it is necessary to make at least five measurements on polished deposited surface of the test specimen. Hardness is determined as an average value of five measurements.

Hardness of base metal in HAZ should not exceed allowable maximum values, given in Table 2. In case of wear-resistant surfacing it is

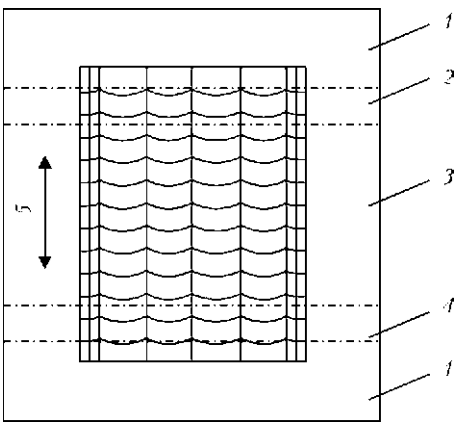

Figure 3. Sequence of specimens cutting out from surfaced plate (test specimen): *1* — non-controlled zone ≥25 mm; *2* — region for specimen cut out for transverse bend tests; *3* — region for specimen cut out for examination of macrostructure, specimen for chemical analysis and determination of delta-ferrite content; specimen for examination of microstructure with hardness measurement; region for cut out of specimens for repeated examinations; *4* — region for specimen cut out for transverse bend tests; *5* — direction of surfacing

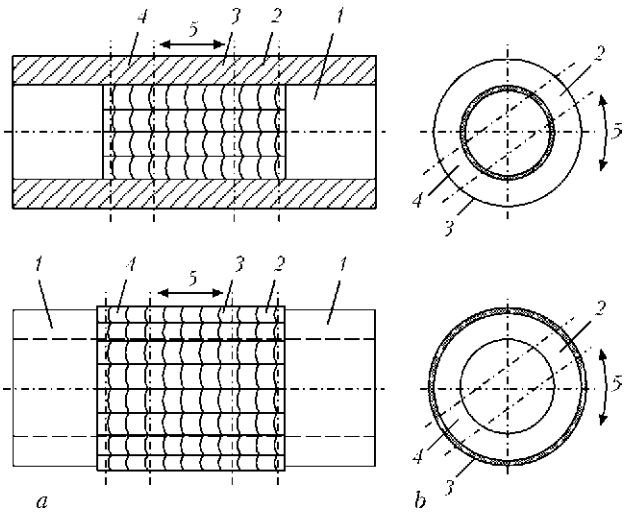

Figure 4. Sequence of cutting out of specimens from pipe (test specimen): *a* — longitudinal deposited layer; *b* — circumferential deposited layer (designations are the same as in Figure 3)

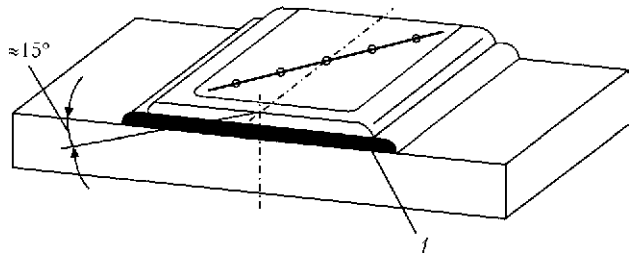

Figure 5. Line of hardness measurement of surfaced specimen: *1* — buffer layer (sublayer)

necessary to determine the maximum value of hardness of the deposited layer. At test for lateral bending the specimen should not have single cracks of length of more than 3 mm in any direction.

WPQR. If as a result of testing the inadmissible defects were not detected, then the expert body makes a protocol of qualification of surfacing procedure (WPQR). This protocol contains the following data:

- areas, covered by qualification;
- information on technology of surfacing and heat treatment of test specimen;
- results of testing.

It is indicated in the chapter of protocol WPQR, devoted to the areas, covered by qualification:

- process of surfacing according to EN ISO 4063;
- application of surfacing (wear-resistant or another);
- structure of deposited layer (single-layer or multi-layer, number of layers).

In all methods of surfacing, except wear-resistant one, the qualification of single-layer surfacing is valid for the multi-layer one, if the similar technology of surfacing is applied. However, the qualification of the multi-layer is not valid for the single-layer one. In case of the wear-resistant surfacing the qualification of single-layer surfacing is not valid for the multi-layer surfacing. Qualification of the multi-layer surfacing with N layers is valid also to the multi-layer surfacing with number of layers up to $(N + 4)$.

Grade, designation and size of electrode (filler) material. Allowance for electrode (filler) material, used in qualification, is valid for other electrode (filler) materials at the conditions that they have equivalent mechanical properties, same type of covering and chemical composition according to designations in a proper standard for electrode (filler) material.

Surfacing current (welding), its kind and polarity. The amount of heat used in surfacing (welding) is determined by EN 1011-1. The upper limit of area of validity of qualification by the amount of heat used for each layer is allowed to

Table 2. Allowable maximum values of HAZ metal hardness ($HV10$)

Group of steels acc. to ISO/TO 15608	Without heat treatment	With heat treatment
1[a]: Unalloyed and fine-grained steels	380	320
2: Heat-hardened steels	380	320
3[b]: Heat-hardened and dispersion-hardened steels	450	380
4: Low-vanadium Cr–Mo–(Ni) steels	380	320
5: Vanadium-free Cr–Mo steels with C ≤ 0.35 %	380	320
6: Cr–Mo–Ni steels with increased vanadium content	–	350

[a]If determination of hardness is required.
[b]For steels with R_{eH} > 890 N/mm^2 the maximum hardness should be specified.

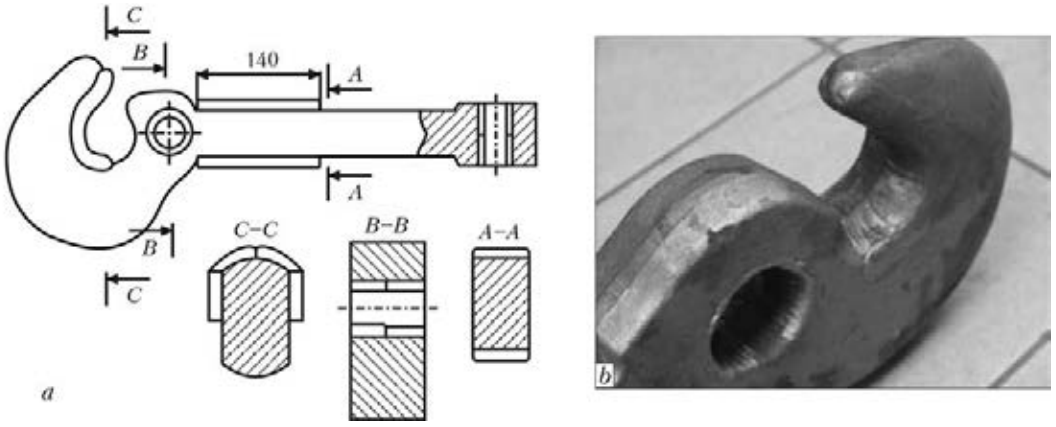

Figure 6. Scheme (*a*) and appearance of drawhook (*b*) with deposited layer 4.0–6.2 mm thick

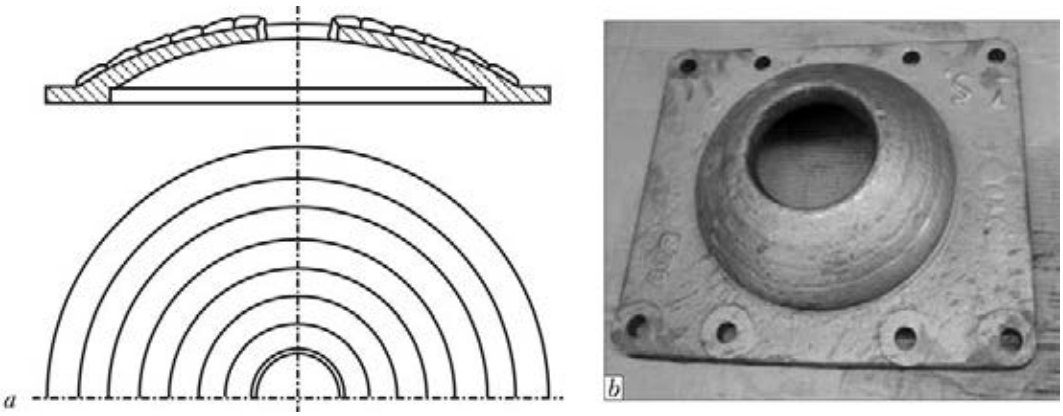

Figure 7. Scheme of cast pivot of steel 45L (with outside diameter of 350 mm, wall thickness of 30 mm (*a*), and appearance of surfaced part with deposited layer 4.0–13.8 mm thick (*b*)

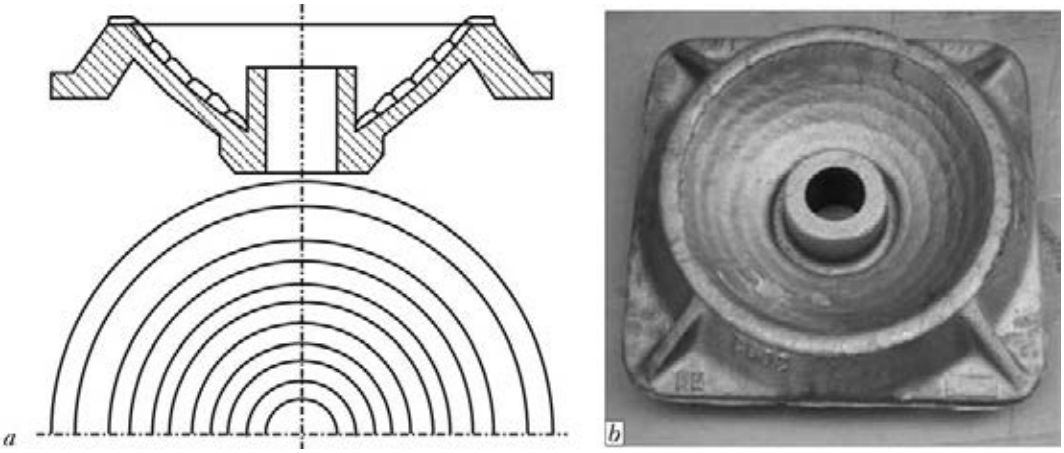

Figure 8. Scheme of cast pivot pocket of steel 45L (with outside diameter of 380 mm, wall thickness of 32 mm (*a*), and appearance of surfaced part with deposited layer 9–13 mm thick (*b*)

be set by 25 % higher than the amount of heat supplied for such layer in test specimen surfacing. The lower limit is set by 10 % lower than the amount of heat used in surfacing of the same layer of test specimen.

Position of surfacing. It is allowed to perform surfacing in such a position, at which the surfacing of test specimen was performed.

Temperature of preheating, temperature between passes and heat treatment after surfacing. Adding or refusal of heat treatment after surfacing are not admitted.

Examples of qualification of surfacing procedures. In industrial practice the qualification of procedures of surfacing (welding) is carried out in accordance with ISO 15614-1 [4, 5]. Rods of hydraulic-powered supports are referred to those parts, the technology of surfacing of which was qualified by using this standard, making surfacing of standard test specimens. Qualification of mechanized surfacing with consumable electrode in active gases, under flux and laser surfacing of rods of 38–329 mm diameter of steel 40Kh, 32KhA and 45G2 was carried out. The pre-industrial tests of surfaced non-standard test specimens by ISO 15613 taking into account the requirements of ISO 15614-7, were carried out as applied to crane wheels, parts of power stop vales and parts of railway cars (Figures 6–8).

As a result of tests the qualification of procedures of surfacing of all above-mentioned parts in accordance with ISO 15614-7 was carried out. Protocols of qualification of procedure of surfacing (WPQR) were transferred to the enterprises, which are dealing with surfacing of these parts.

1. *EN ISO 15614-7:2007*: Specification and qualification of welding procedures for metallic materials. Welding procedure test. Pt 7: Overlay welding.
2. *EN ISO 15613*: Specification and qualification of welding procedures for metallic materials. Qualification based on preproduction test.
3. *ISO/TO 15608*: Welding. Guidelines on system of grouping of metallic materials.
4. *ISO 15614-1:2009*: Spefification and qualification of welding procedures for metallic materials. Verification of welding procedure. Pt 1: Arc and gas welding of steels and nickel alloys.
5. Kuzio, T. (2007) Kwalifikowanie technologii spawalniczych przez Instytut Spawalnictwa. *Biuletyn Instytutu Spawalnictwa*, **2**, 50–54.

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