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EXAMINATION AND DETECTING DISCONTINUITIES IN THE AUSTENITE INCONEL 625 LAYER USED ON THE SHEET PILE WALLS OF THE BOILER'S EVAPORATOR TO UTILIZE WASTE THERMALLY

WYMAGANIA JAKOŚCIOWE STAWIANE POWŁOCE AUSTENITYCZNEJ INCONEL 625 STOSOWANEJ NA ŚCIANACH SZCZELNYCH PAROWNIKA KOTŁA DO TERMICZNEJ UTYLIZACJI ODPADÓW

There are practical aspects of a quality control of the Inconel 625 surfacing weld in terms of undergone examinations and detected defects in chapter three of the article. Visual inspections, examinations of the thickness of the surfacing weld, examinations of an iron content on the surface of the surfacing weld and detecting surface cracks are described. A process of undergone practical examinations is presented.

Keywords: surfacing by welding, surfacing layer, incinerator

W rozdziale trzecim przedstawiono praktyczne aspekty kontroli jakościowej napoiny Inconel 625 w ujęciu wykonywanych badań i wykrywanych niezgodności. Omówiono badania wizualne, badania grubości napoiny, badania zawartości żelaza na powierzchni napoiny oraz wykrywanie pęknięć powierzchniowych. Zaprezentowano przebieg praktycznie wykonywanych badań.

1. Basic examinations and detecting defects – practice

Basic examinations which the Inconel 625 [1-12] surfacing weld needs to undergo during a quality acceptance are [13]:

a) Visual inspections;
b) Examinations of the thickness of the surfacing weld;
c) Examination of an iron (Fe) content on the surface of a surfacing weld;
d) Detecting surface cracks.

2. Visual inspections

Visual inspections are the basic examinations taken on all kinds of welds and surfacing welds. Non-destructive testing follow visual inspections, however, positive visual assessment is a key to the further and more complex control such as surface cracking, ultrasonic testing on fusion or examinations of an iron content in the surfacing weld. It is made to reduce a cost of examinations, if a visual inspection reveals defects in the surfacing weld, it is unfounded to undergo any other expensive examinations until all the defects are removed [14-16].

Visual inspections can be carried out by the staff who have an appropriate authorisation according to the PN-EN ISO 9712 standard. On the other hand, the PN-EN ISO 17637 standard describes conditions in which examinations need to be taken:

- light intensity on the examined area should be at least 350 lx, however a recommended value is 500 lx;
- a distance between an eye of the examiner and an examined area should be up to 600 mm;
- an angle of a view should not be lower than about 30°.

2.1 Piping, craters, and cracks

Following defects can be revealed by the visual inspection:

a) piping, end craters, cracks;
b) insufficient overlapping of beads;
c) irregularity of the surface, fastener effect.
d) Piping, end craters and cracks are the basic defects described in the Merkblatt 1166,

which were mentioned in [17-19]. Figure 1 presents piping in the surfacing weld Inconel 625.

Visual inspection, which aim is to detect piping and cracks, is usually carried out in two stages. The first stage is to make an inspection directly after finishing surfacing by welding. Detected defects, on this stage, are removed by hand by the 141 method (fig. 2). Furthermore, the surfacing weld is being cleaned by e.g. the glass shot. The second stage of

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the visual inspection is carried out on the cleaned surface in order to reveal defects previously omitted by the controller. It is advisable to make two-stage inspection because some of defects are better seen before cleaning the surface. On the same time, due to cleaning, piping, and cracks, which became invisible before cleaning, are either highlighted or revealed.

Visual inspection is always made in 100%. It means that if the surfaced by welding element of the sheet pile wall is up to 10 meters long and 0,8 meters wide, an area of an inspection is even 8 m². Therefore, it is easy to omit defects such as piping or cracks in such examined areas. It is recommended to divide an inspected area into segments from 0,5 to 1 meter long. Thus, we obtain sectors, which examining is less difficult, and a risk to omit defects is reduced.

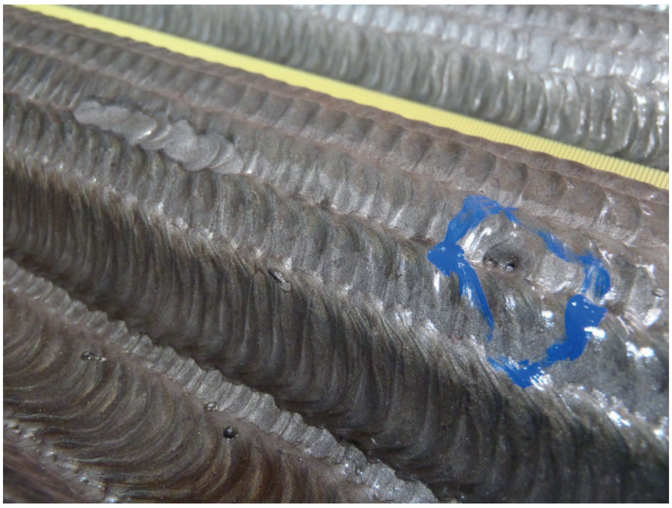

Fig. 1. Piping in the surfacing weld
Source: own collections

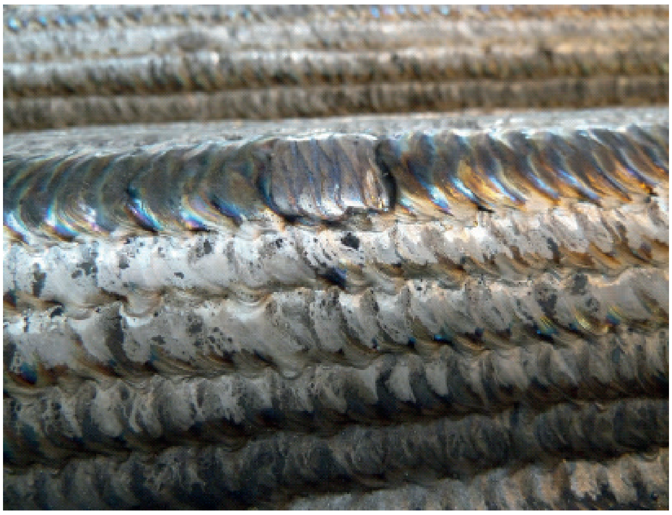

Fig. 2. Piping in the surfacing weld repaired manually by the 141 method
Source: own collections

End craters always appear on the initial and final line of the surfaced by welding area. It is recommended to remove them as they appear on the areas subject to corrosion. The easiest, and often the only way of getting rid of them is to make transverse beads by the 141 method in this place. Thus, we obtain a smooth transition to the base material (fig. 3).

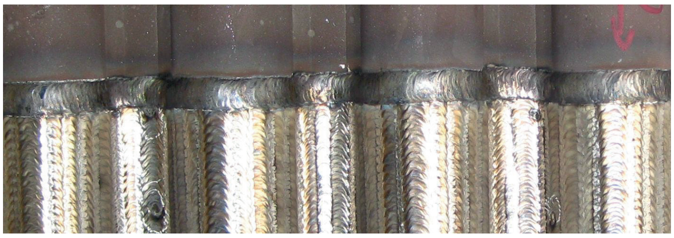

Fig. 3. Initial line of the surfaced by welding area with a transverse bead made manually by the 141 method
Source: own collections

3. Insufficient overlapping of beads

An examination of overlapping beads of the surfacing weld is used for a single-pass surfacing if there is a requirement of 50% overlapping the beads. This requirement conditions the system of beads of the surfacing weld, which needs to be precisely described by the welder before starting welding in the WPS (Welding Procedure Specifications) – an instruction given to the welder. Numerous factors should be taken into account while preparing a system of beads:

- a width of a singular bead;
- a scale of the panel of the sheet pile wall;
- curvature of the pipe;
- a minimal thickness of the surfacing weld bigger or equal 2mm.

Properly prepared system of beads beside guaranteeing 50% of beads overlapping should eliminate an accumulation of beads, and an excessive increase of the surfacing weld. In the picture 4, the WPS sketch, which illustrates an order of making beads of the surfacing weld on the sheet pile wall, is provided.

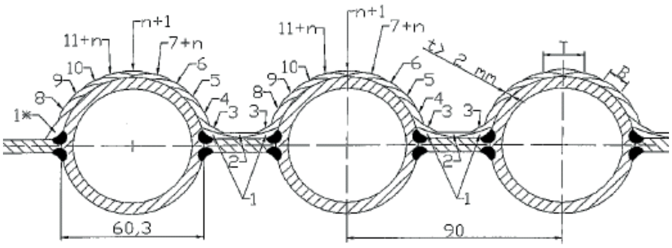

Fig. 4. The WPS sketch showing the way of making beads of the surfacing weld on the sheet pile wall in the scale 90 mm (Ø 60,3 mm pipe)
Source: own study

In order to check if beads are overlapping each other in 50% before starting to control the surfacing weld it is necessary to determine an average width and thickness of a bead. Figure 5 shows the bead made by the CMT method, which in comparison to beads made by the 135 method is relatively convex, and its edges are steep on both sides. Width of the bead in this case is 18 mm, and its thickness is 1,8 mm.

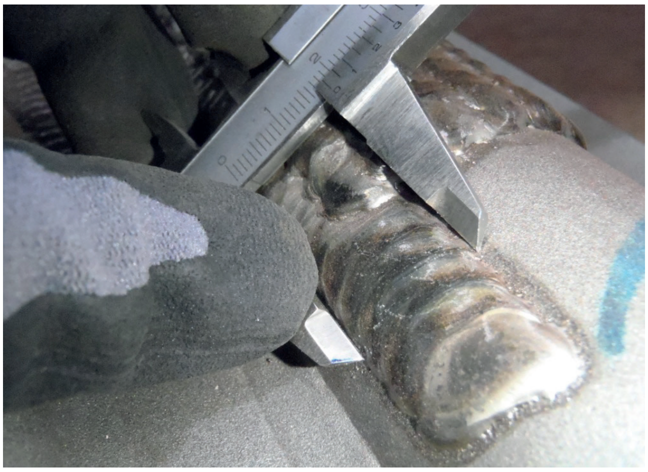

Fig. 5. Bead made by the CMT method. Width of the bead is about 18 mm, and its thickness is 1,8 mm
Source: own collections

Assuming that an average thickness of the bead is 18 mm, and that beads are overlapping in 50 %, thickness of a visible part of the bead is 9 mm. It means that in case of beads for which thickness of a visible part is more than 9 mm, there is a risk that beads are not over lapping in 50 %. There is a measurement of a width of a visible part of the bead, which in this case is 11 mm, in the picture 6. There are well-founded reasons that a condition of 50% of overlapping the beads in this place is not fulfilled.

Fig. 6. Measurement of the beads' thickness
Source: own collections

4. Irregularity of the surface, fastener effect

Despite there are not any formal guidelines about an acceptance level of an irregularity of the surface, a practice shows that the smoother the surface is the more resistant to corrosion it becomes [11]. It means that the least irregular surface of the surfacing welds is preferred.

Comparing surfacing welds made by different producers it can be noticed that there is a considerable difference in the appearance of the surface. The key factor which determines an appearance of the surfacing weld is a method of surfacing by welding, however there are noticeable discrepancies within the same methods (fig. 7A and B). As it is seen from the picture below, besides a method of surfacing by welding there are factors which have an influence on an appearance of the surfacing weld. These are primarily parameters of welding such as speed and oscillation of the welding torch, current intensity, voltage, speed of surfacing by welding and shielding gas.

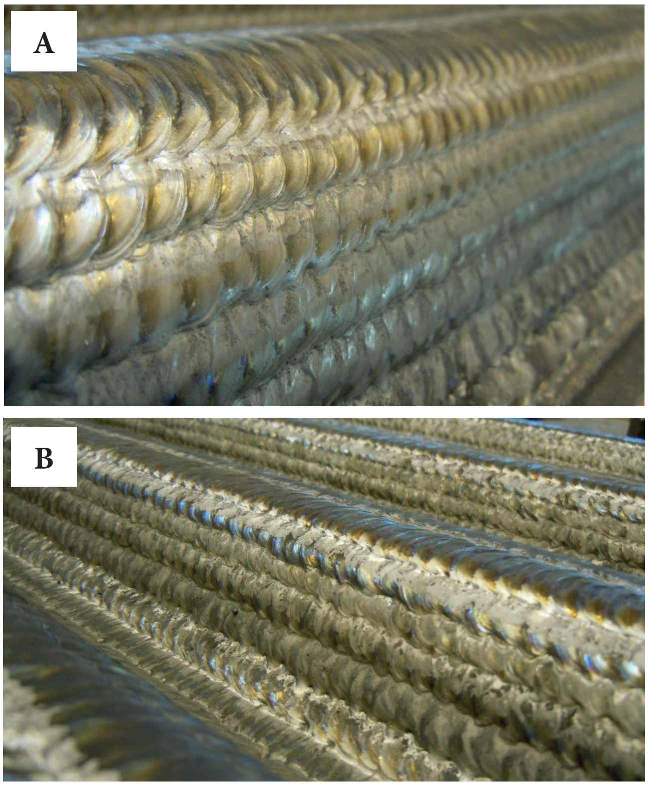

Fig. 7. Two different surfacing welds made by the CMT method
Source: own collections

One of the signs of the surface irregularities are regular hollows on the beads' boundaries forming so called "fastener effect" (fig. 8). These hollows are the places where corrosion will appear faster during the boiler's operation.

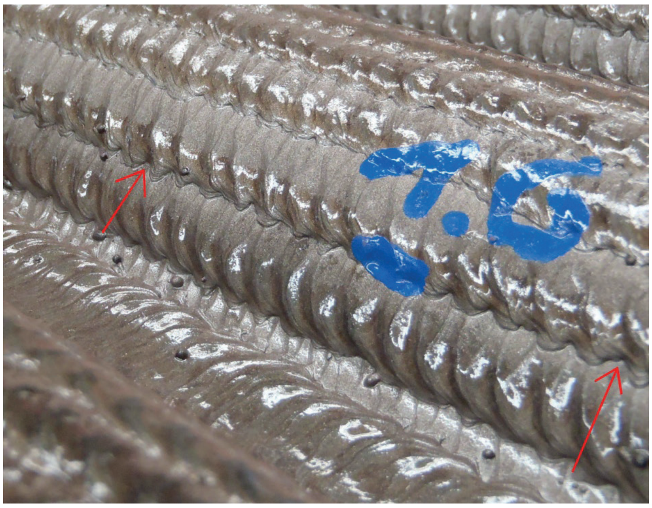

Fig. 8. Systematic irregularities on the beads' boundaries – "fastener effect"
Source: own collections

5. Examinations of the thickness of the surfacing weld

Ultrasonic testing is the basic method of examining a thickness of a surfacing weld. As a result of an ultrasonic testing we receive a total thickness of an examined element which consists of the thickness of a surfaced by welding material and the thickness of the surfacing weld. In order to get the thickness of the surfacing weld we need to take away from an obtained value of the total thickness the thickness of the surfaced by welding material. Thus, it is an indirect method of examining the thickness. Additionally, before starting an examination, it is necessary to prepare properly a surface by grinding irregularities on the measurement points to guarantee a suitable coupling.

Above limitations caused that nowadays the most frequent method of measuring the thickness of the surfacing weld is the method of a magnetic induction. Therefore, we receive direct values. A value is read on the display screen. There are devices in the picture 9 made by two different companies widely used to control the thickness of the Inconel 625 surfacing weld.

Fig. 9. Devices used to measure the thickness of the Inconel 625 surfacing weld
Source: own collections

A surface of the surfacing weld is not homogenously smooth because it consists of singular beads. There are hollows on the boundaries of the beads, which spread lengthwise a surfaced by welding element. These are exactly the places, on the beads' boundaries, where the probability of the least thickness is the highest. These areas are the most precisely controlled.

In case of a single-pass surfacing when a condition of a proper overlapping of beads is not kept, linear areas of an insufficient thickness of the surfacing weld may appear on the beads' boundaries (fig. 10)

Fig. 10. An area on the beads' boundaries of an insufficient thickness
Source: own collections

On the other hand, improper set of layers which results in an excessive accumulation of the surfacing weld's material, causes that we obtain thickness much higher than 3 mm (fig. 11). A key issue is a geometry of the surfacing by welding area, which in case of sheet pile walls causes that it is unavoidable to obtain the surfacing weld bigger than 3 mm thick in some areas. These areas are e.g. flat bars or fillet welds joining pipes with flat bars.

Fig. 11. Measurement of the thickness of the Inconel 625 surfacing weld on the flat bar
Source: own collections

A character of the surface requires that used probes allow to measure hollows on the beads' boundaries. It is necessary to take into account a shape of the probes used to make measurements. There are two different probes, which are used to control the thickness of the surfacing weld in the picture 12. The probe on the left is characterised by a sticking ball, thus even small diameter hollows are possible to measure. On the other hand, the probe on the right does not have such extended measuring element. Therefore, in some areas of hollows it is impossible to touch an examined surface and make a measurement. It means that the probe on the left is more appropriate to examine surfacing welds of huge irregularities of the surface.

Fig. 12. Probes used to measure the thickness of the surfacing weld
Source: own collections

6. Examinations of an iron content on the surface of the surfacing weld

X-ray spectrometer is used to examine an iron content on the surface of the surfacing weld (fig.13). According to the Merkblatt 1166 an iron content on the surface of the surfacing weld should not exceed 10%. Although, there are much sticker requirements, which specify a content of iron on the level of 5%, put by the customers. It is also necessary to point that the content of iron is different for surfacing welds made by the machine, and by hand. In case of surfacing welds made by the machine for the CMT method values are rarely higher than 3% of an iron content on the surface.

Fig. 13. Examining an iron content on the surface of the surfacing weld by the X-ray spectrometer
Source: own collections

An iron content for the surfacing welds made by hand ranges from 5% to 10%. However, there are often values which exceed 10%. Key issues are skills of the welder. Additionally, manual surfacing by welding is usually made in difficult positions, and difficult areas to reach. It also happens that it is impossible to guarantee a proper circulation of water in the pipes in the manual surfacing by welding. Therefore, cooling is limited, and as a result an iron content is increased.

In order to obtain reliable results examining a content of iron needs to be taken on all areas of sheet pile wall i.e. on the top of the pipe, side of the pipe, and on the flat bar. Places of examinations are shown in the picture 14.

Fig. 14. Places of examining a content of iron on the surface of the surfacing weld
Source: own collections

7. Examining a presence of surface cracks

The Inconel 625 surfacing weld is not a ferromagnetic structure. Therefore, among two different methods of detecting surface cracks (magnetic-powdered method and penetrant test) only penetrant test (PT) is possible.

According to the Merkblatt 1166 a scope of PT is as following [13]:

- initial and final parts 100%;
- at least 2% of a total surface.

Some of the customers require an additional examination by spreading penetrant tests:

- manual surfacing welds – scope of tests 100%;
- starting and finishing lines leading to the base material – scope of tests 100%;
- reparations made manually – scope of tests 100%;
- surfacing welds made on the elements, which are bent in the further production process (fig. 15 and 16) – scope of tests 100%;

The Merkblatt 1166 specifies a minimal time of penetrating a penetrant for 20 minutes, and the time of induction for at least 10 minutes. After this time, we can start to assess the values, however piping leading into the base material, end craters and cracks are unacceptable. On the same time, piping which do not lead into the base material, due to a possible accumulation of corrosive factors, and resulting from it an increased corrosion, should be avoided [13].

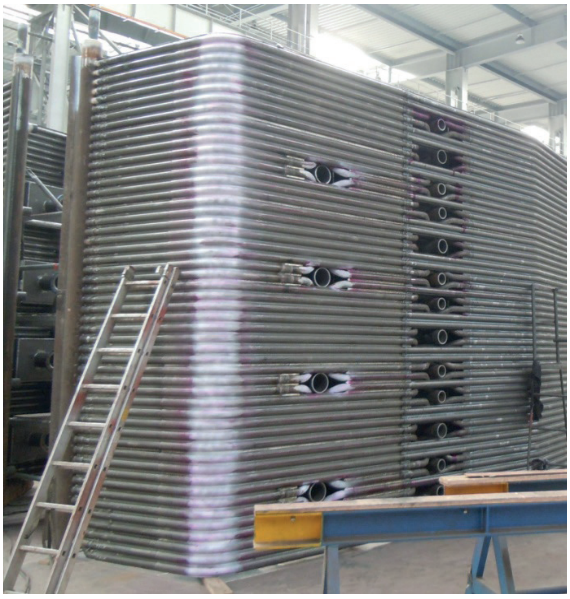

Fig. 15. Surfaced by welding and bent part of sheet pile wall of the boiler after PT
Source: own collections

It is vital to point that surfacing welds' cracks happen very often due to bending singular spirally surfaced by welding pipes. It is connected with a technology of spirally surfacing by welding where pipes are covered by beads. They run perpendicularly to the tensile force influencing the surfacing weld on an external bending arc. It happens that cracks appear on the boundaries of beads during bending pipes spirally surfaced by welding. It is illustrated in the picture 16.

Fig. 16. An indication of the crack after PT on the singular pipe spirally surfaced by welding
Source: own collections

If cracks after bending do not move into the base material of the pipe, then it is possible to make a reparation by removing the crack by grinding, and a manual resurfacing by welding by the 141 method (fig. 17).

Fig. 17. Cracks after bending repaired by the 141 method
Source: own collections

8. Conclusion

There is not any unified European standard which contains acceptance requirements for the surfacing layers made by the surfacing by welding method. Conditions of carrying out examinations of surfacing by welding technology and acceptance criteria of qualifying technologies of surfacing by welding are presented in the PN-EN ISO 15614 standard, part 7. There are basic quality requirements for surfacing layers made by the surfacing by welding method in the Merkblatt 1166, a document published by the German experts association.

According to the Merkblatt 1166 the surfacing weld needs to be free from such defects as piping, craters and cracks with a content of iron on the surface less than 10%. Due to an increasing knowledge about corrosive processes, which appear in the boilers used to thermally utilize waste, and technological progress in terms of welding application of surfacing layers cause that quality criteria put on the Inconel 625 surfacing weld become more and more restrictive.

Nowadays, it is not a problem if a content of iron on the surface of the surfacing weld is 10%. On the other hand, though, not only a content of iron, but also an appearance of the surface plays a major role. As well as a belief that he smoother and flatter the surface is, the better resistance to corrosion is.

A lack of unification of quality requirements in the forms of widely used standards results in the fact that producers of boilers make their own technical specifications which contain quality criteria. If the Inconel 625 surfacing weld is ordered to be made by the subcontractor a reference surfacing layer, which is an example of the subcontractor's production possibilities, is recommended to be prepared. On the same time, a continuous supervision during making surfacing by welding, which aim is to detect technological mistakes and to avoid expensive reparations, is requires.

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