POLYSOUDE
THE ART OF WELDING

Press Release

Polysoude TIG^{er} Technology

Introduction

Tests on the new TIG^{er} technology have been conducted by the Italian Welding Institute. Developed, manufactured and provided by Polysoude, specialist in orbital welding and in the construction of automated and robotic welding and cladding equipment, TIG^{er} (Fig.1) has been developed from HW TIG/GMAW technology.

Hot wire technology is already used extensively in the cladding field. It consists of the preheating of a filler material, usually wire, by Joule effect due to the current. This condition reduces the quantity energy taken from the electrical arc, which is required to melt the wire, consequently the efficiency of the thermal source is improved by assuring increased productivity in terms of welding speed and deposit rate, so that a better joint of the welding seam is achieved.

TIG^{er} Technology is an evolution in Hot Wire technology, because in addition to the pre-heated filler wire, TIG^{er} incorporates a unique system of two tungsten electrodes in tandem configuration, with each electrode being separately fed. Contrary to the most common tandem configurations on the market, in the TIG^{er} process, the two thermal sources join, in order to create a single arc (Fig.2). In this special configuration, the two conductors are placed parallel to each other, a current is passed through them, flowing in the same direction. There is an attraction between the two electrical arcs from the conductors to reach the same point of interpenetration. Thus, a single arc is formed, which even though generated from two different electrodes, means lower arc pressure than in classic tandem configurations. For this reason, with the TIG^{er} Technology, higher current intensities can be used by assuring higher speeds and higher deposit rates, whilst at the same time achieving lower dilution rates. These features make the process highly suitable for cladding.

The requirements of this field are not easily met. The challenge is to achieve enhanced productivity, by increasing deposit rate and cladding speed, whilst keeping the lowest possible dilution, in order to reduce the number of layers and thereby optimize production times and costs of consumables.

Polysoude S.A.S.
ZI du Bois Briand
2 rue Paul Beaupère - F - 44300 NANTES
Tél. : +33(0)2 40 68 11 00 - Fax : +33(0)2 40 68 11 88
www.polysoude.com - E-mail : info@polysoude.com
Société par actions simplifiée, au capital de 4 105 452 Euro,
R.C.S. Nantes B 858 800 931
TVA N° : FR 64858800931 - a member of Global Welding Technologies AG

From an economical point of view, the benefits are evident. As a result of its characteristics, the TIG^{er} process is suited to both horizontal and vertical cladding. Obviously, there are new parameters to be considered during the development of the process, in particular with regard to the orientation of the electrodes and the filler wire. Regarding the first parameter, in order to reduce the penetration depth and consequently the deposit dilution, Polysoude stipulates that the tungsten electrodes must be aligned, otherwise, if they are side by side, the penetration depth increases. (Fig.4: a comparison of the effects of the different configurations.)

C	Si	Mn	P	S	Cr	Ni	V	Al	Cu	Nb	N	Fe
0.15	0.23	1.21	0.01	0.006	0.02	0.01	0.019	0.03	0.02	0.02	0.005	98.20

Table 1 Chemical analysis of the base material ASTM A5 16 Gr. 60

C	Si	Mn	P	S	Cr	Mo	Ni	Cu	Ti	Al	Nb	Fe	Ta
< 0,01	0,05	< 0,01	0,005	<0,001	22,51	8,94	64,2	0,01	0,19	0,10	3,62	0,25	0,004

Table 2 Chemical analysis of the consumable UTP A6222 Mo-3

With regard to the configuration between electrodes and wire, Polysoude recommends keeping an angle of 65° between the electrodes and the base material and of about 20° between wire and base material (Fig.5.). Polysoude confirms that such a configuration, allows the capacity to achieve clads, which are characterized by extremely reduced dilution rates (about 11% for the first pass and 1.5% for the second pass), together with well-cladded seams, realized using cladding speed values, which can reach 950 mm/min and by deposit rates up to 6 kg/h. Such values are very close to the usual deposit rates of MIG-MAG (GMAW) cladding with less quality.

Realization of a cladded specimen using the TIG^{er} process

As previously stated, the deposit quality, good dilution rates and deposit rates much higher than those reached by the traditional TIG process, make the TIG^{er} process ideally suited to cladding. For this reason, the consumable was tested by realizing a cladded specimen, with 2 passes on carbon-manganese steel (ASTM A516 Gr.60) based material, thickness 60 mm. Tables 1 and 2 report respectively the chemical analysis of the base material and the filler material (UTP A6222 Mo-3 wire). A phase of implementation of the specimen carried out at Polysoude premises in Nantes, is illustrated in Fig.6. As seen in Fig.6, the cladded specimen has a regular aspect – typical of the TIG process – characterized by the absence of oxides and/or discoloration. On completion of the second layer, the welded specimen was shipped to an independent Laboratory, to run the usual tests on the characterization of the overlay.

Characterization of the overlay realized with the TIG^{er} process:

The aim of the tests carried out on the specimen was to evaluate the quality of the cladded joint for a typical application, such as the weld overlay of nickel alloy on a substrate in ferritic steel. The main properties required of a component like this are:

- correct adherence between cladded layer and substrate,
- control of the dilution rate and, consequently, of the chemical analysis of the surface of the cladded layer
- corrosion resistance for given types of corrosive agents
- optimized heat cycle in order to avoid the presence of particularly fragile structures inside the heat affected zone (ferritic side)

Such features were evaluated after the completion of non-destructive surface tests such as visual tests and dye penetration inspection, which were carried out on the specimen by:
- checking adherence by means of ultrasonic testing according to ASME code, sec. V, art. 4
- side bend tests according to ASME code, sec. IX, art. II
- chemical analysis of the first and second layers
- macrographic and micrographic analysis of the specimen
- hardness analysis
- corrosion tests according to ASTM G48, method A

Check of the correct adherence of the layer:

The check of the correct adherence between layer and substrate was evaluated by means of non-destructive ultrasonic tests and destructive side bend tests.
For the first control, the pulse-echo reflection technique with calibration block for technique 1 was used, as suggested by the ASME code, sec. V, art. 4 (Fig.7). This is also mandatory, since it is an essential variable in writing a qualification procedure for the ultrasonic testing. The scan was realized on the base material side.
The result of the ultrasonic analysis of the specimen was positive and later confirmed by the side bend testing.

Side bend testing:
For the side bend test, the samples were extracted in a direction perpendicular to the cladded one and subsequently bent to an angle of 180°.
The results, illustrated in Fig.8, were positive, since they did not show any discontinuities relating to operative faults, such as gluing or areas characterized by inadequate adherence.

Cladded layer	C	Mn	Fe	P	S	Si	Cu	Ni	Ti	Cr	Nb	Mo
First	0,029	0,135	12,16	0,0046	0,0063	0,018	0,0278	57,04	0,1309	19,25	3,279	7,74
Second	0,004	0,0218	1,04	0,0050	0,0066	0,001	0,0178	63,97	0,1568	21,93	3,701	8,93

Table 3 Chemical analysis of the specimen realized with TIG^{er} technology

Chemical analysis of the cladded layer:

The cladded layer, realized with AWS A5.14 ERNiCrMo-3, incorporated the chemical features of a nickel alloy UNS N06625. As one of the main applications of the TIG process is the cladding of components designed for aggressive environments, this alloy is ideal as it affords optimal mechanical resistance to corrosion in different aggressive environments. Within its chemical composition, are elements such as Mo, Nb and Cr. Molybdenum and Niobium, produce a hardening of the Ni-Cr matrix of this alloy, assuring yield points of between 400

and 600 MPa, with percentage elongations of about 40%. The presence of Molybdenum, moreover, assures the alloy an optimal resistance to localized corrosive attack, avoiding such typical phenomena, as pitting and crevice corrosion. In addition, the presence of stabilizing elements, such as Nb and Ta, reduces the susceptibility of the alloy to the phenomenon of sensitization, especially during welding. Finally, chromium ensures good resistance in oxidising environments.
It is essential, during cladding with this material, to check and preserve the chemical analysis of the cladded layer, in order to guarantee specific characteristics of the alloy. For example, some customers may require that the iron content is less than 5% in order to ensure excellent corrosion resistance.
In order to evaluate the dilution generated from TIG^{er} process, two different chemical analyses were carried out on the first and second cladded layers respectively, as shown in Fig.9. Table 3 reports the results of the chemical analyses carried out with an emission spectrograph (Fig.10). The results of the chemical analyses are extremely positive. From the first cladded layer all elements, except for iron, are within the limits of AWS A5. 11 ENiCrMo-3 for weld metal, where the limit for iron is 7%. In the second layer, the iron value is extremely low, close to 1%, so that an optimal corrosion resistance of the cladded layer could be expected. For these reasons, it was decided to further test the specimen by submitting it to the ASTM G48 method A corrosion test: “Standard Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution”.

Evaluation of the resistance to the localized corrosive attack:

From the achieved specimen, a sample was taken for the analysis of localized corrosion resistance (pitting and crevice). The evaluation was made by means of a corrosion test according to ASTM G48 method A standard. A sample with a surface of almost 20 cm^3 was immersed for at least 72 hours in a preparation of Ferric Chloride, which had been heated to 50°C. At the end of the test, the sample (Fig.12) shows no corrosion points; this is congruent with the previous chemical analysis, which highlighted, that the second cladded layer had a very low iron value (less than 5%).

Hardness analysis:

The macrograph of the specimen can be observed in Fig.13, where hardness sampling areas are highlighted. As it’s is clear from the picture, the heat affected zone is not large. As expected from the results of the UT and bend tests, the macrograph shows no faults, neither two-dimensional nor three-dimensional. Vickers hardness tests HV10 were carried out at the areas highlighted in Fig.13; the results are indicated in Table 4. The hardness values show no anomalies. Certainly, the most interesting areas are the ones on the ferritic side, where there is the risk of the formation of hardening structures due to the low heat input and heavy thickness of the substrate. In order to better characterize the process and related influence on the properties of the material, forming the cladded layers and the substrate, microstructural investigations were carried out.

Metallurgical analysis:

In order to evaluate the microstructural characteristics of the cladded layers and of the substrate, a micrographical investigation of the areas was carried out, in particular of the heat affected zone (Fig.14 and 15) and the molten zone (Fig.16). The micrographical analysis confirms the results of the hardness tests, in that the heat affected zone shows no off-balanced structures, but an acicular ferrite microstructure, generated from the heat cycle, with dispersed carbides. The molten zone shows the typical aspect of a monophasic dendritic solidification.

Specimen	Zone	Hardness
1	ZF	254
2	ZF	235
3	ZF	241
4	ZTA	258
5	ZTA	207
6	ZTA	157
7	MB	152
8	MB	149
9	MB	154

Table 4 Results of HV_{10} hardness tests carried out on the specimen realized by TIG^{er} process

Conclusions:

In conclusion, the following is a summary of opinion on the production of the TIGer system, together with the various test results and findings.

Voluntary technical documentation	Completeness of the information	The product is disclosed in an exhaustive way both on the manufacturer's website and in the several brochures downloadable from the website. The features of the process and the main fields of application are well-highlighted.
	Quality of the information	Explicative tables and pictures are present and make it possible to understand immediately the properties of the TIG^{er} technology.
Characteristics of the technology	Process principle	The presence of two tungsten electrodes in tandem configuration allows the ignition of two electrical arcs which, by way of the mutual attraction, convey in a single heat source, able to reach welding speeds and deposit rates higher than the classic HWTIG/GMAW process, by keeping the same characteristics.
	Welding speeds and deposit rates	The reachable values of welding speeds and deposit rates vary as a function of the welding and cladding position, however, it is possible, in any case to reach 950 mm/min with a deposit rate from 2.7 to 5.8 kg/h.

	Process applications	The TIG^{er} process finds its main expression in cladding applications, which could be vertical or horizontal in position, both inside (minimum diameter 100 mm) and outside (maximum length 12 m).
Characteristics of the specimen	Adherences of the cladded layer	Both the adherence checks by means of UT tests and the side bend tests according to ASME IX code, Art. II completed on the specimens, had positive results.
	Intergranular corrosion resistance	The intergranular corrosion test, realized according to ASTM G48 – Method A standard, showed no localized corrosion points.
	Chemical analysis of the cladded layer	The chemical analyses realized on the first and the second cladded layer showed an iron content of respectively 12.16% and 1.04%.

Pictures

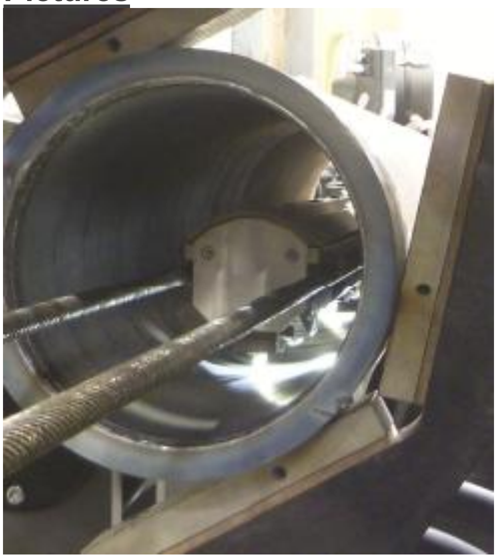

Fig.1 Application of TIG^{er} technology for cladding

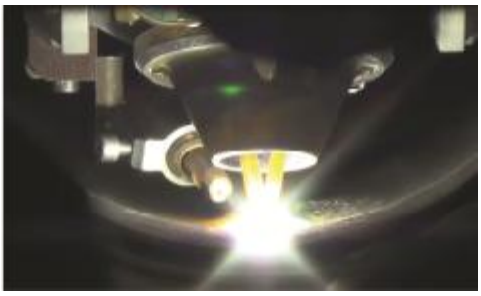

Fig.2 Detail of a working TIG^{er} torch

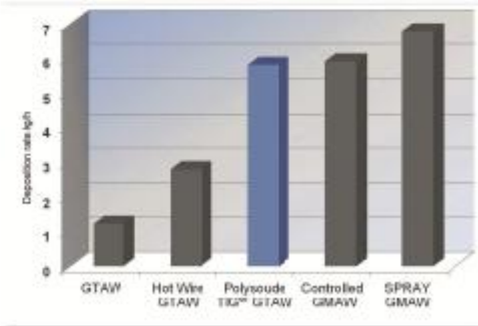

Fig.3 Deposit rate of TIGer technology in comparison with other processes (Source: Polysoude)

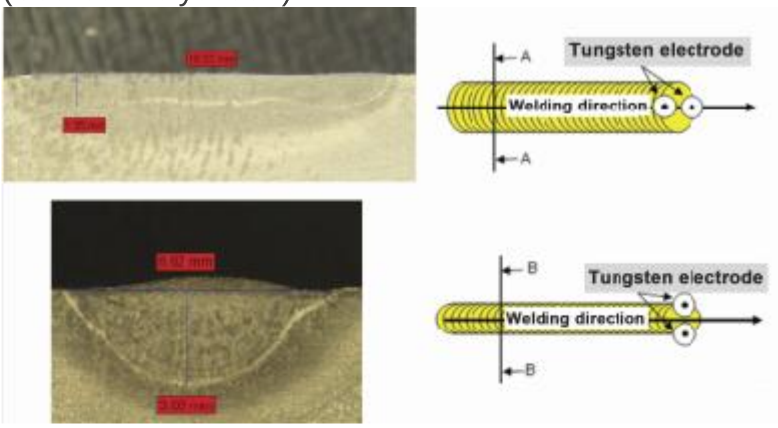

Fig.4 Effect of the linear configuration of the tungsten electrodes on the seam geometry and on the penetration

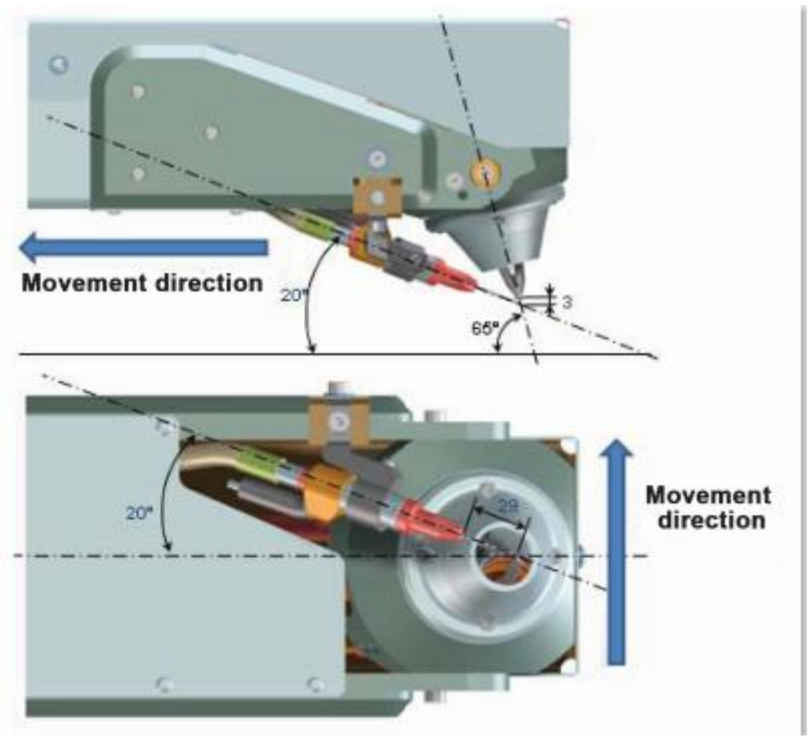

Fig.5 Configuration of a TIGer welding head

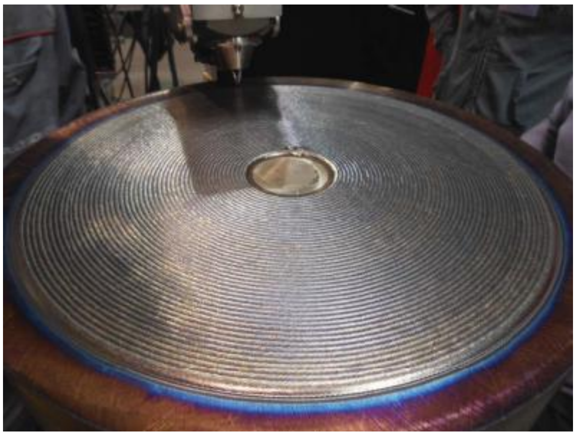

Fig.6 Realisation of the cladded specimen with TIG^{er} process (end of the first cladded layer)

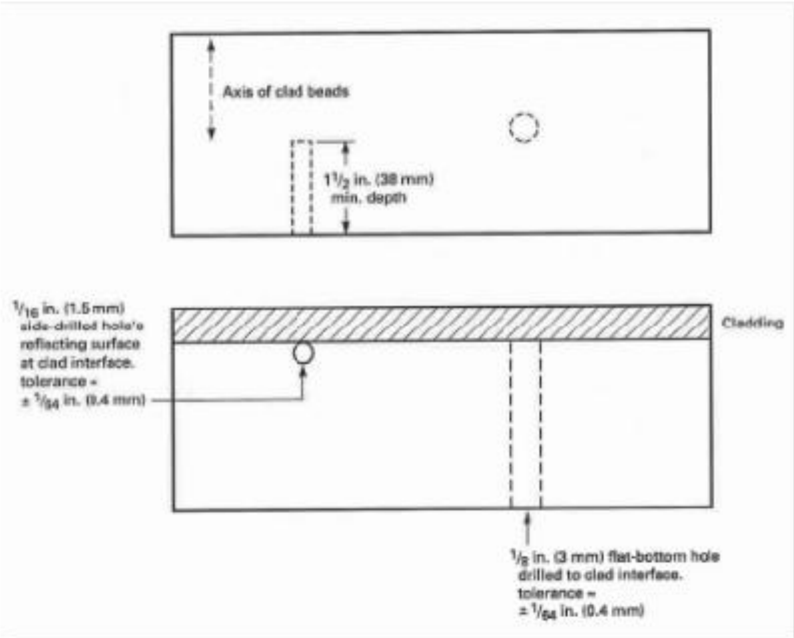

Fig.7 Calibration block for technique 1 (extract from Fig.T-434.4.1, ASME V)

Fig.8 Samples subjected to bend tests according to ASME sec. IX, art II

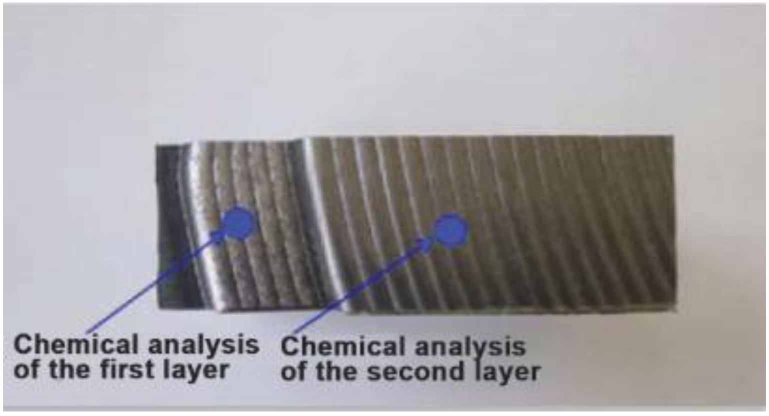

Fig.9 Specimen realised by TIG^{er} process, highlighting areas of investigation for chemical analysis on the first and second layers.

Fig.10 Optical emission spectrograph used for the chemical analysis of the cladded layers

Fig.11 Sample subjected to corrosion tests ASTM G48 method A (before the test)

Fig.12 Sample subjected to corrosion tests ASTM G48 method A (after the test)

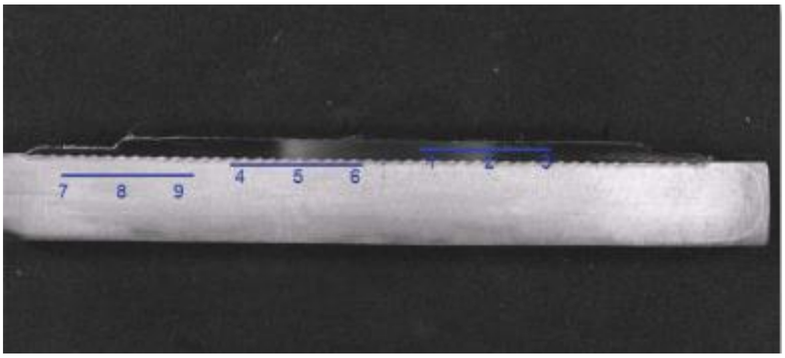

Fig.13 Macrograph of the specimen realized by TIG^{er} process (highlights on hardness sampling areas)

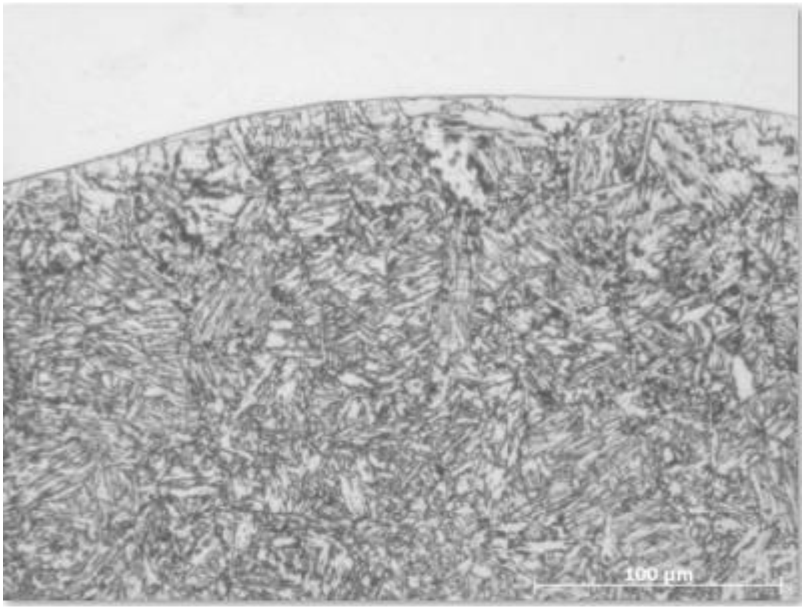

Fig.14 Transition between the heat-affected zone and the molten zone

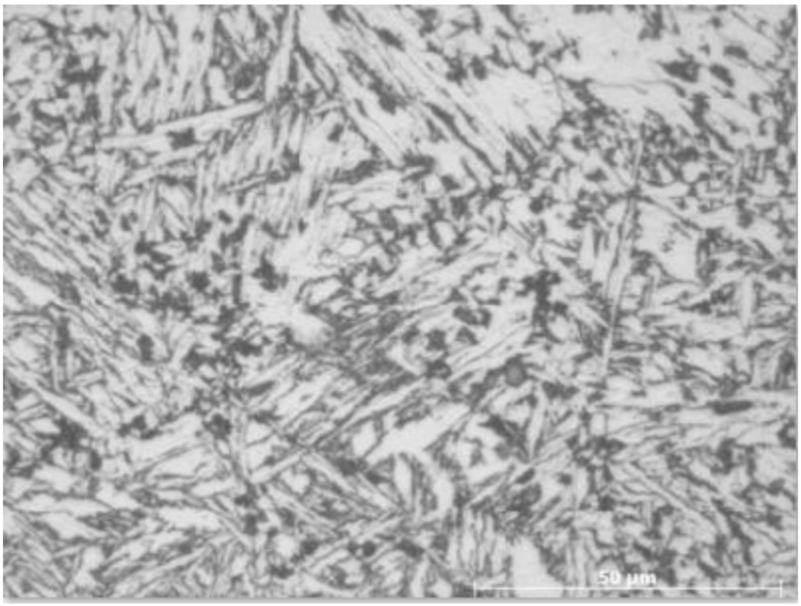

Fig.15 Microstructure of the heat affected zone

Fig.16 Dendritic structure of the molten zone

Source

Rivista Italiana della Saldatura . 3 . Maggio - Giugno 2015 written by Giuseppe Garbarino translated into English by Polysoude SAS

Bibliografia

[1] AWS A5.14 Specifications for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods.
[2] ASME Code BPV Section V Art. 4 - Ultrasonic Examination Methods for Welds.
[3] ASME Code BPV Section IX - Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators.
[4] ASTM G48-11 - Standard Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution.