THE ROLE OF METALLOGRAPHIC ANALYSIS FOR QUALITY EVALUATION OF WELDED STEEL PIPES

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Abstract: *Submerged arc welding is one of the most extensively used process for production of spiral welded steel pipes. Production process includes pipe forming by cold plastic deformation of hot rolled strips and double-sided submerged arc welding of the strip edges. The double-sided welded seam as an integral part of the final steel pipes must be carefully controlled because plays principal role on the quality of welded steel pipes. In this respect, optical metallographic analysis of the welded joint cross section were used as efficient and effective method to control the double-sided welded seam.*

The article presents a brief review of the role of optical metallographic analysis commonly used for quality evaluation of double-sided submerged arc welded steel pipes.

Keywords: METALLOGRAPHIC ANALYSIS, WELD JOINT, SUBMERGED ARC WELDING

1. Introduction

Submerged arc welding (SAW) is one of the most extensively used process for production of spiral welded carbon steel pipes suitable for pipelines [1]. Submerged arc welding (SAW) is traditionally considered as an efficient and highly productive joining technology for medium to high thickness steels. In Submerged arc welding (SAW) process, the welding arc is always covered with a layer of granular flux that protects the arc. The flux melts by arc heating forming a slag that protects the weld pool from the atmosphere, figure 1 [2, 3, 4].

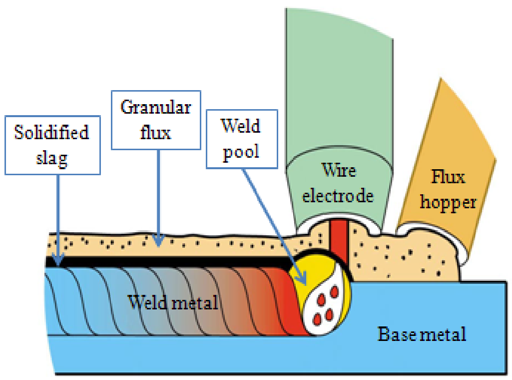

Fig.1 *Schematic representation of SAW*

Double sided spiral welded steel pipes produced from hot rolled strip which is gradually formed into round shape through three-roll-bending system, and its edges are joined inside and outside by submerged arc welding (SAW), figure 2.

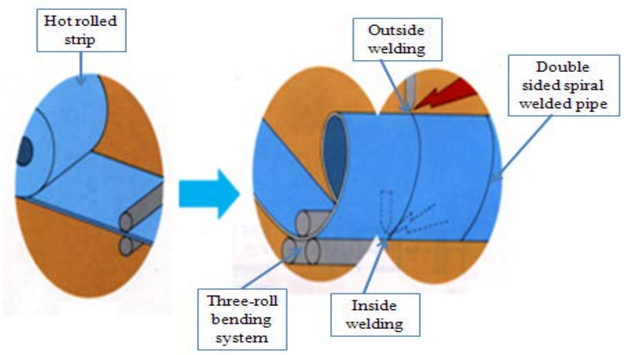

Fig.2 *Production of spiral welded steel pipes by SAW*

During pipe production, there is a need to precisely control all the processes with respect to the different operating parameters. There are several parameters which must be controlled during pipe production. Monitoring and control issues is of a great importance in SAW for the purpose of making pipes with consistent and defined quality at a high productivity. Monitoring the SAW process under industrial conditions is however not an easy task. Inspection and testing to ensure conformance to order requirements are integral parts of the production process and can be broadly classified into nondestructive and destructive testing /5/.

In steel pipe production by SAW, destructive testing within framework of quality assurance is widely used not for final inspection alone but also serves an important tool for efficient in-process control.

Metallography is the well known technique to reveal macrostructure and microstructure. Optical metallography, one of three general categories of metallography, entails examination of materials using visible light to provide a magnified image of the macro and microstructure [6].

Metallographic analysis also plays an important role to establish the causes of failures and the service condition of welded pipes as a constitutive parts of pipelines. These analysis provide the information regarding presence of defects and others metallurgical phenomena that manifest impact on the integrity of the welded pipes and pipelines. Metallographic examination is a key tool in the destructive examination of weldments, both as a process control tool and as a post-mortem examination of failed components [7].

Metallographic examination of weldments reveals macrostructural and microstructural features clearly when good metallographic preparation and the right etchant are used [7, 8].

Optical metallographic analysis of welded joint is a valuable analytical procedure widely used within the pipe industry. It is used for a variety of reasons including: set up of the production process, monitoring of the production process and finally, quality control activities for detecting fabricating defects and causes of the welded joint failures. In steel pipes production, metallographic analysis covers the range of pre-SAW, during-SAW and post-SAW activities. Metallographic analyses combined with others investigations can extract the most detailed information that can lead to a better understanding of the causes of the flaws and enabling to eliminate them.

Optical metallographic analysis can be carried out with little physical effort using apparently simple equipment and it is frequently regarded as easy operation but in the essence this is a skilled operation. Proper training of metallographers in the methodology and interpretation of the results is very important. Optical metallographic analysis is essential in order to understand the relationship between microstructure and properties of welded joints of steel pipes.

This article presents a brief review of the role of optical metallographic analysis commonly used for quality evaluation of welded joint of spiral welded steel pipes by submerged arc welding (SAW).

2. Experimetal procedure

Double sided spiral line pipes Ø813x12mm, welded by submerged arc welding (SAW) were used to review the role of optical metallographic analysis for quality evaluation. For this purpose, pipe rings (20-30cm long) were cut out from the several produced pipes Ø813x12mm in the production line and from these rings were extracted specimens for optical metallographic analysis, transversal to the spiral weld, figure 3.

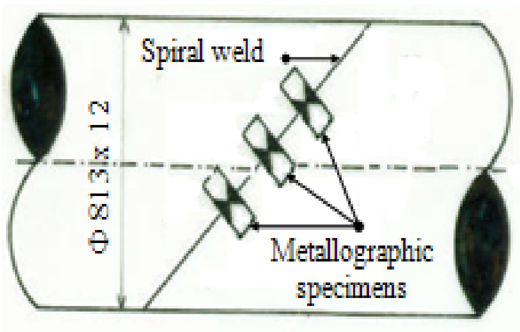

Fig.3 *Schematic illustrating of metallographic specimens*

In order to perform metallographic macro and micro analysis, the metallographic specimens were prepared by standard metallographic techniques that includes grinding, polishing and etching with suitable etchant, to reveal the macro and microstructure. Mechanical grinding is performed in successive steps using SiC abrasive papers of different grit sizes, usually 180, 220, 320, 600, 800 and 1000. Cooling is always necessary to avoid structural changes. Mechanical polishing is usually performed using diamond paste on a short nap cloth disc. After polishing, the specimens were etched with 3% natal (ethyl alcohol +3%HNO_3), followed by thorough washing and finally rinsed in alcohol and dried in a stream of warm air. It is important that care is taken at all stages of the preparation process to obtain a correct metallographic analysis of the welded joint.

Macro metallographic analysis is performed on etched cross section of the welded joint by standard visual examination with the naked eye and with optical microscope NEOPHOT 21 at low magnification.

Micro metallographic analysis is performed on etched cross section of the welded joint by optical microscope NEOPHOT 21 at high magnification.

3. Results and discussion

Figure 4 shows macrograph of the welded joint of double sided submerged arc welding (SAW) of spiral welded line pipes Ø813x12mm, after etching with 3% nital (ethyl alcohol +2%HNO_3) at room temperature. This technique is very useful and simple to use for revealing macrostructure of welded joint in pipe production.

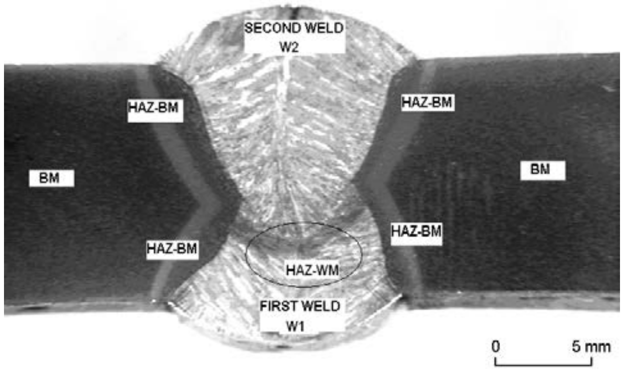

Fig.4 *Schematic illustrating of metallographic specimens*

The macrostructure of double sided submerged arc welding (SAW) of spiral welded line pipes Ø813x12mm generally shows two pass X-shape weld joint, being composed of areas of as deposited metal with columnar grains and areas that have been reheated by subsequent pass. Proper fusion has been achieved throughout the full thickness of the joint with good interpenetration and overlap between inside (W_1) and outside weld (W_2). No evidence of any weld defects such as undercut, lack of side wall fusion, gas porosity, etc. This macro-metallographic analysis is necessary at the beginning of the production process of welded pipes to determine the main parameters of welding. Without performing this analysis and without positive results arising from this analysis can not continue pipes production process.

It should be noted that macro-metallographic analysis is very important analysis in welded steel pipes production and also can be used for additional purposes, such as measuring of geometrical dimensions of welded joint, figure 5, hardness measuring, figure 6 as well as for milling of the V-notch in the constitutive parts of the welded joint for toughness testing, figure 7.

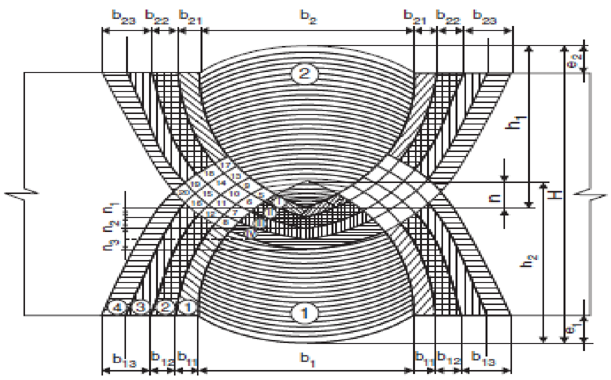

Fig.5 *Schematic illustrating of metallographic specimens for geometrical dimensions measuring*

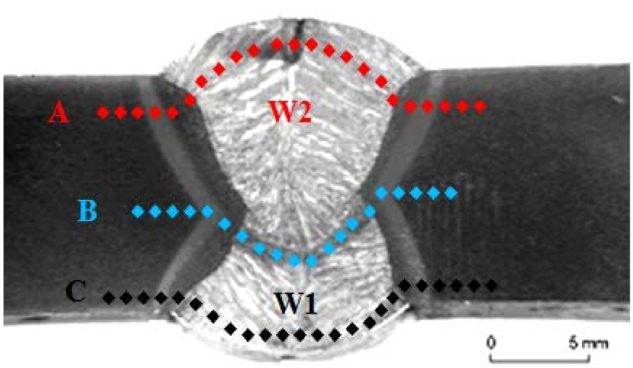

Fig.6 *Schematic illustrating of metallographic specimens for hardness measuring*

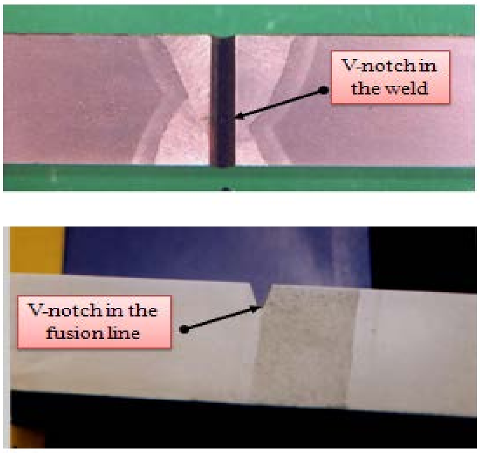

Fig.7 *Schematic illustrating of metallographic specimens for V-notch milling*

Micro-metallographic analysis is performed for a number of purposes, the most obvious of which is to assess the microstructure of the constitutive parts of welded joint (base metal-BM, heat affected zone-HAZ and weld metal-WM), figure 8. It is also common to analysis specific grain size, grain orientation, porosity, lack of fusion, lack of penetration, presence of inclusions, presence of cracks and others metallurgical phenomena such as local brittle zone, precipitation and reprecipitation of certain microparticles in the welded joint.

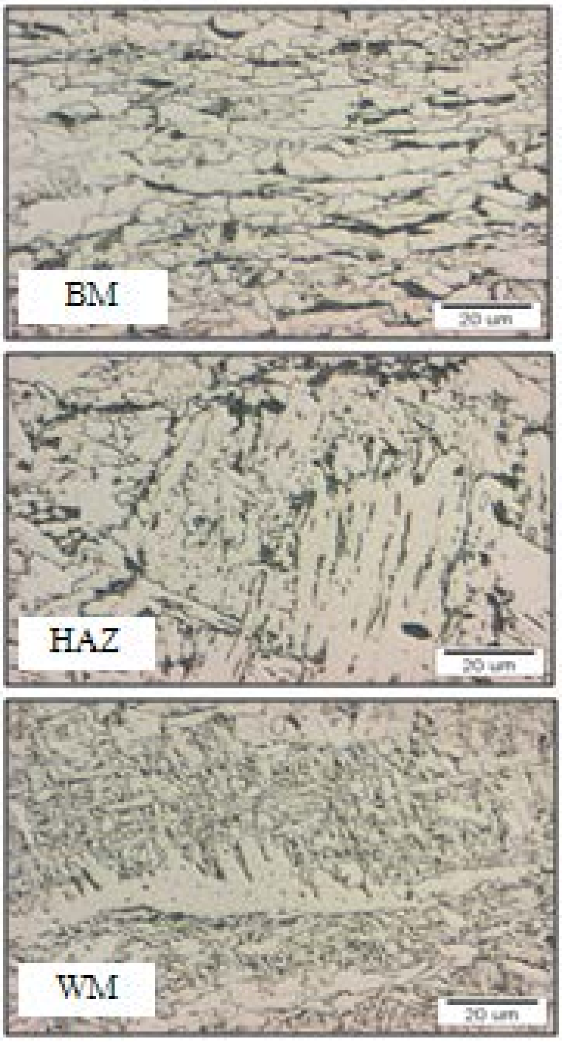

Fig.8 *Microstructure of welded joint*

4. Conclusion

From the results presented in this work, it is possible to draw the following conclusions:

Optical metallographic analysis of welded joint is a valuable analytical procedure widely used within the pipe industry and extremely important indispensable key tool for quality evaluation of the welded steel pipes. It is used for a variety of reasons, including evaluation of the production set up process, monitoring of the production process and quality evaluation of the welded steel pipes.

Macro-metallographic analysis is a fundamental step for evaluation of the quality of the welded joint of steel pipes and prelude to micro-metallographic analysis.

In conjunction with others equipment, metallographic analysis can extract the most detailed information about the assurance of a consistent top quality of the welded steel pipes and research and development (R&D) activities in the field of production of these pipes.

5. Literature

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