WELDED MICROGRAPHIC STRUCTURE DETERMINATION USING ULTRASONIC ANALYSIS.

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Abstract:
In this paper, the aim of our study is the use of ultrasound to show experimentally the change of the microstructure of a material after a welding operation. Two welded carbon steel plates have been selected to be investigated. Two processes are considered: The flux wire process and manual arc process.

INTRODUCTION

Grain size of materials is an important engineering characteristic which influences its properties. Traditionally, optical metallographic technique is used to evaluate the grain size in the material. New trend is to use non-destructive testing (NDT). This NDT is widely applied in many applications due to the fact that it will not impair the future usefulness of the test object. Many efforts had been done to use longitudinal normal incident ultrasonic waves as a non-destructive evaluation technique for the estimation of the average grain size of carbon steel. In many cases, correlations have been noted between ultrasonic parameters such as velocity and attenuation, and material properties [1-3].

In our work, we are interested by the use of ultrasound to show experimentally that the micrographic structure changes from layer to layer in the fusion zone of welds. In fact, the wave propagation in such complicated Medias like welds is hardly understood because of their heterogeneous and anisotropic nature. Within this context, an ultrasound bench is developed to quantify the change in the ultrasonic parameters.

Two welded carbon steel plates have been selected to be investigated. Two processes are considered: The flux wire process and manual arc process.

PRESENTATION OF WELDS

Many technical welding processes are used to join metals (TIG: Gas Tungsten Arc Welding, MIG: Gas Metal Arc Welding, MAG, SAW,...) [4].

In addition to these common arcs welding processes, other welding processes such as laser beam welding, electron beam welding, friction welding, and submerged arc welding can be used. In our study, two welded Carbon steel plates with geometry as shown in figure 1 were made using two processes: flux wire automatic process and manual arc process. The plates are 38 mm of thickness manufactured in flat position; their shape is “V”.

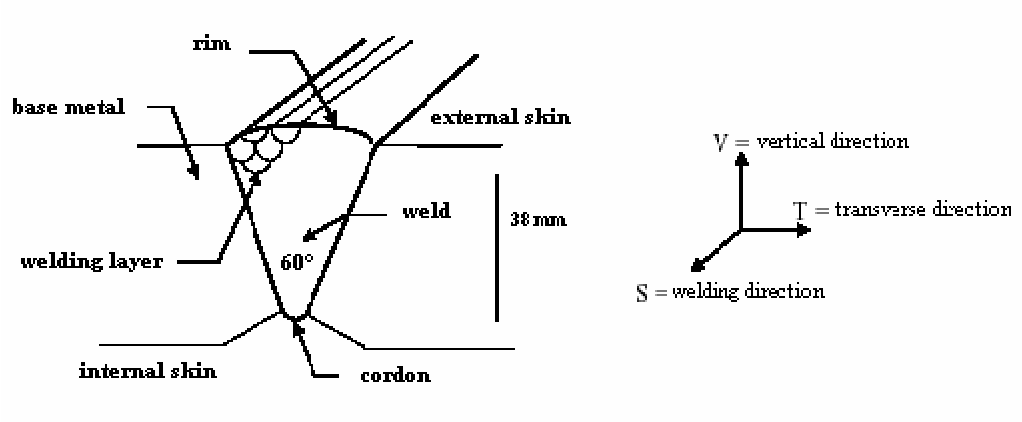

Figure 1 - References and welding terms

Flux Wire Process (High Energy)

In this process, a naked wire electrode is smelted under a flux of mineral granulated powder which constitutes the slag. This process is generally used in automatic mode, it is characterised by a heat supply and energy more intense than the manual process. This type of process is generally used for constructions of 2 - 450 mm of thickness; it has some advantages such as:

- High efficiency: from 0.90 to 0.99.
- Good quality of joint, good mechanical proprieties.
- A moderate consummation of electrical energy and welding products against the manual process.

In this process, the welding energy E has been more or less estimated to 1.07 KJ/mm.

Where:

$$E = U I / V.$$

U is the voltage, I is the current intensity, V is the welding velocity.

Manual arc process (low energy)

In this process, the coating around the electrode intended to fill the joint has two principals functions:

- Stabilize the arc and produce a liquid phase which protects the melted from the atmospherical contamination.
- It contributes to good metallurgical properties.

This process is characterised by low energy, the welding current has been about 150A and the welding voltage about 200V.
The chemical composition of the Carbon steel used is:
C 0.117, Si 0.261, Mn 0.587, P0.009, Mo 0.001, Cu 0.064 and slights of Cr And for both welds, the chemical composition of the electrode is: C0.1, Mn 0.5, Si 0.9.

For the elaboration of the first weld (flux wire), we have followed the stages described in figure 2. To get a good penetration of layers, the first and the second layer have been done by manual process.

	1st layer	2nd layer	3rd layer	19 layers
Process	manual	manual	automatic	automatic
Electrode diameter (mm)	3	4	4	4
Voltage (V)	100	200	25	
Current (A)	380	380	350	
Velocity (mm/min)	*	*	490	392

Fig 2- Welding's stages

MACROGRAPHIC AND MICROGRAPHIC OBSERVATIONS:

In welding, as the heat sources interacts with materials, the severity of thermal excursions experiences by the material varies from region to region resulting in three distinct regions in the weldment. These are the fusion zone (FZ), the heat affected zone (HAZ) and the unaffected base metal (BM) [5]. Figure 3.

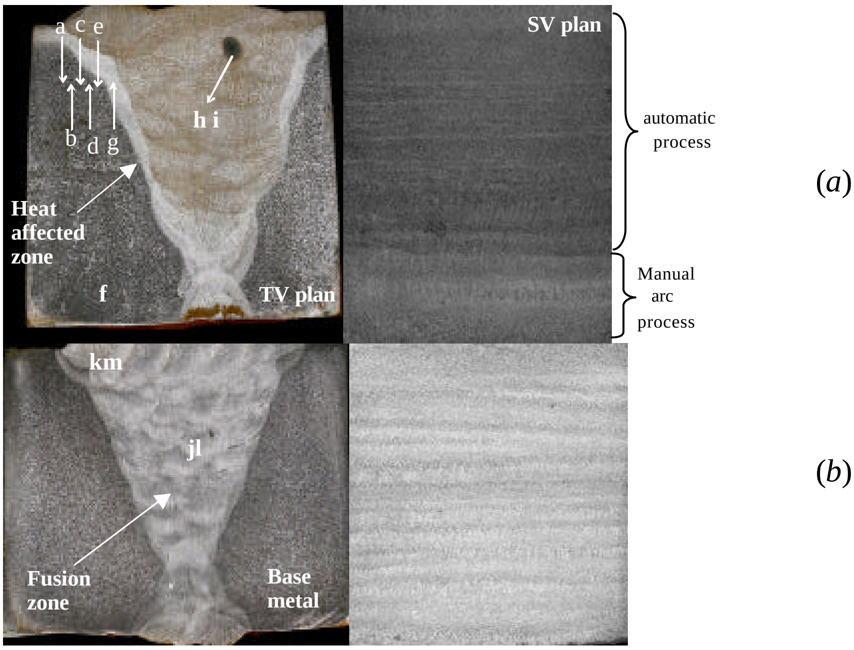

Fig 3 - Macrographic observations. (a): Automatic process, (b): Manual process.

We can easily observe that the heat affected zone in the first weld manufactured at high energy is larger than the second one because of the importance of the heat supply.

The microstructure development in the fusion zone depends on the solidification control, the size and the shape of the grains. However, it is more complicated because of physical processes that occur due to the interaction of the heat source with the metal during welding.

The micrographic observations are important to know the structure change after a welding operation. With an optical microscope (ZEISS type), equipped with a camera, many pictures have been taken at different zones along the pieces, figure 4.

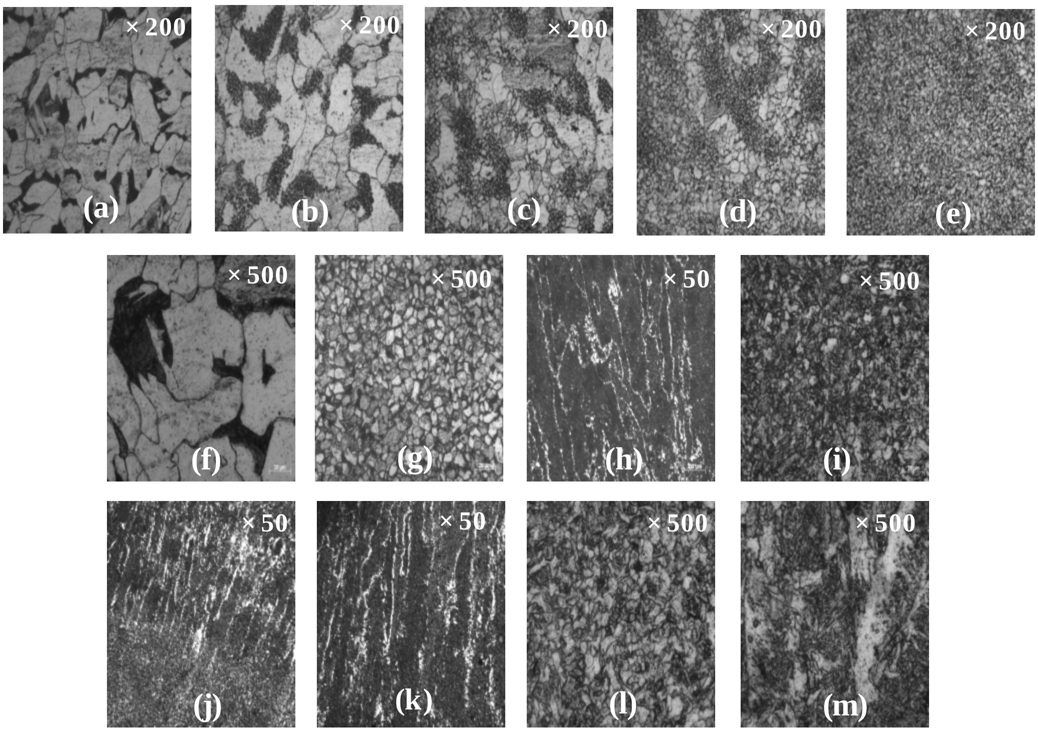

Fig 4 - micrographic observations

DIRECTION FOR USE

A typical ultrasonic inspection system consists of several functional units, such as the pulser/receiver, transducer, and display devices. A pulser/receiver is an electronic device that can produce high voltage electrical pulse. Driven by the pulser, the transducer generates high frequency ultrasonic energy. The sound energy is introduced and propagates through the materials in the form of waves. When there is a discontinuity (such as a crack, porosities, slag inclusions, incomplete fusion,) in the wave path, part of the energy will be reflected back from the flaw surface. The reflected wave signal is transformed into electrical signal by the transducer and is displayed on a screen. In this method, all informations are contained in the electrical signals.

When making precise measurements, an immersion technique is often used. In immersion ultrasonic testing both the transducer and the piece are immersed in the couplant, which is typically water. This method of coupling makes it easier to maintain consistent coupling while moving and manipulating the transducer and/or the piece.

A schematic representation of the site for the tests is shown in figure 5. It is an immersion tank (khaurkhamer), specially used in immersion control of small pieces, it is equipped of three wags which can displace along three axes XYZ.

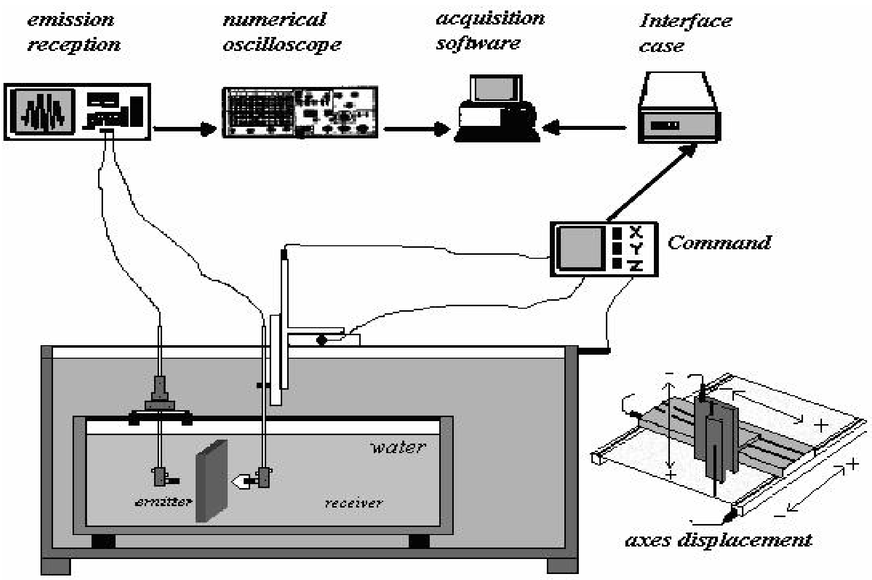

Fig 5 - Experimental mechanism

An emitter transducer is positioned on the bloc to be characterised with a precision of one millimeter. It's a Krautkramer piezoelectric transducer, which converts electrical signals into mechanical vibrations. It generates longitudinal waves at normal incidence (L0 mode) with 2.25 MHz frequency and 9.5 mm of diameter. This frequency has been chosen in order to get a compromise between a good penetration and a good resolution power [6].

After crossing the metal base or the joints of welds, the ultrasonic beam is received by another piezoelectric transducer of the same frequency and diameter, fixed on conical sole made such as the contact surface should be a 2mm diameter disc [7].

Changes in ultrasonic wave propagation speed, along with energy losses, from interactions with materials microstructures are often used to non-destructively gain information about a material's properties. Measurements of sound velocity and ultrasonic wave attenuation can be related to the elastic properties that can be used to characterize the texture of polycrystalline metals. These measurements enable industry to replace destructive microscopic inspections with non-destructive methods.

For both welds used in this work, three samples were cut from each steel weld to a thickness of 15mm; these samples were cut in TV, SV, and TS of the welds. We have measured the ultrasonic velocity of longitudinal waves in each sample; the signal obtained is shown in figure 6.

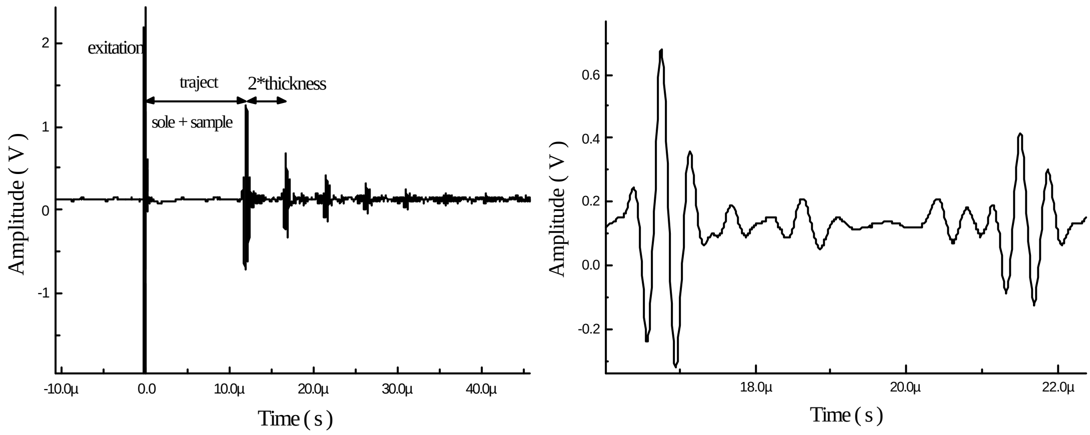

Fig 6- Velocity measurements

RESULTS AND DISCUSSIONS

On the wave length scale, a welding can be considered like a multitude of anisotropic zones with special orientations of symmetric axes. It is generally admitted that the ultrasound velocity is closely influenced by the structure; it decreases with the increase of the grain size [8].

We have measured the ultrasonic velocity in each sample for both welds, the results are shown in figure 7, and we can observe that the velocity changes from one plan to another because of the difference of the thermal cycles undergone by these layers [9].

Velocity (m/s) / plan	TV	SV	TS
Automatic process	5975	5911	5991
Manual arc process	6033	5930	5984
Base metal	5982	5982	5982

Fig -7: Velocity measurements in welding plans.

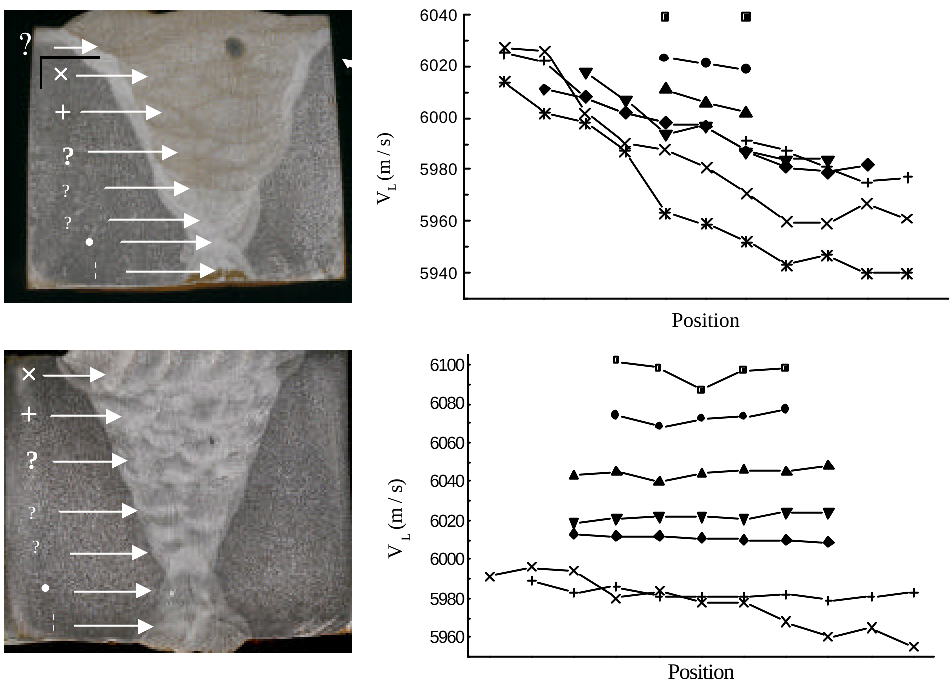

Fig 8- Velocity measurement in the TV plan.

The velocity has been, also, estimated at each layer in both welds in the TV plan, the results show that the grain size changes significantly from region to region. The change is more important in the weld manufactured under high energy as shown in figure 8, In fact, the high energy and the rapid velocity implicated, in this process; don't favour the column growth of grains. So, this structure presents many changes of grain orientation and is more heterogeneous than the structure manufactured by manual arc process.

CONCLUSION

In this paper, the welding parameters influence on the final structure of welds is shown. The anisotropic and the heterogeneous character of welds have been put in evidence.

The results presented here lead to some interesting conclusions. In brief, it is important to know the welding process and the operating mode to understand the structure evolution in the welded zone.

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