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Research and proposal on welding technique for longitudinal crack defect welding

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Abstract: Manufacturing of intentional crack defect welding as designed and similar to realistic crack defects for researches of mechanical properties of welding and training of non-destructive testing (NDT) operator is a difficult and challenging work. Nowadays, methods for manufacturing of specimens of welding with cracking defect still exists some disadvantages such as difficulty in manufacturing, reactionless of the cracks to NDT techniques, the difference between the crack shape and that in nature, and high cost, etc. In this research, we propose a new approach to create welding crack with residual stress using cast iron electrodes. The process to create the welding cracks based on this technology using the SMAW combining with GTAW allows to create the welding with cracks similar to those in nature. Cracks are created with lateral deviation not more than ± 0.5 mm, well response to the phased array ultrasonic testing technique and have similar shape to natural shape of the crack defect.

Keywords: Crack Defect, SMAW, GTAW, Nondestructive Testing (NDT), Phased Array Ultrasonic Testing (PAUT)

1. Introduction

Cracking is a defect generated by a local rupture causing discontinuities on the weld in the metal or on the adjacent heat affected zone when freezing weld is solidified [10]. Cracking is considered one of the most serious defects of welded joins, should be removed completely before putting the product into use. Cracks may appear on the surface of the weld, inside the weld and heat affected zone [10].

Cracks with different nature, positions and shapes, can be microstructure cracks or cracking of crude crack. The crude cracks can cause destruction of the structure in working. The microscopic cracks in the process of structural work will spread gradually forming crude cracks [6, 10].

Some cracks on the surface can be detected by means of visual inspection. For microscopic cracks in the weld metal, NDT methods such as magnetic, radiographic, ultrasound, etc. can be used [5]. Depending on the cause, location and shape, cracks generally have several categories such as: longitudinal cracks, transverse cracks, branching cracks, crater cracks as shown in Figure 1 [1, 10].

Manufacturing intentional crack welding's defect welding to do research in mechanical properties and to train NDT operator is a real challenge in practice. At present, experiments in specimens of welding with cracking defect are mainly conducted by: stressing two different tensile strength electrodes and the "allocating" of the welding lines (a process of welding in which a welding line was made on one side of the welded bars, then another line was made on the other side; this way of welding turn was adopted until the bars were fully welded) mechanical processing, EDM notching, adding bronze to create cracks… [4, 8]. In general there are still some defects with the cracks created by the just-mentioned-methods: some of them are the complexity of the process, the unresponsiveness to the NDT technique as realistic crack defects, and high cost,…

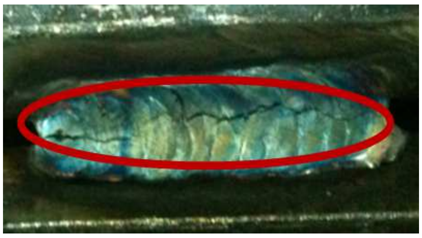
In this paper, we propose a technique to create cracks by combining crated stress with cast iron electrode [9]. This process allowed us to made defects similar to those in the nature. In our experiment adopting the process and technique to create weld specimens with crack defect. The deviation of the crack can be guaranteed within ±0.5mm in height and ±0.5mm in length, there was good response to the phased array ultrasonic testing technique and wave shape of defect was similar to natural crack [4, 5].

2. Materials and Methods

2.1. Method to Create Test Cracks

The cracks can be created by changing the chemical composition of base metal welding consumables such as:

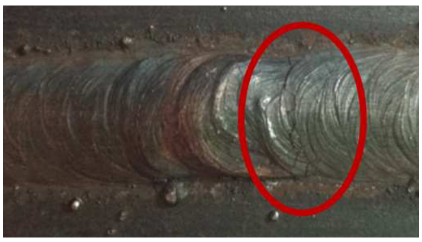
- Using wet electrodes to create cracks when welding. This method is difficult to implement, cracks appeared quite random, difficult to control the shape and size of cracks [4].



(a) Longitudinal cracks

(b) Transverse cracks

(c) crater cracks [3]



(d) branching cracks

Figure 1. *Typical cracks of welding.*

- Create branching cracks on steel materials by means of the copper in the weld metal. In general, this method easy to implement, but difficult to control the size of cracks and check size of cracks by NDT [4, 8].

- Create longitudinal cracks by two-electrodes with different tensile strength distributing on both sides of the base metal. The distribution of the order and location of weld layers give rise to residual stress creating cracks. The types of electrode usually chosen are E11016 and E7016 [1]. This method requires highly skilled workers, difficult to implement uniform welding procedure specification for the different welds, high cost. However, the created cracks are quite similar cracks in nature [4].

- Some other types of cracks can also be made by intentional impact on the weld metal with a certain agent, can be folded or can be part of a small groove simulated cracks. However, cracks are created in this way when examined by NDT would result in ambiguous (ultrasonic wave), which is very similar to lack of fusion in nature [8].

2.2. Creating of Cracks by Residual Stress with Cast Iron Electrode

Longitudinal crack welding defect can be generated by different welding techniques with the following requirements: (i) cracks appear within the weld in the metal; (ii) cracks can be detected well by the phased array ultrasonic testing technique (PAUT) [4, 8]. In this study, flaw specimens with longitudinal crack defect are used in training of technicians inspecting weld defects by means of ultrasonic phased array method.

The principle proposed to create longitudinal crack defects was performed using cast iron electrode [1] to weld at specific locations. High carbon content in the weld will make it more brittle than base metals, which creates stress cracking the welds. Then GTAW welding method is used to remove unwanted defects around the cracked weld. Mechanical manufacturing methods are employed for modification of the cracks to achieve the design geometry. The procedure for this is shown in Figure 2.

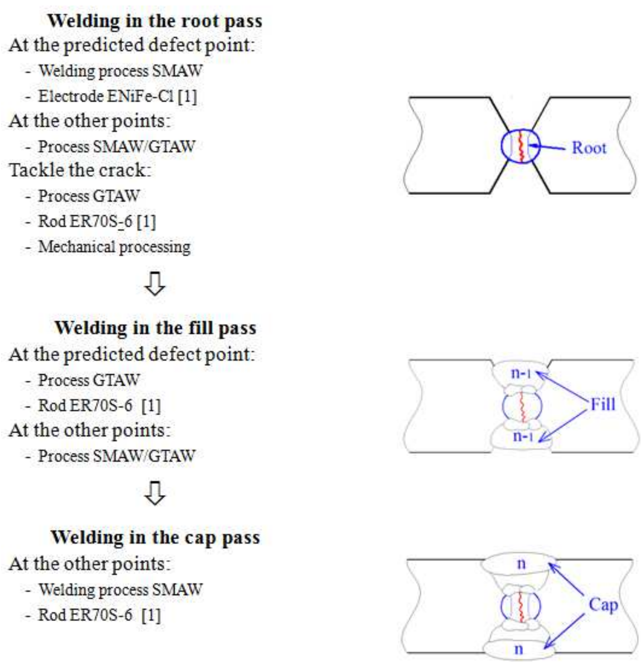


Figure 2. *Crack creating process*

2.3. Experimental Welding Procedure

Weld specimens making with longitudinal crack defect by crated stress with cast iron electrode includes three steps:

- Choosing welding materials

- Design of welded joints
- Making defect

2.3.1. Choosing Welding Materials

Welding materials choosing is based on the following criteria:

- Base materials and consumables materials being the standard base and consumables materials in welding [4, 7].
- Base materials not causing any prevention on the welding technique and the planned checking methods [4].
- Meeting the purposes of the product users [4].

In this experiment, the product was weld specimens with longitudinal crack defect, the chosen base materials was low carbon steel [2], consumables materials are ENiFe-Cl electrodes and ER70S-6 rod [1].

2.3.2. Design of Welded Joints

Geometrical dimension of weld joints will affect the process of check defects when adopting phased array ultrasonic method. The designing of longitudinal cracks must follow the following rules [4]:

- Weld joint is designed based on the application standard in welding.
- The weld joint is designed for complete joint penetration weld.
- The geometrical dimension of the weld joint is compatible with ultrasonic testing method [4, 5].

To check and evaluate the technique creating the proposed transverse cracks, some experiments on flaw specimens were carried out for double-V joint.

Figure 3 describes the flat position weld done under Standard AWS D1.1 (1G).

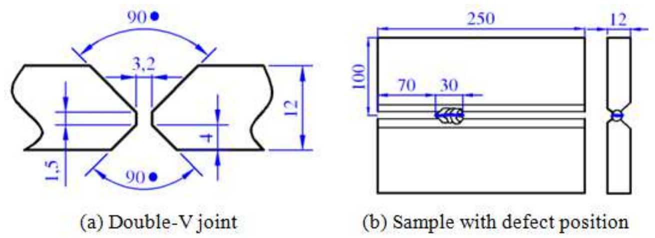


Figure 3. *Design of double- V joint but and defect position on the sample.*

2.3.3. Welding Technique

- Welding in the root pass

Welding variables at the crack defect and the root pass area are described in Table 1.

Table 1. *Welding variables to create crack defect*

At the crack defect	At the root pass area
AWS D1.1 standard	AWS D1.1 standard
Welding process: SMAW	Welding process: GTAW
Position: 1G	Position: 1G
Welding equipment:	Welding equipment:
SMAW WIM 200A	GTAW-ACCUTIG 300P
Electrode: AWS ENiFe-Cl, Φ3,2mm	Fillet: AWS ER70S-6, Φ3,2mm
Current type and Polarity: AC	Current type and Polarity: DCEN
Amps: 110A-120A	Amps: 125A-130A

Tack weld two plates together by GTAW method, using SMAW method and ENiFe-Cl electrode, Φ3,2 mm welding about 30mm on welding variables in table 1 at a point locating 70mm from the edge of the welding bar. The crack appeared automatically after welding; then, the surface of the weld was cleaned to evaluate the shape and size of the crack (Figure 4a). After that, using GTAW method to process the porosity and reduce carbon content (Figure 4b). Next, make another weld line to cover the crack to frame the length form and the size of the crack. The crack can be processed with mechanical ways to gain an accurate size)

(a) Create the crack by SMAW process

(b) Tackle the crack by GTAW process

Figure 4. *Created defect.*

The root pass area (Figure 5) was welded by GTAW method under the welding variables in table 1. Noting that the weld pool just hits the defect area so that the length of the crack remained unchanged.

Figure 5. *Welding at the other points in the fill pass*

- Welding in the fill pass

This layer was welded by GTAW method and SMAW method with welding variables showed in Table 2)

Table 2. *Welding variables in the fill pass*

At the other points	At the crack defect
Standard apply: AWS D1.1	Standard apply: AWS D1.1
Welding process: SMAW	Welding process: GTAW
Position: 1G	Position: 1G
Welding equipment:	Welding equipment:
SMAW WIM 200A	GTAW-ACCUTIG 300P
Electrode: AWS E6013, Φ3,2mm	Electrode: AWS ER70S-6, Φ3,2mm
Current type and Polarity: AC	Current type and Polarity: DCEN
Amps: 110A-120A	Amps: 135A-140A

Welding both sides of the defect with GTAW method under the conditions listed in Table 2. Then, all another area of this layer was welded.

Adopting the GTAW technique (see Table 2 for the conditions) for both of the front and the back side of the item. More layers of weld were added so that their thick can help to keep the original size of the crack when processing the filling weld.

Using SMAW welding method for the front side and GTAW method for the back side of the item to made different layers in order to gain the required thickness (not crossing the welding edge).

(a) Welding the front side by SMAW

(b) Welding the back side by GTAW

Figure 6. *The fill pass welding*

- Welding in the cap pass

Table 3 show welding variables to in the cap layer for the front, back side by SMAW technique and Figure 7 describes the result after welding cap layer.

Table 3. *Welding variables in the cap*

At the cap	
Standard apply	AWS D1.1
Welding process	SMAW
Position	1G
Welding equipment	SMAW WIM 200A
Electrode	AWS E6013, Φ3,2mm
Current type and Polarity	AC
Amps	135A-140A

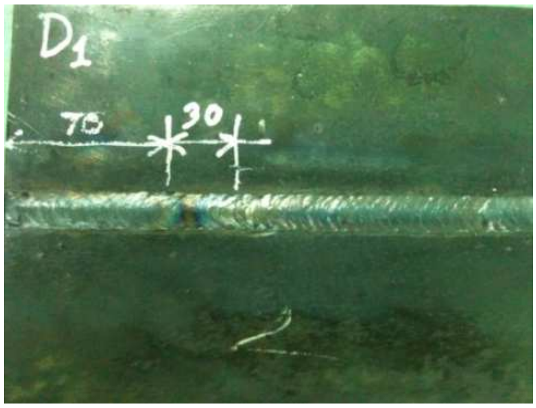


Figure 7. *Cap layer welding.*

3. Measurements

To evaluate cracks created by residual stress with cast iron electrode and welding procedure specification, three flaw speciments with longutudinal cracks have been proposed and manufactured as shown in Figure 8.

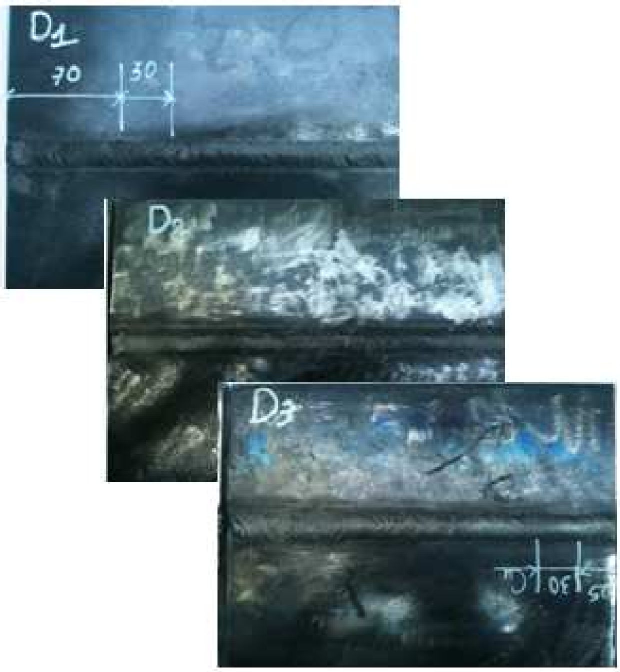
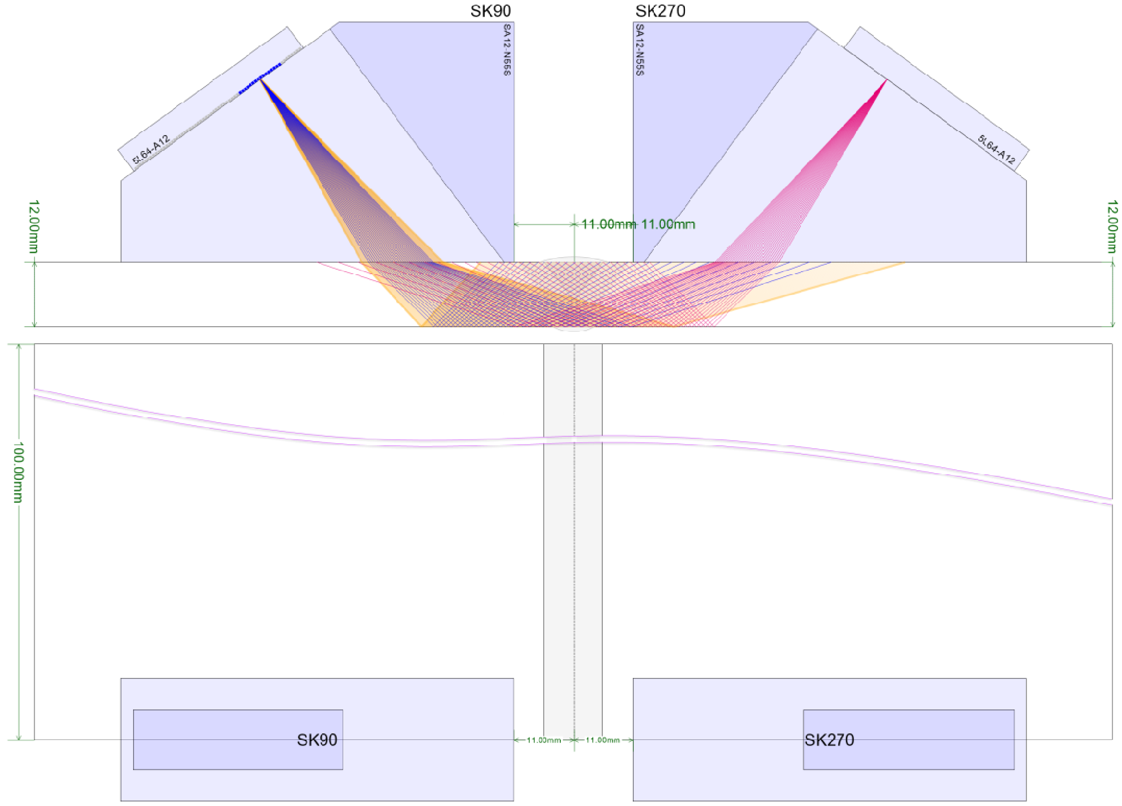


Figure 8. *Flaw speciments with longutudinal cracks.*

The flaws specimens are tested by the phased array ultrasonic method (PAUT) with parameters are set as shown in Figure 9 (design with software BeamTool version 6, Eclipse Scientific Inc.).



Thickness	Width	Length	Index Offset	Material	Shear Velocity	Compression Velocity
12mm	200mm	100mm	0mm	Steel 1020	3.24mm/µs	5.89mm/µs

Figure 9. *Adjustment of parameters for flaw specimens test on PAUT machine*

The test results of the flaw specimens with the above parameters are obtained and presented in Table 4.

Figure 10 shows the photograph of a crack defect of a flaw specimen detected by PAUT.

Table 4. *Test results of the flaw specimens*

Specimen	Visual inspection	PAUT testing (mm)
D1	Not good response	29,5
D2	Not good response	30,5
D3	Not good response	30,0

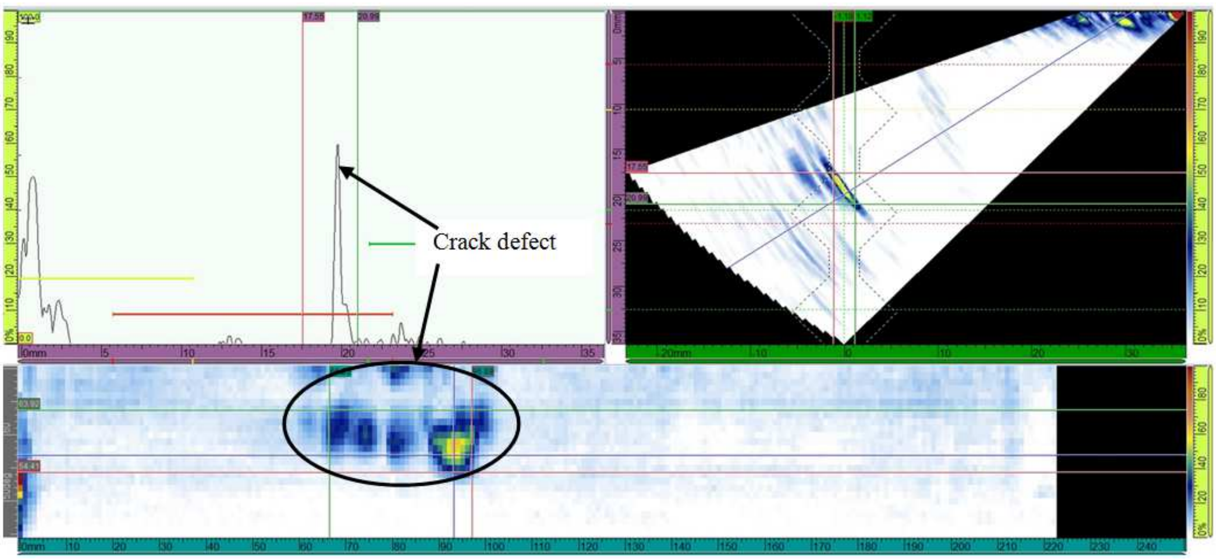


Figure 10. *The crack defect response to the NDT technique.*

5. Conclusion

- The technique to create welding crack with residual stress using cast iron electrodes has been proposed to produce welding specimens with crack defects.
- The crack defect can only be detected by radiographic, ultrasonic methods. Inspection results by PAUT (phased array ultrasonic testing) showed that the created crack defects are similar to those in nature.
- The appropriate size and position of crack defects on the prototype flaw specimens compared to the design showed that the proposed technological processes are high repeatable (false horizontal dimension, the along with the designs in the range of ± 0.5 mm).
- The proposed technology is suitable for skilled workers, who hold SMAW / GTAW 3G certificates according to AWS standard and effective in creating weld flaw specimens for training and research.

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Biography

Dang Thien Ngon (1969, Binh Dinh - Vietnam) graduated the PhD. course from the Dresden University of Technology (Germany) in 2008. He is the member of VDE, VFMEA, and VWS. His researches are concerned with Automatic Production System, Agent Technology and Welding Technology.

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