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The Influence of Preheat on Distortion and Fatigue Crack Propagation Rate of FCAW Weld in A 36 Steel Structure.

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Abstract Welding is one of the joining processes and it has been widely used, especially for steel welded structure in off-shore, pipeline or ship construction. Advantages of the welding joint are inexpensive, process joining can be done quickly and can produce light structure compared to other joining processes. One of welding techniques mostly used for joining steel construction is flux cored arc welding (FCAW). The commonly problems arise in this welding technique are distortion and low resistance of crack propagation. The aim of this study is to minimize distortion and to increase fatigue crack growth resistance of weld joint.

In this research, FCAW welding was conducted without preheat and the other was preheated around welding area with temperature of 200 °C. Each of temperature welding process was measured using data acquisition. After completing the welding process, a sequence of experiment was conducted including chemical compositions, distortion and fatigue test. Result of this research shows that preheat temperature of 200 °C can decrease distortion and improve fatigue performance.

Introduction

Welding technique has been widely used for metal joining, in industry that produce machine and structure such as: ship industry, aircraft, automotive, piping, off-shore building and other constructions. Welding technique has important role in production process because it can decrease production cost, operational can be optimized, easy in maintenance and cheap inspection cost. This product can be challenge for welding scientists and experts in finding solution [1].

The commonly problem in plat welding for ship construction is distortion and bending in steel structure joint. Heat generated during welding can cause buckling, distortion and r*esidual stress*. Control on distortion and residual stress is very important, despite it needs more operation time. Buckling, distortion and residual stress tend to decrease quality and therefore more repairmen's are required expense in every ship production. More methods have been tested to measure residual stress; they performed analytically, numerically or even experimentally. The main cause or method for calculating residual stress on welding and distortion is still to be important discussion topic to find solution [2].

The most appropriate method to reduce distortion buckling and residual stress of thin plate can be conducted after welding (post-weld) or during welding (in-process welding). In-process welding includes: preheating[3], and thermal tensioning [4]. Transient thermal tensioning is technique to control residual stress and distortion by giving heat to both sides of welding area whether it is coated in the front, in the side or the back and this heat source moves together with force. The use of TTT on welding can decrease propagation rate of fatigue crack [5].

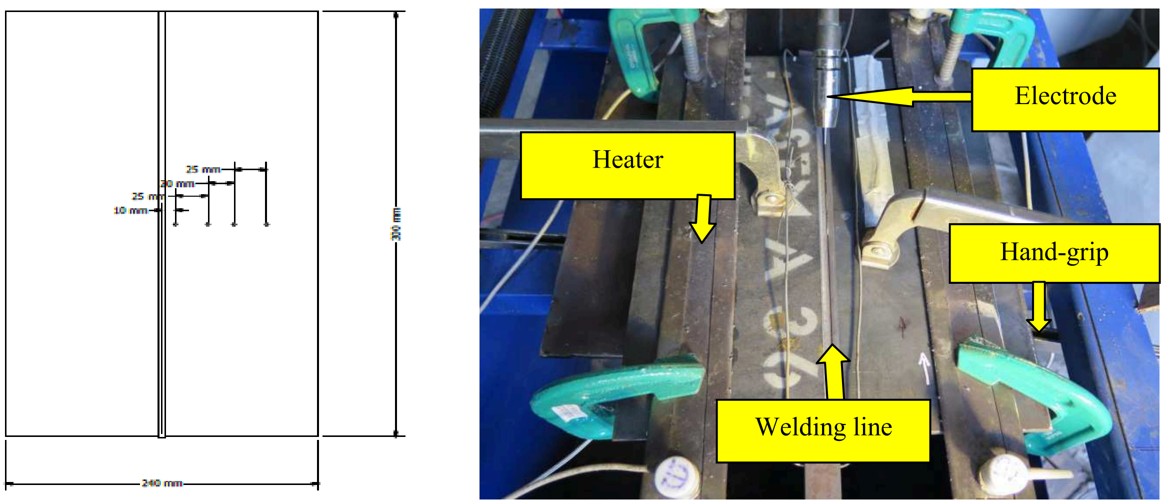
The material commonly used in panel construction of ship are A 36 or SS 400 steels. These materials are used due to their low carbon content, so that they have good weldilly. One of welding techniques mostly used for joining steel construction is flux cored arc welding (FCAW) by technique basically FCAW is similar to operating machine like *metal inert gas* (MIG) welding, but they are different in filler metal based. Ease in operating process and can be used continuously make FCAW to be one choice. In FCAW, filler wire base was also functioned as electrode fed continuously. Electric arc occurs between filler wire and main metal, and to protect the arc Argon (Ar), helium (He) gases or mixture between them are used. Filler metal in the form of flux cored wire fed continuously that welding can be conducted in semi-automatic. Therefore, it give convenience in its operation and has high reliability. FCAW used in seal welds were done on the bottom side of the joint and for longitudinal fillet welding and for transversal joining conducted semi-automatic [4,6]

The problem mostly arose in welding is distortion, residual stress, and easy to be fatigue crack that after welding there is needed post weld heat treatment and welding repairmen to straighten distortion and reduce the residual stress. Commonly, distortion can be straightened by reheating, yet it will decrease corrosion endurance of materials especially stainless steel. Therefore, experiment should be conducted to solve the problem on distortion, to reduce residual stress, and to have ability to avoid propagation rate of fatigue crack. Heat intake is very influencing mechanical characteristic and micro structure of welding result [7,8]. There should also be reviewed by conducting experiment on FCAW welding process toward the influence of adding heat around welding area to reduce distortion and avoid propagation rate of fatigue crack.

Material and method of research

Material used in this study was A36 steel plate with thickness of 5 mm. The material has maximum yield stress of 248 MPa and maximum tensile stress of 400 MPa with elongation of 20 %. Electrode used in this research was K-71T (AWS A5.20/ASME SFA-5.20 E71T-1C) with 1,2 mm in diameter and 15 kg/roll weight.

In this experiment, FCAW technique was used with welding parameter including voltage, current and heat input respectively used were 40 volt, 210 Ampere and 2.184 kJ/mm. In this research is FCAW welding machine, thermocouple, semi-automatic welding device, polishing machine, micro photo, dial indicator, fatigue machine. FCAW semi-automatic welding process. The welding process was conducted with and without preheating as shows in Figure 1



a). b).

Figure 1 Welding mechanism includes a) thermocouple attachment position and b) FCAW welding mechanism

FCAW welding conducted by using forward welding movement of 3.846 mm/s. On the first welding, it is not necessary preheat treatment. In the next welding, 200 ^{o}C heat added. Maximum temperature measured with thermocouple placed in welding joint by space of 10 mm, 35 mm, 55 mm and 80 mm, in which the thermocouple with space of 35 mm was placed at the upper side plate, the rest of the thermocouples were placed at the bottom side plate.

Temperature measure conducted with lab view from National Instrument by distance like explanation above. Distortion test is conducted with dial indicator in longitudinal and transversal directions. Test on fatigue propagation rate is conducted with Servopulser machine type EHF-EB 20 capacity 20 Ton with ASTM E 647-00 standard crack tension (CCT) model center.

Result and discussion

Chemistry composition in % weight (wt %), micro structure and mechanical characteristic is an infuence unit. Chemistry composition can determine joint strength of a construction. To determine it, each result of the test conducted should be reviewed.

Table 1 Chemistry composition (%)

Element	C	Si	S	P	Mn	Al	Cr	Cu	Fe
Main metal % W	0.1246	0.2485	0.0105	0.0149	0.4711	0.0583	0.0195	0.0123	99.02
Welding metal % W	0.0796	0.7357	0.0092	0.0053	1.5834	0.0316	0.0275	0.0238	97.34

Table 1 shows that based on chemistry composition C and Mn, A36 main metal is carbon steel and with % weight Mn of 0,4711 is different with main metal. Different with main metal, welding metal had Mn increment of 1,5834 % while its % C decrease to 0,1246 % to be 0,0796 %, the steel as the result of this welding known as C-Mn steel. The change on carbon (C) element weight and manganese (Mn) on welding metal can increase tensile strength and welding joint strength [9]. On welding metal, it is proven that chemistry composition of C is smaller and Mn content is higher. The bigger Mn content in weld metal has several characteristics; they are it can increase strength and hardness, it complies with critical cooling rate, it binds sulfur that it minimize the formation of ferrous sulfide (FeS) which can cause embrittlement.

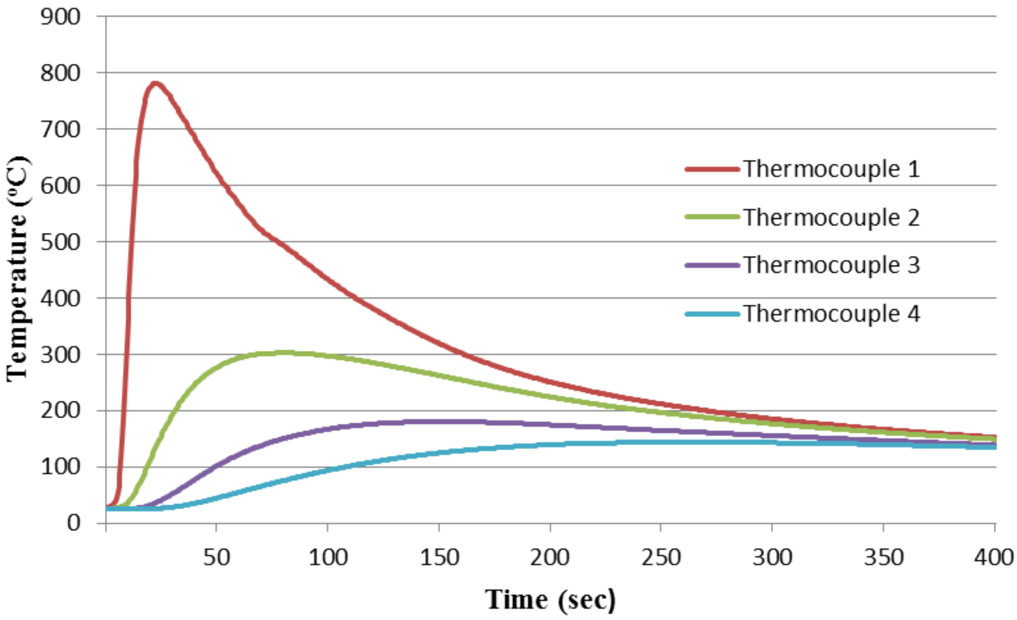


Figure 2 Temperature graphic toward welding time without heating addition

Figure 2 shows welding thermal cycle, where thermocouples were located at the distances of 10 mm, 3.5 mm, 5.5 mm and 80 mm from weldline. heat distribution in welding area to outside of it is decrease. In attaching thermocouple 1 with space of 10 mm has occur temperature peak of thermocouple 1 is 782 °C in the center line of welding, while thermocouple 2 has peak temperature of 302 °C, With increasing distance thermocouple 3 the peak temperature decrease 180,174 °C, finally, the lowest peak temperature is observed at the distance of 80 mm from the weld center line is 143, 410 °C which it is further from the welding center. The temperature around the torch reaches 1440 °C and decreased greatly to the range of 600-650 °C around the edge where the welding direction [10].

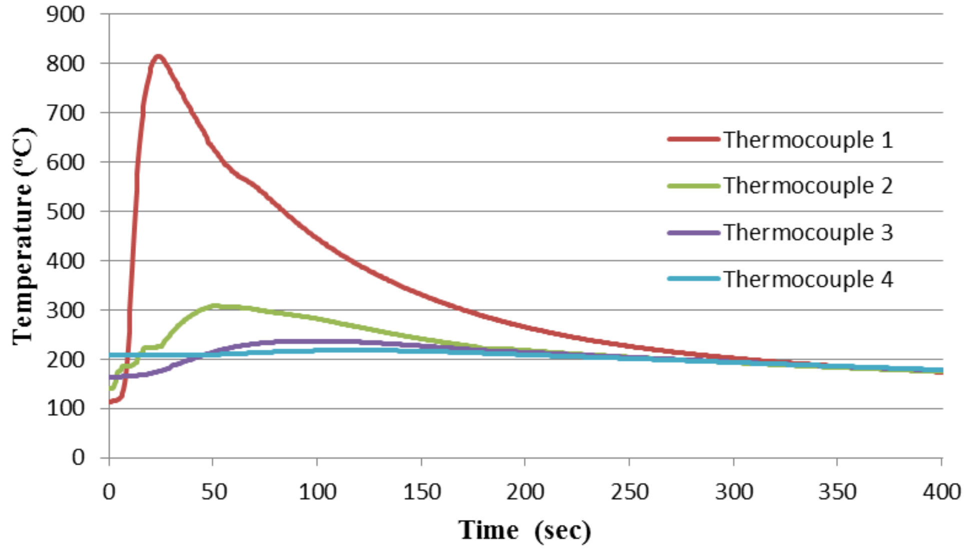
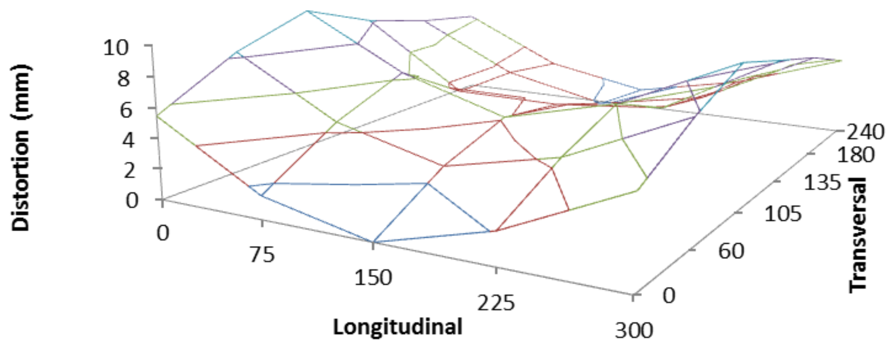


Figure 3 Temperature graphic toward welding time with preheatof 200 °C.

Figure 3, shows weld thermal cycles with preheat of 200 °C, where thermocouples were located at the distances of 10 mm, 3.5 mm, 5.5 mm and 80 mm from weldline. The peak temperature recorded by thermocouple 1 at the distance of 10 mm from the weld centerline is 815,571 °C, while thermocouple 2 has peak temperature of 308,737 °C, With increasing distance thermocouple 3 the peak temperature decrease 237.168 °C, finally, the lowest peak temperature is observed at the distance of 80 mm from the weld center line is 218.112 °C. The increasing distance from the weld centerline, it make decreasing the peak of temperatures. In comparison, welds with preheat of 200 °C have higher peak temperatures than weld no preheat. especially at the distance of 10 mm, 35 mm, 55 mm and 80 mm the weld centerline. Suggestion that preheating could be reduces the temperature gradient between the weld region and base metal. The addition of heat around welding can increase the temperature in welding area. The impact of high temperature on welding area could be increase the tensile strength, the double fillet welding resulted the highest temperature in welding center and tensile strength is the biggest [11].

The form and the number of distortion can be seen in Figure 4 below. Result of distortion measurement on welding without preheat occurred with longitudinal and transversal curve forms by maximum distortion of 10.56 mm and transversal distortion measurement shows 5.8 mm number of distortion. This result shows that cooling process post-welding is very influencing the form of distortion.



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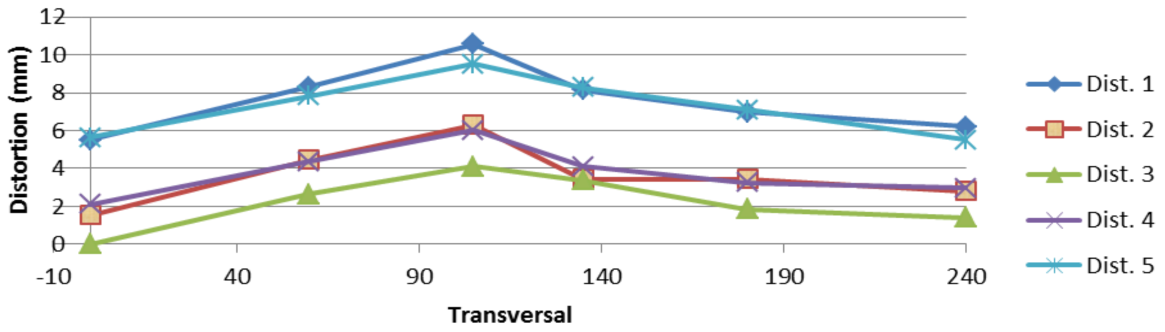
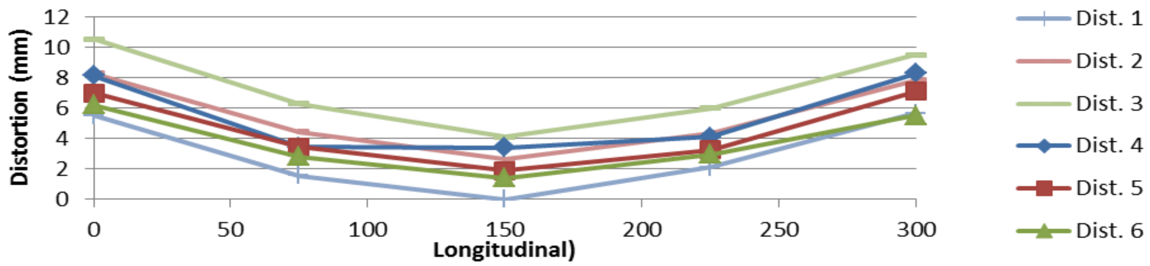
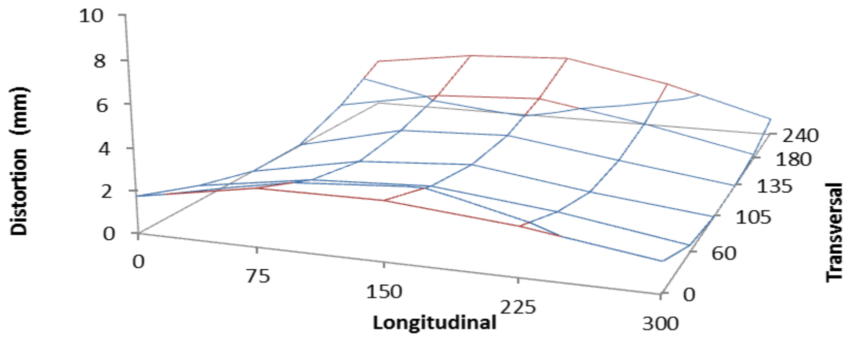


b).

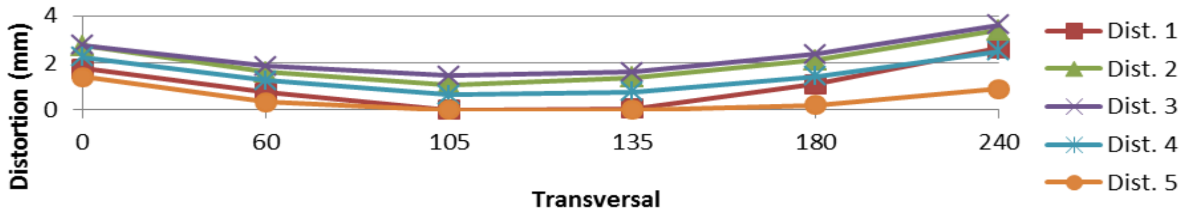


c).

Figure 4 Graphic of distortion on the result of welding without preheat (Dist : Distortion)



a)



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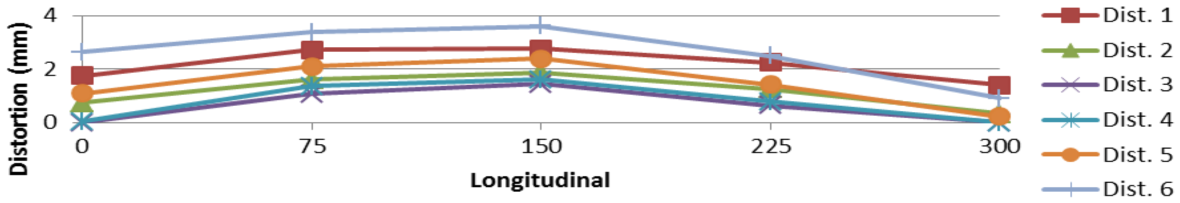


c)

Figure 5 Graphic of Distortion in welding with preheat temperature of 200 °C (Dist : Distortion)

It seem that preheat change the temperature distribution which in turn distortion as show in Figure 5. The result of distortion measurement in the form of 3-dimension and 2-dimension for welding with 200 °C preheat temperature. Distortion occurs along longitudinal and transversal direction. The number of longitudinal distortion is 2 mm and transversal is 3,2 mm. This result shows that preheat process around welding area is very influencing the form of distortion. Distortions from welding with 200 °C of preheat could be decreases distortion.

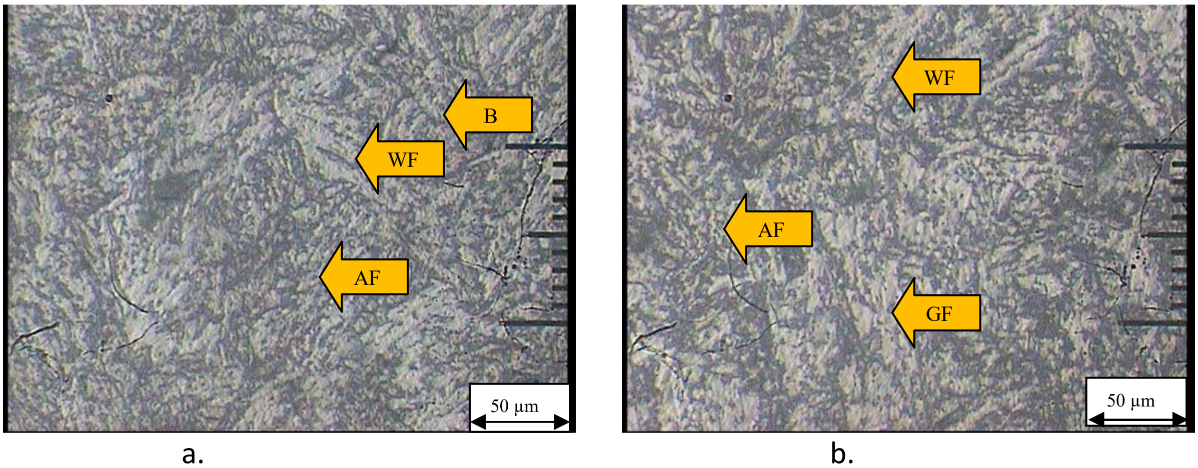


Figure 6 Microstructure of welding area a). without preheat, b). preheat 200 °C.

Figure 6 show the microstructure of the weld metal without preheat is Bainite (B) Widmanstatten Ferrite (WF) and Acicular Ferrite (AF), weld metal with 200 °C of preheat is Widmanstatten Ferrite (WF) Acicular Ferrite (AF) and Graind boundary Ferrite (GF), and also on SAW welding gas and oil pipes resulted the highest heat input in welding center, the sum of acicular ferrite microstructure is high [8]. Becouse of the microstructure in weld metal with 200 °C of preheat is dominate with Acicular Ferrite and Grain boundary Ferrite, it make the crack propagation rate is slower than weld metal without preheat.

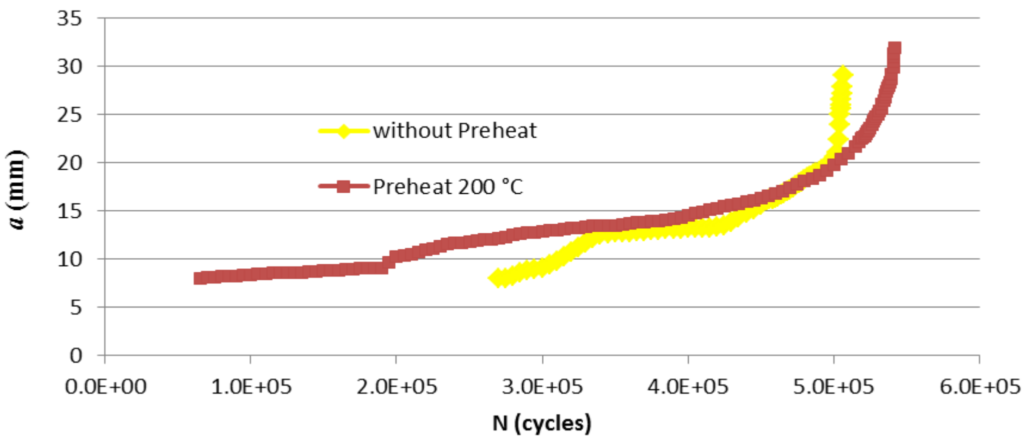
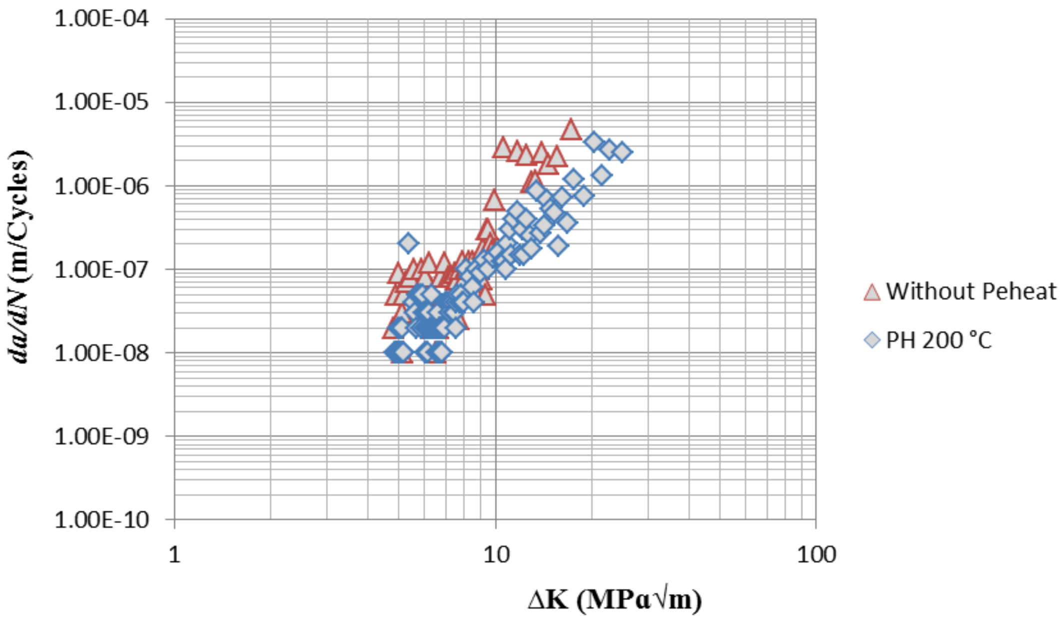
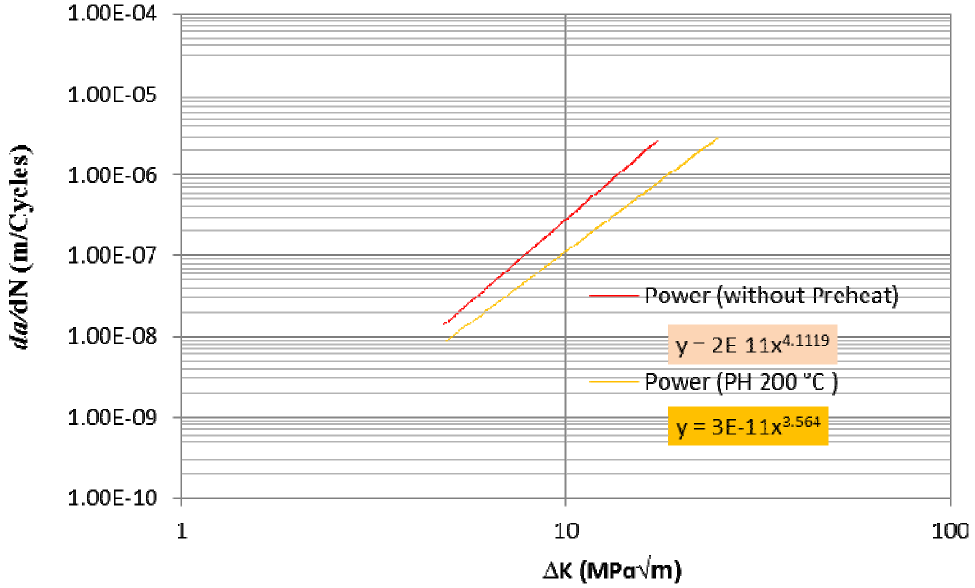


Figure 7 Graphic of crack toward cycle on welding without preheat and with 200 °C of preheat.

It seem that preheat change the temperature distribution and weld thermal cycles which leads to improve fatigue performance as shows in Figure 7. Fatigue crack propagation on welding without preheat and with 200 °C preheat. Fatigue breakage has occurred begin with high load on a component [12]. Preheat can increase fatigue life, it means that it is able to restrain propagation rate of fatigue crack from cyclic loading. It is also that transient heat addition on friction stir welding can decrease propagation rate of fatigue crack [5].



a).



b).

Figure 8 Graphic of fatigue crack growth toward stress intensity factor on welding without preheat and with 200 °C of preheat: a). Witout trendline, b). With trendline

The propagation rate of fatigue crack dα/dN is influenced by C and N values. C value determines the position of dα/dN curve while n value shows propagation speed of fatigue crack. Figure 8 shows the characteristic of fatigue crack propagation between welding without preheat and with 200 °C of preheat. On 200 °C of preheat, fatigue rate is slower if it compared with welding without preheat. It shows that preheat is able to increase welding joint life time. The stir friction welds under treatments with heating temperature 200 ^{o}C lowered fatigue growth rate (dα/dN) [13].

Table 2 Paris C and n constants on each speciment

Specimen	C	n
Without Preheat	2-E11	4.112
Preheat 200 °C	3-E11	3.564

Constant value of Paris C and n can be seen on Table 2. n value on 200 °C of preheat is smaller than without preheat, it is that the propagation of fatigue crack by using 200 °C of preheat is better. The endurance toward fatigue crack propagation can be influenced by Change on microstructure in welding metal and temperature gradient in welding process is decreased by preheat that residual stress in decreased. It causes propagation rate of fatigue crack decrease.

Conclusion

The conclusions the research of FACW welding without preheat and preheat 200 °C can be drawn as follows:

(1). In general, welding FCAW process with preheat 200 °C produce a lot of acicular ferrite micro structure, It is improved fatigue crack growth than without preheat.

(2). Preheat 200 °C, where thermocouples were located at the distances of 10 mm, 3.5 mm, 5.5 mm and 80 mm from weld line is higher than without preheat. Preheating could be reduces the temperature gradient between the weld region and base metal, It made the distortion welding with preheat lower than without preheat.

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