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Experimental study of pulse TIG welding on SA335 P22 to evaluate creep properties

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Abstract – *The present study is to investigate the effect of pulse current welding on microstructure specifically the carbide refinements on SA335 P22 by using pulse current TIG. In case of constant current weld the microstructure observed is hypo-euctectoid ferrite + pearlite while in case of pulse current welding the microstructure observed is hypo-euctectoid ferrite + bainite. Also the refinement in the carbides can be observed from the microstructure in case of pulse current compared to constant current.Further the effect of pulse current frequencies also observed. The physical properties showed unconsiderable changes.*

Key Words: Cr-Mo, Creep Life, Pulse TIG, Carbides.

1. INTRODUCTION

SA335 P22 is a Cr-Mo alloys pipe grade material, finds its major application at high temperature such as boilers. As we know, for any material to operate at high temperature, it needs excellent creep properties which determines its life at high temperature known as creep life. SA335 P22 is a Cr-Mo alloy which gain its creep strength i.e. high temperature strength from the carbides that it contains. At elevated temperature this carbides coarsens which results in the degradation of material's property and ultimately failure of the component. That's why components operating at elevated temperature has a limited service life time. In this study welding trials are taken on SA335 P22 by using pulse current and the microstructure of the same is observed and compared with the weld done by using constant current weld so that to evaluate the effect of pulse current on refinement of carbides, which is also observed while casting by using electric current during solidification.

2. LITERATURE REVIEW

A combined heat and power (CHP) plant with a steam turbine consists of a boiler with a steam-water system for heat and electricity production. To achieve high electrical efficiency for the plant high steam temperature and pressure is required. This involves that the service lifetime will be limited by creep in the parts of the plant that are exposed to the highest temperatures.[1]

Alloys containing Chromium and Molybdenum are extensively used in high temperature application like steam generators, steam pressure piping systems, petrochemicals applications etc, and the reason being is the properties offered by this alloys at low cost as compared to stainless steel grades. This properties include creep strength i.e. high temperature strength, resistance to high temperature corrosion and excellent weldability.

2.1 Creep Phenomenon

In simple terms creep is nothing but the deformation at the high temperature. At high temperature material start to deform at the stresses much lowers then the stresses it require to deform at room temperature with respect to time.

The diffusion control processes and phenomenon dominates at high temperature as the mobility of the atoms increases. The motion of dislocations also fastens at high temperature by means of climb. New deformation mechanisms may come into play at elevated temperatures. In some metals the slip system changes, or additional slip systems are introduced with increasing temperature. Deformation at grain boundaries becomes an added possibility in the high-temperature deformation of metals. [2]

The main deformation processes encountered at high temperature in any material are slip, sub grain formation and grain boundary sliding. Measurements of local creep elongation at various locations in a creep specimen have shown that the local strain undergoes many periodic changes with time that are not recorded in the changes in strain of the total gauge length of the specimen. [2]

Apart from the above mentioned primary phenomena, couple of secondary phenomena also takes part in deformation at micro level. Also from the basic theory of creep we know that for creep application the coarse grain is suitable, so that to have lower grain boundary and to reduce the slip phenomena at high temperature which can result in deformation as we discussed above. However different works indicated that slip phenomena only accounts for 10% of the high temperature deformation while dislocation climb is mainly responsible for the same, thus if we can reduce or control the dislocation climb by blocking their motion we can reduce the deformation at high temperature i.e. creep upto an greater extend even in the case of coarse grain structure.

2.2 Service characteristics of SA335 P22

The alloys present in this material are in quantity over than the solubility limit of ferrite (BCC), thus its microstructure shows multiple phase i.e Hypoeutectoid +pearlite. The excess alloys present in the material present as the form of carbides over the matrix of ferrite.

When any Cr- Mo alloy alike this material goes into service i.e at high temperature, these carbides changes the composition and morphology to approach the equilibrium. Their equilibrium form strongly depends on their initial structure, size and distribution. Thus we can say that the deformation rate and time of the material also depends on it.

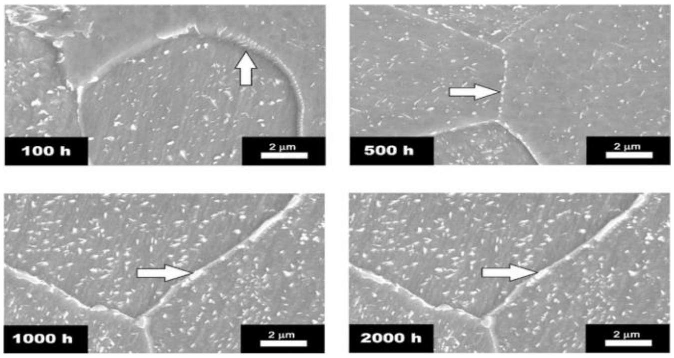


Fig -1: SEM image of in service material at different time[3]

2.3 Nucleation during weld solidification

The structure of weld grains, grain formation, grain size and direction of grain growth depends on the weld solidification mechanism.

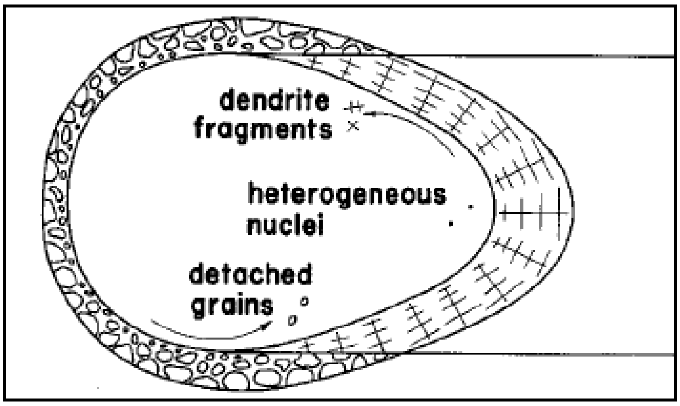


Fig -2: Nucleation mechanism during welding [4]

The above figure indicates three phenomenon that takes place whenever there is any disturbance is observed in weld pool during solidification, pulsing the current during welding can be considered as one of the means of disturbance. Thus when we use pulse current over constant current these stated mechanisms takes place in weld pool which results in additional nucleation in weld pool and even distribution of alloying elements. This mechanisms are discussed by Sindo Kou in their book " Welding Metallurgy", A John wiley& Sons, INC., Publication as briefly given below.

2.3.1 Dendritic fragmentation

When the tips of the dendrites breaks due to solidification disturbance into the weld pool which then act as a nuclei for further grain formation.

2.3.2 Grain detachments

When the partially melted grains detach themselves into the weld pool they again acts as independent nuclei for another grain formation.

2.3.3 Heterogeneous nucleation

Foreign particles present in the weld pool upon which atoms in the liquid metal can be arranged in a crystalline form can act as heterogeneous nuclei.

Thus we can use the pulse current in welding SA335 P22 so that to achieve the more refined arrangement and refined size of the carbides in the weld with the help of the above discussed mechanisms.

3. EXPERIMENTAL WORK

Initially the bead on trials are taken on the SA335 P22 pipe at various frequency with variable background current as shown below.

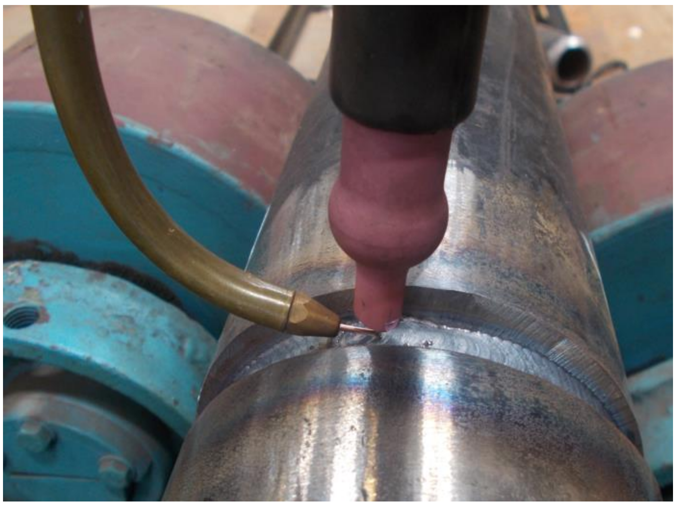


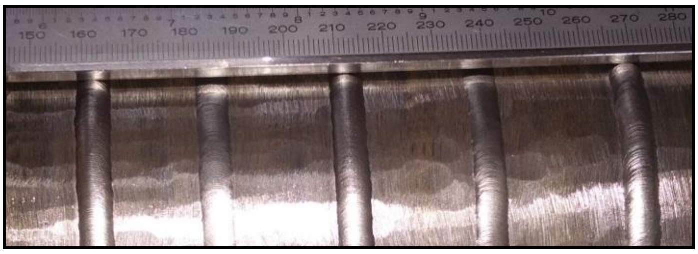
Fig -3: Arrangement of tungsten and filler feeder Cu tube above the groove.

Chemical Composition of SA335 P22(as per ASME sec II A) and 90S-B3(as per ASME sec. II C) –

Elements	SA335 P22	90S-B3
C	0.05-0.15	0.07-0.12
Mn	0.3-0.15	0.4-0.7
P	0.025	0.025 max
S	0.025	0.025 max
Si	0.5 max	0.4-0.7
Ni	-	0.2 max
Cr	1.9-2.6	2.3-2.7
Mo	0.87-1.13	0.9-1.2

Table -1: Chemical composition of base metal and filler wire

I1=180A	I1=180A	I1=180A	I1=180A	I1=180A	I1=180A
I2=100%	I2=60%	I2=70%	I2=80%	I2=60%	I2=70%
-	3Hz	3Hz	3Hz	4Hz	4Hz



I1=180A	I1=180A	I1=180A	I1=180A	I1=180A
I2=80%	I2=60%	I2=70%	I2=80%	I2=70%
4Hz	5Hz	5Hz	5Hz	20Hz

Fig -4: Bead on trials on SA335 P22

Above figure shows the bead on trials taken on SA 335 P22 pipe by 90S-B3 wire spool. The microstructure of the above taken trials are studied to investigated the effect of pulse frequency on carbide refinement as compared to constant current.

Further for analyzing the effect of using pulse current in place of constant current on physical properties i.e. UTS, bend strength and the hardness, destructive testing is conducted.

After analysing the microstructure of above bead on trials and further to evaluate the physical properties, Secondary current of 70% and frequency of 3Hz is selected.

Below are the parameters developed by taking number of groove trails. During the trials porosity is encountered in main cases, which can be eliminated by maintaining the correct combination of travel speed with other parameters.

Constant Current(CC) Welding Parameter (T1)		
	Root Pass	Hot and Fill up
Main Current (I)	110 Amps	110 Amps
Voltage	11-14 V	13.5 V (AVC)
Primary feed rate	0.90 m/min	0.90 m/min
Travel speed	8-11cm/min	8-11cm/min

Table -2: Groove weld parameters for CC case

Pulse Current(PC) Welding Parameter (T2)		
	Root Pass	Hot and Fill up
Main Current (I1)	160 Amps	170 Amps
Secondary Current (I2)	70% (112 Amps)	70% (119 Amps)
Voltage	11-14 V	13.5 V (AVC)
Primary feed rate (Fd1)	0.90 m/min	0.90 m/min
Secondary feed rate (Fd2)	70% (063)	70% (0.63)
Frequency	3Hz	3Hz
Travel speed	8-11cm/min	8-11cm/min

Table -3: Groove weld parameters for PC case

Following are the parameters that are kept constant for the above trials:

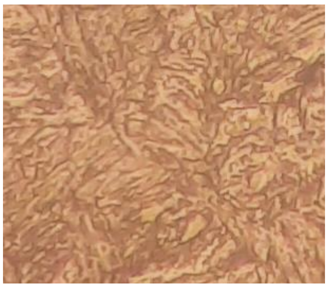
S No.	Constant Parameters	
1	Tungsten Size	3.2 mm
2	Start Current (I-S)	35%
3	Upslope time (UPS)	0.5 sec
4	Down slope time (DSL)	2.0 sec
5	End Current (I-E)	35%
6	Gas pre flow (GPr)	0.5 sec
7	Gas post flow (GL)	2 sec
8	Gas flow rate	12-15 LPH

Table -4: Constant parameters in each case

4. RESULTS

4.1 Microstructure evaluation

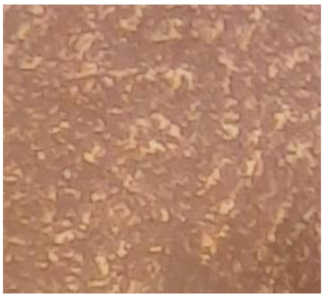
From the bead on trials after analysis the macro, and for further microstructure analysis 70% background is selected at each frequency i.e 3Hz, 4Hz, 5Hz, and 20Hz to compare it with microstructure of constant current case.



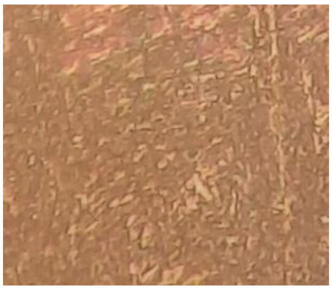
(a)

(b)

(c)



(d)



(e)

Fig -5: Microstructures of weld at 200X using various frequencies(2% nitalis used for etching) (a) CC (b) 3Hz (c) 4Hz (d) 5Hz (e) 20Hz

From the above figure we can see that the dendritic structure is getting fine when we shift from constant current to pulse current and further it gets fine as we increase the pulse frequency. In the (e) case the dendrites can't be not be differentiated at this magnification as it can be at lower frequencies.

4.2 Transverse Tensile Testing

Specimen No.	C/S Area (mm^2)	Ultimate Load (KN)	UTS (N/mm^2)	Type of Fracture
Transverse (T1)	70.85	40.25	568.10	Ductile(PM)
	70.85	40.55	572.34	Ductile(PM)
Transverse (T2)	72.28	40.55	561.01	Ductile(PM)
	71.15	40.65	568.53	Ductile(PM)

Table -5: Result of tensile test

From the above table we can see that the UTS for both the cases i.e for constant current weld and pulse current weld the result found is satisfactory and the value of UTS is almost same in both the cases. The specimen is failed from the parent metal and the minimum required UTS for the SA 335 P22 is 415MPa.

4.3 Bend Test

Specimen No.	Type of bend	Result
T1	Root bend 1	No opening
	Root bend 2	No opening
	Face bend 1	No opening
	Face bend 2	No opening
T2	Root bend 1	No opening
	Root bend 2	No opening
	Face bend 1	No opening
	Face bend 2	No opening

Table -6: Result of bend test

Fig -6: Bend test result

4. CONCLUSION

From the above conducted experiment and analysis it can be concluded that pulse current can be be used instead of constant current which offers following advantages :-

- Reduction in heat input, in this case heat input is reduced by 17.46 %.

- From the microstructure analysis we can observe that we are getting hypo-euctectoid ferrite + pearlite in case of constant current weld while hypo-euctectoid ferrite + bainite in case of pulse current weld, and we know that later one is more desirable.
- The distribution of the carbides is even in case of pulse current weld as compared to constant current case with no considerable effect on physical properties of weld, which can substantially play role in creep life of the weld.
- Further creep test can also be done to get the more rigid information on the exact increment on the creep life.

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