Journal of Applied Sciences

ISSN 1812-5654

science alert

ANSInet
an open access publisher
http://ansinet.com

Journal of Applied Sciences 13 (20): 4206-4210, 2013
ISSN 1812-5654 / DOI: 10.3923/jas.2013.4206.4210

A Welding Process Test of Nickel Based Superalloy N06625 and its Composite Plate

Wen-Chao Zhou, Shan-Hua Xiao and Guo-Qi Luo
Department of Automatic Control Technology, Yibin Vocational and Technical College,
644003, Yibin, China

Abstract: Nickel based superalloy N06625 welding quality is directly related to whether to maintain good mechanical properties and excellent corrosion resisting property before welding. The test studies welding process of Nickel based superalloy N066255 and Its Composite Plate. The test results show that, strictly cleaning before welding, the pure argon protection, selecting welding consumables which have reasonable composition and making suitable welding parameters and pertinent operation techniques, can avoid such deficiencies as hot cracks and poor corrosion resisting property and obtain high-quality welds. The welded test plates tested in tensile test, bending test, impact test, metallographic examination and corrosion test are qualified.

Key words: Nickel based superalloy N06625, welding measures, mechanical properties, corrosion resisting property

INTRODUCTION

A new type alloy N06625 belongs to the nickel-base superalloy of Nickel Chromium Molybdenum Niobium Series, which is corrosion resistant, heat-resistant and solution strengthening. Below 6500C, It has excellent durability, fatigue resistance, corrosion resistance and oxidation resistance, especially has excellent resistance to pitting, resistance of crevice corrosion and resistance to chloride ion stress corrosion crack and can work below 9820C. It is very suitable to be used on the conditions which need high corrosion resistance and high strength or heat resistance and it basically is not corroded in such weak media as atmosphere, water, seawater, neutral salt and alkaline. In phosphoric acid, hydrochloric acid, hydrofluoric acid, nitric acid, organic acid, alkali, reduction salts, oxidation salts, its corrosion resistance is very good (Huang, 1994). Therefore, this alloy is corrosion-resistant and heat-resistant and is widely applied to chemical industry, maritime facilities, environmental protection equipment, heat exchanger, aerospace industry, shipbuilding industry, nuclear industry, petrochemical industry, gas turbine, heat treatment equipment, electrical elements and industrial furnace. It is not only costly, but also wasteful of resource to use nickel-base alloy N06625 to manufacture pressure vessel. Using the method of Explosive Cladding to make nickel base alloy N06625 and steel plate into composite plate, the composite plate as a pressure vessel body material not only can take advantage of N06625 alloy and steel, but also greatly reduces the cost of manufacture.

The purpose to explore the problem of N06625 welding is to develop new clad steel plates of nickel base alloy N06625 in future for the company. The test focuses on the strict cleaning before welding, the pure argon protection, reasonable selection of welding consumables, making suitable welding parameters and pertinent operation techniques.

Problems of alloy N06625 welding: In general, nickel-base alloy N06625 has good welding performance. But the welding performance of nickel-base alloy N06625 is determined by its special thermo physical properties, in the welding process there are many difficulties, such as:

- Because of its low thermal expansion coefficient and big modulus of elasticity, the welding deformation and residual stress appear in welding. B. Nb content in the alloy N06625 is high, up to 3.15~4.15% and Nb can be combined with C, Si, S, P and form intermetallic compounds and low melting points such as Fe4Nb5Si3, which will lead to hot cracks. C. The crystallizing points of the weld bead of alloy N06625 range widely. Its liquid temperature is 1360°C, the final crystallization temperature is 1152°C and crystallization temperature ranges 208°C, during which the thermal expansion coefficient changes greatly as the temperature drops. Cooling shrinkage is affected by pulling force and the weld is easy to crack, so the hot crack is easy to appear. D. Mo content in Alloy N06625 is up to about 9%. Mo' solubility in austenite is low and it is easy to

Corresponding Author: Wen-Chao Zhou, Department of Automatic Control Technology, Yibin Vocational and Technical College, 644003, Yibin, China

segregate into the liquid (Yang *et al*., 2009). Therefore, the center of solid-state dendrite which crystallizes in advance is easy to be corroded because of forming lean Mo. E. Intergranular corrosion is very serious as alloy N06625 is heated between 700-950°C because in this temperature range a large number of Cr and Mo carbides are precipitated. the rapid cooling after welding shall pass this temperature range as soon as possible. F. When Alloy composite plate is welding, due to the dilution effect, iron (Fe) into the welds, which is harmful to corrosion resistance of the sensitized NiCrMo alloy. Because it can promote the precipitation of harmful intermetallic phase i and P, moreover, with the addition of iron (Fe), which make Mo's and Nb's solubility decrease in austenite and increase segregation tendency of Mo and Nb and then increase the hot crack and corrosion tendency. G. After welding the welding defects may appear such as gas holes and slag inclusion

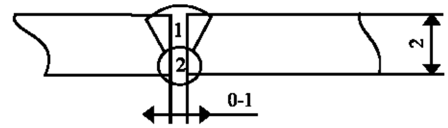

Fig. 1: Groove shape and weldong bead layout of the 2 mm plate

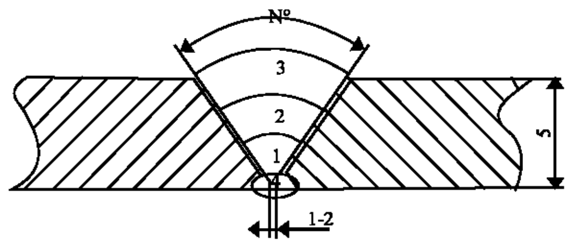

Fig. 2: Groove shape and welding bead layouot of the 5 mm plate

MATERIALS AND METHODS

The welding test carries out N06625 plate butt welding, N06625+16MnR composite plate butt welding and N06625+16MnR composite plate bead weld.

N06625 plate butt welding test: The nickel-base alloy plates in the test are N06625 made in USA, with thickness: 2 and 5 mm and their test numbers respectively are No.1 (thin plate) and No. 2 (thick plate); the solder wire's type in the test is ERNiCrMo-3, with high content of Mo, 2 and 2.4 mm in diameter. Test plates' grooves are made with machine. The groove shape (Li, 2011) and welding bead layout are shown in Fig. 1 and 2.

The test uses the manual argon tungsten-arc welding (GTAW, DCEN). Before welding, the groove and the foreign matter on both sides of it in the range of 50 mm are carefully cleaned first by electric angle grinder and then with acetone to clean up. When welding, it is protected by the argon from backwards, whose flow rate is 18 L min^{-1}. The first weld layer is polished and back chipped with a grinding wheel machine and then welding the second layers. The interlayer temperature should be less than 80°C and welding parameters are shown in Table 1. After welding, the plate is tested for mechanical property and corrosion resistance (Wang and Zheng, 2007) and the test data are shown in Table 2 and 3.

Metallographic phase test results of the plate No. 2: The metallurgical structure of welds is Single-phase Austenite (solid-state dendrite); the metallurgical structure of mother-plate is Single-phase Austenite, its grain size: Grade 6.

N06625+16MnR composite plates butt welding test: For welding N06625+16 MnR composite plates, the tests, according to heat treatment and non - heat treatment state, are divided into two groups. The serial numbers of the test plates are named as test plate No. 3 (by post-weld non-heat treatment), test plate No. 4 (by post-weld heat treatment), respectively. Their groove shape and welding bead layout are shown in Fig. 3.

The base layer is welded by shielded metal-arc welding (SMAW, DCEP), with welding wire E5015 as welding material. The transition layer and clad layer are welded by manual gas tungsten arc welding (GTAW, DCSP), with welding wire ERNiCrMo-3 which contains high content of Mo. The temperature of the transition layer and clad layer must be less than 80°C. The welding parameters of two test plates are shown in Table 4. Plate No. 3 is on the performance test as welded. Plate No. 4 is processed by 1000°C/25 min heat treatment, with air cooling. The mechanical property and corrosion test results are shown in Table 5 and 6.

N06625+16MnR composite plate bead weld: Composite plates N06625+16MnR are used in the two group of welding tests. The serial numbers of the test plates are named as test plate No.5 and test plate No.6. The transition layer and clad layer are welded by manual tungsten argon arc welding (GTAW, DCSP), with welding wire ERNiCrMo-3 which contains high content of Mo. The interlayer temperature must be less than 80°C. The bead weld and weld layers layout are shown in Fig. 4. The welding test parameters are shown in Table 7.

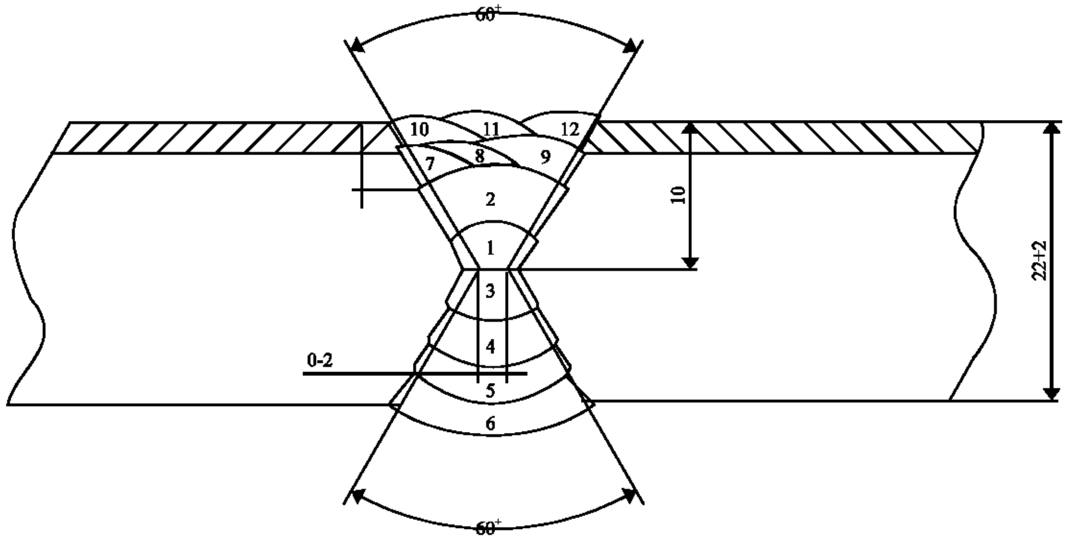

Fig. 3: Groove shape and welding bead layout of the N06625 composite plate

Table 1: Welding parameters of N06625 plate

Serial No.	Layer No.	Wire diameter (mm)	Welding current (A)	Welding voltage (V)	Welding speed (cm min^{-1})	Linear energy (kJ cm^{-1})	Ar Gas flow (L min^{-1})	Diameter of tungsten electrode (mm)	Orifice size (mm)
No. 1	1	φ2.0	65	12-13	10.4	4.5-4.9	16-18	2.5	φ18
	2	φ2.0	65	12-13	11.4	4.1-4.4	16-18	2.5	φ18
No. 2	1	φ2.4	110-120	12-13	17-19	4.2-5.5	16-18	2.5	φ18
	2	φ2.4	120-130	12-14	17-18	4.8-6.4	16-18	2.5	φ18
	3	φ2.4	120-130	12-14	17-19	4.5-6.4	16-18	2.5	φ18
	4	φ2.4	130-140	12-14	17-19	4.9-6.9	16-18	2.5	φ18

Table 2: Test data of mechanical property

	Tension test		Bending test			
Serial No.	Rm (Mpa)	Fracture location	Bend mandrel (mm)	Bend angle (°)	Face bend	Root bend
No. 1	750	welds	8	180	qualified	qualified
	750	welds	8	180	qualified	qualified
No. 2	760	welds	8	180	qualified	qualified
	760	welds	8	180	qualified	qualified

Table 3: Data of corrosion test

	Corrosion test methods (ASTM G28 boiling 120 h) Corrosion Rate			(ASTM G48A 50±1 24 h) corrosion rate		
Serial No.	g m^{-2} h	mm (a)	Conclusion	g m^{-2} h	mm (a)	Conclusion
No. 1	0.482	0.500	Qualified	1.351	0.006	No Pitting
	0.467	0.485	Qualified	3.417	0.015	No Pitting
No. 2	0.2099	0.302	Qualified	0	0	No Pitting
	0.195	0.285	Qualified	0	0	No Pitting

Table 4: Welding parameters of plate No. 3 and 4

Serial No.	Layer No.	Wire diameter (mm)	Welding current (A)	Welding voltage (V)	Welding speed (cm min^{-1})	Linear energy (kJ cm^{-1})	Ar Gas flow (L min^{-1})	Diameter of tungsten electrode (mm)	Orifice size (mm)
No.3	Base layer	φ3.2	90	20-22	8-9	12.7-13.9	/	/	/
		φ4.0	175	22-24	9-10	24.1-26.3	/	/	/
		φ3.2	125	20-22	8-6	17.2-18.9	/	/	/
		φ4.0	175	22-24	9-10	24.3-26.5	/	/	/
No.4	Transition layer	φ2.0	120	12-14	13.5	6.4-7.5	18	φ2.5	φ18
	Clad layer	φ2.0	120	12-14	14	6.2-7.2	18	φ2.5	φ18

Table 5: Test data of mechanical property of plate No. 3 and 4

	Tension test		Bending test			Impact test	
Serial No.	Rm (Mpa)	Fracture location	Bend mandrel (mm)	Bend angle (°)	Side bend	Temperature (°C)	Impact Absorbed Energy A_{kV} (J)
No. 3	615	Base metal	40	180	No crack	WM	135.150.151
No. 3	620	Base metal				HAZ	97.100.93
No. 4	540	welds	40	180	No crack	WM	148.146.137
No. 4	550	welds				HAZ	110.90.74

Table 6: Data of corrosion test of plate No. 3 and 4

	Corrosion test methods (ASTM G28 boiling 120 h) corrosion rate			(ASTM G48A 50±1 24 h) Corrosion Rate		
Serial No.	g m^{-2} h	mm (a)	Conclusion	g m^{-2} h	mm (a)	Conclusion
No.3	1.211	1.257	Qualified	0.004	0.874	No pitting
	1.245	1.293	Qualified	0.007	1.566	No pitting
No.4	2.965	3.077	Qualified	0.007	1.589	No pitting
	2.880	2.990	Qualified	0.007	1.581	No pitting

Table 7: Welding parameters of Plate No.5 and 6

Serial No.	Layer No.	Wire diameter (mm)	Welding current (A)	Welding voltage (V)	Welding speed (cm min^{-1})	Linear energy (KJ cm^{-1})	Ar gas flow (L min^{-1})	Diameter of tungsten electrode (mm)	Orifice size (mm)
Plate No. 5	transition layer	φ2.4	140-160	12-13	10.4	9.7-12	18	φ2.5	φ18
Plate No. 6	Clad layer	φ2.4	140-160	12-13	10.1	10-12	18	φ2.5	φ18
	Clad layer	φ2.4	140-160	12-13	9.75	10.3-12.8	18	φ2.5	φ18

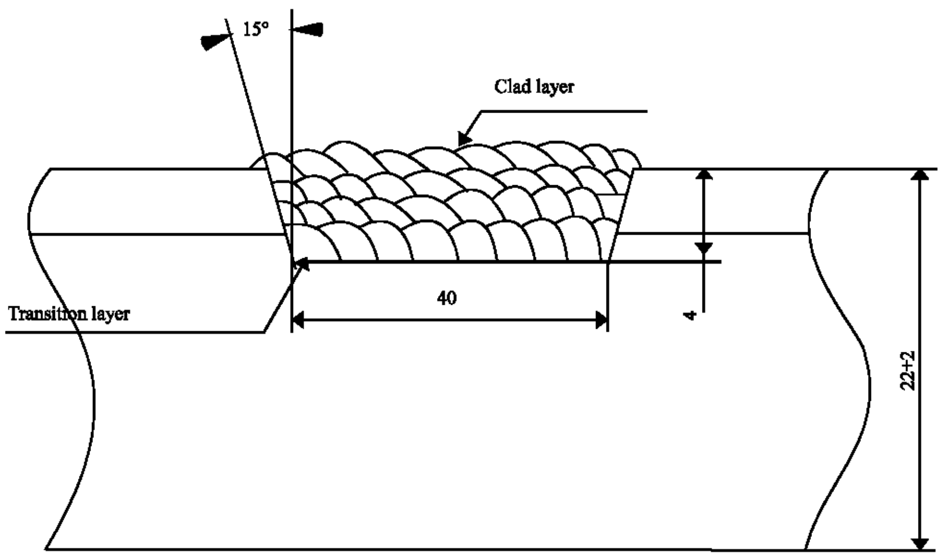

Fig. 4: Welding beads layout of N06625

Plate No. 5 is on mechanical properties and corrosion tests after welded. Plate No. 6 is processed by heat treatment of 1000°C/25 min, with air cooling and then begins the test. The test results are shown Table 8, 9 and 10.

RESULTS AND DISCUSSION

The test results above have shown that, all test items for the test plate No. 1 and 2 (Alloy N06625 pure material butt welding test) were qualified for one time. N06625+16MnR composite plates butt welding test and their mechanical properties tests were qualified for one time. In the corrosion test, there was something wrong with the corrosion specimens which had the problem of exceeding the standard in different degree. By repeated tests and the strict welding operation, new basically qualified specimens were made finally. The causes of corrosion data exceeding the standard may have the following factors: When the transition layers were welded, too big amount of dilution Fe increased segregation of Mo and Nb and then increased the corrosion tendency of

Table 8: Test data of mechanical property of plate No.5 and 6

	Bending test		
Serial No.	Bend mandrel (mm)	Bend angle (°)	Side bend
Plate No.5	40	180	No crack
Plate N0.6	40	180	No crack

Table 9: Data of corrosion test of plate No.3 and 4

	Corrosion test methods (ASTM G28 boiling 120 h) corrosion rate			(ASTM G48A 50±1 24 h) corrosion rate		
Serial No.	$g\ m^{-2}\ h$	mm (a)	Conclusion	$g\ m^{-2}\ h$	mm (a)	Conclusion
Plate No. 5	0.702	0.728	Qualified	0.007	1.578	No pitting
Plate No. 6	0.748	0.776	Qualified	0.010	2.343	No pitting

Table 10: Chemical composition of welding beads of plate No. 5 and 6

	Chemical composition (%)											
Serial No.	C	Si	Mn	P	S	Cr	Mo	Ni	Ti	Cu	Al	Nb	Fe
Plate No. 5	0.012	0.030	0.24	0.003	0.004	21.44	9.15	63.94	-	0.01	0.20	4.19	0.45
Plate No. 6	0.005	0.036	0.023	0.003	0.002	21.68	9.15	93.54	0.27	0.01	-	4.06	0.91

alloy; The welding parameters were specified improperly: Occasionally, welding current parameters that were too big made the certain elements overfireed in the welds.

CONCLUSION

The following conclusions are drawn from the test results above:

- Before welding, the oil stain, sundries, marks and handwriting on the welding wire, groove face and its both sides should be carefully cleaned with stainless steel wire wheel grinding or washed by acetone
- The welding materials of low carbon content, low impurity content of sulfur and phosphorus and low iron content should be used, which can avoid hot cracks and enhance corrosion resistance
- Small size of welding materials should be used, welding current parameters must be small and welding linear energy should be strictly controlled: Preferably less than 1.5 kJ cm^{-1} and the interlayer temperature had better be controlled less than 80°C
- As clad steel plates are being welded, the transition layer should be done with small welding wires and by such technical measures as small welding current, fast welding and no swing. The dilution of Fe of mother material into the alloy should be reduced as much as possible

REFERENCES

Huang, J.H., 1994. Practical Handbook of Pressure Vessel Materials-Special Materials. 1st Edn., Chemical Industry Press, New York.

Li, J.S., 2011. Electric Welder. 1st Edn., China Labor Press, New York.

Wang, J.C. and S.P. Zheng, 2007. Analysis on the cause of corrosion of C-276+16MnR clad steel plate used in the reactor of phosphate. China Chem. Industry Equip., 1: 44-45.

Yang, R.C., S.R. Niu and K.X. Wang, 2009. Homogenizing treatment and microstructure evolution of corrosion-resisting nickel-base alloys diffusion. J. Jiangsu Univ. Sci. Edn., 30: 32-35.