Microscopic Research of 18% Ni Maraging Steel Weld

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Abstract

The present paper considers the weld process of the 18% Ni super-high strength maraging steel makes strict control for its weld heat input and interpass temperature and adopts the new technology of High Frequency Pulse Automatic Gas Tungsten Arc Welding. Therefore, the methods mentioned above could reduce and refine austenite segregation phase and the overall may improve weld property.

KEY WORDS: (Maraging Steel)(Austenite Segregation Phase)(Weld Heat Input) (High Frequency Pulse Arc Welding) (Microprobe) (Service Life)

1. Introduction

The 18%Ni super-high strength maraging steel is one kind of the advanced structural materials. Since International Cooperation of Nickel studied and worked it out, it has been famous for its good characters of super-high strength and toughness, and attracted all the industry, such as metallurgy, space navigation, mechanical manufacture and so on. Now 18% Ni steel is being widespread applied in the world. But when the super-high strength maraging steel is welded, austenite segregation phase often appears, which

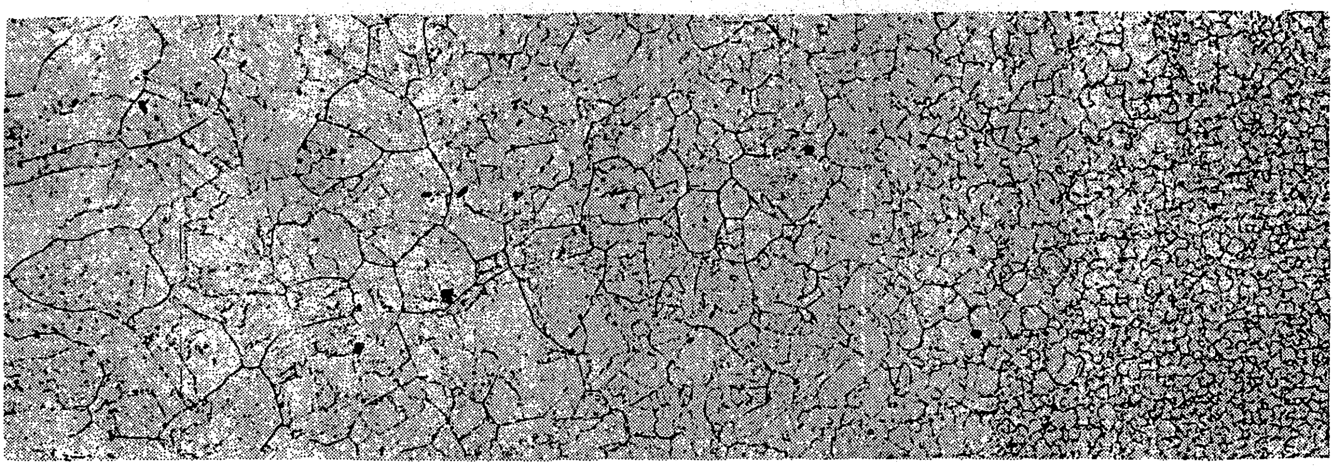

Fig.1 The structure of each part of the heat-effected zone X250

lowers its toughness and applied result. To suit the development of 18% Ni steel, we'd better start our research on its welding technological strategy for the 21st century. Tests demonstrated that the structure of each part of the heat-effected zone has certain influence on its properties (See Figure 1), but the action of weld austenite segregation phase is paramount.

2. Austenite Segregation Phase

2.1 As the composition of the 18% Ni steel filler wires is similar to that of the base metal (Table 1), the weld cast microstructure takes on the characteristics of the base metal. After aging treatment, the precipitate and dispersion causes a reversion from martensite to austenite. But because of the inhomogeneity in the chemical composition of the weld during crystallization process, micro-segregation phase arises in the weld structure which is thus much more complex than the base metal.

Table 1 Composition of 18% Ni steel base metal

No. of furnace	C	Mn	Si	P	S	Ni	Mo	Co	Ti	Al
718-667	0.015	trace	0.08	0.05	0.009	17.60	4.92	7.94	0.46	0.07
818-170	0.015	0.075	0.06	0.05	<0.01	18.05	4.93	7.77	0.46	0.08

The weld is composed of columnar crystal and equal axle crystal. After etching by electrolysis the weld in the aging state shows dendrite crystals and honeycomb crystals inside the original crystal. Observation of the weld through high metalloscope shows that a lot of white pools appear among the dendrite crystal boundary and the inter-space of the honeycomb crystal, especially more so near the fusion line. These white pools are surrounded by a dark etching band. This is the austenite reversion produced by the alloy segregation during the aging process. High metalloscope shows clearly that the austenite pool is often gathered by inclusion, microcracks and voids. (See Figure 2)

Fig.2 Diagram showing the gather of microcrack, inclusion and void inside austenite segregation phase X2000

2.2 The Forming Mechanism of Austenite Phase

The alloy content of 18% Ni steel is more than 33%, and the solidifying point is different in each alloy constituent. Therefore, the crystallization process of weld should occur a certain temperature range. When the melting pool locates the common solidifying temperature of the solid and liquid phase the element with the higher solidifying point form the crystal nucleus first followed by a drop in temperature and the crystal nucleus becomes larger and forms crystal particles. As different crystal compositions are separated out at different temperatures, the chemical composition inside a crystal particle is also inhomogeneous. The solidifying temperature of the alloying element of Ti, Ni, Mo and other impurities in the 18% Ni steel weld is lower than that of other elements and thus the melting pool solid phase is surrounded by elements composed of Ti, Ni, Mo and other impurities in the form of segregation phase appear around the dendrite crystal and the crystal boundary. The austenite phase of the normal 18% Ni steel occur at about 650℃, but for the liquid phase with high concentration of alloying element (Ti, Ni, Mo), the transition temperature of martensite is very low. It can achieve the austenite phase only after treatment by aging at 480°C-520°C and than cooling to room temperature.

2.3 The Microprobe Microanalysis of Weld Austenite Phase and Inclusion

The segregating curve of Ti, Mo of the austenite phase was obtained by means of a scanning electron microscope microprobe via the element quantitative line analysis of the austenite phase. The curve shows that the austenite white pool is really composed of a very high proportion of Ti (See Figure 3) and relatively high proportion

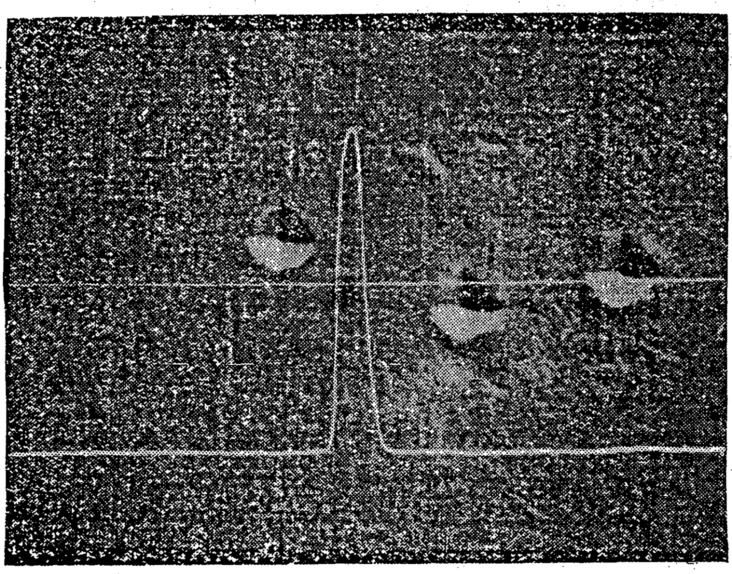

Fig.3 Microprobe quantitative line analysis curve of inclusion Ti

of Mo at the segregating phase. In order to understand exactly the distribution of weld austenite segregating phase and the surrounding structure. The Japanese X-ray diffraction microscope was used for microanalysis and the result is as follow (See Table 2).

Table 2 The analysis result of X-ray diffraction

Sample name	Analytic site	Content of each alloy % Ni	Ti	Mo
18% Ni steel weld	light-etching region	16	0.25	3.0
	dark-etching region	17	0.54	4.5
	austenite phase	18	2.65	5.7

The microprobe quantitative analysis shows that austenite white pool itself is rich in Ti, Ni, Mo with Ti being most concentrated, reaching 2.65%. The alloy content of martensite dark-etching region which surrounds it is just less than the austenite white pool, but more than that in the martensite light-etching region.

The forming mechanism of weld austenite segregation phase and microanalysis of microprobe segregation phase high-lights the following two points:

(1) The forming of austenite segregation phase is related to the percentage of alloying element in the melting pool and the latter comes from base metal and wires. We can not eliminate the influence of alloy composition of the base metal on the weld, even if we use wires of low Ti or Mo. Therefore, the author feels that the maraging steel weld segregation phase can be reduced and refined but it is impossible fully eliminate it.

(2) As the austenite white pool has high alloy content with very high proportion of Ti, it is very easy to form TiN inclusion at high temperatures. Under high-powered microscope (X 2000) almost every austenite phase has different sizes of TiN in the shape of light yellow diamonl-shaped pieces or in the shape of a line of fine pieces. Because of the existence of non-metallic inclusion, microcracks and voids, the weld tends to deform or be damaged under applied stress before the base metal does. At the same time, we should say that the more weld austenite segregation phase there is, the less weld martensite precipitate. The reduction of dispersion strengthening phase causes an obvious drop in weld toughness. Therefore, the break often occurs at the place with a concentration of weld austenite white pool and mostly along the dendrite crystal or the honeycomb crystal. The break thus produced is mostly brittle fracture.

So limiting austenite phase to the utmost is an important factor for improving weld toughness.

3. Method of Increasing Weld Toughness

According to the foregoing, in order to find the way to increase weld toughness, the author has made three comparative tests using two kind of general Automatic Gas Tungsten-Arc Welding of weld heat input and High Frequency Pulse Automatic Gas Tungsten-Arc Welding. On the basis of test data and fracture feature the analysis shows that the three layer weld Automatic Gas Tungsten-Arc Welding has large gauge and that the interpass temperature is high, heat input is the biggest, the average elongation is δ_5%=4.25%, with the break of tensile sample mostly happening in the weld, part of them having the feature of brittle fracture. The plane strain fracture toughness value K_{IC}=92.7 $MPa\sqrt{m}$. The High Frequency Pulse Automatic Gas Tungsten-Arc Welding has relatively small gauge and that the average elongation is δ_5%=5.83% and most break in the heat-affected zone or base metal. There is obvious necking and cone and cup fracture at the plastic region. The plane strain fracture toughness value K_{IC}=103.9

$MP_a\sqrt{m}$, and the plane-strain region has obvious dimples.

Analysis from weld metallograph structure, shows that there is high content of three layers weld austenite phase and that the crystal particle is thick and large. But using the technology of H.F.P.A.T.A.W, because weld has high frequency vibration fine grain during crystal process, the content of weld austenite phase is comparatively less, discontinuous, small and fine. The four layer weld is in middle. The comparison of different welding method strongly indicates that the High Frequency Pulse Automatic Gas Tungsten-Arc Welding is better than the general Automatic Gas Tungsten-Arc Welding.

4. Conclusions

To sum up the analysis of test, we can consider reducing, refining austenite phase and raising weld toughness as following:

4.1 Enforce strict control weld heat input and interpass temperature during the welding process.

4.2 Use filler wires with low Ti, Mo, the range of contents is as follow:
bottom: Ti≅0.10%; Mo≅3.00%.
other layer: Ti≅0.25%; Mo≅3.50%.

4.3 Use High Frequency Pulse Automatic Gas Tungsten-Arc Welding.

High microstructure and microprobe analysis demonstrated the close relationship between the inevitability of the phase segregation of the austenite weld and its properties.

The author feels that welding pressure vessels using the weld technology of maraging steel weld suggested in this article should prolong its service life.