Stainless Steel Welding and Development Trend of Welding Technology

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Abstract. In this paper, the research and application status of brazing technology, pulsed arc welding technology and resurfacing welding technology in stainless steel materials are introduced. The effects of temperature, weld gap and brazing material on brazing are analyzed. The influence of pulse arc welding parameters on welding performance is analyzed; the influence of surfacing alloy on surfacing welding was analyzed; the development prospect of welding technology was analyzed.

1. Introduction
Since stainless steel has excellent corrosion resistance, heat resistance and formability, it has been widely used in heavy industry, light industry, daily necessities industry and building decoration industry, especially in national defense. At present, the propellant storage tanks of rockets and missiles in China are mainly made of 1Cr18Ni9Ti of which chemical composition is shown in table 1.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|c|c|}
\hline
Constituent Elements & C & Si & Mn & S & Cr & Ni & Ti \\
\hline
Content & $\leq 0.12\%$ & $\leq 1.00\%$ & $\leq 2.00\%$ & $\leq 0.030\%$ & 17-19\% & 8-11.00\% & 5(C-0.02)$\sim 0.80\%$ \\
\hline
\end{tabular}
\caption{Chemical composition of 1Cr18Ni9Ti austenitic stainless steel}
\end{table}

The widespread use of stainless steel places higher demands on manufacturing and maintenance. Welding technology is an important aspect of manufacturing and maintenance. Therefore, this paper introduces and analyzes the brazing, pulsed arc welding and surfacing technology related to stainless steel, and summarizes the development prospects of welding technology.

2. Research Status of Stainless Steel Welding Technology

2.1. Brazing Technology
Brazing technology refers to the technology of metallurgical bonding between parent metal by means of the wetting phenomenon and capillary action of liquid and the melting filler metal whose melting point is lower than the parent metal. This welding method can produce small welding deformation, easy to ensure the precision size of the workpiece, the obtained joint smooth and beautiful, wide range of welding materials.
Temperature is an important factor affecting brazing joint performance. CHEN Sijie et al. [1] brazed YG8 cemented carbide and 1Cr18Ni9Ti stainless steel with L304 silver welding sheet, and found that the wettability of the filler metal was poor at low temperature and a continuous black structure formed at the interface. JIANG Wenchun et al. [2] conducted vacuum welding of 304 stainless steel plates with bni-2 solder and found that the increase of thermal insulation temperature could improve the structural strength (As show in Fig. 1), which was consistent with the experimental results of YU Zhishui et al. [3].

![Fig. 1 Effect of heat preservation temperature on structural strength](image)

Some scholars have found that the metal compounds in the center of the welds will reduce the mechanical properties of the welded joints when nickel-based filler metals are used for welding. In this regard, SUN Lei [4] found that adding certain Cu alloy into bni-7 solder can reduce the amount of brittle compounds and increase the shear strength of joints.

Brazing gap also affects brazing quality. YU Zhishui et al. [5] used nickel foil for brazing and concluded that the central compound of the joint gradually decreased with the decrease of the welding seam. E. Lugscheider [6] used BNi-5 to brazen 1Cr18Ni9Ti stainless steel, and found that the compounds in the weld will disappear completely when the weld clearance decreases to 20 microns. Fine micro-structure and uniform fine grain micro-structure are the micro-structure of fine brazing joint and the core problem to be solved in brazing.

2.2. Pulse Arc Welding Technology

Pulsed arc welding refers to the technology of maintaining the ionization channel of the arc with the base value current to ensure that the arc does not go out between the two welds. When the peak of the pulse current is reached, the welding wire and the base material melt to form the melting pool, and when the base value current ACTS, the melting pool solidifies to form the welding spot. Compared with dc welding, this method has less heat input, so it can obtain better welding joints.

Wang Zhanying et al. [7] optimized the current and pulse parameters of pulse submerged arc welding and found that the peak current and pulse frequency of pulse were the main technological factors that affected the mechanical properties of welded joints. In addition, the pulsed current can refine the grain and improve the mechanical properties of the joint. As one of the most widely used welding methods in modern industry, pulse MIG welding is restricted from further promotion and application due to its numerous parameters and complex adjustment process. Yang Yachao et al. [8] established the BP neural network prediction model of welding machine parameters (As show in Fig.2), and realized the prediction of welding machine output parameters under any given welding current state.
Fig. 2 Prediction model of welding machine parameter BP neural network

This method has high accuracy, stable welding process, beautiful welding seam formation, and can achieve good unified adjustment. Gu Yufen Et Al. [9] took the change of average arc voltage as feedback signal to control the welding process of aluminum alloy plate and obtained a good welding joint. At present, the main problem faced by pulsed arc welding technology is how to match a large number of welding parameters to achieve control of the welding process.

At present, the main problem faced by pulsed arc welding technology is how to match many welding parameters to each other so as to control the welding process.

2.3. Surfacing Technology
Surfacing welding refers to cladding alloy material with specific properties on the surface of the parent material by means of heat source to make the parent material have special properties or restore the original function of damaged parts. Surfacing layer and base material can realize metallurgical combination, and suitable surfacing alloy can be selected according to different performance requirements in application.

Some pressure vessels need to have good corrosion resistance, and corrosion resistant alloys can be surrounded on the inner wall of the vessel. LI Yimin et al. [10] used WELFCAW329J4L as the surfacing layer and WELFCAW309MoLT welding wire as the transition layer for surfacing welding to improve the corrosion resistance of pressure vessels. At present, in the surfacing welding of pressure vessels, TIG welding can achieve the best welding quality, but the deposition efficiency of single TIG welding is low, which greatly affects the production efficiency. For this reason, MA Qiyuan et al. [11] adopted the method of TIG welding with double tungsten electrodes as shown in figure 3, and the welding efficiency is 4 times higher than that of TIG surfacing with single tungsten electrodes. Focused beam surfacing is a new surface surfacing technology developed in recent years. When the welding power is the same as that of traditional surfacing welding technology, the beam has no mechanical influence on the molten pool, so a lower dilution surfacing layer can be obtained [12]. Surfacing has higher requirements on the surface before welding. YOU Guangwei et al. [13] found that there are a large number of pores and a small amount of metal inter-layer near the transition layer and the fusion line of cemented carbide due to the uncleaned slag and oxidation layer on the surface of welding seam after heat treatment.

When a particular surfacing layer metal cannot form a good combination with the surfacing base material, it can be solved by introducing a transition layer. Therefore, the method of transition welding layer is an effective way to expand the application of surfacing welding.
3. Welding Technology Development Trend

Through the study of brazing, pulsed arc welding and surfacing welding technology, it can be concluded that the purpose of welding is to pursue the consistency of the properties between the welding seam and the base material. Therefore, the future development direction of various welding technologies is to improve the performance of welded joints at a lower cost through various ways. The development of welding technology mainly includes the following aspects:

3.1. Fine Crystallization of Weld Micro-structure

The essence of good properties of welded joints is good micro-structure. Uniform and fine grain is the key to improve weld performance. Therefore, various processes should be adopted in welding to obtain fine and uniform grain. For this reason, the crystal structure can be refined by pretreatment of the surface before welding. For example, WANG Zhiping [14] used supersonic particle bombardment technology to weld 0Cr18Ni9Ti stainless steel and found that the anti-h2s stress corrosion performance of the sample was significantly improved after welding. When spot welding 1Cr18Ni9Ti, LIU Zhongguo et al. [15] found that the electromagnetic stirring effect caused by external magnetic field could play a role in refining grain. Figure 4 shows the micro-structure of the unapplied magnetic field and external magnetic field. FAN Xiangfang et al. [16] conducted laser melting test on 1Cr18Ni9Ti stainless steel and showed that the laser melting layer had stronger corrosion resistance than the stainless steel matrix. In the future welding, various technological methods such as ultrasonic hammering, arc remelting and solid solution treatment can be explored to refine the grain of the welding seam so as to obtain high-performance welding joints.

![Fig. 4 No magnetic field (a) and external magnetic field (b) micro-structure of the weld](image)

3.2. Optimization of Solder

The effect of the metal elements in the solder is mainly divided into two types: one is a metal element that forms an intermetallic compound during melting, and the other is a metal element that promotes mutual diffusion between the solder and the base material, such as LUO Meiqing [17] who found that...
the addition of Ti in 1Cr18Ni9Ti produces δ ferrite (As show in Fig. 5), and the presence of the two-phase structure makes it more excellent in corrosion resistance. The presence of intermetallic compounds is a major source of brittleness of the joint and is a condition for the development of cracks; in addition, the presence of intermetallic compounds can cause coarsening of the grains and affect the properties of the joint. Metal elements that help to increase diffusion can form a more complete metallurgical bond to the joint to improve the performance of the joint. Therefore, a soldering material which is advantageous for diffusion and which is advantageous for forming a brittle intermetallic compound should be used in the soldering. Therefore, in the future, the

![Fig. 5 Ferrite in the metal](image)

Diffusion and chemical reaction of metal elements in solder will be a focus of welding research.

3.3. Automation, Specialization and Intelligence of Welding Equipment
Professional welding equipment is the guarantee of excellent welded joints. At present, China still has a large gap with foreign countries in welding equipment. In the case of surfacing, for example, there are fewer dedicated and intelligent equipment, and more are modified equipment or mechanized equipment. There is a great demand for efficient automation equipment in various industries. The characteristics of China's surfacing materials are large proportion of manual welding rods, and the proportion of automatic welding materials is small. In particular, there are few flux-cored welding wires with high technology content. The welding consumables are incomplete and not serialized. Many surfacing materials need to be imported from abroad. Better localization of imported products. Equipment for other welding techniques also has a long way to go.

The intelligence of welding equipment. The intelligent welding equipment is mainly embodied in two aspects of welding: one is the process selection before welding. The process selection before welding refers to the equipment that can automatically select the welding process and welding materials according to the welding material and performance requirements, design the welding plan, give instructions to the welder, tell the welder what to do, what to do degree. Second, the welding equipment can perform real-time parameter measurement and feedback on the welding state. The equipment dynamically adjusts the output parameters according to the feedback information, so as to ensure that the welding process is always in the optimal parameter state, such as the welding voltage according to the arc voltage during welding. Signal to pulse frequency parameter adjustment.

4. Summary
This paper concludes by reading and analyzing the literature related to stainless steel materials:
(1) For brazing, fine micro-structure and metallographic structure, uniform fine grain structure are the microscopic performance of excellent brazed joints, and also the core problem to be solved by
brazing; for pulse arc welding, the main face currently. The problem is how to match the welding parameters to achieve the control of the welding process; for surfacing, the introduction of the transition welding layer is an effective way to expand the surfacing application.

(2) Comprehensive analysis proposes three trends in the development of welding technology: fine-grained welding structure, optimization of solder, automation of welding equipment, specialization and intelligence.

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