Advances in Engineering Research : Possibilities and Challenges
ISSN Print: 3079-5192
ISSN Online: 3079-5206
https://doi.org/10.63313/AERpc.9055

Research on Welding Methods of Monel Alloy

Chunyun Wang
Air supply chamber with annotations, Hainan Wenchang Space Launch Support Co.Ltd., Wenchang 571300, China
Email: 354700951@qq.com

How to cite this paper: Wang, C. Y. (2025). Research on Welding Methods of Monel Alloy. Advances in Engineering Research : Possibilities and Challenges, 2(3), 39-45. ISSN Print: 3079-5192; ISSN Online: 3079-5206.
https://doi.org/10.63313/AERpc.9055
Published: 2025-11-05

Copyright © 2025 by author(s) and Erytis Publishing Limited.
This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).
http://creativecommons.org/licenses/by/4.0/

Abstract

Monel 400 alloy boasts excellent mechanical and processing properties, along with good corrosion resistance in high-temperature acid-base and strongly alkaline media. It is widely applied in high-pressure gas supply systems across aerospace, shipbuilding, chemical, pharmaceutical, and other industries. This article primarily analyzes and studies the welding issues of Monel 400 alloy pipelines, as well as the determination of welding process parameters, aiming to improve the welding process of Monel 400 alloy and ensure welding quality.

Keywords

monel metal; welding technology; high pressure gas supply pipeline

1. Introduction

The microstructure of Monel 400 alloy is a single-phase austenite structure. Its weldability is similar to that of stainless steel. The main difficulty in welding lies in the high content of alloy elements such as Ni and Cu, which leads to a high viscosity of the liquid metal in the welding pool and poor fluidity of the pool, thereby reducing the side-wall fusion; the second is that impurity elements such as S, P, Pb, Sn, Zn and their products like oil stains and dust are prone to form low-melting-point eutectics with Ni, which is likely to cause porosity and crack defects [1-2]. **Table 1** shows the chemical composition of Monel 400 alloy tubes.

Table 1. Chemical Composition (by mass fraction) of Monel Alloy Tubes

Chemical composition (%)						
Ni	Cu	Si	Mn	C	S	Fe
63-70	Bal.	≤0.3	≤2.0	≤05	≤2.5	≤0.03

Since the application environment of Monel 400 alloy pipelines is mostly high-pressure and highly corrosive, it is necessary to analyze the welding of Monel

400 alloy pipelines.

Table 2. Mechanical Properties of Monel 400 Alloy

Yield strength (MPa)	Tensile strength	Elongation (%)	Hardness (HV)
200	550	40	110

Table 3. Physical properties of Monel 400 alloy

Density (g/cm^3)	Specific heat at 20℃ (J/kg·K)	Thermal conductivity at 20℃ (W/m·k)	Thermal expansion coefficient	Melting range °C	Electrical resistivity
8.83	420	21.7	14.1	1300~1350	51.0

Table 2 and **Table 3** respectively present the mechanical and physical properties of the Monel 400 alloy. When conducting the pipeline welding operation with the Monel 400 alloy, the operation requirements were strictly followed according to the standards.

2. Welding properties of Monel 400 alloy

As can be seen from Table 1, the Monel 400 alloy has strong strength, high impact toughness and good ductility. However, it is prone to thermal cracks, which occur at high temperatures and do not extend at room temperature. The liquid metal has poor fluidity and can dissolve gases such as oxygen, nitrogen, and hydrogen, easily causing pores.

Therefore, the main problems that may occur with the Monel (Monel 400) alloy are as follows:

- During welding, an intermetallic alloy forms in the high-temperature range and solidifies, reducing the metal's fluidity and thermal conductivity, resulting in a prolonged high-temperature stay in the overheated area and a significant decrease in the plasticity of the weld joint.
- During welding of the Monel (Monel 400) alloy, it is highly prone to absorbing gases (mainly H2, CO, etc.). If the gases cannot be removed in time after welding, dispersed pores will form, causing honeycomb-like defects and even penetrating the entire weld seam [3].
- Due to the high content of alloy elements in the weld seam and the poor fluidity of the molten pool, it is prone to poor surface formation of the weld seam, deterioration of the back formation of the root weld bead, and roughness of the surface of the cover weld bead, greatly affecting the welding quality.

Therefore, in order to avoid the occurrence of the above problems during welding, the welding method of the Monel (Monel 400) alloy needs to be analyzed and studied.

3. Monel 400 alloy welding process

This article takes a 16×3 diameter Monel (Monel 400) alloy pipeline as the research object for analysis. The welding method is that the welding machine uses the Miller 350LX manual argon arc welding machine for argon arc welding. The weld grade of the nickel-copper alloy pipe is level II. Before welding, the parts to be welded must undergo degreasing treatment, and the welded parts must be welded within the specified time; otherwise, they should be re-degreased. After welding, water pressure test and air tightness test should be carried out on the joint and the pipe assembly.

3.1. Pre-welding preparations

Before welding operations commence, first verify all parts and components are complete according to the detailed list. Cut Monel400 alloy pipes per blueprints and prepare V-groove bevels with angles of 35-40° ±1.5 and gaps of 0-1mm. Sand the pipe and fitting surfaces to be welded, ensuring clean inner holes, burr-free end faces, and smooth cross-sections. Clean the prepared surfaces with a degreaser, then rinse with anhydrous ethanol and blow-dry thoroughly. For pipes over 2m or heavily bent sections, use a heat gun for drying. After cleaning, store the welded-ready pipes and fittings in a rotating tray, arranging them neatly to prevent collisions.

3.2. Welding process

After completing the above preparations, the pipeline welding work begins.
The welded pipe is clamped to the positioner, and the pipe or pipe fitting is positioned with a copper core rod. Then, the welding point is positioned with spot welding. Before welding, the pipe is purged of internal gas with protective gas (argon), and one end of the pipe is sealed. After positioning, the base welding and multi-layer multi-pass welding are carried out. **Figure 1** shows the welding diagram of Monel (Monel 400) alloy pipeline and ball head.

Figure 1. Welding of pipeline and ball head

Pre-fill argon gas, replace the gas in the tube, and maintain for a period of time. The specific operation is as follows: one end is filled with argon gas, the other end is sealed, and a hole with a diameter of approximately 2mm is reserved. After the argon gas in the tube flows stably (about 15 seconds), welding is carried out. The welding current is 66A, the welding voltage is 38-43V, the protection gas flow rate is 8L/min, the welding wire is 1.2mm ERNiCu-7, the interlayer temperature is 60-80℃, and the welding layer is 2 layers. During the welding process, each weld seam is naturally cooled after each weld, and the interlayer temperature is controlled between 60℃ and 80℃ to prevent large welding deformation after welding. After the welded parts are left to stand at room temperature for a while, protective caps or soft foam wrapped with rubber bands are installed at both ends, and they are placed in a clean turnover box.

Perform 100% appearance inspection and internal surface inspection (endoscope) on all welded joints. The welding joints should be uniform and beautiful, and no phenomena such as incomplete penetration, weld seam deviation, or excessive weld bead should occur.

Figure 2. Welding of pipes and pipes

3.3. Cleaning Work

After the welding work is completed, clean the surface of the weld seam. After the welded parts are left to cool to room temperature, install protective plugs at both ends or wrap them with soft foam and secure them with rubber bands. Place them in clean turnover boxes, and ensure that the slag at the weld seam is cleaned thoroughly.

4. Using the Template

The inspection capability for Monel 400 alloy welding after completion

After welding, the inspection should be carried out in accordance with the procedures of self-inspection, mutual inspection and special inspection.

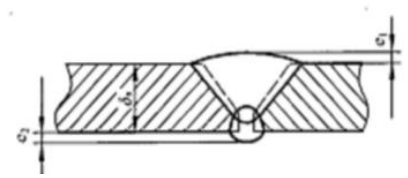
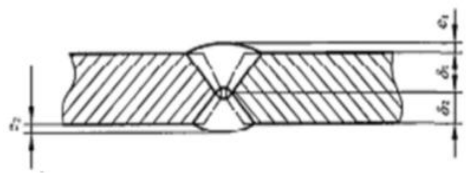
(1) Visual inspection of welds

- After welding, the slag, spatter, etc. should be removed, and the welds should be ground clean and smooth;
- The visual inspection of welds must be carried out in accordance with the procedures of self-inspection, mutual inspection and special inspection (quality inspector). Only after the welds pass the visual inspection can the quality inspection be carried out;
- 100% radiographic testing shall be conducted on butt welds, in accordance with the requirements of no less than Grade II as stipulated in the National Energy

Department standard NB/T 47013.2. 100% dye penetrant testing shall be conducted on fillet welds, meeting the requirements of Grade I as stipulated in NB/T 47013.5;

- The weld reinforcement of the welded joint shall meet the requirements as specified in **Table 4**.

Table 4. Welding joint overhang requirement

<table>
<tr><td colspan="2">single groove</td><td colspan="2">double groove</td></tr>
<tr><td>e_1</td><td>e_2</td><td>e_1</td><td>e_2</td></tr>
<tr><td>0~15% δ_n and ≤ 4</td><td>≤1.5</td><td>0~15% δ_1 and ≤ 4</td><td>0~15% δ_2 and ≤ 4</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
</table>

(1) The appearance requirements of the weld are shown in **Table 5**:

Table 5. Weld appearance requirements

<table>
<tr><td rowspan="2">Defect name</td><td rowspan="2">GB/T6417.1 code</td><td colspan="4">defect system</td></tr>
<tr><td>I</td><td>II</td><td>III</td><td>IV</td></tr>
<tr><td>Not welded (means insufficient) design requirement</td><td>511</td><td colspan="2">not allow</td><td>The total defect length within every 100mm weld seam shall be ≤25mm, with ≤0.2+0.02δ and ≤1mm</td><td>The total defect length within every 100mm weld seam shall be ≤25mm, with ≤0.2+0.04δ and ≤2mm</td></tr>
<tr><td rowspan="2">Root contraction</td><td rowspan="2">5155013</td><td rowspan="2">not allow</td><td>≤0.2+0.02δ and≤0.5 mm</td><td>≤0.2+0.02δ and≤1mm</td><td>≤0.2+0.02δ and≤2mm</td></tr>
<tr><td colspan="3">Length limit</td></tr>
<tr><td>undercut</td><td>50115012</td><td colspan="2">not allow</td><td>≤0.05δ and ≤0.5mm, continuous length ≤100mm, total undercut length on both sides of the weld ≤10% of the total weld length</td><td>≤0.1δ and ≤1mm, length is not limited</td></tr>
<tr><td>flaw</td><td>100</td><td colspan="4">not allow</td></tr>
</table>

Defect name	GB/T6417.1 code	defect system			
		I	II	III	IV
crater crack	104	not allow			Individual arc pit cracks of length ≤5mm are allowed to exist
Arc scratches	601	not allow			Individual arc scratches are allowed
splash	602	Clear			
Poor connection	517	not allow		The gap depth shall be ≤0.05δ and no more than one weld shall be 0.5mm	Gap depth≤0.1δ≤1 mm (No more than one weld per meter)
overlap	506	not allow			
Not fully penetrated (according to the designed weld thickness)	402	not allow		For Allowable value for single-sided welding without padding ≤15% of the δ and ≤1.5mm, The total length of defects in every 100 meters of welds is ≤25mm	The total defect length within every 100 meters of weld seam shall be ≤0.1δ and ≤0.2mm, with a maximum of 25mm
Surface slag	300	not allow		Depth ≤0.1δ, length ≤0.3δ, and ≤10mm	Depth ≤0.2δ, length ≤0.5δ, and ≤20mm
surface pores	2017	not allow		Permissible diameter per 50mm weld length ≤0.3δ and ≤2mm air hole with two holes spaced apart≥6x aperture	Permissible diameter per 50mm weld length ≤0.4δ and ≤2 air holes with a 3mm spacing ≥6x aperture
Insufficient weld thickness (according to the designed weld thickness)		not allow		The defect length should be ≤0.3+0.05δ and ≤1mm, with the total defect length within each 100-meter weld seam not exceeding 25mm.	The defect length should be ≤0.3+0.05δ and ≤2mm, with the total defect length within each 100-meter weld seam not exceeding 25mm.
The weld foot is asymmetrical	512	Difference ≤ 1+0.1a		Difference ≤ 2+0.15a	Difference ≤ 2+0.2a
		a-Effective weld thickness			
inherent vice		GB/T3323I	GB/T3323 II	GB/T3323 II	Not required
		GB/T11345 I		GB/T11345 II	
Note: Except for specified fillet weld defects, all others are general butt and fillet welds.					

Defect name	GB/T6417.1 code	defect system			
		I	II	III	IV
(1)If the edge is ground and the transition is smooth, only the minimum allowable rating of the weld is applied (2)Under specific conditions requiring smooth transition, this standard does not apply (e.g., tower joints, or combinations of dissimilar thicknesses in butt and fillet welds)					

5. Conclusion

When welding a 16×3 pipeline, by continuously optimizing the welding parameters based on various problems identified, the optimal welding scheme and parameters for welding the Monel pipeline were finally obtained. The following main ideas are summarized:

(1) When welding the Monel pipeline, pay attention to maintaining the neatness of the pipeline ports;

(2) The spot welding time should not exceed 3 seconds; if it is too long, the color of the weld seam will change.

(3) Spot welding cannot be accompanied by adding welding wire; otherwise, the weld point will be too thick.

(4) When inflating the pipeline interior, it should be maintained for more than 30 seconds, and then welding should be performed after the airflow is stable.

(5) For the tail end of the pipeline, current-limiting treatment should be applied, leaving a width of 2 mm; otherwise, the inner wall color of the weld seam of the Monel alloy pipeline will change.

(6) When inflating the 16×3 Monel alloy pipeline, the pressure range is 8 to 10 MPa; for thin-walled pipelines (with a pipeline size of less than 10), the pressure range is 5 to 8 MPa.

(7) After welding, it is necessary to stand still for more than 30 seconds to ensure that the weld seam is completely closed.

(8) After the welded pipeline cools down, the weld seam should be cleaned with a wire brush.

References

[1] Liu Minghui, Liu Yulan and Huang Jiawen. High-power marine engine high-pressure gas supply system. Mechanical Equipment, 2018. 35(1): pp. 4-6.

[2] Zhou Mingyang et al. Design of a high-pressure gas supply device. Mechanical Engineer, 2015(4): pp. 264-265.

[3] Sun Yunxiang. Relevant technical requirements for welding Monel alloy. Petrochemical Equipment, 1989, 18(6): pp. 41-42.