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Application of Vacuum Brazing Method on Inconel 718 Material

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ABSTRACT: Super alloys are used in aviation parts, especially in engine components exposed to high temperatures, due to their high resistance at high temperatures. Due to the difficulties experienced in producing these components in one piece, these components are joined by different welding methods or by brazing. In this study, brazing process was applied in a high temperature furnace in vacuum environment by using nickel foil filler to join two different Inconel 718 (AMS 5662) materials together.

KEYWORDS: Inconel 718, Vacuum Brazing, Super alloys, Nickel foil filler.

I. INTRODUCTION

Inconel 718, invented in 1965, is a widely used industrial metal today[1]. It is also referred to as a refractory superalloy because it can be used at temperatures above 600°C. Especially in turbojet engines, the main parts of the discs are used in the parts of the compressor and the discs and blades of the turbines which are subjected to high pressure[2].

For the hot chambers of turbo reactors, a material is needed that can withstand severe corrosive conditions at high temperatures. Superalloys are readily available and cost-effective option in all forms and for use in the manufacture of jet engines. Superalloys are materials that can withstand intense mechanical stresses and pressures in extreme conditions while are retaining their high temperature corrosion and creep resistance properties. Nickel-Iron-based superalloys are well suited for applications in high temperature conditions that require creep, corrosion and thermal shock resistance[3]. Additionally, it can be hardened by applying solution and aging heat treatments.

Inconel 718 (AMS 5662) is an excellent option for parts requiring creep and stress-break resistance up to 705°C and oxidation resistance up to 982°C. The chemical composition of Inconel 718 is given in Table 1[4].

Element	Min.	Max.
Carbon	--	0.08
Manganese	--	0.35
Silicon	--	0.35
Phosphorus	--	0.015
Sulfur	--	0.015
Chromium	17.00	21.00
Nickel	50.00	55.00
Molybdenum	2.80	3.30
Columbium (Niobium)	4.75	5.50
Titanium	0.65	1.15
Aluminum	0.20	0.80
Cobalt	--	1.00
Boron	--	0.006
Copper	--	0.30
Lead	--	0.0005 (5 ppm)
Bismuth	--	0.00003 (0.3 ppm)
Selenium	--	0.0003 (3 ppm)
Iron	Remainder	

Table 1. The chemical composition of Inconel 718

Brazing under vacuum; a joining process in which materials are joined together using a filler metal that has a melting (liquid) temperature higher than 450 °C (840 °F) but lower than the melting temperature of the base metal. Filler metals are generally alloys of silver (Ag), aluminium (Al), gold (Au), copper (Cu), cobalt (Co), or nickel (Ni). Braze range of filling materials are given in Table 2[5].

Filler Material	Nickel (Ni)	Cobalt (Co)	Silver (Ag)	Gold (Au)	Aluminium (Al)	Copper (Cu)
Braze Range	927 – 1205 °C	1175–1245 °C	620-980 °C	890 – 1230 °C	570 – 620 °C	705–1150 °C

Table 2. Braze Range of Filler Material

This process takes place in vacuum furnaces. Due to the number and complexity of joining complex designed parts, these parts can be joined by vacuum brazing instead of traditional welding methods. Vacuum brazing can be applied to join a wide variety of metals such as nickel-based superalloys, stainless steels, high alloy steels, as well as non-metallic materials such as aluminium oxide, silicon carbide, cubic boron nitride (CBN), sapphire, diamond, polycrystalline diamond (PCD), ceramic, graphite.

Advantages of vacuum brazing over other conventional welding methods;

1. Processing time is shorter.
2. No special labor required.
3. It is suitable for joining all kinds of materials.
4. Minimal deformation (homogeneous heating and cooling).
5. High penetration.
6. Easier joining of parts in complex shapes.
7. Minimum porosity.
8. Since it is made under vacuum, there is no oxidation on the surface.
9. Easier for parts that require many joints.
10. Parts are cleaner after brazing.
11. High alloy steels with low weldability can be joined by brazing.
12. High mechanical property.
13. It can also be applied on very thin and very thick parts.
14. Joining and hardening can be done at the same time.
15. Small and large gaps can be filled.
16. Process thermal cycles are predictable.
17. It is more economical.

The brazing is done in a furnace with electrically heated elements surrounding the work area that heats the filler metal until it liquefies, thereby creating a capillarity effect in the brazing material. An oxygen-removing pumping system is used to allow brazing of alloys that are susceptible to oxidation at high temperatures[6].

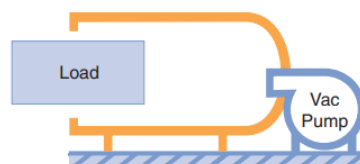


Fig. 1 Vacuum Furnace

Brazing filling materials can be used in different forms.

1. Braze Powder
2. Braze Paste
3. Braze Tape
4. Braze Foil
5. Braze Preforms

There are different forms of Brazing Joint Designs.

1. Butt Joint
2. Lap Joint
3. Butt-Lapp Joint
4. Scarf Joint
5. Tee Joint

II. EXPERIMENTAL PROCEDURE

In this study, six pieces of Q16x40mm Inconel 718 (AMS 5662) were used as base metal.



Fig.2 Six pieces of Q16x40mm Inconel 718

Brazing was applied to these parts using the butt joint type and three pieces of Q16x80mm brazed parts were obtained. The chemical composition of the material used as the base metal is 52.5Ni - 19Cr - 3.0Mo - 5.1Cb (Nb) - 0.90Ti - 0.50Al - 18Fe. Nickel in foil form was used as filling material.



Fig 3. Nickel in foil form

These foils are cut and shaped according to the region of the main material to be joined.



Fig. 4 Nickel foil shape and placement



The main parts are precision ground to ensure full contact on the mating surfaces prior to brazing. All undesirable impurities such as oil, dirt, rust have been cleaned by using alkaline solvent. It was applied to the external areas with the "ForteBrazestopoff" substance so that the filling material does not flow out of the area to be joined when it melts in the oven.



Fig.5 Application of Stop Off

In order for the coupons to remain stable in the furnace, the mold was prepared from graphite sheets. A load of 2kg was applied to the mold to keep the parts stable.



Fig. 6 Mold

The brazing process was applied at 1050°C for an average of 10 minutes. The processes were carried out in a vacuum furnace with 800x800x1150mm dimensions and 1000kg loading area. The inside of the furnace was kept in a vacuum of approximately 5×10^{-5} mbar throughout the brazing process. The heating rate of the oven was set to 10°C/min. After waiting for 10 minutes at 1050°C, the furnace was cooled using nitrogen gas. While the cooling rate is 20°C/min at high temperatures, it is around 5-10°C/min at low temperatures. Vacuum brazing process graphic is given in Figure 7.

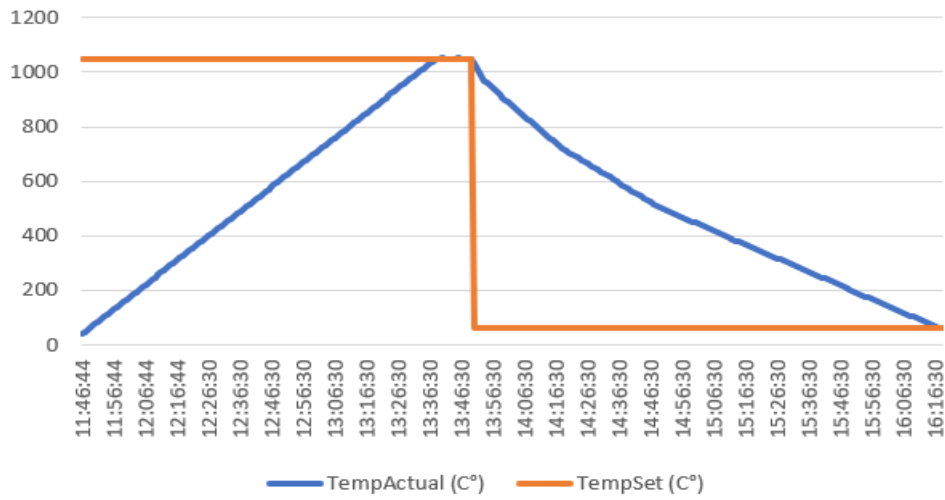


Figure 7. Vacuum brazing process graphic

III. EXPERIMENTAL RESULTS

Visual inspection was applied to the parts whose process was completed in the vacuum furnace.



Fig.8 Brazing applied parts before machining.



Fig.9 Brazed joints

In order to see the middle part of the pieces, the pieces were machined according to the dimensions given in Figure 10. and Table 3.

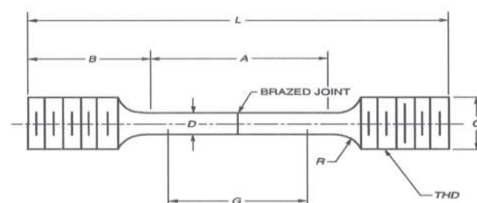


Figure 10. Area of Brazed Joint Control

Description	Mm
G	25
D	6
A	30
L	75
C	13
THD	M12*1.75
B	16
R	6

Table 3. Dimesions of speciemens



Fig. 11 Machined parts

The machined parts were examined by radiographic inspection and visual inspection.

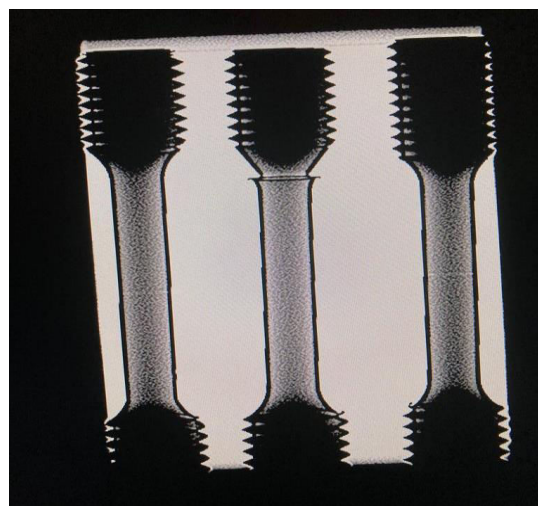


Fig. 12 Radiographic inspection images

IV. CONCLUSION

Visual inspection of the finished parts in the vacuum furnace was performed and no slippage or misplacement errors were observed in the parts. After machining, radiographic examination was performed on the parts and good adhesion was observed. As a result of this study, it has been seen that vacuum brazing method can be an alternative to traditional welding methods.



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