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MICROSTRUCTURAL AND MECHANICAL ASPECTS OF FRICTION WELDED DISSIMILAR JOINTS FOR AERO ENGINE APPLICATION

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ABSTRACT

Gas turbine engines demand material with unique properties like high-temperature oxidation and corrosion resistance, high specific strength, etc. All over the world material development to meet these requirements has led to the development of novel alloys. While Titanium base alloys are used in the low-temperature regime of the gas turbine engine, Nickel-basedsuperalloys are used for hot end components of the engine. With the increase in the temperature requirement for the turbine parts, the form of the Ni-based superalloys changed from wrought to cast superalloys. As an inherent process of investment cast superalloy blades and vanes which has serpentine passages for air cooling, these passages are required to be closed after casting. The numerous adapters also need to be joined on the cast superalloy casings for various instrumentation, lube oil ports. These cast superalloys are non-weldable and joining these pose a challenge. In this present investigation, the joining of the Ni-basedsuperalloy BZL12Y and martensitic stainless steel AE961W using rotary friction welding process. The mechanical properties of the dissimilar joints were evaluated as per the ASTM standards. Microstructural features of various regions of welded joints using optical microscopy (OM) and scanning electron microscopy (SEM). The material is welded in different condition to obtain the maximum tensile strength of the weld joint. From this investigation, it was found that the combination of aging and h & t condition weld joint gives good strength and a stable hardness value. Correlation between tensile properties and microstructural features were analyzed and reported in this paper.

Keywords: *Ni-base superalloy, Martensitic stainless steel, Rotary Friction Welding, Tensile Properties, Different condition and Combination of conditions.*

1. Introduction

Nickel-base superalloys are the most complex, the most widely used for the hottest parts. They currently constitute over 50% of the weight of advanced aircraft engines. The principal characteristics of nickel as an alloy base are the high phase stability of FCC nickel matrix and the capability to be strengthened by a variety of direct and indirect means. Further, the surface stability of nickel is readily improved by alloying with chromium and/or aluminium. The latest generations of superalloys incorporate expensive alloying metals such as rhenium and ruthenium to achieve the desired characteristics. Because of this, the cost of some new superalloys can be five times more expensive than high-quality turbine steel. The outlook is for considerable growth in usage in these areas, in particular as the aircraft manufacturing.

BZL12Y BE is a cast superalloy of Russian origin. It is heat resistant and strengthened by intermetallic gamma prime (γ') phase and also by elements like Cr, Mo, W in solid solution. Very low content of W and high Al and Ti contents of the alloy cause formation of Ni_3 (Ti, Al) γ' phase in large quantities (up to 60%). Chiefly due to low density, this alloy possesses maximum high-temperature strength up to 1000°C. Addition of Co (12-15%) increases the ductility of the alloy. Further increase in high-temperature strength, without a reduction in ductility, is achieved by the addition of V (0.05-1.5%). Microalloying element Zr (0.02%) acts as a strong γ' former. This alloy is chiefly developed as a material for gas turbine engines, where the temperatures exceed 1000°C.

Applications

BZL-12Y BE is used for gas turbine blades and spacers in aero-engines.

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2. Experimental procedure

Ni-basesuperalloywas recovered in the form of cast condition as 12mm diameter rod and 80mm length and the martensitic stainless steel were in H&T condition. The Ni-basesuperalloy is undergone different conditions like solutionizing, ageing-I, ageing-II. And also, in a different condition like solutionizing only, ageing-I only, ageing-II only, ageing-I +ageing-II, solutionizing+ageing-I+ ageing-II. The steel studied in this work is AE961Wmartensitic stainless steel. The material was subjected to hardening and tempering at 1010°C for 45 minutes oil quench.

2.1 Friction welding of BZL12YBE and AE961W

In this process, two material is welded using a friction welding process.

The AE961W is in H&T condition and the BZL12YBE is in varies condition they are (1) Solutionizing only, (2) Solutionizing + Ageing-1 + Ageing-2, (3) Ageing-1 + Ageing-2,(4) Ageing-1 only,(5) Ageing-2 only.

2.2 Heat treatment technique

- Solutionizing 1210°C 1hr + 1220 °C 3hr + GFQ. Heating rate Up to 1200 °C temp. 15 °C /min + up to 1210 °C temp. 1.5 °C /min + hold 60 min + up to 1220 °C temp 1 °C /min + hold 180 min + GFQ.
- 1st ageing 1080 °C for 240 min + GFQ. Heating rate up to 1070 °C temp. 15°C/min + hold 5 min. + 2 °C/min + hold 240 min + GFQ.
- 2nd Ageing 870 °C for 20hr + GFQ. Heating rate up to 860 °C temp. 15 °C/min + hold 5 min. + 1.5 °C/min up to 870 °C + hold 20hr + GFQ.

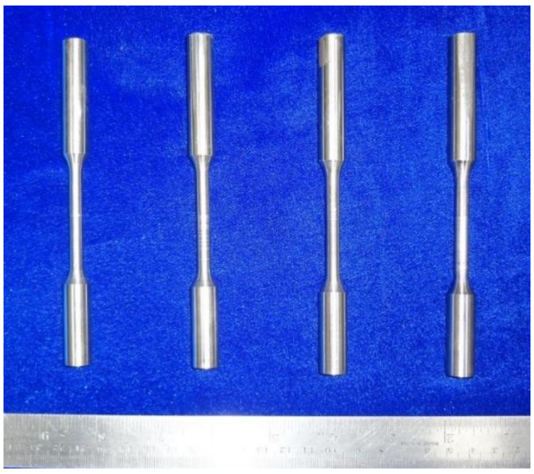


Fig. 1Tensile Specimen before Tensile Test

In the above Fig. 1 it is showing the tensile specimen machined as per the ASTM E8M Standards. It is the photograph of the specimen before tensile testing is done on the specimen.

In Fig. 2 shows the tensile specimen after the tensile testing is done on the specimen. From observing the specimen during tensile testing can come to the conclusion that the specimen is a ductile specimen due to its forming necking before breaking.

And then the rotary friction welding is done between the different condition ni base superalloy and hardened and tempered martensitic stainless steel like the condition follows ni base superalloy in Solutionizing + Ageing-1 + Ageing-2 and mss in H&T condition and another combination is ni base superalloy Ageing-II only and mss in H&T condition.

3. Results and discussion

3.1 Mechanical properties of friction welded joints

Fig. 2 Tensile Specimen after Tensile Test

3.2 Observation of the welded product

By observing the welded material, we came to know the flashes were coming from mostly AE961W and there is hardly any from BZL12YBE. This shows us that the hardness of the BZL12YBE significantly increased after the material gone through many different conditions

3.3 Microhardness of friction welded samples

In Table 2 it is showing the hardness of the matrix and the hardness of the ni base eutectic. The hardness of the eutectics is higher than the matrix and it is far spread on the surface of the material.

Table 1 Mechanical Property of Weld Metal

Peak load (kgf)	Peak Stress (MPa)	Yield Stress (MPa)	Stress at Offset Yield (MPa)	Elongation (%)	Condition of the material
2533	878	797	812	4	AE961W(H&T) and BZL12Y (Ag2)
2600	901	791	809	3.6	AE961W(H&T) and BZL12Y (Ag2)
2910	1009	870	921	2.7	AE961W(H&T) and BZL12Y (Sol+Ag1+Ag2)
2616	908	635	864	1.2	AE961W(H&T) and BZL12Y (Sol+Ag1+Ag2)

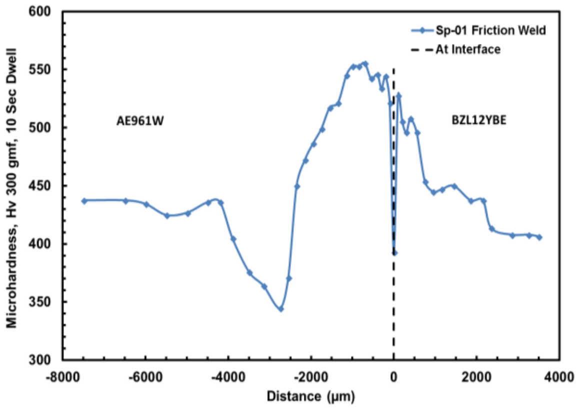


Fig.3 Micro Hardness FW BZL12Y-AE961W

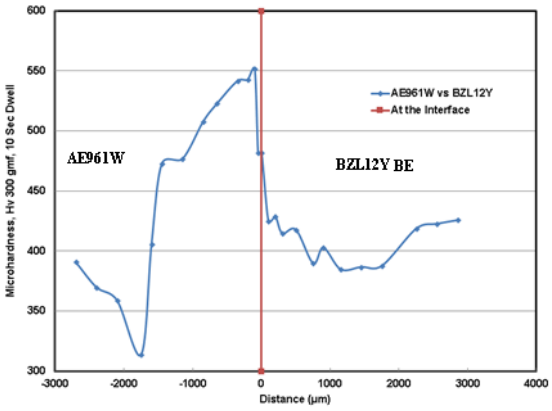


Fig.4 Micro Hardness FW BZL12Y-AE961W

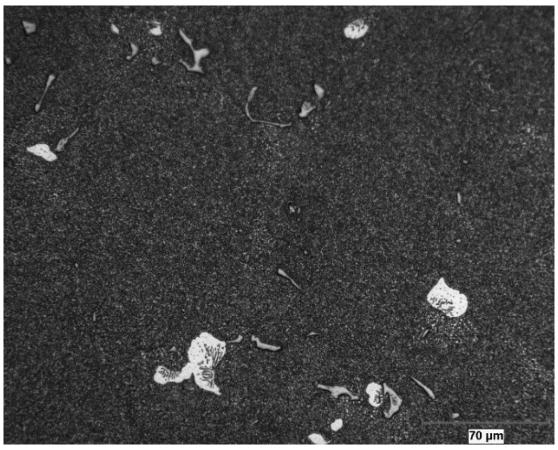
In fig 3 and 4 it shows the hardness graph of the weld joints of the AE961W in H&T condition and BZL12Y in Ageing-II condition, and AE961W in H&T condition and BZL12Y in ST+A-I+A-II condition respectively

Table 2 Base metal hardness value

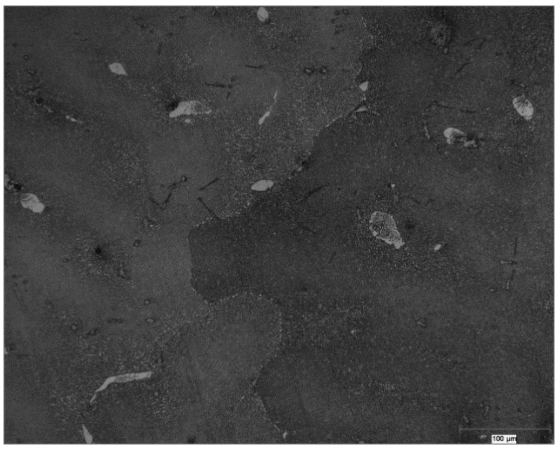
Sl. No.	Condition	Matrix	Eutectics
1	ST+A1+A2	380	410
2	A2	380	423

3.4 Microstructure of base metal and weld metal

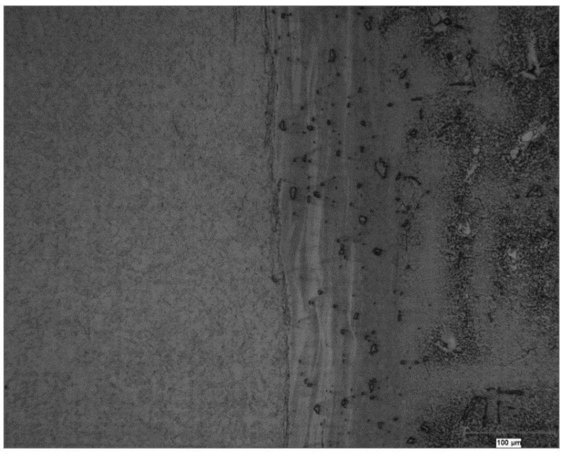
The microstructure of the base metal and weld metal are shown in the above figures. In the base metal microstructure, we can clearly see the matrix and carbides formed on the surface of the material. In the pictures, the magnification of the microstructure is taken in 200x,600x. In the 200x mag we can see the bigger area of the material surface with lots of matrix formations and precipitates and carbides and Ni-based eutectics. In the 200x and 600x magnification, the structure of the eutectics can be seen clearly the cauliflower structure of the eutectic.



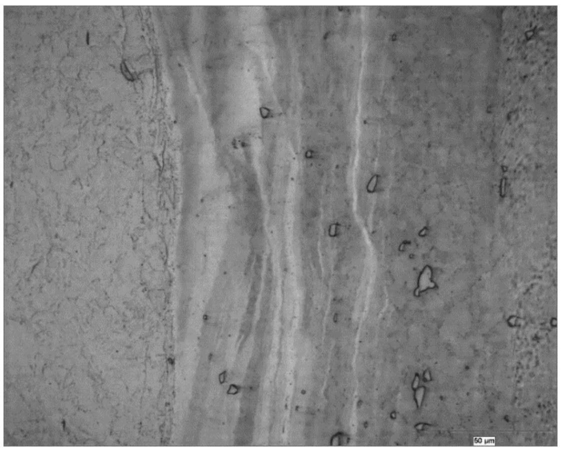
Solutionizing+Ageing I+Ageing Ii



Ageing II



200X



600X

Fig. 5 Friction welded BZL12Y and AE961

4. Conclusions

The microstructure, tensile strength and microhardness of the joints between BZL12Y and AE961 after conventional rotary friction welding done in different conditions like solutionizing, Aging-I, Aging-II.

i. Friction welding of BZL12Y and AE961 is successfully carried out without any interlayers and heat treatment.
ii. The maximum tensile strength can be obtained in the solutionising+ Aging-I+ Aging-II condition BZL12Y and AE961 H&T condition.
iii. EDS-SEM maps and scan line analysis across the interface have confirmed the diffusion of BZL12Y and AE961.
iv. Microstructural characteristics of weld joints were analyzed using an optical microscope (OM) and SEM and correlating with mechanical properties.
v. In the aging II only, condition it gives 878 MPa and the Sol+A1+A2 condition it gives 1009 MPa.

From the overall observation, it can be concluded that the condition AE961 (H&T) and BZL12Y (Ageing II) gives the stable hardness and good acceptable strength, even though they give less strength than another specimen due to application limitation the specimen one is selected as the most suitable condition for the aero engine application.

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References

1. *Ananthapadmanaban D, Seshagiri Rao V, Nikhil Abraham and Prasad Rao K (2009), “A study of mechanical properties of friction welded mild steel to stainless steel joints”, Materials and Design, Vol. 30, 2642–2646.*

2. *Haitao Qu, Hongliang Hou, Pengfei Li, Shuxia Li and Xueping Ren (2016), “The effect of thermal cycling in superplastic diffusion bonding of heterogeneous duplex stainless-steel”, Materials & Design, Vol. 96, 499-505.*

3. *Hazman Seli, Ahmad Izani Md. Ismail, Endri Rachman and Zainal Arifin Ahmad (2010), “Mechanical evaluation and thermal modelling of friction welding of mild steel and aluminium”, Journal of Materials Processing Technology, Vol.210, 1209–1216.*

4. *Jagroop Singh and Karamdeep Singh (2014), “Fabrication of Friction Welding on Centre Lathe: A Case Study”, IJRMET, Vol. 4(2), 145-147*

5. *Kimura M, SuzukiK, KusakaM and Kaizu K (2017), “Effect of friction welding condition on joining phenomena and mechanical properties of friction welded joint between 6063 aluminium alloy and AISI 304 stainless steel”, Journal of Manufacturing Processes, Vol. 26, 178-187*

6. *Kimura M, Suzukib K, Kusaka M and Kaizu K (2017), “Effect of friction welding condition on joining phenomena, tensile strength, and bend ductility of friction welded joint between pure aluminium and AISI 304 stainless steel”, Journal of Manufacturing Processes, Vol. 25, 116-125*

7. *Mohamad Zaky Noh, Luay Bakir Hussain, Zainal Arifin Ahmad (2008), “Alumina–mild steel friction welded at lower rotational speed”, Journal of materials processing technology, Vol. 204, 279–283.*

8. *Eslami P, Karimi Taheri A (2011), “An investigation on diffusion bonding of aluminum to copper using equal channel angular extrusion process”, Materials Letters, Vol. 65, 1862–1864.*

9. *Radosław Winiczenko and Mieczysław Kaczorowski (2013), “Friction welding of ductile iron with stainless steel”. Journal of Materials Processing Technology, Vol. 213, 453– 462*

10. *Shubhavardhan R N and Surendran S (2012), “Friction Welding to Join Dissimilar Metals”, Vol. 2(7), 200-210*

11. *ShuxiaLi, Xueping Ren, HongliangHou (2015), “The effect of thermal cycling in superplastic diffusion bonding of 2205 duplex stainless steel”, Materials & Design, Vol. 86, 582-586*

12. *SlaEce Atabay, Arcan F Dericioglu (2016), “Optimization of the Diffusion Bonding Parameters for6063 Aluminum Alloy”. 18th International Metallurgy & Materials Congress*

13. *Somsak Kaewploy, Chaiyoot Meengam (2015), “Determination of Optimal Parameters for Diffusion Bonding of Semi-Solid Casting Aluminium Alloy by Response Surface Methodology”. MATEC Web conferences, Vol. 26.*