Studies on Metal Joining Aspects of Super Alloy for Aero-engine Applications

Indranand Bhusala[1], Satyanarayana G[2], Dr.Sudhakar I[3]

[1-3]MVGR College of Engineering, Department of Mechanical Engineering, Vizianagaram, Andhra Pradesh, India

---

Abstract - *Nickel base super alloys are mainly used for fabrication of hot end components of power plants, automobiles, aero engines etc. These components are realized by laser cladding & brazing techniques. Welding of super alloys becomes difficult when Al & Ti content in the alloys is more than 4.5 % as it may lead formation of deleterious brittle phase Ni3 (Al ,Ti) resulting in weld joint cracking. Therefore brazing and cladding operation is well adopted technique where in difficult to weld material, inaccessible areas for welding and for batch production & repeatability of the result is important. In this work, Nickel base super alloy BZL12Y BE was brazed in a high vacuum furnace using BNi9 filler material and Specimens were brazed at 1100 °C for 20 minutes and then heat treated at 1080 °C and 800°C for the duration of 3 hours and 8 hours respectively and laser cladding was done on the brazing area with inconel625 filler material. The mechanical and metallurgical characterizations were investigated on microstructure and micro hardness of the BZL12Y BE. The resultant microstructures were examined using optical and micro-hardness on Vickers.*

Based on this studies, both brazing &laser cladding was performed on samples as well as on the sub-component.

Key Words: Aero-engines, Joint Cracking, Microstructure, Micro hardness Nickel-base super alloy, vacuum brazing, laser cladding

1. INTRODUCTION

Laser Cladding is the most advanced technology which is in high demand in aeronautical industries and engineering maintenance services. This technique is mostly used for rapid manufacturing, parts repair, and surface coatings. Components in aero engines and gas turbines like turbine and compressor blades are exposed to extreme conditions. Due to Higher working temperature defects such as cracks and impact damages can occur, resulting in a high cost to replace these parts. For Repairing and Refurbishing critical worn surfaces laser cladding technique is used [1][2]. Nickel Based super alloys are most commonly used in hot components of gas turbines which are continuously exposed to high heat conditions such as hot corrosion and oxidation[3]. Inconel 625 is a nickel-based super alloy that is mostly used as corrosion coating to gas turbine components [4].laser cladding and tig welding technologies which were used to coat on Inconel 738 substrate with Inconel 625. They carried out tests for coated and uncoated specimens subject to hot corrosion test carried out at 900°C. They found laser cladding specimens have better corrosion resistance when compared with uncoated specimens [5].laser powder and wire feeding techniques on different specimens to find their broad field of application. From the results, they concluded that for low feeding rates of laser cladding the powder feeding is best suitable as it coats with low dilution and small heat-affected zones. Whereas for high feeding laser cladding the wire feeding technique is used to sustain the heat and good surface coats are obtained [6].the powder feeding system has a wide process window for depositing continuous single tracks. However, the wire feeding technique produced continues single tracks with better surface quality and higher dimensional accuracy [7].electro spark deposition and pulsed Nd-YAG laser cladding techniques which are low heat input welding processes. They made a comparative study between microstructural characteristics and electro spark deposition. From the results, they concluded the structures obtained in the electro spark coating are finer and homogeneous when compared to the Nd-YAG laser coating technique [8]. Nd-YAG laser welding are investigated for super alloys (Inconel 600, Inconel 625). From the results, they found the strength of the welding part is similar to the base material in both laser welding and electron beam welding [9].stated the lack of laser cladding knowledge is on the mechanical properties of the deposited materials. So they fabricated two types of specimens and tested them to study the function and parameters of cladding properties. The first specimen was hybrid parts which are built layer by layer and the second specimen was the complete rapid manufactured sample. After the tests, they concluded the complete laser cladding specimens is 75% stronger than the hybrid specimens [10]

The present work evaluates the mechanical properties and microstructural analysis of specimens that are made by Ni-based super alloy [BZL-12YBE]. Inconel 625 is used as filler material for coating and joining of BZL-12YBE specimens

2. Experiment

2.1Base, Braze and laser cladded Materials

2.1.1 Base-Material: Nickel base super alloys components are mainly used in aero engines because they can be used at high temperatures while maintaining a significant amount of strength. They also have excellent oxidation and corrosion resistance at elevated temperatures. Nickel and cobalt super alloys can be used up to 1100 °C; however, nickel-base superalloys tend to be higher in strength than cobalt-base superalloys. The base-material used in our study is BZL12Y BE that is a nickel-chromium alloy. It has density of 7.93 g/cm³ and tensile strength is 915Mpa. BZL12Y BE is extensively used in aircraft parts and aero-engines for the manufacture of turbine blades, jet-pipes, nozzle blades etc. This alloy is specifically developed as a material for 'turbine engines'

Table 2.1: Nominal Compositions of BZL12Y BE

C	Cr	Ti	Al	Mo	W	Co	Nb	V	B	Zr	Ce
0.20	10.50	4.70	5.70	3.40	1.80	15.00	1.00	1.00	0.015	0.02	0.025

(a) Braze filler material

Brazing filler begins with one of several common primary metals like silver, aluminium, gold, copper, cobalt or nickel. The primary metal or alloy with other metals to improve their properties. BNi-9 is a eutectic nickel brazing alloy suitable for brazing nickel, super alloys, and stainless steels and other assemblies with good joining strength.

Table 2.2: % elemental composition of braze alloy BNi9

C	Si	B	Cr	S	P	Al	Fe	Ti	Co	Zr	Se	Ni
0.06	_	4	16.5	0.02	0.02	0.05	1.5	0.05	0.10	0.05	0.005	Bal

(b) Laser cladding filler materials

In laser cladding the inconel 625 is used as a filler material is has high strength excellent fabrication outstanding corrosion resistance service temperature range from cryogenic to 1800°F

2.2 Brazing and cladding of materials:

The base materials BZL12Y BE is wrought material, precipitation harden-able and solution treated: was received as cylindrical block with 10 mm diameter. The material was first visually inspected for any defects. The test coupons were cut to the dimensions of 10mm dia and 15 mm length. Test specimens were cleaned and then combination of specimens according to the requirement. The braze filler alloy BNi9 was measured to cover the joining surfaces of the base metal blocks, with a slight overhang. The extra braze alloy helps to ensure full wetting of the joint. The blocks to be joined were stacked with the braze filler metal in between. The brazing heat cycles were performed. All of the test coupons and sub-components were fixture and placed in the vacuum brazing furnace. The coupon assemblies were heat treated with different temperature conditions. During the entirety of the braze cycle, the furnace was kept at low pressure, approximately 10^{-5} torr. After the heating was completed the vacuum was removed and the samples were fan cooled to room temperature. After that the laser cladding was done on the brazing area of the coupons and sub-components as explained in section 2.3

2.3 Brazing and cladding plan:

The brazing is performed at 1080°C by using eutectic filler material BNi9 having liquids temperature of 1050°C. In as-brazed condition the BZL12Y BE is in soft condition. Diffusion Heat Treatment-I is given to the joint as per the diffusion cycle of BNi-9 diffusion cycle to give strength to the brazed zone and cladding was done on the brazing area by using AC power supply at 200W at the welding angle 45° by using wire feeding (Inconel 625) filler material

Visual inspection was conducted after completion of cladding and brazing. The visual inspection report reveals that there are no defects in the brazing and cladding. Indication of the cladded alloy observed around the joint periphery of all the samples, suggesting sufficient flow of the alloy during cladding. For metallographic examination, samples were sectioned normal to the cladding joint. To reveal the joint and base material microstructures, cross sections of the joints are ground, polished, etched with marbles reagent, and examined with optical microscope and the micro hardness values of various phases were measured using Vickers hardness tester, with 30 g impression weight.

3 Results and Discussion

3.1 Optical Microscopy

The typical microstructure of the Similar BZL12Y BE cladding joint to evaluate the effect of heat treatments given at temperatures. It can be seen that there are three zones across the cladding joint: (1) solid solution zone along the base metal (BZL12Y BE); (2) Diffusion layer between base metal and cladding surface; (3) cladded surface. From fig 1 (a&b), base metal and cladded material can be seen that there is no cracks, porosity or loss of material is observed in any of such clad joints. The Top cladding surface is shows uniform cladding without any segregation, cracks or defects are shown in

Fig1(c).In transverse cross section shows the thickness of the interface about the 100 microns from fig 1 (d&e)

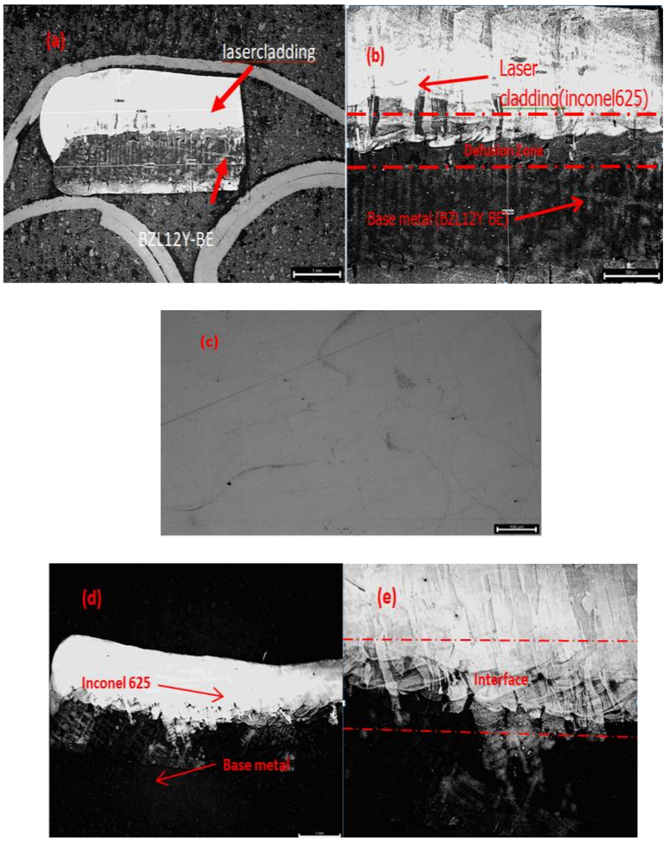

Fig 1: Interfacial microstructure of the BZL12Y BE joints (a)Longitudinal cross section on BZL12Y BE 100-X (b) longitudinal cross section on 250-X (c) Top cladding surface on 250-X (d)Transverse cross section on 100-X (e) Transverse cross section on 250-X

3.2 Micro hardness

Hardness profile is a good indicator of bond microstructure and can be used to assess the effect of secondary phase precipitates on mechanical properties. The Vickers micro hardness (M.H) of each specimen is measured for as-brazed condition and for different heat treatment cycles. Micro hardness values are taken at load of 30 grams for 10 seconds. Figure 2 below shows the variation of microhardness across the brazed zone for the joints.

Figure 2, shows the micro hardness of similar BZL12Y BE cladded joints for various as samples 1, 2, and 3. Figure 2 exhibits the variation of micro hardness values in the joint region as a function of distance from the centre. Here the maximum hardness is found in the eutectics, followed by diffusion zone, followed by parent BZL12Y BE. The average hardness of the base material is 450Hv and that of cladding material is 260Hv. Then micro hardness of the cladded material is same at every point with the average value of 300Hv and the average value of base metal is 466Hv and that cladding material is 295Hv. The hardness of the interface is in between parent and cladding material that is 300-400Hv

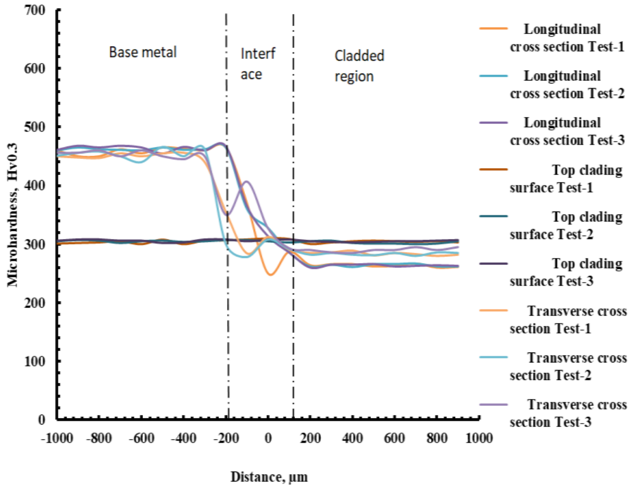

Fig 2: Variation of micro hardness for similar BZL12Y BE

4. CONCLUSIONS

In this current study starting nozzle of high-pressure gas turbine is made from BZL-12Y BE super-alloy. Sample material is cut and samples are prepared from it. The samples are brazed, laser cladded and optimize for the joint strength. Metallography is then performed on the samples. Optical microscope reveals three zones (i) base metal (ii) interface and (iii) cladded region. No cracks, porosity or loss of material is observed in any of the joints or the parent material. The Micro hardness of the samples was taken to correlate with microstructures.

The highest hardness is found in parent (BZL-12Y BE) followed by Interface zone and the least hardness is found in cladded zone. The average hardness of parent material is 450Hv and that of Cladding material is 295 Hv. The hardness of interface lies between parent and cladding material that is 315Hv.The micro hardness of the cladded material is same at every point with the average value of 300 Hv.

After getting the satisfactory results from the coupon level testing, the brazing and cladding was done on the aero-engine sub component i.e., the starting nozzle. After being cleared from the N.D.T the sub-component was tested on the universal testing machine (U.T.M). During the test, the nozzle was successfully loaded for a maximum load of 225 kg for 5-7 seconds. On visual observation no distress marks, cracks or any untoward marks were observed on the joints of the nozzle. This, fulfilling the acceptance criteria laid down in the test schedule. Hence the brazing and cladding for the joint of the nozzle is accepted

REFERENCES

[1] E. Toyeserkani, A.Khyajepour, S.Corbin, Laser Cladding, CRC Press LLC, 2005.

[2] Irene Alfred, Martin Nicolaus, Jorg Hermsdorf Et al, Advanced High Pressure Turbine Blade Repair

Technologies, 10th CIRP conference on photonic Technologies[LANE 2018]

[3] I. Hemmati, V.Ocelik, et al, Compositional modification of nickel base alloys for laser deposition technologies, University of Groningen, The Netherlands

[4] Abioye, T.E., McCartnay et al, Laser cladding of Inconel 625 wire for corrosion protection. Journal of Materials processing Technology. Vol 27: 232-240. (2015)

[5] Mohammad Naghiyan Fesharaki, Reza Shoja-Razavi et al. Hot corrosion behavior of Inconel 625 coatings on the Inconel 738 Substrate by laser and TIG Cladding techniques. Department of Materials Engineering (sep 2018)

[6] Alexander Laschkow , Alexander Lauffs et al.Wire and Powder laser cladding of Inconel 625 , 59th ILMENAU SCIENTIFIC COLLOQUIUM (sep 2017)

[7]T.E. Abioye, P.K. Farayibi and A.T. Clare. A Comparative Study of Inconel 625 Laser Cladding by Wire and Powder Feedstock, Materials and Manufacturing processes, (Apr 2017)

[8] Yu-Jiang Xie, Mao-Cai Wang, Da-Wei Haung. Comparative Study of Microstructural Characteristics of Electrospark and Nd: YAG laser epitaxial growing Coatings, Applied Surface Science 253:6149-6156 (2017)

[9] Jeng O Kim, Jeong Suh et al.Welding characteristics of super Alloys for Nd: YAG Laser 10.4028/www.scientific.net/MSF.580-582

[10] Taberenero , A.Lamikiz et al, Evolution of Mechanical properties of Inconel 718 Components Built by Laser Cladding , International Journal of Machine tools and manfactur 51 (2011) 465/470