International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 6, Issue 7, July 2019

Investigation of Microstructure and the Mechanical Properties of Inconel 625

Srihari Dodla *, Saurav Sameer Sahu, Shashvat Agarwal, R Tejdeep Reddy

Department of Mechanical Engineering, Faculty of Engineering and Technology, SRM Institute of Science and Technology, Kattankulathur - 603203, India

Abstract

In this paper we try to find the suitability of Inconel 625 superalloys for aerospace applications. Compression test on the specimens is carried out in the longitudinal and transverse directions and the difference in the strength for the two directions is studied for commercially available Inconel 625. Classification of precipitates was done for the Inconel 625 alloy. X-Ray Diffraction patterns of the specimen were also found out where the peaks were compared with the references to determine the crystallographic orientation.

Keywords: ***Nickel based alloy, X-ray diffraction (XRD), deformation behavior, hardness, precipitates***

1. Introduction

Nickel and its alloys are used in various industries due to its good fatigue, plastic and corrosion properties [1, 2, 3, 4]. Alloy of Nickel or pure Nickel material can also be used in the fabrication of structural components. Grain refinement process enhances corrosive resistance of Nickel based superalloys [5]. Nickel based superalloys are mainly used in aerospace applications such as gas turbines where the working temperature is above 1093°C, exhibiting resistance to oxidation at temperatures over 550°C, it is also used in marine, rocket engines, space vehicles, nuclear reactors, experimental aircraft, steam power plants, submarines, petrochemical equipment and other hightemperature applications. Nickel based alloys are known to be among the most difficult-to-machine superalloys [6].

Tool life of conventional cemented carbide tools when machining nickel-based alloys are insufficient. Most of the major parameters including the choice of tool materials, tool geometry etc., must be controlled in order to achieve the adequate tool life while machining. Nickel based superalloys can be used to a higher fraction of their melting point than just about any other commercially materials. Their strength is related not only to the chemistry but also to melting procedures [6]. In section 2 we discuss about the experimental material and procedure. In this the mechanical behaviour of the Inconel 625, based on the compression test carried out the stress-strain behaviour of the material was obtained. Besides classification of precipitates in the microstructure, the comparison of yield strength and hardness in the longitudinal and transverse direction was studied. X-ray diffraction pattern is obtained to study the diffraction peaks [7]. Section 3 shows the results and discussion. Section 4 discusses the conclusions.

2. Experimental material and procedure

Inconel 625 was bought in the form of a cylindrical ingot from Tanish Steel Mumbai with initial dimensions of 100 mm length and 50 mm diameter. Two discs were cut from the ingot having

Element	C	Si	Mn	P	S	Cr	Fe	Mo	Ni	Al	Co	Nb	Ti
Weight (%)	0.045	0.12	0.21	0.008	0.006	21.01	3.95	8.65	62.01	0.21	0.1	3.25	0.22

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 6, Issue 7, July 2019

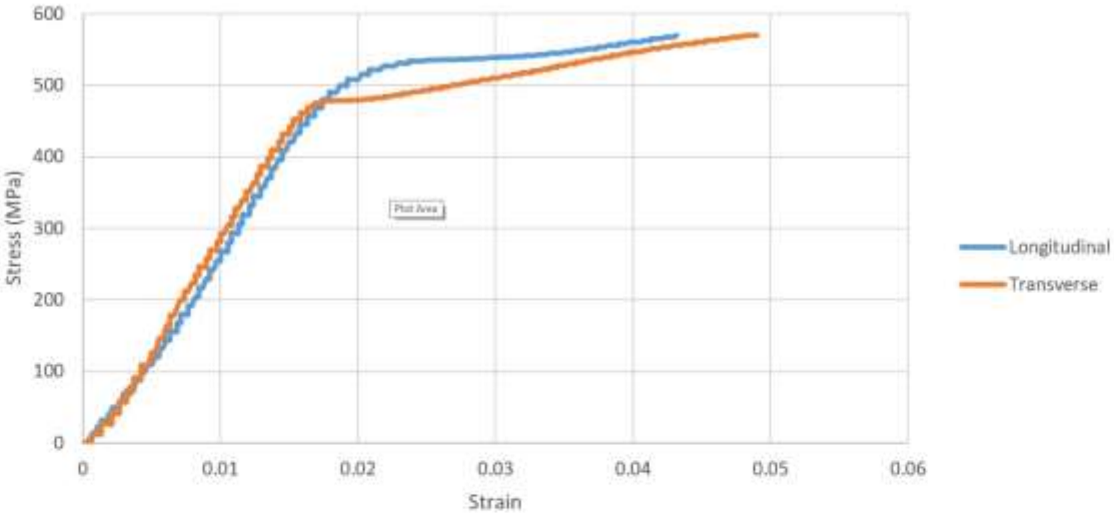


Figure 1: Stress-strain behavior of Inconel 625 in uni axial compression

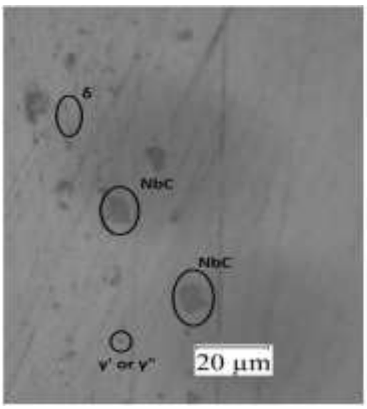
10mm thickness and 4 cubes of 10*10*10 mm^3 were cut along the transverse and the longitudinal direction by Electric Discharge Machining (EDM) wire cut process. Bakelite powder was used for making the mounts, hot mounting was done and the temperature is allowed to rise to 105°C ,for every rise by 10°C beginning from 40°C the butterfly handle is tightened whilst gradually increasing the pressure, after reaching 105°C the heater is turned off and the temperature is allowed to fall back to 30°C before the mount is removed, grinding was carried out followed by polishing, red velvet cloth was used and diamond paste having particle size in the range 0.5 to 1 μm was used. Hand grinding has been done using the grit sheets, changing the direction by rotating 90 ° clockwise when changing the grit sheet. The polishing was done on red velvet disc where the machine rotates clockwise at a speed of 1500 rpm. The lubricant used is Hifin spray and diamond paste of particle size 0.5-1 μm. The specimen is polished for a total of eight minutes where the direction is changed 90 ° clock-wise direction after two minutes. The etchant used in the surface preparation is Marbles Reagent.

2.1. Mechanical behavior

Compression tests were carried out according to ASTM standards. The samples were cut using wire cut EDM process in two different directions (longiudinal and transverse). Mechanical testing is done on universal testing machine. Stress-strain data was obtained from the measured force as well as displacement as a function of time.

2.2. Classification of precipitates of Inconel 625

The precipitates observed in the Inconel microstructure are gamma prime γ^0, $\gamma^{"}$ and δ. The $\gamma^{"}$, Ni_3Nb is dispersed in matrix has a body centred tetragonal crystalline structure which contributes



γ''	BCT-Ni_3Nb [8]
γ'	FCC-NiCr [8]
δ	Orthorhombic-$Ni_3(Al, Ti)$ [8]

Figure 2: Identification of precipitates in the optical micrograph of Inconel 625

0 towards the high temperature strength. The γ , $Ni_3(Al, Ti)$ which has face-centre-cubic crystalline structure supplies additional strength to the alloy. The δ, Ni_3Nb phase having orthorhombic crystalline structure plays a major role in improving creep properties of the alloy. As seen in the chemical composition, the Aluminum and Chromium form a Al_2O_3 and Cr_2O_3 which improves the corrosion resistance [8].

2.3. Yield strength

Yield point on a stress-strain curve is where we observe that the behaviour of a material changes from elastic to plastic. This point gives us the yield strength of the material. It is observed that the yield strength in the longitudinal direction is 508 MPa and in the transverse direction is 478 MPa. The difference in the yield strength is 6 %. Hence the material is isotropic in most of the region.

2.4. Hardness of specimen in the transverse and longitudinal direction

The hardness of the Inconel sample in both the directions is found out using Rockwell Hardness B scale. The machine used was digital Rockwell Hardness Machine where a load of 150 kgf was

00 applied using 1/16 Ball indenter, the difference in the hardness value was observed for both cases (i.e., in both longitudinal and transverse directions).

2.5. Determination of crystallographic orientation

Small angle X-Ray scattering diffractometer (BRUKER USA D8 Advance, Davinci) used for obtaining diffraction pattern of the Nickel samples. Data acquired from X-Ray Diffraction are imported to Origin Pro for plotting the diffraction patterns. The peak values are compared with literature data. The peaks are observed at angles of 44°, 51°, 74 ° respectively having a count of 8809, 3651, 2784.

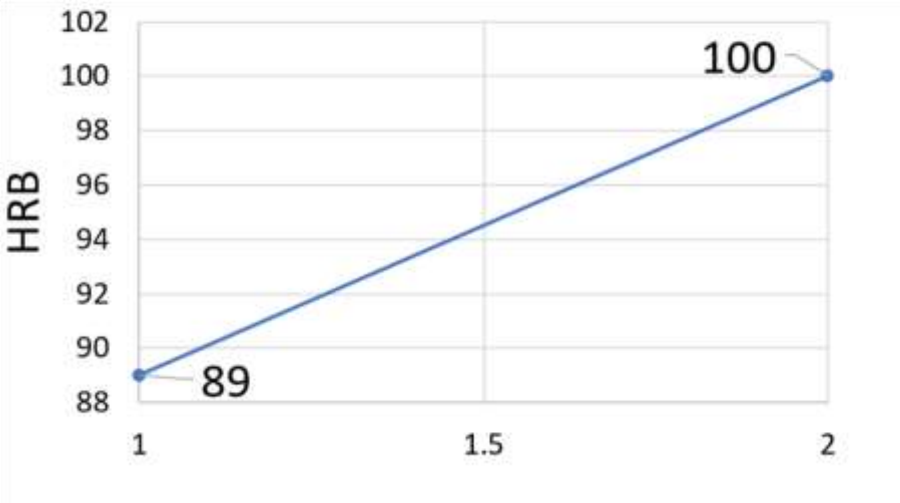


Figure 3: Hardness value in longitudinal (bottom left) and in transverse (top right) of Inconel 625

3. Results and discussion

Figure 1 shows the stress-strain curve for Inconel 625 in the longitudinal and transverse direction. It is observed that the material is isotropic with increase in the deformation. However the material is anisotropic in the strain between 2% - 3%. This is due to the heterogeneity in the microstructure. Figure 2 reveals the precipitates in the microstructure. Depending on the shape and morphology the precipitates are identified [8]. Figure 3 shows the results of Rockwell hardness tests. It is observed that there is a minor difference in the hardness values depending on the direction of the specimen. The decrease in hardness is due to heterogeneity in the microstructure.

The X-ray analysis has been performed on a received sample and it is shown in Figure 4. From the diffraction pattern, it is observed that the peak intensity at (111), (200), (220) plane. The maximum peak intensity at (111) plane was 8809 cps. In addition, the observed peak intensities was around 3651 cps and 2784 cps for planes of (200), (220) respectively.

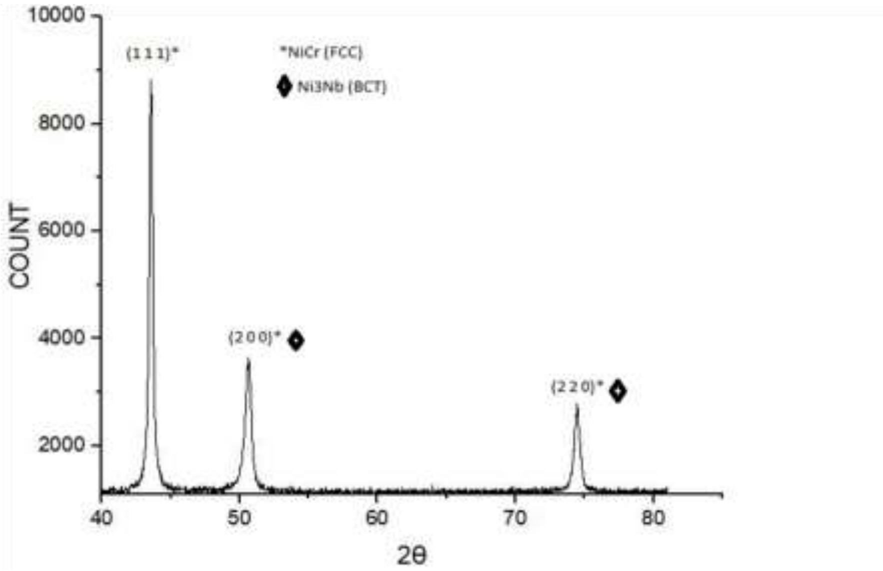


Figure 4: X-ray diffraction patterns for Inconel 625

4. Conclusion

The material is isotropic. However the anisotropy is observed in the strain range 2 % to 3 %. γ^0, $\gamma^{''}$, δ precipitates are observed in the optical microscope for Inconel 625. There is a minor difference in the hardness and yield strength in the longitudinal and the transverse direction. This is due to the heterogeneity in the microstructure. From the diffraction pattern, it is clear that the important diffraction peaks (111), (200), (220) for Inconel 625 has been observed.

5. References

[1] A. N. Benitez P. M. Hernandez J. F. Cardenes M. D. Monzon, M. D. Marrero. A technical note on the characterization of electroformed nickel shells for their application to injection molds. Journal of Material Processing Technology, 176:273–277, 2006.

[2] URL https://www.neonickel.com/generate-alloy-pdf/?id=109.

[3] J. F. Bingert J. J. Thornton A. M. Dangelewicz Y. Li W. Liu Y. Zhu Y. Zhou E. J. Lavernia Y. Zhao, T. Topping. High tensile ductility and strength in bulk nanostructured nickel. Advanced Materials, 20:3028–3033, 2008.

[4] K. B. Sundaram V. Desai T. Du, A. Vijayakumar. Chemical mechanical polishing of nickel for applications in mems devices. Material Letters, 58:2306–2309, 2004.

[5] Sivasankaran Subbarayan Osama M. Irfan Zahid Hussain, Fahad A. Al-Mufadi. Microstructure and mechanical properties investigation on nanostructured nickel 200y alloy using multi-axial forging. Materials Science and Engineering: A, 712:772–779, 2018.

[6] A. R. Machado E. O. Ezugwu, Z. M. Wang. The machinability of nickel-based alloys: a review. Journal of Materials Processing Technology, 86:1–16, 1999.

[7] L. E. Murr E. Martinez S. M. Gaytan P. W. Shinda K.N. Amato, J. Hernandez. Comparison of microstructures and properties for a ni-base superalloy (alloy 625) fabricated by electron and laser beam melting. Journal of Materials Science Research, 1:3–41, 2012.

[8] M. Jahazi M. Asadi A. Weck A. K. Koul A. Chamanfar, L. Sarrat. Microstructure and mechanical properties investigation on nanostructured nickel 200y alloy using multi-axial forging. Materials and Design, 712:772–779, 2018.