Study of Nickal based Super Alloy

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Abstract— Super alloys are metallic materials for service at high temperature, so one of their most important properties is high temperature creep resistance. Other crucial material properties are fatigue life, phase stability, as well as oxidation and corrosion resistance. A conventional metal may be failed in high temperature machining condition and has poor creep resistance, so materials for working at high temperature and which having also good creep resistance are a critical issue in manufacturing. this paper present a review about the Ni- base super alloys, which working at high temperature and also having a good machining property and having good creep resistance.

Key words: Super alloys, Ni-based super alloys, temperature, corrosion, strengthening. A alloy that exhibits excellent mechanical strength and resistance to creep at high temperature; good surface stability; and corrosion and oxidation resistance

I. INTRODUCTION

Super alloys developed high temperature strength through solid solution strengthening .The most important strengthening mechanism is through the formation of secondary phase precipitates such as gamma prime and carbides through precipitation strengthening.

Super alloys are designed to be used at temperature of 540˚C and higher, typically up to 0.7× their absolute melting temperature, which may be up to around 1000˚C. At 760˚C most super alloys have yield strength in excess of 500MPa. They are also corrosion resistant. [1]

There are three types of super alloys:

- Iron nickel based – these are an extension of stainless steel technology and are frequently wrought. Typically contain 20-40% NI, 15-20% CR, 30-50% Fe, plus Mo, Al, Ti.
- *Nickel based* – may be wrought or cast. Typically more than 40%Ni, 10-20%Cr, up to 10%Al, and T, 5-10% Co, and small amount of B, Zr, and C. Mo, W and Nb are also commonly added.
- Cobalt based – may be wrought or cast. Typically contain 35-60% Co, 20-30%Cr, up to 35%Ni with some W and Mo.

HSS – High Speed Steel
HIP – Hot Isostatic Pressing
FCC – Face Centered Cubic
Ni - Nickel
Al – Aluminum
Cr – Chromium
Zr – Zirconium

Table 1 Nomenclature

II. IMPROVEMENT OF SUPER ALLOYS BY CHEMISTRY CONTROL

The production of super alloy components initially requires some sort of melting process. The melting produces ingots which are remelted, converted to powder for subsequent con- solidation to a component, or investment cast. Remelting is used to produce an ingot which can be processed to wrought mill forms (e.g., bar stock) or forged. Until the start of the second half of the twentieth century, melting of super alloys was conducted in air or under slag environments. The properties of modern super alloys derive principally from the presence of many elements which are reactive with oxygen and so were being lost to some or a great degree in the melting and casting process. When vacuum melting techniques were introduced to commercial production of articles, they were pioneered by superalloys. The vacuum en- abled the melting of superalloys containing higher amounts of the hardeners aluminum and titanium. Furthermore, the concurrent reduction in gases, oxides, and other impurities created a significant improvement in the ductility of superalloys. Moreover, with more hardener content, strengths of superalloys began to increase dramatically. [2]

III. NI-BASED SUPERALLOYS

Nickel-based superalloys are unusual class of metallic materials with an exceptional combination of high temperature strength, toughness and resistance to degradation in corrosive or oxidizing environment. These materials are widely used in aircraft and power generation turbine, rocket engines, and other challenging environment, including nuclear power and chemical processing plants. [3]

Nickel based superalloys are the most complex, the most widely used for the hottest part, and too many metallurgists, the most interesting of all superalloys.

Nickel based – may be wrought or cast. Typically more than 40%Ni, 10-20%Cr, up to 10%Al, and T, 5-10% Co, and small amount of B, Zr, and C. Mo, W and Nb are also commonly added.

IV. CHARACTERISTICS OF NI-BASED SUPERALLOYS

Nickel-containing super alloys are selected for use in certain applications due to their characteristics. Among the important characteristics are creep resistance at high temperatures, good surface stability, and corrosion and oxidation resistance. One of their most important properties is high temperature creep resistance. [4]

Some other characteristics as follows:-

- FCC (γ) austenitic matrices based on Ni.
- Solid solution strengthening is through alloy element that partition to γ.
- Alloys are also precipitation hardened via intermetallic borides or carbides.
- Alloys are also precipitation strengthened by modifying grain boundaries.

A listing of some of the super alloys, with information on their composition and some of the uses is provided here:-

– Inconel Alloy 600 (76Ni-15Cr-8Fe) is a standard material of construction for nuclear reactors, also used in the chemical industry in heaters, stills, evaporator tubes and condensers,
– Nimonic alloy 75 (80/20) nickel-chromium alloy with additions of titanium and carbon) used in gas turbine engineering, furnace components and heat-treatment equipment.
– Alloy 601. Lower nickel (61%) content with aluminum and silicon additions for improved oxidation and nitriding resistance chemical processing, pollution control, aerospace, and power generation.
– Alloy X750. Aluminum and titanium additions for age hardening. Used in gas turbines, rocket engines, nuclear reactors, pressure vessels, tooling, and aircraft structures.
– Alloy 718. (55Ni-21Cr-5Nb-3Mo). Niobium addition to overcome cracking problems during welding. Used in aircraft and land-based gas turbine engines and cryogenic tankage.
– Alloy X (48Ni-22Cr-18Fe-9Mo + W). High-temperature flat-rolled product for aerospace application.[5]

V. APPLICATION

The applications of Ni-based superalloys are bellows:-

– Aircraft gas turbines: disks, combustion chambers, bolts, casings, shafts, exhaust systems, cases, blades, vanes, burner cans, afterburners, thrust reversers.
– Steam turbine power plants: bolts, blades, stack gas re-heaters
– Reciprocating engines: turbochargers exhaust valves, hot plugs, valve seat inserts.
– Metal processing: hot-work tools and dies, casting dies.
– Medical applications: dentistry uses, prosthetic devices.
– Space vehicles: aerodynamically heated skins, rocket engine parts.
– Heat-treating equipment: trays, fixtures, conveyor belts, baskets, fans, furnace mufflers.
– Nuclear power systems: control rod drive mechanisms, valve stems, springs, ducting.
– Chemical and petrochemical industries: bolts, fans, valves, reaction vessels, piping, pumps.
– Pollution control equipment: scrubbers.
– Metals processing mills: ovens, afterburners, exhaust fans.
– Coal gasification and liquefaction systems: heat exchangers, re-heaters, piping.

VI. CREEP DAMAGE CHARACTERIZATION OF NI-BASE

The Ni-base super alloy has very good mechanical properties even at high temperature. It has high tensile strength and very good creep corrosion resistance, therefore Ni-base super alloy are used for heat exchanger or turbine which are working at high temperature.

These alloys can be found in two-phase equilibrium microstructures, consisting of gamma (g, disordered fcc and nickel-based solid solution)and gamma- prime (g', ordered fcc andL12) [6,7]. The chemical composition of γ is generally modeledasNi3Al butinfactits composition is much complex, with the aluminum atoms occupying the corners and the nickel occupying the faces of the unit cell. Since both phases have a cubic lattice with similar lattice parameters, the g' precipitates in a cube orientation ([001]//[001])relationship with the g matrix so that its cell edges are exactly parallel to the corresponding edges of the g phase [8,9].

VII. FGH95 POWDER NI-BASED SUPERALLOY

FGH95 powder Ni-base superalloy has long found wide applications in producing turbine disks because it possesses a high volume fraction of Jc strengthening phase and better mechanical properties at upward of 650 qC. The preparation of FGH95 powder Ni-base superalloy includes powder pretreatment, hot isostatic pressing (HIP), and heat treatment. Microstructure of the alloy consists of J, Jc phases and carbides. Moreover, the size, shape, and distribution of Jc phase depend on the HIP and heat treatment technology. In the pretreatment, the powder particles inside a billet are diffusely linked with each other, and some finer carbide precipitate along the grain boundaries to in- crease the linking strength of the particles. At high temperatures during HIP, the density of the alloy may improve to enhance the creep property of the alloy at elevated temperatures. [10]

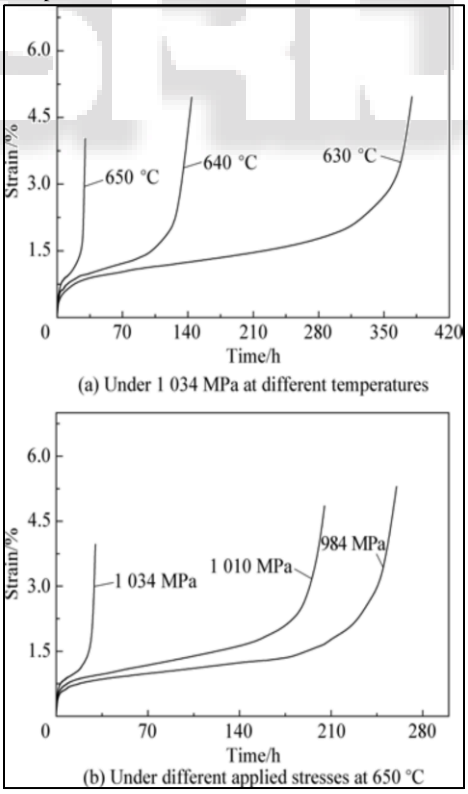

Fig.1 (b) shows the creep curves of the superalloy under different applied stresses at 650 °C, which displays a shorter initial and a longer steady creep stage under the applied stress of 984 MPa with the strain rate at steady creep stage being 3.55x10^{-5}/h and the creep life being about 260 h. As the applied stress increases to 1 010 MPa, the strain rate rises to 5.78x10^{-5}/h, and the creep life decreases to about 205 h. The creep life drops to 32 h when the applied stress increases to 1 034 MPa. Therefore, the superalloy is sensitive to the applied stress when it exceeds 1 010 MPa. [10]

VIII. MACHINED SURFACE INTEGRITY OF NI-BASED SUPER ALLOYS

Nickel-based super alloys, owing to their superior mechanical properties, have become an attractive choice of materials in numerous engineering applications. However, these materials pose considerable challenge during machining due to low thermal conductivity, work hardening tendency, chemical affinity and presence of abrasive carbide particles in their microstructure. Surface integrity plays a vital role on the final performance of the machined product. It includes properties of the materials at the surface and sub-surface regions including surface morphology, surface roughness, residual stress, microstructure, and micro hardness. During the machining of Nickel-based super alloys, surface defects such as surface drag, material pull out/cracking, feed marks, adhered material particle, debris of chips, surface plucking, deformed grain surface cavities and slip zone were found.[11]

IX. EFFECT OF NI-BASED SUPERALLOYS ON SUBSURFACE DEFORMATION

Among the factors affecting surface integrity, subsurface deformation produced by machining process is one of essential factors to determine the mechanical properties of the material beneath the machined surface, such as residual stresses, hardness, and fatigue strength and has substantial influence to the performance and life time of final products. Subsurface deformation is inherent to a metal cutting process.[12.] where a sharp tool is used to remove a preset depth of material by moving in a direction perpendicular to its cutting edge and produces the chip with thickness. Deformation occurs by shear concentrated in a narrow zone (shear plane). The shear zone is formed by shearing the work piece material. The plastic deformations are also introduced as the result of friction at the interface of chip/rake face and surface/flank face, and the area where the work piece material is deformed and separated under the high compressive stresses. Nickel based superalloy is well-known as one of the most difficult materials to machine due to high cutting temperatures and high strength encountered during the machining. The finishing operations of aerospace parts are commonly conducted by using WC tools at relatively low cutting speeds (30 – 60 m/min) due to the uncertainty of surface quality produced with other tool materials and their associated operation parameters [13]

X. CONCLUSION

It is concluded that superalloys are widely used for manufacturing of turbine discs, heat exchanger etc. Because of its excellent machined properties. Ni-based super alloys are those materials which are widely used because of its high strength,, at high temperature and also it posses very good creep resistance, and corrosion at high temperature.

Ni-based superalloys posses' very good machining properties and some machining operations for manufacturing of complex profile and in manufacturing of turbine discs. Its having a good creep resistance. FGH95 powder Ni-based superalloys under the applied stress of 1 010MPa at 650°C, FGH95 powder based super alloy is characterized by a lower strain rate and a longer keep lifespan and strong sensitivity to applied temperature and stress in experimental range. The apparent activating energy and stress exponent of the alloys during creeping are measured to be 381.1 kj/mol and 17.9, respectively.[14]

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