Review on High Performance Nickel based Super Alloy

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ABSTRACT
Nickel is a high-density, high-strength metal with good ductility and excellent corrosion resistance and high temperature properties. Ni-base super alloys are a unique class of materials having exceptionally creep and oxidation resistance. Used in many high temperature applications like turbine engines. Nickel-containing materials are used in buildings and infrastructure, chemical production, communications, energy, environmental protection, food preparation, water treatment and transportation.

Keywords---- Friction welding, Turbine blade, strength, Nickel super alloy

I. INTRODUCTION
Super alloys are a group of materials that are used in high temperature applications, for example gas turbines and aero engines. Gas turbines are most commonly used for power generation, and it is only the very critical component which is made from super alloy material [1]. Ni-based super alloys are extensively used during the manufacturing of aircraft aero-engines and it is resisting cracking when conventional fusion welding is used. Friction welding is a solid state joining process and can be used to successfully weld a range of Ni-based super alloy base materials [2]. The joining parameters during friction welding operation depend upon friction pressure, time, and rotational speed. The friction time must be sufficient to allow frictional heating but not so long during the welding operation. The torque produced during the direct drive friction joining process increases with reduction in rotational speed is also controlled by friction pressure [2].

II. NI, FE, CO-BASED SUPER ALLOYS
Ni, Fe and Co base super alloy base materials are generally used at temperatures above 550°C because of their excellent creep strength properties and some super alloy material compositions can be forged and rolled into sheet. Fabricated components are also made using welding or brazing. Many highly super alloy composites contain large contents of hardening phases and are difficult to weld since they are highly resisting property to cracking. The mechanical properties of nickel based super alloy materials are controlled by composition and thermal processing. Figure 1 compares the rupture strength properties of three alloy classes [3].
III. NICKEL BASED SUPER ALLOY

Nickel super alloy parts and components can withstand harsh environments, and exhibit high heat resistance, corrosion resistance and acid resistance, they are ideal materials for use for pumps, valves, piping systems, process equipment, turbines and assemblies in the marine, chemical processing, oil and gas, aerospace and military industries.[3].

<table>
<thead>
<tr>
<th>Ni</th>
<th>Cr</th>
<th>Co</th>
<th>Mo</th>
<th>Ta</th>
<th>Al</th>
<th>Ti</th>
<th>C</th>
<th>B</th>
<th>Zr</th>
<th>Fe</th>
<th>S</th>
<th>Si</th>
</tr>
</thead>
<tbody>
<tr>
<td>57</td>
<td>14.61</td>
<td>15.32</td>
<td>4.52</td>
<td>0.05</td>
<td>4.73</td>
<td>3.49</td>
<td>0.07</td>
<td>0.015</td>
<td>0.01</td>
<td>0.08</td>
<td>0.001</td>
<td>0.017</td>
</tr>
</tbody>
</table>

Table 1 chemical composition of nickel super alloys

![Material Strength](image)

Figure 2: Material strength of different alloys

IV. TYPES OF NICKEL SUPER ALLOYS

Nickel-chromium-iron series of alloys have higher strength and resistance to elevated temperatures. 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) 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 and used in aircraft, land-based gas turbine engines and cryogenic tankage
- Alloy X (48Ni-22Cr-18Fe-9Mo + W). High-temperature flat-rolled product for aerospace applications
- Waspaloy (60Ni-19Cr-4Mo-3Ti-1.3Al). Proprietary alloy for jet engine applications
- ATI 718Plus. A lower cost alloy which exceeds the operating temperature capability of standard 718 alloy by 100 Fº (55 Cº) allowing engine manufacturers to improve fuel efficiency.
- Nimonic 90. (Ni 54% min Cr 18-21% Co 15-21% Ti 2-3% Al 1-2%) used for turbine blades, discs, forgings, ring sections and hot-working tools
- Rene’ N6. (4Cr-12Co-1Mo-W6 -Ta7- Al5.8 - Hf 0.2 -Re5- BalNi) 3rd generation single crystal alloy used in jet engines
• TMS 162 (3Cr-6Co-4Mo-6W-6Ta-6Al-5Re-6Ru-balance Ni) 5th generation single crystal alloy for turbine blades [3]

V. APPLICATIONS OF NICKEL SUPER ALLOYS

Nickel-based super alloys are an unusual class of metallic materials with an exceptional combination of high temperature strength, toughness, and resistance to degradation in corrosive or oxidizing environments. The nickel-based alloys show a wider range of application than any other class of alloys [5]. In aerospace applications nickel-based super alloys are used widely as components of jet engine turbines. Fuel efficiency and emissions are also key commercial and environmental drivers impacting turbine-engine materials. To meet these demands, modern nickel-based alloys offer an efficient compromise between performance and economics. The parts of gas turbine engine in which Nickel-based super alloys (marked red) commonly used are shown in Figure 3.

VI. PHASE DIAGRAM

A pseudo binary phase diagram for Ni-based super alloy is show in Figure 7. The following points should be noted:

• The solution temperature varies km one super alloy to another. For example, alloy #3 requires a higher solution zing temperature then alloy #1.

The temperature difference is entirely dependent on the amount of y’ prime in super alloy.

• Following the solution treatment, the alloys are heat treated to promote further hardening. Alloy #1 requires only one heat treatment cycle to precipitate all the particles while alloys #2 and #3 require two different heat treatment cycles for this to occur (see the figure 6). These subsequent heat treatments comprise a stabilization treatment at
The oxide formed in Ni based super alloy at ambient temperature is by impurities from the atmosphere such as chlorine or sulfur, when a freshly prepare surface is exposed. Oxidation process is the diffusion of ions in to the oxides and these oxides are not the corrosion products. Oxide development on a clean or contaminated, freshly prepared metal surface involves absorption of gas, appearance of two-end three-dimensional nuclei. The uniform oxide film, thicken by metal or oxygen transport through the film, usually diffusion or ion transfer [6].
VIII. CONCLUSION

Nickel-based super alloys can be used for a higher fraction of melting temperature and its good mechanical properties, easy machinability and low cost. Therefore more favorable than cobalt based and iron-nickel-based super alloys at operating temperatures close to the melting temperature of the materials. In oxidizing conditions the alloy showed parabolic kinetics. The weight gain increases with increases with increase in temperature. The oxide scales developed on the alloy under purely oxidizing condition except at a test temperature of 7500 °C.

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