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Feasibility of manufacturing combustion chambers for aeronautical use in Mexico

Alonso Romero-Jabalquinto, Abraham Velasco-Téllez, Patricia Zambrano-Robledo, Bárbara Bermúdez-Reyes *

Universidad Autónoma de Nuevo León, Facultad de Ingeniería Mecánica y Eléctrica, Centro de Investigación e Innovación en Ingeniería Aeronáutica, Av. Universidad s/n, Ciudad Universitaria, C. P. 56451 San Nicolás de los Garza, Nuevo León, Mexico

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Abstract

The aeronautical sector is strategically important for the economic development of Mexico and has grown steadily over the last 10 years. Furthermore, it generates high added value for its products. In Mexico, the aircraft manufacturing sector mainly focuses on the fabrication of heat exchangers, seals, fuel ducts, and engine support rings. Currently, this sector is not involved in the manufacture of engine hot section components such as combustion chambers and turbine blades. Estimation of the associated costs enables assessment of the feasibility of fabricating such components. This study investigates the feasibility of establishing production lines for aeronautical combustion chamber fabrication in factories dedicated to the manufacture of aeronautical gas turbine engines.

Keywords: Combustion chamber; Superalloy; Forming; Forging

1. Introduction

The federal government of Mexico, together with several state governments, has implemented strategies to increase investment in the aerospace industry, hence Mexico has the scientific and technological capability to manufacture specialized components of gas turbine motors for aeronautical use – an industry hotspot. Thus, both domestic and foreign industries established in the country can analyze the convenience of manufacturing these sections (Pro-Aéreo, 2011).

Companies dedicated to the design, engineering, and manufacture of aeronautical motors constitute 2.9% of the total number of aerospace firms existing in Mexico, and these companies design and manufacture the following components (Plan de Vuelo Nacional, 2009; Pro-Aéreo, 2011):

- Motor support rings
- Compressor blades
- Seals
- Couplings
- Motor covers
- Fuel ducts
- Heat exchangers

However, these companies only manufacture cold section components and auxiliary parts of gas turbines for aeronautical use. Hot sections such as combustion chambers and turbines are not manufactured domestically towing to the restrictions imposed by the International Traffic in Arms Regulations; however, these restrictions are not applicable to foreign companies operating in Mexico (Plan de Vuelo Nacional, 2009). The materials used in the manufacture of combustion chambers must have the following characteristics (Campbell, 2008):

- High mechanical resistance to high temperatures
- High resistance to oxidation and corrosion
- Low density

* Corresponding author.
E-mail address: barbara.bermudezry@uanl.edu.mx (B. Bermúdez-Reyes).
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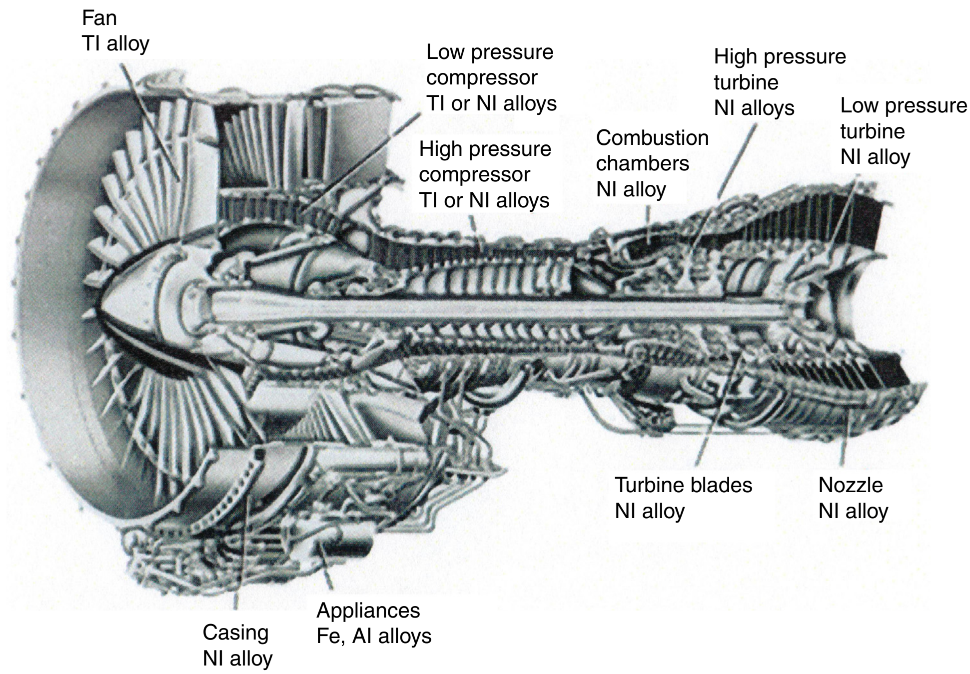

Figure 1. Aircraft engines are manufactured using superalloys, mainly for hot turbine sections (Reed, 2006).

- Low thermal expansion
- Low elastic modulus
- High resistance to thermal fatigue
- Low cost
- High feasibility for manufacturing

Superalloys such as nickel, iron-nickel, and cobalt alloys meet most of the abovementioned requirements; furthermore, they frequently operate at temperatures exceeding 800 K and have a combination of high resistance to applied loads, resistance to fatigue and creep, and resistance to corrosion at high temperatures for long periods of time. Therefore, superalloys are the most extensively used alloys in the manufacture of hot section components of gas turbine motors, which constitute more than 50% of the motor's total weight (Fig. 1) (Pollock & Tin, 2006; Reed, 2006).

Nickel-based alloys are solutions that are stabilized with aluminum, copper, chromium, iron, molybdenum, tungsten, and tantalum and maintain a face centered cubic structure. Aluminum and titanium are hardening and precipitating elements, whereas molybdenum and tungsten are beneficial for because of their ability to reduce creep (Pollock, Dibbern, Tsunekane, Zhu, & Suzuki, 2010; Reed, 2006).

The most important precipitate in nickel and iron-nickel alloys is the γ' phase (Fig. 2), in the form of Ni_3Al or Ni_3Ti. This phase is precipitated during thermal hardening and aging treatments (Reed, 2006).

The γ' phase is only 0.1% dispersed throughout the austenitic matrix; thus, it precipitates homogeneously on the surface (Pollock et al., 2010). The balance between γ and γ' is maintained at high temperatures, even hold at 70% of the fusion temperature of the material (T_m). The presence of niobium in the superalloy leads to the formation of a precipitate with a body centered tetragonal crystalline structure known as γ' (Fig. 3), which is a product of the reaction between Ni and Nb (Ni_3Nb). This precipitate increases hardness in Ni–Fe-based alloys; therefore, it is an important constituent of superalloys. Note that this property contributes to the control of the superalloy microstructure during the forging process (Reed, 2006).

The composition of commercial superalloys is complex (some contain more than a dozen alloy components). The function of each of these alloyed elements is shown in Table 1.

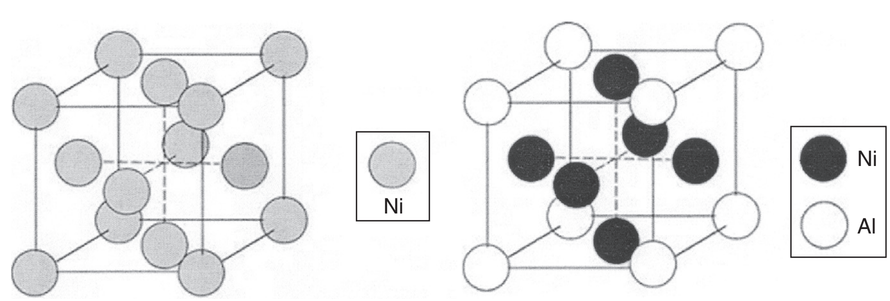

Figure 2. Cell unit arrangements. (a) Nickel has a face centered cubic structure forming the γ phase. (b) Nickel and aluminum also form a face centered cubic structure forming the γ' phase Ni_3Al (Reed, 2006).