ISSN:0971-1260
Vol-22-Issue-4-October-December-2019

A Review On Forged Blades To Increase Mechanical Properties

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Abstract: The number of blades in modern aircraft engines is counted in hundreds of pieces, and simultaneously the blades are responsible for correct running of the engine. Failure of even one blade could cause engine stoppage and/or its serious damage. In each engine many kinds of blades with miscellaneous shapes are working. They fulfil different roles and they run a risk of different working factors. Therefore, these are manufactured with different methods with use of various materials. Basic factors which guarantee the required operating properties of blades are shape and high precision of dimensions and also proper material used for production. To check possibilities to fulfil these requirements numerical modelling of forging processes is used.Turbine compressor blade in aircraft engine works in severe conditions, i.e. under large temperature gradient and high mechanical loads. This paper focuses on the mechanical properties of turbine blades, the blade under forged loads.

Key words; Forging process, Blades, mechanical properties.

1.0 Introduction

Advancements made in the field of materials have contributed in a major way in building gas turbine engines with higher power ratings and efficiency levels. Improvements in design of the gas turbine engines over the years have importantly been due to development of materials with enhanced performance levels. Gas turbines have been widely utilized in aircraft engines as well as for land based applications importantly for power generation. Advancements in gas turbine materials have always played a prime role – higher the capability of the materials to withstand elevated temperature service, more the engine efficiency; materials with high elevated temperature strength to weight ratio help in weight reduction [1]. A wide spectrum of high performance materials - special steels, titanium alloys and superalloys - is used for construction of gas turbines. Manufacture of these materials often involves advanced processing techniques. Other material groups like ceramics, composites and inter-metallics have been the focus of intense research and development; aim is to exploit the superior features of these materials for improving the performance of gas turbine engines. The materials developed at the first instance for gas turbine engine applications had high temperature tensile strength as the prime requirement. This requirement quickly changed as operating temperatures rose. Stress rupture life and then creep properties became important. In the subsequent years of development, low cycle fatigue (LCF) life became another important parameter [2]. Many of the components in the aero engines are subjected to fatigue- and /or creep-loading, and the choice of material is then based on the capability of the material to withstand such loads. Coating technology has become an integral part of manufacture of gas turbine engine components operating at high temperatures, as this is the only way a combination of high level of mechanical properties and excellent resistance to

ISSN:0971-1260
Vol-22-Issue-4-October-December-2019

oxidation / hot corrosion resistance could be achieved. The review brings out a detailed analysis of the advanced materials and processes that have come to stay in the production of various components in gas turbine engines. While there are thousands of components that go into a gas turbine engine, the emphasis here has been on the main components, which are critical to the performance of the engine. The review also takes stock of the R&D activity currently [3].

2.0 Aim of study

Forging is one of the promising processes for high strength mechanical properties achievements at high temperatures for blade applications used in gas turbines. For the above blade requirements test mathematical model is capable to simulate operation of the thermo-elements and potentially suitable for compensation of the dynamic errors has not been investigated yet in details.Even still insufficient (for the current phase of developments) accuracy of the employed observer cannot serve as explanation for such a large quality divergence between diagrams for the T4t and T4 temperatures during the engine deceleration and for the fact that the diagrams do not intersect at the 'd' point. Additionally, a slight phase displacement visible on both diagrams for the deceleration phase indicates herein that the predominant mechanism for heat exchange between measuring joints of the thermo-elements and the ambient environment is probably radiation, whereas the mechanism of forced convection prevails on the acceleration area.

3.0 SCOPE OF STUDY

The destructive processes affecting gas turbine vanes and blades begins with destruction of the aluminium coating. Consequently, the parent material of vanes and blades is exposed to the direct thermal and chemical effects of exhaust gases. Such circumstances lead, first and foremost, to the overheating of that material, which is manifested by adverse changes in the material microstructure. The factors that influence that effect include the s recent advancements in the development of creep-resistant superalloys and their microstructural control, including stable gamma-prime raft structures. Then a comparative analysis of recently developed SC superalloys is presented to enable GT designers to select appropriate materials for hotter energy-efficient GT engines. It is recommended to develop new creep-limited alloys based on the metals with higher melting temperatures (e.g., Mo and Nb alloyed with silicon); these future alloys are proposed as prospective candidates for hotter energy-efficient GTs. The achieved results make it possible to conclude that the damaged turbine blade was operated at the temperature of exhaust gases that exceeded the maximum allowed limit of 1013K for the time of about 1h (i.e. the time comparable to the heating time of a new blade) during air missions.

4.0 Materials and observations

Selection of material is prime requirement during design of gas turbine engine components, since the selection of proper material can enhance the life of component in gas turbine engine. Temperature limitations is one of the most crucial limiting factors to gas turbine efficiencies and performance. [4] At high temperature, some material fails to maintain its strengths due to varying criteria in gas turbines individual components materials selection.

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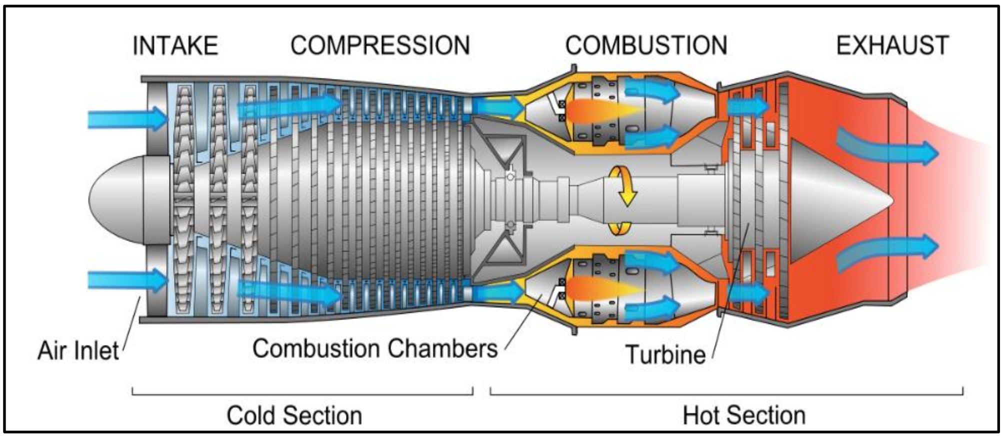

Figure.1 Schematic diagram of Gas turbine Engine

In the early years of turbine development, increases in blade alloy temperature from the blade alloy temperature capability accounted for the majority of the firing temperature increase until air-cooling was introduced, which decoupled firing temperature from the blade metal temperature. Also, as the metal temperature approached the 1600^0F (870^0C) range, hot corrosion of blades became more life limiting than strength until the introduction of protective coatings.During the 1980s, emphasis turned towards two major areas: *improved material technology,* to achieve greater blade alloy capability without sacrificing alloy corrosion resistance and *advanced, highly sophisticated air cooling technology* to achieve the firing temperature capability required for the new generation of gas turbines. The use of steam cooling to further increase combined-cycle efficiencies in combustors was introduced in the mid to late 1990s. [5]Steam cooling in blades and nozzles were introduced in commercial operation in the year 2002.

Turbine Blades of a gas turbine engine are very prone to damage from flying debris, moreover they also sustain thermal stresses and local overheating on their surface of gases that are coming out from combustion chambers. So, the use of titanium or its alloy is very meaningful because it has a great strength, durability and having such properties that makes it useful in construction of turbine blades. Titanium is also up to 40 percent less dense than any other material giving a high enough strength to weight ratio. This means that a small quantity of it has an equal strength of a larger quantity of such a nickel or aluminum based alloy. In

ISSN:0971-1260
Vol-22-Issue-4-October-December-2019

order to overcome these difficulties, the application of advanced and modern alloys or super alloys is being introduced in aviation industries [6].

Titanium is very easily forged and cast into various forms. Also, its alloys are very resistive against corrosion and oxidation changes occurring in environment. The modern technology of manufacturing the turbine blade is also uses the alloy grain in the single crystal blade which increases its elastic properties and in turn, the natural vibration frequencies of blade can be controlled. However, the biggest change has occurred in the nickel, where high levels of tungsten and rhenium are present [7]. These elements are very effective in solution strengthening.

An important recent contribution has come from the alignment of the alloy grain in the single crystal blade, which has allowed the elastic properties of the material to be controlled more closely. These properties in turn control the natural vibration frequencies of the blade.

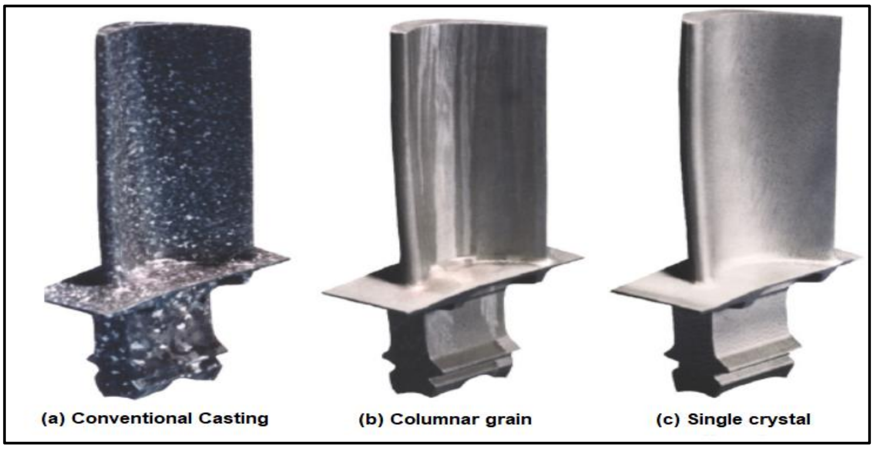

Figure.2 Gas turbine blade with different microstructures

A compressor blade is a blade machined to a precise and exacting standard to be used for application inside a turbine or compressor engine. The blades are the driving force to move air to the compression unit. The air is then forced into the tank for a compressor unit. The material, that compressor blades are typically made out, is of lightly weight, yet strong. A compressor blade is generally made using an alloyed metal that is able to be machined to a precision angle and dimension. Sometimes, the blades are machined out of aluminum because of the material’s weight and ease of shaping[8].

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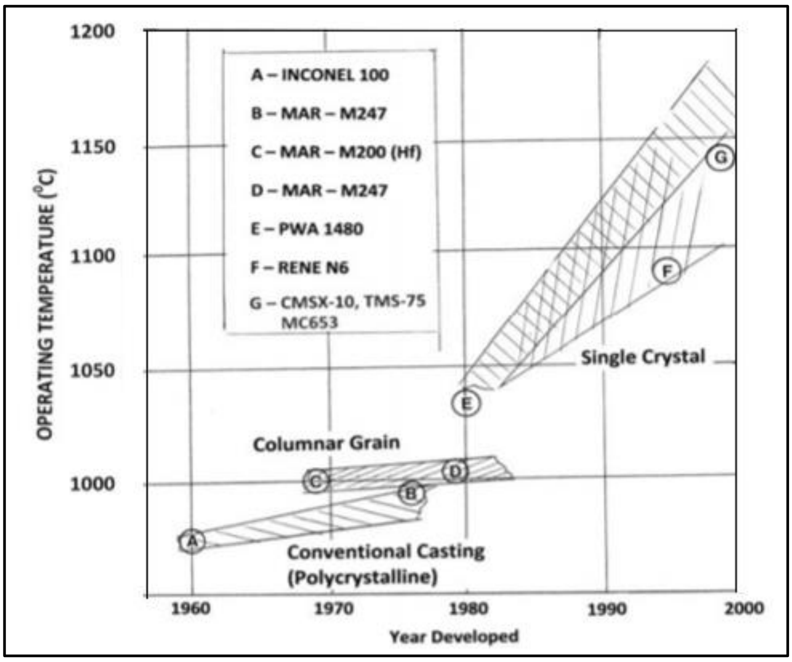

Figure3.Turbine blade Ni-base superalloy development examples[11]

Double-hatched region shows proposed regime projected into the twenty-firstcentury approaching1,200°C operating temperatures for high-performance gas-turbine operations.[11].Substantial increase in the high-cycle fatigue and corrosion fatigue strength are also achieved with this material, compared to Type AISI-403. Superior corrosion resistance is also achieved due to high concentrations of chromium and molybdenum in compressors.

Compressor blades corrosion is usually caused by moisture and salt ingested by the turbine to avoid, thus coating of compressor blades is also highly recommended. For small to intermediate gas turbine compressors, the temperature loadings experienced currently range from - 50 to about 500ºC [9]. In the short to medium term, the continued use of improved low-alloy and ferritic stainless steels will be adequate. This situation will continue until significant increases in compressor temperatures are needed because of much higher-pressure ratios and rotor speeds.

Table.1 Materials of Gas turbine engine components [12]

Name of the Component	Material	Remarks
Suction Fan	Titanium Alloys	Fracture against foreign objects and debris on rotating blades
Intermediate compressor	Titanium and Nickel Alloys(Inconel 625)	Experiences a very high pressure
Combustion chamber	Titanium and Nickel Alloys with ceramic coatings	Ability to withstand a very high temperature
Turbine blades	Titanium and single crystal castings of Nickel alloys with ceramic coatings	Must endure the intense of heat engine
Exhaust systems (Inner and Outer ducts)	Titanic Composite - synthetic fibers held together with resins	Resistant to very high temperature

ISSN:0971-1260
Vol-22-Issue-4-October-December-2019

This would, however, presents a significant increase in cost and manufacturing complexity (forgings, machining, joining, component lifting) as well as operational difficulties (component handling, overhaul, repair, cleaning) and may introduce additional problems associated with thermal mismatch and fretting fatigue from adjoining ferritic alloys. Consideration has also been given towards lightweight materials, such as aluminum matrix composites, polymer composite blading and vanes, as well as intermetallic Ti-Al-based alloys to provide reduced rotor and overall engine mass, and lower disc stresses to enable higher rotational speeds [10]. In addition, design and materials concepts have evaluated the application of integrally bladed discs (bliscs) based on steel, titanium or nickel alloy technology using friction welding.

5.0 Conclusions

Although the presented methodical approach to identification of reasons for failures of gas turbine blades during the process of the turbine operation ignores mechanical loads that occur during the turbine operation, it is sufficiently useful in case of engine defects when information of its operation conditions is incomplete. Nevertheless, although the metallographic examinations enable determination of the material microstructure in an unbiased, trustworthy and dependable manner, it is still a destructive examination method. That is why there is a need to develop a set of non-destructive diagnostic tests aimed at assessing technical condition of gas turbine blades when the machine is still in operation. Each of non-destructive diagnostic methods that have already been applied to diagnostics of technical structures features a specific performance and applicability to assessment of that condition. Therefore, a combination of these methods, aided by computer technologies and with application of artificial intelligence, offers supreme research opportunities, much wider than any of the single method. Such an examination program shall enable really unbiased, trustworthy and dependable assessment of actual condition demonstrated by gas turbine blades during the process of operationthereof against the three-threshold scale: applicability, partial (provisional) applicability and inapplicability. The land based industrial gas turbine industry has placed its own demands on materials, bringing in resistance to hot corrosion as an important requirement. Several SC superalloy compositions have been developed for aircraft gas turbines on one side and land based gas turbines on the other side. Partial γ' suctioning has been adopted in a number of SC IGT alloys to avoid incipient melting and control the extent of re-crystallisation.

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