The Academic
International Journal of Multidisciplinary Research

An Online Peer Reviewed / Refereed Journal
Volume 2 | Issue 8 | August 2024
ISSN: 2583-973X (Online)
Website: www.theacademic.in

Jet Engine – Modifications and Development

A.Garwol

Gdańsk University of Technology

ARTICLE DETAILS

Research Paper

Keywords:

Engine, Blades, Cooling, Solution, Concept, Development

ABSTRACT

The paper begins with the principle of operation of a typical turbine jet engine - which consists in obtaining energy through a chemical reaction of combustion of fuel dispersed in the air stream. Air enters the combustion chamber after prior compression in the compressor, and after combustion with fuel is used to drive the engine turbine. The main task of the engine turbine is to drive the compressor. It is the compressor that is the most critical part of the engine and due to its operation at high temperature and under high mechanical loads, it is the most critical element of the engine. In the following parts of the article, concepts of engine modification are presented, by adding a reduction gear and a heat exchanger for better cooling of the device. Then, the concept of cooling the blades of the rotating elements of the engine and the construction of the system that makes it possible are presented.

1. Introduction

The turbine jet engine is a thermal machine that is responsible for providing propulsion to an aircraft. Thanks to this, the aircraft can generate lift, allowing it to lift off the ground and fly. Its development and greatest development occurred in the first half of the twentieth century. At that time, many industries experienced significant technological progress, which was caused by the war. Aviation was not spared either. In this industry, especially towards the end of the war, work was carried out on increasing the use of turbine jet engines on the battlefield. Over time, this technology began to penetrate the civilian world - as is the case with many other tools and devices used by us in everyday life.

A turbine jet engine consists of an inlet part, a compressor, a combustion chamber, a turbine and an exhaust part of the engine. The diagram of its construction is shown in Fig. 1.

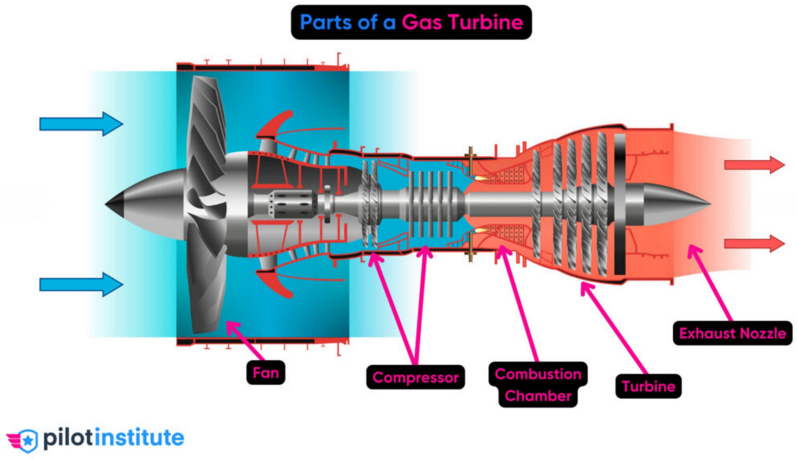

Fig.1 – Turbine jet engine's construction, Source [1]

The principle of its operation is to obtain energy from the dispersed fuel in the air stream. Air is sucked in by the engine via the inlet. Then the air pressure increases in the compressor. The compressed air then enters the combustion chamber, where it mixes with the fuel and is ignited. The fuel combustion reaction generates thrust. The heated air then enters the turbine blades. The turbine is an element whose main task is to drive the compressor. An afterburner may be located behind the turbine, whose task is to provide additional thrust. The afterburner is an optional element, especially used in military aviation. Additional thrust is obtained by injecting fuel into the heated air and igniting it due to the presence of high temperature.

The purpose of this article is to present the most critical parts of a turbine jet engine, with particular emphasis on the possibilities of improving their performance, which will allow the engine to achieve better performance.

2. Jet turbine engine development opportunities

Despite the development of turbine jet engines in the first half of the twentieth century, their continuous use in aviation generates the need for their continuous development.

This is particularly visible through the increasingly frequent efforts to reduce emissions of harmful greenhouse gases. This goal cannot be achieved otherwise than through the development of turbine jet engines used in aviation. It should not be forgotten that the development of the engine design itself should be combined with the development of fuel technology used in aviation. This issue, however, goes beyond the issues discussed in this paper.

2.1. The Geared Turbofan Engine Concept

In specific operating conditions of the engine fan, the rotor speed may decrease. In such conditions, it is necessary to increase the torque in order to maintain satisfactory efficiency of the entire rotor assembly. For this purpose, the shaft diameter must be increased, which increases the core size [2].

A solution to these problems may be to introduce a reduction gear system to separate the fan from the rest of the engine's low-pressure system [2]. The position of the reduction gear in the engine is shown in the diagram in Fig. 2

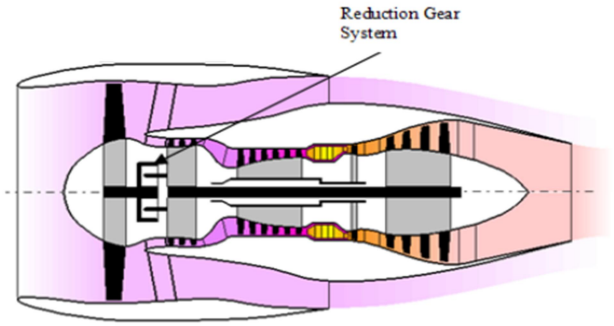

Fig. 2 – The Geared Turbofan Engine layout, Source [2]

2.2 The Intercooled Recuperated Aero-Engine Concept

One of the key parameters that determine the operation of a turbine jet engine is the temperature in the combustion chamber. The higher it is, the more thrust the engine can produce. However, raising the temperature in the combustion chamber generates effects in the form of increased emissions of harmful greenhouse gases into the atmosphere, which is also caused by the dependence of this parameter on the temperature of the engine compressor supply. Increasing the compression ratio above a certain value can pose a serious challenge to the last stages of the compressor, and in addition, the efficiency of the entire

compressor can deteriorate. Another unfavorable factor is the increase in the mass of the entire engine, in the case of increasing the compression ratio [2].

The solution to this problem may be to develop an engine equipped with a heat exchanger. The diagram of this solution, which was developed by MTU Aero Engines, is shown in Fig. 3.

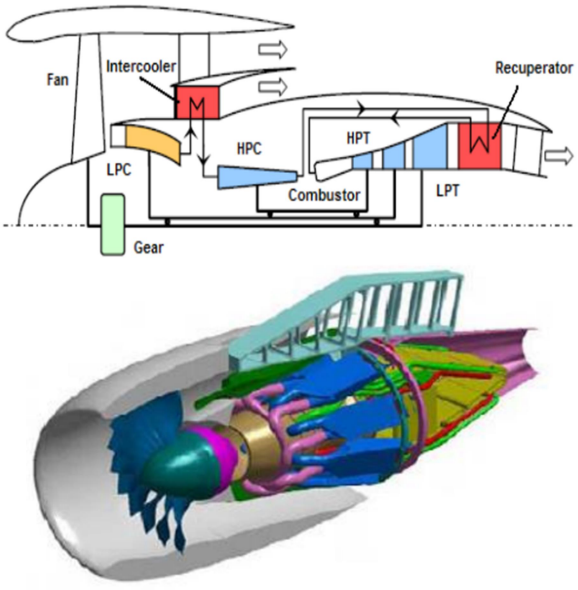

Fig.3 – Intercooled Recuperated Engine layout, Source [2]

The use of a heat exchanger in the engine design will save fuel, because part of the temperature needed for the correct operation of the combustion chamber is provided by the recovered heat energy at the combustion chamber inlet.

3. The importance and methods of cooling jet engine turbine blades for its performance

The solutions presented above are interference in the internal structure of a turbine jet engine.

The turbine is a critical element of a turbine jet engine. Its main task is to drive the compressor. In addition, it operates behind the combustion chamber, and therefore at a high temperature. Taking into account this temperature and high rotational speed, we get a component that must be able to withstand extremely high loads.

In order to reduce the thermal loads of the turbine, it is possible to cool the turbine blades. This solution allows to reduce the thermal loads of the blades.

The simplest solution is to cast turbine blades with internal coolant channels to increase heat exchange. These channels are modeled as short channels with different aspect ratios in the shape of a square or rectangle. The increase in heat exchange depends primarily on the geometry, flow angle, and Reynolds number of the flow. The element that conditions the air flow inside the blade are the so-called rib tabulators. One of their tasks is to disrupt the near-wall flow, which increases heat exchange[3]. The most common methods of cooling turbines are shown in Fig. 4.

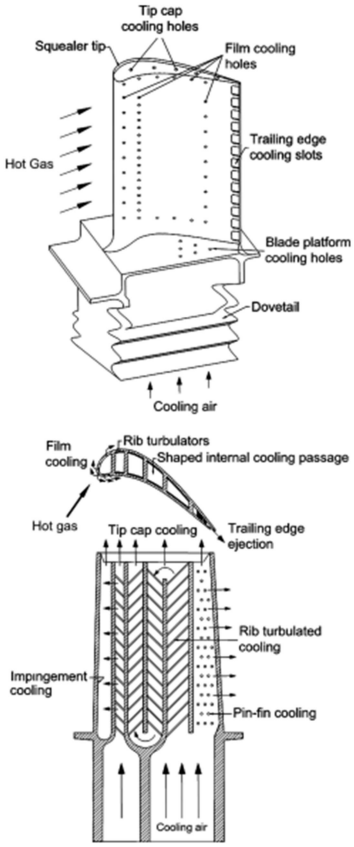

Fig. 4 – "The schematic of a modern gas turbine blade with common cooling techniques", Source [3]

In order to cool the blade elements, it is necessary to properly adapt the entire drive unit by implementing additional engine construction elements. The construction diagram of such a system is shown in Fig. 5

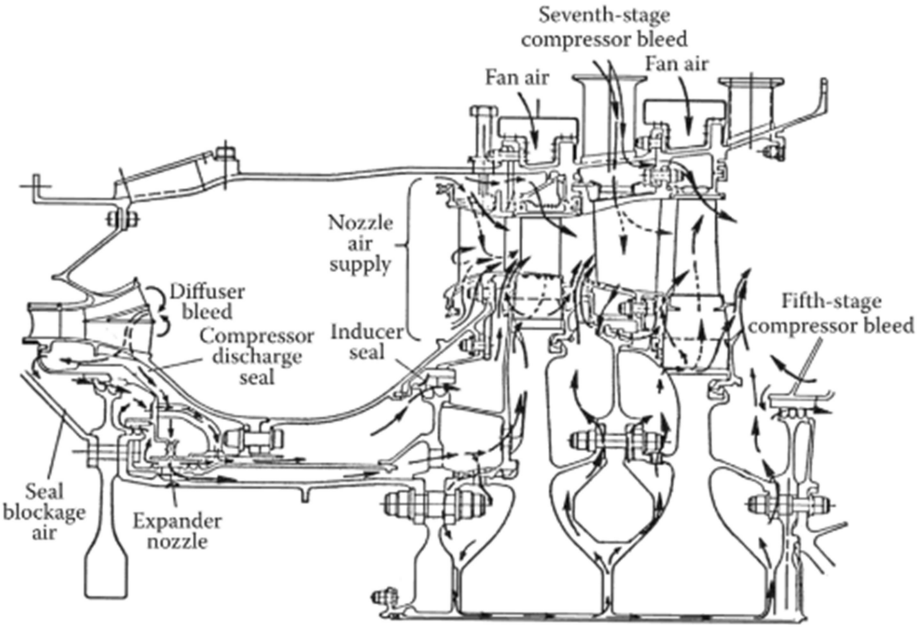

Fig.5 – Overall view of the rotor, stator and casing cooling supply system for E^3 engine, Source [4]

The diagram above shows that the first-stage nozzle is cooled by air taken from the internal and external cavities of the combustion chamber. The first-stage rotor is cooled by air taken from the center of the compressor diffuser. The cooling medium for the stage-2 nozzles comes from the Stage-7 compressor discharge. Moreover, the Stage-2 rotor cooling air is taken from the Stage-1 rotor inductor system

4. Conclusions and summary

The turbine jet engine, despite its seemingly simple structure, is a very complex element. This results from its task, which is to propel aircraft. On the one hand, the complexity of the structure is a disadvantage - because the production of the entire engine requires the involvement of a large number of specialists supported by machines. This feature can also be an advantage, because it is possible to apply many interesting technological solutions, the purpose of which is to increase the performance of this type of device.

The methods presented above, which are the application of new elements to the engine and cooling of the turbine blades, prove that it is possible to improve the working conditions of individual engine sections, and consequently it is possible to improve the performance of the entire engine. The presented

concept of the engine cooling system is very versatile, as it uses air that is waste from the operation of some engine components to cool other sections.

The presented paper is only a preliminary definition of the areas and methods in which it is possible to improve the capabilities of turbine jet engines. This article can be successfully used for an even deeper analysis of turbine jet engines as an extremely interesting device that can and should be successfully improved.

References

1. www.pilotinstitute.com "How Does a Jet Engine Work?" [Online] Available: https://pilotinstitute.com/jet-engine-explained/ [Accessed August 26, 2024]
2. Dewanji D., Rao A.G., van Buijtenen J.P. "Conceptual Study of Future Aero-Engine Concepts" *International Journal of Turbo and Jet Engines, 26,263276 (2009),* [Online] Available: https://www.researchgate.net/publication/258358336_Conceptual_Study_of_Future_Aero-Engine_Concepts [Accessed August 27, 2024]
3. Han J.Ch. „Recent Studies in Turbine Blade Cooling" [Online] Available: https://onlinelibrary.wiley.com/doi/pdf/10.1155/S1023621X04000442 [Accessed August 27, 2024]
4. Han J.Ch., Dutta S., Ekkad S. „Gas Turbine Heat Transfer and Cooling Technology - Second Edition" ISBN: 978-1-4398-5568-3, CRC Press