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Exergy Analysis of a PT6 Engines In Specific Temperature Of Cruise Process

The study was carried out with reference to ambient temperature of -27 ° C for the cruise line at the specified altitude. The engine in operation has been studied in the potential of improvement for each torque defined in reducing the non-reversibility due to entropy production. In the analyzes carried out, it was seen that the fuel consumption due to the produced torque decreased with the decrease in the fuel consumption.

1. Introduction

The engines belonging to the air vehicles are working on thermodynamic basis. Exergy is defined as the highest theoretical work that can be obtained from the system when a system becomes a thermodynamic equilibrium with the environment [1]. Many studies in the international literature reveal the necessity of exergy analysis as a thermodynamic modeling method. It is possible to determine the energy losses and their locations in the system by making an exergy based thermodynamic analysis. Thus, losses will be reduced and minimized. In addition, exergy analysis gives a clue as to whether the efficiency of the system during the design phase is realistic. [2], [3]

2. PT-6 Engine Technology

PT6 engine is a turboprop engine developed by Pratt Whitney from mid-1960’s. The PT6 turboprop engine is a lightweight turbine engine driving a propeller via two-stage reduction gearbox. Two major rotating assemblies compose the heart of the engine. The first is the compressor and gas generator turbine and the second, the two stage power turbines and power turbine shaft. The two rotors are not connected and rotate at different speeds and in opposite directions. This design is referred to as a “Free Power Turbine Engine” like given in Figur e 1. This configuration allows the pilot to vary the propeller speed independently of the compressor speed. [4]

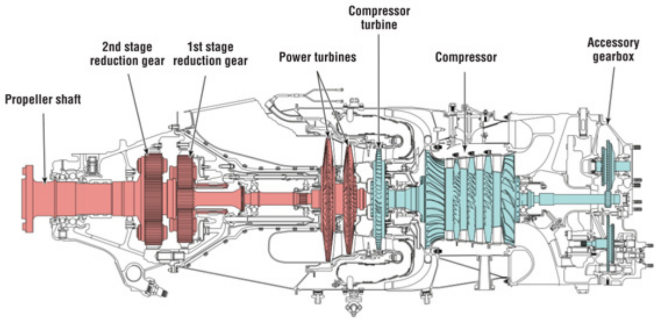

Fig.1 PT6 engine and prencipe shema [5]

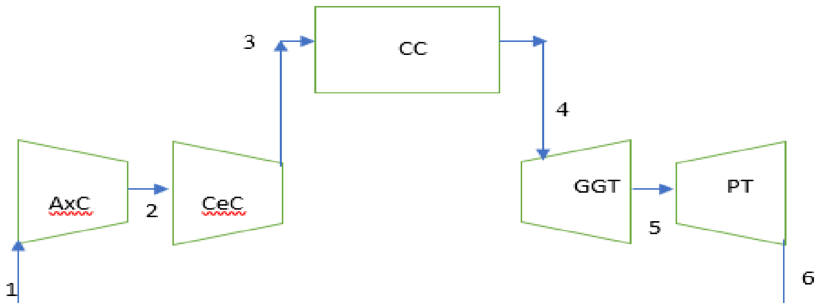

Fig.2 PT6 engine cycle

3. Exergy theory and analyses

Exergy; potential energy contained in a thermodynamic system is indicative of its usability according to any reference. Exergy is one of the indispensable calculation methods for useful performance measurement in aircraft engines. [6-9] In this study, equations used exergy analysis for all componenets are given belov as table 1.

Table 1

Exergy Exergetic balance of All Components

No	Name	Equation
1	Axial Compressor	$\sum \dot{E}x_{in,\,AxC} - \sum \dot{E}x_{out,\,AxC} = \sum \dot{E}x_{dest,\,AxC}$
2	Centrifugal Compressor	$\sum \dot{E}x_{in,\,CeC} - \sum \dot{E}x_{out,\,CeC} = \sum \dot{E}x_{dest,\,AxC}$

3	Combustion Chamber	$\sum \dot{E}x_{in,CC} - \sum \dot{E}x_{out,CC} = \sum \dot{E}x_{dest,CC}$
4	Gas Generator Turbine	$\sum \dot{E}x_{in,GGT} - \sum \dot{E}x_{out,GGT} = \sum \dot{E}x_{dest,GGT}$
5	Power Turbine	$\sum \dot{E}x_{in,PT} - \sum \dot{E}x_{out,PT} = \sum \dot{E}x_{dest,PT}$

4. Results and dıscussıons

In this study, The PT6 engine performance is examined with reference to cruise conditions. In this context, the temperature and pressure values defined for each point of reference motor are given in Table 3.

*Table 3.*PT6 Engine Thermodynamic Cycle Parameters

STATION NUMBER	m (kg/sn)	T (K)	P (kPa)
1	2.8	246	44,645
2	2.8	265	48,093
3	2.8	420	76,222
4	2.835	1385	76,222
5	2.835	931	51,236
6	2.835	892	49,089

Reference values are valid for cruise conditions only. In this process, the engine is most efficient as a fuel and a straight flight is carried out. Accordingly, the thermodynamic performance of the flight for each component is considered at each point. However, the basic assumptions for this process are listed below:

- The air and combustion gas flows in the engine are assumed to behave ideally
- The combustion reaction is complete Compressors and turbines are assumed to be adiabatic
- Dead state temperature and pressure values are 288 K and 101.3 kPa, respectively
- Energy and exergy analyses are performed for lower heating value (LHV) of kerosene (JET A1) which is accepted as 42,800 kJ/ kg
- Engine accessories, pumps (fuel, oil and hydraulic) are not included in the analysis
- The kinetic and potential exergies are neglected

• The total airflow mass is 5.5 kg/s that includes at ambient temperature of 288 K and ambient pressure of 101.3 kPa.

• In gas turbine engines, a part of compressed air is extracted to use for ancillary purposes, such as cooling, sealing and thrust balancing. And the cooling airflow is neglected since it doesn't have meaningful effect on energy and exergy analyses.

In the basic analyzes, the average exergy efficiency for the adiabatic conditions of the engine compared to the cruise performance was found to be 24.16% for 2660 kW. In this context, the exergy rates for each point of the engine are given in Figure 3.

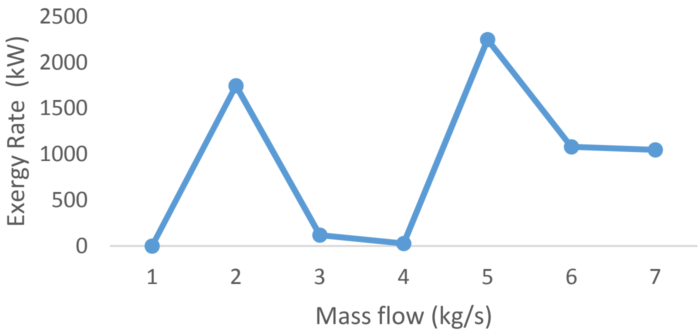

Fig.3 Exergy rate of the components

In the analyzes, the highest exergy rate for dade state conditions was found as 2249.3 kW and 1080.9 kW respectively at the inlet and outlet of the turbine. In the analyzes, the components of each component were analyzed separately and their performance effects were examined. Component efficiency are given in Figure 4.

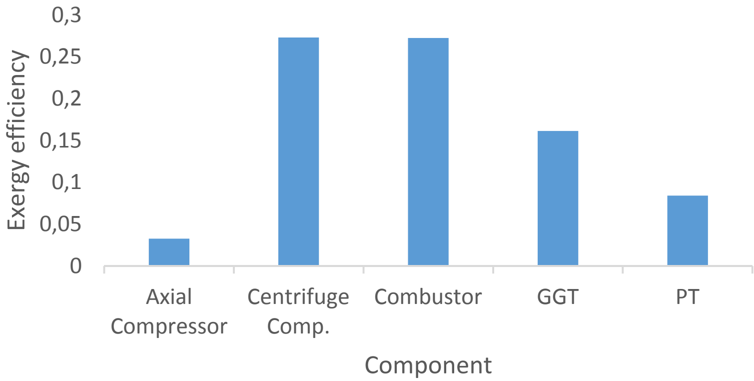

Fig. 4 Exergy efficiency of the components

The highest exergy yield was found as 27.29% in the centrifugal compressor. Total exergy destruction was found as 4413 kW. In this respect, it is important to make an assessment of the loss analysis in the engine. In particular, the basic evaluation of loss analysis is the improwement potential of engine performance. Analyzes which are considered as improvement potential in this respect should be seen as target ratios for design processes in the engine.

5. Conclussions

Aircraft engines vary greatly in performance for different temperatures under different altitude conditions. In particular, the power produced by the altitude depends on the condition of the atmospheric conditions it is in. In this context, especially cruise performance is an important part of flight processes and important parameters can be reached with performance analysis.

In this study, performance of atmospheric conditions based on cruise conditions, in which a turboprop motor for 6400 meter (21000 Ft) was observed, was examined by energy and exergy analysis. Total exergy efficiency was found to be 24.16%. This study should be supported with exergo-economic and exergo-enviromental analysis.

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