Task 6 - OLVHN

Meisel, Carlos Juarez, Albert Quintero, Osvaldo

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1 Overview

This report contains the results and summary of the 12 step process described in Dr. Cizmas notes for computing the Operating Line. Also included in this report is the engine performance vartiatio with wheel speed, altitude and aircraft speed.

2 Methodology for Computing the Operating Line

As we determine the Operating Line of our engine, we first define our operating parameters:

$$\dot{m}_{air} = 1.64089 \left[\frac{kg}{s}\right] \tag{1}$$

$$w_{c_n} = 283.91025 \left[\frac{kJ}{kg}\right] \tag{2}$$

$$\eta_{compressor_n} = 0.90 \tag{3}$$

$$\sigma_{comb} = 0.90 \tag{4}$$

$$\eta_{turbine} = 0.94 \tag{5}$$

$$\pi_{c_n} = 9.2 \tag{6}$$

$$\lambda = 2.85377 \tag{7}$$

$$T^*_{1_n} = 288.16[K] \tag{8}$$

$$T^*_{3_n} = 1410[K] \tag{9}$$

$$p^*_{1_n} = 1.01325[bar] \tag{10}$$

$$p^*_{3_n} = 9.042243[bar] \tag{11}$$

$$h^*_{3_n} = 1574.3477 \left[\frac{kJ}{kg}\right] \tag{12}$$

$$N_n = 52612.464822[rpm] \tag{13}$$

$$\pi_D = 0.99 \tag{14}$$

$$\gamma_g = 1.2804 \tag{15}$$

1. Calculate the compressor work w_c, given an angular speed calculated in Task2, as a function of nominal compressor work and nominal angular speed.

$$w_c = w_{c_n} \left(\frac{N}{N_n}\right)^x \tag{16}$$

Usually $x \in [1.9, 2.1]$, for convience we will start with $x = 2$.

Note:

$$N = 1.1N_r \tag{17}$$

Recall when at nominal conditions:

$$N_r = \frac{N_n}{1.05} \tag{18}$$

2. Estimate the compressor efficiency η_c, given an angular speed calculated in Task2, as a function of nominal compressor efficiency and nominal angular speed. We start by calculated the pressure ratio π_c^*

$$\pi_c^* = \left[\left(\pi_{c_n}^{\frac{\gamma-1}{\gamma}}\right)\frac{\eta_c}{\eta_{c_n}}\left(\frac{N}{N_n}\right)^x + 1\right]^{\frac{\gamma}{\gamma-1}} \tag{19}$$

To begin the caluation we can start by assuming $\eta_c = \eta_{c_n}$. Once the pressure ratio is calculated, read that π_c^* from the compressor map, and find the corresponding $\dot{m}\frac{\sqrt{T_1^*}}{p_1^*}$. Once you have that, find the corresponding η_c from the compressor map. If $\eta_c \neq \eta_{c_n}$ then iterate until the change is less than a allowed tolerance. For our engine, we allowed a tolerance of 0.01.

3. Calculate the T_3^* from:

$$\pi_c^* = \frac{1+f}{\sigma_{comb}}\left(\frac{p_3^*}{\dot{m}\sqrt{T_3^*}}\right)_n \sqrt{\frac{T_3^*}{T_1^*}}\frac{\dot{m}\sqrt{T_1^*}}{p_1^*} \tag{20}$$

Where:

$$\frac{1+f}{\sigma_{comb}}\left(\frac{p_3^*}{\dot{m}\sqrt{T_3^*}}\right)_n = constant \tag{21}$$

From here, calculate h_3^* from:

$$h_3^* = \left(\frac{1+minL}{1+\lambda minL}\right)h_{\lambda=1} + \left(\frac{(\lambda-1)minL}{1+\lambda minL}\right)h_{air} \tag{22}$$

Where:

- h_λ - enthalpy of the combustion products for λ excess air
- $h_{\lambda=1}$ - enthalpy of the combustion products for stoichiometric combustion
- h_{air} - enthalpy of the air

Check to see if the ratio $\frac{w_c}{h_3^*}$ is equal to the nominal ratio $\frac{w_{cn}}{h_{3_n}^*}$. If not, iterate x until it is, within a reasonable tolerance of about 1%.

4. We are now to find the critical conditions by:

$$\pi_{c_{cr}}^* = \frac{1}{\sigma_{comb}\pi_D}\left[\frac{\frac{\gamma_g+1}{2}}{1-\frac{w_c}{h_3^*}\frac{1}{\eta_{turbine}}}\right]^{\frac{\gamma_g}{\gamma_g-1}} \tag{23}$$

$$N_{cr} = N_n\sqrt{\frac{\eta_{c_n}}{\eta_{c_{cr}}}\frac{\pi_{c_{cr}}^{\frac{\gamma-1}{\gamma}}-1}{\pi_{c_n}^{\frac{\gamma-1}{\gamma}}-1}} \tag{24}$$