Wrocław University of Science and Technology

CFD Simulations of Power Generation Units

Title

**Parameterization of the work using Matlab/Octave.**

Wrocław 2024

**Introduction**

The aim of the course is to create a thermodynamic model of an energy installation, to determine the parameters of the working gas at characteristic points and to determine the efficiency of the cycle. Data on the operation and efficiency of individual components of the installation will be determined by means of three-dimensional CFD (computational fluid dynamics) calculations and included in the main model. The basis for completing the course is five partial reports presenting the analysis of the operation of: pipelines, heat exchangers, pumps, heat sources, compressors / expanders and the final report on the analysis of the operation of the entire system. Tools used during the course:

- Matlab or Octave
- Ansys software
  - Workbench
  - SpaceClaim
  - Ansys Meshing
  - Ansys Fluent or CFX
- MS Excel
- MS Word or Overleaf

**Software access:**

One of the software sources available to students is the Platon platform (registration required):

https://cloud.pionier.net.pl/

An alternative to commercial Matlab is the free Octave:

https://www.gnu.org/software/octave/

Ansys CFD computer fluid dynamics calculation package is available in the educational version on the
manufacturer's website:

https://www.ansys.com/academic/free-student-products

Sample exercises on the basic use of Ansys are available at:

Instructions to the course Numerical calculations

Instructions to the course Selected problems of thermal-flow processes

Matlab course:

Instructions to the course Pakiety obliczeniowe (includes Matlab)

**Energy installation model**

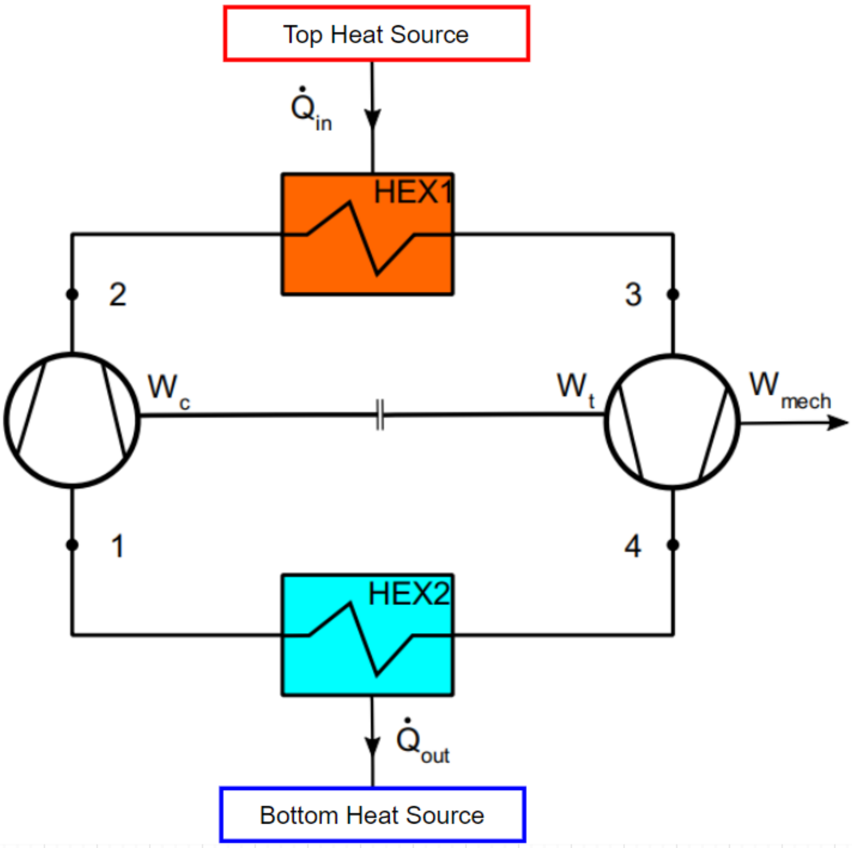


Fig. 1 Schematic diagram of the installation implementing the closed Brayton cycle.

**Tasks**

1. Specify the input parameters for the model:

   - Type of working gas and its mass flow.
   - Temperature T1 and circuit initial pressure p1.
   - Pressure ratio of compressors and turbines (expanders).
   - Gas temperature downstream of the HEX1 (T3).

2. Calculate the thermodynamic parameters at characteristic points in the cycle.

3. Calculate the power output from the system, the amount of heat supplied and received, and the thermodynamic efficiency of the cycle. Assume that the efficiency of all system components is 100% and treat the working medium as an ideal gas.

4. Plot the efficiency and output power characteristics (see Fig.2) from the system as a function of:

   - Assumed pressure ratio
   - Turbine inlet temperature

- Mass flowrate of a working fluid.

5. Modify the model code to draw the plane as a function of two variables: pressure and temperature T_3 - use the function *meshgrid* i *surf*.

   - Efficiency
   - Net power

6. For the selected set of parameters, try to find the actual machines, devices and accessories that can meet the design assumptions in the manufacturers' catalogs. Try to select the upper and lower heat source and determine the dimensions of the entire installation. Save catalogs and data in a separate file and paste to the report.

**Sample program code in the Matlab/Octave environment**

```
clc
clear all
close all
%% Initialization
m_air = 1; %Air mass flow, kg/s
cp_air = 1.006; %Specific heat, kJ/kg/K
k = 1.4; %Adiabate exponent
T_1 = 293; %Temp. in point 1, K
p_1 = 1013e2; %Pressure at point 1, Pa
T_3 = 900; %Temp. in front of turbine, K
sprezC = 6; %compressor pressure, -
sprezT = sprezC; %turbine pressure, -
etaC = 1.0; %Compressor efficiency, -
etaT = 1.0; %Turbine efficiency, -
%% Compressor Calculations
i_1 = T_1 * cp_air; %Enthalpy, kJ/kg/K
p_2 = p_1 * sprezC;
T_2s = T_1 * (p_2./p_1).^( (k-1)/k );
i_2s = T_2s * cp_air;
i_2 = i_2s / etaC;
T_2 = i_2 / cp_air;
Wc = m_air * (i_2-i_1); %Compressor power, W
%% Exchanger Calculations 1
p_3 = p_2;
Q_in = m_air * cp_air * (T_3-T_2); %Heat supplied, kW
%% Turbine calculations
i_3 = T_3 * cp_air; %Enthalpy, kJ/kg/K
p_4 = p_3 * 1/sprezT;
T_4s = T_3 * (p_4./p_3).^( (k-1)/k );
i_4s = T_4s * cp_air;
i_4 = i_4s / etaT;
T_4 = i_4 / cp_air;
Wt = -m_air * (i_4-i_3); %Turbine power, kW
%% Exchanger Calculation 2
p_4 = p_1;
Q_out = -m_air * cp_air * (T_1-T_4); %Heat received, kW
%% Results
eta = (Wt-Wc)./ (Q_in);
fprintf('Circulation efficiency: %3.3f \n Compressor power: %3.2f kW \n
    Heat supplied: %3.2f kW \n Turbine power: %3.2f kW \n',eta,Wc,Q_in,
    Wt);
```

Listing 1: Sample program code

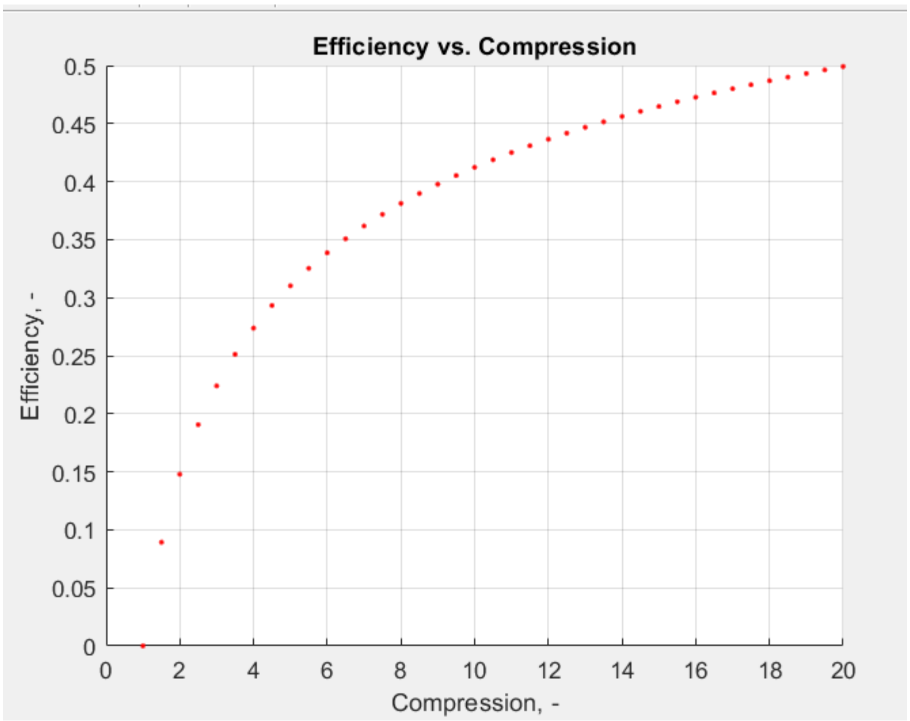


Fig. 2 Example 1

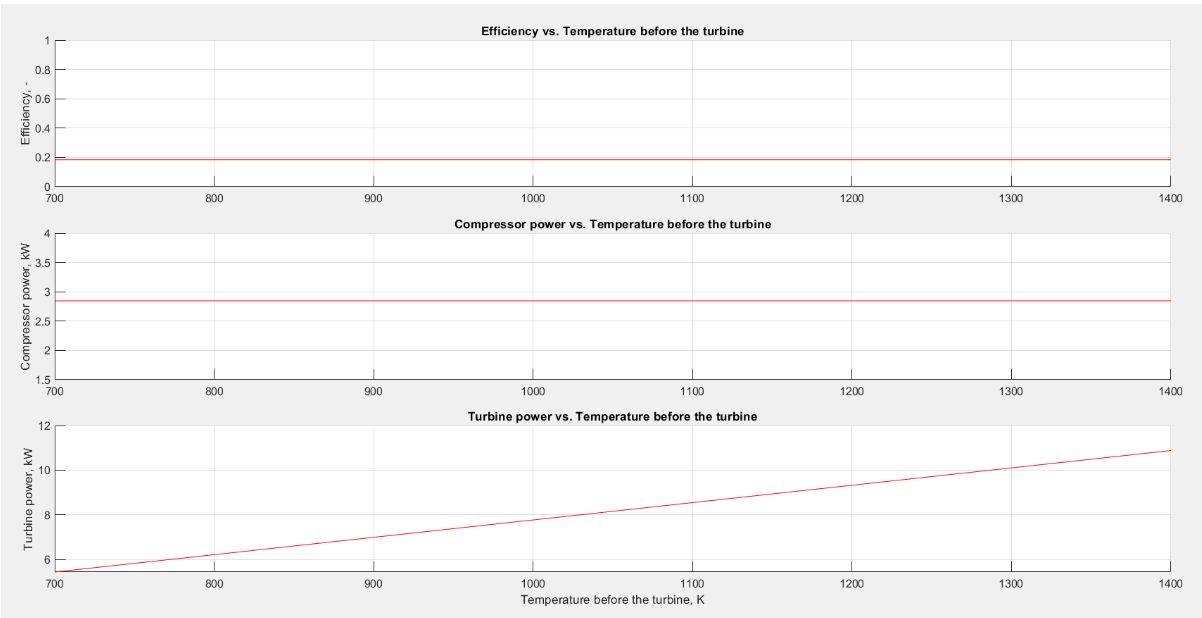


Fig. 3 Example 2

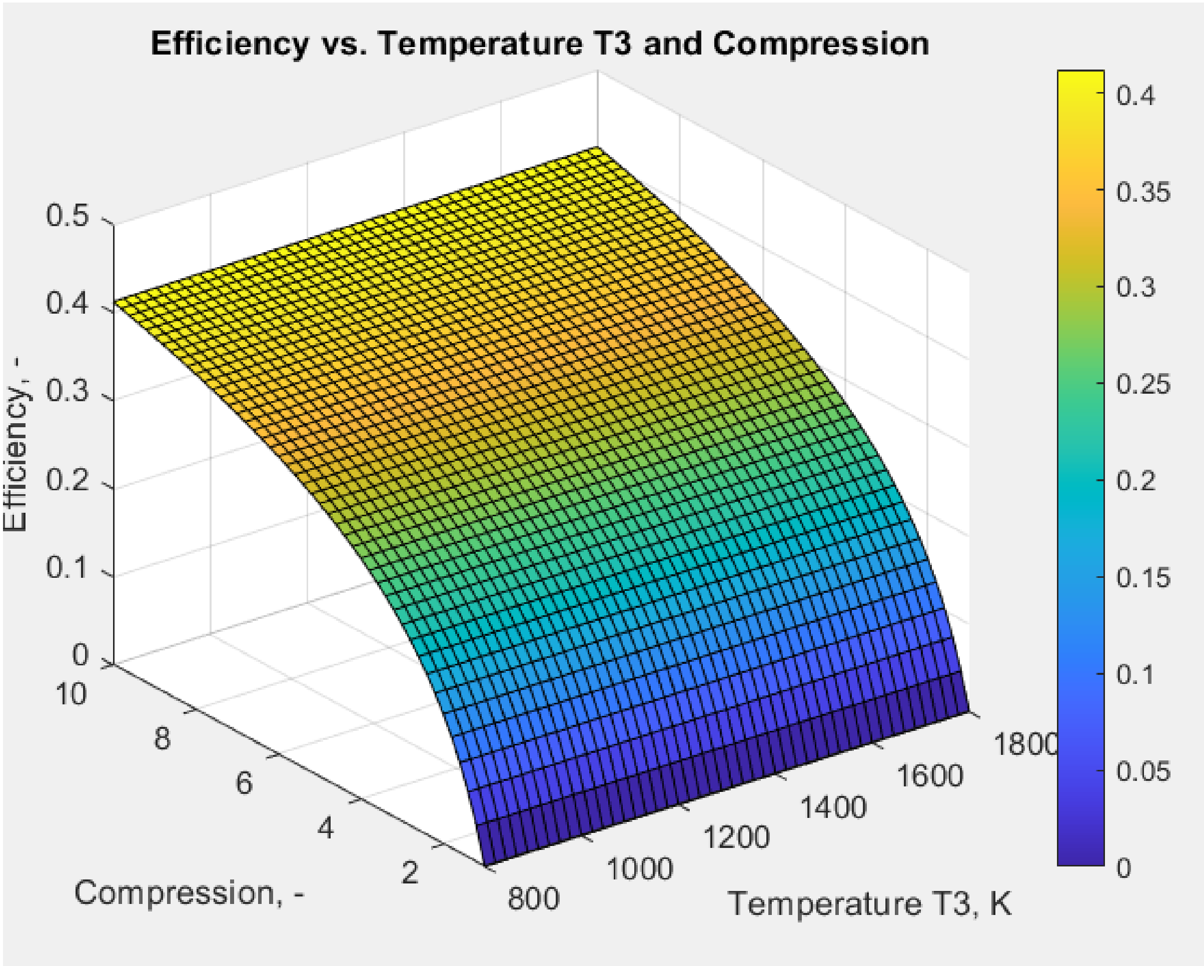


Fig. 4 Example 3