Power Cycle Components/Processes Ideal vs Real Operation Analysis

An Online Continuing Education Course for Engineers

Course Number: M-2061

Credit: 2 Hours / 2 PDH / 2 CPD

Power Cycle Components/Processes Ideal vs Real Operation Analysis

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Course Description

The power cycle components/processes (compression, combustion and expansion) are presented in this two hour course. In the presented power cycle components/processes analysis, air is used as the working fluid.

For compression and expansion, the technical performance of mentioned power cycle components/processes for ideal and real operation is presented with a given relationship between pressure and temperature and compression and expansion efficiency.

Complete combustion with and without heat loss is presented. Six different fuels (carbon, hydrogen, sulfur, coal, oil and gas) react with air as the oxidant at different stoichiometry values (stoichiometry => 1) and oxidant inlet temperature values.

Reactants and combustion products specific enthalpy values change with an increase in the temperature and such specific enthalpy values are presented in a plot where one can notice the flame temperature definition. Physical properties of basic combustion reactants and products species are presented in an enthalpy vs temperature plot.

The combustion technical performance at stoichiometry => 1 conditions is presented knowing the specific enthalpy values for combustion reactants and products, given as a function of temperature. Combustion products composition on both weight and mole basis is given in tabular form and plotted in a few figures. Also, flame temperature, oxidant to fuel ratio and fuel higher heating value (HHV) are presented in tabular form and plotted in a few figures. The provided output data and plots allow one to determine the major combustion performance laws and trends.

In this course, the student gets familiar with the power cycle components/processes, their T - s and h - T diagrams, ideal and real operation and major performance trends.

Performance Objectives

At the conclusion of this course, the student will:

- Understand basic energy conversion engineering assumptions and equations
- Know basic elements of the compression, combustion and expansion processes and their T - s and h - T diagrams
- Be familiar with the compression, complete and stoichiometry => 1 conditions combustion of carbon, hydrogen, sulfur, coal, oil and gas, with and without heat loss, with standard air as the oxidant, combustion products composition on both weight and mole basis, flame temperature, stoichiometric oxidant to fuel ratio, fuel higher heating value and expansion
- Understand general compression, combustion and expansion performance trends

Introduction

Most power and propulsion devices can be considered to comprise a number of simple processes. The most common are: expansion, chemical reactions including combustion of fuels and expansion.

In applications such as power plants, compressed air installations, gas pipelines and liquefaction plants, compression usually starts at approximately environmental temperature. In refrigeration plants and heat pumps, compression processes start at temperatures lower than the ambient temperature, but usually end above it.

Furthermore, whenever a gas needs to be stored and or transported, compression needs to be carried out.

Combustion is a process of active oxidation of combustible compounds such as: carbon, hydrogen and sulfur. High amount of heat released during the combustion process is used to provide work and/or power.

In addition to knowing the reactants and combustion products physical properties, for any kind of combustion analysis and calculations, it is important to know both oxidant and fuel compositions. As a result, one can calculate and analyze combustion products composition on both weight and mole basis, flame temperature, stoichiometric oxidant to fuel ratio and fuel higher heating value (HHV).

Today, global warming is becoming more evident and it is being said that it is primarily caused by CO_2 emissions. A detailed combustion analysis can be very useful in determining different fuel and technology scenarios that would result in the reduction of current CO_2 emissions.

In power plants, expansion generally occurs at temperatures above the environmental temperature. Except for throttling, the purpose of an expansion process is to deliver power at the expense of a reduction in the energy of the stream of the working fluid. Most common expanders are rotodynamic and are usually treated as adiabatic. Expansion can occur as a single or a multi-stage expansion process.

Compression

This section provides a compression analysis when the working fluid is air.

Analysis

In the presented compression analysis, only air is considered as the working fluid behaving as a perfect gas -- specific heat has a constant value. Ideal gas state equation is valid -- pv = RT.

Air enters a compressor at point 1 and it exits the compressor at point 2.

Figure 1 presents a compression schematic layout.

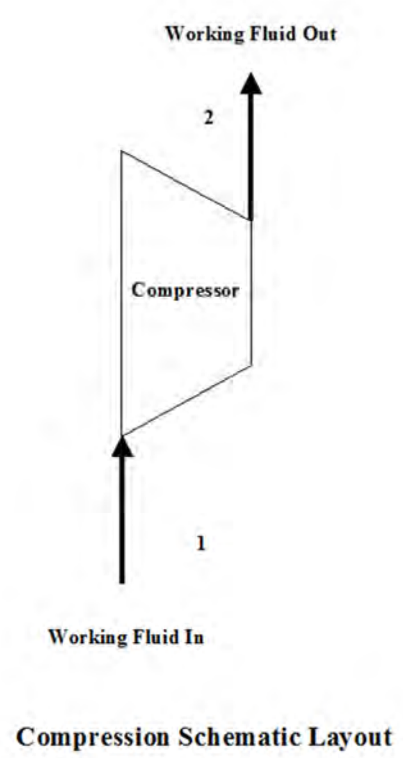

Figure 1 - Compression Schematic Layout

Figure 2 presents a compression temperature vs. entropy diagram.

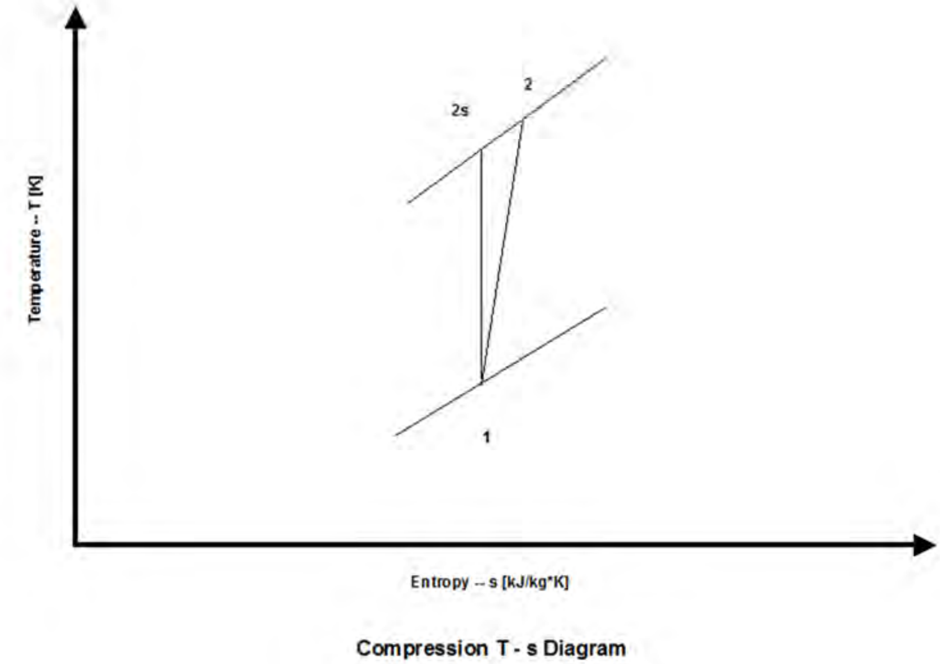

Figure 2 - Compression Temperature vs Entropy Diagram

Figure 3 presents compression specific power input requirements for a few typical compression ratio values. It should be noted that the air enters the compressor at standard ambient conditions of 298 [K] and 1 [atm] of absolute pressure.

Compression Specific Power Input

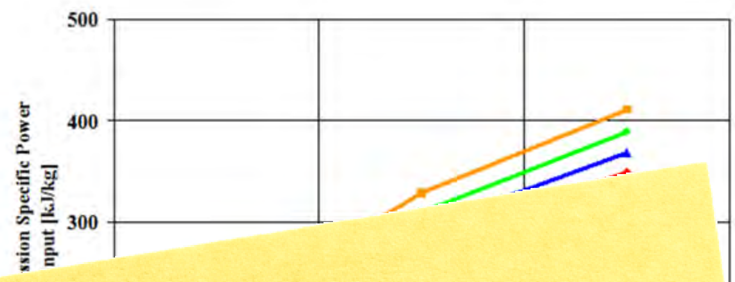

Figure 4 presents co tio value and a few different working fluid value.