



Advanced Power Cycle Components/Processes Analysis

An Online Continuing Education Course for Engineers

Course Number: M-3058

Credit: 3 Hours / 3 PDH / 3 CPD

Advanced Power Cycle Components/Processes Analysis

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Course Description

The ideal power cycle components/processes (compression, combustion and expansion) are presented in this three hour course.

When dealing with power cycle components/processes (compression and expansion), air, argon, helium and nitrogen are used as the working fluid.

When dealing with combustion, six different fuels (carbon, hydrogen, sulfur, coal, oil and gas) react with air and oxygen enriched air as the oxidant at different stoichiometry values (stoichiometry \Rightarrow 1) and oxidant inlet temperature values.

For compression and expansion, the technical performance of mentioned power cycle components/processes is presented with a given relationship between pressure and temperature. While for combustion, the technical performance at stoichiometry \Rightarrow 1 conditions and is presented knowing the specific enthalpy values for combustion reactants and products, given as a function of temperature. This course provides the compression and expansion T - s diagrams and their major performance trends plotted in a few figures as a function of compression and expansion pressure ratio and working fluid mass flow rate. For each combustion case considered, combustion products composition on both weight and mole basis is given in tabular form and plotted in a few figures. Also, flame temperature, stoichiometric 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 ideal power cycle components/processes and their T - s and h - T diagrams, 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, p - V and h - T diagrams
- Be familiar with the compression, complete and adiabatic combustion of carbon, hydrogen, sulfur, coal, oil and gas, with no heat loss, with air and oxygen enriched air as the oxidant, combustion products composition on both weight and mole basis, flame temperature, oxidant to fuel ratio, fuel higher heating value (HHV) 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 CO₂ emissions. A detailed combustion analysis can be very useful in determining different fuel and technology scenarios that would result in the reduction of current CO₂ 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 an isentropic compression analysis when air, argon, helium and nitrogen are considered as the working fluid.

Analysis

In the presented compression analysis, air, argon, helium and nitrogen are considered as the working fluid behaving as a perfect gas -- specific heat has a constant value. Ideal gas state equation is valid -- $p v = R T$.

Working fluid enters a compressor at point 1 and it exits the compressor at point 2. Isentropic compression is considered with no entropy change.

Figure 1 presents a compression schematic layout.

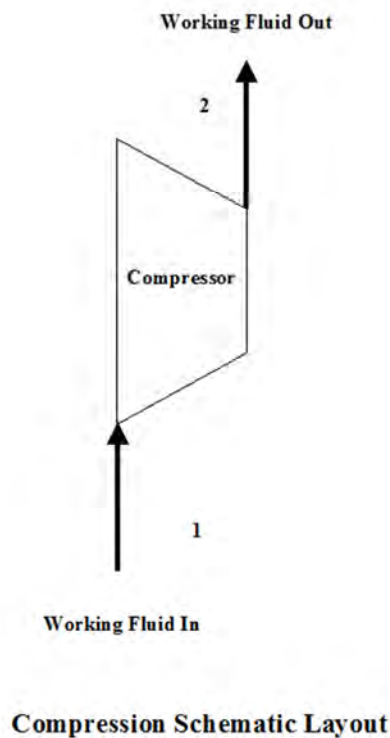


Figure 1 - Compression Schematic Layout

Figure 2 presents a compression temperature vs entropy diagram.

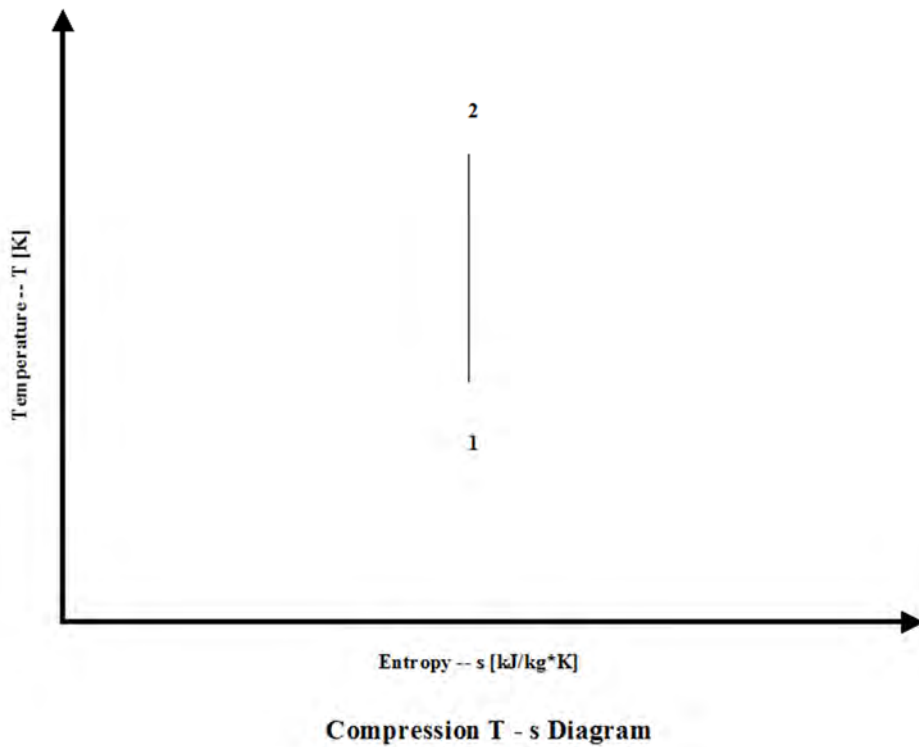
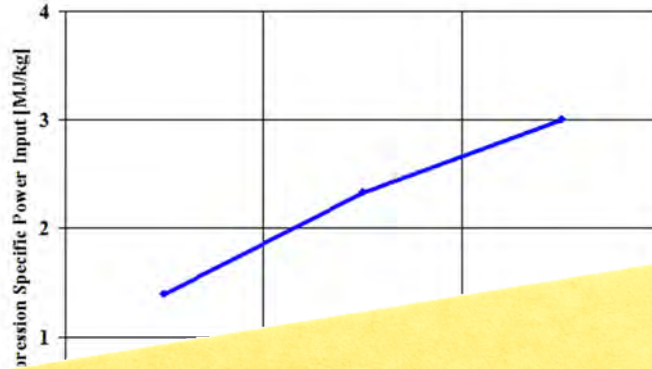


Figure 2 - Compression Temperature vs Entropy Diagram

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

Compression Specific Power Input



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Figure 4 presents few different worki

ratio value and a