Dissociating Gases as Working Fluids for Power Cycles

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Introduction

From a strictly thermodynamic point of view all fluids regardless of their state of aggregation, can be employed in perfect power cycles, i.e., in power cycles yielding the maximum theoretical efficiency.

However, if only comparatively simple cycles are considered, making reference to the actual thermodynamic processes which can be realized by the ordinary dynamic and static components, some important differences between the various classes of fluids become evident. A first step in the transition from ideal to actual cycles is to take into account only constant pressure and adiabatic processes (or, exceptionally, constant volume processes), neglecting other processes, such as the isothermal expansion of gases, expansions or compressions with heat addition or subtraction, which are not within the capability of ordinary equipment. When this is done, it is no longer possible, in general, to obtain, from actual working fluids, the performance of a Carnot cycle.

Rankine cycles with superheating and Brayton cycles cannot reach the theoretical maximum performance even if realized by means of perfect engines and heat exchangers.

A second step is the introduction of actual engines' efficiencies and temperature differences in heat transfer equipment. It

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is known that the transition from ideal to actual component efficiencies penalizes, in a different degree, the different kinds of cycles, Brayton cycles exhibiting, for example, the largest efficiency drop owing to turbomachinery irreversibilities. Brayton cycles performance, which is satisfactory under ideal assumptions, becomes deceivingly low, when actual components' behaviour is considered. Rankine cycles, on the other hand, maintain a good efficiency level even when engines losses are taken into account.

The basic reason for the severe efficiency drop in real Brayton cycles in comparison with the ideal case is the large compression plus expansion work with respect to the net output. As the departure of the average compression temperature from the average expansion temperature increases (owing to an increased turbine inlet temperature or to a reduced compressor inlet temperature) the performance difference between real and ideal cycles becomes less marked and the thermodynamic "quality" of Brayton cycles approaches that of Rankine cycles. This happens, however, only at very high turbine inlet temperatures. In perfect gas cycles the action on the temperature is the only instrument to control specific volumes and, then, turbomachinery work. In Rankine cycles vaporization and condensation processes secure a much more effective tool for specific volume dilatation and contraction without the need to resort to large temperature variations. In dissociating gas cycles an additional parameter is available for specific volume and work control: the average molecular weight or the degree of molecular association. The contraction of specific volume due to molecular recombination