# Stagnation and Static Property Correlations for Equilibrium Flows

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## 1. INTRODUCTION & OBJECTIVE

The stagnation and static property relations for calorically perfect gases can be derived analytically [1]. Similarly, for thermally perfect gases where specific heat varies with temperature, the analytical derivation of relationship between stagnation and static properties have been worked out by Zebbiche [2]. All the earlier studies considered a single non-dissociating gas. The aim of this work is the numerical development of stagnation-static property correlations for gaseous phase equilibrium flows where both specific heats and compositions vary with temperature.

Equilibrium flows are often encountered in rocket engines, where combustion products remain in equilibrium as they undergo expansion. The practical application of the study is hence linked to rocket engines and in particular liquid engines, which use a liquid fuel along with a liquid oxidizer.

The stagnation-static correlations are established for a variety of fuel-oxidizer combination and the effect of varying mixture ratio and chamber (stagnation) pressure is studied.

## 2. METHODS OF ANALYSIS

The principle of Gibbs free energy minimization subject to constraint of mass conservation is used to compute equilibrium compositions and properties. The method of analysis is loosely based on the work of Gordon and McBride [3] with the exception that a newly developed method called Element Potential Method [4]; [5] has been incorporated here. The inclusion of Element Potential Method utilizes lesser memory than the method of Gordon and McBride [3].

The values of equilibrium compositions and properties are hence generated at different values of pressure at fixed entropy. This value of entropy physically corresponds to the entropy of combustion products in the chamber of rocket engine. The ratios of stagnation and static properties are finally computed.

## 2. RESULTS & HIGHLIGHTS OF IMPORTANT POINTS

For the LOX/LH2 bi-propellant system, stagnation to static ratio of temperature and pressure are plotted against Mach number in Fig. 1 and Fig. 2, respectively. The effect of varying mixture ratio on the stagnation to static ratios is clearly evident from the figures and MR=8 line (shown in cyan) stands as a critical limit. Unlike single non-dissociating gases, where the relationship between stagnation to static properties depend only on Mach number and specific heat ratio, the equilibrium flows also depend on other parameters, namely mixture ratio and stagnation pressure. However, the specific heat ratio in equilibrium flows is decided by mixture ratio and stagnation pressure, and as a result stagnation to static ratio depends on Mach number, mixture ratio and stagnation pressure.

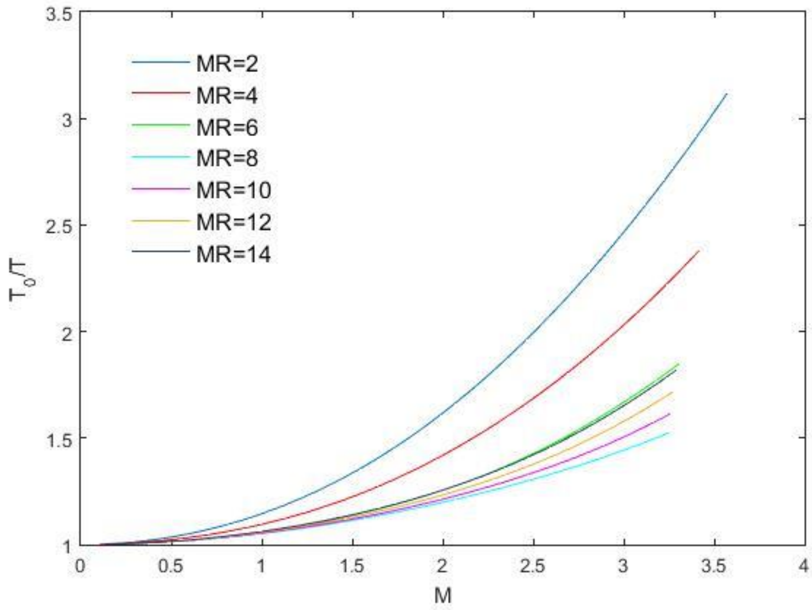


Figure 1 Ratio of stagnation to static temperature vs. Mach number at fixed chamber pressure of 10 MPa and varying mixture ratio

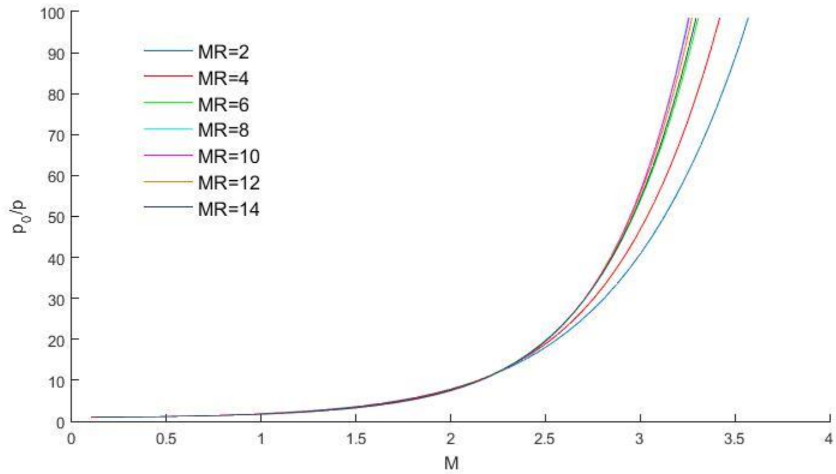


Figure 2 Ratio of stagnation to static pressure vs. Mach number at fixed chamber pressure of 10 MPa and varying mixture ratio

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