Experimental Validation of CO_2 Radiation Simulations

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I. Introduction

Spacecraft entering planetary atmospheres at high velocities will experience significant levels of radiative heating. In recent years, a number of studies have been performed to determine the vehicle and mission requirements that would enable the human exploration of Mars [1-4]. High-mass crewed Mars vehicles would be larger than previously-flown unmanned robotic spacecraft and would experience higher levels of radiative heating. Design of the vehicle heatshield and other components of the entry vehicle will require an accurate assessment of the radiative emission in the shock layer.

The atmosphere of Mars is composed of primarily carbon dioxide (CO_2) and a small percentage of diatomic nitrogen. When the temperature in the shock layer is high, the primary radiators are CN and carbon monoxide (CO) [5]. At moderate temperatures of 3000-4000 K, the primary radiating species will be CO_2. Radiation from CO_2 will also be dominant in the base region of a Mars entry vehicle. Computation of radiative spectra and radiative heating rates are typically generated using detailed radiation codes, such as the NEQAIR line-by-line radiation code [6]. The spectroscopic databases and physical models used by radiation codes must be validated against experimental data to ensure solution accuracy. In this paper, results from NEQAIR will be compared against experimental data in either pure CO_2 or CO_2 gas mixtures.

II. Experimental Data

Experimental data in pure CO_2 and CO_2 gas mixtures has largely been measured at low-to-moderate temperatures but is still useful for code validation. For example, Modest and Bharadwai measured transmittance in a 50% CO2, 50% N2 gas mixture at the Penn State drop-tube facility [7] at temperatures ranging from 300 and 1550 K. Transmittance is defined by the following equation:

$$\tau = e^{-\alpha x} \qquad (1)$$

In Eq. (1), α is the volumetric absorption coefficient and x is the path length. Measurements were taken for path lengths of 10 and 20 cm. Preliminary results for the 2300 and 3600 cm^{-1} band systems as a function of wavenumber are shown in Fig. 1. The NEQAIR results are based on the HITRAN96 CO_2 line database [8] and there is generally good agreement between the experimental and computational values between 2200-2400 cm^{-1} and 3500-3800 cm^{-1}. There are differences at the lower end of each band system. The HITRAN96 line database has a reference temperature of 296K and may be missing some lines that are significant at 1300 K. The full paper will include results from more extensive CDSD-1000 CO_2 line database to assess if the more detailed database will give better comparisons.

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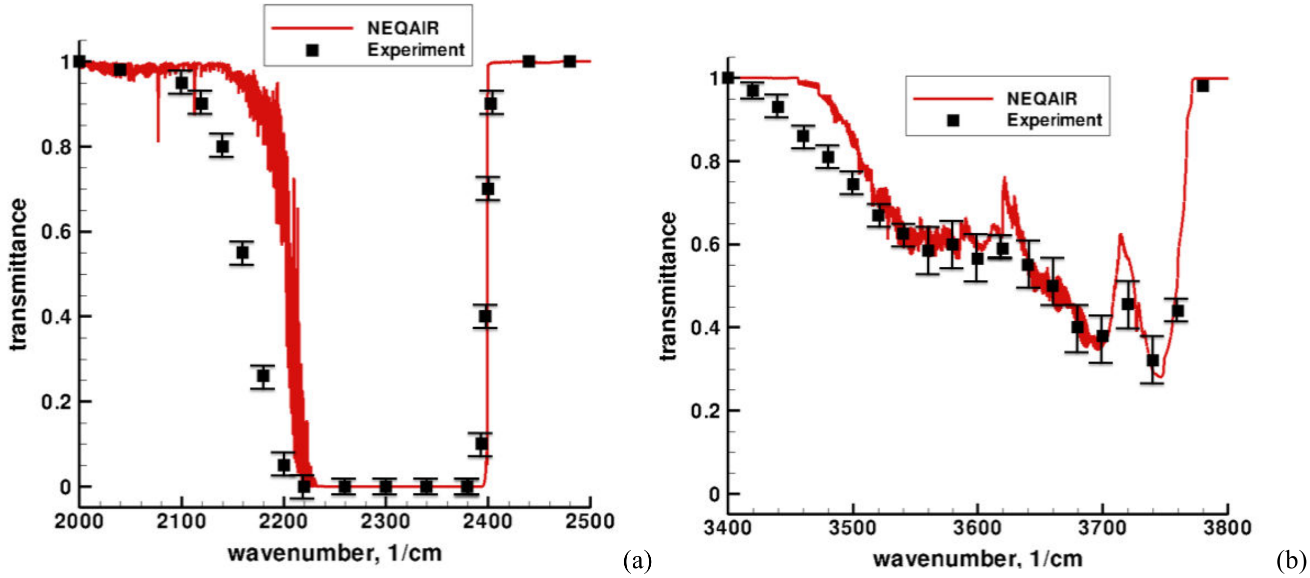

Figure 1. Experimental and computational transmittance, 50% CO_2 gas mixture at 1300 K.

In addition to the Modest transmittance data, the full paper will include NEQAIR comparisons against spectral radiance measurements taken in the Air Force Cambridge Research Laboratory [9] as well as recent measurements in CO_2 taken in the NASA Ames EAST facility at a shock velocity of 3.07 km/s and pressure of 1 Torr.

III. References

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