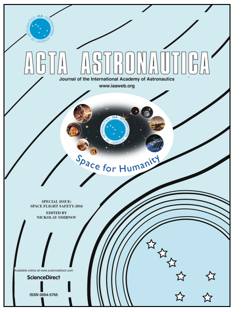
Accepted Manuscript



Validation of vibration-dissociation coupling models in hypersonic non-equilibrium separated flows

G. Shoev, G. Oblapenko, O. Kunova, M. Mekhonoshina, E. Kustova

PII: S0094-5765(17)31298-5

DOI: 10.1016/j.actaastro.2017.12.023

Reference: AA 6603

To appear in: *Acta Astronautica*

Received Date: 15 September 2017

Revised Date: 13 November 2017

Accepted Date: 15 December 2017

Please cite this article as: G. Shoev, G. Oblapenko, O. Kunova, M. Mekhonoshina, E. Kustova, Validation of vibration-dissociation coupling models in hypersonic non-equilibrium separated flows, *Acta Astronautica* (2018), doi: 10.1016/j.actaastro.2017.12.023.

Validation of vibration-dissociation coupling models in hypersonic non-equilibrium separated flows

G. Shoev[a,b,c], G. Oblapenko[b,*], O. Kunova[b], M. Mekhonoshina[b], E. Kustova[b]

[a] *Novosibirsk State University, 2 Pirogova str., Novosibirsk 630090, Russia*
[b] *Saint Petersburg State University, 7/9 Universitetskaya nab., St. Petersburg, 199034, Russia*
[c] *Khristianovich Institute of Theoretical and Applied Mechanics, Institutskaya 4/1, Novosibirsk 630090, Russia*

Abstract

The validation of recently developed models of vibration-dissociation coupling is discussed in application to numerical solutions of the Navier–Stokes equations in a two-temperature approximation for a binary N_2/N flow. Vibrational-translational relaxation rates are computed using the Landau–Teller formula generalized for strongly non-equilibrium flows obtained in the framework of the Chapman–Enskog method. Dissociation rates are calculated using the modified Treanor–Marrone model taking into account the dependence of the model parameter on the vibrational state. The solutions are compared to those obtained using traditional Landau–Teller and Treanor–Marrone models, and it is shown that for high-enthalpy flows, the traditional and recently developed models can give significantly different results. The computed heat flux and pressure on the surface of a double cone are in a good agreement with experimental data available in the literature on low-enthalpy flow with strong thermal non-equilibrium. The computed heat flux on a double wedge qualitatively agrees with available data for high-enthalpy non-equilibrium flows. Different contributions to the heat flux calculated using rigorous kinetic theory methods are evaluated. Quantitative discrepancy of numerical and experimental data is discussed.

Keywords: multi-temperature, high enthalpy, separated flows, vibration-dissociation coupling

1. Introduction

Under cruising conditions and during maneuvering in super- and hypersonic flights, shock waves arise near air vehicles. Depending on the free-stream parameters and the construction of the flying craft these shock waves can intersect

*Corresponding author

Email addresses: gerashoev@yandex.ru (G. Shoev), kunstmord@kunstmord.com (G. Oblapenko), kunova.olga@gmail.com (O. Kunova), mekhonoshinama@gmail.com (M. Mekhonoshina), e.kustova@spbu.ru (E. Kustova)