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The effects of rarefaction and thermal non-equilibrium on a blunt body and a bicone in hypersonic flow and their shape optimization for reducing both drag and heat transfer

Design of space vehicles pose many challenges due to their hypersonic speeds since they travel through many flow regimes due to changes in the density of the atmosphere with altitude. Some of the key characteristics associated with hypersonic flow are extremely high temperatures and heat transfer to the wall of the spacecraft. At these temperatures the assumption of thermal equilibrium is no longer valid and the effect of rotational non-equilibrium must be included in the modeling the diatomic gas flow. This paper employs the Navier-Stokes equations which are modified to include a rotational non-equilibrium relaxation model to analyze the heat transfer, drag, and shock standoff distance for hypersonic flow past an axisymmetric blunt body and a bicone for various levels of rarefaction including the rotational non-equilibrium effect. The customized flow solver, ZLOW, is used to calculate the numerical solutions for laminar viscous hypersonic flow past a blunt body and a bicone at Knudsen numbers Kn in slip flow regime with and without rotational non-equilibrium. The effects of rarefaction in slip flow regime are modeled by applying the Maxwell's velocity slip and temperature jump boundary conditions on the surface. The effects of including the rotational non-equilibrium terms are discussed for both the continuum (Kn = 0) and slip flow regime (Kn ≤ 0.1). In addition, both the blunt body and bicone are optimized in hypersonic, rarefied flow with rotational non-equilibrium by using a multi-objective genetic algorithm (MOGA) for reduction of both drag and heat transfer.

Biography

Ramesh K Agarwal received PhD from Stanford University in 1975 and Post-doctoral training at NASA Ames Research Center in 1976. From 1976 to 1994, he was the Program Director and McDonnell Douglas Fellow at McDonnell Douglas Research Laboratories in St. Louis. From 1994 to 2001, he was the Sam Bloomfield Distinguished Professor and Executive Director of National Institute for Aviation Research at Wichita State University in Wichita, KS. He is currently the William Palm Professor of Engineering at Washington University in St. Louis. He is the author/co-author of nearly 250 archival papers and over 500 conference papers. He is on the editorial board of 20+ journals. He is a Fellow of 18 societies including AIAA, ASME, ASEE, SAE, IEEE, APS, and AAAS among others. He is the recipient of many honors and awards.

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