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HYPERSONIC SIMULATION OF MARS ENTRY ATMOSPHERE BASED ON GUN TUNNEL

Abstract

Mars exploration is a focus because of its scientific significance since 1960s. Mars atmosphere is mainly composed of CO_2 (almost 95.32%) and is different from air of the earth, leading to a different entry environment. Thus an experiment environment should be established to obtain aerodynamic parameters of Mars mission entry vehicle. From previous researches, it can be established through replacing test gases of impulse tunnel. However, how to calculate the flow parameters at the nozzle exit accurately is still a challenge. The objective of present study was to establish a hypersonic Mars entry condition by gun tunnel and determine its flow parameters.

In the present study, a series of wind tunnel modifications were conducted. First, a new supply system was used to replace the driven gas by CO_2. Second, a vacuum system and control system were introduced to satisfy the operation conditions. Third, an advanced piston was designed to achieve the conditions of high temperature and long test period, and the effective test period was about 25ms enough to perform the force measurements.

After the driven gas is changed to CO_2, how to determine flow parameters is critical for the vehicle design and numerical method verification. When the test gas is air, all the flow parameters are calculated directly using total pressure and Pitot pressure measured during a run. If it was replaced by CO_2, many factors must be considered in determining flow parameters. According to our studies, flow velocity is dramatically affected by total temperature, and slightly by total pressure. A combination method of nozzle calibrations results, shock theory and CFD has been established for nozzle flow.

The major step of this method is to determine total temperature. First, assuming specific heat ratio is the same in the flow, some solutions of Mach number and specific heat ratio can be obtained from Rayleigh equation. Second, according to the total pressure, driving pressure and driven pressure, total temperature can be gained from shock theory. Third, calculate the nozzle flow Mach number using Navier-Stokes equations. Integrating the three steps, Mach number and total temperature can be calculated. Finally, once temperature is determined, adding total pressure and nozzle profile, all the flow parameters can be calculated. The Mach number of the nozzle exit is 6.04, and the uniformity of the nozzle is pretty good for the force and heat flux measurements.