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DEVELOPMENT OF AN ARC HEATER OPERATING IN AIR USING A ZIRCONIUM CATHODE

Abstract

For the investigation of Thermal Protection Systems (TPS) for re-entry vehicles, it is necessary to simulate the atmospheric re-entry conditions. An arc-heater is one of the promising plasma generators that can be used to simulate the re-entry environment in a ground test. We developed an arc-heater using zirconium as cathode material in order to operate under an atmospheric condition and to reduce the cathode corrosion and erosion during an arc heater operation. Nitriding of zirconium cathode is performed by a microwave plasma generator (MPG). Zirconium forms a nitride ceramic layer of zirconium nitride (ZrN) on the cathode surface. ZrN is a promising candidate for a cathode of the arc heater because of its good corrosion/erosion resistance. ZrN has excellent physical properties such as high melting point, superior work function, and thermal conductivity. With these properties ZrN provides a high current density which allows applying a higher input current, resulting in a higher specific enthalpy. Several experiments with different electric currents and gas flow rates were carried out to determine the suitability for application in an arc heater with reactive gas flow. Nitrided cathodes yield a stable plasma flow of argon-air mixture gas flow up to 80 A at a maximum flow rate of 4 l/min argon and 0.8 l/min air for a long duration of over 30 minutes. The specific input power corresponds to 11.8 MJ/kg. During arc heater testing, nitriding is a governing reaction and golden zirconium nitride is formed at the tip of the cathode surface, whereas oxynitriding and/or oxidation seem to occur at the edge area. The formation mechanism of ceramic layer during nitriding of a cathode and arc heater testing will also be discussed. The goal of our study is to produce an arc heater that can achieve higher plasma temperatures by means of a high input current, and which can produce a plasma flow without significant erosion of the cathode using dry air as the working gas.