ABSTRACT

Theoretical and experimental studies have been carried out to determine the fluid flow and heat-transfer characteristics of porous flat plates suitable for injector face plate of cryogenic rocket engines.

There is an ever increasing demand for materials which can withstand very high temperatures. Besides the development of such materials, research work for efficient means of cooling the medium to operate in a high heat-flux environment is scarce. In the present investigations a porous medium is developed which can withstand high temperature environment of the order of 3500 K, achieved by transpiration cooling. The porous medium is a multi-layer Rigimesh developed from AISI type 304 stainless steel wire-mesh joined together using vacuum brazing technique. They were tested against the heat-flux of an oxy-acetylene flame for a considerable duration with and without the coolant, nitrogen gas, at ambient pressure and at various temperature levels. A cylindrical duct with thermally insulated test section to mount the specimen is designed and fabricated, which serve as the essential experimental set up. Adequate instrumentation at appropriate locations in the test set-up to indicate pressure, temperature, flow rate of coolant etc have been provided. The pressure drop, the temperature distribution and the coolant flow rate for the extreme heat-flux environment have been optimised.

Also, a theoretical model has been developed for transpiration cooling where the coolant with the aid of applied pressure transpires through the capillary flow passages embedded in the fabricated Rigimesh porous medium. The heat and fluid flow are assumed to be one dimensional and counter flow in the porous specimen during the experiment. Making approximations applied to porous medium and the realistic boundary conditions, heat-transfer equations under transpiration cooling are derived and validated. Generalised techniques for determining the properties of porous materials related to transpiration cooling have been developed.
From the experimental results, the pressure drop characteristics of coolant flow, the influence of microstructure of the porous test specimen, porosity requirement of the medium for various temperature levels and distribution of heat-flux are evaluated. The theoretical model have been validated with the experimentally observed results, which are found to be in reasonable agreement.