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Measuring The Anisotropic Heat Transfer Coefficients In Carbon Fiber Felt

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Thermal protection systems (TPS) are used to ensure acceptable temperatures for the outer surface of a spacecraft during all mission phases and particularly during atmospheric re-entry. Carbon fiber felt is widely used in TPS systems due to its high porosity and low thermal conductivity [1]. It is an anisotropic material. In local thermal non-equilibrium (LTNE) models, a heat transfer coefficient (HTC) is used to represent the internal heat exchange between the fluid and solid phases. Some correlations for metal foams, packed beds and ceramic foam are proposed in the literature for the prediction of the HTC [2]. However these correlations are not suitable for carbon fiber felt due to its geometric parameters, namely smaller fiber diameter (50μm), lower thermal conductivity (0.23W/(m3 K)) and its anisotropic structure. In this work, an inverse method was used to determine the anisotropic HTC between a gas stream and a carbon fiber felt sample. This method consists of three steps: transient single-blow technique (TSBT) experiments, macroscopic numerical simulation and error minimization between the results of the two first steps. To investigate the influence of the anisotropic structure of the materials on HTC, different experiments were performed by changing the orientation of the sample (Through-Thickness (TT), In-Plane (IP)), the inlet gas velocity varying from 0.23m/s to 0.94m/s. The experimental data are input into the macroscopic simulation process as initial and boundary conditions. The computational area includes a fluid (gas flow in the tube) and a porous domain. The energy conservation equations are solved using a finite volume method in the Porous material Analysis Toolbox based on OpenFoam (PATO) [3]. Besides, a numerical model of the thermocouple allowed to compute the temperature difference between the gas and the thermocouple probe. At last, a method for minimizing the error between calculated and measured temperatures is introduced, so that we can get the most suitable value of HTC. When the orientation of the sample is changed while keeping the same conditions, different values of the HTC are found. To take explicitly into account the flow direction, a new formulation with HTC has been proposed. This formulation will also be verified using pore-scale simulation in the future [4].

Keywords: Local thermal non-equilibrium; Anisotropic materials; Macroscopic numerical simulations; error minimization

Time Block Preference

Time Block B (14:00-17:00 CET)

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Primary author: Mr LIU, Shaolin

Co-authors: Prof. AHMADI, Azita; Mr SCANDELLI, Hermes; Dr LEVET, Cyril; Prof. LACHAUD, Jean

Presenter: Mr LIU, Shaolin

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