HIGH-TEMPERATURE TURBINE APPLICATIONS USING OPEN POROUS METALLIC FOAMS WITH THERMAL BARRIER COATINGS AND COOLING HOLE ARRAYS

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ABSTRACT

For further improvement of combined cycle power plants the combustor outlet temperature has to be increased up to 1520° C in combination with a simultaneous reduction of the cooling fluid mass flow. Both improvements can be realized by an effusion cooling of the thermally highly loaded turbine components. A two-dimensional cooling strategy in combustion chambers which allows the outflow of the cooling medium over the complete wall area of the combustion chamber is realized by an open porous metallic foam structure. Open porous and high temperature resistant Ni-base structures (Inconel 625) are developed for the requirements of an effusion cooling. The SlipReactionFoamSintering is used to produce a metallic foam, as the open porous structure. To withstand the high temperatures in the combustor of a gas turbine up to 1520° C, the samples are covered by thermal barrier coatings using thermal spraying, which hermetically seals the open porous structures. Laser radiation is used to open the thermal barrier coating in order to form subsequently a blind hole in the metallic foam establishing vias to a number of pores enabling a cooling mass flow through the blind holes to the surface of the sample. The required depth of the blind hole depends on the thickness of the coatings and the porosity of the metallic foam. The cooling holes are drilled at an inclination angle of up to 45° with a diameter of approximately 0.2 mm and a density of 100 holes per cm². Therefore, the laser energy has to be adapted to avoid a structural damage of the metallic foam. Due to the drilling time of less than 0.2s per hole laser percussion drilling is suitable for processing metallic foam based multi layer systems. The drilled blind holes are reproducible concerning depth and diameter, but their geometry depends on the thickness of the thermal barrier coating and the bond coat as well as the porosity of the metallic foam governed by the sintering process.

As a final challenge the design of a multi-layer structure based on a graded metallic foam is presented, which influences the performance of the outflow of the cooling medium into the combustion chamber. The general feasibility of the production steps of the multi-layer component made out of the open porous foam and the thermal barrier coating is demonstrated, which combines metallic and ceramic materials with differing structural and thermal properties.

Keywords: combustion chamber, high-temperature turbines, cooling holes, metallic foams, thermal barrier coatings, cooling hole arrays