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Interferometric Analysis of Thermomechanical Deformations in Thermoelectric Generators

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In thermoelectric applications, optimized thermal contacts are essential to enable efficient and homogeneous flow of heat currents. Thermomechanical stresses may lead to surface deformation, which alters the thermal contact. As a result, the heat current density is reduced and no longer homogeneous. Also an undesired temperature gradient perpendicular to the heat flow develops, and hence this temperature gradient again causes thermomechanical stresses. The described thermomechanical problems are particularly important in applications where high operating temperatures and hence large temperature differences are used. Also, system durability is a crucial aspect, especially in applications where thermal cycles occur (i.e., in the field of waste heat regeneration of car combustion engines). We describe a measuring technique to detect and evaluate the influence of these deformations. To analyze the surface and external points of contact of a thermoelectric generator (TEG), a measurement setup based on speckle interferometry is used. Temperature gradients as well as small surface deflections in the μm range have to be measured simultaneously. Therefore, an optical as well as a thermography camera are used to create a holistic image of the deformation and to analyze the influence of this deformation on the TEG structure.

Key words: Thermoelectric generator, thermomechanical stress, thermal contact, electronic speckle pattern interferometry

INTRODUCTION

In almost all industry sectors, energy-saving techniques are becoming more important. These include thermoelectric generators (TEG), which provide the opportunity to generate clean electric current. The larger the temperature difference between the heat source and heat sink, the higher the electrical yield of the system. In vehicles with combustion engines, this desired large temperature difference is available and offers the basis for research and development. It emerges that, in addition to materials matching this application, the installation settings are important. Optimum thermal coupling of the heat source and heat sink to the TEG is essential. This thermal contact influences the flow of heat currents and therefore the efficiency of the whole system. Due to the large temperature differences, the surface becomes deformed, resulting in an altered thermal contact. As a consequence, the heat flow is no longer homogeneous. During cyclic loading, the temperature difference and hence the deformation changes several times, which influences the durability.[1]

To investigate the influence of large temperature differences, it is necessary to take a closer look at the following aspects. The thermal coupling conditions in a conventional installation situation have to be characterized. The quality of the coupling is commonly investigated with the help of pressure-sensitive foil. Also, the deformation of the surface during operation as a function of temperature has to be measured. Therefore, optical measurement techniques are suitable, as they do not disturb the thermoelectric process. Electronic speckle pattern interferometry (ESPI) is a technique which fulfills these requirements, as already shown by Chang and Wang.[2] Additionally, a thermal image of the TEG

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