



Use of ultrasonic waves in sub-cooled boiling

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ABSTRACT

This work focuses on the use of ultrasounds in heat transfer fields. Under particular conditions, ultrasonic waves induce a convection coefficient increase. This initial research work, indicates that there are some practical applications in the cooling of the latest generation electronic components.

In the first part of this paper, some background on this subject is reported. The ultrasound's influence on heat transfer rate has been observed since the 60's; different authors studied the cooling effect due to ultrasonic waves from different heat transfer regimes. The most investigated configuration was a thin platinum wire immersed in water. Later, a bibliographic research on possible practical applications of ultrasounds was carried out. This research focused in particular on the issue for 3D highly integrated electronic components. For these systems the thermal problem is a major challenge, because they cannot exceed critical temperatures, after which they could be damaged irreversibly. On the basis of our experimental results, ultrasounds could represent a valid means to overcome these thermal problems.

Finally, the paper presents a series of experiments performed in the Thermal-Fluid- Dynamic Lab at the Energy and Engineering Systems Department of the University of Pisa. The experiments provide systematic evidence of ultrasonic waves effects, on free convection heat transfer, from a heated circular cylinder to sub-cooled water, at atmospheric pressure. Many variables involved in the heat transfer rise were tested, for example: the ultrasonic generator's power, the position of the heater inside the ultrasonic tank, the variation of the water sub-cooling degree, as function of the heat flux needed dissipating. The aim of the experiment was to find out the set of optimal conditions, in order to successively apply all the results to real packaging systems, as mentioned before. The maximum increase in the heat transfer coefficient, due to ultrasonic waves, was 57%.

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1. Introduction

The aim of this experimental investigation is to clarify and extend the use of ultrasounds in cylindrical cooling surfaces, as well as to explain the same phenomenon and find out the optimal conditions which will increase the heat transfer coefficient.

The present paper collects the results of basic research experiments on ultrasound's influence on heat transfer enhancement from a circular cylinder, heated up by the Joule effect, to distilled water. Water was chosen as the cooling fluid, and not air, because the ultrasound's attenuation coefficient in air is four orders of magnitude higher than in water. The heat flux values supplied to the heater were obtained thanks to a bibliographic research on particular electronic elements. This appears to be a valid practical application field for ultrasound cooling systems. These elements are the latest generation 3D electronic packaging components,

whose thermal problem is a critical challenge, because they need high-level dissipating heat fluxes and, however, cannot exceed certain critical temperatures.

The tests were carried out in sub-cooled boiling conditions, because, according to scientific literature, in this regime the effect of the ultrasonic waves on the convection coefficient is the highest.

The absence of any diffraction phenomena was also verified: for the tested frequency of 40 kHz, assuming 1500 m/s for the ultrasound propagation velocity in water for the tested temperatures, the wave length is about 0.038 m. This is one order of magnitude bigger than the heater diameter (3 mm).

In this paper the results from the experimental of 40 kHz ultrasonic frequency, at different sub-cooling degrees (ΔT_{SUB}), are reported, with ΔT_{SUB} varying from 55 to 5 K, at atmospheric pressure. The main variables involved in the mechanism are:

- The water sub-cooling degrees, ΔT_{SUB} ;
- The ultrasonic generator's power, P_{gen} ;
- The position of the heater inside the ultrasonic tank;
- The heat flux dissipated by the Joule effect, q'' .

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