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Experiments with Al_2O_3 nanofluid in a single-phase natural circulation mini-loop: Preliminary results

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ABSTRACT

Natural circulation (NC) is a heat transfer mechanism which occurs in case of density gradients inside a fluid. Even if the heat transfer coefficients are lower than in case of forced convection, NC guarantees a good reliability and low costs of maintenance as it does not need any mechanical part. Therefore the main industrial applications of NC systems are in the field of nuclear power plants, solar heaters and passive cooling systems of engines, turbines and electronic components. Most researchers focused their attention on large size systems, with particular care to performance optimization and stability analysis, while there are few studies about natural circulation inside small size devices. In this paper an experimental study focused on the macroscopic effects on the thermal performance of a mini-loop is presented. In particular, two working fluids were used during the tests: distilled water and a nanofluid (distilled water and Al_2O_3) characterized by two different concentrations (0.5% and 3.0% by volume). The analised parameters were: power transferred to the fluid, mini-loop inclination and temperature at the cooler. Experimental results of the two fluids were compared to the Vijayan's correlation, developed for large scale natural circulation loop, showing good agreement.

1. Introduction

Natural circulation is a widely used mode of heat removal due to its passive nature. It is self starting and the driving force necessary for the fluid motion is obtained from the density differential between the heated and cooled sections. Therefore, NC loops have in-built safety feature of being driven by heat input. Different type of NC loops could be considered.

Single-phase NC loops find practical applications in large scale thermal systems [1–3] such as nuclear power plant [4] or solar water heating system. Moreover, NC systems have recently been introduced in electronic circuit cooling as alternative to two-phase systems. For this reason it is also necessary to study the thermo-hydraulic behaviour of mini-NC loops.

Garibaldi and Misale [5] studied the thermal performance of mini-loops, using distilled water and FC-43 as working fluids, varying both power transferred to the fluid and mini-loop inclination. The thermo-hydraulic behaviour was always stable for both fluids and for all combinations analysed. The best thermal performance of the mini-loop was a flux density of about 40 kW/m^2 with distilled water. All the data showed a very good agreement with the Vijayan's correlation [2].

Recently, a new family of fluids called "nanofluids" are intensively studied. Nanofluid is the name conceived by Argonne National Laboratories to describe a fluid in which nanometer-size particles are suspended [6]. Nanofluids enhance the thermal conductivity and convective heat transfer performance of the base liquid [7].

In particular the addition of small amount of nanoparticles (less than of 1% by volume), with typical length scale of 1–100 nm, increases up to twice the thermal conductivity of the nanofluid [8,9]. At the same time, the viscosity of the nanofluid increases as the nanoparticles concentration increases [10,11].

Most papers concerning nanofluids are generally focused either on their rheological behaviour or on characterising their thermo-physical properties. Only few papers analyse industrial applications, in particular in the field of transportation [12,13], electronic cooling [14], space [15,16], biomedicine [17], and nuclear reactor safety systems [18].

Concerning single large scale phase NC systems, an interesting study about the use of Al_2O_3 nanofluid was recently presented in Ref. [19]. The presence of the nanoparticles causes both the stabilisation of the thermo-hydraulic behaviour in the loop and the increment of the flow rate in stable cases.

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