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PERFORMANCE OF A SINGLE ROW HEAT EXCHANGER WITH METAL FOAM COVERED TUBES

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ABSTRACT

Open cell metal foam is a novel engineering material that offers an interesting combination of materials properties from a heat exchanger point of view such as a high specific surface area, tortuous flow paths for flow mixing and low weight. A new heat exchanger design with metal foams is studied in this work, aimed at low airside pressure drop. It consists of a single row of aluminum tubes covered with thin layers (4-8 mm) of metal foam. Through wind tunnel testing the impact of various parameters on the thermo-hydraulic performance was considered, including the Reynolds number, the tube spacing and the foam height. The results indicated that providing a good metallic bonding between the foam and the tubes can be achieved, metal foam covered tubes with a small tube spacing and small foam heights potentially offer strong benefits at higher air velocities (> 4 m/s) compared to helically finned tubes. The bonding was done by conductive epoxy glue and was found to have a strong impact on the final results, showing a strong need for a cost-effective and efficient brazing process to connect metal foams to the tube surfaces.

INTRODUCTION

Heat transfer as an energy transfer process affects every facet of our day-to-day lives, ranging from the generation of power (electricity), to preserving food and providing a suitable indoor climate (air conditioning). Because of the variety in the nature of the heat transfer processes, heat exchangers can take on many different forms. Regardless of their form, the heat exchangers are very important to the overall efficiency of the energy transfer process, and to the cost and size of the system. A very typical application is the exchange of heat between a liquid and a gas (e.g. air conditioning, energy recovery from air streams…). Two commonly used heat exchanger designs for this application are the fin-and-tube and the plate-fin design. These heat exchangers are most often constructed using copper, aluminum or steel. A large amount of technical literature can be found on how to enhance the heat transfer rate or performance of these conventional designs by e.g. using interrupted fins or vortex generators. However, the operating limits of metallic heat exchangers in some applications have created the need to develop alternative designs using other materials. One of the materials that have been drawing a lot of attention over the past decades is open cell metal foam.

NOMENCLATURE

A_c	[m²]	minimal free flow area
A_{ext}	[m²]	exterior surface area
C^*	[-]	heat capacity ratio
d_{ext}	[m]	exterior tube diameter
d_f	[m]	mean strut diameter
d_p	[m]	mean pore diameter
h	[W/m²K]	heat transfer coefficient
H	[m]	height
k	[W/mK]	thermal conductivity
L	[m]	length
NTU	[-]	number of transfer units
8p	[Pa]	pressure drop
R_{bond}	[K/W]	bonding resistance
R	[m²K/W]	convective heat transfer resistance
R^*_{ext}	[m²K/W]	exterior convective heat transfer resistance lumped with the bonding resistance
T	[K]	Temperature
U	[W/m²K]	Overall heat transfer resistance
V	[m/s]	Air velocity
X^*_T	[-]	dimensionless transversal tube pitch, Eq. (1)

Special characters

	[-]	porosity

Subscripts

air	air
ext	exterior
in	inlet
int	interior
ref	reference value
T	tube