Applied Thermal Engineering 80 (2015) 118–126

Contents lists available at ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Research paper

An experimental investigation on fluid flow and heat transfer characteristics of sintered woven wire mesh structures

Yangpeng Liu, Guoqiang Xu, Xiang Luo, Haiwang Li*, Jiandong Ma

National Key Laboratory of Science and Technology on Aero Engines Aero-Thermodynamics, The Collaborative Innovation Center for Advanced Aero-Engine of China, Beihang University, Beijing 100191, China

HIGHLIGHTS

- A new empirical equation of friction factors for the sintered woven wire mesh structures was obtained.
- The porosity is one of the most important parameters to influent the flow and heat transfer of structure.
- The sintered woven wire mesh structures have higher heat transfer capability comparing with other structure.

ARTICLE INFO

Article history:
Received 9 September 2014
Accepted 19 January 2015
Available online 28 January 2015

Keywords:
Sintered metal wire mesh
Porosity
Fluid flow
Heat transfer

ABSTRACT

The structure of sintered woven wire mesh is one of classical porous medium. Internal flow fluid and heat transfer characteristics of sintered metal wire mesh structures with various porosities were investigated experimentally. All the test pieces made of stainless steel wires with the same wire (d = 0.14 mm) were sintered after woven. In the experiments, the air which was applied by the gas source was used to investigate the performance of the structure. Pressures and flow rate at the inlet and outlet were obtained to get the permeability and inertia coefficient of each specimen as well as the friction factors. The Reynold numbers of the inlet changes from 3.22 to 24.98. At the same time, the sintered metal wire mesh structure was heated electrically depending on the electric residence of the wire. The wall temperature of the test pieces was measured using infrared camera. For the flow behavior, the results showed that the permeability increases with respect to porosity, while the inertia coefficient shows the opposite trend. Friction factor decreases as the Reynolds number increases. The results also showed that the porosity shows an insignificant impact on friction factors defined in this study. A new empirical equation of friction factors was proposed to predict the flow behavior of the sintered metal wire mesh structures. For the heat transfer characteristics, increase of Nusselt number has always been keeping pace with the Reynolds number. At the same time, porosity affects the Nusselt number.

1. Introduction

Cooling technique is one of the most important methods to improve the performance of the aero engine. It is also the powerful method to ensure the safety of the aero-engine. The traditional cooling methods, such as inner channel, impingement cooling, film cooling, are approaching the limitation of the cooling effect. Innovation of cooling method is sought by researchers and engineer of aero-engine. Transpiration cooling is one new cooling method with high cooling efficiency, which is generally realized by porous media. Therefore, porous media is a good candidate for the heat transfer enhancement applications because of large values of surface are density [1]. Porous media has been widely used in chemical reaction, cooling of electronic equipment (such as phased array radar system [2]), solar energy collection [3], and other applications [4,5]. In a word, it is necessary to investigate the fluid flow and heat transfer characteristics of porous media before applying it to the cooling technique of the aero engine.

Advantages of porous media structures have attracted the attention of many researchers. For decades, the fluid flow and heat transfer characteristics of porous media structures have been extensively studied by many researchers through experimental [6,7,9–17], numerical and analytical [18–21] methods.

* Corresponding author.
E-mail address: 09620@buaa.edu.cn (H. Li).

http://dx.doi.org/10.1016/j.applthermaleng.2015.01.050

Nomenclature

K	permeability [m^2]
k	thermal conductivity [W/(m^{2}K)]
P	pressure [Pa]
g	acceleration of gravity [m/s^2]
H	distance [m]
m	mass flow rate [kg/s]
A_c	cross-sectional area of the channel [m^2]
u	velocity [m/s]
ΔP	pressure drop [Pa]
R_f	inertia coefficient [m^{-1}]
d_s	wire diameter [m]
d_p	particle diameter [m^2]
d_h	averaged pore diameter [m]
f	friction factor
Re	Reynolds number
Nu	Nusselt number
h_{sf}	heat transfer coefficient [W/(m^2 K)]
q	heat flux [W/m^2]
Q	heating power [W]
S	heat transfer area [m^2]
T	temperature [K]
c_p	specific heat capacity [kJ/(kg K)]
M	mass of test piece [kg]
V	volume of test piece [m^3]

Greek symbols

ε	porosity
δ	thickness of test piece[m]
μ	dynamic viscosity [Pa s]
ρ	density [kg/m^3]
α_{sf}	specific surface area[m]

Subscripts

w	wall
eff	effective
s	solid
f	fluid
H_2O	water
0	atmosphere
in	inlet
out	outlet
e	Ergun equations
t	test piece

Hawang and Chao [6] presented the results of heat transfer measurement for two porous channels with different mean diameters. The fully developed Nusselt numbers were analyzed theoretically by using a non-Darcy, two-equation flow model and were in good agreement with the measured values. Hetsroni [7] investigated the heat transfer and pressure drop experimentally in a rectangular channel with sintered porous inserts made of stainless steel of different porosities. It should be noted that the $\sqrt{K}$ was used as the effective characteristic size to generalize the heat transfer data instead of k_{eff} (where $k_{eff} = \varepsilon k_f + (1 - \varepsilon)k_s$ [8]). By

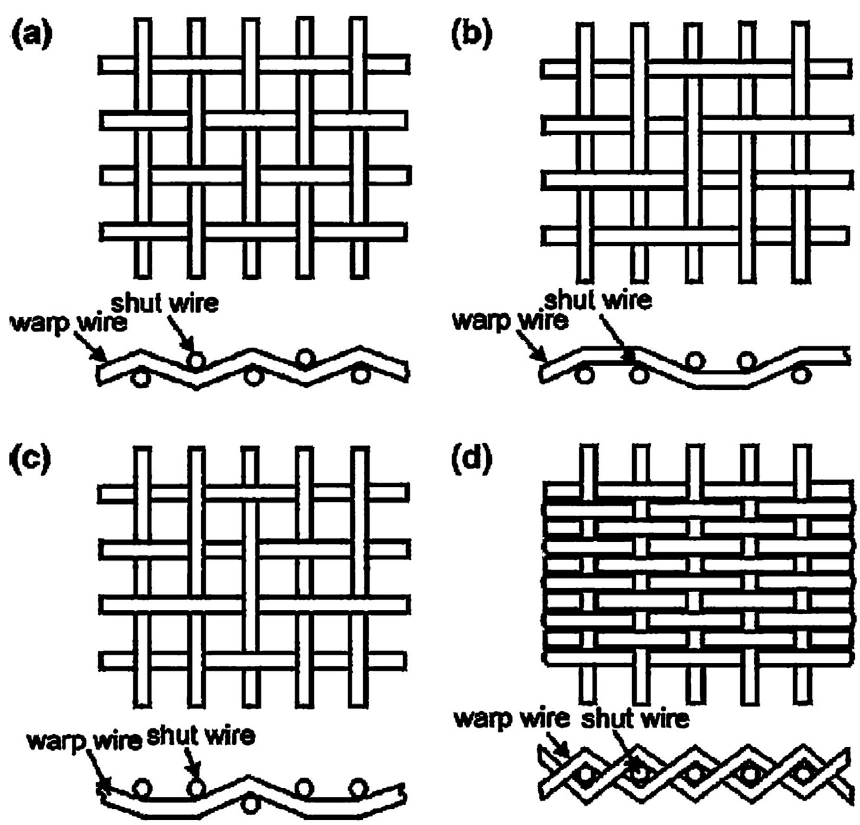

Fig. 1. Schematic diagram of the wire mesh structures: (a) plain weave; (b) twill weave; (c) fourdrinier weave; (d) dutch weave.