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Energy Conversion & Management 41 (2000) 1019–1028

ENERGY CONVERSION & MANAGEMENT

www.elsevier.com/locate/enconman

# Thermal performance analysis for solid and perforated blocks attached on a flat surface in duct flow

O.N. Şara*, T. Pekdemir, S. Yapici, H. Erşahan

*Faculty of Engineering, Atatürk University, 25240, Erzurum, Turkey*

Received 2 April 1999; accepted 20 September 1999

**Abstract**

The thermal performances of solid and perforated rectangular blocks attached on a flat surface in a rectangular duct were determined with respect to the heat transfer from the same plate without blocks. The data used in the performance analyses were obtained experimentally for varying flow and geometrical conditions. It was found that the solid blocks generated a net energy loss despite significantly enhanced heat transfer due to the increased heat transfer surface area. When the blocks were perforated, the loss in the net energy was recovered and depending on the geometrical and flow conditions, a net gain in energy, up to 20%, was achieved. For both the solid and the perforated blocks, increases in Reynolds number led to decreases in the performance. 

*Keywords:* Thermal performance; Forced convection; Heat transfer; Heat transfer enhancement; Duct flow; Rectangular blocks

## 1. Introduction

The increasing necessity for saving energy and material imposed by diminishing world resources has prompted the development of more effective heat transfer equipment for more efficient use of energy and material. In many industrial systems, heat must be transferred either to input energy into the system or to remove the energy produced in the system. Considering

* Corresponding author. Tel.: +90-442-218-41-20; fax: +90-442-233-69-61.
*E-mail address:* onuri@rocketmail.com (O.N. Şara).


PII: S0196-8904(99)00163-6

**Nomenclature**

$A$ heat transfer area
$C$ clearance between tip of blocks and ceiling of duct
$D$ perforation hole diameter
$D_e$ hydraulic diameter of the duct
$f$ friction factor
$H$ height of blocks
$\overline{Nu}$ average Nusselt number
$\overline{Nu}_s$ average Nusselt number for smooth surface
$Pr$ Prandtl number
$Re$ Reynolds number
$S_x$ uniform distance between blocks in $x$ (main flow) direction
$U$ total heat transfer coefficient
$\beta$ perforation open area ratio
$\alpha$ angle between central axis of perforation holes and surface of plate
$\eta$ performance efficiency

*Subscripts*
$s$ smooth
$sl$ solid
$pr$ perforated

the rapid increase in energy demand worldwide, both reducing energy loss due to ineffective use and enhancement of the energy transfer in the form of heat has become an increasingly important task for design and operation engineers.

In recent years, many techniques have been proposed for the enhancement of heat transfer. These can be classified into two main groups. Those which do not require an additional power source may be named as passive techniques and those with additional external power requirements active techniques [1,2].

In the case of passive techniques, attachments of heat transfer promoters of different shapes and geometries, such as fins, ribs and blocks, on the heat transfer surface have been widely exploited. Heat transfer is enhanced by the increase in the surface area and also by the turbulence or mixing generated due to the attachments. Enhancement in convective transfer rates is obtained at the expense of the energy dissipated by extra friction caused by non-smooth surfaces and insertions. In the case of active techniques, in addition to frictional energy dissipation, the external power input must also be taken into account. Therefore, for practical applications, a thermal performance analysis is worthwhile for evaluation of the net energy gain in the form of heat. The simplest way to evaluate the heat transfer enhancement performance of a given heat transfer promoter is to compare the ratio of the Stanton number ($St$) to the friction factor ($f$), $St/f$, obtained with and without the heat transfer promoter [3,4]. Zimparow and Vuchanow [5] developed a performance evaluation criterion based on an