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# A MODIFIED STANTON NUMBER FOR HEAT TRANSFER THROUGH FABRIC SURFACE

by

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*The Stanton number was originally proposed for describing heat transfer through a smooth surface. A modified one is suggested in this paper to take into account non-smooth surface or fractal surface. The emphasis is put on the heat transfer through fabrics.*

Key words: *Stanton number, heat transfer, fabric, fractal*

## Introduction

The Stanton number (St) is a dimensionless number that measures the ratio of heat transferred into a fluid to the thermal capacity of fluid. It is used to characterize heat transfer in forced convection flows [1]:

$$\mathrm{St} = \frac{h}{\rho u C_p} \tag{1}$$

where $h$ is the convection heat transfer coefficient, $\rho$ – the density of the fluid, $C_p$ – the specific heat of the fluid, and $u$ – the speed of the fluid.

The Stanton number is widely used in engineering, however, it becomes invalid for heat transfer through a fabric. Fabric thermal comfort [2-5] is an important factor in clothing design, and the heat transfer through the fabric plays a vital role in functional garments, such as fire-proof garments, water cooling garments, and space suits. With a same Stanton number, the heat transfer differs greatly with fabric geometries. A nanoscale flow in a non-smooth boundary always behaves fascinatingly, Majumder *et al*. [6] showed that liquid flow through a membrane composed of an array of aligned carbon nanotubes is 4 to 5 orders of magnitude faster than would be predicted from conventional fluid-flow theory, similar phenomena can be observed in nature, such as dunes and porous surface. Those phenomena imply that the non-

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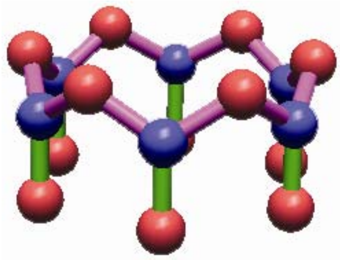

**Figure 1. Non-smooth boundary of carbon nanotube**

-smooth surface will greatly affect heat transfer. The non-smooth surface can be considered as a fractal surface as illustrated in fig. 1 for the carbon nanotube [7].

## A modified Stanton number

It is necessary to introduce a new number, He, characterizing heat transfer through a fractal surface:

$$\mathrm{He} = \frac{hA}{\rho u C_p A_0} \tag{2}$$

where $A_0$ is the projected area of flowing area, and $A$ – the actual area considering the non-smooth effect. For a fractal surface, $A$ can be expressed as:

$$A = k\lambda^{\alpha} \tag{3}$$

where $k$ is a constant, $\alpha$ – the value of fractal dimensions of the surface, and $\lambda$ – the original unit, for a fabric illustrated in fig. 2, we have:

$$\lambda = \sqrt{ab} \tag{4}$$

$$A_0 = ab \tag{5}$$

where $a$ and $b$ are the length and width of the unit, respectively.

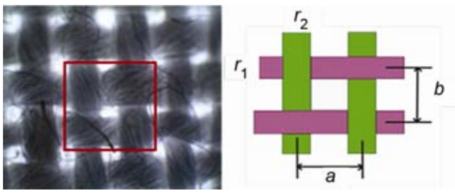


**Figure 2. A fabric unit**

The fractal dimensions of a fabric can be calculated as [8, 9]:

$$\alpha = \frac{\ln \dfrac{\pi r_1 a + \pi r_2 b - \pi r_1\ \pi r_2}{r_1^2}}{\dfrac{\sqrt{ab}}{r_1}} \tag{6}$$

where $r_1$ and $r_2$ are the fiber radius illustrated in fig. 2.

For 1-D flow, eq. (2) can be simplified:

$$\mathrm{He} = \frac{hL}{\rho u C_p L_0} \tag{7}$$

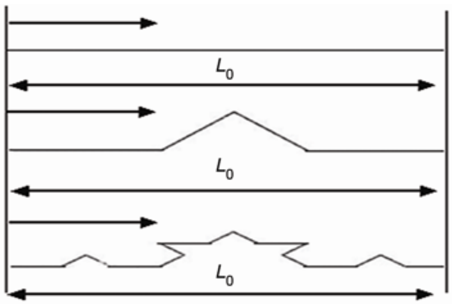


**Figure 3. Non-smooth boundary**

where $L_0$ is the unit length, see fig. 3, $L$ – the actual length considering the non-smooth effect, $L$ = 4/3 $L_0$ for the middle one, and $L$ = 16/9 $L_0$ for the bottom one in fig. 3.

The modified Stanton number for fractal surface can be written in the form:

$$\mathrm{He} = \frac{h}{\rho u C_p} \frac{\lambda^{\alpha - i}}{\Gamma(\alpha + 1 - i)} \tag{8}$$

where $i$ = 2 for surface flow, $i$ = 1 for 1-D flow, $\Gamma$ is the gamma function, it can also be represented in terms of the fluid's Nusselt, Reynolds, and Prandtl numbers as discussed in [1]. The modified number is especially suitable for describing heat transfer through a fabric.

## Conclusions

This paper suggests a modified Stanton number for fractal surface, and it is especially suitable for describing heat transfer through a fabric.

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