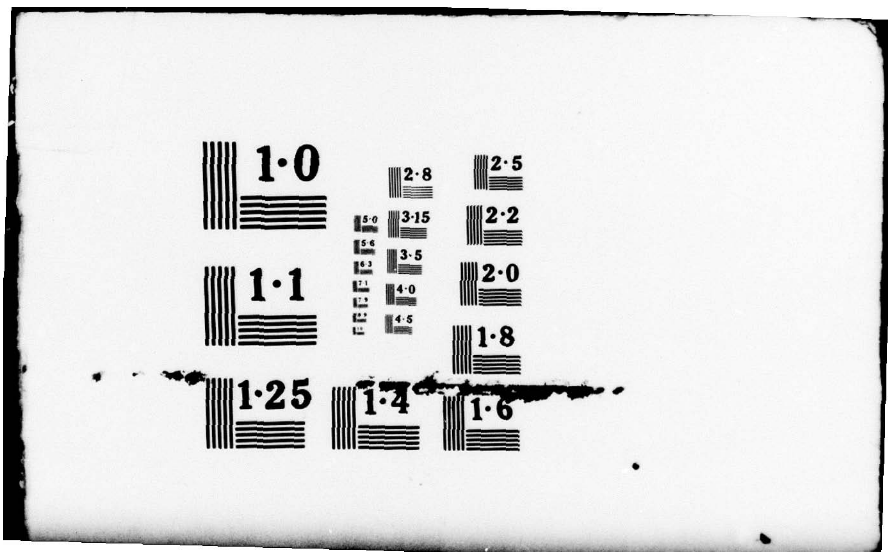
AD-A065 852 FOREIGN TECHNOLOGY DIV WRIGHT-PATTERSON AFB OHIO F/G 20/13
THE EFFICIENCY OF HEAT CONDUCTIVITY OF HONEYCOMB FILLERS, (U)
SEP 78 G N ZAMULA
UNCLASSIFIED FTD-ID(RS)T-1631-78 NL

| OF |
ADA
065852

END
DATE
FILMED
4-79
DDC


1·0
2·8
2·5
3·15
2·2
5·0
5·6
3·5
2·0
1·1
4·0
4·5
1·8
1·25
1·4
1·6

FTD-ID(RS)T-1631-78

AD-A065852

FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

THE EFFICIENCY OF HEAT CONDUCTIVITY OF HONEYCOMB FILLERS

By

G. N. Zamula

FOREIGN TECHNOLOGY DIVISION

78 12 27 250

EDITED TRANSLATION

FTD-ID(RS)T-1631-78 27 September 1978

MICROFICHE NR: FTD-78-C-001295

THE EFFICIENCY OF HEAT CONDUCTIVITY OF HONEYCOMB FILLERS

By: G. N. Zamula

English pages: 8

Source: Issledovaniya po Teploprovodnosti, Minsk, 1967, pp. 255-261

Country of Origin: USSR
Translated by: Charles T. Ostertag, Jr.
Requester: FTD/TQTA
Approved for public release; distribution unlimited.

THIS TRANSLATION IS A RENDITION OF THE ORIGINAL FOREIGN TEXT WITHOUT ANY ANALYTICAL OR EDITORIAL COMMENT. STATEMENTS OR THEORIES ADVOCATED OR IMPLIED ARE THOSE OF THE SOURCE AND DO NOT NECESSARILY REFLECT THE POSITION OR OPINION OF THE FOREIGN TECHNOLOGY DIVISION.	PREPARED BY: TRANSLATION DIVISION FOREIGN TECHNOLOGY DIVISION WP-AFB, OHIO.

U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

THE EFFICIENCY OF HEAT CONDUCTIVITY OF HONEYCOMB FILLERS

G. N. Zamula

The use of multilayer panels with a honeycomb filler in constructions which operate at high temperatures requires a calculation of effective heat conductivity of the filler, taking into account radiant heat exchange, which plays a significant role here. In work [1] an analysis is made of asymmetric aerodynamic heating and effective heat conductivity of a thin-wall panel with a circular cylindrical filler. The solution was constructed in a linearized formulation under the assumption of constancy of the nuclei of integro-differential equations, describing heat exchange in a honeycomb cell. We obtained the solution of a problem for different forms of a thin-walled cylindrical honeycomb filler when it is functioning in a system of a multilayer panel with absolutely black radiating surfaces on the basis of exponential approximation of the nucleus. An optimal form of filler cell is found depending on the dimensionless parameters which determine the process.

A cylindrical honeycomb filler is formed by identical cells which are adjacent to each other and which are made in the form of thin-walled hollow cylinders of different form in a plane with generatrices which are perpendicular to the plane limiting surfaces, which further are considered isothermic. Figure 1 gives an example of a honeycomb filler, the bases of the cells of which are true hexagons.

A honeycomb cell, thermally insulated on the side surface, is shown in Figure 2, where L and F - length of the nonconcave contour and area of the upper and lower bases of the cell with temperatures T_1 and T_2 respectively. The bases radiate according to the law of an absolutely black body, and the walls - ideally gray with a degree of blackness ε. We disregard heat exchange with the diathermic medium within the cell. The temperatures and radiant flows for a cell of arbitrary form in a plane will be averaged for each section parallel to the bases and the problem considered as unidimensional, which corresponds precisely to reality in the case of a round cylindrical filler and a filler in the form of an infinite set of parallel walls (axisymmetric and plane case).

With the accepted assumptions the equation of heat conductivity in a filler with consideration of heat radiation has the form

$$\frac{d^2 t(\xi)}{d\xi^2} - \sigma q(\xi) = 0; \qquad (1)$$

the integral equation of radiant heat exchange

$$\frac{q(\xi)}{\varepsilon} = t^4(\xi) - K(\xi) - t_2^4 K(1-\xi) - \int_0^{\xi}\left[t^4(\eta) - \frac{1-\varepsilon}{\varepsilon} q(\eta)\right]\varphi(\xi-\eta)\,d\eta - \int_{\xi}^{1}\left[t^4(\eta) - \frac{1-\varepsilon}{\varepsilon} q(\eta)\right]\varphi(\eta-\xi)\,d\eta; \qquad (2)$$

boundary conditions:

$$t(0) = 1;\; t(1) = t_2, \qquad (3)$$

where it is designated

$$t = \frac{T}{T_1};\ \xi = \frac{z}{H};\ q = \frac{q_{pes}}{c_0 T_1^4};\ \sigma = \frac{c_0 T_1^3 H^2}{\delta\lambda};$$

$K(\xi)$; $K(1-\xi)$ - coefficients of irradiance of an element of the cylindrical surface of the filler at a distance ξ from the upper base of the cell by the upper and lower bases respectively;

$\varphi(r) = -\frac{dK(r)}{dr}$ - mutual coefficient of irradiance of two elements of the cylindrical surface at a distance r from each other.

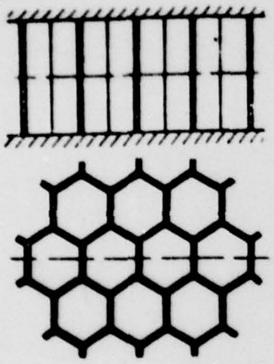


Figure 1. Hexagonal honeycomb filler.

The function $K(\xi)$, which is fading rapidly with an increase of ξ, for cells of arbitrary form in a plane we will approximate by the exponential function

$$K(\xi) = \frac{1}{2}\exp(-2l\xi), \tag{4}$$

where $l = \frac{LH}{4F}$ - dimensionless geometric parameter. In the case of a round cylindrical filler

$$l = \frac{H}{D},\ K(\xi) = \frac{1}{2}\exp\left(-2\frac{H}{D}\xi\right)$$

we obtain the known approximation of work [2], and with a filler in the form of a set of parallel walls -

$$l = \frac{H}{2a}, \quad K(\xi) = \frac{1}{2}\exp\left(-\frac{H}{a}\xi\right).$$

A comparison of the precise coefficients of irradiance $K(\xi)$ and their first derivatives, which for these two cases can be obtained readily by the differential method (see [3], and also [2]), with those calculated according to formula (4) is shown in Figure 2.

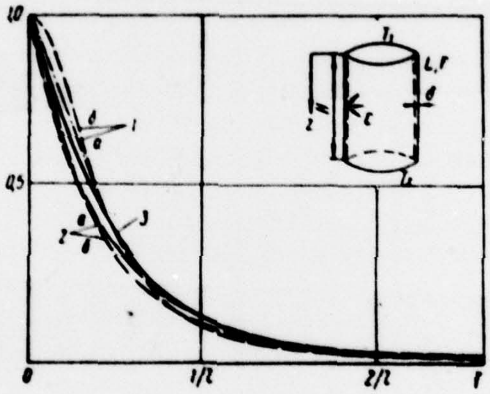


Figure 2. Comparison of the approximating function $\exp(-2l\xi)$ (3) with the precise angular coefficients $2K(\xi)$ (2) and $\frac{1}{l}K'(\xi)$ (1): a - for a round cylinder, approximation of work [2]; b - for parallel walls.

After substitution of (4) into (2) the integral equation (2) is replaced by the equation

$$\frac{q(\xi)}{\varepsilon} = t^4(\xi) - \frac{1}{2}\exp(-2l\xi) - \frac{t_2^4}{2}\exp[-2l(1-\xi)] -$$
$$-l\int_0^{\xi}\left[t^4(\eta) - \frac{1-\varepsilon}{\varepsilon}q(\eta)\right]\exp[-2l(\xi-\eta)]\,d\eta -$$

$$-l\int_{\xi}^{1}\left[t^4(\eta)-\frac{1-\varepsilon}{\varepsilon}q(\eta)\right]\exp[-2l(\eta-\xi)]\,d\eta, \tag{5}$$

which after the appropriate transformations can be reduced to the differential

$$\frac{d^2q(\xi)}{d\xi^2}-4\varepsilon l^2q(\xi)=\varepsilon\frac{d^2[t^4(\xi)]}{d\xi^2} \tag{6}$$

with boundary conditions:

$$\begin{gathered}\frac{q(0)}{\varepsilon}=\frac{1}{2}-\frac{t_2^4}{2}\exp(-2l)-\\-l\int_{0}^{1}\left[t^4(\eta)-\frac{1-\varepsilon}{\varepsilon}q(\eta)\right]\exp(-2l\eta)\,d\eta,\\\frac{q(1)}{\varepsilon}=\frac{t_2^4}{2}-\frac{1}{2}\exp(-2l)-\\-l\int_{0}^{1}\left[t^4(\eta)-\frac{1-\varepsilon}{\varepsilon}q(\eta)\right]\exp[-2l(1-\eta)]\,d\eta.\end{gathered} \tag{7}$$

The problem is reduced to two differential equations of the 2nd order (1) and (6) or their equivalent equation of the 4th order

$$\frac{d^4t(\xi)}{d\xi^4}-4\varepsilon l^2\frac{d^2t(\xi)}{d\xi^2}-\varepsilon\sigma\frac{d^2[t^4(\xi)]}{d\xi^2}=0 \tag{8}$$

with boundary conditions (3), (7). After linearization of the equations and boundary conditions (7) relative to $\theta(\xi)=t(\xi)-1$ the solution can be obtained in a closed form:

$$\begin{gathered}q(\xi)=2(1-t_2)\frac{\varepsilon(l^2+\sigma)}{lf(\sigma,l,\varepsilon)}\left\{\exp(-k\xi)-\exp[-k(1-\xi)]\right\},\\\theta(\xi)=\frac{1-t_2}{f(\sigma,l,\varepsilon)}\left\{\frac{\sigma}{2l}\left(\exp(-k\xi)-\exp[-k(1-\xi)]\right)-\right.\\\left.-\frac{\sigma}{2l}[1-\exp(-k)]-\varphi(\sigma,l,\varepsilon)\,\xi\right\}.\end{gathered} \tag{9}$$

where

$$k = 2\sqrt{\varepsilon(l^2+\sigma)},$$

$$f(\sigma, l, \varepsilon) = \sigma + \sigma/l + l^2 + l\sqrt{\varepsilon(l^2+\sigma)} -$$

$$- \exp(-k)[\sigma + \sigma/l + l^2 - l\sqrt{\varepsilon(l^2+\sigma)}],$$

$$\varphi(\sigma, l, \varepsilon) = \sigma + l^2 + l\sqrt{\varepsilon(l^2+\sigma)} -$$

$$- \exp(-k)[\sigma + l^2 - l\sqrt{\varepsilon(l^2-\sigma)}]. \tag{10}$$

At values of the dimensionless parameter σ, characterizing the ratio of heat transfer in the honeycombs by radiation and heat conductivity, close to 0 and ∞, we obtain correspondingly

$$t(\xi) = 1 - (1 - t_2)\xi$$

- the solution with disregard of radiation;

$$t(\xi) = 1 - \frac{1 - t_2}{2(1 + l)} - \frac{(1 - t_2)l}{1 + l}\xi$$

- the solution, in the case of a round cylindrical filler coinciding with the distribution found in [2] for temperatures in a cylindrical tube in the absence of heat conductivity and corresponding to the approximate solution of the classical Vlasov-Khottel problem [4, 5, 6].

Introducing the generally accepted concept of effective heat conductivity of a honeycomb filler in the direction of axis z:

$$\lambda_{эф} = \frac{QH}{FT_1(1 - t_2)}, \tag{11}$$

where Q - total heat flow arriving from the upper base of the cell onto the lower

$$Q = -\lambda\delta L\frac{dT}{dz}(0) + c_0T_1^4\Big\{F - [1 - 4(1 - t_2)] \times$$

$$\times \int_1^\infty \frac{1}{2}\exp(-2l\xi)LHd\xi -$$

$$- \int_0^1 \left[1 + 4\theta(\xi) - \frac{1-\varepsilon}{\varepsilon}q(\xi)\right]\frac{1}{2}\exp(-2l\xi)LHd\xi\Big\} =$$

$$= -\frac{\lambda\delta LT_1}{H}\frac{d\theta}{d\xi}(0) + 2Fc_0T_1^4\frac{q(0)}{\varepsilon},$$

we obtain for $\bar{\lambda}_{э\phi} = \frac{\lambda_{э\phi}}{\lambda}$ the expression

$$\bar{\lambda}_{э\phi} = 4\frac{\delta}{H}(l + \sigma/l)\frac{\varphi(\sigma, l, \varepsilon)}{f(\sigma, l, \varepsilon)}, \quad (12)$$

being determined by dimensionless parameters $\bar{\delta} = \frac{\delta}{H}, l, \sigma, \varepsilon.$
In the case of little influence of radiation ($\sigma \simeq 0$) or heat conductivity ($\sigma \to \infty$) formula (12) turns into formula

$$\bar{\lambda}_{э\phi} = 4\bar{\delta}l = \frac{\delta L}{F} \quad (13)$$

and

$$\bar{\lambda}_{э\phi} = 4\bar{\delta}\frac{\sigma}{1+l} = \frac{4c_0T_1^3H}{\lambda}\frac{1}{1+\frac{LH}{4F}} \quad (14)$$

correspondingly; in the case of a radiating capacity of the filler close to 0($\varepsilon \simeq 0$) the effective heat conductivity of a honeycomb filler, as it should be expected, is determined by the sum of equations (13) and (14)

$$\bar{\lambda}_{э\phi} = 4\bar{\delta}\left(l + \frac{\sigma}{1+l}\right). \quad (15)$$

The solution of (12) makes it possible to select the form of the honeycomb filler cells which possess the least effective heat conductivity. When $\varepsilon=0$ we obtain from (15) for the optimal magnitude of geometric parameter l:

$$l_{опт} = \sqrt{\sigma} - 1 \quad \text{when } \sigma > 1,$$
$$l_{опт} = 0 \quad \text{when } \sigma < 1.$$

This and the analogous dependence of $l_{опт}$ on σ when $\varepsilon=1$, constructed according to (12), are shown in Figure 3.

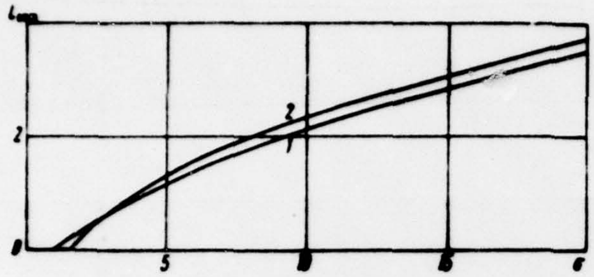


Figure 3. Dependence of $l_{опт}$ on σ:
1 - when ε=0; 2 when ε=1.

DESIGNATIONS

T - temperature (^{O}K); z - coordinate on height of filler; $q_{рез}$ - density of resulting radiant heat flow; c_0 - Stefan-Boltzmann constant; λ, ε, H, δ - heat conductivity, degree of blackness, height and half-thickness of the filler wall; L, F - length of contour and area of cell base; D - diameter; a - distance between parallel walls; $\lambda_{эф}$ - effective heat conductivity of a honeycomb filler in the direction of axis z.

BIBLIOGRAPHY

1. Поварницын М. С. ИФЖ, № 10, 1961.
2. Usiskin C. M., Siegel R. Journal of Heat Transfer, Nov., 1960.
3. Суринов Ю. А. Сб. «Теплопередача и тепловое моделирование». М., Изд-во АН СССР, 1959.
4. Власов О. Е. Известия ВТИ, № 1, 1929.
5. Якоб М. Вопросы теплопередачи, М., ИЛ, 1960.
6. Шорин С. Н. Теплопередача. М., изд-во «Высшая школа», 1964.

DISTRIBUTION LIST

DISTRIBUTION DIRECT TO RECIPIENT

ORGANIZATION		MICROFICHE
A205	DMATC	1
A210	DMAAC	2
B344	DIA/RDS-3C	9
C043	USAMIIA	1
C509	BALLISTIC RES LABS	1
C510	AIR MOBILITY R&D LAB/FIO	1
C513	PICATINNY ARSENAL	1
C535	AVIATION SYS COMD	1
C591	FSTC	5
C619	MIA REDSTONE	1
D008	NISC	1
H300	USAICE (USAREUR)	1
P005	DOE	1
P050	CIA/CRB/ADD/SD	1
NAVORDSTA (50L)		1
NASA/KSI		1
AFIT/LD		1
LLL/Code L-389		1

ORGANIZATION		MICROFICHE
E053	AF/INAKA	1
E017	AF/RDXTR-W	1
E403	AFSC/INA	1
E404	AEDC	1
E408	AFWL	1
E410	ADTC	1
E413	ESD	2
	FTD	
	CCN	1
	ASD/FTD/NIIS	3
	NIA/PHS	1
	NIIS	2