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HEAT TRANSFER IN LAMINAR FLOW BETWEEN PARALLEL POROUS PLATES

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Abstract—The laminar incompressible flow in a two-dimensional channel with two equally porous walls has been discussed previously by the author [1, 2]. In this paper the heat-transfer problem of a discontinuous change in wall temperature is solved. It is found that for small suction Reynolds numbers the limiting Nusselt number Nu_∞ increases linearly with the suction Reynolds number. In particular injection reduces whereas suction increases the Nusselt number.

NOMENCLATURE

ψ,	stream function;
$2h$,	channel width;
x, y,	distances measured parallel and perpendicular to the channel walls respectively;
U,	velocity of fluid at $x = 0$;
V,	constant velocity of fluid at the wall;
η	$= y/h$, non-dimensional distance perpendicular to the channel walls;
$f(\eta)$,	function defined in equation (1);
ν,	coefficient of kinematic viscosity;
R	$= Vh/\nu$, suction Reynolds number;
ρ,	density;
C_p,	heat capacity at constant pressure;
K,	thermal conductivity;
T,	temperature;
x	$= x_o$, position where temperature of walls changes;
T_o, T_1,	temperature of walls for $x < x_o$, $x > x_o$ respectively;
θ	$= \dfrac{T - T_1}{T_o - T_1}$, non-dimensional temperature;
ξ	$= \dfrac{x - x_o}{h}$, non-dimensional distance along the channel;
R^*	$= Uh/\nu$, channel Reynolds number;
Pr	$= \mu C_p/K$, Prandtl number;
λ_n,	eigenvalues;
$B_n(\eta)$,	eigenfunctions;
$B_n^{(0)}$,	eigenfunctions for $R = 0$;
$B_o^{(i)}$, $B_o^{(ii)}$,	change in eigenfunctions when $R \neq 0$;
$p(\eta)$, $q(\eta)$,	functions defined by equation (15);
K_n,	constants given by equation (17);
h_1,	heat-transfer coefficient;
Nu,	Nusselt number;
Nu_∞,	the limiting Nusselt number given by ξ large;
θ_m,	mean temperature;
c_n,	constants defined by equation (25);
$\alpha, \beta, \gamma, \delta$,	constants given in equation (30).

1. INTRODUCTION

THE LAMINAR incompressible flow in a two-dimensional channel with two equally porous walls has been discussed by the author [1, 2] elsewhere. (References to other papers are contained in reference [1]). The flow through porous channels is of interest in certain heat-transfer problems. For instance, when hot fluid flows down the channel, problems which arise from overheating of the walls may be overcome by the injection of fluid through the walls. Methods of decreasing rates of heat transfer may become important in combustion chambers, exhaust nozzles and porous walled flow reactors. In the present paper the work of the author [1] is extended to include heat transfer. The problem will be treated as a forced convection problem so that, by assuming that the viscosity is independent of the temperature, the equation of motion can be solved independently to obtain the velocity distribution.

The possibility of obtaining a solution for the flow between parallel plates with equally porous walls was first observed by Berman [3]. Let x and y be distances measured parallel and perpendicular to the channel walls respectively and let u and v be the velocity components in the directions of x and y increasing respectively. Then Berman showed that the Navier–Stokes equations and the equation of continuity can be satisfied by assuming a stream function of the form

$$\psi = [hU - Vx]\, f(\eta), \quad \eta = y/h \qquad (1)$$

where $2h$ is the channel width, V is the constant velocity of suction at the wall and U is the velocity of the fluid in the x direction at $x = 0$. The velocity components are given by

$$u = \frac{1}{h}\,[hU - Vx]\, f'(\eta) \quad v = Vf(\eta) \qquad (2)$$

where the prime $'$ denotes differentiation with respect to η. The function $f(\eta)$ satisfies the non-linear differential equation

$$f''' + R\,(f'^2 - ff'') = k \qquad (3)$$

where $R = Vh/\nu$ is called the suction Reynolds number and k is a constant. If $\eta = 0$ is chosen at the centre of the channel so that the walls are given by $\eta = \pm 1$ the boundary conditions on equation (3) can be taken to be

$$\left.\begin{array}{ll} f(0) = 0 & f''(0) = 0 \\ f(1) = 1 & f'(1) = 0 \end{array}\right\} \qquad (4)$$

The condition $f(1) = 1$ implies that $R > 0$ for suction at both walls while $R < 0$ for blowing at both walls.

The series solution of equation (3) subject to conditions (4) for small R is

$$f(\eta) = \left(\frac{3}{2}\,\eta - \frac{1}{2}\,\eta^3\right) + \frac{R}{280}\,(-\eta^7 + 3\eta^3 - 2\eta) + \frac{3R^2}{280}\left(\frac{\eta^{11}}{990} - \frac{\eta^9}{36} + \frac{\eta^7}{70} + \frac{146}{2310}\,\eta^3 - \frac{703}{13860}\,\eta\right) + 0(R^3) \qquad (5)$$

and k is given by

$$k = -3 + \frac{81}{35}\,R - \frac{468}{35\cdot 770}\,R^2 + 0(R^3).$$

In Terrill [1] the solution for $f(\eta)$ given in equation (5) was found to be accurate within the range $|R| < 7$. The first term of solution (5) is the parabolic velocity profile for laminar flow through impermeable parallel plates. The solution of equation (3) for large positive R has been discussed by Terrill [1] and for large negative R by Yuan [4] and Terrill [2]. However, for a heat-transfer problem the case of small injection or suction rate appears to be of most interest.

Numerous heat-transfer problems for laminar flow between parallel impermeable plates have been considered by various authors. Prins, Mulder and Schenk [5] solved the problem of a fluid experiencing a discontinuous change of wall temperature assuming walls of infinite thermal conductivity; van der Does de Bye and Schenk [6] extended this solution to plates of finite conductivity. The temperature distribution when the walls are at different temperatures has been considered by Yih and Cermack [7] and by Schenk and Beckers [8]. Cess and Schaffer have considered both the cases of symmetrically prescribed heat flux [9] and unsymmetrically prescribed heat flux [10].

In principle it appears that any of these problems could be extended to laminar flow through a channel with porous walls; in the present paper only the case of fluid experiencing a discontinuous change in wall temperature where the walls are of infinite thermal conductivity will be investigated.

Let the temperature of the walls and the fluid be $T = T_o$ for $x < x_o$ and let $T = T_1$ be the constant temperature of the walls for $x > x_o$. The energy equation for incompressible flow neglecting viscous dissipation is

$$\rho\, C_p \left(u\,\frac{\partial T}{\partial x} + v\,\frac{\partial T}{\partial y}\right) = K\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2}\right) \qquad (6)$$

where C_p is the specific heat at constant pressure and K is the thermal conductivity. Introducing a non-dimensional temperature

$$\theta = \frac{T - T_1}{T_o - T_1}$$

and neglecting the longitudinal heat conduction we can rewrite the equation as

$$u \frac{\partial \theta}{\partial \xi} + v \frac{\partial \theta}{\partial \eta} = \frac{K}{\rho\, C_p\, h} \frac{\partial^2 \theta}{\partial \eta^2} \qquad (7)$$

where $\xi = (x - x_o)/h$. If the velocity components from (2) are substituted into equation (7) then

$$\left(1 - \frac{R}{R^*}\,\xi\right) f'(\eta) \frac{\partial \theta}{\partial \xi} + \frac{R}{R^*} f(\eta) \frac{\partial \theta}{\partial \eta} = \frac{1}{PrR^*} \frac{\partial^2 \theta}{\partial \eta^2} \qquad (8)$$

where $R^* = (Uh/\nu)$ is the channel Reynolds number and $Pr = (\mu C_p/K)$ is the Prandtl number.

The boundary conditions on θ are

$$\left.\begin{array}{ll} \theta = 0 & \text{at } \eta = \pm 1 \\ \theta = 1 & \text{at } \xi = 0 \end{array}\right\} \qquad (9)$$

If the plates are impermeable then $R = 0$ and equations (8) and boundary conditions (9) reduce to the problem considered by Prins, Mulder and Schenk [5].

2. SOLUTION

To separate the variables we make the substitution $\theta(\xi, \eta) = A(\xi)B(\eta)$ in equation (8) which yields

$$\left(1 - \frac{R}{R^*}\,\xi\right) \frac{A'(\xi)}{A(\xi)} = - \frac{2\lambda_n^2}{3PrR^*} \qquad (10)$$

and

$$B''(\eta) - RPrf(\eta)\, B'(\eta) + \frac{2}{3}\lambda_n^2 f'(\eta)\, B(\eta) = 0 \qquad (11)$$

where λ_n is a constant.

Equation (10) can be integrated to give

$$A(\xi) = \left(1 - \frac{R}{R^*}\,\xi\right)^{2\lambda_n{}^2/3RPr} \qquad (12)$$

It should be noted that as $R \to 0$,

$$A(\xi) \to \exp\left[- \frac{2\lambda_n^2}{3R^*Pr}\,\xi\right]$$

It is worth noting that Pr only occurs in the non-dimensional product RPr; this can be regarded as a mass-transfer Péclet number.

The solution of the heat-transfer equation is

$$\theta = \sum K_n \left(1 - \frac{R}{R^*}\,\xi\right)^{2\lambda_n{}^2/3RPr} B_n(\eta) \qquad (13)$$

where K_n are constants to be determined from the boundary condition at $\xi = 0$ and where $B_n(\eta)$ are the eigenfunctions of (11) corresponding to the eigenvalues λ_n for which solutions of (11) can satisfy the boundary conditions $\theta = 0$ at $\eta = \pm 1$. There will be an infinite set of eigenvalues λ_o, λ_1, λ_2, . . . and corresponding eigenfunctions $B_o(\eta)$, $B_1(\eta)$, $B_2(\eta)$, ...

Before we discuss the eigenvalues it is worthwhile considering equation (11) in more detail to obtain formulae for the constants K_n and for the Nusselt number.

Equation (11) may be rewritten

$$\frac{d}{d\eta}\{p(\eta)\, B_n'(\eta)\} + \lambda_n^2\, q(\eta)\, B_n(\eta) = 0 \qquad (14)$$

where

$$p(\eta) = \exp\{- RPr \int_0^\eta f(\eta)\, d\eta\}$$

$$\text{and } q(\eta) = \frac{2}{3} f'(\eta)\, p(\eta). \qquad (15)$$

For boundary conditions $B_n(\pm 1) = 0$ it can easily be shown that any two eigenfunctions $B_m(\eta)$ and $B_n(\eta)$, corresponding to different eigenvalues λ_m and λ_n respectively, are orthogonal in the range $(-1, 1)$ with respect to the weight function $q(\eta)$, that is

$$\int_{-1}^{1} q(\eta)\, B_m(\eta)\, B_n(\eta)\, d\eta = 0, \quad m \neq n. \qquad (16)$$

Substituting one of the boundary conditions (9) $\theta = 1$ at $\xi = 0$ into the solution (13) we obtain

$$\sum K_n\, B_n(\eta) = 1.$$

Hence using the relationship (9), we find the constants K_n to be given by

$$K_n = \frac{\int_{-1}^{1} q(\eta)\, B_n(\eta)\, d\eta}{\int_{-1}^{1} q(\eta)\, B_n^2(\eta)\, d\eta}. \qquad (17)$$

From the differential equation (14) it can be shown that

$$\lambda_n^2 \int_{-1}^{1} q(\eta)\, B_n(\eta)\, d\eta = -2 \left[p(\eta) \frac{\partial B_n(\eta)}{\partial \eta} \right]_{\eta=1} \tag{18}$$

and

$$\lambda_n \int_{-1}^{1} q(\eta)\, B_n^2(\eta)\, d\eta = \left[p(\eta) \frac{\partial B_n(\eta)}{\partial \eta} \frac{\partial B_n(\eta)}{\partial \lambda_n} \right]_{\eta=1} \tag{19}$$

so that

$$K_n = \frac{-2}{\lambda_n\, [\{\partial B_n(\eta)\}/\partial \lambda_n]_{\eta=1}} \tag{20}$$

Thus if the eigenvalues and eigenfunctions of equation (11) are found then the complete solution for θ can be obtained from equations (13) and (20).

The Nusselt number based on the channel width is given by

$$Nu = \frac{2hh_1}{K} = -\frac{2}{\theta_m} \left(\frac{\partial \theta}{\partial \eta}\right)_{\eta=1} \tag{21}$$

where h_1 is the heat-transfer coefficient and θ_m the mean non-dimensional temperature is given by

$$\theta_m = \frac{\int_{-1}^{1} \theta u\, d\eta}{\int_{-1}^{1} u\, d\eta}. \tag{22}$$

Substitution of θ from (13) and u from (2) gives

$$\theta_m = \sum c_n \left(1 - \frac{R}{R^*} \xi\right)^{2\lambda_n{}^2/3RPr} \tag{23}$$

where

$$c_n = \int_{-1}^{1} \frac{K_n\, B_n(\eta)\, f'(\eta)\, d\eta}{2}. \tag{24}$$

Integration of equation (11) gives

$$\int_{-1}^{1} B_n(\eta) f'(\eta)\, d\eta = -\frac{2\, (\partial B_n/\partial \eta)}{(\frac{2}{3}\lambda_n^2 + RPr)}$$

so that

$$c_n = -\left(\frac{\partial B_n}{\partial \eta}\right)_{\eta=1} K_n/(\tfrac{2}{3}\lambda_n^2 + RPr). \tag{25}$$

Hence the Nusselt number is

$$Nu = -2 \frac{\sum K_n \left(1 - \frac{R}{R^*}\xi\right)^{2\lambda_n{}^2/3RPr} \left(\frac{\partial B_n(\eta)}{\partial \eta}\right)_{\eta=1}}{\sum c_n \left(1 - \frac{R}{R^*}\xi\right)^{2\lambda_n{}^2/3RPr}} \tag{26}$$

where c_n are given by (25) and K_n by (20).

Finally sufficiently far downstream only the first term will remain in each of the series expansions† so that the limiting Nusselt number is

$$Nu_\infty = 2\, (\tfrac{2}{3}\lambda_o^2 + RPr)$$

When $R \to 0$ the above solution reduces to the solution given by Prins, Mulder and Schenk [5]. It should be noted that the Nusselt number given in this paper is based in the channel width whereas Prins, Mulder and Schenk used a Nusselt number based on half the channel width; hence the appearance of the factor 2 in equations (21), (26) and (27).

In the above solution no restrictions have been placed on the function $f(\eta)$ and therefore, provided longitudinal heat conduction is negligible, there is no reason why the solutions given by the author [1, 2] for various ranges of suction Reynolds number could not be substituted and the resulting heat-transfer equation solved. For practical purposes it seems reasonable to suppose that R is small and so only the solution for small R will be discussed more fully.

† For this statement to be true we have to show that $[1 - (R/R^*)\,\xi]^{2/3RPr}$ can be made as small as we require by taking ξ sufficiently large. When R is small it has already been seen that $[1 - (R/R^*)\,\xi]^{2/3RPr}$ behaves like $\exp[-(2\xi/3R^*Pr)]$ which clearly can be made as small as we desire by choosing ξ sufficiently large. If R is negative then $1 - (R/R^*)\,\xi$ is greater than one and, by choosing ξ sufficiently large, can be made as large as we require; since $(2/3RPr)$ is negative $[1 - (R/R^*)\,\xi]^{2/3RPr}$ can be made as small as we require for any negative value of R. If R is positive then $[1 \geqslant 1 - (R/R^*)\,\xi > 0]$, the lower bound being the condition for fluid to remain in the tube. Thus $[1 - (R/R^*)\,\xi]$ is small far downstream and since $(2/3RPr)$ is positive $[1 - (R/R^*)\,\xi]^{2/3RPr}$ can be made as small as we require by choosing ξ sufficiently large.

3. THE SOLUTION FOR SMALL SUCTION REYNOLDS NUMBERS

To obtain a complete solution of the problem the eigenvalues and eigenfunctions of equation (11) subject to the boundary conditions

$$B(\pm 1) = 0$$

are required. The solution for $R = 0$ has been given by Prins, Mulder and Schenk and their results for the first three eigenvalues λ_o, λ_1 and λ_2 and the corresponding eigenfunctions $B_o^{(0)}(\eta)$, $B_1^{(0)}(\eta)$ and $B_2^{(0)}(\eta)$ are given in Table 1 and Table 2 respectively.

Table 1. Eigenvalues for $R = 0$

n	λ_n	$\left(\frac{\partial B_n^{(0)}}{\partial \lambda_n}\right)_{\eta=1}$	$\left(\frac{\partial B_n^{(0)}}{\partial \eta}\right)_{\eta=1}$	K_n	c_n
0	1·6816	−0·990	−1·434	+1·201	0·914
1	5·6699	+1·21	+3·86	−0·292	0·053
2	9·6678	−1·35	−5·9	+0·153	0·015

For a flow with porous walls only the change in the first and most important eigenvalue λ_o will be discussed. The second and third eigenvalues for $R = 0$ will be included to show the magnitude of the succeeding terms of the series

Table 2. Eigenfunctions for $R = 0$

η	$B_o^{(0)}(\eta)$	$B_1^{(0)}(\eta)$	$B_2^{(0)}(\eta)$
0	1·0000	1·0000	1·0000
0·1	0·9859	0·8437	0·5686
0·2	0·9443	0·4261	−0·3512
0·3	0·8772	−0·1206	−0·9842
0·4	0·7876	−0·6346	−0·8414
0·5	0·6793	−0·9833	−0·0750
0·6	0·5566	−1·1014	+0·7539
0·7	0·4238	−0·9974	+1·1669
0·8	0·2848	−0·7311	+1·0500
0·9	0·1429	−0·3788	+0·5813
1·0	0·0000	0·0000	0·0000

and also because the effect of suction can be compared with these terms. The equation for λ_o is

$$B_o''(\eta) - RPrf(\eta)\, B_o'(\eta) + \tfrac{2}{3}\,\lambda_o^2 f'(\eta)\, B_o(\eta) = 0 \tag{28}$$

where $f(\eta)$ is given by equation (5). If we write

$$\lambda_o^2 = 2{\cdot}828 + \alpha RPr + \beta R^2 Pr^2 + \gamma R^3 Pr^3 + \delta R + 0(R^2, R^2 Pr, R^4 Pr^4)$$

and

$$B_o(\eta) = B_o^{(0)}(\eta) + B_o^{(i)} RPr + B_o^{(ii)} R^2 Pr^2 + B_o^{(iii)} R^3 Pr^3 + B_o^{(iv)} R + \ldots \tag{29}$$

and substitute into equation (28) then we can show that

$$\left.\begin{aligned} \alpha &= -0{\cdot}750 & \beta &= 0{\cdot}065 \\ \delta &= 0{\cdot}0076 & \gamma &= 0(0{\cdot}001) \end{aligned}\right\} \tag{30}$$

In equation (30) and in the following results $0(x)$ means that the numerical value is close to the value x. The function $B_o^{(0)}(\eta)$ has been tabulated in Table 2 and the functions $B_o^{(i)}(\eta)$ and $B_o^{(ii)}(\eta)$ are tabulated in Table 3. The functions $B_o^{(iii)}(\eta)$ and $B_o^{(iv)}(\eta)$ are only significant in the fourth decimal place and have, therefore, been omitted.

The non-dimensional temperature θ is given by equation (13) which requires the value of K_o given by equation (20). Now

$$\left[\frac{\partial B_o(\eta)}{\partial \lambda_o}\right]_{\eta=1} = -\,0{\cdot}990 - 0{\cdot}18\, RPr - 0{\cdot}01\, R^2 Pr^2 + 0{\cdot}002\, R + \ldots \tag{31}$$

so that

$$K_o = 1{\cdot}201 - 0{\cdot}06\, RPr + 0{\cdot}020\, R^2 Pr^2 + 0{\cdot}001\, R + \ldots \tag{32}$$

Hence the non-dimensional temperature distribution is

Table 3. The functions $B_o^{(i)}(\eta)$ and $B_o^{(ii)}(\eta)$

η	0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
$B_o^{(i)}(\eta)$	0	0·0037	0·0141	0·0292	0·0460	0·0612	0·0710	0·0726	0·0634	0·0423	0
$B_o^{(ii)}(\eta)$	0	−0·0003	−0·0011	−0·0018	−0·0027	−0·0019	−0·0006	0·0013	0·0029	0·0029	0

$$\left.\begin{aligned}\theta = {} & [1{\cdot}201 - 0{\cdot}06\, RPr + 0{\cdot}020\, R^2Pr^2 \\ & + 0{\cdot}001\, R + \ldots]\, [B_o^{(0)} \\ & + RPr\, B_o^{(i)} + R^2Pr^2\, B_o^{(ii)} \\ & + \ldots] \left(1 - \frac{R}{R^*}\,\xi\right)^{2\lambda_o{}^2/3RPr} \\ & - 0{\cdot}292\, B_1(\eta) \left(1 - \frac{R}{R^*}\,\xi\right)^{+21{\cdot}43/RPr} \\ & + 0{\cdot}153 \left(1 - \frac{R}{R^*}\,\xi\right)^{+62{\cdot}31/RPr} \\ & \times B_2(\eta) + \ldots\end{aligned}\right\} \quad (33)$$

where

$$\lambda_o^2 = 2{\cdot}828 - 0{\cdot}750\, RPr + 0{\cdot}065\, R^2Pr^2 + 0{\cdot}0076\, R + \ldots \quad (34)$$

In the second and third eigenfunctions in the above equations the effect of suction has not been calculated.

The mean temperature can be obtained from equations (23) and (25). Now $[\partial B_o(\eta)/\partial\eta]_{\eta=1}$ is given by

$$\left[\frac{\partial B_o(\eta)}{\partial\eta}\right]_{\eta=1} = -1{\cdot}434 - 0{\cdot}39\, RPr - 0{\cdot}05\, R^2Pr^2 - 0(0{\cdot}001)\, R$$

so that

$$c_o = 0{\cdot}914 - 0{\cdot}04\, RPr + 0{\cdot}025\, R^2Pr^2 - 0(0{\cdot}002)\, R. \quad (35)$$

Hence the mean temperature is

$$\begin{aligned}\theta_m = {} & (0{\cdot}914 - 0{\cdot}04\, RPr \\ & + 0{\cdot}025\, R^2Pr^2 + \ldots) \left(1 - \frac{R}{R^*}\,\xi\right)^{2\lambda_o{}^2/3RPr} \\ & + (0{\cdot}053) \left(1 - \frac{R}{R^*}\,\xi\right)^{-21{\cdot}43/RPr} \\ & + 0{\cdot}015 \left(1 - \frac{R}{R^*}\,\xi\right)^{-62{\cdot}31/RPr}\end{aligned} \quad (36)$$

where λ_o^2 is given in equation (34). If we substitute the above value for θ_m we can obtain the Nusselt number from equation (26). In particular for ξ sufficiently large the limiting Nusselt number is given by

$$Nu_\infty = 3{\cdot}77 + RPr + 0{\cdot}087\, R^2Pr^2 + 0{\cdot}010\, R + 0(0{\cdot}001)\, R^3Pr^3 + \ldots \quad (37)$$

Table 4. Nusselt number for various RPr

RPr	−3	−2	−1	−0·5	0	0·5	1	2	3
Nu_∞	1·5	2·1	2·9	3·3	3·77	4·3	4·9	6·1	7·6

Values of the limiting Nusselt number have been given for various values of RPr in Table 4. In Terrill [1] the solution for $f(\eta)$ given in equation (5) was found to be accurate within the range $|R| < 7$ and in the same way expansion (37) suggests that the limiting Nusselt number will be accurate for RPr in the range $|RPr| < 3$. The Nusselt number increases with increasing Reynolds number; in particular injection decreases Nu_∞ whereas suction increases Nu_∞. In Terrill [1] the skin friction was found to increase with R for small suction Reynolds number and so it is consistent that the Nusselt number increases with R.

REFERENCES

1. R. M. Terrill, Laminar flow in a uniformly porous channel, *Aeronaut. Q.* **15**, 299–310 (1964).
2. R. M. Terrill, *Aeronaut. Q.* To be published.
3. A. S. Berman, Laminar flow in channels with porous walls, *J. Appl. Phys.* **24**, 1232 (1953).
4. S. W. Yuan, Further investigations of laminar flow in channels with porous walls, *J. Appl. Phys.* **27**, 267 (1956).
5. J. A. Prins, J. Mulder and J. Schenk, Heat transfer in laminary flow between parallel plates, *Appl. Scient. Res.* **A2**, 431 (1950).
6. J. A. W. van der Does de Bye and J. Schenk, Heat transfer in laminary flow between parallel plates, *Appl. Scient. Res.* **A3**, 308 (1952).
7. C. S. Yih and J. E. Cermack, Laminar heat convection in pipes and ducts, Report No. 5, Civil Engineering Dept., Colorado Agricultural and Mechanical College (September 1951).
8. J. Schenk and H. L. Beckers, Heat transfer in laminar flow between parallel plates, *Appl. Scient. Res.* **A4**, 405 (1954).
9. R. D. Cess and E. C. Schaffer, Heat transfer to laminar flow between parallel plates with a prescribed heat flux, *Appl. Scient. Res.* **A8**, 339 (1959).
10. R. D. Cess and E. C. Schaffer, Heat transfer between parallel plates, *Appl. Scient. Res.* **A9**, 64 (1959).

Résumé—L'écoulement laminaire incompressible dans une conduite bidimensionnelle avec deux parois poreuses identiques a été discuté auparavant par l'auteur [1, 2]. Dans et article, le problème du transport de chaleur avec une variation discontinue de la température pariétale est résolu. On trouve que, pour de petits nombres de Reynolds d'aspiration, le nombre de Nusselt limite Nu_{∞} augmente linéairement avec le nombre de Reynolds d'aspiration. En particulier, l'injection diminue tandis que l'aspiration augmente le nombre de Nusselt.

Zusammenfassung—Die laminare, inkompressible Strömung in einem zweidimensionalen Kanal mit zwei gleich porösen Wänden ist vor kurzem vom Author diskutiert worden [1, 2]. Hier wird das Wärmeübergangsproblem für nicht kontinuierliche Änderung der Wandtemperatur gelöst. Es zeigt sich, dass für kleine Absaug-Reynoldszahlen die Grenz-Nusseltzahl Nu_{∞} linear mit der Absaug-Reynoldszahl zunimmt. Einblasung vermindert die Nusseltzahl währen Absaugung sie erhöht.

Аннотация—Ранее в работах [1, 2] автор рассматривал ламинарный несжимаемый поток в двумерном канале с двумя равнопористыми стенками. В данной статье решается задача теплообмена при изменении температуры стенки скачком. Найдено, что для малых чисел Рейнольдса отсоса предельное число Нуссельта $Иu_{\infty}$ линейно увеличивается с увеличением числа Рейнольдса отсоса. Найдено, что вдув уменьшает, а отсос увеличивает число Нуссельта.