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Note on the Effect of Variable Wall Temperature on Heat Transfer

By

H. B. SQUIRE, M.A.,
of the Aerodynamics Division, N.P.L.

(Being an Addendum to "Heat Transfer Calculation for Aerofoils" by H. B. Squire (R. & M. 1986, November, 1942))

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Two recent papers[1,2] have investigated the effect of variable surface temperature on heat transfer. It seems therefore worth while to record the extension of the method given in R. & M. 1986 to the case of variable surface temperature.

Using the same notation as in R. & M. 1986, T_1 the surface temperature is now assumed to be a function of x, the distance along the surface from the front stagnation point. In place of the equation following (6) in R. & M. 1986 we have

$$\frac{d}{dx}\left[U(T_1 - T_0)\delta_2\phi\left(\frac{\delta_2}{\delta_1}\right)\right] = \frac{0\cdot 5715\kappa(T_1 - T_0)}{\delta_2}$$

for which the integral is

$$\left[U(T_1 - T_0)\delta_2\phi\left(\frac{\delta_2}{\delta_1}\right)\right]^2 = 1\cdot 143\kappa\int_0^x U(T_1 - T_0)^2\phi\, dx.$$

In place of (7) we get

$$\frac{\delta_2^{\,2}}{\delta_1^{\,2}}\,\phi\left(\frac{\delta_2}{\delta_1}\right) = \frac{0\cdot 3861}{\sigma}\;\frac{U^4\int_0^x U(T_1 - T_0)^2\phi\, dx}{(T_1 - T_0)^2\phi\int_0^x U^5\, dx}, \qquad (7')$$

and in place of (8)

$$\frac{\delta_2^{\,2}}{\delta_1^{\,2}}\,\phi\left(\frac{\delta_2}{\delta_1}\right) = \frac{0\cdot 3861}{\sigma}\;\frac{U^4\int_0^x U(T_1 - T_0)^2\, dx}{(T_1 - T_0)^2\int_0^x U^5\, dx}. \qquad (8')$$

For the case of a flat plate with uniform stream velocity the exact solutions for variable wall temperatures of the form $(T_1 - T_0) = a_n x^n$ have been worked out by Chapman and Rubesin[1] for $\sigma = 0\cdot 72$ and $n = 0, 1, 2, 3, 4, 5$ and 10, and Lighthill[2] has applied his method to this case. A comparison is given in Table I between the accurate values of the surface temperature gradient and the values given by (7′) or (8′) for this case. It will be seen that the approxi-

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mate method gives an error of 16 per cent for $n > 2$. Lighthill's method gives errors of order 2 per cent for this case. However, the present method is more accurate than Lighthill's method for non-uniform stream velocity and uniform surface temperature. No comparison for a case of variable stream velocity and variable surface temperature is available at present.

TABLE I

Values of $-\left(\frac{\nu x}{U_0}\right)^{1/2} \frac{(\partial T/\partial y)_1}{(T_1 - T_0)}$ *for the flat plate with* $\sigma = 0 \cdot 72$, $(T_1 - T_0) = a_n x^n$

n	0	1	2	3	4	5	10
Exact solution	0·296	0·489	0·597	0·684	0·744	0·799	1·006
Approximate solution	0·295	0·436	0·519	0·579	0·633	0·681	0·842
Error, per cent	—	10	16	16	16	16	16

REFERENCES

No.	*Author*	*Title, etc.*
1	D. R. Chapman and M. W. Rubesin	*Journ. Aero. Sciences.* Vol. 16, p. 547. (1949).
2	M. J. Lighthill	*Proc. Roy. Soc.* Vol. A.202, p. 359. (1950).

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