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VORTICAL INTERACTION OF A SPATIAL LAMINAR BOUNDARY LAYER ON A C--ETC(U)  
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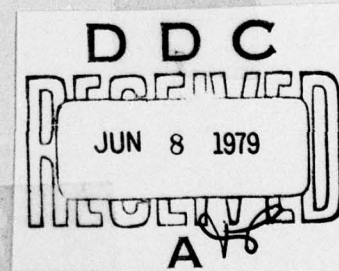
# FOREIGN TECHNOLOGY DIVISION



VORTICAL INTERACTION OF A SPATIAL LAMINAR BOUNDARY  
LAYER ON A CIRCULAR CONE WITH THE EXTERNAL  
(NONVISCIOUS) FLOW AT SUPERSONIC SPEEDS

by

B. M. Bulakh



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## EDITED TRANSLATION

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

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

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	sinh <sup>-1</sup>
cos	cos	ch	cosh	arc ch	cosh <sup>-1</sup>
tg	tan	th	tanh	arc th	tanh <sup>-1</sup>
ctg	cot	cth	coth	arc cth	coth <sup>-1</sup>
sec	sec	sch	sech	arc sch	sech <sup>-1</sup>
cosec	csc	csch	csch	arc csch	csch <sup>-1</sup>

Russian	English
rot	curl
lg	log

VORTICAL INTERACTION OF A SPATIAL LAMINAR BOUNDARY LAYER ON A CIRCULAR CONE WITH THE EXTERNAL (NONVISCIOUS) FLOW AT SUPERSONIC SPEEDS

B. M. Bulakh

We have detected the phenomenon of a vortical interaction of a boundary layer and external flow with moderate supersonic speeds. It was shown that for a circular cone the phenomenon of vortical interaction is described by a self-modeling solution.

We are examining the problem of a boundary layer on a circular cone, streamlined by a uniform supersonic flow of gas under the angle of attack  $\alpha$ . The author established earlier (in a work published at the MZhG) that in a system of spherical coordinates  $r, \theta, \varphi$ , where axis  $\theta=0$  coincides with the axis of symmetry of the cone, the behavior of density  $\rho$ , component of speed  $u, w$ , in the direction of an increase, respectively, of  $r$  and  $\varphi$  in the vicinity of the surface of the cone is determined by the formula

$$f = f_0(\varphi) + f_1(\varphi)(\theta - \theta_0)^B + \dots \quad (1)$$

where  $f = \rho, u, w; f_0, f_1$  - some functions of  $\varphi; \theta_0$  - angle of the partial opening of the cone;  $B$  - the constant which in the majority of

cases is less than a unit; a dotted line designates the members of a higher order of smallness with respect to  $\epsilon \rightarrow 0$ , than those given. For cases of  $B \ll 1$  the nonviscous flow near the surface of the cone whirls powerfully, which renders a significant influence on the boundary layer. If  $Re$  is the Reynolds number of the problem,  $\epsilon = (Re)^{-1/2}$  then in the system of coordinates where  $s$  is read off from the top of the cone along its generatrix,  $n$  - along the normal to the surface of the cone, the solution to the problem on the boundary layer has the form:

$$\left. \begin{aligned} u &= u_1(\zeta, \varphi) + \epsilon^2 s^{-2} u_2(\zeta, \varphi) + o(\epsilon^2), \\ w &= w_1(\zeta, \varphi) + \epsilon^2 s^{-2} w_2(\zeta, \varphi) + o(\epsilon^2), \\ v &= \frac{\epsilon}{\sqrt{s}} \left[ V_1(\zeta, \varphi) + \epsilon^2 s^{-2} V_2(\zeta, \varphi) + o(\epsilon^2) \right], \\ \rho &= \rho_1(\zeta, \varphi) + \epsilon^2 s^{-2} \rho_2(\zeta, \varphi) + o(\epsilon^2), \\ T &= T_1(\zeta, \varphi) + \epsilon^2 s^{-2} T_2(\zeta, \varphi) + o(\epsilon^2), \\ p &= p_1(\zeta) + o(\epsilon^2), \end{aligned} \right\} \quad (2)$$

here  $u, v, w$  - components of the speed of particles of gas in the direction of an increase, respectively, of  $s, n, \varphi$ ;  $\rho, p$  - density and pressure,  $T$  - absolute temperature:  $\rho = \frac{N}{V}, N = n s^{-1}$ .

The members with subscript "1" in formulas (2) give the known (self-modeling) solution to the problem of boundary layer; members with subscript "2" occur as a result of the vortical interaction of the external flow and the boundary layer. Equations for  $u_2, w_2, V_2, \rho_2, T_2$  are analogous to the equations for  $u_1, w_1, V_1, \rho_1, T_1$ ; boundary conditions are different; therefore they are given thusly:

$$\left. \begin{aligned} \zeta=0, \quad u_1 = V_1 = w_1 = 0, \quad T_1 = T_\infty, \\ \zeta \rightarrow \infty, \quad u_1 \rightarrow u_0(\varphi), \quad w_1 \rightarrow w_0(\varphi), \quad T_1 \rightarrow T_0(\varphi); \\ \zeta=0, \quad u_2 = V_2 = w_2 = 0, \quad T_2 = 0, \\ \zeta \rightarrow \infty, \quad u_2 \sim A_1(\varphi) \zeta^2, \quad w_2 \sim A_2(\varphi) \zeta^2, \quad T_2 \sim A_3(\varphi) \zeta^2. \end{aligned} \right\}$$

Here functions  $\varphi_1, \varphi_2, \varphi_3, A_1, A_2, A_3$  are determined from the solution to the problem for the external, nonviscous flow;  $T_w$  - temperature of the surface of the cone. An indirect evaluation of the value of a check for the results of the normal theory of the boundary layer due to the vortical interaction can be done by means of evaluating the multiplier  $\varepsilon^B$  in formulas (2).

For example, for the Mach number of an undisturbed flow  $M=5$   $\theta_0=20^\circ, \alpha=10^\circ, B \approx 0.33$ ; for values  $M=7$   $\theta_0=30^\circ, \alpha=5^\circ, B \approx 0.075$ ; if we take  $Re=10^6$ , then  $\varepsilon=10^{-3}$  and for the modes given above the flows of the cone are, respectively:

$$\varepsilon^B \approx 0.1 \text{ and } \varepsilon^B \approx 0.6.$$

Consequently, we can anticipate that the corresponding checks are achieved in a number of cases to tens of percents.

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