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POSSIBILITIES OF LAMINARIZATION OF ELECTROHYDRODYNAMIC FLOWS.(U)
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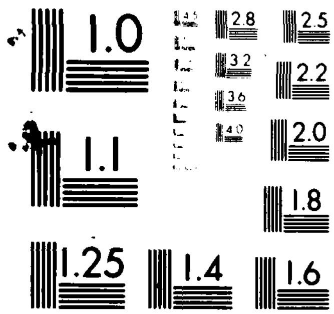

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FOREIGN TECHNOLOGY DIVISION

POSSIBILITIES OF LAMINARIZATION OF ELECTROHYDRODYNAMIC FLOWS

by

Ye.P. Udartsev

EDITED TRANSLATION

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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

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POSSIBILITIES OF LAMINARIZATION OF ELECTROHYDRODYNAMIC FLOWS

Ye. P. Udartsev. (Kiev)

The investigation of the stability of electrohydrodynamic flows is interesting from the viewpoint of their use for active influence on the boundary layer. Electrophysical action can lead both to increase of the critical Reynolds number and to its decrease. Raising the critical Reynolds number - laminarization of flow - is a problem which can be examined in linear formulation by methods of the theory of hydrodynamic stability [2]. With the presence of charged gas component in the flow, being characterized by the value of volume charge q, and the application on flow of an electrical field with intensity $\bar{E}$ the mass pondermotive force, appearing in the flow, is expressed in the form [1]

$$\bar{F} = q\bar{E} = \frac{\bar{E}}{4\pi} \operatorname{div} \varepsilon \bar{E}, \qquad (1)$$

where ε - dielectric constant of medium. This mass force at certain moments of development of instability of laminar flow can compare in value with the forces, causing the instability.

Interest in the problem of instability of charged gas in an electric field appeared during investigation of heat transfer in the loop of a nuclear reactor [3]. In work [3] was formulated the Poiseuille problem of flow instability with the presence of nonunipolar charge in the flow and application of the field perpendicular to flow.

On the basis of the linear theory of instability, equations of thermodynamically irreversible processes and equations of electrodynamics the basic Orr-Sommerfeld type equation of stability was obtained:

$$(U-c)(f''-\alpha^2 f)-(U-c)fU''+\frac{Eel\,\mathrm{dn/dy}}{\varrho U^2}f=$$
$$=\frac{1}{\alpha\,\mathrm{Re}}(U-c)[\alpha^2(f''-\alpha^2 f)-(f''-\alpha^2 f)''], \qquad (2)$$

where f - perturbation amplitude of flow function; n - ion concentration; e - elementary charge.

During the derivation of equation (2) the drift of ions was not considered, but it was noted that such simplifying assumption cannot be correctly justified. With constant value of ion concentration the additional term, caused by the electrical action, becomes zero.

This problem was examined from the positions of electrohydrodynamics. The system of equations obtained as a result, describing the stability of Poiseuille plane flow, has the form

$$(U-c)(f''-\alpha^2 f)-U''f+\frac{\mathrm{Eu}_э}{4\pi}[E_0'h-E_0(h''-\alpha^2 h)]=$$

$$=-\frac{i}{\alpha\,\mathrm{Re}}(f^{\mathrm{IV}}-2\alpha^2 f+\alpha f), \qquad (3)$$

$$(U-c)(h''-\alpha^2 h)=\frac{i}{\alpha\,\mathrm{Re}_э}[2E_0(h''-\alpha^2 h)+E_0(h''-\alpha^2 h)+$$

$$+E_0''h']+E_0''f, \qquad (4)$$

where U - velocity profile of the main flow; c - parameter of growth of oscillations; f - perturbation amplitude of current function; h - perturbation amplitude of electric field potential; $\mathrm{Eu}_э=\frac{qUE_0}{\varrho U_m^2}$ — "electric" Euler number; $\mathrm{Re}_э=\frac{U_m}{bE}$ — "electric" Reynolds number; b- ion mobility.

Equation (3) includes parameter $\mathrm{Eu}_э$ determining the degree of electrophysical action. During formulation of the problem on eigenvalues this parameter will enter the secular equation. The curve of neutral stability now is determined from equation

$$F(\alpha, \mathrm{Re}, \mathrm{Eu}_э, c)=0. \qquad (5)$$

The system of equations (3), (4) is rather complex for analysis. It is considerably simplified with the assumption of constancy of the amount of volume charge, which can be assumed on certain small sections. In this case the equations are reduced to the form

$$(U-c)(f''-\alpha^2 f)-U''f-\frac{\mathrm{Eu}_9}{4\pi}E_0(h''-\alpha^2 h)=$$

$$=-\frac{i}{\alpha\,\mathrm{Re}}(f^{IV}-2\alpha^2 f+\alpha f), \qquad (6)$$

$$(U-c)(h''-\alpha^2 h)=i\frac{4\pi bq}{\mathrm{Re}_9}[2(h''-\alpha^2 h)+y(h''-\alpha^2 h)']. \qquad (7)$$

This system can be solved by methods of the theory of hydrodynamic stability. However, such a solution is complicated. As in the classical case of theory of hydrodynamic stability (2), the total stability of flow can be determined by sufficient conditions of stability. In our problem such conditions are determined during examination of the acceptability of the Rayleigh theorem for some problems of stability in electrohydrodynamics.

Assuming that the field is directed from the axis of the channel to the walls, determining the boundary conditions on the axis of the channel and on the wall as

$$f'(0)=0; \qquad f'(1)=f(1)=0, \qquad (8)$$

we obtain that the velocity component of the disturbing motion in the critical layer (y_c) has characteristic

$$u'\approx f'=\frac{1}{U_c'}\left[U_c''-\frac{\mathrm{Eu}_9}{4\pi}E_c(h''-\alpha^2 h)_c\right]\ln(y-y_c). \qquad (9)$$

The rise of velocity u' in the final analysis leads to the development of instability. But if in the critical layer

$$U'_c = \frac{Eu_2}{4\pi} E_c (h'' - \alpha^2 h)_c, \qquad (10)$$

then u'=0; thus, the disturbing motion cannot appear under the previous conditions. On the basis of equation (10) it is possible to estimate the electrohydrodynamic parameters, sufficient for laminarizing action. Assuming $q_0 = 1k/м^3, Z = 1 м, y_c = 10^{-3}_м$, we obtain

$$E_0 = 10 \times 10^6 \frac{кГм^{(1)}}{a\, сек^{(2)}}.$$

Key: (1) kg-m. (2) s.

Value E_0 corresponds to the breakdown voltage in air. With increase of the volume charge E_0 is decreased. Radioactive isotopes can provide ionization 0.5 k/m^3 and considerably larger.

The use of radioactive isotopes is the basis of one of the possible methods of laminarization of electrohydrodynamic flows. The radioactive isotopes serve as the source of ions of different signs. The presence of ions of different signs in the field lowers the electrohydrodynamic effect, and counterdirected motion of ions can lead to instability. For confirmation of the possibility of laminarization of flows by the EHD method with the use of radioactive isotopes tests were conducted on the division of ions of different signs with the use of tritium ionizers. The experiments showed that the division of ions is achieved. As a result a scavenging ionizer was created, which can serve as the source of unipolar charge up to $q=0.5\ k/m^3$. For achievement of a large amount of volume charge it is necessary to use more powerful ionizers - polonium or other types.

It is interesting to note that during the experiments nonunipolar charged gas [1] the laminarizing action of the electrical field was noticed. Covering of the surface with a powerful source of ionization with subsequent application of an electrical field can also be one of the methods of stabilization of perturbations.

The electrohydrodynamic methods of laminarization of flows can find technical application. The main complexity for the wide development and application of these methods is the necessity of using powerful sources of ions, which is linked with technological difficulties of their manufacture and the necessity of providing biological protection.

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