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STABILITY OF A ROTATING GAS STREAM IN THE CHANGE IN THE EXTENT OF ITS TWIST

Oleg Zaitsev*, Sergey Toporen*, Vasiliy Shmonyak**, Vasiliy Nakonechniy**

* The National Academy of Nature Protection and Resort Construction
** Odessa State Academy of Construction and Architecture

Summary. The results of theoretical studies of swirling flow with a developed zone of reverse currents and the precessing vortex core, the dependences for determining the stability of the structure flow.

Key words: swirling flows, the precession, the vortex core.

INTRODUCTION

In developing the new energy-saving techniques and design solutions to reduce fuel consumption in the decentralized heat supply systems, localization of heat sources of low power and dispersion of pollutants in outdoor air is often used swirling flow. For example, one method of improving the efficiency of gas combustion in the , which [1, 3] heat-generating plants is to use the synergies of swirling flows allows for the least cost to regulate the temperature of coolant in a large range by changing the position of the maximum temperature in the space of the furnace. However, this method requires the stability of both the structure of the vortex, and exclusion flameout in the interaction of the torches. In addition, the position of the maximum temperature will depend on the penetration depth of swirling CCIP, the interaction with the zone of reverse currents of the main part of the jet, the distance between the jets and their degree of twist, the oscillation frequency of vortex cores in jets, ie the processes are not sufficiently studied at present [1].

OBJECTS AND PROBLEMS

The analysis of theoretical data and the study of factors affecting the stability of vortex structures, showed that the extent of motion of a vortex flow is an increase in the size of the vortex core and its further destruction [3]. At the same time know that the minimum angular velocity of rigid body rotation, necessary for sustained its motion is defined by [1]:

$$\omega_{\min} = \frac{2}{I} \cdot \sqrt{P \cdot a \cdot A}\text{, s}^{-1}\text{,} \qquad (1)$$

where: P - power Kareolisa, N; a - distance from the fulcrum to the center of a rotating body rotation, m; A - the moment of inertia about an axis perpendicular to the axis proper rotation, kg.m2; I - the polar moment of inertia about the central axis, kg.m2.

Given that the rotation of the vortex core is described as a rigid body rotation as the main parameters of precessing vortex core (PVC) are defined in [1] and contain the dimensionless parameter S, which characterizes the degree of twist of the gas flow, the flow of angular momentum of Go, (kg.m2/s2) , volumetric gas flow rate Q (m3 / s) associated with the oscillation frequency of the vortex core f, (Hz), we can obtain the dependence of the dimensionless parameter S, which characterizes the degree of twist of the flow of consumption, structural parameters and vibrational frequencies PVC provided the stability of the swirling flow . So, taking a foothold for the center of the jet defining moment of inertia as the moment of inertia PVC about an axis perpendicular to the axis of rotation and substituting the values of P, a, A, I in equation (1) taking into account the expressions for the main parameters P, a, A, I [1], we obtain:

$$V_{\min} = \frac{2 \cdot a^2 \cdot f}{\sqrt{R \cdot L}} \text{, m / s ,} \tag{2}$$

where: R - distance along the radius to the center PVC, m; a - distance from the center of the jet prior to the section PVC, m; L - distance from the jet to PVC in this section, m; f - frequency oscillations of the vortex core, Hz.

The flow of angular momentum of gas in a swirling flow is determined by the expression given in [2]:

$$V_{\min} = \frac{2 \cdot a^2 \cdot f}{\sqrt{R \cdot L}} \text{ , Kg·m}^2\text{/s}^2 \text{ ,} \tag{3}$$

where: ρ - density, m3/kg; umo - the maximum axial flow velocity, m / s; ωmo - maximum tangential flow velocity, m / s; d - equivalent to ¬ valence nozzle, m.

Degree steep, characterized by the dimensionless parameter S, represents the ratio of the flow of angular momentum to the flow of axial momentum times the equivalent valence nozzle. Thus, the dimensionless parameter S is defined as follows, according to [1]:

$$S = \frac{\pi}{2} \cdot \frac{G_0 \cdot d}{\rho \cdot Q^2} \text{ ,} \tag{4}$$

where: Q - volumetric flow of gas, m^3 / s.

Then, equating (2) to ωmo in (3) and substituting the expression (4) we obtain the following dependence of the degree of twist of the flux from the mass flow and the precession frequency of the vortex core in a stable equilibrium swirling jet:

$$S = \frac{\pi^2}{4} \cdot \frac{d^5 \cdot f \cdot u_{mo}}{2 \cdot Q^2} \cdot \sqrt{(\frac{a}{R})^3} \text{ ,} \tag{5}$$

where: u_{mo} - the maximum axial flow velocity, m / s; f - frequency of precession PVC, Hz; d - equivalent to ¬ valence nozzle, m; a - distance from the center of the jet prior to the section PVC, m; R - distance along the radius to the center PVC, m; Q - volumetric flow of gas, m3 / s.

Analysis of the obtained dependence shows that the degree of swirl flow is directly proportional to the oscillation frequency of precessing vortex core and is inversely proportional to the square of the mass flow of gas, that is ensuring the sustainability of vortex flow by varying the flow rate requires a corresponding change in the degree of twist (Fig. 1) or effects on the oscillation frequency PVC [1-3].

Thus, the results of studies obtained the equilibrium conditions of swirling flow in the existence of a developed zone of reverse currents and the precessing vortex core, which helps to determine the rational parameters of the equipment at a variation of its performance and the way of stabilization of swirling flow.

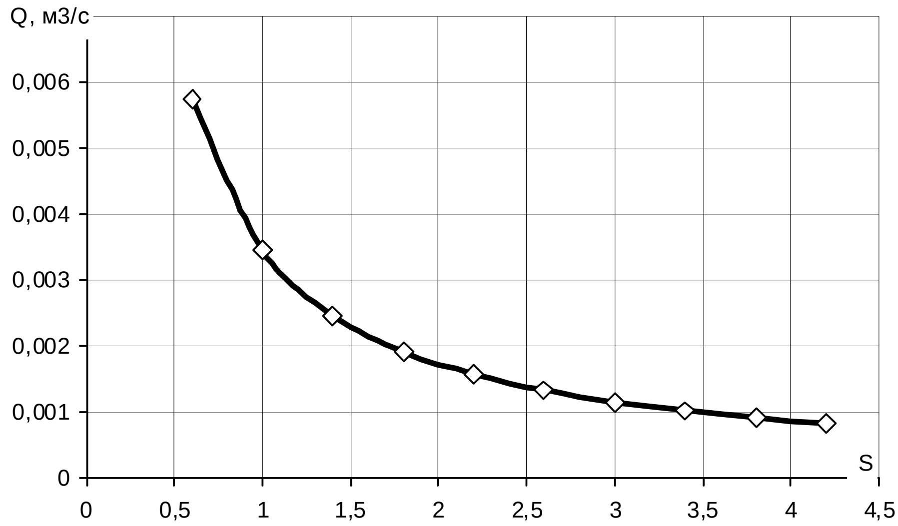

Fig.1. The dependence of the volume flow of gas from the degree of twist of the flow S

CONCLUSIONS

As a result of theoretical studies of swirling flow with a developed zone of reverse currents and the precessing vortex core obtained the following results:
1. A comparative analysis of the processes of stability in swirling flows and rotating solids obtained the degree of twist of the flow of the gas flow rate, the oscillation frequency of the vortex core and the design parameters in terms of stability of the swirling flow.
2. It was revealed that the degree of twist of the flow is directly proportional to the oscillation frequency of precessing vortex core and is inversely proportional to the square of the mass flow of gas, that is ensuring the sustainability of vortex flow by varying the flow rate requires a corresponding change in the degree of twist or effects on the oscillation frequency of precessing vortex core.

REFERENCES:

1. Закрученные потоки: Пер. с англ. / А. Гупта, Д.Лилли, Н.Сайред,-М.: Мир, 1987,—588с.
2. Штихлинг Г. Теория пограничного слоя.-М.: Наука, 1974,—711 с.
3. Зайцев О.Н. Управление аэродинамической обстановкой в рабочем объеме теплогенерирующих установок // Вісник ОДАБА №7, 2002, с. 60—64.

УСТОЙЧИВОСТЬ ВРАЩАЮЩЕГОСЯ ГАЗОВОГО ПОТОКА ПРИ ИЗМЕНЕНИИ СТЕПЕНИ ЕГО КРУТКИ

Олег Зайцев, Сергей Топорен, Василий Шмоняк, Василий Наконечный

Аннотация. Приведены результаты теоретических исследований устойчивости вращающегося потока с развитой зоной обратных потоков и прецессией вихревого ядра, при изменении степени крутки последнего.

Ключевые слова: вращающийся поток, прецессия, вихревое ядро.