NUMERICAL MODELLING CIRCULATION STREAMS UNDER ISOTHERMAL CONDITIONS

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ABSTRACT: *On the basis of a computer simulation circulation zones are formed in a rotational streamline in a chamber, the inlet of which suddenly becomes wider. The geometry of the chamber imitates a device, working with gas fuel and with central gas feed. As a result angular and axial circulation zones were formed and it is also presented how the gas feeding pipe sizes and the degree of swirl influence their dimensions.*

Introduction

Circulation zones are very important for combustion practice. They make a flow of combustion products with high temperature at the beginning of the flame and they are used to stabilize the combustion process. Under stationary conditions and combustion in the field of the flow well formed angular and axial opposite streamlines [1], [2], [3] appear.

The combustion process greatly influences the size and location of the circulation zones [4]. Some other factors also influence the streamline structure, the most important of which are:

- Degree of swirl of the air stream in the combustion chamber;
- Centrally located object and its absolute dimensions;
- Type and construction of the device, used for starting the rotation;
- Relationship between the diameters of the main chamber and the air register D/D_1.

In order to study the origin and progress of circulation zones in combustion devices, their activity under isothermal conditions is also of great interest.

Fig. 1 presents a combustion chamber with central gas fuel feed, studied in this survey. Air, necessary for the combustion, comes **through** a ring channel with inner diameter $\mathbf{D_2}$ and outer diameter $\mathbf{D_1}$ and average flow rate $\mathbf{u_a}$. Gas with velocity $\mathbf{u_f}$ enters the combustion zone through the central pipe. Air velocity and gas speed correspond to mass flows in a ratio the same as the stoichiometric of natural gas.

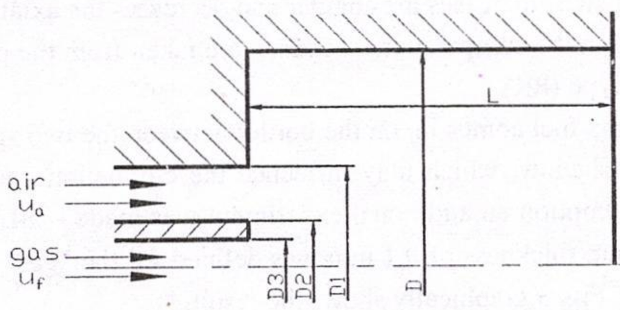


Fig. 1

Mathematical model

For the research of circulation zones in a cylindrical combustion chamber a mathematical model, including equations of saving energy, quantity of motion and keeping mass, was used. They were supplemented by the combustion equation.

It is typical that entering the vortex of speed $\vec{\Omega} = \text{rot}\vec{V}$ changes the basic combined differential equations.

The speed vortex is defined as:

$$\Omega = -\left[\frac{\partial}{\partial z}\left(\frac{1}{\rho.r}.\frac{\partial \psi}{\partial z}\right) + \frac{\partial}{\partial r}\left(\frac{1}{\rho.r}.\frac{\partial \psi}{\partial r}\right)\right]$$

where **z** is a co-ordinate, coinciding the chamber axis of symmetry and **ψ** is a streamline function.

The basic differential equations are written down like a characteristic equation of elliptic type:

$$\sum_{i=1}^{3} a_i.\frac{\partial \Phi}{\partial x_i} + \sum_{i=1}^{2} b_i.\frac{\partial}{\partial x_i}\left(c_i.\frac{\partial \Phi}{\partial x_i}\right) + d = 0,$$

where **Φ** is a natural dependent variable and the values of $\mathbf{a_i}$, $\mathbf{b_i}$, $\mathbf{c_i}$ and **d** are tabulated depending on the missing variable.

Numerical experiment.

Numerical experiments have been carried out for a combustion chamber with a diameter D=750 mm and length L= 1000 mm. The diameter of the air orifice D_1= 460mm.

Gas flows from a centrally located pipe with outer diameter D_2= 100mm and inner diameter D_3= 90mm.

These experiments were conducted with three different geometrical configurations of the central pipe. The degree of swirl (swirl number) S is also varied from 0 to S=2. It is the ratio between average integral values of the tangential and axial components of velocity [5].

Fig. 2 presents the results from Alternative one. The gas pipe wall thickness is $\frac{D_2 - D_3}{2} = 5\text{mm}$. "Fuel" has flown through the central pipe in equal quantity and mixed with air, coming through the ring channel. Some specific regular characteristics are noticed when comparing the curves. Angular and axial circulation zones exist simultaneously when the degree of swirl is S= 0,5; S= 1 and S= 2. The axial zone has maximum stretching when S=2. Reducing the degree of swirl increases the angular and decreases the axial zone.

Dimensions, used in the computational scheme, are taken from the pipe burner modified furnace steam furnace type (PK).

The wall where gas fuel comes in, on the border between the two streams – air and gas, originates streamlined shadow, which may influence the circulation zones development. In order to prove this assumption an additional experiment was made – all initial data was kept the same and a minimum thickness of 0,1 mm was defined for the "gas" pipe wall. Diameter D_1 was left unchanged. Fig. 3 graphically shows the result.

It is clearly noticeable that the central circulation zone has grown considerably and the angular is missing. This unexpected result, with only wall thickness changed, proves how important construction dimensions are in combustion practice.

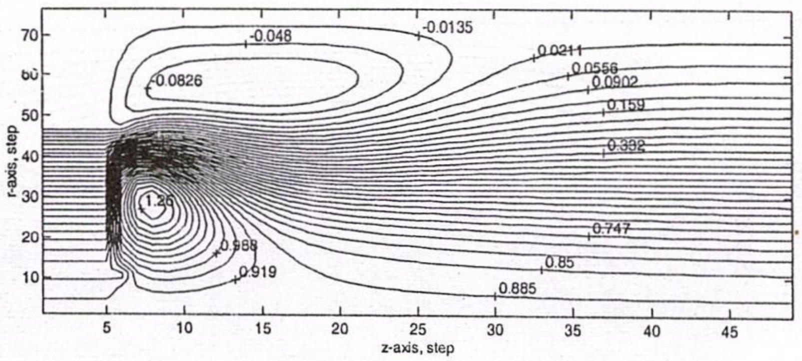


Fig. 2a) S=0,5

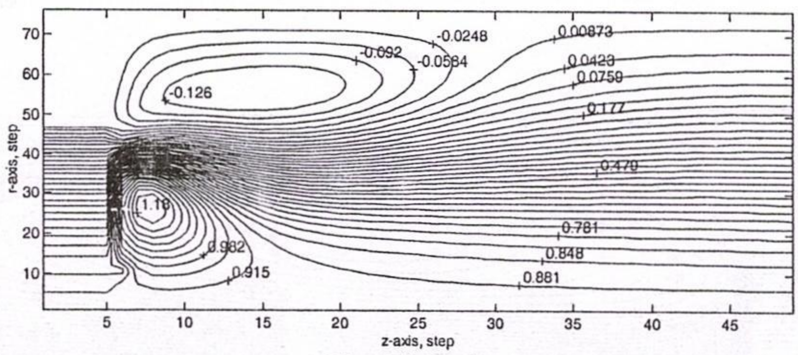


Fig. 2b) S=1

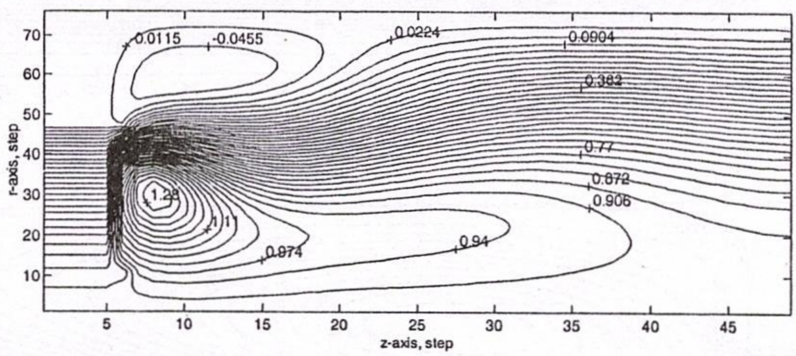


Fig. 2c) S=2

Fig. 4 shows the results of a numerical experiment in which the central gas pipe has been "removed", without giving the flow, which comes through the pipe in a real combustion apparatus.

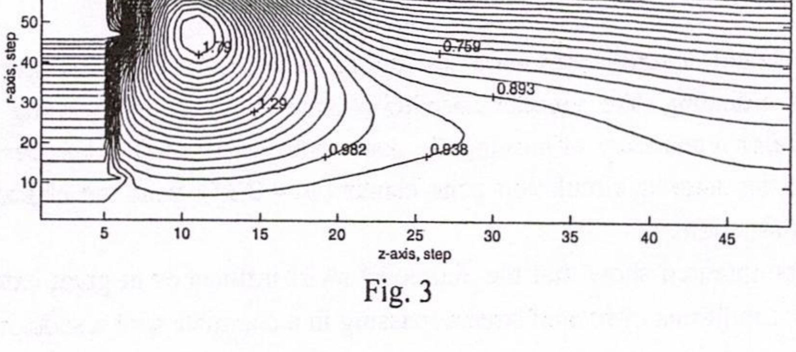
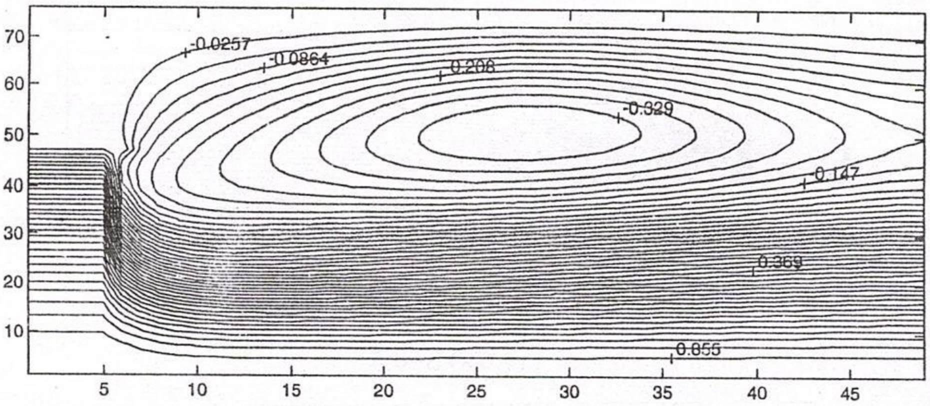
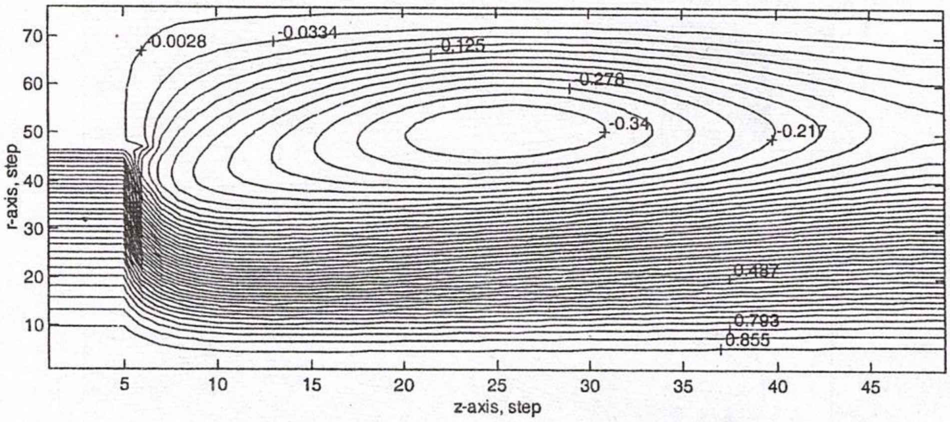


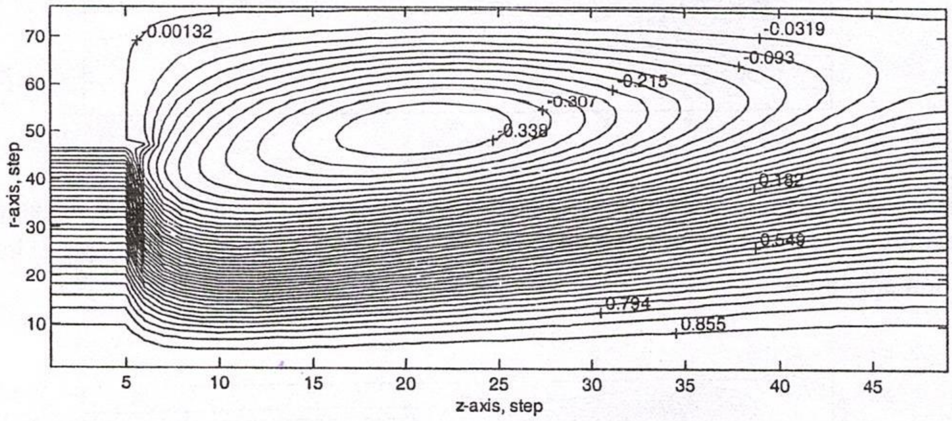
Fig. 3



a) s=0,5



b) s=1



c) s=2

Fig.4

This experiment actually presents a simulation of rotated stream, passing in a chamber with a sudden widening. The angular circulation zone decreases with rising the degree of swirl. There is also a tendency of moving the zone to the entry of the chamber. Fig. 5 shows the position of the angular circulation zone center ($\psi \approx 0,34$) from the chamber entry as a degree of swirl function.

The results obtained show that the degree of swirl influences in great extent the stream structure under conditions of rotated stream, passing in a chamber with a sudden widening.

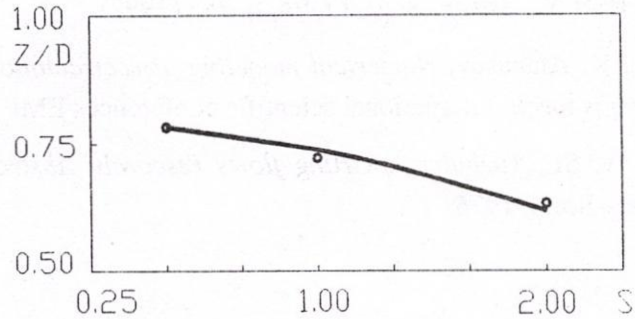


Fig.5

Conclusion

Results obtained for the distribution of rotational isothermal streamline in a chamber with a sudden widening can be used to draw the following conclusions:

1. The numerical model used herewith, gives results referring to circulation zones with axial and angular location. It is of great practical value, considering the fact that under conditions of limited stream their experimental research is actually impossible.

2. The dimensions of a centrally located gas pipe greatly influence the location of circulation zones. The influence of wall thickness is remarkable.

3. The results obtained here refer to particular geometrical characteristics, but they allow as well to conclude that, when there is a centrally located gas pipe, a stabilizing effect can be expected and reached.

MÔ HÌNH SỐ NHỮNG DÒNG HỒI LƯU TRONG ĐIỀU KIỆN ĐẲNG NHIỆT

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TÓM TẮT: *Trên cơ sở của việc mô phỏng số khu vực hồi lưu được hình thành do chuyển động xoáy ốccủa dòng phun trong buồng đốt với thiết diện đầu vào được mở rộng một cách đột ngột. Hình dáng hình học của buồng đốt được mô phỏng theo thiết bị đầu đốt với nhiên liệu khí đốt được cung cấp từ thiết bị trung tâm. Kết quả là những chuyển động góc tạo thành các vùnh hồi lưu dọc trục và các tính toán cũng cho thấy các ảnh hưởng của kích thước ống cung cấp nhiên liệu và hệ số xoáy lên kích thước của buồng đốt.*

REFERENCES

[1] Roberts L. W., *Turbulent swirling flows with recirculation*, Ph. D. Thesis, Imperial College, London University, 1993.

[2] Lilley D. Gq Yut Y. *Computers and Fluids* 4, p. 45, 1976.

[3] Syred N., Beer Y., *Astron, Acta,* 17 4/5, p. 783 (1992).

[4] Kostov P., K. Atanasov, *Numerical modeling of recirculation zones in a rotational restricted gas torch,* International scientific conferences EMF 2004.

[5] Antonov Iv. Sl., *Turbulent swirling flows research, Abstract of a dissertation of candidates,* Sofia, 1976.