Distribution of gaseous pollutants at impact of the wind

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***Abstract**: It is investigating the influence of the wind at curvature of the trajectory of flat vertical non-isothermal flow. The receiving numerical results show some possible adverse effects of distribution of harmful or eventual smoke or flames from fires.*

***Key words:** pollutants, non-isothermal flow, numerical investigation.*

INTRODUCTION

Investigation of the spatial arrangement of the torch of fire, taking into account the wind direction and its velocity is particularly important in forest fires. Without going into details the consequences can list at least two important extinguishing practice times:

- Move (export) of fire across in the integrated fire extinguisher semi axis. And from here is the problem how to be their width?
- Targeting the fire in the direction of power lines through semi axis that are made below. Particularly potentially dangerous for practice is that a so-called. "higher fires", which "outbreak" is not jon the surface of the earth

When fires are in cities, the wind may transfer the fire to neighboring objects (buildings, industrial plants, schools, etc.).

Smoke formation and its movement and evacuation [4],[5] create one of the reasons for contamination of environment. When the task is solved it is necessary to know what the history of the flow is.

In regard to this decision is considering a direct effect of the wind in the surface boundary layer, assuming the absence of stratification of its velocity and air temperature. From an environmental perspective, it is necessary to take into account the presence of rising flows of air which are occurs at a certain temperature and relief conditions. Also can be mention so-called inversion of the temperature.

MODEL OF THE FLOW

It is consider the gas stream flowing in the vertical direction. In general case it can be assume the existence of flowing jet under angle α, which will give more versatility and applicability of the task (Figure 1). Both flow, jet and wind have different velocity, density and temperature. This problem is solve as non-isothermal and the velocity of wind and the flow in the initial section is assume to be constant i.e. $u = const.$ and $w_0 = const.$ The problem is consider in the axis $x - y$ and wind velocity is note with u and that of the flowing stream with w. In general decision will not comment the reasons for the arising of the jet and its nature also is assume that its initial velocity is constant $w_0 = const$.

Approach is use by []. On figure 1 is consider an element of the "curvature" jet. It is assuming that it acts two forces which are balance to each other: dynamic pressure of wind force Δp and inertial force ΔI (which is resulting in a high curvature flow).

$$\Delta p = \rho_{в} \frac{u^2}{2} h \sin^2 \alpha dl \qquad (1)$$

$$\Delta I = \rho_c \frac{w^2}{R} Scdl \qquad (2)$$

where: h - width of the jet in given cross section, Sc - face of the section, R - local radius of curvature

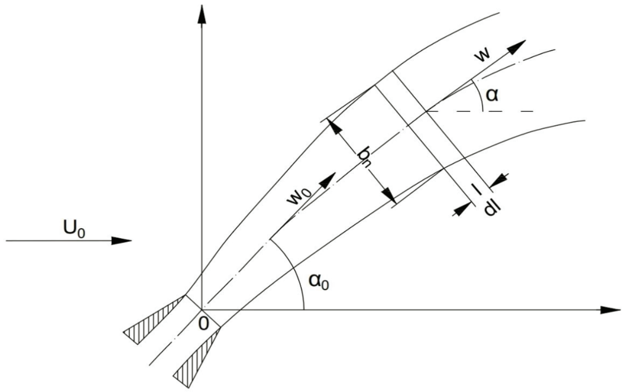

Fig.1

Equating the two forces leads to the expression:

$$\rho_b u^2 h \sin^2\alpha = -2\rho_c \frac{w^2}{R} S_c \tag{3}$$

From equation (3) is define radius of the curvature of the trajectory

$$R = \frac{\left(1+y'^2\right)^{1,5}}{y''} \tag{4}$$

Where y' and y'' are the first and second derivative of trajectory of the axis of jet at x:

$$y' = \frac{dy}{dx} = tg\alpha \tag{5}$$

On geometric considerations can be writing:

$$\sin\alpha = \frac{tg\alpha}{\sqrt{1+tg^2\alpha}} = \frac{y''}{\sqrt{1+y'^2}} \tag{6}$$

In the turbulent flows as is known, the quality of movement is kept constant along their length [2], [3]. This means that the amount of movement in any section will be equal to the initial:

$$J = J_0 \tag{7}$$

$$\rho_c w^2 S_c \sin\alpha = \rho_{c0} w_0^2 S_0 \sin\alpha_0 \tag{7a}$$

The parameters with subscript “0” refer to initial sections (section during which flowing upward flow)

Taking into account equation (4) and substituting in (7a) is obtained:

$$R\sin^2\alpha = \frac{y'^3}{y''} \tag{8}$$

After using equation (3) follow:

$$R\sin^3\alpha = \frac{2S_{c0}\rho_{c0}w_0^2}{h\rho_b u_0^2}\sin\alpha_0 = \frac{y'^3}{y''} \tag{9}$$

It is make the substitution:

$$\frac{dy}{dx} = y' = U \tag{10}$$

And form (10) follows:

$$y^{"} = \frac{dU}{dx} \tag{11}$$

Replace (10) and (11) in (9), for which after divided of the variables are obtain:

$$\frac{dz}{z^3} = -\frac{h\rho_b w_0^2}{2S_{c0}\rho_{c0}u_0^2 \sin\alpha_0} dx \tag{12}$$

When velocity of the wind u_0 and density of ambient air ρ_b are assuming as constant value at $h = const.$ the condition is follow:

$$h\rho_b u_0^2 = const. \tag{13}$$

NUMERICAL SOLUTION

At flat axis symmetrical stream flowing through a opening with of infinite length $h = const.$ In this case can be determine the flow rate of jet in the initial section:

$$b_0 = \frac{Su_0}{h} \tag{14}$$

As assuming $u_0 = const.; \rho_b = const.$ (wind parameters) for the equation for z is obtained:

$$z = \frac{dy}{dx} = \pm\sqrt{\frac{\delta_0\rho_{c0}w_0^2 \sin\alpha}{\rho_b u_0^2 x + C_1}} \tag{15}$$

Respectivly for reciprocal value of z:

$$\frac{1}{z} = \frac{dx}{dy} = \pm\sqrt{\frac{\rho_b u_0^2 x + C_1}{\delta_0\rho_{c0}w_0^2 \sin\alpha}} \tag{16}$$

According to [1] from the analysis of 15 ÷ 16 the conclusion is that z has real values for both root of the equation:

- At $\alpha_0 < \frac{\pi}{2}$ is taking "+" signs because the derivative is $\frac{dy}{dx} > 0$

- At $\alpha_0 > \frac{\pi}{2}$, is taking "-" sign corresponds according to fig. 2 the zone immediately after the curvature of the trajectory of the jet under the influence of the wind velocity u_0 and the new intersection of the axis y. The point of intersection of this axis is determine by equation 16 at assuming "+" sign and value for $x = 0$.

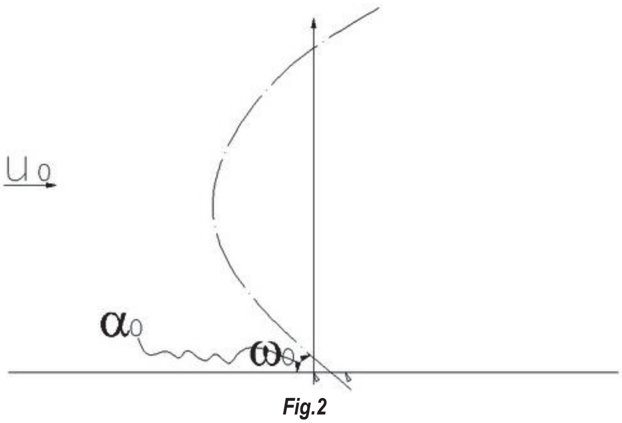

Fig.2

The constant C_1 is defined from the initial condition:

$$x = 0; y = 0; \frac{dy}{dx} = tg\alpha_0 \qquad (17)$$

From here for C_1 follow:

$$C_1 = \frac{\delta_0 \rho_{c0} w_0^2 \sin\alpha_0 \cot g\alpha_0}{\rho_b u_0^2} = \frac{\cot g^2\alpha_0}{m} \qquad (18)$$

Parameter m has value:

$$m = \frac{\rho_b u_0^2}{\delta_0 \rho_{c0} w_0^2} \qquad (19)$$

Parameter m has positive value for whole possible angle of incline of jet $0 \le \alpha_0 \le \pi$.

At assuming indications magnitude $\frac{dx}{dy}$ is determined by the equation:

$$\frac{dx}{dy} = \pm\sqrt{mx + \cot g^2\alpha} \qquad (20)$$

Integral of (20) is as follow:

$$\pm\frac{2}{m}\sqrt{mx + \cot g^2\alpha_0} = y + C_2 \qquad (21)$$

From initial condition of leakage of the jet:

$$x = 0, y = 0 \qquad (22)$$

Then for C_2 follow:

$$C_2 = \frac{2}{m}\cot g\alpha_0 \qquad (23)$$

At accepted condition for the constant value of the wind and its density (in the absence of stratification) ($\rho_b = const., u_0 = const$)

For equation of the trajectory of the jet follow:

$$y = \frac{2}{m}\left(\pm\sqrt{mx + \cot g^2\alpha_0} - \cot g\alpha_0\right) \qquad (24)$$

ANALYSIS OF RESULTS

Equation (24) has two real roots. The sign "-" in front of the square root give a solution for $\alpha_0 > \frac{\pi}{2}$. For value of $x = 0$ (beginning of coordinate system $x - y$) has two roots at y: $y = 0$ and $y > 0$, which give the intersection of the trajectory of the jet axis y.

NUMERICAL INVESTIGATION

The initial width of the burning semi axis δ_0 is account at a normal in the direction of the flowing. The main parameters that influence over the flow are: the initial value of the flow parameters: velocity w_0, density ρ_{c0}, angle of flowing α_0 and the width of the semi - axis of the fire, and the corresponding value of the wind: velocity u_0 and density ρ_b.

On figures 3 ÷ 6 is given the influence of two basic initial parameters: the power of the fire Q_0 and wind velocity u_0.

The increase of the wind velocity leads to bigger curvature of the trajectory of the jet, which is logically (Fig.3).When the power of the source Q_0 is increasing, which corresponding of reducing the density of the jet flow which is causes to increase of the curvature of the jet at the same wind velocity.

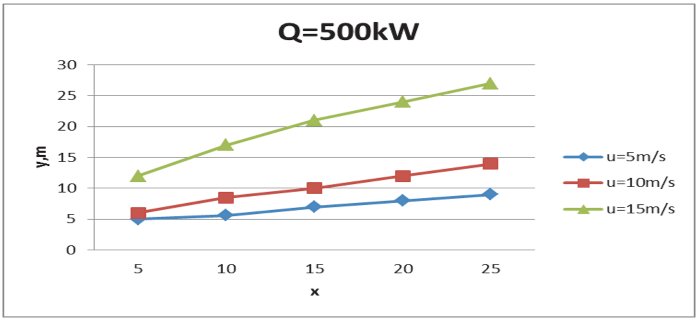

Fig.3

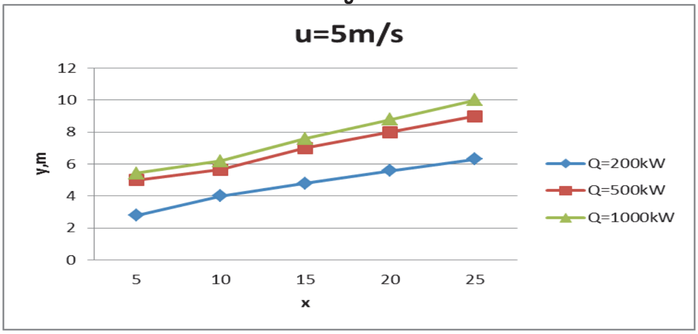

Fig. 4

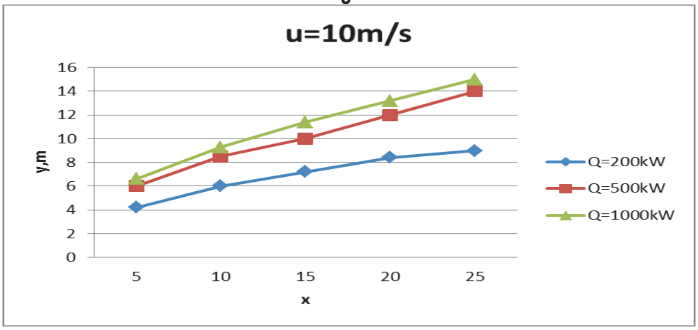

Fig.5

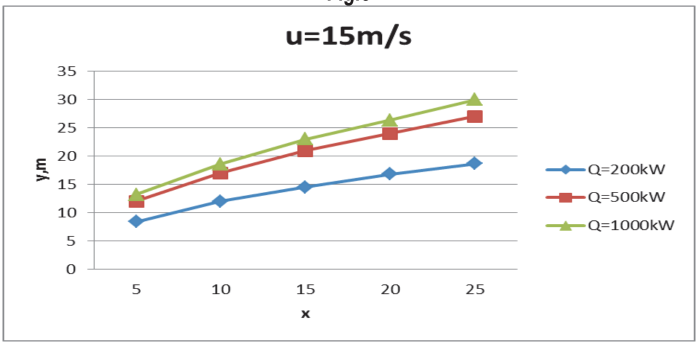

Fig.6

CONCLUSION

The results which are received show the applicability of the described method in the article for one fast method to determinate the changes of trajectory of non-isothermal vertical jet

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