A THEORETICAL SENSOR MODEL FOR HYDRO SPURT CONCRETE CUTTING

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Abstract: A theoretical sensor model of a nozzle-cover type intended for control and often change a distance from a nozzle cut to a treated surface is considered in this article. The specified feature of this sensor that it can be used as a transformer of a water spurt formed in a circle while flowing from a nozzle.

Key words: sensor, building, model, hydro spurt cutting instrument.

Having based on a theory of a possible character of water flow in a circulation zone situated between a circle nozzle and a cover, a new theoretical model for a definite liquid movement in this zone can be obtained and analyzed. New analytical dependent variables for sensor parameters are obtained. One of the perspective ways of a concrete cutting used in a construction and reconstruction by a high-pressure water spurt. The highest efficiency of this technological process is achieved in destruction of defects in concrete layers and reinforced concrete layers. The productivity of this process is increased into 30-50 times in comparison to traditional methods. High-pressure water spurt has a selective influence destroying only those concrete layers, which are less solid. In this case a corrosion steel fittings are also destroyed.

To ensure high productivity of the process it is necessary to keep a constant minimum distance from a nozzle of a spurt head to a surface of treated material otherwise a phenomenon of a so called “hydro air cursion” may appear which will protect a treated surface from further treatment. Let’s analyze a theoretical model of a hydraulic sensor of a nozzle-cover type intended for controlling after changing of the distance from a nozzle cut to a treated surface. The peculiarity of the sensor is the usage as a transformer of a water spurt formed in a circle when a spurt flows from a nozzle.

As a basis in a theoretical model one may consider a scheme of a spurt sensor of a circle type. Calculations of such sensors are rather difficult in our time for the lack of an appropriate theoretical model All known calculation formulas are approximate and some of them are based on experimental data [1,2]. Let us consider the scheme of water flowing from a circle nozzle (Fig.1) to examine analytical dependent of its work.

In section A-A1 an unindignant spurt has a constant in size and direction speed V1. In a space between a nozzle cut and a hypothetical cover a circle zone appears it is like a tor. The boundaries of this zone are determined by lines, the inner boundary is by the D-K-F line the outward boundary is by D-M-E-M1-F line. In the point E the outward boundary crosses the symmetry axes of a circular nozzle. All the lines of a water being inside of the boundary are closed curves. As it is shown on the picture 1 this position may appear some rarefaction as a result of sucking from space of D-E-F in a received channel.

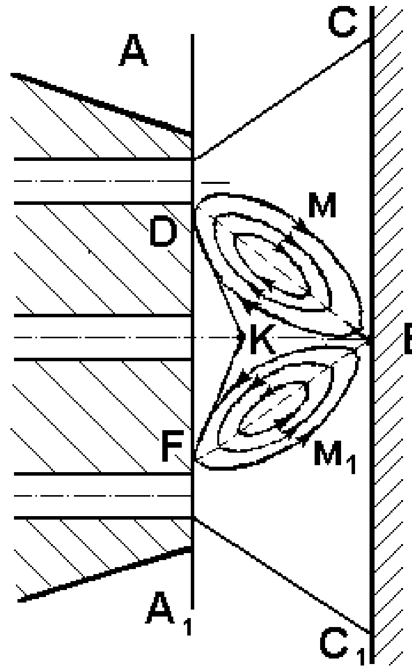

Figure 1. The scheme of water flowing from a circle nozzle

The quantity of this rare faction may be used as a signal for estimating a change in a distance from a nozzle to a treated surface.

Examining the scheme of liquid flow from a circular nozzle we can see that on the boundary of ejectional zone D-E-F a gap surface will appear inside of a flow. It is known that under the influence of this surface there will be some change in a speed of a flow as in direction or in size. In this transitive layer of liquid particular systems of vortex appear, so called vortex layers. [3]. Receiving the direction of speed on the boundary of a gap the axes [x] on the line D-E-J we may write a formula for the transitional layer.

$$rot\, v = \frac{\partial v_y}{\partial x} - \frac{\partial v_x}{\partial y} \qquad (1)$$

Where V – speed of liquid particles
V_y – projection of speed liquid particles to the axes Y
V_3 – projection of speed liquid particles to the axes X

But derivative

$$\frac{\partial v_y}{\partial x} = 0 \text{, and } \frac{\partial v_x}{\partial y} \neq 0 \text{, so } rotv \neq 0 . \qquad (2)$$

As a result of this in the transitive layer liquid particles will have some rotation. In this case in the transitional layer we will get a vortex layer. In general the gap surface will have a cone form and vortex layer a form of a tor. On the basis of a possible character of a liquid flow in a circulation zone between a nozzle and a cover we may obtain a theoretical model for a stable movement of liquid in this zone (Fig. 2).

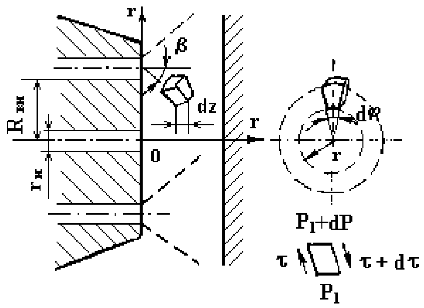

Figure 2. The scheme for calculation of pressure between a nozzle and a cover

Let it be axes, as it is shown on the picture 2. The axis Z has a rightward direction and axis r an outward direction to the surface of a nozzle cut. Now let us pick out elementary volume of liquid in this zone; the length is dz, high dr, and width rdφ. On this volume different forces of pressure and friction will influence. It is depended by a concerning tension. In general liquid flow will have molecular and turbulence tenacious [4]. So considering a turbulent movement as a whole in a space between a nozzle and a cover (Bussinek`s model) a summary tension may be written as follow [4]:

$$\tau = \eta \frac{du}{dz} + \eta_T \frac{du}{dz} ,. \qquad (3)$$

Where u – mean liquid speed
η - Coefficient of turbulent tenacious
η_T - dynamic coefficient of turbulent tenacious.

In case of turbulent movement with high members Reynolds the second element in the right part of the equation greatly exceeds the first element (molecular tenacious is out).

As to L Prandtle`s coefficient $\eta_T = \rho\, l^2 \cdot \frac{du}{dz}$. Then

$$\tau = -l^2 \cdot \rho \cdot \left(\frac{du}{dz}\right)^2 , \qquad (4)$$

Where l is used to be a length of a displacement way. We must say that different authors ascribe to l different physical sense. This element may be expressed as follow [4]

$$l = \chi z_2 , \qquad (5)$$

Where Z_2 is the distance between a channel wall to the point where a turbulent tension is determined

X- universal constant Prandtle different forces.

On the basis of a determined by volume of liquid P_1 and P_2 influence. On lateral surface friction will influence. So as we consider established movement the force of inertia is equal to zero.

Let us make a proection of all forces influencing on the volume Axis r.

$$-dP \cdot dz \cdot r \cdot d\varphi = -d\tau \cdot r \cdot d\varphi \cdot \ dr \cdot \sin \beta , \qquad (6)$$

Where P- pressure influenced on its border has the coordinate r

$$\beta = \arcsin \frac{R_{вн}}{\sqrt{R_{вн}^2 + z_2^2}} ; \qquad (7)$$

$R_{вн}$ – the inner radius of a circular nozzle

Let us differentiate the equation (4) and the get it into equation (6). After necessary reduction we will have

$$\frac{dP}{dr} = -2\rho l^2 \frac{du}{dz} \frac{d^2u}{dz^2} \sin \beta , \qquad (8)$$

Where P –strength of liquid.

Further integration of a given equation via z. As a result it is a constant integration figures that we can find from former conditions

$$u = 0 \text{ and } \frac{du}{dz} = 0 ,\ z = 0 . \qquad (9)$$

As a result we will get

$$u = -\frac{2}{3 \cdot l}\sqrt{\frac{dP}{dr} z^3 \frac{1}{\rho \sin\beta}} \qquad (10)$$

Let us define expenditure of radical liquid flow. It can be found from elementary water expenditure. The elementary water expenditure through the dzrdφ space will be

$$dQ = u\, dz\, r\, d\varphi \qquad (11)$$

Substitute this equation to the meaning of speed of the equation (10) we will define the summary water expenditure

$$Q = \int_0^{2\pi}\int_0^{z_2} u \cdot r\, dz\, d\varphi \qquad (12)$$

Having integrated the equation (12) twice, at first according to dф. and the according d2 we will have

$$Q = -\frac{8}{15}\frac{\pi r}{l}\sqrt{\frac{dP}{dr} z_2^5 \frac{1}{\rho \sin\beta}} \qquad (13)$$

To define the law of a pressure changing on a definite space we will solve the equation (13) according to $\frac{dP}{dr}$:

$$\frac{dP}{dr} = \left(-\frac{15}{8}\frac{Ql}{\pi r}\right)^2 z_2^5 \frac{1}{\rho \sin\beta}.$$

Having integrated it according to *dr* we will get

$$\frac{dP}{dr} = \left(-\frac{15}{8}\frac{Ql}{\pi r}\right)^2 z_2^5 \frac{1}{\rho \sin\beta}.$$

Paying attention to the initial conditions.

$P = P_н$ Where $r = R\%o'$,

Where $P_н$ – pressure before the nozzle.

As a result of integration paying attention to the equation (7) we will have

$$P = P_н + \left(\frac{15}{8}\frac{Ql}{\pi}\right)^2 \frac{\rho}{z_2^5}\frac{R_{вн}}{\sqrt{R_{вн}^2 + z_2^2}}\left(\frac{1}{R_{вн}} - \frac{1}{r}\right) \qquad (14)$$

Out of the equation (14) we may define the parameters of liquid flow

With $\Delta P = P - P_н$ and $r = r$

$$\Delta P = \left(\frac{15}{8}\frac{Ql}{\pi}\right)^2 \frac{\rho}{z_2^5}\frac{R_{вн}}{\sqrt{R_{вн}^2 + z_2^2}}\left(\frac{1}{R_{вн}} - \frac{1}{r_н}\right), \qquad (15)$$

$$\Delta P = \left(\frac{15}{8}\frac{Q}{\pi}\right)^2 \frac{\rho \chi^2}{z_2^3}\frac{R_{вн}}{\sqrt{R_{вн}^2 + z_2^2}}\left(\frac{1}{R_{вн}} - \frac{1}{r_н}\right) \qquad (16)$$

$$\tau = f\rho\frac{u^2}{2}, \qquad (17)$$

Where f – is a coefficient of friction in turbulent water flow, received experimentally.

Having fulfilled analogue work but using the equation (17) we will have

$$P = P_н + \left(\frac{3}{4}\frac{Q}{\pi}\right)^2 \frac{f\rho}{2z_2^3}\frac{R_{вн}}{\sqrt{R_{вн}^2 + z_2^2}}\left(\frac{1}{R_{вн}} - \frac{1}{r}\right). \qquad (18)$$

Where $\Delta P = P - P_н$ and $r = r$

$$\Delta P = \left(\frac{3}{4}\frac{Q}{\pi}\right)^2 \frac{f\rho}{2z_2^3}\frac{R_{вн}}{\sqrt{R_{вн}^2 + z_2^2}}\left(\frac{1}{R_{вн}} - \frac{1}{r_н}\right) \qquad (19)$$

Let us make a comparative analyze of results of calculation according to the given formulas (16) and (19).

The test of these equations (conditions for calculation p=998, 2kg.) m^3; $R_{вн}=0,3*10^2$, $r_h=0,1*10^2$m, Q= $0,5*10^3 m^3/8$, f=2, $z=0,8*10^2$m, X=0,4) showed its similarity (adequateness) modeling of pressure and friction of turbulent flow F=2 (Fig. 3 and Fig. 4). Its corresponds to theoretical

The distance from a nozzle to a cover

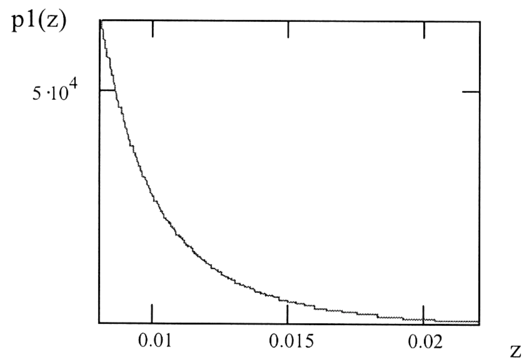

Figure 3. The depedence on 1 hypothesis

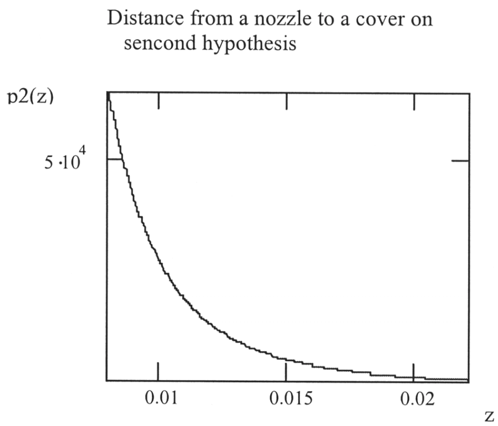

Figure 4. The dependence on the second hypothesis

analyses which explain the process of circle vortex appeared in the exit from the circle channel to the space ranging by a cover (Fig. 1)

$$p1(z) = \frac{9}{32} \cdot \frac{9982}{3{,}14^2} \cdot \frac{(0{,}5 \cdot 10^{-3})^2 \cdot 2 \cdot (0{,}3 \cdot 10^{-2})}{z^3 \cdot \sqrt{(0{,}3 \cdot 10^{-2})^2 + z^2}} \cdot \left(\frac{1}{0{,}1 \cdot 10^{-2}} - \frac{1}{0{,}3 \cdot 10^{-2})} \right),$$

$$p2(z) = \left(\frac{15}{8} \right)^2 \cdot \frac{9982}{3{,}14^2} \cdot \frac{0{,}4^2 \cdot (0{,}5 \cdot 10^{-3})^2}{z^3 \cdot \sqrt{(0{,}3 \cdot 10^{-2})^2 + z^2}} \cdot \left(\frac{1}{0{,}1 \cdot 10^{-2}} - \frac{1}{0{,}3 \cdot 10^{-2}} \right).$$

Out of the Fig. 3 and Fig. 4 we can see that the reduction of the distance led to the increasement of pressure which appears between a cut nozzle and hypothetical cover. It is well explained by the same low.

CONCLUSION

1. It is proved that hydro spurt cutting instrument of a circular nozzle construction for cutting concrete that can be used as a sensor in controlling change of the distance from a nozzle cut to a treated surface during its work. The peculiarity of the sensor is the usage of it as a controller and transformer of a water flow that is formed as a circle when flowing from a nozzle.
2. Based on a theoretical model by Bussiesh it is proved by two adequate independent theoretical hypothesizes concerns liquid flow in a working space of sensor.
3. Received analytical dependents may be used for elaboration instrument for controls and transformation of a water flow and change of the distance from a nozzle to a treated surface.
4. The usage of a circular hydro spurt as a cutting instrument gas all qualities of a sensor let us set such conditions which reduce the effect of hydrocurshion and will let us use the energy of a water flow and reduce the capacity of a hydro pump.

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