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Vladislav KŘIVDA*

OPPORTUNITIES OF USE OF TRAFFIC LIGHTS ON ROUNDABOUTS

MOŽNOSTI POUŽITÍ SVĚTELNÉHO SIGNALIZAČNÍHO ZAŘÍZENÍ NA OKRUŽNÍCH KŘIŽOVATKÁCH

Abstract

The paper deals with opportunities of use of traffic lights on roundabouts. It issues from problems, which are monitored on roundabout on Prokeš's square in Ostrava-city and on near intersection with traffic lights (Sokolská tř.-30. dubna and Sokolská tř.-Českobratrská).

Abstrakt

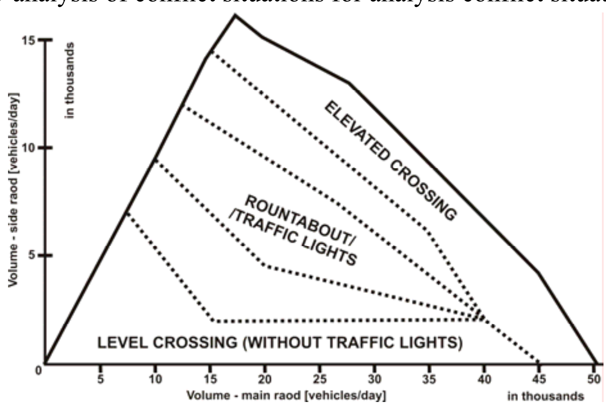
Příspěvek se zabývá možnostmi použití světelného signalizačního zařízení na okružních křižovatkách. Vychází z problémů, které jsou sledovány na okružní křižovatce na Prokešově náměstí v Ostravě a blízké křižovatce se světelným signalizačním zařízením (Sokolská tř.-30. dubna a Sokolská tř.-Českobratrská).

Klíčová slova: okružní křižovatka, světelné signalizační zařízení

1 INTRODUCTION

The traffic on roads is more complicated every year and mainly in point, when they intersect, i.e. on the intersections. The capacity of intersection is filled up and their reconstruction to more capacity (i.e. for example to elevated crossing) is not in many places possible (area reasons, financial reasons etc.). According to informative graph (see picture 1) is possible approximately to decide, that roundabout and intersection with traffic lights would be sufficient for approx same volume on main and side road.

However the problems often can be created, when for example two near intersections (the first roundabout and the second with traffic lights) interacts negatively together. This is for example the part of Sokolská Street in Ostrava between intersections Sokolská-Českobratrská (with traffic lights) a Sokolská-30. dubna (roundabout), i.e. circa 150 m (see picture 2). In 2000 there were monitored situations on roundabout, when the front of waiting vehicles on intersection with traffic lights reached to roundabout. In 2006 these situation created more frequently and moreover the traffic on intersection with traffic lights was interacted by roundabout (by influence of giving way to pedestrians on pedestrian crossing or to vehicles on circulatory roadway of roundabout). There was used Folprecht's video-analysis of conflict situations for analysis conflict situations (see [2]).



Picture No. 1 Informative graph for approximate diagnosis of type of intersection [6]

* Ing. Ph.D. ING-PAED IGIP, Institute of Transport (342), Faculty of Mechanical Engineering, VŠB – Technical University of Ostrava, 17. listopadu 15, 708 33 Ostrava-Poruba, Czech Republic, tel. (+420) 59 732 5210, e-mail vladislav.krivda@vsb.cz; http://www.id.vsb.cz/krivda

Picture No. 2: The view on the part of Sokolská Street in Ostrava between intersections Sokolská-Českobratrská (with traffic lights) a Sokolská-30. dubna (roundabout)

2 Experiences in the czech rebublic and abroad

In the Czech Republic the roundabouts with traffic lights almost don't exist, with only exception – atypical roundabout in Hradec Králové City. The roundabout is controlled during day. The traffic lights are out of order during night and the traffic is controlled like typical roundabout. The traffic lights are relatively safe for pedestrians and cyclists.

There are the great experiences with traffic lights on roundabouts mainly in Great Britain. From other countries we can mention for example Poland, France, Sweden (see picture 3), the U.S.A. (for example New York City), Egypt, Mexico etc.

Picture No. 3: Roundabout with traffic lights (Stockholm, Sweden)

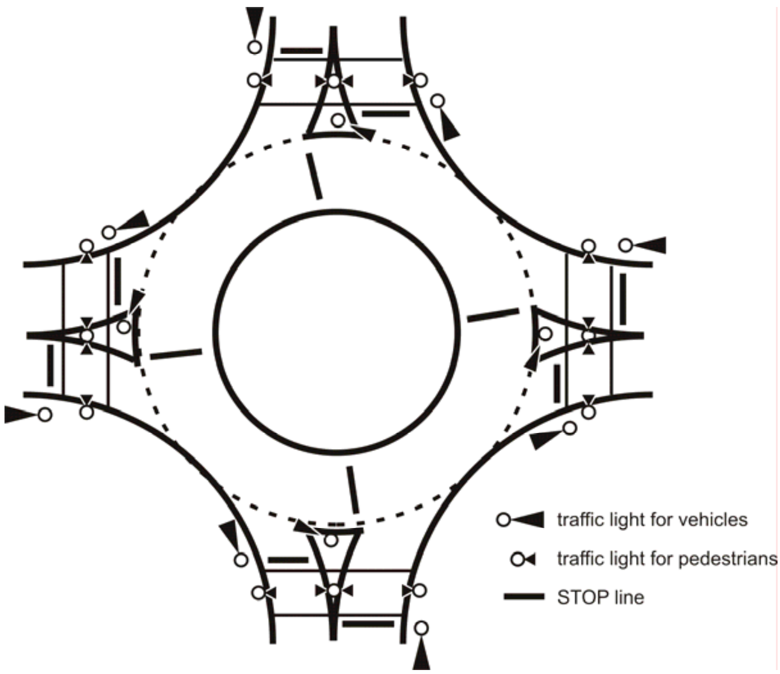
3 Problems of introduction of traffic lights

Mainly volume of vehicles (on main and side roads), volume of pedestrians and accident frequency are essential for introduction of traffic lights on the intersections. According to abroad experiences it follows, that for roundabouts with traffic lights are suitable three ways of controlling of road traffic:

- sequence of phases circulating clockwise
- twice phase controlling with the green phase for opposite vehicles turning to the left
- the combination of previous

The traffic lights for vehicles and pedestrians must be put by relevant way on roundabout with traffic lights – see picture 4.

We take roundabout with traffic lights like the system of tree-arm intersections with traffic lights and with one-way traffic, which are coordinated together – *but*: for roundabout with bigger size (see [1]). The capacity of big roundabout with traffic lights (according to [1]) and with two-line entry, exit and circulatory roadway is circa 55 000 vehicles per day, without traffic lights then circa 45 000 vehicles per day. *Will this theory hold true also for roundabouts of smaller sizes?*

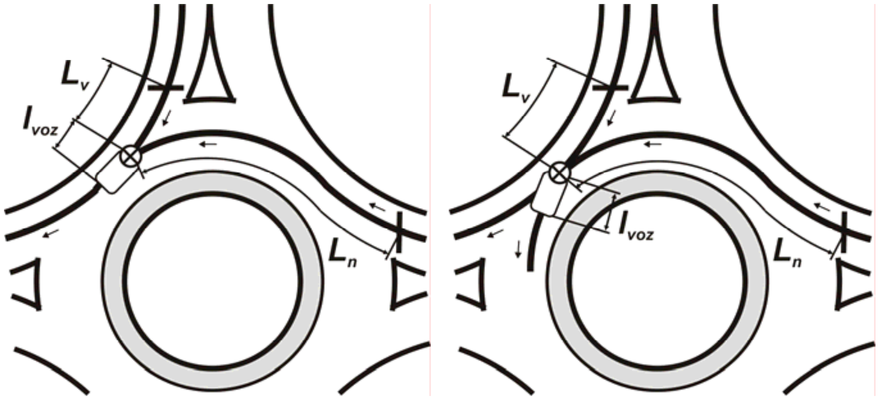


Picture No. 4: Position traffic lights on roundabout

It is necessary to thing with extended of "between-time" t_m [s] and mainly for the left turning (i.e. near the third exit of roundabout):

$t_m = t_v - t_n + t_b \, [s]$, where $t_v = \frac{L_v + l_{voz}}{v_v} \, [s]$ and $t_n = \frac{L_n}{v_n} \, [s]$ (see [4] and picture 5),

t_b ... safety time [s].



Picture No. 5: The examples of analysis of separate movements on roundabout for calculation of "between-time" t_m

The "Method of consumption of time" seems probably like suitable. It is ordinarily used for typical intersections. The cycle length C_v [s] is calculated from this formula:

$$C_v = \frac{\sum t_m}{1 - \frac{\sum M}{S}} \quad [s] \quad \text{(see [4]).}$$

The calculation of fictive volume M [vehicles per hour] is very important problem. The saturated flow of vehicles S [vehicles per hour] would be the same like for typical intersections.

The other process (i.e. the calculation of green length etc.] would be also the same like the process for typical intersections.

4 CONCLUSION

The previous text is for now only the advisement about the using of traffic lights for controlling of road traffic on roundabouts. On roundabout on Prokeš's square in Ostrava-city the controlling is suitable manly in afternoon rush hours, when two near intersections (Sokolská tř.-30. dubna and Sokolská tř.-Českobratrská) interacts together most of all – see [3] and [5]. We will deal with this problem in future in Laboratory of Road Transport (www.id.vsb.cz/lsd).

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Vilém MÁDR[*], Libor HLAVÁČ[**], Jana VILIAMSOVÁ[***]

ANALYSIS OF LONGITUDINAL VELOCITY IN THE FOCUSING TUBE OF THE ABRASIVE WATER JET CUTTING HEAD

ANALÝZA PODÉLNÉ RYCHLOSTI V USMĚRŇOVACÍ TRUBICI ŘEZACÍ HLAVICE ABRAZIVNÍHO VODNÍHO PAPRSKU

Abstract

The analysis of longitudinal velocity in the focusing tube of the abrasive water jet cutting head serves for determination of the negative pressure in the mixing chamber of the cutting head. The value of the negative pressure is one of the boundary conditions for mathematical modelling of water jet flow through the cutting head. Several ways for determination of the interval of water jet exit velocities from the focusing tube into the free space were tested to evaluate the longitudinal velocity in the focusing tube of the abrasive water jet cutting head. The calculation includes the evaluation of the longitudinal velocity in the axis of water jet at the exit from the focusing tube, the calculation of the expansion velocity of water jet at its divergence in the air and the calculation of the mean velocity of the water jet by the end of the focusing tube. Specification of the mean outlet velocity from the mixing conditions is also performed.

Abstrakt

Analýza podélné rychlosti v usměrňovací trubici řezací hlavice abrazivního vodního paprsku slouží ke stanovení podtlaku ve směšovací komoře řezací hlavice. Hodnota podtlaku je jednou z okrajových podmínek matematického modelování proudění vodního paprsku řezací hlavicí. Bylo testováno několik způsobů určení intervalu hodnot výtokových rychlostí čistého vodního paprsku z usměrňovací trubice do volného prostoru, aby bylo možno stanovit podélnou rychlost v usměrňovací trubici řezací hlavice abrazivního vodního paprsku. Výpočet zahrnuje určení podélné rychlosti v ose vodního paprsku na výstupu z usměrňovací trubice, výpočet expanzní rychlosti vodního paprsku při jeho divergenci ve vzduchu a výpočet střední rychlosti vodního paprsku na konci usměrňovací trubice. Byla také určena hodnota střední výtokové rychlosti ze směšovacích podmínek.

1 INTRODUCTION

The analysis of the process of mixing of the liquid with air and particles of materials in the cutting head is of importance to improvement in the efficiency of injection abrasive liquid jet. The mathematical description of liquid jet flow through the mixing chamber and the focusing tube can be done on the basis of knowledge of mass or volume concentration of air in the jet. It can be used for determination of the influence of jet aeration on its cross-section velocity profile or on its mean velocity. The analysis of longitudinal velocity in the focusing tube of the abrasive water jet cutting head is of importance not only to the mathematical description of the phenomenon, but also to the determination of pressure of air in the mixing chamber of the equipment concerned.

At each point of the stream, a fluctuating quantity, e.g. velocity, can be decomposed into two components, the mean (time-smoothed) velocity and the fluctuation velocity, the magnitude and direction of which changes very quickly in time. The mean velocity is the average value of the

[*] Prof. RNDr., CSc., Institute of Physics, Faculty of Mining and Geology, VŠB – Technical University of Ostrava, 17.listopadu 15/2172, Ostrava – Poruba, tel. (+420) 59 732 3128, e-mail: vilem.madr@vsb.cz

[**] Prof. Ing., Ph.D., Institute of Physics, Faculty of Mining and Geology, VŠB – Technical University of Ostrava, 17.listopadu 15/2172, Ostrava – Poruba, tel. (+420) 59 732 3147, e-mail: libor.hlavac@vsb.cz

[***] RNDr., Ph.D., Institute of Physics, Faculty of Mining and Geology, VŠB – Technical University of Ostrava, 17.listopadu 15/2172, Ostrava – Poruba, tel. (+420) 59 732 3175, e-mail: jana.viliamsova@vsb.cz

instantaneous velocity in the time interval, which is great enough with regard to the time of turbulent oscillation in fluctuation velocity. In the corresponding time interval, the mean value of fluctuation velocity is equal to zero. Similar considerations hold also true for other fluctuating quantities, such as pressure, density, and others. Although the time mean values of fluctuating components of quantities are equal to zero, the mean time value changes along the cross sectional area of flow of tubes. If we take, in the course of dynamical calculations, their mean value along the cross sectional area of flow into account, then the turbulent flow may be considered to be a one-dimensional and steady. So the relationships derived for this kind of flow can be used.

2 WATER JET EXIT VELOCITIES FROM THE FOCUSING TUBE TO THE FREE SPACE

The water jet used for cutting of materials passes, after exiting the water nozzle, through the mixing chamber and the focusing tube (Fig.1).

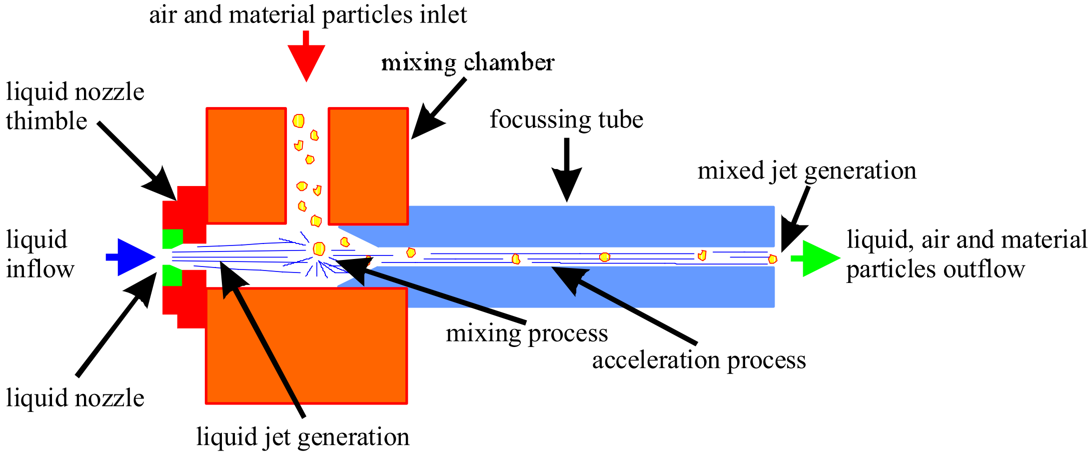

Fig. 1. A diagrammatical section through the cutting head of abrasive waterjet with the representation of processes leading to the generation of abrasive liquid jet at its exit.

To cut a material intended for cutting, a pure water jet or abrasive water jet can be used. When an abrasive is used, it is mixed with the water jet in the mixing chamber. In the following considerations and calculations, we shall be concerned with a pure water jet. Calculations are executed on the following conditions:

- ❑ the liquid is incompressible,
- ❑ the liquid remains in the jet; it does not accumulate in the mixing chamber,
- ❑ the jet is not aerated.

In the course of calculations, we take the turbulent flow of water in the jet as a steady flow with the flow field characterised by mean time values of fluctuating quantities [1].

At the beginning of calculations, we shall determine the interval of mean velocities at which the liquid can move at the exit from the focusing tube. From the equation of continuity it follows that

$$v_1 = \frac{S_0 v_0}{S_1} = \frac{\pi \left(\frac{d_0}{2} \right)^2 v_0}{\pi \left(\frac{d_1}{2} \right)^2}, \tag{1}$$

where S_0 is the cross-section of the nozzle at the entry into the mixing chamber, S_1 is the exit cross-section of the focusing tube, d_0 is the diameter of nozzle, d_1 is the diameter of the focusing tube and v_0 is the mean velocity of water jet at the entry into the mixing chamber.

The value of velocity is the maximum one if the jet does not extend radially from the axis, which is, with reference to the existence of radial components of velocity, impossible. The value of velocity is the minimum one if the jet expands in the radial direction with regard to the axis of flow so that its cross-section at the exit from the focusing tube will be identical with the cross-section of flow by the end of the focusing tube.

Specific calculations are performed in a case of cutting head for the following parameters and values of quantities characterising the state of the water:

the nozzle at the entry into the mixing chamber: (index 0), d_0 = 0.25 mm (r_0 = 0.125 mm),

the mixing chamber: (index s), l_s = 13 mm, d_s = 7.14 mm,

the focusing tube: (index 1), l_1 = 76 mm, d_1 = 1.02 mm (r_1 = 0.51 mm),

where l is a relevant length and d is a relevant diameter of parts of the cutting head.

The temperature t, water density ρ, pressure p_0 and mean velocity v_0 of the water jet by the inlet into the mixing chamber are expected to be close to the following values:

t = 20°C, ρ = 998 kg.m^{-3}, p_0 = 400 MPa, v_0 = 650 m.s^{-1}.

For the cutting head set like that, the mean exit velocity of liquid jet by the outlet from the focusing tube lies in the interval as follows

$$v_1 \in \langle 36,650 \rangle \, m.s^{-1} . \quad (2)$$

3 THE LONGITUDINAL VELOCITY VALUE AT THE AXIS OF THE WATER JET BY THE OUTLET FROM THE FOCUSING TUBE

The water jet moving in the air begins expanding after overcoming a certain distance from the nozzle, called initial section. Along the initial section the velocity in the jet axis is uniform. Behind this section, the velocity begins to diminish as a result of jet expansion. The length of the initial section l_p is given by the relationship of A. J. Milovič [2]

$$l_p = 145 d_0 . \quad (3)$$

The longitudinal maximum velocity v_1 along the axis of water jet moving in the air is, within its compact part behind the initial section, given by relationship [2]

$$v_l = \frac{145 v_0 d_0}{l} , \quad (4)$$

where l is the distance measured along the jet axis from the end of initial section.

For the cutting head with the above-presented parameters, we shall get the length of the initial section l_p = 36 mm and the velocity within the section v_s = 650 m.s^{-1} after inserting into these relationships. At the distance l_k = 53 mm from the end of the focusing tube, the velocity of water begins to decrease according to the relationship (4). Hence we shall determine the value of velocity at the axis of the jet by the end of the focusing tube; the velocity reaches the value v_1 = 265 m.s^{-1}.

4 THE EXPANSION VELOCITY OF WATER JET DIVERGING IN THE AIR

After outlet from the water nozzle the water jet radially expands. The calculation of the expansion velocity v_e in the direction perpendicular to water jet axis can be performed using the relationship derived by L. Hlaváč [3]

$$v_e = \left[\frac{2}{\rho_0} \left(p_0 - \frac{1}{2} \rho_0 v_{0u}^2 - p_{at} \right) \right]^{-\frac{1}{2}} , \tag{5}$$

where p_0 is the pressure of liquid before the nozzle, ρ_0 is the density of liquid under normal conditions, v_{0u} is the velocity of the water jet at the inlet into the mixing chamber taken approximately as equal to v_0.

In a case of the set cutting head, we shall obtain for the value of temperature t = 20°C and the density of water $\rho_0 = 998$ kg.m^{-3} the value of the expansion velocity $v_e = 615$ m.s^{-1}. The expansion lasts the time that takes the information to pass from the jet core to the jet skin by the expansion velocity. This time is about $2*10^{-9}$ s. The jet moves at its axis the length 1.3 µm. Its radius changes from 0.125 mm up to 0.126 mm. With the water nozzle length we can determine the approximate angle of divergence. It is about 0.1° ($1.63*10^{-3}$ rad).

5 RADIUS OF THE WATER JET BY THE FOCUSING TUBE OUTLET

We shall determine the radius of jet y_1 as a sum of its radius r_0 at the entry into the mixing chamber and the distance y, i.e. the distance travelled by the marginal part of jet in the radial direction perpendicularly to the axis of the tube per time needed by the jet to travel the distance from the inlet into the mixing chamber to the outlet from the focusing tube

$$y_1 = r_0 + y = r_0 + \left(l_s + l_l \right) tg\vartheta , \tag{6}$$

where ϑ is the angle of divergence of the water jet.

The total internal path l is taken as a sum of the length of mixing chamber l_s and the length of focusing tube l_l. We shall divide the internal path into two sections, i.e. the initial section and the section in which the velocity of jet diminishes.

We shall designate:

$\bar{v}_1$ … the mean velocity of jet along the initial section,

$\bar{v}_2$ … the mean velocity of jet along the section with the decreasing velocity.

In a case of the initial section, the velocity along the path is uniform. With the other section, we shall determine the mean value of velocity from equation (4) by replacing distance l by variable x. By subsequent integration along the length of section we shall obtain

$$\bar{v}_2 = \frac{1}{l_x} \int_{l_p}^{l} \frac{145 v_0 d_0}{x} dx = \frac{1}{l_x} 145 v_0 d_0 \ln \frac{l}{l_p} , \tag{7}$$

where $l_x = l - l_p$.

For the set parameters of cutting head, the following velocities then holds true as the one in the initial section and the attenuating section respectively: $\bar{v}_1 = 650\ m.s^{-1}$, $\bar{v}_2 = 371\ m.s^{-1}$.

The presented time is given by a sum of times needed for covering the two above-mentioned sections, i.e.

$$t = t_1 + t_2 = \frac{l_p}{\bar{v}_1} + \frac{l_k}{\bar{v}_2} \quad . \tag{8}$$

For the set cutting head we shall obtain the approximate value t = 2*10^{-4} s.

From the relationship (6) we shall obtain the value of radius of water jet y_1 at the exit from the focusing chamber. For the set values of cutting head it has the value y_1 = 0.27 mm. The width of gap $r = r_1 - y_1$ between the focusing tube and the water jet at the outlet from the cutting head is then r = 0.24 mm.

5 THE MEAN VALUE OF WATER JET VELOCITY BY THE END OF THE FOCUSING TUBE

The equation of continuity rewritten for the cross-section of the jet at its inlet into the mixing chamber and the outlet cross-section of the jet by its outlet from the focusing tube appears

$$S_0 \bar{v}_0 = S_{y_1} \bar{v}_1 , \tag{9}$$

where S_0 = 0.049 mm^2 is the cross-section of jet at the inlet into the mixing chamber, $\bar{v}_0$ = 650 m.s^{-1} is the mean velocity of water jet at the inlet into the mixing chamber, S_{y1} = 0.229 mm^2 is the cross-section of the water jet at the outlet from the focusing tube and v_1 is the mean value of velocity of the jet in its outlet cross-section. With the set cutting head, the mean velocity of the water jet by the outlet from the focusing tube is v_1 = 139 m.s^{-1}.

6 CONCLUSION

The analysis of a longitudinal velocity in the focusing tube of the abrasive water jet cutting head consists in determination the subsequent quantities: the minimum velocity, at which the jet can exit from the focusing tube into a free space; the initial section of the jet and its velocity at the end of the focusing tube; an average velocity along the internal path of the jet; the expansion velocity of the jet at its divergence in the air inside the mixing chamber and the focusing tube. The mean value of water flow velocity by the end of the focusing tube was also evaluated.

The performed analysis of a longitudinal velocity in the focusing tube of the abrasive water jet cutting head is necessary for determination of the negative pressure in the mixing chamber of the cutting head. This quantity is one of the boundary conditions of mathematical modelling of the water jet flow through the cutting head.

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Reviewed by: Prof. Ing. Horst Gondek, DrSc., Department of Production Machines and Design, Faculty of Mechanical Engineering, VŠB – Technical University of Ostrava