The use of pulsed high-speed liquid jet for putting out gas blow-out

Alexander N. Semko[1], Oksana A. Rusanova[1], Oleg V. Kazak[1,2,*], Marina V. Beskrovnaya[1], Stanislav A. Vinogradov[3] and Igor N. Gricina[3]
[1]Donetsk National University, Donetsk, Ukraine
[2]Ilmenau University of Technology, Ilmenau, Germany
[3]National University of Civil Protection of Ukraine, Kharkov, Ukraine

ABSTRACT
The experimental analysis of putting out a gas blow-out with the help of pulse liquid flow with high velocity, which generates by powder pulse water-cannon are carried out. The flow velocity resides in range from 300 to 600 m/s in experiments depends on charge energy. Velocity of the flow head right near the gas flame determined with the help of laser contactless measuring instrument of velocity. Photography of flow was carried out. According to the preliminary test results the hydrodynamic parameters of powder pulse water-cannon for obtaining liquid flow with depend velocity are calculated. It is shown, that around the liquid flow of high velocity in air produced fine water spray with high velocity in large cross section area that effective knock down the gas blow-out at the distance 5-20 m from installation.

Keywords: Putting out a gas blow-out, Pulse liquid flow with high velocity, Pulse water-cannon, Measurement of flow velocity

1. INTRODUCTION

An open blow-out is the uncontrolled release of crude oil and/or natural gas from an oil well or gas well after pressure control systems have failed and which could not stopped immediately. The blow-out is major accident and often natural disaster, which paralyzes normal work of industry. The open blowout impairs economy and environment. The gryphons could appear at a different distance from the blowout well, gas accumulation at low place threatens detonations and fire. Thus the blow-out is the threat not only for gas field, but also for settlements. The blow-out liquidation leads to involve a big financial resources and lots of people.

The fire of open gas blow-out is one of the most complicated types of industrial accidents. There are many ways of putting out gas blow-out which depends on blow-out type and power, pressure value and heat radiation, blow-out height, well head state, lay of land, distance between well head and flame front and other factors. Putting out the blowout can cost millions of dollars, needs big material and technical resources and take a lot of time. The height of big powerful blowout flame reaches 80 – 100 m, blow-out heat generation intensity is several millions kilowatt.

*Corresponding Author: Oleg V. Kazak, Department of Physics and Technology, Donetsk National University, 24 University str., Donetsk, Ukraine. E-mail: olegkazak@yandex.ru.

The experimental research of putting out gas blowout using high speed impulse water jets is presented at this paper. The high speed impulse water jets are obtained by impulse hydrogun. Present research was done on model devices, gives positive results and shows perspective of this direction.

2. MODERN WAYS OF PUTTING OUT GAS BLOWOUT

At least ten methods are developed for blow-out liquidation. It caused by complexity of the problem from the one hand and limited efficiency of each method from the other hand. The main methods presented by [1]:

- Water bull heading into the well;
- Closing of preventer stopcock;
- Putting out by jets of gas-water firefighting cars;
- Impulse delivery of powder by special setups;
- Water jets from carriages;
- Explosion of high explosive charge;
- Vortex-powder method;
- Fire extinguisher powder from firefighting cars;
- Combined method;
- Drilling of inclined well and special solution bullheading.

The carriage barrels (hydraulic monitors), gas-water firefighting cars (AGVT-100 and AGVT-150) and pressure-operated powder flame-arresters (PPP-200) are widely used in Ukraine and CIS [1].

The hydraulic monitors are used for putting out gas, gas-condensate and oil open blow-out of small power, because their barrel should be located at 15 m distance, which is not appropriate for the blow-out with big output [2]. Several hydraulic monitors are used for putting out the open blow-out of medium-sized power and water delivery is implemented at two levels. During the long time it was lead method of putting out the gas blowouts. Water jets from hydraulic monitors are directed on well mouth at blowout base. When the water jets are raised up synchronously until flame losses of contact. The weak points of this method are high risk for people and necessity of synchronous operations.

The gas-water firefighting cars (AGVT-100 and AGVT-150) are used for putting-out all kind of the blowout, but often for powerful blowouts. The gas-water jets have 60% of water and 40% of gas. The concentration of oxygen is not more than 14% at barrel outlet. The water evaporates partially at gas burning hot jets, water at sprayed state comes at burning zone [4]. The gas-water jet has high cooling effect. For example: AGVT 100, admission is 60 liter/s, the blow-out reinforcement temperature is reduced from 950 to 100 – 150°C during 5 minutes. The optimal distance is 15 m, which is not enough for safety.

The pressure-operated powder flame-arresters PPP-200 are used for putting out powerful blow-outs [1]. The putting-out is realized due to powder influence. The powder discharge is carried out at the expense of compressed air energy. The fire extinguishering powder concentration is created during short period (1–2 s) by directed volley discharge. The weak points of this method are low discharge delivery and bad influence on environment.

The similar principle is realized at devices based on tank chassis (Impulse–1, Impulse–2, Impulse–3, Impulse–Storm). The device has 50 barrels, each of them has 30 kg of powder. Impulse–Storm can deliver 1.5 tones of extinguishering powder for 4 s. The effective distance is 50 – 100 m. The main difference of this installation is a powerful shock effect on the fire with extinguishers effects produced by a special powder formulation. The weak point of this method is bad influence on environment.

Main weak point of these methods is low delivery distance of fire-extinguishing substance which is not appropriate at high heat radiation of gas blowout. The optimal distance for hydraulic monitors is 15 m, but safety distance L for personal is 50 m for output V = 0.5 mln m^3/day.

So, the development of device, which can provide putting out from big distance (more than critical safety distance) is promissory task.

3. FUTURE DIRECTIONS OF DEVELOPMENT OF DEVICES FOR EXTINGUISHING GAS BLOW-OUTS

Always, in all times most available and simple resource for putting out the fire is water. It is widely used in firefighting practice except putting out alkaline metal or electrical equipment under voltage. Obviously the water has leading position at putting out of the blow-out due to availability, cheapness, simple delivery and exploitation, as well as high firefighting property. Today most perspective method of putting out the fire is using of fine-water mist. The main mechanism of putting out the fire by fine-water mist is cooling of burning material and formation of steam cloud, which localize the burning center. If the drops have not enough kinetic energy, they can't overcome the barrier of convective stream of hot gas, which is generated by flame, and as the result can't reach the flame surface and neutralize this process. In this case fine-water mist could be only used as auxiliary mean.

The efficiency of putting out by fine-water mist depends on the following factors: drop diameter, drop steam speed, presence of additive, nature of burning medium. The drop diameter influences mainly for effectiveness of putting out. Decreasing of drop diameters in fine-water mist can considerably decrease water rate for putting out the flame. At the same time decreasing of particle size obstructs maintenance of drop high speed and promote faster drop evaporation in zone, which is previous to flame. This factors decrease the effectiveness of fine-water mist putting out. The analysis of different authors prove that optimal drop diameter is equal to $d_{drop} \in (100 \div 150)$ mkm.

For water delivery from safety distance it is necessary to support the high speed at firefighting device output. Calculated value of this speed should take into account losses during the jet flight and provide required speed directly before blow out for overcoming convective stream, as well as "separated" impact on blow out. The equilibrium position of blow-out flame drifts with flow with increasing of the flow speed. This is the matter of "separated" impact. The recent aero-steam ignitable mixture became more and more diluted with moving away at the expense of reciprocal diffusion with steam. This mixture speed decreases proportionally dilution degree and exceeds burning speed at some critical steam value; the jet is broken for a moment, and flame is thrown upward and separated from it.

The speed of flame separation can be estimated based on empirical formula [3]

$$V_{separation} = 100\sqrt[3]{d},$$

where d – initial diameter of flame blow-out in meters.

The analyses of specified data for flame character changes from increasing the speed of burning jet shows that separation of diffusion flame is going on at 80 – 100 m/s, obviously than mentioned value of speed from safety distance (110 – 130 m) could be supplied with high speed liquid jets. These jets are generated by devises which are similar to impulse water-gun.

4. THE MATHEMATICAL MODEL IMPULSE WATER-GUN

The layout of impulse water-gun used for experimental research are shown at Fig. 1 [4, 5]. A powder hydro-cannon consists of combustion chamber (2), barrel (4), and nozzle (6) which ends with a collimator (7). The most stressful part of the barrel is strengthen by band 5 for hardening. Water charge (3) is in a barrel and is held by wads (8). The processes in powder hydro-cannon begin from the moment of powder ignition (1). Generated gunpowder gases accelerate the water charge in a barrel which then flows into a nozzle. The water continues to be accelerated and considerably increases its speed during flow in a narrowing nozzle. The outflow begins with small speed, which rapidly increases simultaneously which increasing of powder gas pressure.

To elaborate on the mathematical model of powder hydro-gun, one should accept the following assumptions: the liquid is assumed to be ideal and compressible. Its viscosity, heat conduction, and radial flow are neglected (quasi-one dimensional approximation). An influence of the wads is also neglected. As the initial time, we take the time of ignition of the powder charge, the origin of coordinates is located at the entrance of the nozzle, and the x-axis is directed along the axis of the installation.

The quasi-one dimensional motion of water in the water-cannon is described by the system of equations of nonstationary gas dynamics

$$\begin{aligned} &\frac{\partial \rho F}{\partial t}+\frac{\partial \rho v F}{\partial x}=0, \\ &\frac{\partial \rho v F}{\partial t}+\frac{\partial(\rho v^2+p)F}{\partial x}=p\frac{dF}{dx}, \\ &p=B\left[\left(\rho/\rho_0\right)^n-1\right] \end{aligned} \tag{1}$$

with the following initial, boundary conditions:

$$v(0,x)=0, \quad p(0,x)=0, \quad \rho(0,x)=\rho_0, \quad -L\le x\le L_s; \tag{2}$$
$$p\ (t,L)=0, \quad p(t,x_g)=p_g, \quad v(t,x_g)=v_g,$$

where t – time, x – a coordinate, v – the velocity of water, $F(x)$ – the cross-sectional area of the nozzle, p – pressure, ρ – density, B = 304.5 MPa, n = 7.15, ρ_0 =1000 kg/m^3 – constants in the equation of state of water in the Tait form, L and L_s – length of barrel and nozzle with collimator, x_g – coordinate of the contact surfaces, P_g and v_g – respectively, the pressure and velocity of powder-combustion gases on the contact surface.

The combustion of powder was considered in the quasi-stationary approximation under the following assumptions typical of the problems of internal ballistics in artillery [5]: the ignition of powder is instantaneous and its combustion is adiabatic (in parallel layers according to the geometric law), the chemical composition of combustion products is constant, and their

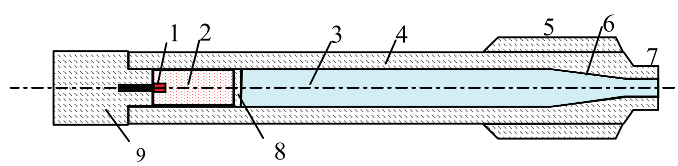

Figure 1: Powder impulse water-gun. 1 – ignition, 2 – combustion chamber, 3 – water, 4 – barrel, 5 – band, 6 – nozzle, 7 – collimator, 8 – wad, 9 – breech-block

parameters are identical over the entire volume and obey the simplified Van-der-Waals equation taking into account only the volume of the molecules.

The system of equations and initial conditions used to describe the process of quasi-stationary combustion of the powder have the form

$$\frac{dz}{dt} = \frac{u_1 p_g}{h_1}, \; Q_g = \frac{dm_g}{dt} = m_{p0}\sigma(z)\frac{dz}{dt},$$

$$\frac{1}{k-1}\frac{d\left(p_g V_g\right)}{dt} + p_g F u_g = qQ_g, \tag{3}$$

$$\frac{dV_g}{dt} = Q_g\left(1/\rho_p - \alpha\right) + v_g F, \quad v_g = \frac{dx_g}{dt},$$

$$m_b = m_{b0}, \; z = 0, \; V_g = V_{g0}, \; m_g = m_{g0}, \; p_g = p_{g0}, \; x_g = -L.$$

where h_1 – the half thickness of powder grains, z – the thickness of the burnt layer divided by h_1, u_1 – a constant of combustion rate, p_g – pressure of powder gases; Q_g – the velocity of delivery of powder-combustion gases, $\sigma(z) = 3(1 - 2z + z^2)$ – the relative area of burning gunpowder grains of spherical shape, α – the covolume (correction for the volume of molecules), m_{p0} – the initial mass of the powder, k – the exponent of the adiabat of powder-combustion gases, q, p – the specific heat of combustion and density of powder, V_g – the volume of the powder-combustion gases, V_{g0}, p_{g0} – parameters of gas after the actuation of the igniter.

The assigned task was solved numerically. The problem of the liquid flow has been decided using Godunov and Rodionov's methods, the powder burning – by modified Euler's method of 2nd order [4]. Some result of calculation for powder water-gun is presented below. The powder water-gun parameters are:

- water charge mass is 450 g,
- nozzle and jet diameter is 15 mm,
- length of impulse water jet $L_{cm} = V_{воды}/F_s$ is 2.56 m

The plots of jet outflow speed variation and pressure inside of impulse water-gun with time are presented on Fig. 2 for 30 g for powder (normal mode of impulse water-gun work). The curve 1 – outflow speed, 2 – powder gas pressure, 3 – water pressure in impulse powder water-gun barrel.

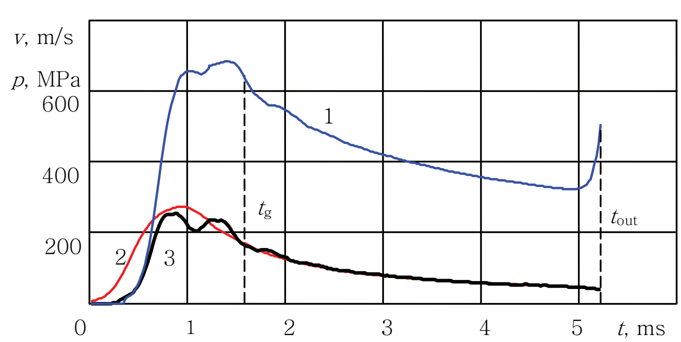

Figure 2: The plots of jet outflow speed variation and pressure inside of impulse water-gun with time. 1 – outflow speed, 2 – powder gas pressure, 3 – water pressure in impulse powder water-gun barrel, t_g =1,57 ms – powder burning time, t_{out} = 5,2 MC – end of water jet outflow

It is shown that jet outflow of impulse powder water-gun begins zero speed. During powder burning outflow speed increases rapidly and reaches maximum value 685 m/s after 1.5 ms from shot beginning. Powder is burned down completely at t_g = 1,57 ms (plotted as dotted line). The jet outflow speed slightly decreases to 647 m/s for this time. After powder complete burning jet outflow speed is slowly decreasing to 320 m/s. The jet outflow stops at moment of time t_{out} = 5,2 ms by discharge of small amount of water with more high speed by powder gas.

The curve 2 – powder gas pressure in impulse water-gun – has typical form for barreled guns. The powder gas pressure reaches the peak 275 MPa at the time 0.95 ms. Then powder gas pressure steadily decreases to 40 MPa at the short end. The water pressure in impulse water-gun barrel (curve 3) doesn't exceed powder gas pressure and has pulsed character which reproduce wave processes inside devise during the short. The wave processes are connected with compression and rarefaction waves which appear at powder gas boundary and nozzle edge.

Pressure pulsations are insignificant and slightly influence on impulse jet outflow speed. Liquid pressure in device and jet outflow speed coincide well with Bernoulli equation for uncompressible liquid and stationary process. Maximum jet outflow speed of impulse water-gun is equal to 678 m/s according to the calculation based on liquid pressure inside device at this moment. This value differs from precise calculation in unsteady problem definition for compressed liquid only on 1%. These calculation results show that powder impulse water-gun parameters could be calculated with enough accuracy in simplest quasi-stationary problem definition without liquid compressibility.

The calculation results of maximum impulse liquid jet speed for powder water-cannon and water-gun are shown in Table 1 for different powder charge mass.

It might be expected that maximum jet speed and pressure inside device are decreasing when powder mass (shot energy) is decreasing, but pressure is decreasing more

Table 1: The parameters of powder water-gun for different powder mass

powder mass, g	30	25	20	15	10	5
maximum liquid jet speed for impulse water-gun, m/s	686	600	504	405	298	178
maximum powder gas pressure for impulse water-gun, MPa	275	205,9	143	89,8	46,5	16,8
water pressure at maximum jet speed, MPa	236	172	122	80,6	42	15
maximum liquid jet, which calculated based on gas pressure (uncompressible liquid), m/s	741	642	535	424	305	183.3
maximum liquid jet, which calculated based on gas pressure (compressible liquid), m/s	724	629	527	420	303	183
maximum liquid jet, which calculated based on water pressure (uncompressible liquid), m/s	687	587	494	402	290	174
maximum liquid jet, which calculated based on water pressure (compressible liquid), m/s	672	577	488	398	288	173

quickly than speed. For example, maximum outflow speed decreases in 2.3 times, but pressure – in 6 times for 10 g powder (powder mass is less than normal mass in 3 times).

Maximum powder impulse water-gun speed was calculated theoretically based on Bernoulli equation for stationary outflow of the jet from barrel under pressure for uncompressed and compressed liquid according the formulas:

uncompressed liquid

$$v_{incomp} = \sqrt{\frac{2p}{\rho_0}},$$

compressed liquid

$$v_{comp} = a_0 \sqrt{\frac{2}{n-1}\left[\left(\frac{p}{B}+1\right)^{\frac{n-1}{n}} - 1\right]}, \quad a_0 = \sqrt{\frac{nB}{\rho_0}}.$$

Here a_0 – speed of sound in water under atmospheric pressure.

A significant decrease in the maximum pressure inside device under insignificant decrease in the maximum liquid jet speed is positive factor for device strength characteristic: the less will be pressure inside device, the less could be barrel thickness, the less will be mass and the more will be mobility.

The specific nature of the dependence of the impulse water-gun jet speed with time (rapid increase at the beginning of outflow from zero to maximum, then decreasing nearly to zero) defines laws of impulse jet. At the beginning of outflowing the fastest particles, which are outflowing from impulse water-gun nozzle, cut slowest particle's way out, which are outflowing earlier. As a result radial flow appears in the jet, which leads to increasing diametrical jet section. Radial flow speed v_r could be estimated based on Bernoulli equation for excess pressure in the jet, which appear during impact of fast back jet part with slow front part, which outflow earlier [7, 8]. This estimation shows that radial flow speed proportional square root of excess pressure $v_r \sim \sqrt{\Delta p} \sim \Delta v$, this pressure in turn proportional square root of speed difference Δv impacted parts of the jet. That is why at the beginning stage the outflowing speed of jet head has been increasing until high-speed parts don't reach jet head. Than the speed of jet head slows down because of air braking. Radial flow causes jet expension and formation spray halo around jet. The halo speed is approximately equal to the speed of core of a jet.

5. SCHEME OF THE EXPERIMENT

The preliminary experiment was done for justification of possibility of putting out blow-out by high-speed impulse jet. The main aim of the experiment was determination of principle possibility of putting out gas blow-out by impulse water-gun, as well as determination of the speed which is enough for extinguishing.

The gas blow-out with flow rate (1÷3)10^6 mln m^3/day was modeled. The well diameter is from 0.3 to 0.5 m which determined by the standard drilling equipment size. The diameter nozzle is equal to (6÷10) mm for model blow-out at model-prototype relationship according linear size M 1:20. The blow-out model with averaged parameters was used in the experiments.

The experiment scheme is shown at Fig. 3, the experimental device for field test is given at Fig. 4. Here 1 – powder impulse water-gun, 2 – impulse jet, 3 – gas blow-out, 4 – speed measuring instrument, 5 – laser bloc, 6 – laser rays.

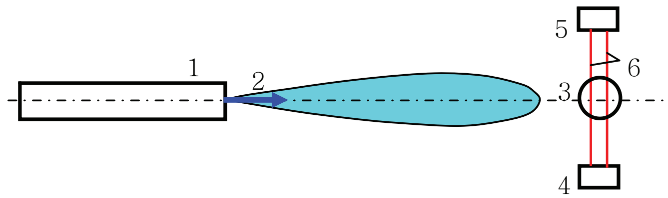

Figure 3: The experiment scheme. 1 – powder impulse water-gun, 2 – impulse jet, 3 – gas blow-out, 4 – speed measuring instrument, 5 – laser bloc, 6 – laser rays

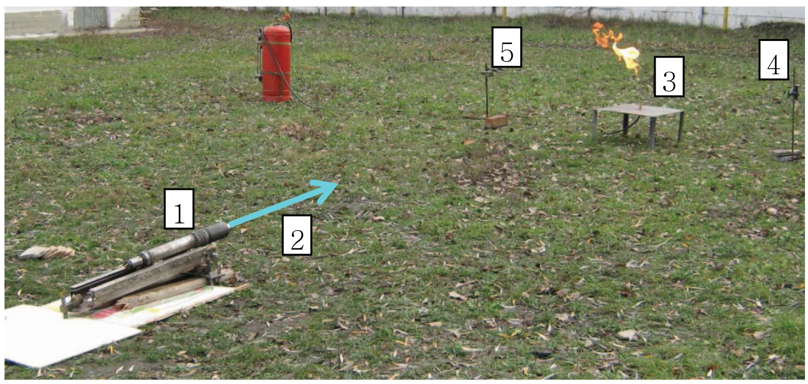

Figure 4: The field experiment scheme. 1 – powder impulse water-gun, 2 – impulse jet, 3 – gas blow-out, 4 – speed measuring instrument, 5 – laser bloc

The distance between impulse water-gun and blow-out and value of powder charge mass are changed at the experiment. The jet speed is depended from powder mass. The distance from device to blow-out is measured by tape measure, the aiming was done by special laser aiming device, which was located on the water-gun barrel.

6. THE EXPERIMENT OF PUTTING OUT GAS BLOW-OUT BY IMPULSE WATER-GUN

The principal possibility of putting out of gas blow-out by impulse water jet from big distance was investigated. The short was done from 5 and 10 m distances for 30, 20 and 10 g of powder charges. The head jet at blow-out location was measured, photo- and videoshooting were done for different stage of jet propagation. The jet head speed was measured by noncontacting gauge, which allow register the speed in the interval from 50 to 3000 m/s.

Some experimental results are given at the Table 2. The flame was knock-off and blow-out was extinguished at all experiments.

The intensive interaction jet with air is present at propagation high-speed liquid impulse jet in the air. The fine-dispersed spray halo is appear around jet, it moves with jet core speed. The frame of high-speed photoshooting of impulse water-gun jet is presented at Fig. 5 [13]. Initial jet diameter is 5 and 10 mm (Fig. a and b), maximum jet speed is 500 m/s.

As mention previously the feature of impulse water-gun short is the fact than jet begins outflow with zero speed, than speed increases and reach the maximum and finally decreases. At the beginning stage of outflow from the nozzle when jet speed increases,

Table 2: The experimental results

No	Powder mass, g	Well flow rate, l/s	Distance to blow-out, m	Jet speed near the blow-out, m/s	result
1	30	0,23	5	316	blow-out was extinguished
2	30	0,347	10	576	blow-out was extinguished
3	20	0,347	5	538	blow-out was extinguished
4	10	0,347	5	–	blow-out was extinguished

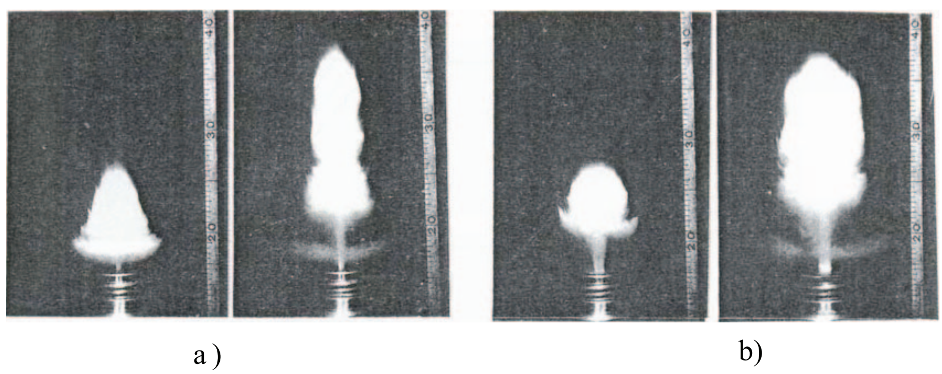

Figure 5: high-speed photoshooting of impulse water-gun jet in the air. a) jet diameter 5 mm, b) jet diameter 10 mm

following portion of water overtakes previous and impact with it. Impact of different jet part is the reason of radial expansion, formation of spread and radial disk, which are good visualized on the photo. The process has wave character for impulse water-gun with the piston [9] which resulted by device construction. The compression waves reflects periodically from piston and barrel end in this construction. This leads to pulsed jet outflow character. The impact of two parts of jet with different speed leads to disk formation on the jet, which are clearly notable at the photo. Disk diameter could be more than jet core diameter. These disks interact with air intensively, are diluted and create fine-dispersed spray around jet core. The lateral dimension of spray is much more than jet core diameter, it is presented at photo also.

The wave processes in the impulse water-gun, which is discussed here, are not so expressed, but the nature of liquid jet outflow is also presented for this impulse water-gun.

The initial stage of liquid jet formation from impulse water-gun is shown at Fig. 6. The characteristic bursts are good visible in the jet. These bursts are formed during outflowing by fastest liquid particles at the beginning outflowing stage. The initial jet form with bursts is very similar to one's from the jet photo from piston water-gun [9].

The middle stage of impulse liquid jet propagation during putting out gas blow-out is shown at Fig. 7. It is demonstrated, that water-gun jet has lance form which is surrounding by light-tight water spray at 2 – 2.5 m distance. This fact proves the theoretical assumption

Figure 6: The initial stage of liquid jet formation from impulse water-gun. 1 – powder impulse water-gun, 2 – impulse jet, 3 – gas blow-out

Figure 7: The middle stage of impulse liquid jet propagation. 1 – powder impulse water-gun, 2 – impulse jet, 3 – gas blow-out

Figure 8: The last stage of putting out of gas blow-out. 1 – powder impulse water-gun, 2 – impulse jet, 3 – gas blow-out

that the jet is peeled by air. Some drops are evaporated, head part of the jet is stretched up to 1 m size. The measured jet speed is equal to 550 m/c near the blow-out if powder charge is equal to 30 g.

The last stage of putting out of gas blow-out is presented at Fig. 8. It is shown that jet comes across blow-out base and cut off it from the well. Top part of the blow-out is still burning, the bottom part is shooting down and extinguished. The liquid impulse jet speed is much more gas inflow speed from the well in the burning zone, this helps to cutoff and extinguish. The water and steam spray is along impulse jet propagation trajectory, it quickly disperses in the air.

These experiments are show that impulse liquid jet from impulse water-gun can extinguish model blow-out from 10 m distance and more. The future research of putting out gas blow-out by high-speed liquid jet should be directed on impulse water-gun parameters optimization, decision of rational construction, investigation of impulse liquid jet propagation dynamics in the air and research of interaction of impulse jet this burning blow-out.

The following model of putting-out of blow-out by impulse water-gun could be offered. The impulse water-gun generates liquid jet of small diameter, but high speed. The jet interacts with air intensively during propagation, as a result the water spray is appear around jet core, which moves faster than jet itself. This stream-liquid medium is inert and does not supply burning. It has a lot of water in form of fine-dispersed drops, has good cooling surface and can decrease temperature of burning gas if it comes in burning zone. Lateral dimension of water spray for this device is near 0.5 m, longitudinal – 3 – 5 m. Spray speed is equal to 300 m/s. The jet is directed in well head, at bottom blow-out zone, where combustible mixture does not satisfy burning condition. The impulse liquid jet reaches this zone, cuts off burning blow-out from the well and break off combustible mixture inflow from the well to blow-out. Impulse liquid jet speed and its size are enough to terminate access of combustible mixture in burning zone and extinguish the blow-out. If jet speed is less 60 – 80 m/s when flame does not cut off and blow-out can’t be extinguished.

For this construction of impulse water-gun maximum distance of putting out is near 15 m. The device range is determined the way how impulse liquid jet is washing out by air during propagation.

If the jet core exists and moves this high speed when water spray which is generated from the core moves this approximately the same speed. When all core turns into water spray, the spray starts decelerate fast and has big resistant from the air. The only water spray stay at 20 m distance which could not stop burning. The device range considerably depend from operating conditions and construction. It is possible increase the device range up to 50 m and even more changing these factors.

7. CONCLUSIONS

Experimental research of putting out gas blow-out by impulse high-speed liquid jets, which are generated by powder impulse water-gun are done. The distance between impulse water-gun and blow-out and value of powder charge mass are changed at the experiment. The head jet at blow-out location was measured by laser non-contact speed measuring instrument, photoshooting was done. Maximum calculated speed of impulse jet depending from powder charge is equal to 200 – 700 m/s. Experimental data and analytical calculation results are found to be in good agreement.

The impulse high-speed liquid jet is washing out by air and high-speed water spray with big diametrical dimension is generated around it. This spray can effectively cut off the flame of gas blow-out from 5 – 20 m distance.

These experiments prove the possibility of putting out gas blow-out by high-speed impulse jet. The future work should be directed on speed and density determination along the jet cross-section.

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