При указанном варианте крепления (нежесткая сцепка с вертолетом) и условии, что вертолет завис в воздухе, не требуется никаких дополнительных устройств, которые бы стабилизировали подвесное устройство пожаротушения для точности попадания в очаг возгорания.

Допустим, устройство шибера устройства таково, что имеется возможность выпускать струю вододисперсной смеси из бака целенаправленно через сопло, как показано на рис. 4. Если на бак со стороны вытекающей из сопла жидкости действует сила F, то с помощью рис. 5 легко найти угол отклонения бака от положения равновесия под действием этой силы:

$$tg\alpha = \frac{F}{M^* g}, \qquad (3)$$

где M^* – суммарная масса бака, поршня и жидкости.

Составим дифференциальное уравнение $dP = mv_2 = v_2 dt S_2 \rho v_2$, откуда

$$F = \frac{dP}{dt} = \rho S_2 v_2^2, \qquad (4)$$

где P – суммарный импульс вытекающей из бака жидкости.

Подставляя в (4) из (2) квадрат скорости и используя (3), окончательно получаем:

$$tg\alpha = \frac{\rho S_2 \left(\frac{2\left(Mg + Q(t)\right)}{\rho S_1} + 2gh \right)}{M^* g}. \qquad (5)$$

Из формулы (5) видно, что при большой массе M^* конструкции с жидкостью величина тангенса угла отклонения подвеса от вертикали – мала, а значит, и угол отклонения мал, что позволяет сделать вывод о точности попадания вододисперсной смеси в область пожара в случае нежёсткой сцепки предлагаемой конструкции с вертолётом.

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FIRE EXTINGUISHING FROM A HELICOPTER IN THE CITIES

Vestyak, Vladimir A. *– Ph.D. (Physics and Mathematics), assistant professor, head of the department of Moscow aviation institute – national research university (MAI).*

ABSTRACT

The author considers various ways of fire extinguishing by means of aviation equipment, the most environmentally suitable and efficient under different conditions. It is suggested to alter a helicopter fire extinguishing system in the cities and to adapt it for «not volley» operation and a fast intake of water from the reservoir, which is the closest to the seat of fire. The work is based on R&D work realized by MAI University and implemented into the practices, is substantiated by relevant mathematical apparatus.

ENGLISH SUMMARY

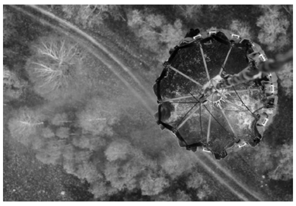
Background. *A serious situation is developing today regarding extinguishing fires in large cities. Accumulation of vehicles in traffic jams, spontaneous parking in courtyards significantly impede passage of fire brigades to the scene. Most often, they come when the fire has done its job and it is time to extinguish firebrands. And here at least a right for delivery of health care is violated, provided in the regulation of Ministry of Emergency Situations and called «golden hour».*

In addition, in connection with the growing day by day height of buildings under construction, an issue of protecting skyscrapers from fire is becoming ever more urgent. Rotary-wing machines come here to the rescue of residents of large cities. A helicopter for several reasons in this case is a single suitable mode of transport for the installation of fire fighting systems. And one of the reasons is speed of arrival to the fire point, damage from which usually increases exponentially over time.

Objective. *The objective of the author is to investigate advantages of helicopters in fire extinguishing and to present a fire extinguishing installation, developed by scientists of MAI.*

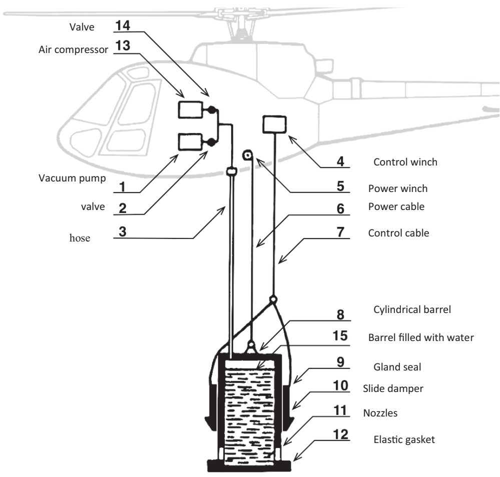
Methods. *The author uses engineering descriptive method, and mathematical modelling based on Bernoulli equation.*

Results. *What are the advantages of extinguishing fires from a helicopter? It does not need a runway. It is able to move in horizontal and vertical directions, as well as hover in the air, so the machine can approach fireplaces, to which ground or other aircraft equipment cannot come. A definite plus of a fire helicopter in an emergency is also flexibility of its use. It is able at the same time to lose a few tons of extinguishing agent on a single point, as well as cover a given area. Some models have a function of horizontal firefighting.*

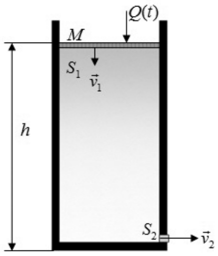


Pic. 1. Soft cylindrical tank with large rigid ring for water intake.

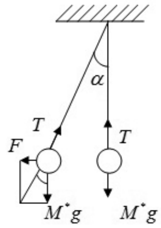
Pic. 2. Fire extinguishing with defoaming agents at oil storage with water dispersing guns.



Pic. 3. Schematic diagram of a device for fire extinguishing from a helicopter.



Pic. 4. Cylindrical shell filled with the water up to the height h.



Pic. 5. Angle of deviation of the tank from equilibrium position caused by force F.

According to statistics, about 40% of the world air fleet amounts to helicopters. However, despite the versatility and wide possibilities for this machine, not so many rescue organizations are willing to buy a helicopter to extinguish fire. Besides, a universal machine of this type does not exist.

After the fire at the Ostankino Tower in Moscow [2000 – ed.note] a task has become particularly urgent to extinguish fire with directed jet at a high altitude. From this point of view an installation developed by MAI scientists draws special interest. It is placed on helicopters KA-32a, MI-26 and allows extinguishing an ignition source with directed horizontal jet. Thus a good range enables to use it on objects, a close approach to which is limited due to high temperature or other reasons (for example, it concerns petrol stations or premises with similar degree of danger with electric equipment under voltage) [4].

As for forest fires a main burden falls on specialized heavy aircrafts IL-76 and Be-200, in the cities helicopter Mi-8 with a suspension device for intake and discharge of water or water disperse mixture was widlely used.

Helicopters use cargo suspension of a drain tank with polley water disposal system from a minimum altitude, when performance of engines is not even disturbed (pump mode due to lack of oxygen). Production of this type of system is organized in the Research Institute of aeroelastic systems for helicopters Mi-8 and Ka-32 with a water capacity of 1300 to 2500 liters and heavy helicopter Mi-26 with a capacity of 15000 liters.

The main element in this system of fire extinguishing is a soft cylindrical tank with a large upper rigid ring for water intake and a lower ring for water discharge.

Overall view of the system from the perspective of a large ring is shown in Pic. 1.

To extinguish burning hydrocarbons defoaming compositions are used together with water dispersing guns (see. Pic. 2).

Scientists of MAI suggest a fire extinguisher, based on the use of a rigid container with nozzle orifices for water output and adjustable slide damper of its consumption, and a vacuum pump to accelerate the intake of a new portion of water [1].

Schematic diagram of the structure is shown in the drawing (Pic. 3). The device consists of a power cable 6, a cylindrical barrel 8, slide damper 10 with gland seal 9. In a lower part of the barrel there are nozzles 11 for water output and elastic gasket 12. A barrel with water 15 is connected to the helicopter by means of a hose 3, connected to an air compressor 13 via valve 14 and to a vacuum pump 1 through a valve 2, and also by means of a cable 7 with a control winch 4. Power winch 5 is attached to the barrel 8 with a cable 6.

The device operates as follows.

A helicopter with a water-filled barrel 8, hanging on the power cable 6 is sent to the fire seat. Above the fireplace with a control cable 7 a slide damper 10 is lifted, opening nozzles 11 for water discharge. At the same time valve 14 opens and an air compressor 13 is turned on, replacing through a hose 3 water from a barrel at a pressure of 2–3 atm. After the displacement of water from a barrel, compressor 13 is turned off and the valve 14 is closed.

Helicopter goes to a nearby water reservoir to take a new portion of water. Barrel 8 glass is immersed in water at lifted slide damper 10, simultaneously valve 2 is opened and the vacuum pump 1is turned on to accelerate filling of a barrel. After water intake slide damper 10 is lowered, valve 2 and pump 1are de-energized. The helicopter returns to the fireplace.

Let consider the problem that approximately simulates the proposed model of a device suspension. A cylindrical shell whose area of cross-section is equal to S_1, is filled with a liquid up to the height h (pic. 4). Side wall of a vessel has an outlet of an area S_2, where from a liquid is coming under a pressure. The shell is covered form above by a plunger of a mass M, and an extra force $Q(t)$ is applied to the plunger in order to increase exhaust fluid head.

According to Bernoulli equation the total pressure at the cross-section S_1 at the height h and the total pressure at the cross-section S_2 are equal to:

$$\frac{\rho v_1^2}{2} + \rho g h + p_1 = \frac{\rho v_2^2}{2} + p_2, \qquad (1)$$

From the continuity equation it is easy to get $v_1 = \frac{S_2}{S_1} \cdot v_2$.

Static pressure p_2 for an open aperture is equal to atmospheric pressure $p_0 : p_2 = p_0$. Static pressure p_1 is larger than the atmospheric one because of a power of gravity of the plunger Mg and of the extra force applied to the plunger $Q(t)$:

$$p_1 = p_0 + \frac{Mg + Q(t)}{S_1}.$$

Taking that into consideration Bernoulli equation will be written as follows:

$$\left(1 - \left(\frac{S_2}{S_1}\right)^2\right) \cdot \frac{\rho v_2^2}{2} = \rho g h + \frac{Mg + Q(t)}{S_1}.$$

If $S_2 \ll S_1$, then the expression $1 - \left(\frac{S_2}{S_1}\right)^2 \approx 1$. Then the square of the speed v_2 of liquid exhausting from the aperture will be defined through the next expression:

$$v_2^2 = 2gh + \frac{2\left(Mg + Q(t)\right)}{\rho S_1}. \qquad (2)$$

If we consider the proposed variant of suspension (not rigid coupling with helicopter) and under the condition that a helicopter is hovering, we don't need any additional devices to stabilize the suspended fire extinguishing device in order to achieve more accuracy of hitting the fireside.

Let us assume that the design of a slide damper (valve) allows to jet water dispersed mixture from the tank through the nozzle as shown in pic. 4. If a force F is applied to the tank by the liquid exhausting from the nozzle, then with the help of the pic. 5 it will be easy to find the angle of deviation of the tank from the equilibrium position, caused by that force:

$$tg\alpha = \frac{F}{M^* g}, \qquad (3)$$

where M^* is total mass of the tank, plunger and liquid.

Let us compare differential equation: $dP = mv_2 = v_2 dt S_2 \rho v_2$, on its basis

$$F = \frac{dP}{dt} = \rho S_2 v_2^2, \qquad (4)$$

where P is a total impulse (momentum) of the liquid exhausting from the tank. By substituting speed square from (2) to (4) and using (3) we definitely get:

$$tg\alpha = \frac{\rho S_2 \left(\frac{2\left(Mg + Q(t)\right)}{\rho S_1} + 2gh\right)}{M^* g}. \qquad (5)$$

From equation (5) we see that with a big mass M^* of a device filled with liquid the value of tangent of the angle of deviation of suspended device from vertical line is rather little and, subsequently, the deviation angle is little, so we can conclude that if coupling of proposed device with helicopter is not rigid, then we can attend accuracy of hitting of the fireside by water dispersed mixture.

Conclusion. Thus, the proposed installation includes not only a method of supplying water to the source of fire, but also a device for rapid intake of water from the water reservoir, with larger volume than similar installations.

Keywords: aviation, fire extinguishers, helicopter, hanger, fire-extinguishing agent, slide damper, water disperse mixture, vacuum pump, city, environmental ecology.

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Координаты автора (contact information): Вестяк В. А. (Vestyak, V.A.) – kaf311@mai.ru.

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