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POSSIBILITIES OF OPEN ERUPTION ELIMINATION BY DRILLING TOOLS

Petr BUJOK[1], **Martin KLEMPA**[1], **Marek YAKUBCHIK**[2], **Yakub RYBA**[1], **Mikhail PORZER**[1]
[1] *Higher Mining and Metallurgical School – Ostrava Technical University, Ostrava, Czech Rebublic*
[2] *Main Mining Rescue Station, Hodonin, Czech Republic*

The most important raw materials for different industries are oil and natural gas. With increasing consumption, the demand for drilling and the quality of production increases. Therefore, the exploration and production of hydrocarbons requires not only first-class machinery and technological equipment, but also qualified personnel.

Exploration and drilling, production of hydrocarbons, like any other industry, cannot avoid accidents, emergencies and catastrophes. The worst type of well accident is undoubtedly an open eruption of the extracted crude oil. Open eruption can lead to serious injuries to the rig personnel, damage and destruction of equipment, negative environmental impact and loss of crude oil.

Exploratory drilling can cause the rise of pressure and its subsequent manifestations. During the first deep drilling, there may not be enough information about the drilled horizons. If the reservoir pressure in the production horizon is higher than the hydrostatic pressure of the fluid in the well (for example, drilling mud), the formation fluids flow into the well and move towards the surface, which causes open eruption. The rig personnel must be properly trained to be able to recognize the occurrence of rising pressure by various signs and to respond effectively to the situation. Sometimes, under the influence of the human factor or equipment failure, open eruption still occurs. The article discusses the possibilities of eliminating open eruptions with drilling tools.

***Kew words*:** drilling tools; eruption; elimination; equipment for utilization; practicality of equipment; rescue station

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Introduction. Problems of pressure manifestation, the theory and practice of their elimination were studied by a number of authors [1-4, 12]. The term pressure manifestation (blowout) is the spontaneous release of the washing fluid from the well. As a rule, this occurs when the existing pressure ratio in the bottomhole and in the wellbore is violated. Such a change can be caused either by a drop in the hydrostatic pressure of the washing, for example, as a result of a decrease in the level of washing in the well bore, or due to a higher pressure in the production reservoir and, consequently, fluid penetration from the bottomhole into the well. The change in pressure ratio occurs both during the drilling process and during the production or start-up of equipment, but also, for example, at well inspection, when the washing fluid does not circulate. Blowout should be understood as a chain reaction, because reservoir fluids that have penetrated the well are usually lighter than the washing fluid and, therefore, lighten the fluid. This contributes to an increase in the inflow of formation fluids to the well, the total volume of inflow fluid gradually increases and the difference between the reservoir and hydrostatic pressure rises. The speed of this process depends on the properties of the reservoir, especially its capacity, on the pressure and the nature of the filtration surface and the thickness of the formation [8, 11].

These emergencies are resolved in the Czech Republic by the Hodonín Main Mining Rescue Station (HBZS). The station is a member of MND SA (Moravian Oil Mines, the most famous hydrocarbon producer in the Czech Republic) with headquarters in MND Drilling & Services a.s. in the village of Lužice.

Currently, the HBZS crew consists of 40 mining rescuers, of which 10 are professionals, and 30 are volunteers from individual parts of the MND SA group. It also controls two ZBZS, formed by Innogy, which subordinates another 59 voluntary mining rescuers. Emergency service works around the clock. A team of mining rescuers, having the necessary equipment, is constantly ready for departure.

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Statement of the problem. To counter the blowout and eruption, different methods are used depending on the immediate situation in the wellbore. A prerequisite for eliminating the blowout, and, if necessary, eruption, is the complete closure of the well, followed by its controlled opening when using an orderly washing fluid. The goal is to achieve equilibrium of hydraulic and surface pressure. A special case is the manifestation of pressure during the extraction and commissioning of the equipment when the drilling string is open.

During the manifestation of pressure, the so-called internal fail-safe is used in most cases to close the inner diameter of the drilling string. In the case of the initial pressure manifestation, the drilling string is lifted or lowered to the level of the working deck and the internal fail-safe is attached. The locking mechanism of the internal fail-safe is a shaft with a polished front part, which is inserted from below onto the seat with a seal. The spring presses the shaft, which keeps the mechanism open. After releasing the shaft lock, the internal fail-safe closes. If drilling with a working pipe, pipe gate can be used.

In fact, we are talking about a modified part of the drilling pipe, in the middle of which a ball valve is located. This valve is controlled remotely by means of a lever, which has two positions – open/closed. The pipe gate is constantly screwed onto the working pipe [7]. However, some of these devices cannot always be used. First of all, these are the cases of the drilling string jamming in the well (sticking) and, consequently, the impossibility of pulling it up or lowering it to the level of the working deck.

If the situation on the ground is such that it is possible to begin work on the elimination of eruption directly from the working deck, anesthetic tool can be used. First of all, it is necessary to cut off the excess part of the drilling string to the required height above the working deck. Another possibility is, for example, the process of water jet cutting with an admixture of abrasive material, however, a hydraulic drive cutter is more advantageous in terms of high-quality, clean and fast cutting.

The next stage is the preparation of the anesthetic tool component part. It represents divided cubes with four outlets. A pin is screwed to the lower outlet, having a replaceable elastomeric sealing gasket of conical shape in the lower part, the lateral outlets are valves with connection to the pressure pipeline, and a stop valve is attached to the upper one [9]. The eruption is successively stopped by closing the upper gate valve, and the well, after being connected to the pressure pipeline and the cementing unit or pumps, may be abandoned.

Methodology. In order to solve some emergency situations, specialized services must be called in; only foreign services exist in the Czech Republic. This was the reason for the Hodonín Main Mining Rescue Station (HBZS) to ponder the creation of special equipment that will allow for the elimination by crushing the drilling pipe, creating access to the drilling pipe under the place of crushing and pumping the sealing elements together with the pumped fluid at any position of the drilling tool. The device must comply with the following conditions: be light and maneuverable; minimize time spent in the immediate vicinity of the pressure manifestation with the necessary number of rescuers; be controlled from a safe distance; to be compatible with other equipment of mining rescuers and applicable for all pipe materials used in the conditions of MND SA.

The first device of this type was developed in HBZS and manufactured in MND Drilling & Services already in 2011. The device consists of three main parts.

Drilling tool. The equipment is designed so that it is possible to drill a drilling pipe with an internal pressure of up to 21 MPa. A step drill bit or a crown drilling bit with a diameter of 40 mm is used as a drilling tool. The drilling tool is driven by a hydraulic unit, and the tool movement is manual.

Crushing device. The crushing device consists of a hydraulic cylinder with a pressing element and its antipode (Fig.1). Crushing elements are wedge-shaped. At the first stage, the hydraulic cylinder was operated by a manual pump, now it is controlled by a hydraulic unit [10].

Fig.1. Prototype of the crushing equipment [9]

Fig.2. Modified device FIB-1 [5]

Sealing elements. These elements should be shaped and sized so that they can be injected with a 2‘‘ (50.8 mm) pumping pipe through a drilled hole. The material must be strong enough not to be pushed by pressure through the place of the crushed pipe, but plastic, to seal the remaining gap after collapse, light so as not to fall under its own weight to the bottom of the well, but be forced out by the medium upwards. The first tested were rubber and lightweight duralumin balls.

Practical tests were carried out in June 2012 in Slovakia at the HBZS Malacky training ground in Lozorn, where there is a training well with water and gas supply, which allows simulating the conditions of open eruption. The result of this test – the sealing of the remaining gap was not ideal, but the release of fluids was significantly reduced, which made it possible to stop the eruption of the well.

Research. After testing this method of dealing with open eruption, the staff of the Engineering Geology Department of the Ostrava Technical University carried out the modification of the entire equipment for drilling and crushing of the equipment, paying particular attention to the shape of the compressor jaw, a suitable pressure force, an improvement in the efficiency of the drilling device, suggested the appropriate type of post-sealing elements.

The first stage of research is an experimental method – crushing various types of drilling pipes and determining the most appropriate minimum pressure for tight crushing of a tubular material [9, 10]. Based on the results of this stage, a new modified equipment was developed, called FIB-1 (by the name of the author of the first proposed model by engineer J.Fibinger), with certain dimensions of the hydraulic shaft (Fig.2).

The second stage of the research is the verification of the functional capabilities of the FIB-1 device, followed by testing of suitable forms of compression elements together with the corresponding crushing process so as to limit or eliminate the longitudinal appearance of cracks in the pipe material. Cracks on the sides of the tubular material (at the point of greatest bend) appeared in almost all experimental cases.

Testing on the experimental press SHREK HL-100T (Fig.3) showed that it is necessary to individually approach the studied tubular material. For a drilling pipe with a diameter of 10.6 cm ball/ball jaw combination turned out to be the best choice in terms of applied pressure. To close the internal profile (test N 5) of this combination, it took about 180 bar/90 t. On the other hand, the wedge/wedge combination required a pressure of 250 bar/125 t; 210 bar/105 t (experiment N 2). Considering the exerted pressure, the ball/flat surface jaw combination (experiment N 4) seems to be the least practical [5]. The comparison is shown in Fig.4.

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The size of the cracks was partially eliminated with the help of a new type of compressor element [6]. At the same time, when using this form, it was possible to significantly reduce the necessary pressure to crush the pipe material.

Carried out tests established the active form of the compression element, which is most suitable for pressing the casing tubes or drilling pipes – the original wedge-shaped form of the compressor elements with the added rounded muzzles regulating their angle.

The third stage of the research is the search for the most suitable sealing material, since the original aluminum or rubber balls could not reliably seal the remaining gap. On the basis of laboratory tests and the factory testing of equipment on the territory of the HBZS Hodonin range, fabric with different surface treatments (imbued with latex and nitrite) was chosen as the base material for further experiments.

New post-sealing elements (in the form of a roller) filled with tested materials were made of this fabric [5]. The composition of the filler provides a suitable density of the element so that it does not fall in the column under washing pressure, sufficient stability of the element to be pushed through the remaining gap, the necessary plasticity when passing through the transporting pipeline, as well as when the remaining gap is post sealed. The used press is presented in Fig.5.

The latest version of the FIB-1 equipment was tested in May 2015 at the training ground of EXALO Drilling SA in Tarnawie Dolna, Sanok (Poland), where rescue teams competitions were held. Unfortunately, due to technical and time constraints, it was not possible to test the subsequent application of new proposed post-sealing elements [6].

Discussion. The durability analysis of the proposed FIB-1 equipment [5] was carried out using computer simulation (finite element method) and the ANSYS Workbench software (Fig.6). The stress reduction is determined according to HMH (Misses) and for a fixed wedge-shaped jaw. The jaw is made of steel, the density is 7850 kg/m^3,

Fig.3. Press SHREK HL-100T [5]

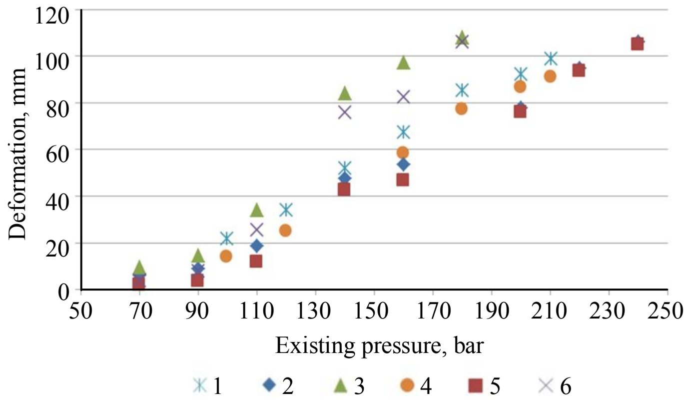

Fig.4. Comparison of existing pressures using different types of jaw: wedge/wedge (experiment N 2); ball / plane surface (experiment N 4); ball/ball (experiment number 5) [5]

Deformations at pressure: N 2 – 1; N 3 – 2; N 4 – 3;
deformations after lifting the pressure: N 2 – 4; N 3 – 5; N 4 – 6

Fig.5. Press 816 Rock Test System [6]

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the module of elasticity is 200 000 MPa, the Poisson's ratio is 0.3. Durability analysis was carried out for all structural elements [5].

Conclusion. Currently, HBZS Hodonín employees use devices (DN 40, PN 350) for drilling (drilling pipes, casing pipes, valves, etc.). A new type of equipment was developed at Ostrava Technical University.

Equipment working abilities:

• drilling of drilling pipes or casing strings with a wall thickness of up to 20 mm with a drill or drilling bit;

• drilling under pressure of the erupted medium in the inner part of the pipe or casing with a working pressure of 21 MPa;

• possibility to use drills or drilling bits with a diameter up to 40 mm for drilling;

• remote control of the drilling process through the hydraulic control panel.

Manipulation abilities:

• dimensions that provide easy transportation to the working deck and the ability to connect to the incriminated drilling pipe or casing pipe;

• weight, allowing working a team of two workers;

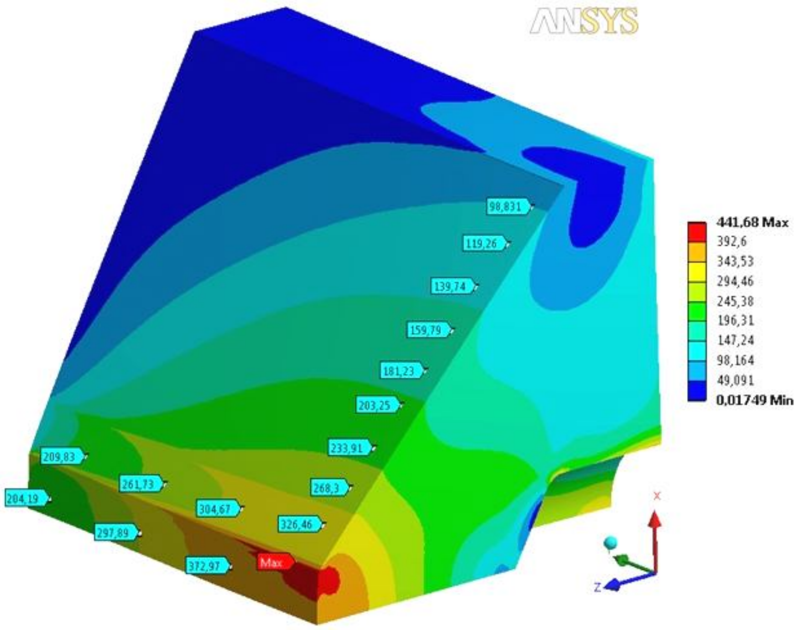

Fig.6. Stress reduction according to HMH [MPa] [5]

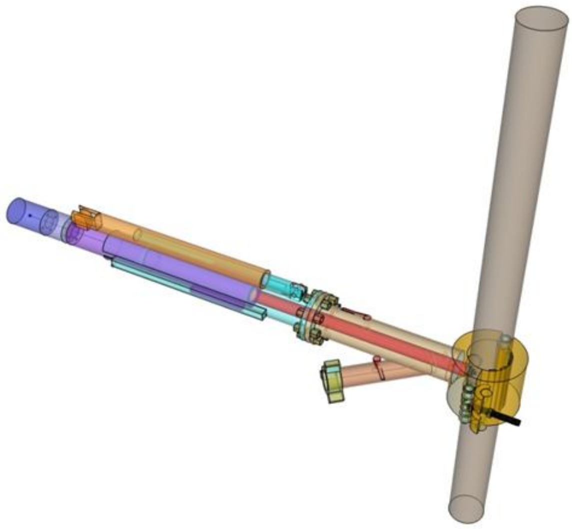

Fig.7. Internal view of a new model of a device for drilling, fastened by a coupling on a drilled tube [6]

Fig.8. Graduated drill and drilling bit [6]

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• preparation, providing connection of the device to the input of the cementing unit's mud pipeline and connection of the bypass to the reservoir of the post-sealing elements; process control remotely without the need to dismantle the drilling device.

Fig.7 schematically shows the new drills. The hydraulic drilling motor is part of the drill body. For drilling, a mobile drill or drilling bits with a diameter of 40 mm are used. Horizontal movement is adjusted by guiding units. A connection for supplying fluid (including post-sealing elements) is installed in front of the clamping valve.

Two types of tools have been developed for drilling a drilling pipe or a casing at the point of compression: a graduated drill bit, and a crown drilling bit with an internal gripping magnet (Fig.8). The combination with the magnet is made to prevent the drilled element from falling inside the pipe or casing.

Further factory testing of the modified FIB-1 device and the proposed post-sealing elements will be carried out in cooperation with the HBZS staff at the Lozorno training ground in Slovakia.

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***Autors*: Petr Bujok,** *CSc, Professor, petr.bujok@vsb.cz (Higher Mining and Metallurgical School – Ostrava Technical University, Ostrava, Czech Rebublic),* **Martin Klempa,** *PhD, Deputy Director, martin.klempa@vsb.cz (Higher Mining and Metallurgical School – Ostrava Technical University, Ostrava, Czech Rebublic),* **Marek Yakubchik,** *Director, jakubcik@mnd.cz (Main Mining Rescue Station, Hodonin, Czech Republic),* **Yakub Ryba,** *PhD student, jakub.ryba@vsb.cz (Higher Mining and Metallurgical School – Ostrava Technical University, Ostrava, Czech Rebublic),* **Mikhail Porzer,** *PhD, michal.porzer@vsb.cz (Higher Mining and Metallurgical School – Ostrava Technical University, Ostrava, Czech Rebublic).*

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