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PELLET IMPACT DRILLING DEVELOPMENT: PROSPECTS AND TRENDS

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Nowadays, there is a trend of increasing amounts of operations in hard and tough rocks in world's drilling practice. Drilling in such types of rocks is characterized by low values of mechanical speed and bit pressure. In this regard, development of alternative ways of hard-rock destruction and new design solutions for rock cutting tool becomes topical. Pellet impact boring method which implies destruction of rocks by blows of metal pellets continuously circulating in a bottom-hole area is one of the most prospective techniques. Circulation is carried out by means of an ejector pellet impact tool string. Potentially, this method can give a considerable gain of penetration rate within the range of hard and tough rocks, reduce costs of a well construction by cutting round-trip time down. Moreover, as pellet impact method can easily fit the existing well technology which involves cutting transport by drilling fluid it will not demand considerable re-equipment of the drilling rig.

For the first time the method of rock destruction by pellet impact was offered in 1955 by a group of scientists from American company «Carter Oil». A jet pump was chosen by them as a device which can cause acceleration and recirculation of pellets. As a result of their laboratory research it was established that the greatest mechanical cutting speed is observed using the pellets of the greatest possible diameter which do not get jammed in mixing chamber. However, in 1961 one of participants of this project L. U. Ledgerwood noted that pellet impact drilling has no practical application and, despite the possibility of destroying rocks, this method is less cost-effective than usual rotary drilling. These conclusions have been brought about owing to a procedure error: while making experiments the American scientists put emphasis on pellet impact physics rather than rock destruction issues. Consequently, the researchers drilled rocks of different hardness at identical pellet launching speed which was equal to 22,8 m/s. Besides, the tool string which was called "gravity-aspirator" had a number of shortcomings. The special feet which were in contact with a hole bottom to maintain the optimal distance to the tool, blocked the part of the area, which in its turn, made it necessary to rotate the tool and subsequently, they wore out rather quickly (fig. 1) [1].

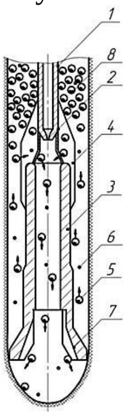

Figure 1. Gravity-aspirator drill bit [1]
1 – drill string; 2 – primary nozzle;
3 – secondary nozzle; 4 – bars;
5 – rock-breaking pellets; 6 – cuttings; 7 – feet;
8 – pellet cloud.

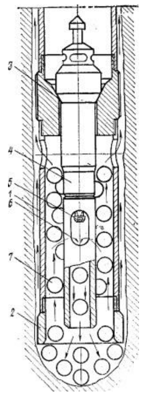

Figure 2. Blade ejector pellet impact drill bit [3]
1 – body; 2 – rock-breaking piston shoe;
3 – seat; 4 – jet apparatus; 5 – nozzle;
6 – mixing chamber with inlet ports; 7 – pellets.

Despite negative conclusions made by pellet impact drilling pioneers, this method continued to arise interest of some researchers. Since 1963 the ejector pellet impact tool string was used for well deviation studies in the Southern Kazakhstan Geological Survey directed by A. B. Uvakov. For this purpose the method turned out to be effective since there was no need to rotate the tool due to new design solutions (fig. 2) [3]. The researches revealed the main analytical dependences which characterize rock destruction caused by pellet impact, and calculation technique for pellet impact drilling procedure was developed. A number of laboratory and field researches were carried out, and as a result economic efficiency of the method was assessed. The experiments proved that in an optimal operating mode mechanical penetration rate increases with increase of rock hardness and can make up to 20 m/h in tough and very tough rocks. Considerable runout can be avoided by choosing optimum pellet launching speed at which there are no rebounds of spheres from a hole [4].

The pellet impact tool string developed by A. B. Uvakov and V. V. Strasser was improved numerous times. In 1995 a Kazakh scientist S. A. Zaurbekov defined the reasonable parameters of destruction process during pellet impact drilling and, on this basis he designed new construction called “PIM-216” (fig. 3). Its industrial testing showed excess of mechanical speed by 20% and bit pressure by 43% over the serial tools [5].

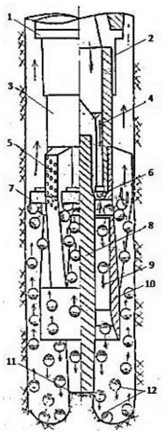

Figure 3. Ejector pellet impact drill bit with the nozzle and circular mixing chamber [5]
1 – calibrating device; 2 – sub; 3 – connector end;
4 – fluid delivery channel; 5 – calibrating and centralizing bars;
6 – circular nozzle; 7 – arrestor; 8 – drill bit holder;
9 – circular mixing chamber;
10 – drill bit body; 11 – hard alloy teeth; 12 – pellets.

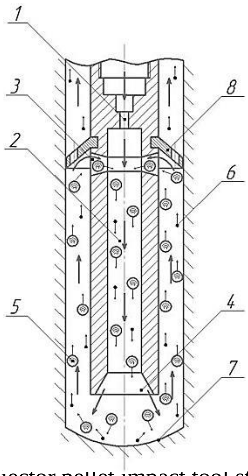

Figure 4. Ejector pellet impact tool string and its operational principle [2]
1 – nozzle; 2 – mixing chamber;
3 – operating windows; 4 – diffuser;
5 – pellets; 6 – drilling cuttings;
7 – rock; 8 – arrestor

Since 2012 the researches of this method have been conducted at the Department of Well Drilling of Tomsk Polytechnic University. During them, an optimal construction of ejector tool string was designed, with the nozzle and the tubular mixing chamber arranged consequently in line (fig. 4). This device functions as it follows: the operating fluid supplied to the tool is accelerated in the nozzle (1) and runs at the high speed to the mixing chamber (2). A suction zone forms in the area outside the nozzle. Operating fluid from annular space is sucked through the operating windows (3) due to effect of ejection along with pellets (5) and drilling cuttings (6). Then two-phase fluid goes through the mixing chamber, diffuser (4) and breaks the rock (7). Then the pellets rise in the annular space until they are stopped by the arrestor (8) and then the cycle is repeated.

On the basis of these theoretical and experimental investigations the following results have been obtained:

– the possibility of increasing pellet impact drilling efficiency in tough rocks by accurate technological process coordination and adequate construction of tool string elements has been proved;
– for the first time high-speed photography (3600 shots per second) has been carried out to explore rapid processes and to develop a physical model of drilling;
– functional correlation between drilling mode efficiency and the pellet diameter, the height of operating windows, the mass of pellet portion, the nozzle diameter, the distance between the nozzle outlet and the top slice of operating windows, the distance between tool string and hole bottom, the length of the mixing chamber, the cone angle of arrestor, mud flow rate, the opening angle of a diffuser have been assessed.

Pellet impact drilling method being considered prospective, the following theoretical and experimental research is further required:

– detailed research of method power expenses to define its energy conversion efficiency;
– analysis of effects of different drilling fluids and rock hardness reducers on the operating process;

– development of eject drilling mathematical model allowing to calculate mechanical speed under various geological conditions;
– development of runout decrease methods;
testing of drilling control methods;
– design of catching-charging device which can replace worn out pellets, run in and pull out pellets to reduce round-trip time;
– research to solve directional drilling problem using the ejector tool string [2].

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GEOECOLOGICAL PROBLEMS OF COAL INDUSTRY (ON THE EXAMPLE OF KEMEROVO REGION)

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The work presents the main data of coal production and indexes of Kemerovo region air pollution level due to the coal industry. The materials of the study were reports of the department of natural recourses and ecology of Kemerovo region and Russian scientists' investigations devoted to the problem of geoecology of the coal industry.

The goal of coal mining is to economically remove coal from the ground. Coal is valued for its energy content, and since the 1880s is widely used to generate electricity. Steel and cement industries use coal as a fuel for extraction of iron from iron ore and for cement production [3]. The environmental impact of mining includes erosion, formation of sinkholes, loss of biodiversity, and contamination of soil, groundwater, surface water by chemicals from mining processes [4]. In urbanized environments mining may produce noise pollution, dust pollution and visual pollution.

The aim of the research is to review the impact of the Kemerovo region coal industry on the general state of air pollution.

The materials of the present study were:

a) reports of the department of natural recourses and ecology of Kemerovo region from 2005 to 2013 years;