Study on the Effect of Emulsion on the Rotary Efficiency of Emulsion Drilling Machine

Pengbo Xu*, Di Wu, Zhi Liu, Fenglei Chen, Peng Fang and Rui Zhang
CCTEG Xi’an Research Institute, Xi’an 710077, China

*Corresponding author. Email: xupengbo@cctegxian.com

Abstract. The emulsion drilling rig uses emulsion as the driving medium. Because of its light structure and easy drilling, it is suitable for the construction of gas extraction hole and pressure hole in the narrow space of the comprehensive mining face of coal mine. It is of great significance for the safe and efficient mining of coal mine. In order to study the influence of different types of emulsified oil and its ratio concentration on the rotary efficiency of emulsion drilling rigs, a column emulsion drilling rig was developed. The cycloidal motor and non-circular motor were selected as the motors used for emulsifying liquid drilling rigs, and the emulsified oil specified by the national standard was selected. The emulsified oils HFA E10-5, HFA E15-5 and HFAE25-5 were matched into emulsion at 7%, 5% and 3%, respectively, to test the rotary efficiency, rotary torque and rotational speed of the emulsion drilling rig in each emulsion. The test data of emulsion drilling rig are analyzed and the optimum emulsion oil and its ratio concentration are obtained, which provides a theoretical reference for the modified design of emulsion drilling rig.

Keywords: emulsion drilling rig, gas extraction, column drilling rig, emulsion.

1. Introduction
In recent years, gas accidents occur frequently in coal mines in China. High gas content, gas overlimit and coal and gas outburst have been the main factors restricting mine production. Small drills (such as coal electric drills) have low borehole formation rate and low efficiency; and light outburst prevention drill drill takes up more researchers, workers labor intensity, the drilling speed is slow, and electrical equipment, more volatile, increases the difficulty to safety management [1-4], hydraulic drilling rig has a large output torque, promote the advantages of quick, low noise, strong ability to adapt, widely used in coal mining working face gas drainage hole, water injection hole, drilling hole, outburst prevention hole and drilling [5-8]. The hydraulic oil drilling rig needs to be independently equipped with hydraulic pump station, and the drilling rig using hydraulic oil as working medium is large in size and inconvenient for relocation. Due to limited working space on the coal face, the hydraulic oil drilling rig cannot play its capacity [9-10]. The emulsion drilling rig directly USES the high-pressure emulsion from the working face emulsion pump station as the power source, and does not need to be separately equipped with the hydraulic pump station and cable towing device, with simple structure, convenient movement and high reliability. The current domestic market of emulsion drilling rig configuration of emulsion motor consists of cycloid motor and non motor, cycloid motor in internal coating anticorrosion coating, the motor due to mass production, the price is cheap, but after using
emulsion as medium due to insufficient emulsion lubrication motor life is short, the efficiency is low, due to internal non-circular motor adopts non-circular structure, in the process of rotor around the stator reciprocating rotary oil suction and discharge of oil, high mechanical efficiency, at the same time also got greatly increase the life expectancy of the motors, this article selects two motor as the research object. Emulsified oil selection of China national standards, HFAE10-5 HFAE15-5 and HFAE25-5three kinds of emulsion and its ratio to 7%, 5% and 3% respectively for three kinds of emulsion concentration, for each type of emulsion driving medium to test two motor respectively, analysis of the two motor rotation parameters such as efficiency, speed and rotary torque, it is concluded that the two motor performance difference, at the same time test, the optimal formula of emulsion concentration.

2. Development of emulsion drilling rig

2.1. Rig structure
Near emulsion drilling rig is mainly used in the fully mechanized coal face, used in the construction of the gas drainage hole, because the space is narrow, the fully mechanized coal face for crawler drilling rig construction, so the emulsion frame column structure is used to drill, due to the industrial test, this project does not plan to do so no design frame, drilling rig is mainly composed of feeding device and power TouShui is composed of two parts.

![Structure diagram of emulsion drilling rig](image)

Figure 1. Structure diagram of emulsion drilling rig.

The power head is connected with the motor by the flat key, and the rear through-cover is designed to connect the cycloidal motor and the non-circular motor without the need of the transition device for connection, which reduces the auxiliary time of replacing the motor during the test and improves the test efficiency.

2.2. Working principle
The power of the emulsion drill comes from the emulsion pump station on the fully mechanized mining face. The hydraulic system principle is shown in figure 2.

![Hydraulic system schematic diagram](image)

Figure 2. Hydraulic system schematic diagram.

Between hydraulic system of the main feed and reversing valve chose the relief valve, considering the motor ability to withstand voltage, the relief valve setting pressure is set to 16 mpa, in the two
emulsion motor and actuator cylinder back to the road are equipped with speed regulating valve, when
the construction so can according to the ratio of the geological conditions of proper drilling rate and
feed speed, reduce the security risks, improve drilling efficiency.

3. Study on selection and concentration of emulsion
To study different types of emulsion and emulsion at different concentrations of emulsion drilling
performance parameters, the influence of the project team selection conforms to the MT 76-2011
hydraulic support with emulsified oil, hydraulic fluid concentrate and high water cut, the standard
HFAE 10 to 5 type hydraulic support with emulsion, HFAE 15 to 5 type hydraulic support with
emulsion and HFAE 25-5 type hydraulic support with three kinds of emulsion type of emulsion, three
kinds of emulsion for hard water level and sulfuric acid root ion content as shown in table 1.

Table 1. Hard water grade and sulfate ion content are suitable for different emulsions.

| Type of emulsion | Hard water level | Water hardness (mg/L) | Sulfate ion content (mg/L) |
|------------------|-----------------|-----------------------|---------------------------|
| HFAE10-5         | 10              | 500                   | 480                       |
| HFAE15-5         | 15              | 750                   | 720                       |
| HFAE25-5         | 25              | 1250                  | 1200                      |

Coal mine general press <<MT. 76-2011 hydraulic support with emulsified oil, hydraulic fluid
concentrate and high water cut>>the concentration of the standard ratio of emulsion and water into
5%, but when the test subjects for drill, main purpose is to test different types and different
concentrations of emulsion influence on the efficiency of rotary drilling rig, so will be three kinds of
emulsion and water ratio of 7%, 5% and 3% respectively for three kinds of concentration, a total of
nine kinds of testing liquid, as shown in table 2.

Table 2. Concentration of emulsion in water.

| Type of emulsion | concentration 7% | concentration 5% | concentration 3% |
|------------------|------------------|------------------|------------------|
| HFAE10-5         | √                |                  |                 |
| HFAE15-5         |                  | √                |                 |
| HFAE25-5         | √                |                  |                 |

Note: the √ in the table indicates the emulsion that needs to be proportioned to this concentration

4. Analysis of test data
The test was conducted on the 15000Nm coal mine tunnel drilling rig comprehensive performance test
test bench of xi’an exploration equipment test and inspection center of state safe production, The test
process was divided into three stages according to the type of emulsion. The test data of the three
motors are shown in table 3, table 4 and table 5:

Table 3. MRF160 motor test data.

| Motor | Type of emulsion | concentration (%) | torque (Nm) | speed (r/min) | The efficiency of rotary (%) |
|-------|------------------|-------------------|-------------|---------------|------------------------------|
| MRF   | HFAE 10-5        | 7                 | 287         | 321           | 33                           |
|       |                  | 3                 | 318         | 274           | 33                           |
|       |                  | 7                 | 301         | 333           | 33                           |
| 160   | HFAE 15-5        | 3                 | 309         | 300           | 34                           |
|       |                  | 7                 | 318         | 277           | 33                           |
|       |                  | 3                 | 331         | 248           | 33                           |
|       |                  | 7                 | 320         | 282           | 33                           |
|       | HFAE 25-5        | 5                 | 321         | 273           | 32                           |
|       |                  | 3                 | 308         | 291           | 31                           |
Table 4. BM4U-200 motor test data.

| Motor Type of Emulsion | Concentration (%) | Torque (N·m) | Speed (r/min) | Efficiency of Rotary (%) |
|------------------------|------------------|--------------|---------------|--------------------------|
| HFAE 10-5              | 7                | 365          | 274           | 35                       |
|                        | 5                | 401          | 183           | 27                       |
|                        | 3                | 400          | 189           | 21                       |
|                        | 7                | 393          | 123           | 19                       |
| BM4U-200 HFAE 15-5     | 3                | 397          | 124           | 19                       |
|                        | 7                | 396          | 186           | 27                       |
|                        | 5                | 397          | 146           | 21                       |
|                        | 7                | 395          | 156           | 22                       |
| HFAE 25-5              | 3                | 407          | 146           | 22                       |

Table 5. BM4U-252 motor test data.

| Motor Type of Emulsion | Concentration (%) | Torque (N·m) | Speed (r/min) | Efficiency of Rotary (%) |
|------------------------|------------------|--------------|---------------|--------------------------|
| HFAE 10-5              | 7                | 464          | 195           | 32                       |
|                        | 5                | 485          | 126           | 22                       |
|                        | 3                | 503          | 115           | 21                       |
|                        | 7                | 509          | 85            | 17                       |
| BM4U-252 HFAE 15-5     | 3                | 488          | 101           | 18                       |
|                        | 7                | 489          | 189           | 16                       |
|                        | 5                | 481          | 149           | 27                       |
|                        | 7                | 493          | 100           | 18                       |
|                        | 3                | 491          | 97            | 18                       |

Table 3, 4.5non-circular motor MRF160, cycloidal motor BM4U-200 and cycloidal motor BM4U-252 were analyzed. The test rotation efficiencies of three types of emulsions, HFAE10-5 type, HFAE15-5 type and HFAE25-5 type, were obtained at the concentrations of 7%, 5% and 3% respectively.

Can be seen from the figure 4, MRF160 motor in emulsion concentration was 7%, in HFAE10-5, HFAE15-5, HFAE25-5 test in three types of emulsion basic unchanged at 33%, the efficiency of rotary motor and BM4U BM4U - 200-252 motor in emulsion concentration was 7%, measured in HFAE10 - emulsion type 5 rotary best efficiency, reached 35% and 32% respectively, in HFAE15-5 type emulsion revolving efficiency and reduce rapidly, down to 19% and 17% respectively, The data in
hfae25-5 emulsions rose again to 27%. Analysis because MRF160 motor for non-circular structure, high volume efficiency, so the measured rotation efficiency is higher than two cycloid motor, two cycloid motor in emulsion concentration was 7%, HFAE10-5 measured rotation efficiency is significantly higher than in the emulsion HFAE15-5 type emulsion and HFAE25-5 type emulsion in the measured efficiency of rotary, is due to test against the ratio is xi’an tap water, water quality is soft, HFAE10-5 type emulsion is more easily dissolved in the water, so the ratio of emulsion solution is more suitable for emulsion drilling work.

Can be seen from the figure 5, MRF160 motor in emulsion concentration was 5%, in HFAE10-5, HFAE15-5, HFAE25-5 test in three types of emulsion basic unchanged at 33%, the efficiency of rotary motor and BM4U BM4U - 200-252 motor in emulsion concentration was 5%, measured in HFAE10 - emulsion type 5 rotary best efficiency, reached 27% and 21% respectively, in HFAE15-5 type emulsion revolving efficiency and reduce rapidly, down to 21% and 18% respectively, The data measured in hfae25-5 emulsion remained stable by 27%. Analysis because MRF160 motor for non-circular structure, high volume efficiency, so the measured rotation efficiency is higher than two cycloid motor, two cycloid motor in emulsion concentration was 5%, HFAE10-5 measured rotation efficiency is significantly higher than in the emulsion HFAE15-5 type emulsion and HFAE25-5 type emulsion in the measured efficiency of rotary, is due to test against the ratio is xi’an tap water quality soft, HFAE10-5 type emulsion is more easily dissolved in the water, so the ratio of emulsion solution is more suitable for emulsion drilling work.

Can be seen from the figure 6, MRF160 motor in emulsion concentration was 3%, in HFAE10-5, HFAE15-5, HFAE25-5 test in three types of emulsion basic unchanged at 33%, the efficiency of
The efficiency of the BM4U—200-252 motor in emulsion concentration was 3%, measured in HFAE10-5 type emulsion revolving efficiency was 21%, the efficiency of rotary in the HFAE15-5 type emulsion down to 16% and 20%, respectively, in HFAE25-5 type emulsion measured data were 18% and 22% respectively. The reason for the analysis is that the MRF160 motor is non-circular structure with high volume efficiency, so the measured rotary efficiency is also higher than the two cycloidal motors.

Contrast figure 6-2, 6-3 and figure 6-4 non-circular motor MRF160 motor rotation during testing efficiency of basic, 33% cycloid rotary motor efficiency as emulsion concentration from 7% to 5% and falling rapidly, emulsion concentration from 5% to 3%, the efficiency of the motor rotation basic remain at around 20%, to a conclusion, BM4U - 200 type cycloid motor and BM4U - 252 type cycloid motor in emulsion concentration 3% ~ 5%, the efficiency of rotary basic at 20%.

As can be seen from table 6-1, when the concentration of hfae10-5 emulsion is 5% and the system pressure is 16MPa, the speed of non-circular motor MRF160 is 264r/min and the torque is 318N·M; the speed of cycloid motor bm4u-200 is 183r/min and the torque is 401N·M; the speed of cycloid motor bm4u-252 is 126r/min and the torque is 485N·M.

5. Conclusion
(1) both the non-circular motor and the cycloidal motor can be used as the emulsifying fluid drilling machine motor. When the concentration of emulsifying fluid is 7%, the rotary efficiency of the three motors is around 33, which can output large torque.

(2) the rotary efficiency of the non-circular motor is obviously better than that of the cycloidal motor. With the change of concentration, the rotary efficiency of the non-circular motor remains unchanged, but with the decrease of the concentration of emulsion, the rotary efficiency of the cycloidal motor decreases linearly.

(3) different emulsions have a great influence on the efficiency of the rotary motor. The appropriate emulsions should be selected according to the hardness of water.

Acknowledgement
Fund project: xi 'an coal academy youth fund project (2019XAYQN02)

References
[1] Zhang Lijuan, Wang Meng. Design of new emulsion drilling rig [J]. Mechatronics, 2015,21 (10):63.
[2] Yu Lihong. Comparative analysis of hydraulic bolt machine and pneumatic bolt machine [J]. Coal, 2006, 15 (5): 49-52.
[3] Xu Pengbo, Liu Zhi, Yang Jiangbo, et al. Research on key technology of zrj16-300/300 emulsion drilling rig [J]. Coal mine machinery, 2019, 40 (5):32.
[4] Li S. analysis on current situation and prospect of emulsion concentration online detection technology [J]. Coal science and technology, 2016, 44 (3):96.
[5] Zhao Liang, Zhao Jiyun. Optimal design of emulsified drilling rig motor [J]. Acta coal sinica sinica, 2009, 34 (1):121.
[6] Li Yaowu, Zhang Ligang. Emulsion hydraulic drill and its development prospect [J]. Coal science and technology, 2004, 32 (10):63.
[7] Yuan Guiling, Yuan Junqiang, Cheng Guodong. Development and application of a new type of mining emulsion drilling rig [J]. Mining machinery, 2010, 135.
[8] Wang Lu, Guo Xiao-xian, Li Yao-wu, Zhang Li-Gang. Dynamic variation trend and influence of hand-held rotary drill in coal mine [J]. Coal mine safety, 2007, 73.
[9] Zhang Zuheng. Development and application of a light emulsion drilling rig in fully mechanized mining face [J]. Coal mine, 2015, 35.
[10] Li Hong, Wang Zhifu. Development and application of pusher emulsion anti-penetration drill [J]. Coal mine machinery, 2009, 127.