The study on optimization of characteristic parameters of electromagnetic abrasive jet pressurize

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Abstract. In view of the poor continuity of the pre-mixed abrasive jet equipment and the non-uniform mixing of the abrasive particles in the post-mixed abrasive jet system, this thesis is based on electromagnetic abrasive slurry jet technology. The affecting factors of jet compression characteristics of electromagnetic abrasive slurry are studied through the combination of numerical simulation analysis and experimental research. According to previous research results, the influence of two parameters of magnetic flux density and voltage on the outlet velocity and kinetic energy of conductive medium are predicted through numerical simulation. Combined with orthogonal test characteristics, we set up a test platform and carry out some experiments. The experimental results show that the biggest influence on jet supercharging characteristics is magnetic flux density and the next one is the voltage. The results of numerical simulation are verified. When the flux density is 0.7T, the voltage is 72V, the concentration of conductive medium is 18% and the characteristics of jet pressurize are best.

1. Introduction

Through the concerted efforts of several generations, high pressure water jet technology has extended a number of different jet varieties on the basis of pure water jet, about abrasive jet, ultra supercritical carbon dioxide jet, excited jet and so on. Water jet are widely used in mechanics, marine engineering and coal mining etc. It is used for machining, hull cleaning and drilling of coal and rock etc [1]. However, traditional abrasive jet technology still has some technical problems that need to be overcome. The working pressure is very high in post mixing abrasive jet equipment, and the damage degree of the seal and the frequency of replacement are high, which also prone to leakage. The pre-mixed abrasive jet equipment has a high frequency of start and stop and poor work continuity [2-5].

In 1961, James B.Friauf first carried out the study of MHD propulsion unit [6]. In 1971, our country developed the MHDT, and carried out experiments in water [7]. Yang Yong-yin [8] etc studied the effect of high polymer concentration on jet performance at high pressure. Liu Xiao-jian [9] etc uses sodium based bentonite to improve the suspension properties of the slurry, Liu Ting-cheng [10] etc successfully applied abrasive jet to the field of cleaning. Zhang Dong-su [11-12] etc proposed the technology of electromagnetic abrasive slurry jet and made this technology possible. Hu Ya-lin [13] carried out the research on the performance of conductive medium in the electromagnetic pressurize device and the ratio of the abrasive paste is obtained. In this paper, this ratio is used in the slurry solution. Jiang Hong [14] pointed out that the circular cross section of the flow channel could obtain
better jet pressure characteristics easier and this structure is adopted in this paper.

However, there is no relevant report on the influence of key factors on the supercharging characteristics of electromagnetic abrasive slurry jet. How to determine the main key factors has not been carried out about the effect of electromagnetic field driving conductive medium on the characteristics of jet pressurize. In this paper, the influence of two parameters of magnetic flux density and voltage on the out velocity and kinetic energy of conductive medium is predicted by numerical simulation. It has constructed a test platform of electromagnetic abrasive slurry jet, combined with orthogonal test characteristics. Finally, an experiment of jet pressurize is carried out. Under the current test conditions, the optimum parameters of the key factors are obtained to determine the main influencing factors.

2. Numerical simulation

It is similar to the principle of MHDT, electromagnetic abrasive jet technology utilizes medium conductivity and the conductive medium moves under the action of electromagnetic force of orthogonal electromagnetic field [15].

USSR Academy of Sciences, the institute of high temperature physics, used superconducting spiral MHDT channels as models to carry out experiments of MHD performance analysis and pressure distribution parameters [16]. According to the literature [17], the relation among the speed of the conductive medium, the density of the conductive medium, conductivity of conductive medium, voltage of electrode plate, runner length, the distance between the plates and the magnetic flux density of the magnetic source is as shown in equation (1).

\[
\nu = \sqrt{\frac{2\eta \sigma U L}{\rho D}}
\]

In equation (1), \(\eta\) is conversion rate; \(\sigma\) is electrode plate conductivity, s·m\(^{-1}\); \(U\) is voltage value between electrode plates, V; \(B\) is magnetic flux density, T; \(L\) is runner length, m; \(\rho\) is density of conductive medium, kg·m\(^{-3}\); \(D\) is runner section diameter, m.

According to the equation (1), the \(K\) value is:

\[
K = \sqrt{\frac{2\eta \sigma L}{\rho D}}
\]

According to the equation of kinetic energy,

\[
E = \frac{1}{2} mv^2
\]

In equation (3), \(m\) is the quality of conductive medium, kg; \(v\) is the speed of conductive medium, m·s\(^{-1}\).

According to the equation (3), change the formula (4) to

\[
E = \frac{1}{2} mK^2 UB
\]

According to the existing experimental conditions, parameters are shown in table 1. The theoretical reference values of each influencing factor are listed and \(K\) values are obtained.

| Table 1. Theoretical reference value of velocity influence factors of conductive medium. |
|-------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Influence factor | Conversion rate \(\eta\) | Conductivity \(\sigma\) (s/m) | Length \(L\) (m) | Density \(\rho\) (kg/m\(^3\)) | Separation distance \(D(m)\) | Concentration \(V\) (%) |
| Numeric al value | 40% | 8.8 | 0.6 | 1.132×10\(^3\) | 0.025 | 18 |

According to the equation (3), within certain range, we obtain the relationship diagram of outlet velocity of conductive medium, dielectric voltage and flux density, Specifics are as shown in figure 1 and figure 2.
According to figure 1, as for the outlet velocity of the conductive medium, it increases with the increase of voltage and flux density. However, with the increase of voltage value, the outlet velocity speed of the conductive medium gradually decreases. In the late part, the main influence factor of the outlet velocity of the conductive medium is the magnetic flux density. According to figure 2, as for the outlet kinetic energy of the conductive medium, the kinetic energy of the conductive medium greatly increases with the increase of the voltage and flux density. In a range, the effects of voltage and flux density parameters on the kinetic energy of the conductive medium can be predicted.

3. Pressurization characteristic parameter test

The experiment uses three different types of conductive material, namely abrasive slurries mixed solutions, saturated NaCl solutions, and diluted NaCl solutions. The platinum electrode is selected as the electrode plate, three-stage magnetic field strength is used as magnetic field source, and we build an experimental platform of electromagnetic abrasive slurry pressurization characteristics. According to the experiment, the height difference of liquid column is recorded.

In order to explain the experiment better, the concentration, voltage, magnetic flux density and plate spacing are chosen as experimental factors. Each factor takes three levels, the orthogonal test table designed by pseudo level method is shown in table 2. The main index of evaluation is the height of liquid column. 9 sets of experiments are designed according to the orthogonal test table L9 (34). The results are analyzed by range analysis and the results of orthogonal tests are shown in table 3.

![Figure 1. The relationship diagram of outlet velocity of conductive medium and voltage and flux density.](image1)

![Figure 2. The relationship diagram of outlet kinetic energy of conductive medium, voltage and flux density.](image2)

**Table 2.** Factor level diagram of orthogonal test.

| Level | Factor | Concentration M/\% | Voltage U/V | Flux density B/T | Separation distance D/m |
|-------|--------|---------------------|-------------|------------------|------------------------|
| 1     |        | 10                  | 6           | 0.1              | 0.09                   |
| 2     |        | 18                  | 30          | 0.4              | 0.05                   |
| 3     |        | 26                  | 72          | 0.7              | 0.02                   |

**Table 3.** Orthogonal test results.

| Level | Factor | Concentration M/\% | Voltage U/V | Flux density B/T | Separation distance D/m | Liquid height H/mm |
|-------|--------|---------------------|-------------|------------------|------------------------|-------------------|
| 1     |        | 10                  | 6           | 0.1              | 0.05                   | 2                 |
| 2     |        | 10                  | 30          | 0.4              | 0.025                  | 10                |
| 3     |        | 10                  | 72          | 0.7              | 0.01                   | 26                |
| 4     |        | 18                  | 6           | 0.4              | 0.01                   | 7                 |
| 5     |        | 18                  | 30          | 0.7              | 0.05                   | 21                |
| 6     |        | 18                  | 72          | 0.1              | 0.025                  | 12                |
| 7     |        | 26                  | 6           | 0.7              | 0.025                  | 14                |


The experimental results show as follows: The magnetic flux density has the great influence on the supercharging characteristics of MHD jet, followed by voltage; The effect of concentration and plate spacing is small and the result is the same as numerical simulation. The greater the magnetic flux density is, the greater the supercharging characteristics show. The flux density 0.7T is appropriate. The greater the voltage is, the better the jet supercharging characteristics show. But in the experiment, the increase in voltage will exacerbate the electrolysis, the experimental results increase interference. In order to get better magnetic fluid jet supercharging effect, the voltage value is selected at 72V. When the concentration is increased, the electrolysis phenomenon is intensified, and the interference degree of the experimental effect is enhanced. Therefore, the concentration can not be too high, while too low concentration will lead to poor conductivity of liquids. It reduces the supercharging characteristics of MHD jet, and the concentration of 18% is appropriate. With the increase of the plate spacing, the electric field strength between the electrode plates becomes weaker, the smaller the plate spacing can improve the jet supercharging characteristics. But in experimenting, too small plate distance makes it possible to cause a short circuit between the electrodes. This is not conducive to the experiment, so, the distance between plates is selected at 0.025m.

4. Conclusion
According to the defects of traditional abrasive jet equipment, the research status of electromagnetic abrasive slurry jet technology is analyzed. According to previous research results, The influence of two parameters of magnetic flux density and voltage on the velocity and kinetic energy of the conductive medium is analyzed by numerical simulation. Combined with orthogonal test characteristics, a test platform for electromagnetic abrasive slurry jet has been constructed. The jet pressurization experiment has been carried out. Experimental results show as follows: when flux density is 0.7T, voltage value is 72V, the concentration of conductive medium is 18% and plate distance is 0.025m, the supercharging effect is better. The two key factors of magnetic flux density and voltage that affect the jet pressure characteristics of the electromagnetic abrasive slurry jet have been identified.

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