

Original Paper

The flow field characteristics and rock breaking ability of cone-straight abrasive jet, rotary abrasive jet, and straight-rotating mixed abrasive jet

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ABSTRACT

Radial jet drilling (RJD) technology is expected to be a technology for the efficient exploitation of geothermal resources. However, the low rock-breaking efficiency is the major obstacle hindering the development of RJD technology. The flow field characteristics and rock breaking ability of cone-straight abrasive jet, rotary abrasive jet, and straight-rotating mixed abrasive jet are analyzed by numerical simulations and experiments. Results show that the axial velocity of the cone-straight abrasive jet is high, the tangential velocity is basically zero, the radial velocity is also small, and the jet impact area is concentrated in the center. A deep hole with a diameter of only 25 mm is formed when the cone-straight abrasive jet breaks the granite. Due to the presence of the guiding impeller, the rotary abrasive jet basically has no axial velocity and has the highest tangential and radial velocity, so it can break the granite to form a hole with a diameter of about 55 mm and a central bulge. The straight-rotating mixed abrasive jet has a large axial/tangential/radial velocity at the same time, so it can break the granite to form a hole with a diameter of about 52 mm with a low bulge. The results show that the straight-rotating mixed abrasive jet combines the advantages of the cone-straight jet and the rotary jet, and is more suitable for the RJD technology. The research results can provide reference for the development of efficient rock-breaking and hole-forming technology, and promote the development of RJD technology in the field of geothermal development.

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1. Introduction

Geothermal energy is believed as one of the promising and clean renewable energy resource alternatives to fossil fuels. Geothermal resources are widely distributed in the Earth's crust, mainly used for power generation, space heating, snow melting and green house (Kubik, 2006; Lund and Boyd, 2016; Konstantinos, 2019). For reservoirs with high permeability, the doublet system is usually developed, that is, one injection well and one production well are drilled, cold fluid is injected from the injection well, and hot fluid or steam is produced from the production well (Crooijmans et al., 2016). In the development of low permeability geothermal well,

it is necessary to carry out hydraulic fracturing operations on the basis of the doublet system to create fractures with high conductivity in the reservoir, that is, enhanced geothermal system (EGS). Currently, many EGS projects are carried out around the world including the Fenton Hill EGS in the United States, Soultz EGS in France, and Cooper Basin EGS in Australia (Breede et al., 2013). Recently, a novel EGS with multilateral wells is presented, which is proved a better alternative for conventional EGS (Song et al., 2018). One main wellbore is drilled and several injection and production multilateral wells are side-tracked from the main wellbore in upper and lower formations, respectively. The working fluid is injected through the annulus and while flowing through injection multilateral wells and it extracts heat from the reservoir. Subsequently, the working fluid is produced from production multilateral wells and returns to surface. Song et al. (2018) and Shi et al. (2018) demonstrated that the heat extraction performance of the

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multilateral-well EGS was equal to or even greater than that of conventional double-well EGS.

Radial jet drilling (RJD) is capable of drilling multilateral wells perpendicular to the main wellbore for the purpose of increasing oil and gas production (Dickinson et al., 1992; Cirigliano and Blacutt, 2007). The diameter of these laterals is approximately 30–50 mm and the length is up to 100 m. RJD technology is widely used in the oil and gas industry to increase production by drilling through the damaged zone, increasing contact areas, and communicating natural fractures. After years of research, RJD technology has been well developed and applied in the United States, China, Canada, Russia and other countries (Li et al., 2000; Buset et al., 2001; Abdel-Ghany et al., 2011; Cinelli and Kamel, 2013; Kamel, 2016). Within the geothermal fields, recently RJD technology are considered to be an effective geothermal resource development technique (Reinsch et al., 2018). Nair et al. (2017) increased the injection volume 14% at Klaipeda geothermal demonstration plant by performing the RJD in a low performing injection well. Salimzadeh et al. (2019) found that the RJD laterals were more effective in enhancing injectivity/productivity in low permeability reservoirs. Ashena et al. (2020) realized 50% increase in oil production using radial jet drilling. Conventional RJD technology uses high-pressure water jet technology to break rock. For example, Li J. et al. (2022) drilled eight laterals successfully using the self-rotating multi-orifices nozzle with 35–40 MPa jet pressure. However, the geothermal reservoirs with low permeability are mostly granite (Li et al., 2023a), which is difficult to be broken by pure water jet. Therefore, the efficient rock breaking and hole-forming technology is the key to the successful application of RJD in the development of geothermal resources.

In order to improve the efficiency of rock breaking, researchers have successively developed multi-orifice nozzle (Ge et al., 2020; Li et al., 2021), rotary nozzle (Dong et al., 2014), and straight-rotating mixed nozzle (Liao et al., 2013). However, all of them are pure water jets, which cannot effectively break hard rocks such as shale and granite. Abrasive water jet (AWJ) technology has strong rock breaking and cutting ability, and is widely used in perforating, casing cutting, hydraulic jet fracturing and so on (Huang et al., 2008). Abrasive jet technology primarily utilizes high-pressure fluid to drive small-sized abrasive particles (such as garnet or quartz sand) for achieving impact cutting (Liu et al., 2018).

Although the abrasive jet possesses excellent rock-breaking ability, the hole diameter formed by existing nozzles is overly small to meet the requirements of RJD (Li et al., 2023b). Hence, cone-straight abrasive jet nozzles, rotary abrasive jet nozzles, and straight-rotating mixed abrasive jet nozzles are designed. Numerical simulation studies are conducted on their flow field characteristics, and experimental studies are carried out to explore their rock-breaking performance. The research results presented herein can provide a reference for the development of efficient rock-breaking and hole-forming technology and promote the development of RJD technology in the field of geothermal development.

2. Structure and principle of different abrasive jet nozzles

In order to select the suitable nozzle for RJD technology, three different type nozzles, such as cone-straight nozzle, rotary nozzle and straight-rotating mixed nozzle, were designed, as shown in Fig. 1. The classic cone-straight nozzle (Fig. 1(a)) is mainly composed of an inlet section, a contraction section and an outlet section. High-pressure fluid and abrasives are pumped into the nozzle inlet by the high-pressure plunger pump. Due to the reduction in the cross-sectional area of the contraction section, a high speed is attained. The jet is then emitted from the cylindrical outlet. The jet energy of cone-straight nozzle is more concentrated, impact force is stronger, and the operating distance is generally longer. The rotary nozzle (Fig. 1(b)) can be obtained by installing a guiding impeller inside the cone-straight nozzle. The high-pressure fluid and abrasives are twisted along the impeller flow path, thereby possessing higher tangential and radial velocity and forming a strong diffusible jet which can hit a large area at once. Further, a straight-rotating mixed jet nozzle can be obtained by designing a through hole on the impeller of the rotary nozzle. Therefore, some high-pressure fluids and abrasives can obtain higher radial, tangential and axial velocity under the action of the guiding impeller at the same time. In theory, this type of nozzle has the advantages of both the cone-straight and the rotary nozzle, that is, it has a strong impact force and a large impact area at the same time. The guide impeller designed here is mainly formed by three blades rotating 360° around the central axis. For a rotary nozzle, the center of the impeller is a solid cylinder, while for a straight

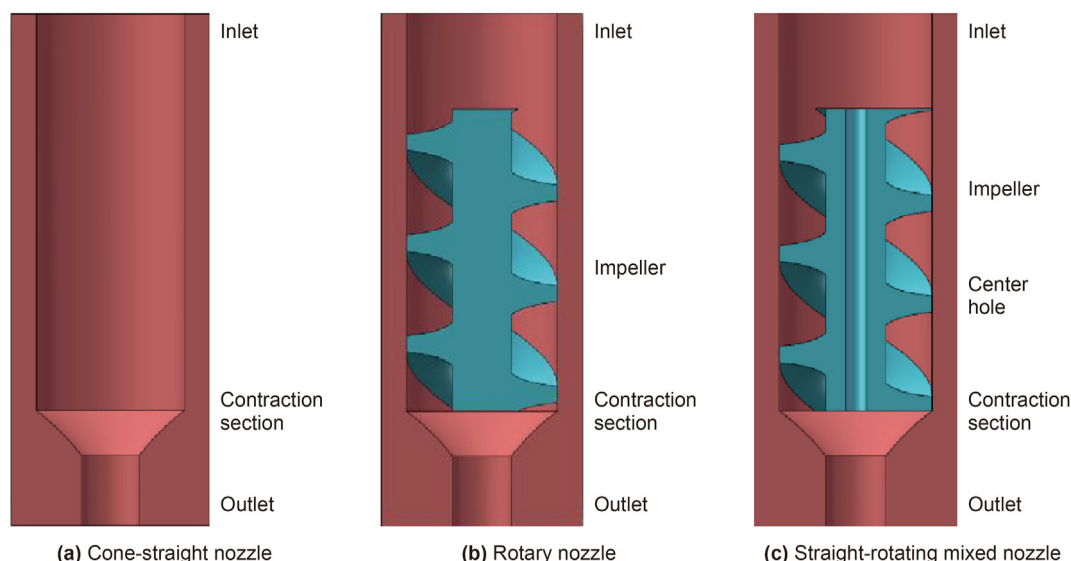


Fig. 1. Schematic diagram of different type nozzles.

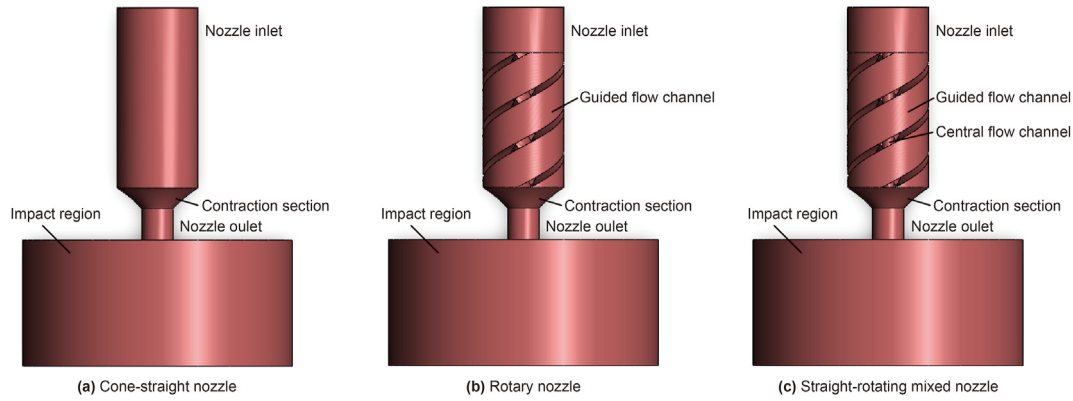


Fig. 2. Physical model of different abrasive jet nozzles.

-rotating mixed nozzle, the center of the impeller is a hollow cylinder.

3. Flow field characteristics of different abrasive water jet nozzles

3.1. Physical models and control equations

(1) Physical models

The internal flow area of different type nozzles is taken as the calculation domain, and an impact domain is set, as shown in Fig. 2. For comparative analysis, the dimensions of inlet, outlet and impact domain of all nozzles are set to be the same. Considering the pressure and displacement of the actual operation, all nozzle outlet diameters are set to 7 mm here. According to the study of Jiang et al. (2021), the optimal standoff distance of the jet is about 3–5 times the outlet diameter, so the impact area length is set to be 28 mm, that is, 4 times the outlet diameter. Specific parameters are shown in Table 1.

(2) Governing equations

In order to ensure the computation accuracy and speed of the numerical model, the widely used standard k-epsilon turbulence model, which is a typical RANS vortex viscosity model, is adopted here. It has a relatively simple calculation format, and better results can be obtained.

The governing equation of the standard k-epsilon model can be expressed follow:

$$\begin{aligned} & \frac{\partial(\rho\phi)}{\partial t} + \frac{\partial(\rho u\phi)}{\partial x} + \frac{\partial(\rho v\phi)}{\partial y} + \frac{\partial(\rho\omega\phi)}{\partial z} \\ &= \frac{\partial}{\partial x} \left(\Gamma \frac{\partial\phi}{\partial x} \right) + \frac{\partial}{\partial y} \left(\Gamma \frac{\partial\phi}{\partial y} \right) + \frac{\partial}{\partial z} \left(\Gamma \frac{\partial\phi}{\partial z} \right) + S \end{aligned} \quad (1)$$

where, ϕ is the independent variable, such as: u , v , ω , etc, Γ is the diffusion coefficient, S is the source term of the equation.

The corresponding transport equations of the turbulent kinetic energy k and the dissipation rate ϵ are as follows:

$$\frac{\partial(\rho k)}{\partial t} + \frac{\partial(\rho k u_i)}{\partial x_i} = \frac{\partial}{\partial x_j} \left[\left(\mu + \frac{\mu_t}{\sigma_k} \right) \frac{\partial k}{\partial x_j} \right] + G_k + G_b - \rho\epsilon - Y_M + S_k \quad (2)$$

$$\begin{aligned} & \frac{\partial(\rho\epsilon)}{\partial t} + \frac{\partial(\rho\epsilon u_i)}{\partial x_i} = \frac{\partial}{\partial x_j} \left[\left(\mu + \frac{\mu_t}{\sigma_k} \right) \frac{\partial k}{\partial x_j} \right] + C_{1\epsilon} \frac{\epsilon}{k} (G_k + C_{3\epsilon} G_b) \\ & - C_{2\epsilon} \rho \frac{\epsilon^2}{k} + S_\epsilon \end{aligned} \quad (3)$$

where, G_k is the turbulent kinetic energy generation term caused by mean velocity gradient, G_b is the turbulent kinetic energy generation term caused by buoyancy, Y_M is the contribution of fluctuating expansion in compressible turbulence, $C_{1\epsilon}$, $C_{2\epsilon}$ and $C_{3\epsilon}$ are empirical constants, σ_k and σ_ϵ are the Prandtl numbers corresponding to the turbulent kinetic energy and the dissipation rate, S_k and S_ϵ are the source terms of the equation.

3.2. Grid division and boundary conditions

Because the structure of the cone-straight nozzle is relatively simple, it is divided by a structured grid and locally encrypted. However, the flow channel of the rotary nozzle and straight-rotating mixed nozzle is complicated due to the existence of impeller. Therefore, tetrahedral mesh is used in the impeller part, and structured mesh is used in other parts, and local encryption is used.

In order to compare and analyze the flow field structure of different nozzles, the simulated displacement is controlled to be the same. The inlet of the nozzle is selected as the velocity inlet (30 m/s) and the side of the impact domain is the outflow outlet.

Table 1
Structure parameter of different abrasive jet nozzles.

Nozzle type	Inlet diameter, mm	Contraction angle, degree	Outlet diameter, mm	Impeller length, mm	Impeller angle, degree	Standoff distance, mm	Center hole diameter, mm
Cone-straight	18	120	7	/	/	28	/
Rotary	18	120	7	30	360	28	/
Straight-rotating mixed	18	120	7	30	360	28	2.5

The reference working pressure is atmospheric. Here, the velocity distribution and impact pressure characteristics are mainly compared and analyzed, so only the flow field of pure water is studied here.

3.3. Flow field and impact pressure characteristics of different abrasive jet nozzles

The velocity distribution and impact pressure characteristics of the jet flow field exert a significant influence on rock breaking and hole formation. Therefore, in the comparative analysis of different abrasive jet nozzles, the velocity contour, impact pressure contour, as well as the distribution and change laws of axial velocity, tangential velocity, and radial velocity are mainly analyzed.

(1) The velocity and impact pressure contour

By taking a longitudinal plane at the center of different nozzles and the impact domain, the velocity distribution contour of different nozzles can be obtained. Meanwhile, the impact pressure distribution contour at the bottom of the impact domain can be acquired, as shown in Fig. 3. Cone-straight nozzles (CSN) generate a jet with a more concentrated velocity distribution. Consequently, its impact area is more focused and smaller in size. The jet formed by the rotary nozzle (RN) has large tangential and radial velocities due to the presence of the impeller. As a result, there is less fluid in the middle part of the jet, and most of the fluid is dispersed in a conical shape. The same conclusion can be drawn from the shape of the impact area. That is, the impact pressure cross-section of the impact is circular, which may form a conical bulge in drilled hole. Due to the presence of the impeller with a center hole, the jet velocity distribution formed by the straight-rotating mixed nozzle (SRMN) is more complex. Its pattern cannot be observed from a single plane. However, from its impact pressure cross-section, it can be seen that the straight-rotating mixed jet combines the advantages of the cone-straight jet and the rotary jet. It has a strong center impact force and a large impact area. Nevertheless, due to the existence of the impeller and the center hole, the impact cross-

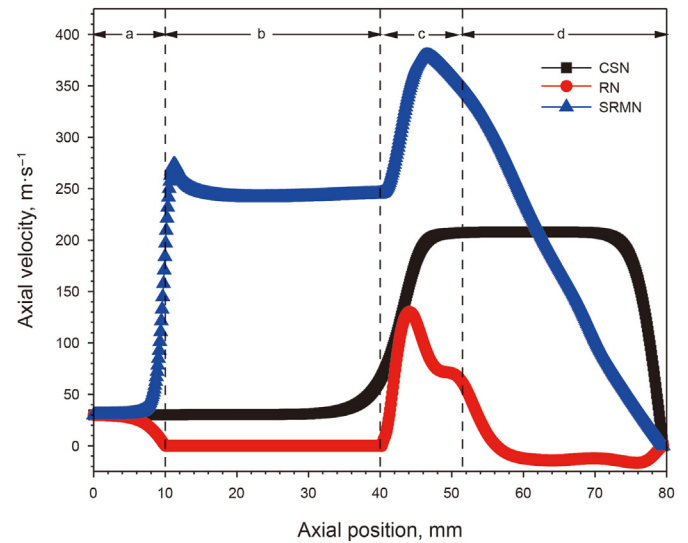


Fig. 4. Axial velocity development of different types of nozzles.

section has an irregular shape.

(2) The axial velocity

To compare and analyze the axial velocity distribution and development law of different nozzles, the axial velocity data of nozzles and impact domains were obtained. As depicted in Fig. 4, all jet regions can be divided into four sections, namely: a) the inlet section; b) the impeller section; c) the contraction and cylindrical outlet section; and d) the impact domain section. In the inlet section, all nozzles maintain the inlet velocity. In the impeller section, the cone-straight nozzle still maintains its inlet velocity as it lacks an impeller. The rotary nozzle has no fluid passing through the middle of the impeller, so its velocity is zero. The straight-rotating mixed nozzle has a center hole in the impeller, and there is a

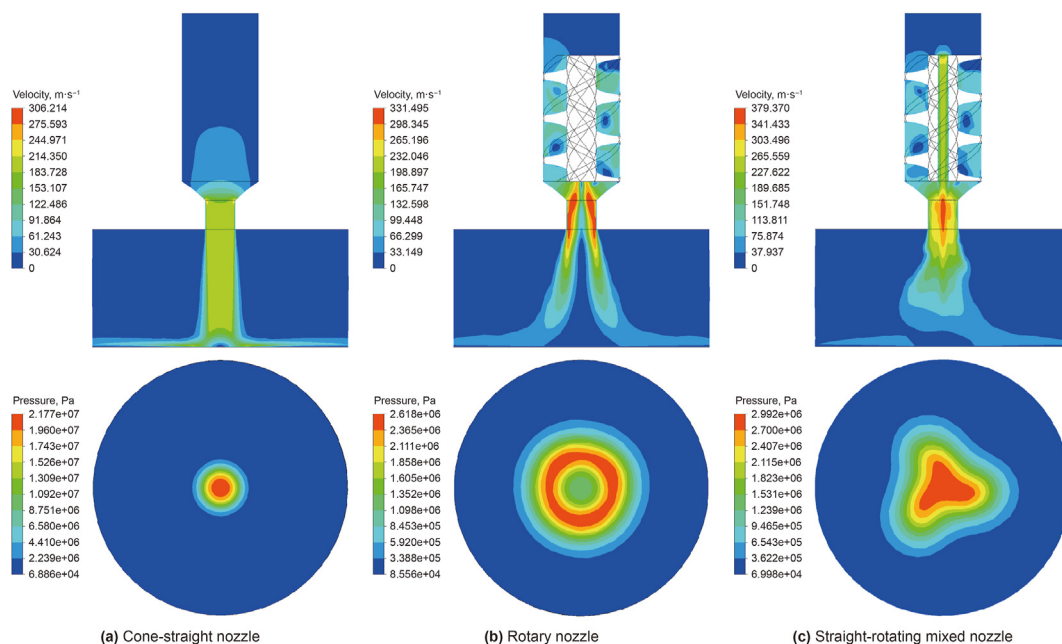


Fig. 3. Flow field and impact characteristics of different abrasive water jet nozzles.

variation in the flow cross-section, so its velocity is higher. In the contraction and cylindrical outlet section, the fluid velocity increases rapidly due to the reduction of the flow cross-sectional area. The axial velocity of the cone-straight jet increases rapidly at first and then remains unchanged. The rotary jet, due to the guiding effect of the impeller, has less fluid in the center. Its axial velocity increases rapidly at first and then decreases gradually, but its value is small. The axial velocity of the straight-rotating mixed jet continues to increase on the basis of the velocity of the impeller section, so that the peak of the axial velocity is the largest. In the impact domain, the axial velocity of the cone-straight jet remains constant at first, which is the potential core. It then decreases rapidly until it approaches the impact base. Since there is relatively little intermediate fluid in the rotary jet, its axial velocity is small and may even be negative, that is, there is fluid backflow. Thus, it may lead to the formation of a central conical bulge when breaking rock. The axial velocity of the straight-rotating mixed jet decreases rapidly after reaching the maximum value, but it is always larger than the axial velocity of the rotary jet. Therefore, it is not easy to have a conical bulge during rock breaking.

In addition, the axial velocity distributions of three nozzles at a standoff distance of three times the nozzle outlet diameter were analyzed. As shown in Fig. 5, the cone-straight jet remains relatively concentrated, with its center velocity still being the potential core velocity. The axial velocity of the rotary jet presents a symmetrical M-shaped distribution, meaning that the maximum velocity exists at a certain distance from the jet center, and the corresponding impact pressure is in the shape of a ring. The velocity distribution of the straight-rotating mixed jet is irregular, and there is a maximum value at the center of the jet. It can be seen that the cone-straight jet still has a large axial velocity over a long standoff distance, so its impact force is strong, and it can form deep holes during rock breaking.

(3) Tangential velocity distribution

The tangential velocity distributions of three nozzles at a standoff distance equal to three times the nozzle outlet diameter were analyzed. As depicted in Fig. 6, due to the absence of an impeller, the tangential velocity of the cone-straight jet is essentially zero. The tangential velocity of the rotary jet exhibits a symmetrical M-shaped distribution, which is in accordance with its

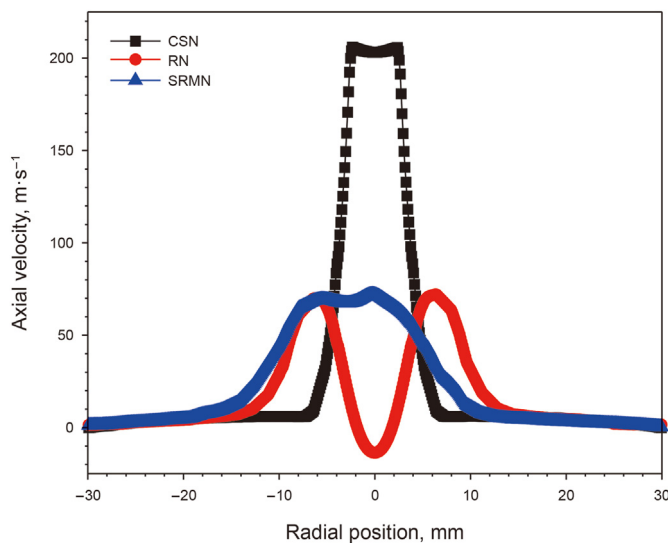


Fig. 5. Axial velocity distribution of different nozzles at 3 d standoff distance.

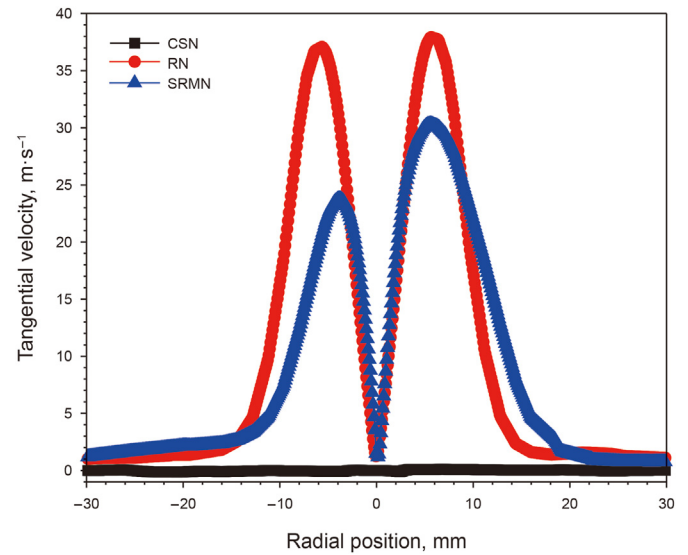


Fig. 6. Tangential velocity distribution of different nozzles at 3 d standoff distance.

axial velocity distribution. The tangential velocity distribution of the straight-rotating mixed jet remains irregular and roughly M-shaped, yet its value is smaller than that of the rotary jet. It is proven that the guiding impeller can enable the high-velocity fluid and abrasive to obtain a larger tangential velocity which can destroy the rock through shear action, and thereby improve the rock breaking efficiency.

(4) Radial velocity distribution

The radial velocity signifies the divergence capability of the jet. The greater the radial velocity, the larger the jet diameter becomes and the larger the impact area is as the standoff distance increases. The radial velocity distributions of three nozzles at a standoff distance equal to three times the nozzle outlet diameter were analyzed. As depicted in Fig. 7, the radial velocity of the cone-straight jet is small, indicating its poor divergence. The radial velocity of the rotary jet remains M-shaped and its value is significantly larger than that of the cone-straight jet. The radial velocity

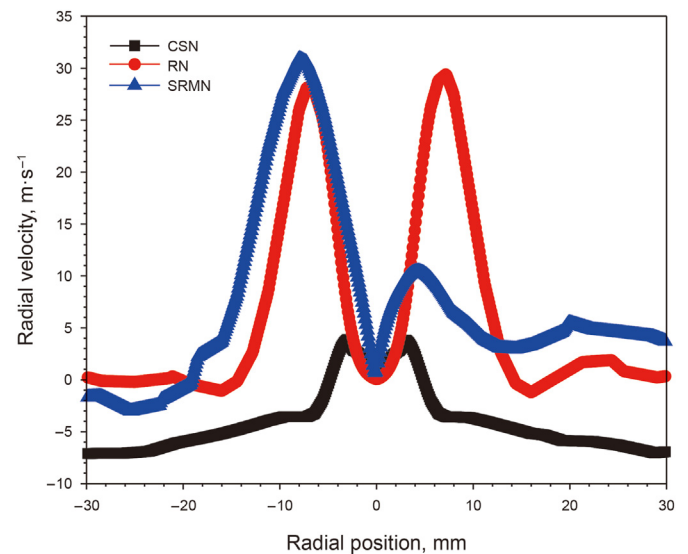


Fig. 7. Radial velocity distribution of different nozzles at 3 d standoff distance.

distribution of the straight-rotating mixed jet is irregular, yet its absolute value is greater than that of the cone-straight jet. This can prove that the guiding impeller will enhance the diffusivity of the jet and create a large area for rock breaking.

4. Experimental investigation of rock breaking mechanisms of abrasive jets

Rock-breaking experiments were carried out in order to validate the results of numerical simulations and to analyze the rock-breaking ability of three different abrasive jet nozzles.

4.1. Experimental set-up

The high-pressure abrasive jet system was used in the rock-breaking experiments. The schematic diagram of the experimental set-up is shown in Fig. 8. The system is composed of five parts: sand mixing unit, power unit, power control unit, data acquisition and control unit, and operation pool unit. The experimental system has a complete liquid circulation system, and the operation pool unit has the function of sedimentation and separation. The experimental system is designed to work under realistic test conditions including, jet pressure of 0–70 MPa, stand-off distance of 0–1000 mm, rock sample size of 0–400 mm, submersion degree of 0–500 mm, sand ratio of 0–30% (mass concentration), and abrasive particle size of 12–120 mm for rock breaking experiments of abrasive jet or conventional water jet. The system can also allow the recycling of water and abrasive in the experimental system.

4.2. Materials

(1) Granite specimens

In order to investigate the prospect of the application of abrasive jets in the field of geothermal development, granite is selected as the test rock here. The basic physical properties of the granite are

known as follows: the average density is 2.64 g/cm^3 , the average compressive strength is 141.5 MPa, the average tensile strength is 12.5 MPa, the average elastic modulus is 45.8 GPa, and the Poisson's ratio is 0.243.

(2) Abrasive

Garnet is commonly used in the abrasive jet cutting industry. Considering the diameter of the central hole of the impeller and the bearing capacity of the equipment, the mesh number of abrasive particles was set as 46 meshes. The true density of the abrasive particles is 3.8 g/cm^3 , the apparent density is 1.8 g/cm^3 , the Mohs hardness is 8.0.

(3) Nozzles

In order to maintain consistency with the numerical simulation, experiments were carried out using the same structural abrasive jet nozzles, mainly including cone-straight nozzle, rotary nozzle and, straight-rotating mixed nozzle.

(4) Experimental parameter settings

For comparative analysis, the jet pressure was kept constant during the experiments. Considering the strong rock-breaking ability of the abrasive jet (Li H. et al., 2022), the jet pressure was set to 20 MPa, the exposure time was 60 s, the standoff distance was 10 mm, and the sand concentration by weight was 6%.

4.3. Experimental results and analysis

The results of rock-breaking experiments with different types of nozzles are shown in Fig. 9. It can be seen that the rock-breaking characteristics of different abrasive jet nozzles are all different and consistent with their flow field characteristics. The cone-straight nozzle crushes the granite, forming a deep hole with a diameter of about 25 mm. Due to the high strength of the granite,

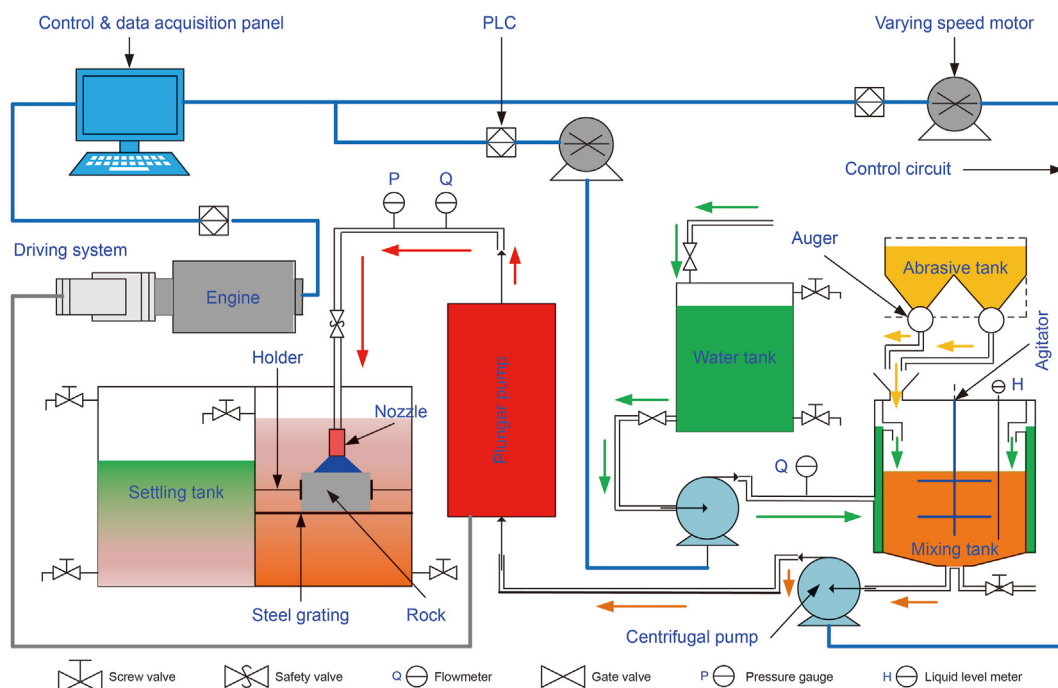


Fig. 8. Schematic of the high-pressure abrasive jet system.

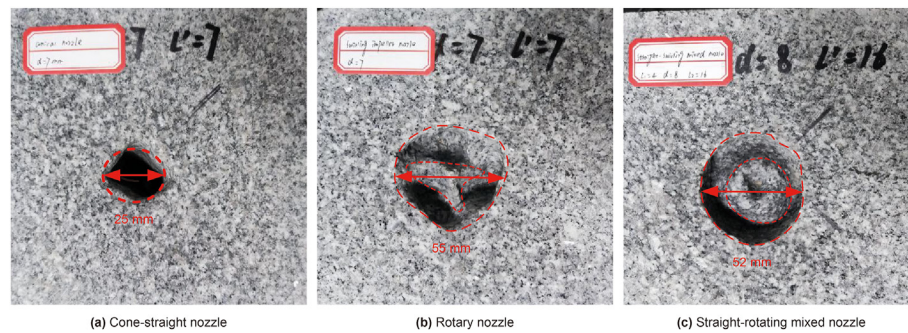


Fig. 9. Hole-forming topography of three different type nozzles.

the shape of the hole formed is not regularly round. The rotary nozzle creates the largest hole diameter, up to 55 mm. The formed hole consists of three main crushing regions corresponding to the three blades of the guiding impeller and is responsive to the direction of rotation of the impeller. The presence of a conical bulge in the center proves that there is less fluid in the center of the rotary abrasive jet, which is consistent with the numerical modeling results. Straight-rotating mixed abrasive jet crushes the granite to form a regular hole, its diameter is about 52 mm, and the conical bulge height is lower, which proves that the straight-rotating mixed abrasive jet combines the advantage of cone-straight jet and the rotating jet. For radial jet drilling technology, hole diameter and maintaining continuous drilling are more important, therefore, straight-rotating mixed abrasive jet nozzles are more suitable for the development of geothermal resource with RJD technology.

5. Discussion

Through the study of the flow field and rock-breaking characteristics of different type nozzles, it is found that the nozzle internal structure determines its flow field characteristics, which in turn determines its rock breaking characteristics. The cone-straight abrasive jet is more concentrated, has stronger impact force and a longer range. It is more suitable for cutting or breaking rock in scenarios where the standoff distance is uncontrollable. Rotary abrasive jets can be used in scenarios that require a large diameter hole and are more suitable for softer rock samples such as sandstone where the conical bulge is easy to be broken. Straight-rotating mixed abrasive jets are suitable for large diameter hole formation and harder materials such as granite, carbonate, casing, etc. It is found that the straight-rotating mixed abrasive jet nozzle is more suitable for the development of geothermal resource with RJD technology. However, the current straight-rotating mixed abrasive jet nozzle structure is not optimal, and further numerical simulations and rock-breaking experiments are needed to optimize it. Meanwhile, the effects of jet pressure, standoff distance, exposure time, abrasive size, abrasive concentration, abrasive type and other parameters on the rock-breaking ability need to be studied.

6. Conclusions

Radial jet drilling is expected to be a suitable technology for the efficient exploitation of geothermal resources. In order to drill out radial branches efficiently in granite reservoir, the flow field characteristics and rock breaking ability of cone-straight abrasive jet nozzle, rotary abrasive jet nozzle, straight-rotating mixed abrasive jet nozzle are analyzed by conducting numerical simulation and experimental studies. The main conclusions of this study are as follows.

- (1) Through comparative analysis of velocity distribution and impact pressure distribution of different nozzles, it can be seen that the jet formed by the cone-straight nozzle is relatively concentrated, and the impact pressure is also concentrated to a point. Due to the presence of the impeller, there is less fluid in the center of the rotary jet, and the impact pressure distribution is circular. However, due to the presence of the impeller with a central hole, the velocity distribution of the straight-rotating mixed jet is complicated and the impact pressure distribution is irregular.
- (2) Studies on the development and distribution of axial velocity show that cone-straight jet still has a large axial velocity over a long standoff distance, so its impact force is strong, and it can form deep holes during rock breaking. The axial velocity of the rotary jet is small, and even negative, which may result in the formation of a central conical bulge when breaking rock. The axial velocity of the straight-rotating mixed jet is always larger than that of the rotary jet, which may be not easy to form a conical bulge.
- (3) The analysis of tangential velocity shows that there is no tangential velocity in cone-straight jet. The tangential velocity distribution of the rotary jet is M-shaped. The tangential velocity distribution of the straight-rotating mixed jet is still irregular and roughly M-shaped, but its value is smaller than that of the rotary jet. It is proven that the guiding impeller can make the high-velocity fluid and abrasive flow, and, hence, obtain a larger tangential velocity, which can break the rock by shear action, and can greatly improve the rock breaking efficiency.
- (4) The analysis of radial velocity shows that the radial velocity of the cone-straight jet is very small, which means that its diffusion ability is very weak, and it can only form small holes. The radial velocity of the rotary jet and the straight-rotating jet is large, and the diffusion ability is strong, which can form a large impact area. The radial velocity of the rotating jet is the largest.
- (5) The experimental results show that under the experimental conditions, a deep hole with a diameter of 25 mm is formed when the cone-straight abrasive jet breaks the granite. The rotating abrasive jet forms a hole about 55 mm in diameter with a central tapered bulge. The straight-rotating abrasive jet forms a hole about 52 mm in diameter with a lower tapered bulge. The straight-rotating mixed abrasive nozzle combines the advantage of cone-straight nozzle and the rotary nozzle therefore, is more suitable to use for the development of geothermal resources.

CRediT authorship contribution statement

Jing-Bin Li: Writing – review & editing, Writing – original draft, Supervision, Investigation, Formal analysis, Conceptualization. **Ergun Kuru:** Writing – review & editing, Supervision, Investigation, Data curation, Conceptualization. **Wen-Bin Li:** Resources, Investigation, Data curation. **Chen-Rui Guo:** Resources, Investigation, Data curation, Conceptualization. **Gen-Sheng Li:** Validation, Supervision, Data curation. **Zhong-Wei Huang:** Validation, Supervision, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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