Simulation and experimental study on the Self-excited oscillation jet device

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Abstract. Nearly 40 years, high pressure water jet technology has developed rapidly and increasingly[1,2], and it also added new methods to foundation engineering and geotechnical engineering for our country[3,4,5], such as High pressure jet grouting[6] and coal or ore mining[7,8], so choose what kind of jet can be more effective to crush rock became the focus of researching[9,10]. In this paper, using the Fluent software numerical simulation technology to research the inlet velocity of jet from 5 m/s to 300 m/s and hit a target from 100 mm to 800 mm, exploring the hit force variation rule of oscillation pulsed jet. Then according to the variation curve draw force formula. Put forward that in the low velocity using exponential function fitting, and high velocity using the polynomial function fitting. Then tested self-excited oscillation pulsed jet force, the results is similar to the numerical simulation. And finally do contrast experiment between self-excited oscillation pulsed jet and consecutive jets, found that at low pressure condition, self-excited oscillation pulsed jet can crushing rock easier.

Introduction

The research background and significance

Nearly 40 years, high pressure water jet technology has developed rapidly and increasingly[1,2], and it has become a perfect new tool to clean, cut and crush. High pressure water jet technology also added new methods to foundation engineering and geotechnical engineering for our country[3,4,5,], such as High pressure jet grouting[6] and coal or ore mining[7,8] ,so choose what kind of jet can be more efficient and broken rock become the focus of researching [9,10]. This paper mainly for exploring the self-excited oscillation pulsed jet device hitting force and it's capacity of crushing rock.

The main research contents and technical route

The main research content of this paper is:

(1) Numerical simulation based on Fluent, establish Self-excited oscillation nozzle internal and external flow field model, and make simulation of different jet distance and entrance velocity. Finally, analyze the data to explore the change rule of the force of the self-excited oscillation pulsed jet.

(2) By using the existing test bench to do force experiment and compared with the results of simulation; Doing crush experiment to standard sample in submerged and non-submerged condition and evaluate the experiment results

Technical route of this paper is shown in Fig. 1.

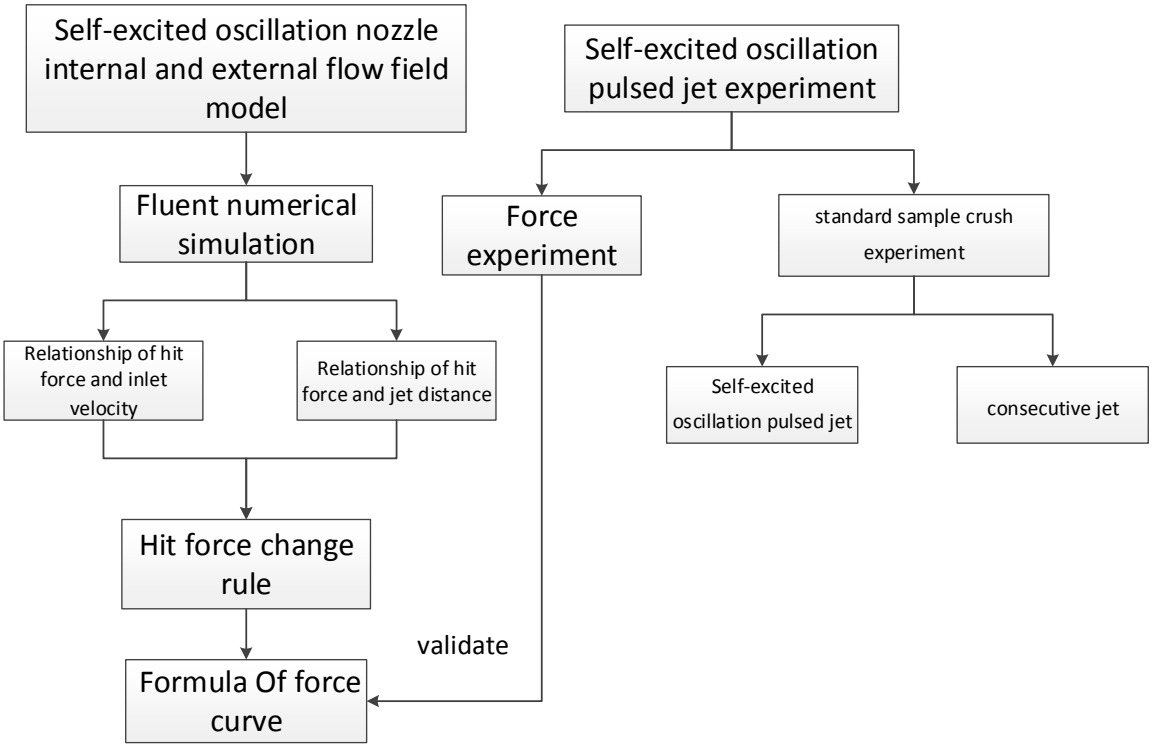
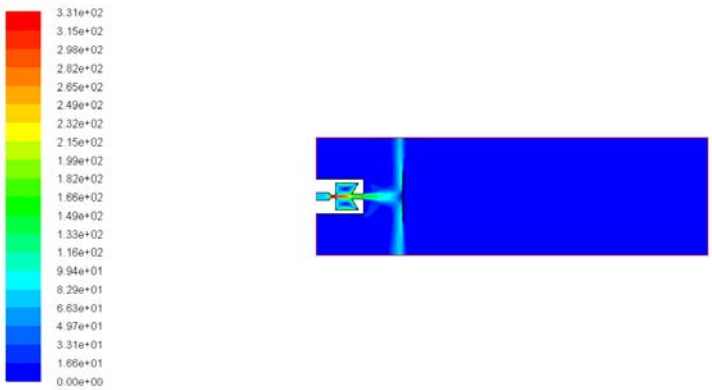


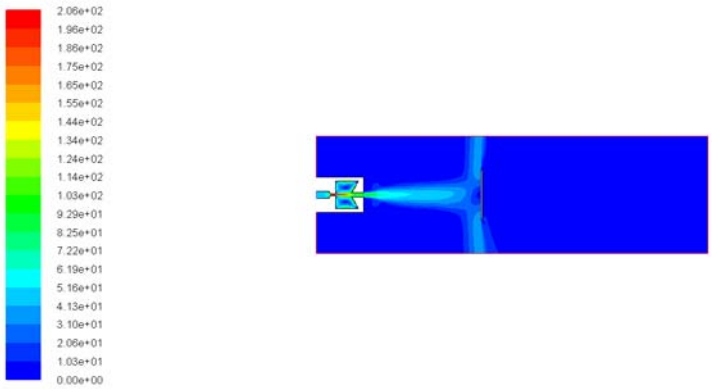
Fig.1 technical route

Numerical simulation

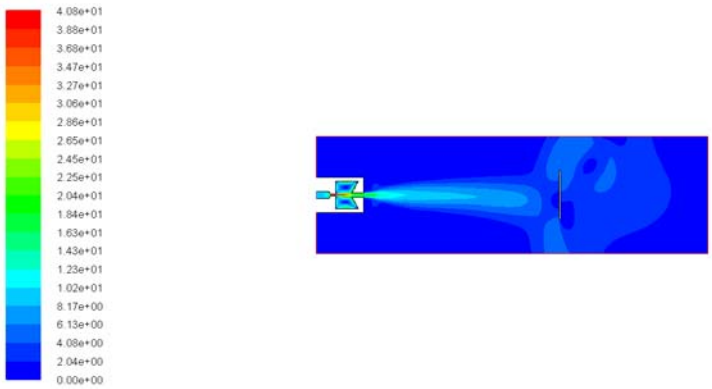
According to the test bench and the size of the self-excited oscillation jet parameters draw different jet distance flow field model, and meshing the model, then importing the model to Fluent software to do simulation of entrance velocity from 5m/s to 300m/s. After post-processing can have pressure, speed of cloud image and target plate force reports. Part of the results of numerical simulation is shown in Fig 2.1.



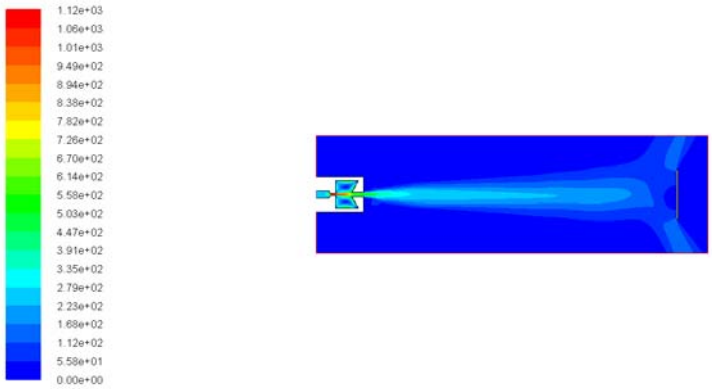
(a)Jet distance 100 mm, inlet velocity of 80 m/s velocity contour



(b) Jet distance 300 mm, inlet velocity of 80 m/s velocity contour



(c) Jet distance 500 mm, inlet velocity of 10 m/s velocity contour



(d)Jet distance 800 mm, inlet velocity of 300 m/s velocity contour

Fig 2.1 part of the results of numerical simulation

Analysis of the force Based on the numerical simulation

The target plate force variation curve of 100mm, 300mm, 500mm and 800mm jet distance is shown in Fig 2.2.

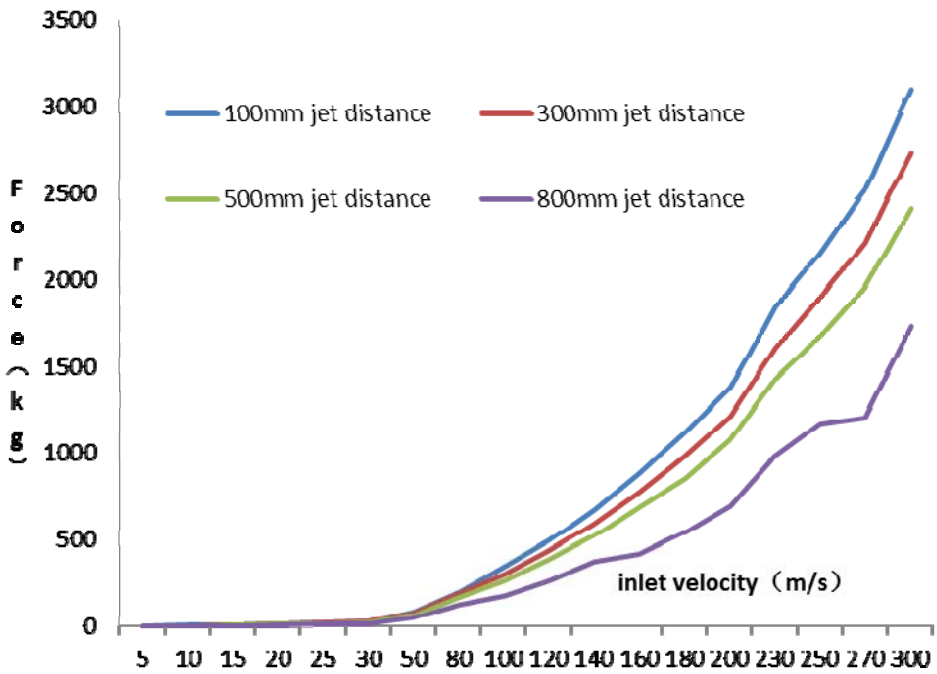


Fig 2.2Curve of hitting force

Make function fitting to the curve of 100mm jet distance, shown in Fig 2.3.

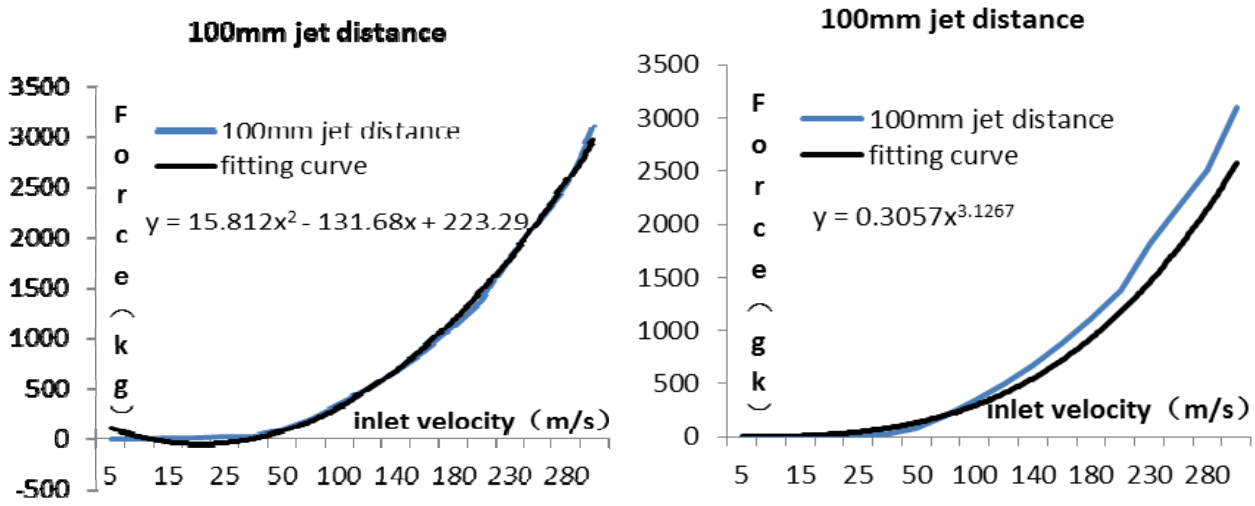


Fig 2.3 fitting curve

The fitting result shows that the power function is suitable for the low inlet velocity condition, while polynomial is more suitable for high inlet velocity condition. So 100 mm force formula should be described by the piecewise function Eq1 :

$$F = \begin{cases} 0.3057v^{3.127}, v \leq 30 \\ 15.812v^2 - 131.68v + 223.3, v > 30 \end{cases} \quad (1)$$

Here F is target plate force (kg), v is entrance velocity.

According to table 2.1 curve of different jet distance have the same change trend, all can be expressed as Eq 2:

$$F = \begin{cases} Av^B, v \leq 30 \\ Cv^2 - Dv + E, v > 30 \end{cases} \quad (2)$$

Here A, B, C, D and E are related to the target distance, the nozzle structure parameters.

The self-excited oscillation pulsed jet force test

In this paper, tested jet force of 100 mm, 300 mm, 500 mm and 800 mm jet distance respectively, compared with the results of numerical simulation, different target distance force test results compared with numerical simulation is shown in Table 3.1. It can be seen that the trends are the same, can think they are approximate matches.

Table 3.1 Force contrast

(a) 100mm

Inlet velocity(m/s)	Fluent results(kg)	Experiment results(kg)
5	0.79	0.42
10	3.35	2.2
15	7.2	4.5

(b) 300mm

Inlet velocity(m/s)	Fluent results(kg)	Experiment results(kg)
5	0.69	0.4
10	2.9	2.1
15	6.7	4.3

(c) 500mm

Inlet velocity(m/s)	Fluent results(kg)	Experiment results(kg)
5	0.6	0.36
10	2.16	2.04
15	5.7	4.2

(d) 800mm

Inlet velocity(m/s)	fluent results(kg)	experiment results(kg)
5	0.50	0.22
10	2.36	2.02
15	4.3	3.96

Self-excited oscillation pulsed jet standard sample crush experiment

Firstly, doing self-excited oscillation pulse jet experiment. After fixed the sample, do the experiment in the condition of target distance 100 mm, 2.2 MPa pressure for 2 minutes. Fig 3.4 is the sample picture of before and after the experiment.

Fig 3.2 self-excited oscillation pulse jet crush experiment

After experiment, the place of red round appeared a diameter of about 3 cm, deep 1.5 mm shallow pits.

Then, doing consecutive jets experiment. After fixed the sample, do the experiment in the condition of target distance 100 mm, 2.2 MPa pressure for 2 minutes. After experiment found that sample has no change. Fig 3.3 is the sample picture of before and after the experiment.

Fig 3.3 consecutive jets crush experiment

Conclusions

(1) By using Fluent software, through changing the inlet velocity and hit the target distance get force change rule: the force difference is not big in low inlet velocity, while, the force difference is more and more big after inlet velocity more than 30m/s;

(2) Force change curves at high velocity are closer to the polynomial function, and closer to the exponential function in low velocity;

(3) At low pressure condition, self-excited oscillation pulsed jet can crushing rock easier compared with continuous jet.

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