Analysis of the Impact of Abrasive Jet’s Concentration on the External Flow Field

Xiaofeng YANG¹,a,* Weifang WANG²,b, Jiaheng ZHOU¹,c

¹Shenzhen Institute of Wuhan University, Shenzhen,518057, China
²Shenzhen Nanxing Marine Engineering Services Co., Ltd, Shenzhen,518067, China
afyang@whu.edu.cn, b wfwang@163.com, c jiaheng161@126.com
*Corresponding author

Keywords: Abrasive jet, particles concentration, impact on the external flow field, hitting power

Abstract: The technology of abrasive jet assisted drilling has the advantages of high efficiency and low energy consumption, which causes its wider application in the field of offshore oil and gas exploitation engineering. This paper used fluid analysis software to simulate and analyze the movement of abrasive jet under submerged condition, studied how the particles concentration and other factors affect the abrasive jet’s hitting efficiency. Using gambit to model a two-dimensional nozzle, simulating in the numerical simulation software fluent, the study found that the change of abrasive concentration could affect the hitting efficiency of the abrasive jet significantly and when the abrasive particle size was 0.2 and the abrasive concentration was 70%, the hitting efficiency was the biggest.

Introduction

The application of abrasive jet is greatly superior to traditional water jet in the marine oil and gas drilling. When cutting the same material, the required water pressure of abrasive jet is lower than that of traditional water jet because of the impact of massive abrasive particles against the cutting material [1]. Marine oil and gas are frequently exploited from the bottom of the sea where the water pressure is very high. Because of the unique characteristics of submerged jets, traditional water jet hardly work at the bottom of the sea, which causes a more general use of abrasive jet in the field of marine oil and gas exploitation [2-3].

This paper used fluid analysis software to simulate and analyze the movement of abrasive jet under submerged condition, studied how the particles concentration and other factors affect the abrasive jet’s hitting efficiency.

Using gambit to model a two-dimensional nozzle, simulating in the numerical simulation software fluent, calculating and comparing the results, this paper studied the factors affecting the hitting efficiency of abrasive jet and worked out effective measures to improve it.

Fluid-solid coupling analysis of abrasive jet external flow field

Taking speed entrance in place of pressure entrance as boundary condition during the simulation, defining the abrasive density as 2600 kg/m³, particle size as 0.2 mm, the water inlet velocity as 6 m/s, abrasive inlet velocity as 1m/s for the first time set, abrasive volume fraction as 0.1, iteration time as 1000, the graph of flow field was as follows:
It was obvious to see that the water accelerated the abrasive as a carrier. But the maximum speed of the abrasive would never reach the speed of the water. Only the density of abrasive is bigger than that of water, the abrasive has edges and corners and its cluster is better than water. So the appropriate mixture of water and abrasive would greatly improve the overall capacity of the abrasive jet [4-5]. Despite the highest speed of abrasive was slightly lower than that of water, its high speed area was much closer to the external flow field, which suggested that the attenuation of abrasive's velocity was slower. Adding abrasive in the water helped to improve the jet's hitting power.

**The affect of abrasive concentration on the flow field**

Simulation scheme: taking speed inlet as boundary conditions during simulation, defining the abrasive density as 2600 kg/m$^3$, particle size as 0.2 mm and considering factors that affect the abrasive jet's hitting power are various, the simulation defaulted other conditions such as the pump pressure, the concentration of abrasive, the abrasive particle size, the target distance, etc., and just changed the abrasive concentration to accomplish the simulation [6-7]. The abrasive volume fraction was: 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, iteration time was 1000. Water flow field distribution was as follows:
Abrasive flow field distribution was as follows:

In the sight of the flow field, the maximum speed of both the water and the sand was reduced with the increase in the volume fraction of sand, which was in line with the actual situation where the total weight of sand increased along with its volume fraction. According to the principle of conservation of energy, the maximum speed would be lower accordingly.

Besides, it can’t be ignored that the increase of abrasive volume fraction would improve the frequency of abrasive particles striking targets and strengthen the jet hitting power at the same time in practical engineering application. But the interference between the particles would reduce the hitting power of the jet when the abrasive volume fraction increased to a certain amount[8-9]. Simply using the core section of the flow speed was not enough to measure the hitting efficiency of abrasive jet, the gaining momentum of the abrasive should also be considered.
The calculation formula of momentum $p$ is:

$$ p = mv $$ \hspace{1cm} (1)

$p$-momentum, $m$-the weight of membrane material, $v$ - the core section speed.

When analyzing the jet with different abrasive concentrations in unit time, the ratio of the mass shot out equaled to the ratio of the concentration. For example, the mass shot out in unit time doubled when the concentration changed from 20% to 40%. In order to simplify the calculation, the mass in the calculating process was replaced by a scalefactor. The core section of speed was simulated by fluent. The concentration and momentum data were as follows:

<table>
<thead>
<tr>
<th>concentration</th>
<th>10%</th>
<th>20%</th>
<th>30%</th>
<th>40%</th>
<th>50%</th>
<th>60%</th>
<th>70%</th>
<th>80%</th>
</tr>
</thead>
<tbody>
<tr>
<td>momentum</td>
<td>16.4</td>
<td>30</td>
<td>40.5</td>
<td>48.4</td>
<td>53</td>
<td>54.5</td>
<td>56</td>
<td>52</td>
</tr>
</tbody>
</table>

The momentum varying with concentration:

![Figure 4 abrasive momentum and concentration](image)

It was seen that the momentum of the abrasive shot out increased along with the concentration’s increasement before the concentration reached 70%. Along with the concentration approached 70%, the growth of the momentum would decrease. The momentum would reach the maximum when concentration was around 70%. On the other hand, when the concentration got higher than 70%, the momentum began to decline. It suggested that when the concentrations was higher than 70%, the abrasive started to interfere with each other because the distance between them got closer, which reduced the speed. The conclusion was that changing the concentration of the abrasive can change the hitting efficiency of the jet significantly. Besides, when abrasive particle size was defined as 0.2 and abrasive concentration was 70%, the hitting efficiency of the jet was the largest. But in engineering application, we should select abrasive concentration according to actual condition. Increasing the abrasive concentration not only improves the hitting efficiency of the jet, but also wears away the jet system, especially the nozzle.

**Conclusion**

We’ve simulated the flow field characteristics of regular abrasive jet under different abrasive concentration and granularity through fluent software. It found that the increasement of both the concentration and the granularity would reduce the speed of core section. But changing the concentration of the abrasive can significantly convert the momentum of the abrasive when it was...
shot out. When the concentration was less than 70%, the increasement of the concentration can improve the hitting efficiency of abrasive jet. Besides, when the abrasive particle size was defined as 0.2 and abrasive concentration was 70%, the hitting efficiency of the jet was the largest. But in engineering application, we should select abrasive concentration according to actual condition. Increasing the abrasive concentration not only improves the hitting efficiency of the jet, but also wears away the jet system, especially the nozzle.

Acknowledgements

This work is supported by the Science and Technology Projects of Shenzhen (Grant No. JSKF20150928142452831)

References


