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Experimental Study of the Effects of Water Jets on Marine Hydrate-Bearing Sediment Erosion

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Abstract

Over 90% of the world's natural gas hydrate (NGH) is contained in fine-grained reservoirs. These reservoirs can be found all over the world. However, conventional methods make it difficult to economically and environmentally exploit this kind of NGH reservoir. Because the production process does not depend on mass and heat transfer within the formations, water-jet cutting is a method for mining such hydrate reservoirs that is both effective and good for the environment. The purpose of this work was to clarify the erosion performance of marine hydrate-bearing sediment (HBS) impacted by water jets through a series of physical experiments. According to the findings, water jet vertical erosion of HBS is severely hampered by the accumulation of sediment and hydrate particles at the bottom of the erosion hole. The optimal jet distance for a given jet flow rate is between 4 and 28 millimetres. Additionally, the erosion of the hole's top is significantly affected by the upwelling flow of solid particles. Erosion holes take on the shapes of a gourd and a bamboo in reservoirs with high hydrate saturation (60–80%) and low hydrate saturation (20–40%), respectively. In addition, jet distance and hydrate saturation are less affected by jet flow rate variation than volume erosion efficiency and depth erosion efficiency.

Keywords: Hydrate-bearing • Jet distance • Hydrate saturation

Introduction

The use of water-jet cutting in the exploitation of marine HBS can benefit from the theoretical and technical guidance provided by this research. Combustible ice also known as natural gas hydrate (NGH) is a solid crystalline compound that forms under certain pressure and temperature conditions. NGH is a brand-new energy source with a lot of room for growth. NGH formation and stability are supported by suitable temperature and pressure conditions in approximately 90% of offshore locations. Exceptionally perfect gaseous petrol can be created from NGH stores, particularly from submarine hydrate repositories. Offshore natural gas reserves are estimated to be approximately. However, the commercial development of NGH is also hindered by the fact that the current marine-NGH exploitation technology is still in its infancy, particularly for fine-grained hydrate reservoirs with low permeability and a weak cementation strength characteristic (mostly clay and clayey silt sediments).

Literature Review

The area of the South China Sea was the location of the first successful offshore natural-gas-hydrate production test. With a total gas recovery of 3 105 m3 within 60 days, the reservoir stimulation techniques were utilized for the first time for the production of marine hydrate. It was demonstrated that reservoir stimulation is a crucial method for the production of NGH. The water jet's ability to effectively cut hydrate-bearing sediment is demonstrated by the results of the hydrate trail production. Based on the low permeability, weak cementation strength, and unconsolidated formation characteristics of the fine-grained marine NGH reservoir, the water-jet cutting technique is also beneficial for increasing the gas and liquid transfer channel, improving the reservoir permeability of the near-wellbore area, and increasing the production efficiency of marine NGH. Water-jet cutting is also a common and mature formation stimulation technique for increasing the production of low-permeability gas and oil reservoirs. Water jets ability to erode hydrate-bearing sediment (HBS) has only been the subject of a few studies at this time. The effect of jet flow rate and traverse speed on HBS erosion efficiency and effect on erosion was experimentally investigated. They designed a straight-rotating mixed nozzle and experimentally investigated the effect of the number of nozzles and structural parameters on erosion efficiency [1,2].

Discussion

They found that erosion efficiency increases with increasing traverse speed, while jet flow rate increases the peak concentration of the solid phase, increasing the risk of pipeline transport. Wang and co. The critical erosion velocities of water jets for HBS at various hydrate saturations were the subject of experimental investigation. The findings demonstrate that the critical velocities for HBS range from 5.71 to 10.85 m/s. However, frozen sand soils were the research targets of the preceding work. Particles and hydrates fill a pore space with cementation force to form HBS in nature. Frozen sand soils and HBS differ in structure and physical properties. Water-jet erosion may therefore perform differently on HBS than it does on frozen sand soils. An HBS simulation model was developed employing the (Arbitrary Lagrangian–Eulerian) ALE method, and the effects of nozzle diameter, jet flow rate, and jet distance on erosion performance were investigated in that work. The findings suggested that while an increase in jet distance was detrimental to HBS's erosion efficiency, an increase in nozzle diameter and jet flow rate could improve it. The jet-erosion process of HBS was also numerically investigated using the ALE method. They discovered that swirling jet erosion of HBS was more powerful than conical jet erosion. However, the numerical calculation methods ignored the effect of detached particles on jet-erosion behaviour and erosion-hole development because the HBS models established in the preceding work were all finite-element models [3-6].

Conclusion

It is necessary to carry out a systematic and in-depth study on the water-jet erosion performance of HBS because there is currently limited research on the topic. A physical experiment was carried out in this work to better understand how water jets affected the erosion of HBS. HBS's erosion performance, which includes erosion volume, erosion depth, erosion-hole top diameter, and erosion-hole bottom diameter, was extensively examined in relation to the water-jet

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parameters (jet flow rate and jet distance) and hydrate saturation. Additionally, the degree to which these parameters affect erosion efficiency was examined.

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Conflict of interest

No potential conflict of interest was reported by the authors.

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