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A new erosion experiment and numerical simulation of wellhead device in nitrogen drilling

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ABSTRACT

During nitrogen drilling in tight sandstone reservoirs, the multifunctional four-way often suffers severe erosion damage after withstanding the erosion of sand and gas over an extended period of time. Such damage may have serious consequences for its functioning. In this study, an experiment was conducted on the erosion of a wellhead device used in nitrogen drilling. The conditions used in the experiment were also used as inputs for numerical simulation of the erosion pattern. The results obtained from the numerical simulation were then compared to those obtained in the experiment in order to determine the reliability of numerical simulation for analysis of erosion pattern in nitrogen drilling. The results of the simulation, scaled down by a factor of 10, were consistent with the results of the experiment. Further, the relative error between the sets of results was less than 5% (the overall mean error is 1.11%) for gas–solid two-phase erosion and flow models implemented using FLUENT software. The results verify that numerical simulation is reliable and can be used to study the erosion of wellhead equipment in nitrogen drilling. This will be of great significance in alleviating the safety problems associated with well control in nitrogen drilling.

1. Introduction

Many advantages can accrue from improving the drilling speed, protecting the reservoir, reducing well leakage, and preventing underground gas explosions during nitrogen drilling (Li et al., 2010; Shu et al., 2007; Xu, 2006). Many studies have been conducted on low pressure and low permeability reservoirs (Bennion et al., 1996; Cao et al., 2008; Yang and Zhang, 2006) and researchers have carried out nitrogen drilling in tight sandstone reservoirs with remarkable success (He et al., 2008; Wei et al., 2005; Zhang et al., 2015). However, some potential problems have also been found. These include severe erosion damage to the multifunctional four-way as a result of it having to withstand the erosion of sand and gas over a prolonged period of time. The actual damages observed on a multifunctional four-way are depicted in Fig. 1.

Erosion damages on a multifunctional four-way leads to serious safety issues in well control. Therefore, it is necessary to conduct research on the problem of erosion of the wellhead equipment used in nitrogen drilling. Numerical simulation is predominantly employed in such research work (He et al., 2014; Zhang et al., 2014) at present, as it provides the necessary technical inputs to support the nitrogen drilling practice. However, the results of numerical simulation lack appropriate verification via a suitable method, and hence the method lacks credibility.

In this study, an experiment was first carried out on the erosion of a wellhead device in nitrogen drilling, and the experimental conditions used as inputs for a numerical simulation. The results obtained experimentally and via numerical simulation were then compared to ascertain the reliability of numerical simulation in analysis of erosion pattern in nitrogen drilling. The results obtained can optimize the structure of wellhead device to improve the anti-erosion ability, and predicting the erosion of wellhead device to avoid the risk of the piercing-caused leakage, and the results are of great significance in alleviating the safety problems associated with well control in nitrogen drilling.

2. Multifunctional four-way erosion experiment

The experiment reconstructs the actual erosion of the wellhead device (multifunctional four-way) in the engineering practice, and the purpose of the experiment is to provide the corresponding data to verify the reliability of numerical simulation.

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(a) Multifunctional four-way bypass entrance (b) Multifunctional four-way bypass outlet

Fig. 1. Actual damages on a multifunctional four-way: (a) damages at the entrance, (b) damages on the inner ring of the sealing groove at the outlet.

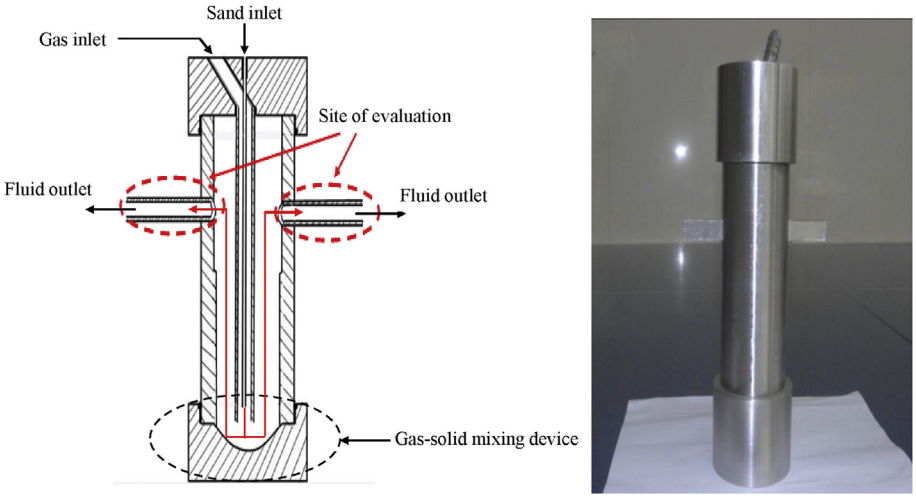

Fig. 2. Experimental multifunctional four-way installation.

2.1. Experimental setup

An experiment was conducted to study the erosion pattern of the multifunctional four-way using a model of the four-way, scaled down by a factor of 10, under the actual conditions used for nitrogen drilling in the MORLAB Laboratory (2014, Xi'an, PR China). The experimental installation is shown in Fig. 2.

2.2. Experimental procedure

The procedure used in the experiment consisted of the following steps:

Step 1. The initial wall thickness along the axial direction of the multifunctional four-way bypass was measured in four directions (12 point direction: top of the bypass; 6 point direction: bottom of the bypass; 3 point direction and 9 point direction: horizontal direction with respect to the bypass) before the experiment, with the measurements conducted at 5 mm intervals, starting from the bypass inlet.
Step 2. The four-way was removed after the experiment, and cut into four pieces in four directions using a line-cutting equipment.
Step 3. The remaining wall thickness of the four-way was measured at 5 mm intervals, starting from the bypass inlet, using a microscope (XL30, PHILIPS) along the four directions.

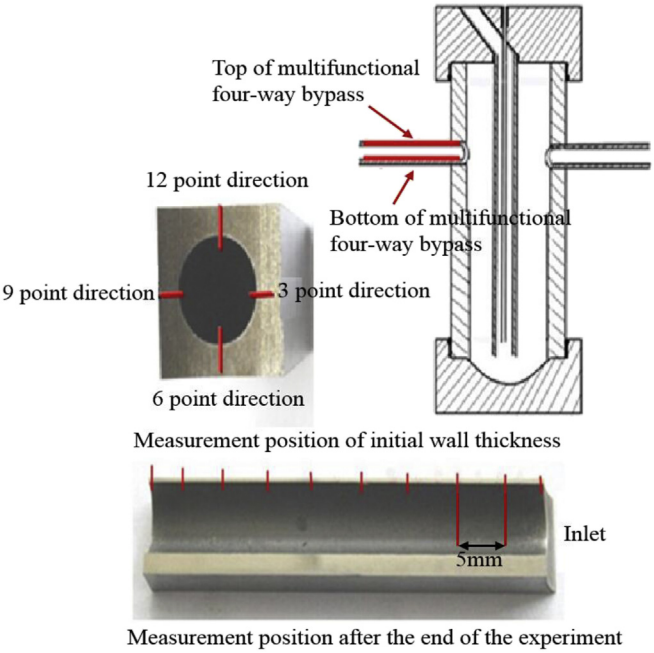

Fig. 3. Measurement zone used in the experiment.