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Engineering characteristics of laser perforation with a high power fiber laser in oil and gas wells

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ABSTRACT: We report a laser perforation presentation with a 6 kW fiber laser in oil and gas wells. Temperature distribution on the rock surface after laser irradiation was numerically analyzed. High power fiber laser perforating experiment was carried out in conditions of different rock types, rock deposition orientations, rock sizes, laser output powers, laser irradiation time and other factors. When boundary effects are eliminated, the rock size and rock deposition orientation have no effect on perforation efficiency. The highest perforation efficiency and the maximum thermal expansion coefficiency of rock are obtained at the same time when laser power reaches a specific value, and the laser perforation efficiency decreases with the increasing of irradiation time.

Key Words: laser perforation; temperature distribution; specific energy; fiber laser;

1. Introduction

Perforating operation is one of the key technologies in oil and gas wells exploration and development because it directly impacts on the production of oil and gas [1, 2]. In recent years, the rapid development of high power lasers, advanced laser and technology make the study of oil and gas wells perforation technology becomes a research hot spot. In 2009, the Armco oil company first completed the on-site operating experiment of the oil and gas wells by high power laser, which demonstrated that laser perforating is a safer and more efficient technology in comparison with bullet perforation, shaped perforation, hydraulic sand blasting perforation, and other traditional perforation technologies [3, 4]. In addition, laser perforation is an advanced alternative technology since the advantages of time saving, no compaction, higher porosity and permeability, no debris, shorter completion time and lower cost [5-9]. Therefore, laser perforation has become one of the hotspots of high power laser applications. For example, Experimental study on the interaction between samples of sandstone, shale, and limestone and a 1.6 kW pulsed Nd: YAG laser beam [10], CO_2 laser perforating experiments on concrete in oil and gas wells [11], moving pulsed Nd: YAG laser perforating experiments for limestone, shale and granite in oil and gas wells [12], or prediction of laser power loss in perforation by artificial neural network [7]. However, high power laser perforation is a complex process, which can be influenced by the factors of different rock types, rock deposition orientations, rock sizes, laser output powers, laser irradiation time etc. In particular, the harsh environment in oil and gas wells will greatly attenuate the laser power. Fiber transmission can well solve the high efficiency and safety problems of laser beam transmission in oil and gas wells [13].

Here, we perform a perforation study with a 6 kW fiber laser, which provides power density range between 5000 W/cm^2 and 10000 W/cm^2, corresponding to the laser powers from 3 kW to 6 kW. The temperature field distribution after laser irradiating rock surface was theoretically analyzed, and the laser perforation under different rock types, rock sizes, laser powers and irradiation times based on a 6 kW fiber laser at 1070 nm was experimentally carried out. The results provide important theoretical and technical support to high power laser perforation in application of the oil industry.

2. Temperature field distribution of the interaction between laser and rock