Research On Explosive Fracturing Technology Of Liquid Explosives In Micro-cracks In Low Permeability Reservoirs

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Abstract. In this paper, the experimental methods and related explosion parameters calculation methods for liquid explosive explosion technology satisfying the explosion critical dimension of 2 mm are introduced. Studies have shown that the developed liquid medicine meets the needs of explosion reconstruction joints with seam crack width greater than 2 mm, it basically determined its formulation and performance optimization parameters. The detonation speed of 1500-3500m/s can be applied to the process test design requirements of different lithological characteristics; The safety and feasibility of on-site construction were verified by the horizontal well CZ44-58 process test application, which provided a reference for optimizing the performance design of liquid drug performance, which laid a foundation for the experimental application research of micro-crack explosion stimulation technology and technology in low permeability oil layer.

1. Introduction

The micro-powder suspended liquid explosive developed by Xi'an Shiyou University realized the explosion in the 2mm simulated crack, and initially solved the key technology research of the formulation of liquid explosive and its critical explosion size, detonation process and matching conditions, and successfully carried out on-site process test in sidetracking horizontal wells. Based on the progress of this technology research [1], this paper introduces the experimental methods of this technology and the application of horizontal well field test, providing reference for optimizing formula, performance parameters and process research and laid the foundation for the experimental application research of the technology and technology of explosion stimulation to achieve micro-cracks in low-permeability oil layers.

2. Experiment study

2.1. Design ideas and experimental methods

Firstly, the experiment solves the liquid explosive suitable for the critical size explosion condition of micro-crack; Secondly, the liquid explosive has stable performance, can meet certain pump pressure and squeeze into the formation and can meet the safety construction requirements of high pressure and high temperature without self-explosion; Third, the explosive performance parameters of liquid explosives are controllable, and a reasonable matching with the lithology of the formation can produce an effective fracture network, but it cannot be too destructive or produce compaction. We focused on a series of explosion simulation experiments of liquid explosives in Φ125mm high temperature and high pressure reactors. We carried out a series of explosion simulation experiments under high temperature and high pressure conditions by squeezing the micronized suspension liquid explosive into different
small crack groove models. Research and solve the key technical problems such as the critical
dimension of the explosion, the formulation of the liquid medicine and the optimization design of the
explosion performance parameters, and the matching conditions of the formation crack. Table 1 shows
experimental data of 2mm trench suspended liquid explosive under high temperature and high
pressure conditions. It can be seen from the table that in the condition of high temperature and high
pressure, the explosion pressure of the suspended liquid explosive in the 2mm trench is simulated, and
the normal explosion is proved by observing the specimen model.

Table 1. Partial experimental date

| Serial number | Pre-detonation pressure (MPa) | Post-explosion pressure (MPa) | Pressure mutation value (MPa) | ExplosionRemarks |
|---------------|-------------------------------|-----------------------------|-----------------------------|-----------------|
| 1             | 41.18                         | 49.12                       | 7.94                        | Complete explosion |
| 2             | 39.85                         | 52.96                       | 13.11                       | Complete explosion |
| 3             | 39.66                         | 53.53                       | 13.87                       | Complete explosion |
| 4             | 38.52                         | 46.88                       | 8.36                        | Not completely exploded Booster less, partially exploded |

Figure 1 is a P-t experimental test curve of a suspended liquid explosive in a 2mm trench suspension explosion under high temperature and high pressure conditions. The process of simulating hydraulic cracks in a 2mm trench with ceramsite is further illustrated. Through engineering experiments and combined with perforating technology, explosive fracturing and high energy gas fracturing, engineering application practice analysis [2-4]. The main parameters of the formation of the seam in the rock strata are that the detonation velocity should be controlled at 1500-3500 m/s, the design parameters of the explosion performance are moderately controllable, and it can be better applied to the requirements of the low-permeability reservoir seam reconstruction of different lithological characteristics.

2.2. Detonation parameter experimental test and initiation conditions
The micronized suspension liquid explosive is mainly a mixed liquid explosive composed of an
oxidant, a combustion agent, a suspending agent and a sensitizer, and its main chemical components
are NH₄NO₃, C₃H₅N₃O₉, TNT, RDX, HMX and the like. Anti-shock, static electricity, mechanical
sensitivity, chemical stability, friction sensitivity and thermal stability test at the National Civil Explosion Testing Center, meeting safety requirements. According to the relevant national explosive product performance testing standards, the detonation performance test results of No. 2 micronized suspension liquid explosives are as follows: explosion heat $4685 \text{KJ/Kg}$, specific volume $507 \text{L/kg}$, detonation speed $2200 \text{m/s}$. The design of the explosion performance parameters is moderate, and it can be applied to the reconstruction of the seam network in the low permeability oil layer. The liquid explosive can be appropriately adjusted according to the matching parameters of the formation lithology. The liquid explosive passes through the indoor experiment and the ground shooting range simulation test, and can be detonated at a pressure greater than $10 \text{MPa}$ and a temperature greater than $140^\circ \text{C}$. Detonation must be triggered by special detonation methods under high pressure and high temperature conditions, and will not burn or explode underground conditions. It has already provided the safety and reliability conditions for oilfield field process application test.

3. Detonation parameter calculation
The composition of the micronized suspension liquid explosive formula is relatively complicated, and the actual calculation process of the detonation parameter is very cumbersome. The calculation process is simplified for ease of explanation. The calculation of the detonation parameters is based on the $5\%$ formulation of the suspended liquid explosive sensitizer.

To calculate the explosion temperature, it can be based on the relationship between the explosive heat and the explosion temperature of the explosive $[5]$:

$$t = [-a_0 + \sqrt{a_0^2 + 4a_0Q_v}] / 2a_0$$  \hspace{1cm} (1)

In the formula, $t$ is explosion temperature, $^\circ \text{C}$; $Q_v$ is explosion heat, $\text{KJ/Kg}$; The average molar heat capacity of the explosive product is generally determined by the Custer average molar heat capacity: $a_0=854.48$, $a_1=0.33$.

In the calculation of fine powder suspended liquid explosives, the method of calculating general detonation parameters according to thermo chemical theory, from the measured explosive heat $Q_v=4685 \text{kJ/kg}$, the explosion temperature of the micro-powder suspended liquid explosive is calculated to be $1502.3 ^\circ \text{C}$.

According to the explosion theory, the calculation formula for detonation pressure is

$$P = \frac{\rho_0D^2 \times 10^{-6}}{\Gamma + 1}$$  \hspace{1cm} (2)

In the formula, $P$ is explosion pressure, $\text{GPa}$; $\Gamma$ is adiabatic index. Calculated $\Gamma=2.69$, the calculation result of the detonation pressure $P=1.46 \text{GPa}$.

4. Downhole pressure and temperature calculation
The test well design charge is $2.6 \text{t}$. Referring to the type of detonation product and the numerical range of pressure and temperature, the van der Waals equation is selected as a more suitable practical gas state equation by modifying the ideal gas state equation:

$$\left(P + \frac{a}{V^2}\right)(V-b) = nRT$$  \hspace{1cm} (3)

The constants $a$ and $b$ in the formula are called van der Waals constants, which are related to the size and interaction force of the molecules, and their values are $1.5 \times 10^8 \text{(Pa•m}^3)/\text{(Kmol}^2\text{)}$ and $3.1 \times 10^{-3} \text{m}^3/\text{Kmol}$, respectively. The substance varies and is determined experimentally. $a/\sqrt{V^2}$ is a correction value that takes into account the attraction between molecules, and $b$ is a correction value that takes into account the volume occupied by the molecule itself.

The explosion performance of liquid explosive No. 3 belongs to the category of low-speed detonation, and the action time is in the order of milliseconds. Therefore, the following assumptions
are made: 1 The explosion process is approximately regarded as a constant volume process; 2 The heat capacity of the explosive product is only a function of temperature, and is independent of other conditions such as the pressure at which the explosion occurs. This downhole explosion is analyzed by closed wellhead test. Considering the leakage of the liquid column in the wellbore, the effective heat of the stratum is set to 85%Q. The calculation of the maximum pressure $P_{\text{max}}$ and the maximum temperature $T_{\text{max}}$ in the downhole combined with the actual experience of the relevant blasting engineering, and calculated according to the measured explosive value of the No.3 liquid explosive detonation performance of 4685KJ/Kg and the detonation speed of 2200m/s. Calculated by the formula (1): $T_{\text{max}}=1502.3^\circ \text{C}$, calculated by the formula (3): $P_{\text{max}}=804.56\text{MPa}$. The result of this calculation is based on the constant volume of the explosion process, and the assumption of explosives with high detonation speed is reasonable.

5. Horizontal well process safety test

The liquid explosive technology was applied in the safety process field test in the CZ44-58 horizontal well. CZ44-58 has a vertical depth of 1984.62m, a window opening position of 1816.2-1820.7m, a horizontal production section of 2042-2191.0m, a fracturing horizontal well section of 143m, and a completion method using a Φ88.9mm large-aperture screen. The formation fracture pressure is estimated to be 41.3MPa, with no artificial cracks or natural cracks. The action of the suspended explosive explosion was completed completely in the horizontal well (large-aperture screen) section, with a designed charge of 2.6t, a spacer fluid of 1.3t, and a displacement of 5.5m³. After installing the device, reach the design ignition position and install the 750 high-pressure wellhead device to prepare for detonation [6]. After the detonation, the pressure rapidly rises to about 5MPa, and after about 10 minutes, the pressure rises to 17MPa, and the amount of spouted water increases. After half an hour, the pressure slowly decreased. Then, the wellhead pressure was about 5MPa for 24 hours. It was maintained at about 2MPa for two consecutive days. During this period, the gas and liquid flow was discharged, and after about 60 hours, the spray was released. The ignition process was successful once. After the detonation, the seismic crack dynamic detection instrument detected the suspension liquid explosives when the explosion occurred, and the stratum response was obvious.

6. Conclusions

The developed micro-powder suspended liquid explosive is suitable for the explosion-creation demand of the seam with a critical dimension greater than 2mm. The formula and performance parameters and process design of liquid explosives were initially determined. The liquid explosives have been tested by the National Civil Explosive Inspection Center and meet the requirements for safe use. The detonation speed of the main parameters of liquid explosives is controlled at 1500-3500 m/s, which can be applied to the reconstruction of low-permeability reservoir explosion seam networks with different lithological characteristics. Based on the theory of explosive mechanics, the calculation method of the detonation parameters of liquid medicine is discussed, and the pilot test of the field explosion of the oilfield is carried out successfully by the liquid explosive in the CZ44-58 sidetracking horizontal well. It proves that the design principle is feasible, the construction process is safe and the operability is strong. The experiment lays a good foundation for the research of intra-layer explosion process and further application of oilfield field test.

7. References

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