定射角定方位射孔技术

Set Firing Angle Oriented Perforating Technology

2012-11-6 AMSTERDAM

NORINCO GROUP
NORTH SPECIAL ENERGY GROUP CO.,LTD
XI'AN WUHUA JUNENG BLASTING EQUIPMENT CO., LTD

周 曌　张 锋 张少程 李勇

ZHOU Zhao, ZHANG Feng, ZHANG Shao-cheng & LI Yong

NORINCO GROUP

[Abstract] At present, there are various tubing and cable conveyed oriented perforating methods of straight and deviated wells at home and abroad, but the perforating direction of perforating charge of all perforators is perpendicular to gun body and most well axes are oblique to oil/gas formations. Therefore, Xi'an Wuhua Juneng Blasting Equipment Co., Ltd. researches and develops a set firing angle oriented perforator that can make each charge in perforating guns fire at the principal stress direction of oil/gas formations according to the set angle so as to significantly increase the production of oil and gas.

This paper introduces the principle, structure, performance characteristics, advantages of set firing angle oriented perforating technology.

[Key words] Principal stress, orientation, dip angle, dip direction, principal angle, firing angle

1 Introduction

China's oil and gas fields are mostly continental deposit. They have thin reservoirs and fine lithology and contain a lot of cements and interbeds. Many belong to low porosity, low permeability and low yield reservoirs. We must take measures to increase production in order to achieve industrial development capacity.

Oriented perforation is a new perforating technology. Because it can perforate towards two principal stress directions of formations, that is, the most easy-to-broken direction and the direction easily linking with high permeability zones, it has obvious production increase superiority.

2.Theoretical basis of oriented perforation

2.1 Principal formation stress

- Various stresses generated by a formation itself due to weathering, deposition and crustal movement, etc. are called formation stress, e.g., self-weight stress, compressive stress, fold stress and dislocation stress of formations. The sum of various stress vectors that a formation is applied is its maximum stress, also called principal stress.

- Principal formation stress is directional and shows irregular surface state extension in formations. Because of stress concentration, the static load of rock masses in the principal stress direction of formations is less than that in other directions, namely, external force required for breaking rock masses in the principal stress direction of formations will be much smaller than that in other directions. Therefore, when perforating, the penetration depth caused by firing perforating charge at the principal stress direction of formations will be much greater than that at other directions. Moreover, by perforating along the principal stress direction, jets will more easily break rock masses of formations and improve the permeability around perforations so as to improve the perforation efficiency and obtain higher productivity.

2.2 Data acquisition of principal formation stress

Each oil and gas-bearing structure has principal stress direction formed by tectonic movement and sedimentary environment. Oilfield geological departments may provide regional data of principal formation stress.

For wells with formation dip angle measured, principal formation stress data of perforation intervals may be acquired from logging interpretation data. Formation dip angle logging interpretation data may also provide the formation dip angle and direction of the target perforation intervals as well as the dip angle and direction of well bores.

2.3 Principle of oriented perforation

Because the principal stress direction presents two directions with a difference of 180° at the intersection of well axis and formation, the phases of oriented perforators must be 0°/180°. The connection between guns should determine direction or adjust direction at a certain angle.

oriented perforators and their orientation principles can be classified as follows：

A—Tubing conveyed straight well oriented perforator:

B—Tubing conveyed deviated well oriented perforator:

C—Cable conveyed straight well oriented perforator:

D—Cable conveyed deviated well oriented perforator:

E—Imported (foreign) cable conveyed deviated well oriented perforator:

F—Cable conveyed deviated well oriented perforator:

The above six kinds of oriented perforator solve only the perforating direction of perforating charge of perforators in oil and gas wells. Actually, perforating charges just fire at the charge direction of the principal stress of oil and gas formations in the plane perpendicular to gun body. The angle of intersection of principal stress and well axis is not taken into account and perforating charge do not really aim at the principal stress direction. It is the main reason why oriented perforation currently does not achieve quite obvious production increase effect.

3. Set firing angle oriented perforator

3. 1 Principle of set firing angle perforation

3.1.1 Basic concept

The vast majority of oil and gas formations are not level. There are two parameters: dip angle and dip direction. Well axes drilling through oil and gas formations mostly are not perpendicular to oil and gas formations. Although principal stress and oil and gas formations are in the same plane, the principal direction and dip direction mostly are not the same. There must be an angle between the principal stress direction and the horizontal plane, which is called principal angle.

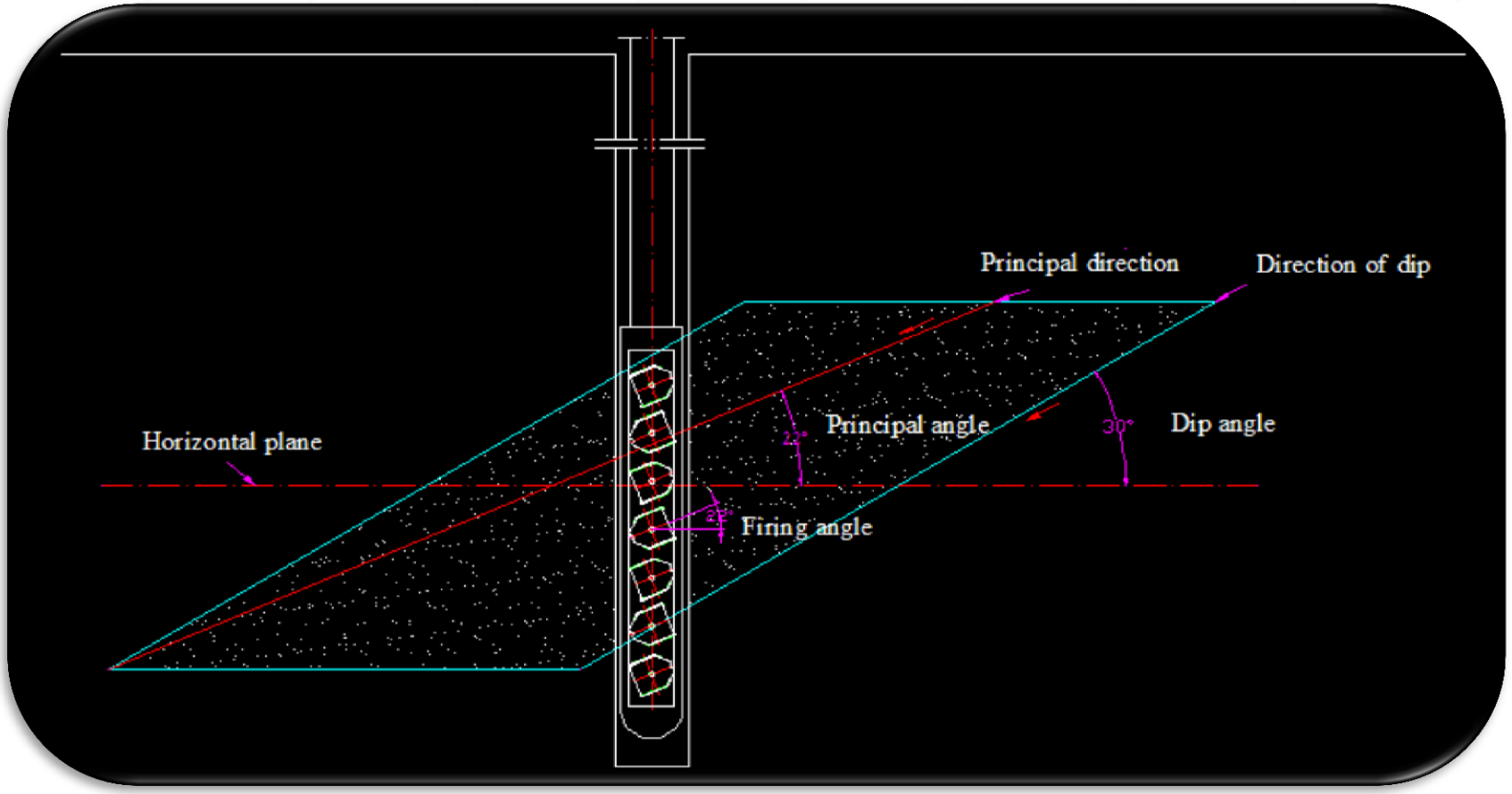

Fig.1 Intersection diagram of well axis and formation

NORINCO GROUP

Dip direction — the tilt direction of formation;

Dip angle — the tilt angle of formation;

Principal direction — the principal stress direction of formation;

Principal angle — the angle between the principal direction and the horizontal plane;

Firing angle — the angle between perforating charge and the radial plane of gun body.

Wherein, dip direction, dip angle and principal direction may be acquired from logging interpretation data, and principal angle needs to be calculated from dip direction, dip angle and principal direction.

From Fig. 1, we can see that:

When principal direction is parallel to dip direction, principal angle = dip angle;

When principal direction is perpendicular to dip direction, principal angle=90°

When the angle between principal direction and dip direction is between 0° ~90° ,

principal angle = dip angle × (90° - the angle between principal direction and dip direction) ÷ 90

NORINCO GROUP

3.1.2 Principle of set firing angle oriented perforation

Previously, perforating charges charged in all perforators are perpendicular to perforating gun body. The perforating jets of oriented perforators actually fire at the projection direction of principal stress in the horizontal plane. Since such an angle of "principal angle" is omitted, the jets do not really aim at the principal stress direction and thus cannot really achieve the purpose of oriented perforation. In recent years, the production increase effect of oriented perforation is not quite distinct. This is the main reason.

If the firing angle of each perforating charge can be set according to the principal angle, the perforating jets may really aim at the principal stress direction. The angle adjusting charge carrier structure we design is mounted in straight and deviated well oriented perforator to form a set firing angle oriented perforator.

Only set firing angle oriented perforator may truly and accurately aim at the principal stress direction of formations to perforate.

3.1.3 Problem of impact angle

Firing of artillery shells has the problem of impact angle. Take hit tanks for example, if we impact vertically, penetration is deepest, but if we impact sideways, the penetration depth will be shallow. Similarly, whether large firing angle will affect the penetration depth is the problem we first encounter in our research and development. Because perforating charge obliquely firing are affected by impact angle when penetrating gun body and casing, and after shooting to formations, the travel of perforations in formation pollution zones will also increase, the feasibility of set firing angle is a question. Therefore, we calculated in-gun standoff and gun outer gap at different firing angle from 0° to 40° based on the data xx perforating gun charging XX perforating charge and perforating in casing of 5-1/2 inches. We processed 12 sets of simulation test steel frame to conduct steel target and cylindrical sandstone target firing test. See Table 1 for test data.

NORINCO GROUP

Table 1 Impact angle ground simulation test data

No.	Firing angle	Target type	In-gun standoff	Outer gap	Penetration depth	Aperture	Remarks
1	0°	Steel target	13	11.20	154	9..9x9.5	
2	10°	Steel target	16	16.45	139	14x13	
3	20°	Steel target	18	17.24	140	13x12	
4	30°	Steel target	21	18.54	143	14x13	
5	30°	Steel target	21	18.54	149	12x12	
6	35°	Steel target	24.5	20.84	134	13.5x11.7	
7	40°	Steel target	28	22.08	155	14.5x12.1	
8	0°	Sandstone target	13	11.20	315	14.5x13.8	
9	20°	Sandstone target	18	17.24	370	11.7x10.9	
10	30°	Sandstone target	21	18.54	480	13.9x13.3	
11	35°	Sandstone target	24.5	20.84	420	15.6x12.3	Few casing rupture
12	40°	Sandstone target	28	22.08	340	15.7x14.8	Casing ruptures and leaks

It can be seen from the ground simulation test results that, within 0° ~40° , in-gun standoff and gun outer gap increase as the firing angle increases so as to increase the penetrating depth of perforating projectiles and make up the influence of impact angle to some extent. The test shows that set firing angle oriented perforation is feasible when the firing angle is less than 40° .

3. 2 Structure characteristics

Set firing angle oriented perforator differs from the aforementioned oriented perforators only in the structure of gun body and projectile carrier. There is no difference elsewhere.

3.2.1 Angle adjusting charge carrier

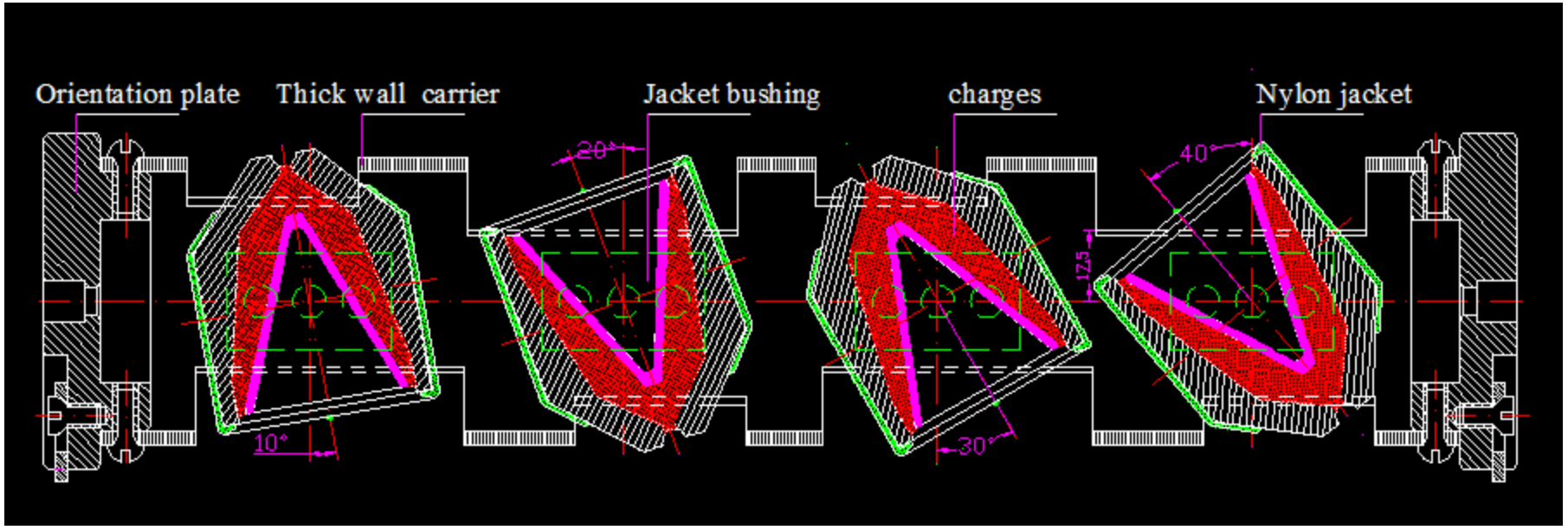

Figure 2 Diagram of angle adjusting charge carrier

3.2.2 Angle adjusting tools

To accurately adjust the firing angle of each charge, we provide special angle adjusting tools.

NORINCO GROUP

3.2.3 Gun structure

Set firing angle perforating gun has three differences from general oriented perforating gun:

1) Shot density reduces. Because perforating charges need to rotate longitudinally in perforating gun, the original shot density does not work. Set firing angle perforating gun of 102 shot density can only reach 13 holes/m; set firing angle perforating gun of 89 shot density can only reach 16 holes/m;

2) The blind hole is elongated. In order to ensure that perforating jet does not overshoot the blind hole, the blind hole is made a long-round;

3) In order to prevent jets damaging the orientation plate, perforating charges at both ends can only fire at the middle obliquely, so each perforating gun should charge perforating charges in even numbers. For example, a perforating gun of 2m charges 26 perforating charges and a perforating gun of 3m should be designed to charge 40 perforating charges, so the gun length is not standard.

3. 3 Pictures of material objects , test and analysis

According to the above structure, we processed test perforating gun charging 8 perforating charges to conduct ground concrete round target perforation test.

Figure 3 Test perforating gun after charging

Figure 4 Concrete round target perforation test

NORINCO GROUP

3. 4 Advantages and disadvantages of set firing angle oriented perforator

Advantages:

1) make perforating charges truly aim at the principal stress direction of oil and gas formations, increase penetration depth, better link the oil flow passage from high permeability zones of oil and gas formations to perforations to achieve the purpose of increasing production;

2) The external orientation structure and joint structure of set firing angle perforating gun are the same with oriented perforating gun, so it may be used in tubing conveyed straight well oriented perforator, tubing conveyed deviated well oriented perforator and cable conveyed deviated well oriented perforator;

3) Set firing angle oriented perforator is very favorable for perforation of thin interbeds that are very close to oil and water zones. This is because set firing angle can make perforating jet form passage along oil zones and not transmit to adjacent water production intervals.

4. Conclusions

After nearly ten years of research and development, test, field application and promotion, oriented perforating technology in China has achieved some results. Understanding gradually deepens. Equipments and field operating technology are improved significantly. But generally speaking, it is still not mature enough and in the phase of research, development and improvement. There are a lot of works to be done.

- Thanks !

NORINCO GROUP