Finite Element Analysis of Casing Holes Model

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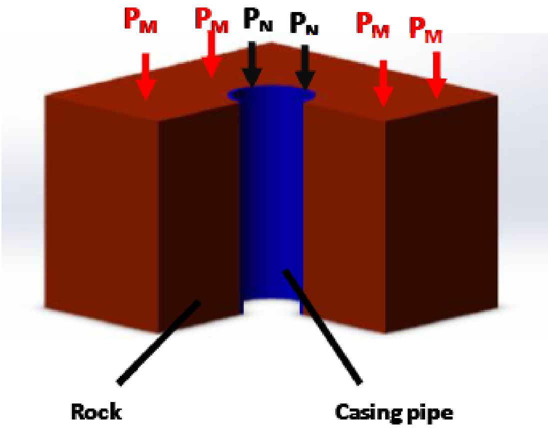
Abstract. The Deep penetration perforation water-jet technology is an effective method of the potential remaining oil exploration. Before the deep penetration perforation of reservoir it needs to open a window on the casing pipe. But the windows easily lead to decrease of casing pipe strength, which cause casing pipe damage easily. In this paper, a mechanical model of downhole casing pipe in working state is established by finite element analysis method with SolidWorks software, for the problem of casing pipe mechanical strength decline. Through the strength analysis of different direction and density perforation of casing, the degree of casing strength in different level of deep penetration perforation cases is concluded, a reasonable perforation scheme is concluded which under the prerequisite of casing strength is ensured.

Introduction

Hydraulic deep penetrating technology can improve flow performance, increase the volume of displacement, it is mainly used for increasing production of oil wells and augmented injection transformation of water wells[1]. There are two main mature technologies at present: perforating window on casing pipe + high pressure water-jet perforating cutting rock; drilling window on casing pipe + high pressure water-jet perforating cutting rock. But too much perforation on the unit casing length damages the strength of casing pipe, make finite element analysis to" perforating window on casing pipe + high pressure water-jet perforating cutting rock "through SolidWorks software, in order to confirm the reasonable perforation number and position of different casing pipe length[1].

Stress Analysis of Downhole Casing Model

Original mechanical parameters of downhole casing model are given initial value according to the 1000 meters underground formation parameters, model of casing is designed in accordance with the Petro China conventional oil or water wells with 5 1/2 inch size parameter, strength type of casing material is N80. The force condition of the model underground is as shown in figure 1.



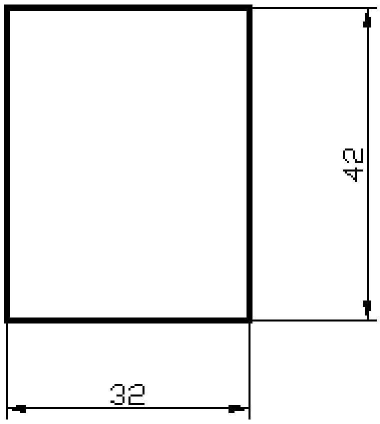


Fig. 1 Force diagram of casing borehole model.   Fig.2 Size figure of square window hole on casing

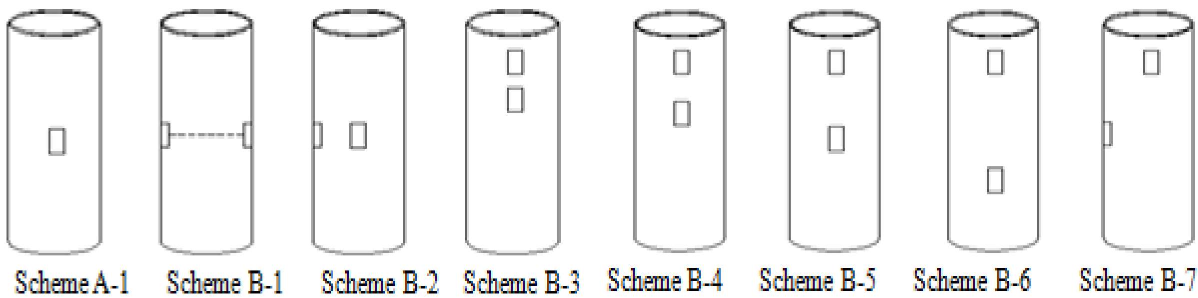
P_N is casing axial pressure, which is produced by 1000 meters casing pipe's own gravity, the pressure P_N works at the top of the casing model is 77.64 MPa. P_M is rock pressure, which is produced by the superposition of 1000 meters thick layers' own gravity, the pressure P_M works on casing lateral is 26.36 MPa. The parameters of the model are shown in table 1[2].

Table 1. The casing size and material parameter table

The casing inner diameter	124.3mm
The casing outside diameter	139.7mm
Casing wall thickness	7.72mm
The casing material type	N-80
Modulus of elasticity	2.06×105 MPa
The yield strength	530～750MPa
Rock parameters	
Rock density	2.72 g/cm3
The rock elastic modulus	1.25X105 MPa

Schemes for Holding Perforation of Deep Penetrating Horizontal

Conventional perforation bullet casing perforation diameter is 8-12 mm, 5 1/2 casing pipe of N80 material perforation density is 8 ~ 20 holes/m. casing window size of deep penetrating hydraulic perforating operation is 32 mm x42mm square hole, stress is concentrated on casing window, density of open the window is too far less than the perforation. The window position of the different situation is set respectively on hydraulic perforating casing model according to the open window of 1 window/m, 2 windows/m, 3 windows /m, 4 windows/m. According to underground perforation construction custom, 22 kinds of potential window scheme is designed. Among them, there are one 1 window/m scheme, ten 2 windows/m schemes, five 3 windows/m, six 4 windows/m schemes, the diagram is as shown in figure 3.



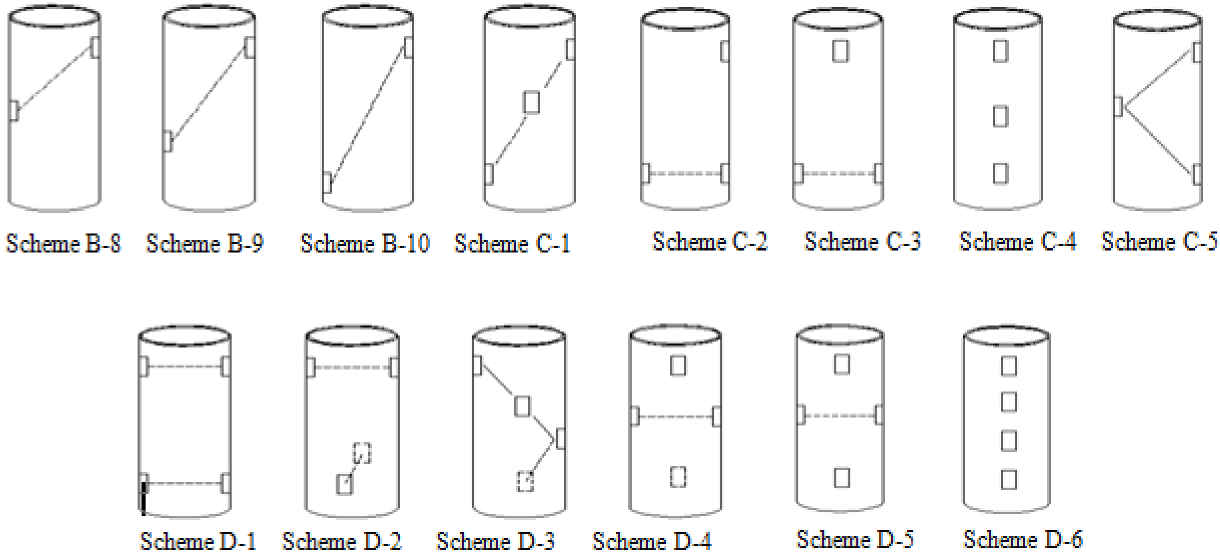


Fig 3. Casing model window scheme

SolidWorks Software is Used to Establish Three-dimensional Model

Draw casing models of different number of perforating holes with SolidWorks, a typical three-dimensional model is as shown in figure 4.

Finite Element Analysis of Downhole Casing Model

Four types of perforation scheme on casing stress model drawing in SolidWorks, which is set parameter according to the actual stress state of casing in the 1000m formation, 4 nodes meshing, bottom axial freedom of model is limited, load PN of gravity direction is applied on the top side of casing model, and rock pressure PM of peripheral direction of is applied on the outer wall of casing. The mechanical model in working state made of SolidWorks software simulation of downhole casing is as shown in figure 5.

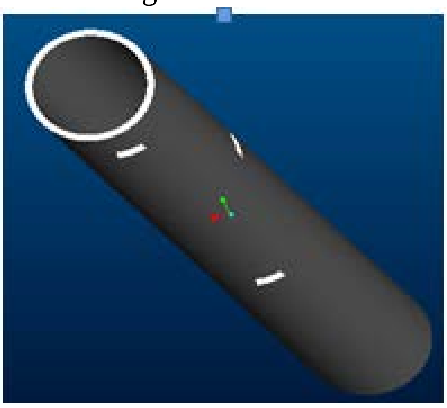


Fig 4. The casing model drawing with SolidWorks software

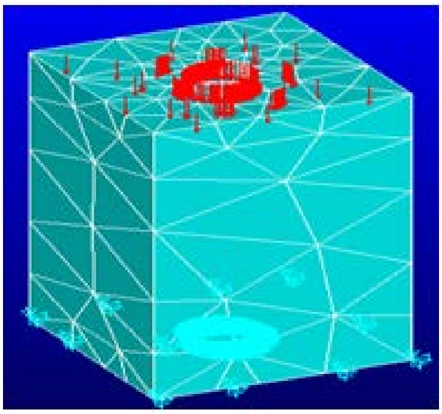


Fig 5. The mechanical model of casing under working state

In order to compare, at first,2m long mechanical window 0/m casing model is used for finite element analysis, application of simulation plug-ins of SolidWorks software adds the actual bearing load in working condition 1000m underground of casing, casing initial boundary conditions of casing pipe is limited, SolidWorks software is used for finite element analysis, It is known from SolidWorks software Von Mises stress nephogram, maximum stress of full casing (no window casing) underground 1000m is 94.9 MPa, mark this value as δ, δ is the benchmark of 1000m downhole casing strength changes [4]. In figure 3, 1 window/m is open according to scheme A-1, combined stress nephogram with SolidWorks software analysis results, is as shown in figure 6.

It is known from figure 6, combined maximum casing stress of the scheme A-1 is 101 MPa, according to the casing yield strength is 530 MPa in table 1, calculation of casing strength decreased degree γ:

$$\gamma = \frac{f_{A-1} - \delta}{E_X} \times 100\% = \frac{101 - 94.6}{530} \times 100\% = 1.1\% < 5\%$$

In this calculation: fA-1 is the maximum stress of scheme A-1 model, δ is the base value stress of downhole 1000m casing, EX is elastic model of casing. Due to scheme A-1 has little affected on casing strength (γ < 5%), so that available scheme A-1 is available, If γ is more than 5%, the scheme is unavailable[3]. All the scheme in figure 2 will be calculated in this calculation method, the calculation results are shown in table 2.

Table 2. The maximum stress distribution table of casing perforation

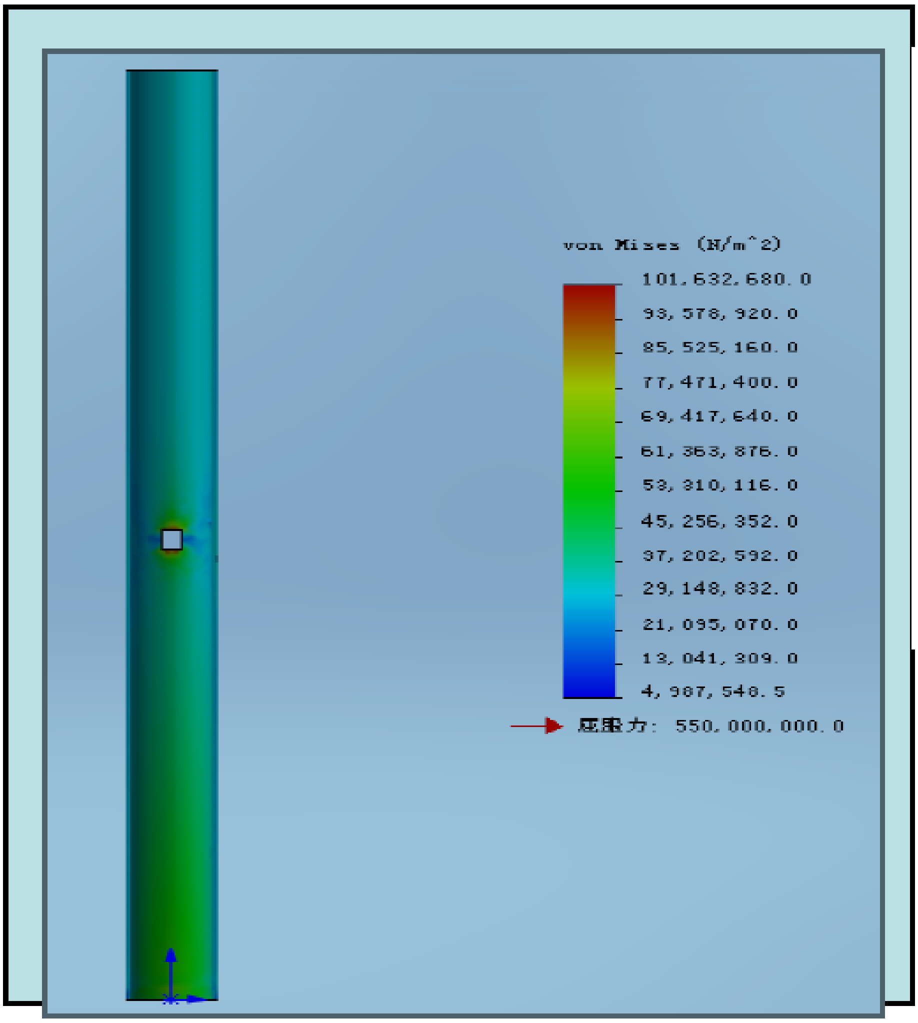
Scheme	Distance between the up and down window (mm)	Angle of the window opening direction (º)	Maximum stress (MPa)	The decrease degree of casing strength (%)	Scheme is available or not
A-1	-	-	101	1.1	available
B-1	0	180	102	1.29	available
B-2	0	90	160	11.84	unavailable
B-3	50	0	125	5.47	unavailable
B-4	200	0	102	1.29	available
B-5	500	0	100	0.93	available
B-6	1100	0	122	4.9	available
B-7	500	90	103	1.47	available
B-8	500	180	107	2.2	available
B-9	300	180	130	6.38	unavailable
B-10	900	180	104	1.84	available
C-1	500	90	139	8	unavailable
C-2	1000	180	110	2.75	available
C-3	1000	90	143	8.75	unavailable
C-4	500	0	119	4.38	available
C-5	500	180	140	8.2	unavailable
D-1	1000	0	119	4.3	available
D-2	1000	90	158	11.47	unavailable
D-3	250	90	152	10.38	unavailable
D-4	500	90	143	8.7	unavailable
D-5	500	90	188	16.9	unavailable
D-6	330	0	133	6.9	unavailable

As shown in table 2, 1 window is open on the casing in schemeA-1, when γ = 1.1%, less than 5%, it has little affect on the strength of casing, can be applied.

In scheme B, the different perforating schemes, the larger influence on the strength of casing pipe.

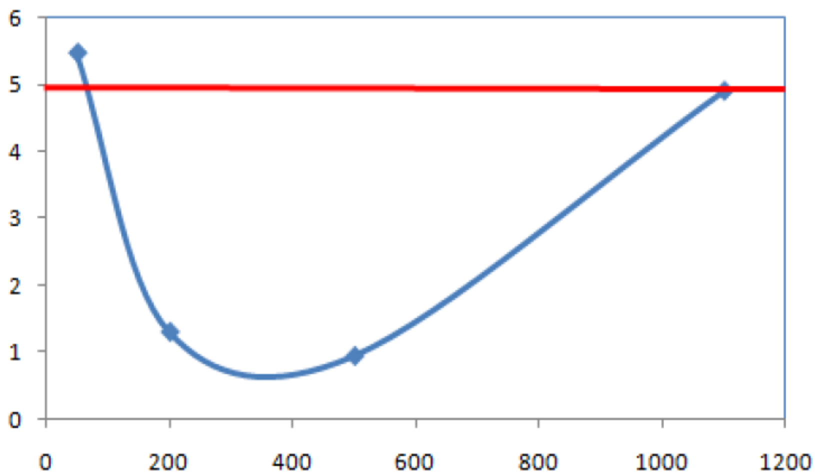
Contrast the scheme B-1 and B-2, casing window height is the same, the casing stress changes with perforating direction angle, when the 2 windows direction angle is 180° symmetrical, γ =1.29%, the casing stress is minimal at this time.

Contrast the scheme B-3, B-4, B-5, B-6, the scheme B-5 has the minimum γ value, only 0.93%, which is the best scheme of double perforating window for casing, at 50mm, the distance between the double windows that casing strength can withstand is in the range of 50-1100mm (as shown in figure 7).



The casing strength decrease degree, %

Fig6. Stress pattern of scheme A-1 casing penetrating



The distance between the two windows, mm

Fig7. Relationship figure of casing strength decrease degree in relation to the distance between the two windows with same angle

Contrast the scheme B-5, B-7 and B-8, the angle of scheme B-5 is 0 ° , γ has value of the minimum, is only 0.93%, in scheme B-7 and B-8, the angle increases, γ increases with it.

Contrast scheme B-8, B-9, B-10, at the angle of 180° between two window, γ is inversely proportional to the vertical distance between two windows, so at this time vertical distance between two windows should be more than 300 mm.

When three windows is open on 2 meters long casing, as known from table 2, scheme C-1, C-2, C-3, C-4, C-5, among them scheme C-2, C-4 is available, γ of casing in scheme C-1, C-3 and C-5 is more than 5%, which is beyond the casing strength limit range.

When four windows are open on the 2 meters long casing pipe, the casing maximum intensity is quite different from each scheme. Contrast four schemes of class D, only scheme D-1 is available, γ is 4.3%, not beyond the casing strength allowed reduce range. Five windows are open on the casing model, the window positions are not symmetrical, and the casing strength reduced to the limit when four windows are open. Therefore, in order to ensure the casing strength requirements, the maximum number of window on the 2m long casing pipe is four [5].

Conclusion

1. One window is open on 2m casing pipe, the window position can be arbitrary, it has little effect on casing strength.
2. When two windows are open on 2m casing, and the direction angle of the hole is 0°, spacing of two windows should be not less than 50 mm, and not more than 1100 mm; when the direction angle is 180°, the spacing should be not less than 300 mm.
3. When three windows is open on 2m casing pipe, scheme C-2 and C-4 is adopted.
4. When four windows is open on 2m casing pipe, the strength of casing pipe decreases close to the critical value.

References

[1] Chunshui Zhang, Hong Li and Sheke Wang, **Fnite element analysis of casing strength**[J], Journal of Beijing Institute of Mechanical Industry. (2003, 18(3), 20-25).

[2] Tao Xu, Guiqin Yin, Gongshe Zhang, etc. **The mechanism research of casing damage caused by high pressure water injection**[J], Fault block oil and gas fields. (2007, 1(1):70-71).

[3] He Liu, **Oilfield casing damage prevention and control technology**[M], (Beijing , Petroleum industry press, 2002:16 20).

[4] Tianyu Chen, Diankui Liu. **The finite element method to calculate casing damage problem**[J], Journal of Harbin Engineering University. (2003.24(3); 330-333).

[5] Jun Li, Mian Chen, Hui Zhao, etc. **The oil casing damage problem of underground complicated stress, Research progress of rock mechanics and petroleum engineering**[M]. (Beijing, Petroleum industry press, 2005).