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Finite Element Analysis of Perforated Casing High Stress Area Compressed Volume Coefficient

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Abstract

In view of the problem that perforation completion result in casing damage, from the perspective of perforating casing overall stress, on the basis of plate and shell opening mechanics model, establishing the cloth of spiral casing perforation holes finite element mechanics model, reflecting the area around the hole stress change after the casing perforation clearly. Comparing different perforation parameters before and after perforating casing under the condition of high stress area volume ratio, concluding the high stress area compressed volume coefficient, Analysis of the differential pressure under the condition of normal production, the influence of different perforation parameters (bore diameter, shooting density, phase angle) to the perforated casing compressed volume coefficient. The results of the analysis shows that different perforation parameters on the perforated casing all affect the compressed volume coefficient. According to the characteristics of the different effect law to different parameters, providing the optimization scheme of perforating parameters that reducing the volume coefficient of perforated casing high stress area. On the whole to reduce perforated casing high stress area compressed volume under normal production conditions.

Key words: Perforation; Casing failure; Finite element method; High stress area; Compressed volume coefficient

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INTRODUCTION

Perforated completion is one of completion method widely used at home and abroad, along with oil and gas development into the late, the problem that perforating causes the casing damaged is attracted people's attention by gradually. Impact in terms of perforation to casing damage, Domestic and foreign scholars have conducted extensive research, G. E. King[1] conducted experimental study obtained perforated casing collapse resistance coefficient. However, no specific recommendations are given for perforating parameters. Some scholars in China such as Wang Hanxiang and Tang Bo for Perforated casing strength do a theoretical analysis made finite element analysis by ANSYS software, giving the recommendations to perforating parameter and the casing selection. In fact, the stress around the hole after perforating the casing is increased significantly. Due to the irregular shape of the hole itself, and there is a high stress area. With the formation rock creep, before the casing does not meet the overall yield strength, in the vicinity of a large volume of casing perforations will first yield. The previous just analyzed the strength around the casing perforations, and no change in the volume of high stress areas overall analysis after casing perforation.

In this paper, through establishing the finite element model of perforated casing and using the simulation modules of software solidworks analyzes the model, by ISO tailoring function of simulation module analyzes perforated casing perforation Von Mises stress under different parameters, obtaining the stress volume change of perforated casing under normal operating conditions producing to analyze the different perforation parameters on the casing perforation high stress area compressive volume coefficient.

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1. FINITE ELEMENT MODELING AND SOLVING EXAMPLE

1.1 Finite Element Modeling

According to the practice field of oilfield perforated completion, usually the spiral choose Hole to ensure the production capacity and casing strength, because of the relatively small wall thickness of the sleeve and the outer diameter ratio, select the plate and shell holes mechanical model to study the perforated casing problems in theoretical analysis phase.

In the maximum extent, to reduce the impact of materials and casing perforation process on the calculation results, need to make the following assumptions in the analysis process: (a) Ignoring the ovality and wall thickness unevenness of the sleeve. (b) There is no perforation eccentric. (c) The projection of perforations in the perpendicular to the axis surface is circular, the diameter and length of the apertures are equal. (d) There is no burr and cracks near the holes. According the basic assumptions to establish the finite element model of perforated casing as shown in Figure 1. In order to react perforated casing situation under working conditions more realistic, while reducing the end effect, it is necessary to define the material parameters of the model, boundary constraints and external loads: (a) As an example in N80 steel casing, establishing 1 m length casing model, outside diameter 177.8 mm, wall thickness 10 mm, material density γ = 1,846 kg/m^3, shear modulus G = 78.5 GPa, Poisson's ratio μ = 0.3, Young's modulus E = 206 GPa, Minimum yield strength 552 Mpa. (b) For more realistic response cement ring fixed on the bottom of the casing, it is necessary to fix the bottom of the model. (c) External load is defined as the internal pressure static 10 MPa, external pressure static pressure 15 MPa, acceleration of gravity g = 9.8 m/s^2, Geothermal gradient 30 °C / 1,000 m, taking surface temperature 20 °C, 3,000 m depth is t = 110 °C.

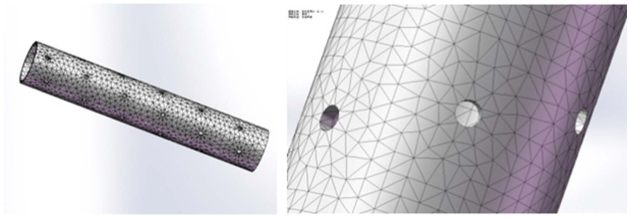

Figure 1
Perforated Casing Finite Element Mesh Model

1.2 Finite Element Model Example

Under the condition of the finite element simulation analysis, and upon the completion of the model mesh modeling, perforation parameters are set as follow: Aperture 20, shooting density 36, by compared to phase angle 60°. The perforated casing model is under the condition of more than 120 MPa. The Von Mises stress by regional stress is shown in Figure 2.

Figure 2
Perforated Casing ISO Tailoring 120 MPa Stress Nephogram

It can be seen from Figure 2 significantly that after casing perforation, there is high stress region near the aperture obviously. The compressive stress exceeds 120 Mpa that the volume of the region is 19.67%. Most of them are near the hole. Under the same conditions modeling, there is significantly improved by compared to non-perforated casing that 5.05% which ISO clipping compressed volume is more than 120 MPa. High stress areas compression volume coefficient is 4.00. As can be seen from Figure 2, after perforating the casing, withstanding high stress volume is increased. Therefore, under the same external conditions is more susceptible to fatigue damage. Thus, it is necessary to choose the perforating parameters of the perforating casing to reduce this harm.

2. EXAMPLES ANALYSIS

For example, N80 steel, internal pressure 15 Mpa and external pressure 10 MPa, under normal working conditions of production, finite element analysis module is used to simulate by solidworks software simulation. Different perforation parameters respectively calculated the effecting of pore size, pore density, perforation phase angle on the perforated casing high stress area (180 MPa) field compression coefficient.

2.1 The Aperture's Relationship With the High Stress Area Compressed Volume Coefficient

When the perforation parameters for perforation density is 36 holes/m, under different phase angles case respectively, Hole diameter under the condition of 10 mm to 24 mm

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changes, stress area volume coefficient of compression curve is shown in Figure 3, the average of different aperture is shown in Table 1.

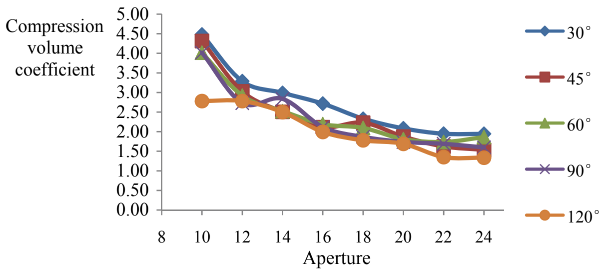

Figure 3
Aperture's Relationship With the High Stress Area Compressed Volume Coefficient

Table 1
Different Aperture Compression Coefficient of Average Volume Table

Aperture	10	12	14	16	18	20	22	24
The average of compression volume coefficient	3.92	2.95	2.67	2.23	2.06	1.84	1.67	1.66

According to the figure curve shows, in the given pore size range, aperture increases, The compressed volume coefficient becomes smaller, the overall strength of the casing is smaller. It is can be seen from Table 1 clearly, when the hole density is 10 mm. The compression volume coefficient is larger, when the size of 24 hole/m compressed volume coefficient is smaller.

Therefore, ensuring the oil production and meeting the conditions of perforating process, the proposed selection is large diameter perforation.

2.2 The Relationship With the High Stress Area Compressed Volume Coefficient and Hole Density

When perforation parameters is aperture 24 mm, under the condition of different phase Angle respectively, perforation holes density range from 12 - 48 mm change. Stress area compression volume coefficient curve is shown in Figure 4. Different pore density compression volume coefficient averages are shown in Table 2.

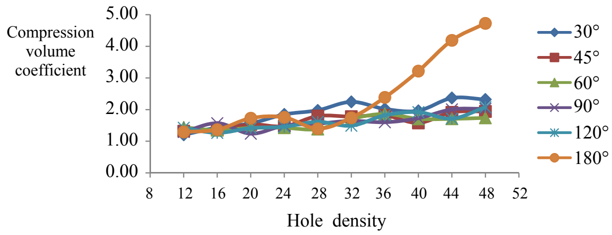

Figure 4
Hole Density's Relationship With the High Stress Area Compressed Volume Coefficient

Table 2
Different Hole Density Compression Coefficient of Average Volume Table

Hole density	12	16	20	24	28	32	36	40	44	48
The average of compression volume coefficient	1.33	1.39	1.48	1.58	1.62	1.77	1.92	2.02	2.32	2.47

It is can be seen from Table 2, with the hole density increases, high stress areas compression volume coefficient averages is larger, but the change is not big. According to Figure 4 it can be seen, when the phase angle is 45°, 60°, 90°, 120°. The amount of increase of compression volume coefficient was 0.62, 0.30, 0.73, 0.65, but the increase is not obvious. When the phase angle is 30° and 180°, compared to other phase angle, the compressed volume coefficient increases significantly, reached 1.12 and 3.43. Therefore, under the conditions of the reasonable choice of phase angle, high hole density can be appropriately selected to increase production.

2.3 The Relationship With the High Stress Area Compressed Volume Coefficient and Phase Angle

In order to give a fine description to the influence of phase Angleto the high stress area compressed volume, so when the aperture 24 mm perforation parameters is chosen, under the different perforation density conditions respectively, perforation phase angle in the range of 15° to 180° uniform change conditions. Stress areas compressed volume curve is shown in Figure 5. Different phase angle compression volume coefficient averages are shown in Table 3.

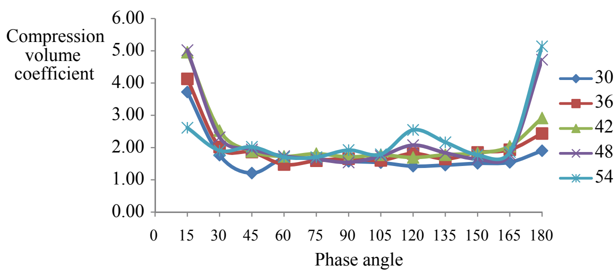

Figure 5
Phase Angle Relationship With the High Stress Area Compressed Volume Coefficient

Table 3
Different Phase Angle Compression Coefficient of Average Volume Table

Phase angle	15	30	45	60	75	90	105	120	135	150	165	180
The average of compression volume coefficient	4.09	2.11	1.78	1.66	1.68	1.68	1.69	1.91	1.78	1.72	1.83	3.42

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The curve can be seen in Figure 5, under the conditions of the same hole density, with the phase angle range from 45° - 90°, high stress areas compression volume coefficient is low relatively. In addition, no matter what the hole density situation, when the phase angle is 15° and 180°, compression volume coefficient becomes significant larger. Therefore, when the phase angle is 45°, 60°, 90°, having little effect on casing collapsing strength. At the same time, as can be seen from Table 3, when the phase angle is 60°, the average compression coefficient is 1.66, lower than the same hole dense in other phase angle conditions corresponding to compression volume coefficient. Therefore, the phase angle of 60° is recommended to choose to perforate operations. Minimize the volume of high stress compression.

CONCLUSION

(a) After casing perforation, the high stress areas mainly surround the perforations, casing high stress areas volume coefficient become larger significantly. It is more likely to occur to damage the vicinity of the hole.

(b) Manageable increases aperture, high stress areas compression volume coefficient become smaller. In order to improve the production, a large aperture can be chosen for production, and play a role in sand control. It's safe to promote oil production.

(c) Hole density changes have an impact on the high stress areas, while compression volume coefficient of perforated casing has little impact. Therefore, in a reasonable choice under the conditions of phase angle, increasing the hole density can be chosen to ensure adequate capacity.

(d) Perforating phase angle significantly affect the volume of high stress areas compression coefficient. In the same hole density, under the same aperture conditions, when the phase angle is 60°, perforated casing compression volume coefficient is the smallest. Therefore, recommended under the 60° phase angle conditions, choose a large aperture, high density perforating parameters to do perforation operations to increase production, reduce the flow rate of oil and gas, prevent sand plug, reduce accidents.

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