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Three-Dimensional Simulation of the Physical Parameters of Cement Sheath on the Stability of Two Interfaces Cementing

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Abstract:

Currently, much study on the stability of geological and cement sheath-casing combinations is primarily based on planes, and the established 3D model is just one example. In 3D models, the effect of physical parameters on the stability of composites under triaxial stress has not been systematically investigated. The effect of the physical parameters of the cement sheath (density, modulus and Poisson's ratio) on the Von Mises stress and total displacement of the two interfaces is only studied by establishing a 3D formation cement sheath casing elastic composite model. And it tends to be demonstrated that the density of the cement sheath has no impact on the stability of the formation, the cement sheath and the casing through a large number of experiments and research on actual working conditions. The permanence of the cemented second interface is proportional to the increase in the elastic modulus of the cement sheath Poisson's ratio (0-0.3); The higher the modulus of elasticity of the cement sheath, the less stable the Poisson's ratio (> 0.3) of the cement sheath at the cementing second joint will be; The higher the modulus of elasticity of the cement sheath, the more stable the Poisson's ratio (> 0.3) of the cement sheath at the first cementing boundary will be; The higher the Poisson's ratio of the cement sheath (0-0.3), the less stable the cementing first interface. Through the above studies, in light of the formation pressure, the physical parameters of the formation optimize the performance of the cement sheath and guarantee the perennial completeness of the combination.

Keywords: *casing; three-dimensional; casing; cement sheath; physical properties; first interface; casing; second interface.*

I. INTRODUCTION

Lately, the sealing integrity of casing and cement sheath is a significant piece of wellbore integrity, which not only ensures safe operation during well construction, but also ensures long-standing stable

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improvement of oil wells in the later stage of production[1]. Gholami et al. belibve that the thickness of the cement sheath protects the casing and can withstand the larger loads from the formation[2]. Tissel et al. analyzed the properties of cement, assuming regular shapes of casing, cement sheath and wellbore, using casing and wellbore surrounding rock as thermoelastic materials, and using elastic plane stress-strain theory to establish a mechanical model of downhole interaction.Bai et al. It is observed that cement sheaths with greater elastic modulus and lower Poisson's ratio are more prone to cracking[3]. Zhao et al. analyzed the Von Mises pressure distribution on the interior wall of the deepest casing by starting with the physical parameters of the cement sheath and casing, the formation temperature and the number of levels of the casing cement sheath. It is concluded that the factors involved have a profound effect on the Von Mises tension distribution on the interior wall of the deepest casing. Looking at the single-layer and multi-laye composite casing concrete development, the Von Mises pressure of the deepest casing mass of the multi-facet composite casing is clearly lower than that of the single-layer composite casing[4].This displays that the multi-layer composite structure has more important engineering value. Wang et al. established a 3D model to research well integrity and found that greater cement cohesion and stiffness would decrease wellbore failure[5]. Zhao et al. found that the internal face of the cement sheath is often subject to the greatest pressure by testing the influence of factors such as the width of the cement sheath, the elastic modulus and Poisson's ratio of cement curing, and in-situ stress on cement completeness[6]. Wei et al. found that changes in casing pressure would lead to changes such as micro-cracks at the second interface of cementing[7]. By concentrating on physical parameters of the cement sheath and formation, Li Ben believes that the tensile modulus of the cement sheath impacts the sealing performance, furthermore Poisson's ratio and cohesion additionally affect it[8]. Feng et al. researched the stress-strain state of the combination of downhole casing-cement casing-well wall surrounding rock and the fracture development state of the second interface of cementing by using the finite element method and combined with the actual working conditions in the field. They also analyzed the characteristics of initial fractures in the formation surrounding the casing.

In this article, the physical parameters of cement sheath cementing interface are studied by establishing a 3D linear elastic composite model. Combination stability determination method: The smaller the Von Mises stress, the more firm the assembly.

II. PROGRESS OF 3D MODEL OF FORMATION-CEMENT SHEATH-CASING COMBINATION

The essence of 3D geological modeling is to complete the 3D shape restoration of the formation casing combination based on exploration data combined with 3D graphic construction technology. In the assembly, the cementation between the cement sheath and the formation acts as a seal and anti-channeling in the separation of the cement sheath from the formation, because in other highly permeable formations, fluid can flow immediately through Highly permeable formations. To this end, the tightness and impermeability of the formation-cement casing assembly were studied. Due to the lower porosity and permeability of the formation and cement sheath, there is basically no liquid leakage phenomenon, so it is considered to be a non-porous and impermeable linear elastomer.

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We constructed a block whose length, width and stature are altogether 1m. The 3D shape is the calculation blend of arrangement, concrete sheath and casing. The opening measurement is 215.9mm.Casing external breadth 139.7mm, divider thickness 9.2mm;The thickness of concrete sheath is 38.1mm.The Von Mises stress distribution and overall displacement contour of the composite structure are displayed in Fig. 1:

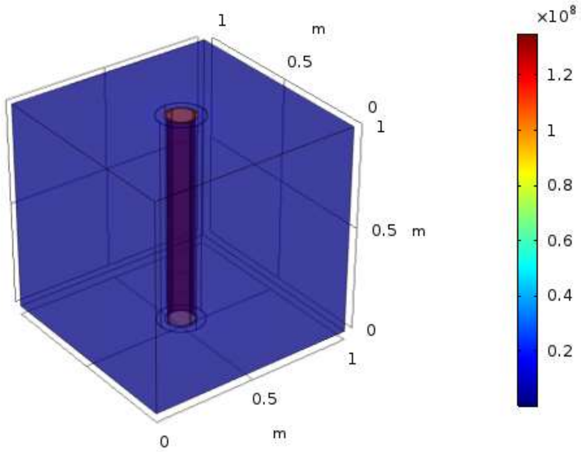

Fig. 1 Nephogram showing the Von Mises stress at the body of the formation-cement sheath-casing composite structure

As shown in Figure 1, the Von Mises pressure of casing is the most elevated, yet concrete sheath and development is almost something very similar. And the shape of the casing-cement sheath-formation composite structure is symmetrical. Consequently, Later, we can use its symmetry properties to study.

III. PARAMETRIC STUDY OF THE FACTORS INFLUENCING STABILITY OF THE COMBINATION

In this article we submit the results of the parameters study of the factors influencing the stability of the composite well structure (i.e. cement sheath, Because the performance of cement ring can be adjusted).

3.1 Ranges of variables used for stability analyses

Range of variables used for parametric study of the causes controlling the stability of the composite well structure are shown in TABLE I. In order to find the law, some parameters extend the usual numerical range. The values of elastic modulus of the cement sheath is set to 0.001GPa, that mean the cement sheath is nearly the water. Setting the Poisson's ratio of the cement sheath to 0.001 indicates that the cement sheath is very hard.

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TABLE I. Range of variables used for parametric study of factors controlling stability of composite well stability analysis

Parameters	Symbols and units	Range
Elastic modulus of the cement sheath	E_c(GPa)	0.001,10,30,60,90,120,150
Poisson's ratio of the cement sheath	Vc(1)	0.001,0.1,0.2,0.25,0.3,0.4,0.449
Density of the cement sheath	ρ_c(kg/m^3)	1000,2000,2300,2600,2800,3000,3500

We taken a point from the interfaces, to draw the law of Von Mises stress and total displacement. The point is just on the wellhead, named point 1. In this model, the interfaces is not separate, so the total displacement of interfaces meant the total displacement of the point, not the gap between the cement-formation and cement-casing. The same goes for the pressure on Von Mises. The interface with cement formation and cement casing is closely related.

3.2 Elastic modulus of the cement sheath

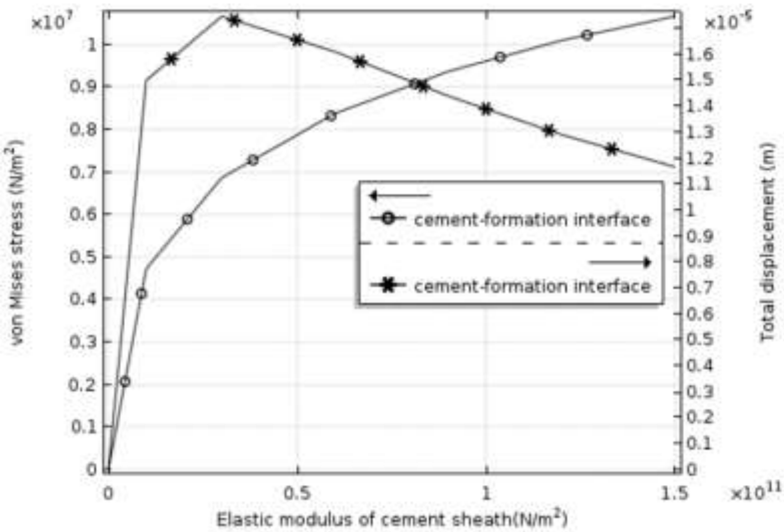

Fig. 2 Von Mises stress and total displacement at the second interface (cement sheath-formation)

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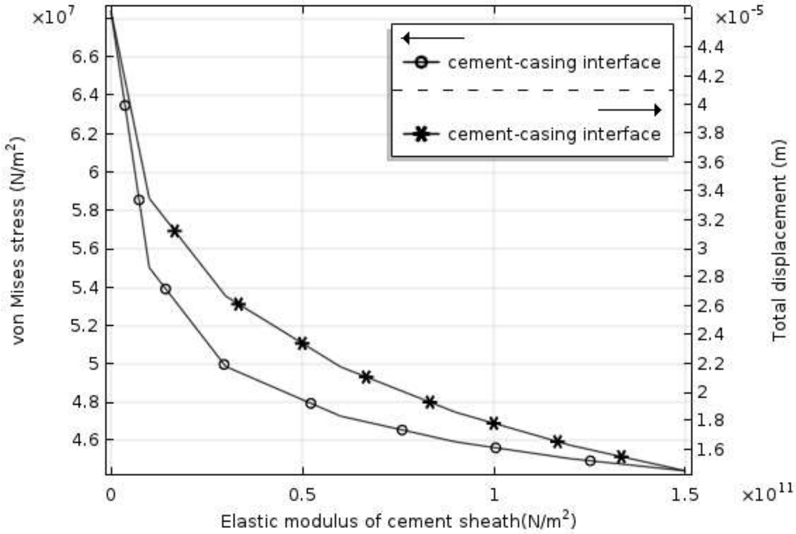

Fig. 3 Von Mises stress and total displacement at the first interface (cement sheath-casing)

As displayed in Fig.2 to 3,as the elastic modulus of the cement sheath increases, the von Mises stress decreases, the overall displacement of the first interface between cement and casing decreases, and the whole displacement of the second interface decreases. It increases when the modulus of elasticity of the cement sheath is less than 30 GPa, and decreases when the modulus of elasticity of the cement sheath exceeds 30 GPa. The lower the elastic modulus of the cement sheath, the more conducive to the stability of the second interface of cement, on the contrary, the greater the elastic modulus, the more conducive to the stability of the first interface. Therefore, the cement sheath near the formation should have low elasticity. It is a modulus and should have a high modulus near the casing position. This presents new requirements for cement slurry systems and cement technology.

Poisson's ratio of the cement sheath

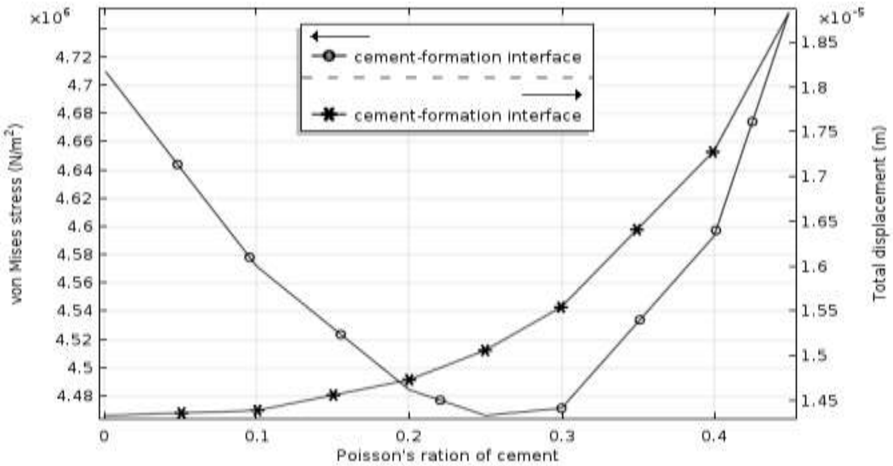

Fig. 4 Von Mises stress and total displacement at the second interface(cement sheath-formation)

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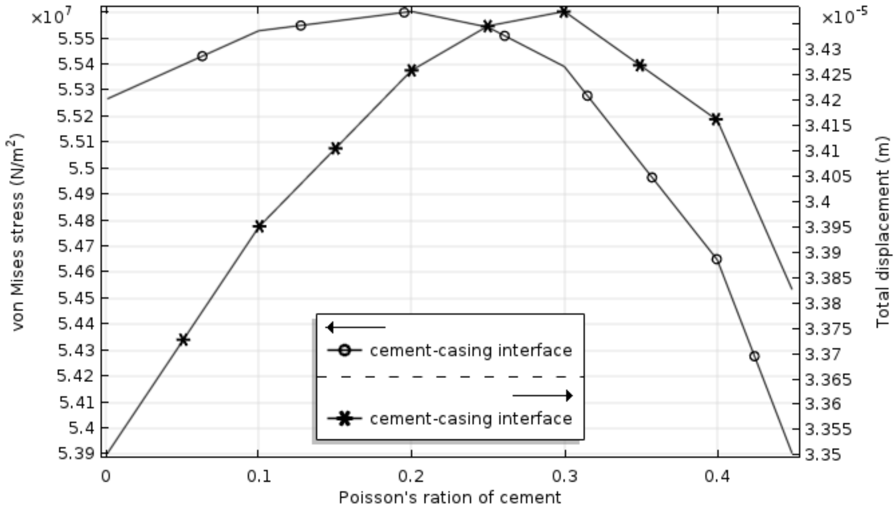

Fig. 5 Von Mises stress and total displacement at the first interface(cement sheath-casing

It is not difficult to find from Fig.4 and Fig.5 that with the increase of the Poisson's ratio of the cement sheath, the Von Mises stress of cemented second interface begins to decrease. And it rises after the cement sheath Poisson’s ratio is more than 0.3, and the total displacement increases with the cement sheath Poisson’s ratio. The Von Mises stress of the first interface with the increase of the Poisson's ratio of the cement sheath, and starts to decrease when the Poisson's ratio of the cement sheath reaches 0.2; the initial displacement increment is positively correlated with the increase of the Poisson's ratio of the cement sheath, When the Poisson's ratio of the cement ring reaches 0.3, the two are negatively correlated. The Von Mises stress and whole displacement of the initial casing are also positively correlated with the Poisson's ratio of the cement sheath. After the Poisson's ratio of the cement sheath reaches 0.3, the Von Mises stress and whole displacement decrease rapidly. When the Poisson's ratio of the cement sheath is higher than 0.3, it is not conducive to the permanence of the second interface, but good for the stabilization of the first interface and the casing. Therefore, we believe that the Poisson's ratio of the cement sheath is optimally 0.3.

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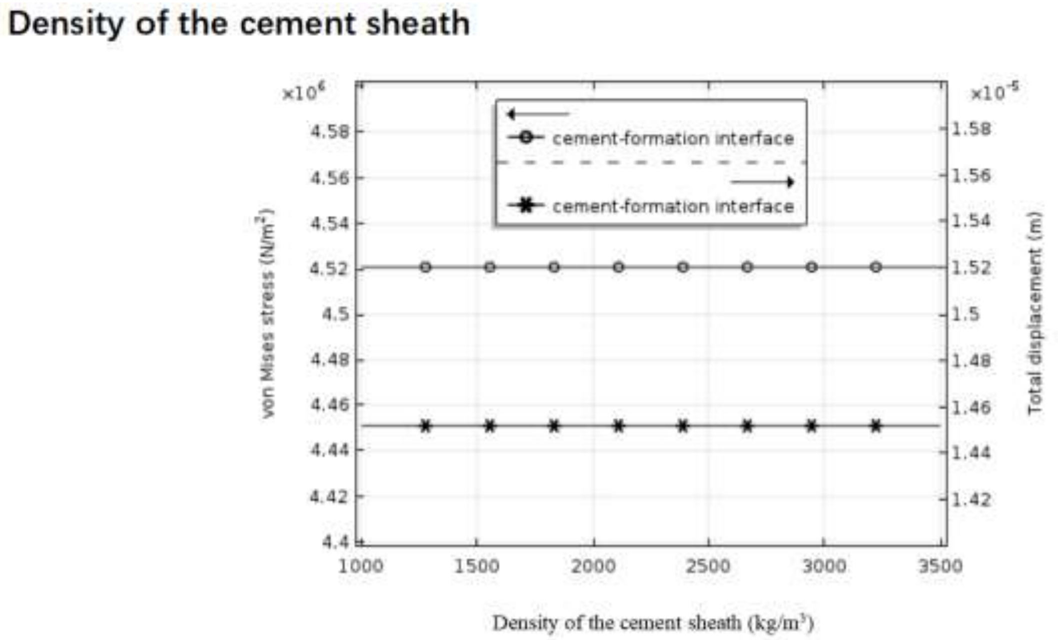

Fig. 6 Von Mises stress and total displacement at the second interface

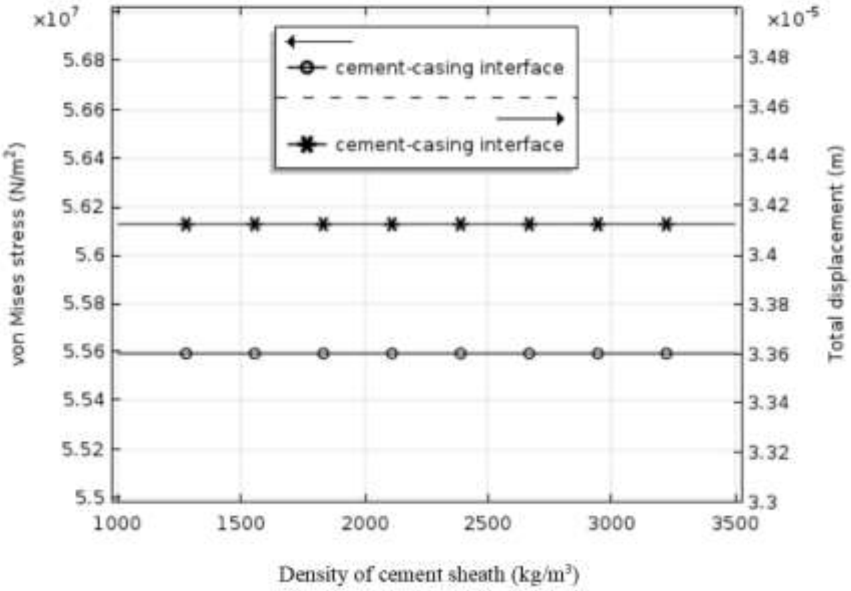

Fig. 7 Von Mises stress and total displacement at the first interface

From Figures 6 to 7, it tends to be seen that the density of the cement sheath does not impact the Von Mises stress and the total displacement of the first interface, which is the second interface.

IV. CONCLUSIONS

This paper fully investigates the domestic and foreign research results on the mechanical integrity model of the casing-cement sheath-well wall surrounding rock combination, and on this basis, establishes a

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three-dimensional deformation model of the combination, and studies the integrity of the cement sheath on the two faces. From this study, the physical parameters of the cement sheath of the composite are optimized according to the formation pressure and physical parameters of the formation, and the integrity of the casing and the cement sheath is realized.

It is generally believed that the lower the elastic modulus of cement sheath and Poisson's ratio of the cement sheath, the better. But we found that the greater the elastic modulus of the cement sheath, the more stable near the first interface of cementing; The lower the elastic modulus of the cement sheath, the more stable near the second interface of cementing; The best value of Poisson's ratio of the cement sheath is 0.3.

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