Safety coefficient method for casing reliability assessment based on failure risk

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Abstract. Casing geometry, mechanical properties and the presence of random external load characteristics were analyzed, taking into account the failure of the pipeline casing damage. According to reliability theory, the failure risk assessment method collapse resistance, tensile strength and internal pressure of. Safety factor method, based on the actual load and the internal and external anti-extrusion and collapse strength is different, according to the security casing reliability coefficient prediction. Casing continuing to take precautions to prevent accidents casing and reduce accident losses and facility maintenance costs, extend the life of the casing to a greater extent, and other related facilities.

Keywords: casing safety, factor loading, residual strength, reliability evaluation.

1. Introduction

With the majority of domestic and foreign oil has entered the middle and late stages of development, the sleeve performance year by year, and underground working conditions and more complex, causing increasing damage to the casing, causing damage more serious nature [1-2]. Oilfield casing damage at home and abroad on the rise, mainly pushed for casing destroyed, dislocation, fracture, severe deformation and severe corrosion [3]. These failures severely hampered the normal oil production, has become one of the current domestic oil production is an important issue need to be resolved [4-5]. Casing damage is a serious problem, but the trend has increased each year, will cover damage caused by injection and production wells system instability, so the annual direct and indirect losses due to damage caused by the sets are incalculable [6]. In the 1990s, foreign middle period QRA method proposed LRFD method of casing strength and reliability evaluation and successfully applied in BP, Armco and other large oil companies. In this paper, the safety factor method, the safety factor strength, tensile strength and compressive strength of the resistance to failure risk assessment method based on Casing crowded outside.

2. The establishment of a risk assessment method of casing failure

According to the structure reliability theory, the casing of the carrying capacity and service performance, service life is referred to as the casing function. The casing failure risk can be expressed as the reliability and the failure probability, the expression for [7].

$$p_r = P[z = g(x_1, x_2, ..., x_n) > 0], \quad (1)$$

$$p_f = P[z = g(x_1, x_2, ..., x_n) < 0], \quad (2)$$

Where p_r is casing reliability and p_f is failure probability.

The description of the basic variables sleeve performance function can be considered as a continuous function $Z=g(x_1, x_2, ..., x_n)$ performance function for probability distribution function, so

$$p_f + p_r = 1. \quad (3)$$

In general, the description of the state $x_i (i=1,2,...,n)$ of the casing can be grouped into two basic variables according to their attributes basic variables, namely the strength of random variables R and random variable loads S , get

$$R = R(x_{R_1}, x_{R_2}, ..., x_{R_n}), \tag{4}$$

$$S = S(x_{S_1}, x_{S_2}, ..., x_{S_n}), \tag{5}$$

Where x_{R_i} is a variable related to the strength of the sleeve, x_{S_i} is the load-related variables.

This allows multiple random variables into two random variables, taking

$$Z = R \cdot S . \tag{6}$$

$$p_r = p(Z > 0) = p(R \cdot S > 0) . \tag{7}$$

Figure 1 is a graph of casing strength and load probability density function. The hatched portion in FIG. 1 represents the overlapping portions of the two curves, an interference area, is the failure of the sleeve region may occur , the interference area of the smaller, the higher the reliability, Since it is assumed load intensity of R and S independently of each other, i.e. $f_R(R)$ and $f_S(S)$ for two independent random variables distribution function, based on the density function Z , reliability and failure probability may be calculated for each sleeve

$$p_r = P(Z > 0) = \int_0^{\infty} f(Z) dZ = \int_0^{\infty}\int_0^{\infty} f_r(Z+S) \cdot f_S(S) dSdZ . \tag{8}$$

$$p_f = P(Z > 0) = \int_{\infty} f(Z) dZ = \int_{\infty}\int_{Z} f_r(Z+S) \cdot f_S(S) dSdZ . \tag{9}$$

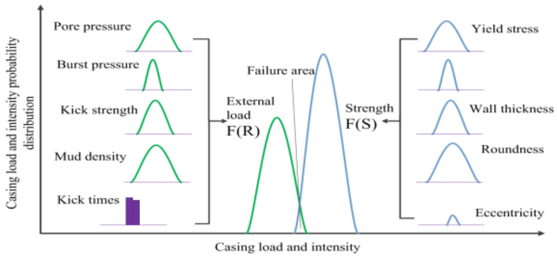


Fig.1 The interference between casing strength and loading

3. Casing residual strength evaluation based on factor of safety

Casing damage in a variety of forms, there are many factors which affect the casing damage, various factors are by applying mechanical load or the effect of casing to casing and eventually cause of casing failure [10].

3.1 Load Analysis.

Effective internal pressure.

Effective internal pressure p_{ie} equation (10) is calculated

$$p_{ie} = p_i - p_o , \tag{10}$$

Where p_i --for pipe stress, according to a full wellhead maximum working pressure ($p_S \max$) is calculated, namely $p_i = p_{s\max}$; p_o --for pipe outside pressure.

Effective external pressure. Effective external pressure according to the formula (11) is calculated:

$$p_{oe} = p_o - p_i , \tag{11}$$

Where p_i is the pressure inside the pipe, the pipe according to the minimum operating pressure ($p_S \min$) calculation, namely $p_i = p_{s\min}$; p_o is the pressure tube $p_o = 0.00981\rho_m h$.

Axial force. Axial force for cementing force, tensile stress caused by its own weight and due to bending and axial forces of the three. Among them, the cementing of casing buoyancy generated by stress:

$$\sigma_c = 0.01 \times \left(-\gamma_1 L - \gamma_2 \left(\mathrm{L} - 1\right)\right), \tag{12}$$

Tensile stress caused by its own weight:

$$\sigma_M = \frac{10\times q（L-h）}{s}, \tag{13}$$

Bending caused by axial force:

$$\sigma_z = \pm 5.8178\times 10^{-4} Ecr, \tag{14}$$

where σ_c compressive stress cementing casing buoyancy generated, MPa; γ_1 is the proportion of the drilling mud, g/cm^3; L for the sleeve length, γ_2 for cementing the gravity, g/cm^3; σ_M for weight tensile stress caused, MPa; q per meter casing weight, kg/m; σ_z for axial stress caused by bending, MPa.

3.2 Residual strength calculation.

Internal axial pressure is mainly due to the reservoir depletion, geological changes cause of formation compaction. The resistance to internal pressure strength formula:

$$p_{bo} = 0.875\frac{2 f_{ymn} t_{fmn}}{D_c}, \tag{15}$$

where $t_{fmn} = \min(t_c, t_{c\min})$, f_{ymn} is casing minimum yield strength, MPa, t_c is the name of bi-thick casing, mm and $t_{c\min}$ is the smallest bi -thick casing detection unit mm.

The collapsing strength. External pressure is caused by one of the most main reason of casing damage; the load type is complex, many factors of uncertainty, resulting in casing damage form is not the same. Based on the detection of wall thickness calculation of inequality ec and ov elasticity, Calculation of limit of manufacturing defects of collapsing pressure p_{ult}, the calculation formula is as follows:

$$p_{\mathrm{ult}} = \{(p_{\mathrm{e\,ult}} + p_{\mathrm{y\,ult}}) - [(p_{\mathrm{e\,ult}} - p_{\mathrm{y\,ult}})^2 + 4 p_{\mathrm{e\,ult}} p_{\mathrm{y\,ult}} Ht_{\mathrm{ult}}]^{1/2}\} / [2(1 - Ht_{\mathrm{ult}})], \tag{16}$$

$$Ht_{\mathrm{ult}} = 0.127ov + 0.0039ec - 0.440(rs / f_{\mathrm{y}}) + h_{\mathrm{n}} \text{ And } Ht_{\mathrm{ult}} \ge 0, \tag{17}$$

where ec degrees as uneven wall thickness, %, $ec = 100(t_{\mathrm{c\,max}} - t_{\mathrm{c\,min}}) / t_{\mathrm{c\,ave}}$; f_{y} typical pull extension of the sample measured yield strength; h_{n} for stress-strain curve shape factor; Ht_{ult} loss factor; ov oval degrees, $ov = 100(D_{\max} - D_{\min}) / D_{\mathrm{ave}}$ 3; elastic limit collapsing pressure; $p_{\mathrm{e\,ult}}$ for ultimate yield collapsing pressure; $p_{\mathrm{y\,ult}}$ for residual stress (rs inner surface compression is negative, the inner surface of the stretch is positive).

Tensile strength. The axial tension sleeve by including axial tension generated by the self-weight of the additional axial tension, water injection, fracturing and acidizing effect induced. A thread of a pipe body strength:

$$T_o = 9.5\times 10^{-4} A_p U_P \left[25.623 - 1.007\ (1.083 - Y_p / U_p) D\right], \tag{18}$$

Where A_P is a cross-sectional area for the tube end, mm^2; A_c for coupling to the cross-sectional area, mm^2; Y_p for the pipe yield strength, MPa; U_{p} for pipe minimum ultimate strength, MPa; U_c for coupling the minimum ultimate strength, MPa?

3.3 Calculation and specification of safety coefficient.

The anti-internal pressure safety coefficient is casing internal pressure strength and casing effective internal pressure ratio, the formula for:

$$n_i = p_{bo} / p_{ie}. \tag{19}$$

Anti-squeeze safety factor is the ratio of the resistance to internal pressure strength and effective external pressure casing, the formula is:

$$n_o = p_{co} / p_{oe}. \tag{20}$$

Tensile safety factor is the ratio of the tube and pipe thread strength of in vitro pressure. The formula for:

$$n_T = T_O / T_{oe} . \tag{21}$$

Represented in API casing design specification pressed against the inner sleeve provides a safety factor of 1.05~1.15, the provisions of the anti-squeeze safety factor of 1.00~1.25, within the provisions of the anti-pressure safety factor of 1.6~2.0.

4. Experimental Analyses

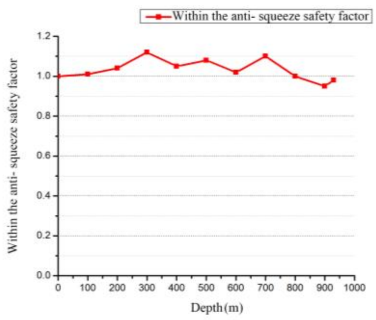
According to the casing safety reliability evaluation method established above, using the method of actual measurement of outer diameter 244.5mm, The inner diameter wall thickness 11.99mm APIP110 and NEWVAM Thread casing body collapsing and resistance to internal pressure strength are analyzed, the measured data such as table; through the method of calculation in Figure 2 and Figure 3, shown in figure4. Table 1;

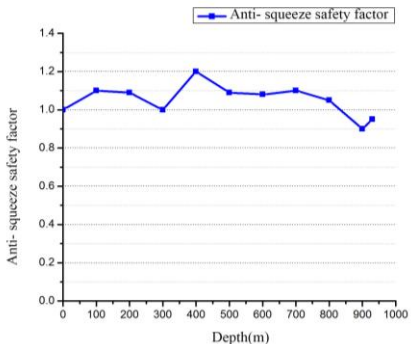
Table 1 gives the depth and the depth of the casing with the change in the effective size of the pressure, the test shows that with increasing depth, the external pressure increases, effective internal pressure decreases.

Table 1 Depth and effective internal pressure

Depth/m	External pressure/MPa	Effective internal pressure (maximum) /MPa	Effective internal pressure (minimum) /MPa
0	0	13.67	6.60
100	1.03	12.73	5.61
200	2.06	11.79	4.63
300	3.08	10.85	3.63
400	4.12	9.91	2.65
500	5.14	8.97	1.67
600	6.17	8.08	0.68
700	7.20	7.09	-0.30
800	8.23	6.14	-1.29
900	9.26	5.21	-2.27
930	9.57	4.93	-2.57

It can be seen from Figure 2 with the increasing depth of the depth, internal pressure decreases after the first increase the safety factor, according to the previous formula to calculate the depth of the safety factor of less than 800m, respectively 1, 1.01, 1.04, 1.12, 1.05, 1.08, 1.02, 1.1, internal pressure within the rated range safety factor of 1.05~1.15, the casing is safe and reliable; between 800~930 meters considered internal pressure safety factor of 1, 0.95, 0.98, less than the rated within the anti-pressure safety factor of 1.05~1.15.





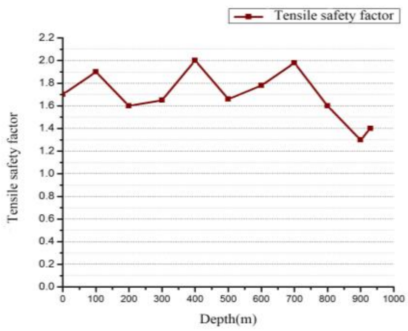


Fig2 Internal pressure safety factor Fig3 Anti-squeeze safety factor Fig4 Tensile safety factor

It can be seen from Figure 3 with the increasing depth of the depth, Anti-squeeze decreases after the first increase the safety factor, according to the previous formula to calculate the depth of the safety factor of less than 900m, respectively 1, 1.1, 1.09, 1, 1.2, 1.09, 1.08, 1.1, 1.05, Anti-squeeze within the rated range safety factor of 1.00~1.25, the casing is safe and reliable; between 900~930 meters considered Anti-squeeze safety factor of 0.9, 0.95, less than the rated within the anti-squeeze safety factor of 1.00~1.25.

It can be seen from Figure 4 with the increasing depth of the depth, Tensile decreases after the first increase the safety factor, according to the previous formula to calculate the depth of the safety factor of less than 900m, respectively 1.7, 1.9, 1.6, 1.65, 2, 1.66, 1.78, 1.98, 1.6, Tensile within the rated range safety factor of 1.6~2.0, the casing is safe and reliable; between 900~930 meters considered tensile safety factor of 1.3, 1.4, less than the rated within the anti- tensile safety factor of 1.6~2.0.

5. Conclusions

According to the probability distribution parameters of casing performance parameters, external load, gives the calculation method of casing load and strength; So the criteria for the application of casing reliability evaluation method and safety coefficient method, can get the casing in different load and strength in the absence of reliability, are located at 1.05~1.15, 1.00~1.25, 1.6~2.0 between the casing is safe and reliable; So as to the measured data obtained in the deep well casing safety, zero to eight hundred meters between the calculated safety factor is measured, rated collapsing and rated tensile safety coefficient range, the casing is safe and reliable, and theory in safe stage, strong reliability; in deep well eight hundred the measured nine hundred and thirty meters between the calculated safety factor is within the rated range, show casing failure possibility is larger, need to take security measures to avoid the hidden dangers and losses.

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