Experimental study of hoop stress of crescent shaped and eccentric worn casing

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Abstract: The decrease of collapse and burst strength of wear casing increases the risk of wellbore failure, and limits the selection of testing and completion operation parameter. For determining the residual strength of wear casing, 95/8"x 11.99mm-P110 casing is processed into the crescent and eccentric wear casing specimens with wear depth as 4 mm and 6 mm respectively. The experiments of wear casing loaded with radial centralized forces are carried out, and the finite element method is used to verify the experimental results. The circular stresses of outer surface at worn and unworn position of casing increase with the load exerted by the compression tester, and reach the yield strength of material of casing finally. The circular stress of the external surface of the worn position of casing is greater than the ones of unworn casing. The differences between the results which come from the analysis of the finite element method and the experimental data are less than 10%. So the results which are obtained by the experiment of the crescent-shaped and eccentric wear casing loaded with radial centralized forces are reliable. The circular stress of the external surface of the worn position of crescent-shaped wear casing is greater than the one of eccentric wear casing. The differences between them are less than 10%.

Key words: Crescent-shaped wear casing, eccentric wear casing, the hoop stress, compression experiment, finite element method.

1. Introduction

The crumble resistance, internal pressure resistance and tensile strength of the worn casing decrease, which increases the risk of wellbore failure. Inaccurate evaluation of residual strength of worn casing often leads to well testing and completion accidents, increases workover cost, and even leads to whole well scrapping.

The cross section of worn casing is crescent. The research work of F.J.Klever [1-2] played an important role in the determination of residual strength calculation formula of worn casing as thick wall cylinder. The calculation of internal pressure strength of API 5C3 and ISO 10400 [3-4] standard casing and collapse strength of defective casing adopt the research results of F.J.Klever and T.Tamano. J. Wu [5] used the strength calculation method of corroded casing for reference, and used the long groove model to calculate the internal pressure strength of worn casing. Based on the research results of
F.J. Klever and T. Tamano, Shen Zhaoxi et al. Improved the formula of casing collapse strength [6-9], which regards wear as defect. Hao et al. [10] realized the dynamic simulation of casing wear process in specific wells by redesigning and reconstructing the software in FORTRAN language, and obtained the wear depth and residual strength law of casing at different positions and at different times. In addition, Han Jianzeng [11-12] and others used numerical method to determine the collapse resistance and internal pressure strength of wear casing.

After the inner surface of casing is worn, the residual collapse resistance and internal pressure resistance can be determined by selecting an appropriate stress function [13-14]. In order to verify the rationality of this method, the compression experiment of worn casing under external load is carried out and verified by finite element method.

2. Materials and experimental process of crescent and eccentric wear casing

In order to compare the experimental and theoretical analysis results of circumferential stress of eccentric wear casing and crescent wear casing under centralized force, the crescent wear casing and eccentric wear casing samples were processed, and the stress measuring device was made.

2.1. Experimental materials for crescent and eccentric wear casing

In order to study the maximum stress of crescent wear casing and eccentric wear casing under external load, 95/8" × The 11.99mm-p110 casing is processed into four kinds of samples as shown in Figure 1. The loading position of the centralized force and the position of the strain gauge are shown in Fig. 2.

![Fig. 1 Crescent and eccentric wear casing samples before and after compression](image1)

![Fig. 2 Strain gauge and loading position of eccentric wear and crescent wear casing](image2)
2.2. Experimental process
According to the resolvable compression force of the compression testing machine, the stress values of the worn and non worn positions measured by two strain gauges are saved once for every 5KN loading.

2.3. Mechanical properties of experimental tubes
Tensile test material: 95 / 8” × 4 tensile samples were processed for 11.99mm-p110 casing material. The tensile results are shown in Table 1. According to the load displacement curve, elongation after fracture and reduction of area, P110 pipe has good plasticity and no obvious yield. After yielding, the material reaches its strength limit and breaks.

| Material | Yield strength σ/MPa | Tensile strength σ/MPa | Elongation after fracture A/% | Fracture surface shrinkage Z/% |
|----------|----------------------|------------------------|------------------------------|-------------------------------|
| Sample 1 | 945                  | 1010                   | 17.9                         | 63.1                          |
| Sample 2 | 951                  | 1000                   | 12.3                         | 68.7                          |
| Sample 3 | 968                  | 1010                   | 14.4                         | 65.5                          |
| Average  | 955                  | 1007                   | 14.9                         | 65.7                          |

3. Comparison between numerical result and experimental data of maximum stress of crescent and eccentric wear casing
In order to verify the circumferential stress values of crescent and eccentric worn casing determined by experiments under centralized force, the finite element analysis model of worn casing under centralized force was established, and the numerical solutions of circumferential stress at worn and non worn positions were determined, and compared with the experimental values.

3.1. Establishment of finite element model of worn casing
Plane42 element is used to map mesh. The circumferential stress contours of crescent and eccentric worn casing under the action of radial centralized force is shown in Fig. 3.

(a) Stress contours of crescent wear casing  
(b) Stress contours of eccentric wear casing

Fig. 3 Finite element model and stress contours of worn casing

3.2. Comparison between numerical result and experimental data of maximum stress of crescent shaped wear casing
The numerical results and experimental data of circumferential stress at the worn and non worn positions of 4mm and 6mm casing with crescent wear are shown in Fig. 4. With the increase of wear depth and centralized force, the numerical solutions of circumferential stress at the worn and non worn positions increase gradually. Under the action of 30KN centralized force, the circumferential stress at the worn
position of the eccentric worn casing with 4mm wear depth is 1.45 times that of the non worn position, while it is 1.71 times under the action of 40kN. The difference between the two increases gradually, which is the same as the experimental results under the action of crescent wear casing centralized force.

![Fig. 4](image1)

**Fig. 4** Comparison of numerical results and experimental data of circumferential stress of crescent wear casing

3.3. **Numerical analysis results of maximum stress of eccentric wear casing**

The numerical results and experimental data of circumferential stress at the worn and non worn positions of 4 mm and 6 mm eccentrically worn casings are shown in Fig. 5. With the increase of wear depth and centralized force, the numerical solutions of circumferential stress at the worn and non worn positions increase gradually. Under the action of 30KN centralized force, the circumferential stress of the worn casing at 4mm depth is 1.11 times that of the non worn casing, while it is 1.18 times under the action of 40kN. The difference between the two increases gradually, which is the same as the experimental results under the action of centralized force of eccentric wear casing.

![Fig. 5](image2)

**Fig. 5** Comparison of numerical solution and experimental results of circumferential stress of eccentric wear casing
3.4. Comparative analysis of numerical and experimental results

The difference between the circumferential stress on the outer surface of crescent wear casing and that on the outer surface of eccentric wear casing is less than 10%. Therefore, it is feasible to simplify the crescent wear model of casing into eccentric wear model, and obtain the theoretical solution of stress distribution of eccentric wear casing, and then determine the collapse resistance and internal pressure resistance strength of inner wear casing.

4. Conclusion

In order to verify the rationality of the method of simplifying the crescent shaped wear casing model into eccentric cylinder model and determining its anti collapse and anti internal pressure strength, the compression experiment of wear casing under centralized force is carried out and compared with the results of finite element analysis.

(1) The circumferential stress on the outer surface of the casing with crescent wear and eccentric wear increases with the increase of load, and the circumferential stress at the worn position is greater than that at the non worn position.

(2) The difference between the circumferential stress on the outer surface of the crescent wear casing and the circumferential stress on the outer surface of the eccentric wear casing is less than 10%. Therefore, it is feasible to simplify the crescent wear casing model into the eccentric wear casing model, and then determine the collapse resistance and internal pressure resistance of the inner wear casing.

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