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Fatigue Life Analysis of Coiled Tubing in Deep Well Jet Plugging Removal

Ju Liu[1], Qiao Wang[1], Wei Zhang[1], Zhihong Zhou[2], Wenzhong Hu[2], Yan Wang[1]

[1]Petrochina Tarim Oilfield Company, Korla, China
[2]Sinopec Jianghan Petroleum Engineering Company, Qianjiang, China
Email: lld1210@qq.com

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Abstract

The coiled tubing plugging has become the main means of plugging in gas Wells in Xinjiang. These Wells are deep and have high pressure, which can easily affect the fatigue life of the operating coiled tubing. In order to improve the life of coiled tubing in high-pressure gas Wells, this paper studies the plugging conditions of coiled tubing in high-pressure ultra-deep Wells. Firstly, the cross section deformation of coiled tubing under high internal pressure is analyzed. Secondly, the factors influencing the fatigue life of coiled tubing and the influence of surface damage on the fatigue life of coiled tubing were studied. Finally, the mechanism of furrow damage caused by coiled tubing and the main measures to reduce furrow damage are analyzed. The following suggestions are made to improve the life of coiled tubing: select the right material and the right size coiled tubing; Use appropriate measures to prevent premature coiled tubing failure and reduce operating costs.

Keywords

Coiled Tubing, Plug Removal by Jetting, Fatigue Life, Plough Surface Damage, Resonance

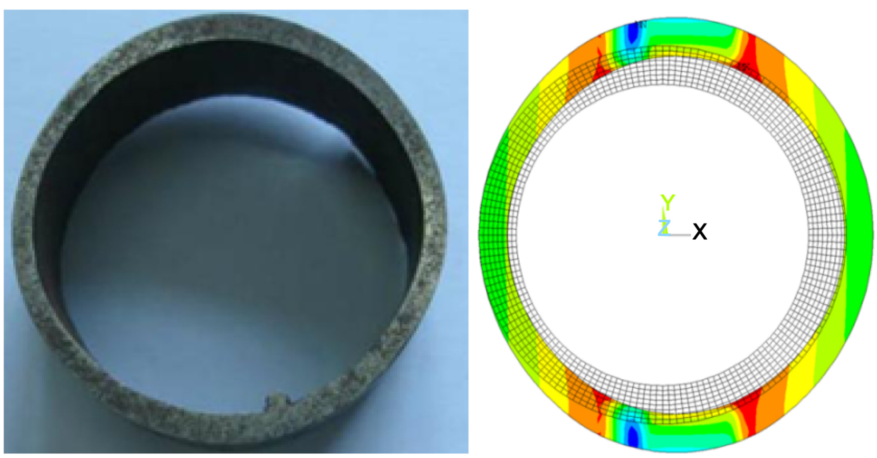
1. Introduction

Some gas wells in Xinjiang were blocked after a long period of production. Taking Dina, Keshen and other gas fields in Tarim Oilfield as examples, there are different degrees of wellbore blockage problems, there are 43 wells with wellbore blockage problems, more seriously 14 wells have been shut down [1]. On-site technicians used coiled tubing flushing and grinding to successfully dredge some severely blocked wells and re-enter production. At present, coiled tubing plugging removal has become the preferred means of operating wells plugged in Xinjiang.

Low cycle fatigue damage is easy to be caused by coiled tubing during plugging removal. The low cycle fatigue life of coiled tubing is related to the geometry of coiled tubing, the material of coiled tubing, the mechanical damage of coiled tubing surface, and the pressure inside the tube when the coiled tubing is bent. A large number of scholars have carried out related research on the plugging conditions of coiled tubing. In 2000, Radovan Rolovic and Steven M. Tipton [2] [3] conducted fatigue test studies on coiled tubing specimens with two materials, and analyzed the deformation law of coiled tubing cross section with the number of bending. In 2009, Christian and Tipton [4] defined the defect damage amount through research. In 2018, Craig S. H. [5] analyzed coiled tubing surface damage from 2006 to 2017 and found that furrows accounted for about 46% of surface mechanical damage. In 2019, Zhou Zhihong *et al.* [6] proposed the hypothesis of furrow damage, arguing that if the operating pressure is relatively high, the cross section of coiled tubing will increase in diameter during repeated bending and straightening. Therefore, the damage analysis of coiled tubing fatigue life is very important in coiled tubing unplugging operation.

2. Coiled Tubing Cross Section Deformation

In order to analyze the cross section deformation of coiled tubing, the bending process is simulated by the finite element. Taking the deformation of a drilling plug as an example, the use of QT900 with a diameter of 2 inches and a wall thickness of 0.156 in 5000 meters of coiled tubing and coiled tubing operation vehicle. In the course of the operation, it has occurred many times stuck drilling pump, workers in the pump pressure of about 45 MPa to carry out about 20 times the lifting down, measured at 3576 meters coiled tubing diameter greater than the nominal diameter of 3.6 mm [7], the diameter increased by 7%. **Figure 1(a)** is the actual coiled tubing cross section, and **Figure 1(b)** is the simulated



(a) (b)

Figure 1. Variation of repeated bending cross section of coiled tubing under internal pressure. (a) Variation of actual coiled tubing cross section. (b) Finite element simulation of cross section changes.

coiled tubing cross section.

The simulation process shows that the coiled tubing under internal pressure has obvious cross-sectional changes after repeated bending corrections. The larger the internal pressure, the faster the diameter growth, the lower the yield strength of the material, and the faster the diameter growth. The speed of diameter growth is related to the ratio of circumferential stress to yield stress, and also to the ratio of coiled tubing diameter to bending radius. The smaller the bending radius is, the faster the diameter changes.

3. Fatigue Life of Coiled Tubing

Although there are various theories on the fatigue life of coiled tubing, the results obtained by the standard coiled tubing testing machine are still widely recognized in the industry. The coiled tubing supplier has its own coiled tubing fatigue test curve for various steel grades. The fatigue characteristics of coiled tubing with different steel grades are very different.

Taking the fatigue test curves of QT-900 coiled tubing and QT-1200 coiled tubing of QT Company as an example, **Figure 2** and **Figure 3** show the fatigue test results of QT-900 and QT-1200 steel grade coiled tubing, respectively [8]. When the stress ratio (the ratio of circumferential stress to yield stress) of QT-900 coiled tubing exceeds 0.33, it drops to less than 100 times, only 25% of 400 times at low stress ratio. However, for QT-1200 coiled tubing, when the stress ratio is 33%, the fatigue life is still 200 times, which is 50% of low stress fatigue. The difference between the two is very large. Therefore, it is very important to select the appropriate coiled tubing materials for improving the fatigue life.

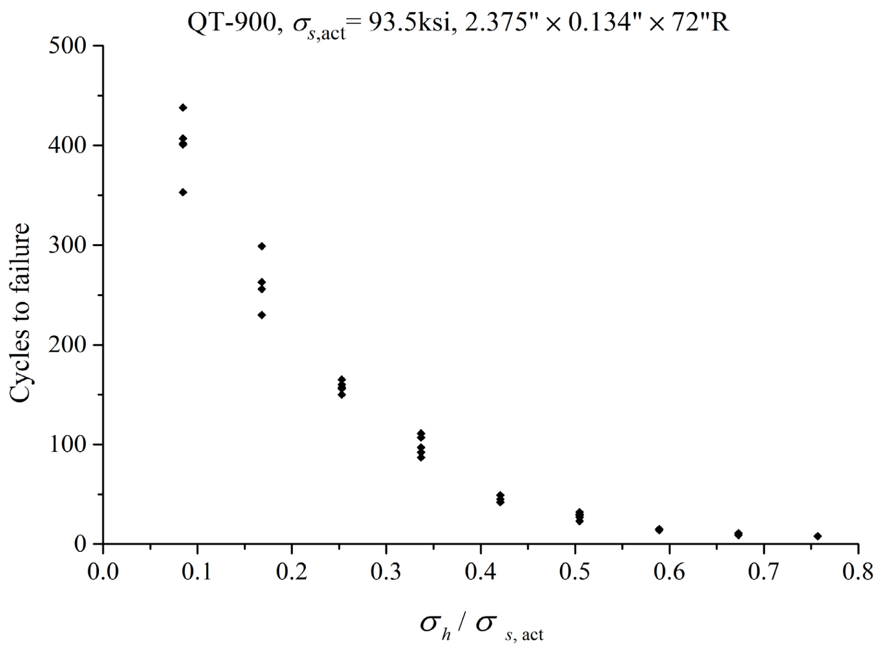


Figure 2. Fatigue test results of QT-900 coiled tubing.

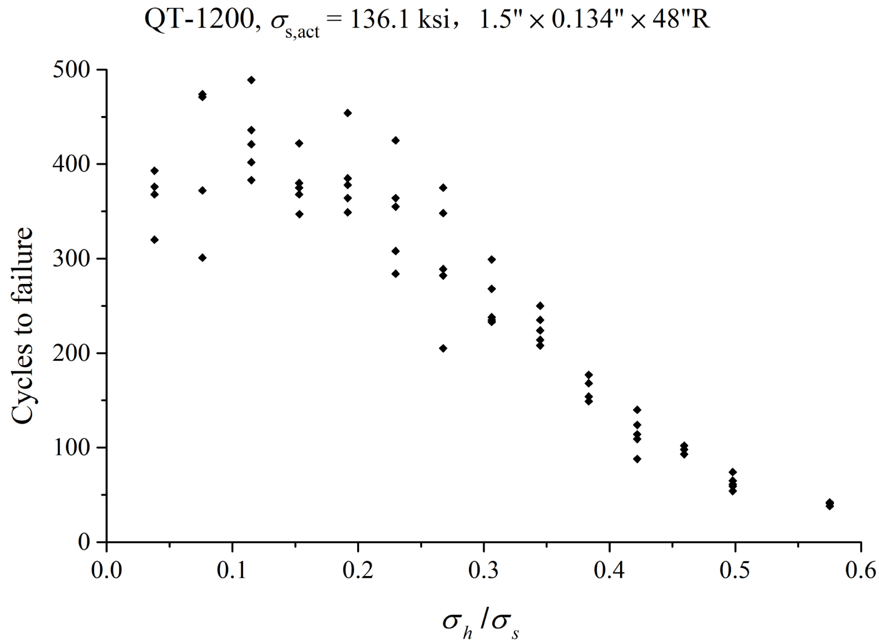


Figure 3. Fatigue test results of QT-1200 coiled tubing.

Since the stress ratio of coiled tubing is inversely proportional to the thickness of coiled tubing, the greater the thickness, the lower the stress ratio is, the higher the life under the same internal pressure is. The test also shows that the greater the bending radius, the higher the life.

4. Fatigue Life of Surface Damaged Coiled Tubing

In the process of coiled tubing operation, it is inevitable to have mechanical damage on the outer surface, such as clamping block injuries, bumps, scratches, and furrows [9] [10] [11]. These defects will produce stress or strain concentration when the coiled tubing continues to work, which will affect the service life of the coiled tubing. In order to study the influence of surface damage on the fatigue life of coiled tubing, the following formulas were used to calculate the amount of defect damage and fatigue life respectively.

Defect damage quantity Q:

$$Q=\left[\left(\frac{d}{t}\right)\left(\frac{w}{x}\right)\sqrt{\frac{A_p}{A_c}}\right]^{\frac{1}{3}} \tag{1}$$

The parameters d, x, w, A_p, A_c describing the external surface defects in the formula are shown in **Figure 4**, and t is the wall thickness of the coiled tubing.

Empirical formula for fatigue life of coiled tubing with defects:

$$\frac{N}{N_b}=\mathrm{e}^{-a+\frac{a}{1+\left(\frac{Q}{b}\right)^c}} \tag{2}$$

where, N is the fatigue life of coiled tubing with defects; N_b is the fatigue life of

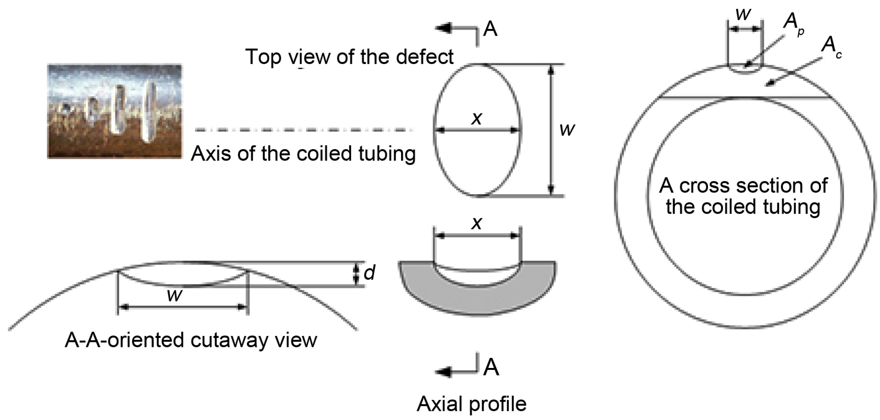


Figure 4. Geometric definition of outer surface mechanical defects.

coiled tubing without defects; Parameter $a = 9.222$, $b = 1.0339$, $c = 2.20735$.

The calculation shows that the surface mechanical defects have a great influence on the fatigue life of coiled tubing. Small mechanical defects can reduce the fatigue life of coiled tubing to 20% or even lower than the fatigue life of non-defective coiled tubing. Therefore, preventing the outer surface damage of coiled tubing is very important to improving the service life of coiled tubing.

5. Defects and Reduction Measures of Coiled Tubing Plough

The coiled tubing under high pressure conditions, repeated bending and straightening can deform the section and increase the coiled tubing diameter. At this point, the clamping block diameter of the coiled tubing is unchanged. During the clamping process, the coiled tubing with a larger diameter is squeezed by the clamping block. The bending moment generated by the extrusion of the clamping block produces a large tensile stress on the outer surface of the coiled tubing near the concave top of the clamping block. Once a-strength (>200 MPa) sand or proppant falls between the clamping block and the coiled tubing, it is easy to produce plastic indentation on the surface of the coiled tubing with existing tensile stress. On the other hand, during the injection or lifting process of coiled tubing driven by a uniform motion hydraulic motor, due to the characteristics of the mechanical structure of the injection head, a certain amplitude of periodic excitation will be generated. Once the periodic excitation coincides with the natural frequency of the coiled tubing, after a period of time, a large resonance will occur. If there happens to be a sand grain stuck between the clamping block and the coiled tubing with increased diameter, the plastic deformation of the indentation produced by the sand in the coiled tubing will form a furrow-like defect with the vibration of the coiled tubing.

Therefore, in order to reduce furrow defects, it is necessary to select proper coiled tubing material and wall thickness from the engineering design, and strictly control and monitor the diameter growth of coiled tubing. Measures need to be taken to avoid greater resonance when coiled tubing is injected or lifted, such as limiting the coiled tubing injection or lifting speed does not exceed 20 m/min, if possible, it is best to install a coiled tubing injection head speed disturbance, so that the coiled tubing speed around the set speed to produce a certain range of slow changes to avoid resonance.

6. Conclusions

In this paper, aiming at the special situation of coiled tubing plugging removal in high pressure and ultra-deep wells, the influence of coiled tubing deformation, coiled tubing fatigue and coiled tubing surface mechanical damage on coiled tubing life under high internal pressure is expounded. The mechanism of furrow damage caused by coiled tubing in high internal pressure operation and the measures to prevent furrow damage are described. In order to increase the life of coiled tubing, it is recommended that:

1) The key to improving the life of coiled tubing is to select the appropriate material, outer diameter and wall thickness.

2) To prevent excessive coiled tubing diameter growth during high internal pressure operations, select a high-strength coiled tubing with appropriate wall thickness and monitor the CT diameter.

3) In order to prevent excessive resonance of constant velocity and reduce the possibility of furrow damage, a measure was put forward to limit the coiled tubing injection and pull out velocity and install a velocity perturbator on the coiled tubing injection head to make the velocity change in a small range and slowly.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Wei, J.H., Zhang, B., Ma, Y.Q., *et al*. (2018) Technology Research and Optimization Application of Ultra Deep High Pressure Coiled Tubing Plugging Removal Process in Tarim Oilfield. *Proceedings of International Petroleum and Petrochemical Technology Conference*, Beijing, 27 March 2018, 233-242.

[2] Rolovic, R. and Tipton, S.M. (2000) Multiaxial Cyclic Ratcheting in Coiled Tubing—Part I: Theoretical Modeling. *Journal of Engineering Materials and Technology*, **122**, 157-161. https://doi.org/10.1115/1.482781

[3] Rolovic, R. and Tipton, S.M. (2000) Multiaxial Cyclic Ratcheting in Coiled Tubing, Part II: Experimental Program and Modeling Evaluation. *Journal of Engineering Materials and Technology*, **122**, 162-167. https://doi.org/10.1115/1.482782

[4] Christian, A. and Tipton, S.M. (2009) Statistical Analysis of Coiled Tubing Fatigue Data. *Proceedings of SPE/ICoTA Coiled Tubing & Well Intervention Conference and Exhibition*, The Woodlands, TX, USA, 31 March-1 April 2009. https://doi.org/10.2118/121457-MS

[5] Padron, T. and Craig, S.H. (2018) Past and Present Coiled Tubing String Failures—History and Recent New Failures Mechanisms. *Proceedings of SPE/ICoTA Coiled Tubing & Well Intervention Conference & Exhibition*, The Woodlands, TX, USA, 27-28 March. https://doi.org/10.2118/189914-MS

[6] Zhou, Z.H., Zhang, G.F., Yuan, F.Y., *et al*. (2019) Study on Mechanism of Coiled Tubing Surface Damage in Injector Head. *Proceedings of SPE/ICoTA Well Intervention Conference and Exhibition*, The Woodlands, TX, USA, 26-27 March 2019. https://doi.org/10.2118/194254-MS

[7] Fuling Shale Gas Company, Coiled Tubing Problems and Countermeasures in 2014. https://wenku.baidu.com/view/c980c2ac0066f5335a8121de.html

[8] Tipton, S.M., Behenna, F.R. and Martin, J.R. (2004) An Investigation of the Effects of the Physical Properties of Coiled Tubing on Fatigue Modeling. *Proceedings of SPE/ICoTA Coiled Tubing Conference and Exhibition*, Houston, Texas, 23-24 March 2004. https://doi.org/10.2118/89571-MS

[9] Padron, T., Luft, B., Kee, E. and Tipton, S.M. (2007) Fatigue Life of Coiled Tubing with External Mechanical Damage. *Proceedings of SPE/ICoTA Coiled Tubing and Well Intervention Conference and Exhibition*, The Woodlands, TX, USA, 20-21 March 2007. https://doi.org/10.2118/107113-MS

[10] Liu, Z.K., Zheng, A., Diaz, O.O., and Hauglund, L. (2015) A Novel Fatigue Assessment of CT with Defects Based on Magnetic Flux Leakage. *Proceedings of SPE/ICoTA Coiled Tubing & Well Intervention Conference & Exhibition*, The Woodlands, TX, USA, 24-25 March 2015. https://doi.org/10.2118/173664-MS

[11] Rolovic, R., Reichert, B., Morales, C., Coloschi, M., Valdez, M., Grimaldo, C. and Nguyen, T. (2017) Field Performance of New Coiled Tubing Technology and a New Grade for Improved Sour Service. *Proceedings of SPE/ICoTA Coiled Tubing & Well Intervention Conference & Exhibition*, Houston, TX, USA, 21-22 March 2017. https://doi.org/10.2118/184796-MS