The Mechanism of PCP Wells' Tubing and Rod Wear Issue in Polymer Flooding in Daqing Oil Field


Abstract

Although PCP technology has been used in Daqing Oilfield from 1980s, and the number of PCP wells in the whole oilfield has reached 2429 till September in 2006, it wasn’t applied in polymer flooding producers with displacement of over 150 m³/d until 2004. However, the application of the high volume PCP systems has witnessed severe wear issue both in tubing and rods. Study indicated that, due to the great increment in displacement, the original design for smaller volume PCPs showed serious incompatibility with high volume PCP systems. For instance, bigger structure parameter resulted in higher rod oscillation in operation, and pipe string bending issue in high volume PCP was more popular than in lower ones using the traditional anchor. In addition, improper rod guiding also played an important role in wear of tubing and rod string. This paper analyzes the mechanism of tubing & rod wear for high volume PCPs in detail, and presents a series of harness treatments including: 1) optimizing pump selection method and operation parameter; 2) improving tubing anchoring method; and 3) optimizing rod string guiding method. Based on the above treatments, a set of optimum design model for high volume PCPs was created. Experiments and application showed that, using this optimum design model, tubing & rod wear failure rate was decreased sharply, and the operation performance was improved effectively for high volume PCPs in polymer flooding area.

Introduction

With the fast expansion of application scale in Daqing Oilfield, PCP lifting technology improved quickly in recent years. PCP was applied in water flooding, polymer flooding, and ASP flooding areas. And due to its advantages in low operating cost, high efficiency and environmental, PCP has become the first choice of lifting methods in EOR stage in Daqing Oilfield. Though PCP got a great success in Daqing Oilfield, some issues still remained. Tubing and rod wear issue in polymer flooding area was one of them. See Fig.1. Till the end of October, 2005, there were 161 PCP wells applied in polymer flooding areas whose displacement were above 150 m³/d. The tubing & rod issues were found in 29 wells, which was 56.9% of all workover wells in polymer wells above 150 m³/d. And the averaged running life was 408 days, much lower than the overall averaged running life of 531 days.

The Mechanism of Tubing & Rod Wear Issue

Based on the study of PCP operating conditions, kinematical and kinetic analysis of PCP rod string and rotor, it was concluded that tubing & rod string wear in higher volume PCP wells in polymer wells mainly came from the following respects:

- Pump Structural parameters’ effect.

- Eccentric motion of rotor.

Due to the eccentric motion characteristics of rotor, rod string oscillation does exit in operation. See Fig.2. And the longer the eccentricity is, the higher the oscillation amplitude will be, which resulted in more sever tubing & rod wear degree. As for higher volume PC pump, the eccentricity is much higher than lower volume ones. That was the main reason that tubing - rod wear issue is much more severe in high volume PC pump (above 150 m³/d) than in lower volume one.
- **Overturn moment effect.**
Due to the existence of pressure difference between the inlet and outlet of the pump, an overturn moment was put on the rotor which resulted in the oscillation of the pump. The overturn moment was added on the center of rotor, and the plane of action could be determined by stator axial and rotor axial. And also, the overturn moment and operating moment were much higher in higher volume than in lower volume pump which led to a more severe oscillation of the pump as well as the tubing and rod wear.

- **Operating Parameter’s effect.**
Statistics indicated that, tubing and rod wear issues were more popular in low liquid level wells than in high volume PCP systems.
After years of study, it was concluded that, when the displacement upper limit of the pump was lower than the real production of the well, the liquid level would be very low even up to zero. In this case, the axial force of the pump would be very small and had no effect on pulling the string downwards. And producing liquid would push the string upward under high flowing pressure, resulting in the helical bending of the string and even rod break out failure.
This issue was very popular in polymer flooding area where high volume PCP was the main lifting method. Contrasted with water flooding area, the producers’ production wasn’t stable in the process of polymer flooding. On the contrary, it often changed dramatically in different stage, which increased the probability of improper displacement capacity design of lifting systems.
In recent years, most PCP wells used special rod design which could avoid rod parting failures effectively. Due to the existence of rod string bending, tubing and rod wear severity of PCP wells wasn’t improved in any degree.
In most cases, tubing bending wasn’t a common issue in vertical wells, especially in 7” and higher diameter casing wells. In Daqing Oilfield, most wells were completed by 5 1/2” casings (a small number of wells were completed by 4 1/2” or 7” casing). The smaller annular increased the risk of tubing bending.
Furthermore, the most common anchoring tool in Daqing Oilfield was back-up-slip anchor. This anchor was set by pressing the tubing string which led to tubing bending in some degree. In PCP wells with a displacement below 150m³/d, the oscillation of the pump was smaller and this anchoring tool was used successfully. But in high volume PCP wells, tubing bending had more severe influence on rod string oscillation and resulted in tubing and rod wear in many cases.

- **Rod guider’s effect.**
In Daqing Oilfield, a kind of movable guider was widely used in PCP wells for the low cost and instant installation. The problem is that this movable guider would slide along the rod freely in operation which decreased its anti-wear function in some degree. In case of low volume PCP wells, the rod string oscillation was slight and operation torque were lower, so that a few of movable guiders per well was enough. While in higher volume PCP wells in polymer flooding, the movable guider couldn’t work effectively in case of strong oscillation and bending of the string. In addition, the distribution of guiders wasn’t designed optimally which also led to low efficiency in rod string guiding.

**Improved High Volume PCP Lifting Methodology**

- **Optimum design of PC pump structural parameters.**
On the basis of ensuring proper pump efficiency and lifting capacity, it has been proved to be effective to decrease PC pump’s oscillation effect and operating torque by adjusting the eccentricity, interference fit and other pump parameters with optimal design method. See Fig.3.
Take pump GLB1200 for example, when the non-dimensional interference fit was decreased from 1 to 0.2, its initial operating torque dropped by 30%. Obviously, the treatment could decrease the friction torque, contact torque and contact stress between rotor and stator, which helps to improve the operating status of the system.

- **Optimal selection of PC pump operating parameter.**
In order to avoid rod string bending issue by lower liquid level, the prime work was to keep PCP system under proper operating parameter.
First, all the producers’ IPR curves in the same block were required to be applied in advance, which could give a detailed reference for new PC pump selection.
Second, a new drive head was developed which could supply a much wider rotation speed than the traditional one. See Fig.4. Using this new drive head, PCP system could be adjusted in a much a wider displacement scale and could meet the requirement of dramatic displacement fluctuation in different stage in polymer flooding. Moreover, the rated displacement of the pump could be decreased to a lower degree which could decrease the operating torque considerably and decrease the tubing & rod wear severity as well. At present, this new drive head has been applied in 15 PCP wells in polymer flooding area.

- **Improving tubing anchoring effect.**
Due to the tubing bending resulted by back-up-slip anchor, a new designed anchor was applied in high volume PCP wells
from 2004. This new anchor was first developed in 1990s. At the time, the volume of PCP wells in Daqing Oilfield were all under 150m³/d, and most were under 100m³/d. Due to the problems in design and material selection, it wasn’t applied in situ after failing in several wells. On the contrary, back-up-slip anchor was applied in large scale for its instant treatment and stable performance in Daqing Oilfield.

Due to the limitation of back-up-slip anchor in high volume PCP wells, the previous anchor was redesigned which improved both in design and material. After a series of experiments in laboratory and in situ, the performance of the anchor was proved to be excellent which could meet the requirement in high volume PCP operating conditions. To date, 57 sets of the new anchors were applied in high volume PCP wells in polymer flooding areas.

The traditional tubing guider of PCP pump in Daqing Oilfield was made of rubber. Under strong oscillation in higher volume PCP system, elastomer tubing guider was easier to be aged and failed due to its low rigidity. Hence, a new metal tubing guider was developed which improved the guiding result effect considerably. This metal guider was used in 10 PCP wells in polymer flooding area and the application result was waited to be estimated.

Improving rod string guiding effect.
Calculation indicated that, rod string deformation was more severe from above the pump to about 550 m’s deep. Statistics also proved that most tubing and rod wear failures focused on the same part of the system. Hence the placement method of rod string guiders was adjusted according to optimal calculation results. And from 2006, a new fixed type rod guider was applied in PCP wells which could ensure the guiding parts along the string.

With new distribution design method and new guider, the tubing and rod wear failure rate decreased and fewer guiders were used in the high volume PCP systems as well.

Conclusions
1. The eccentric motion characteristics of rotor lead to the periodic oscillation of PCP rod string in tubing. Hence it’s the main resource of tubing and rod wear.
2. Tubing and rod wear failures are also related to operating parameters, anchoring method, and rod string guiding effect. As the result, a whole optimal design methodology was required to reduce tubing and rod wearing failures effectively.
3. Apart from the above factors, smaller casing diameter (5 1/2”) and special develop characteristics in EOR of the oilfield also have important effects on PCP tubing and rod wearing failures. In that case, PCP system design is a system engineering which needs to be understood and adjusted in different stage of the oilfield development.

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Reference
Fig. 1 - Picture of tubing-rod wearing in polymer flooding area in Daqing Oilfield

Fig. 2 - Cross section of a single lobe PCP

Fig. 3 - Load curves of PCP with different interference fit

Fig. 4 - A novel PCP drive head