Discussion on the factors affecting the pump efficiency of screw pump

Dongkai Fan
No.4 Oil Mine of No.6 Oil Production Plant of Daqing Oilfield Co., Ltd. 163000, China.
Fan_DongKai@petrochina.com.cn

Abstract. Since the invention of screw pump in 1930, screw pump technology has been continuously improved and perfected, especially the development of synthetic rubber technology and bonding technology, which has made screw pump widely used in oil exploitation. Screw pump wells have the characteristics of low investment, high pump efficiency and energy saving. At present, screw pump has become a common artificial lifting method in oil fields using polymer flooding. In view of the present situation that screw pump wells are used for oil production more and more in Liuchang area, this paper discusses how to improve the production efficiency of screw pump wells in field production to promote the development of oil fields.

Keywords: Rotor; Stator; Screw pump; Wax deposition.

1. Brief introduction of screw pump technology
Screw pump is a positive displacement pump, which has unique advantages in producing crude oil with high viscosity, high sand content and large gas content. At present, the specifications of screw pump have been serialized, and the supporting technology is basically perfect. This oil production method is the simplest, and it is not necessary to install oil drainage device in the underground in actual use, because once the screw pump rotor is separated from the pump barrel, the oil casings are connected with each other, thus playing the role of oil drainage. At the same time, the cost of using this device is low, and it is an ideal oil production method for shallow wells. Screw pump has both advantages and disadvantages. (1) Advantages: First, save one investment; Secondly, the ground device has simple structure and convenient installation; Third, high pump efficiency, energy saving and low management cost; Fourth, it can adapt to wide viscosity and lift heavy oil; The fifth is to adapt to gas wells with high sand content and high water content; (2) Limitations: First, the pump needs lubrication; Second, the stator quality is one of the main reasons that affect the operating life. Third, the strength requirements of special sucker rods are high; fourth, the technical requirements for operation are relatively high.

2. Working principle of screw pump
Screw pumps include single screw pumps and multi-screw pumps (twin-screw, three-screw and five-screw pumps, etc.), which are mainly used for transporting oil products. Screw pump for oil production is a kind of single-screw hydraulic machinery, which discharges oil by cavities, that is, closed cavities which are not connected with each other are formed between the rotor and the stator. When the rotor
rotates, the closed cavities move along the axial direction from the suction end to the discharge end. The closed cavity disappears at the discharge end, and the crude oil in the cavity is evenly squeezed from the suction end to the discharge end. At the same time, a new low-pressure cavity is formed at the suction end to suck the crude oil. In this way, closed cavities are constantly formed, moved and disappeared. Crude oil is continuously filled, squeezed and discharged, so that the crude oil in the well is continuously sucked and lifted to the wellhead through tubing.

3. Factors affecting pump efficiency of screw pump

3.1. Torque of pump
Because there is a pressure difference between the suction end and the discharge end of the screw pump, the liquid in the screw-bushing pair will exert a force on the screw. At the same time, there is interference between stator and rotor, which will cause friction torque between stator and rotor, and affect the output. The torque of screw pump in no-load operation is generally very small, but the torque required when the screw pump is stationary for a long time is very large, which is 20-30 times of the torque in no-load operation and 2-3 times of the torque in full-load operation. The starting torque is related to the length of sealing line of screw pump, the interference between stator and rotor, the hardness and working pressure of rubber, the length of static time and the roughness of friction surface. The more the number of stages, the greater the roughness, the higher the rubber hardness, and the larger the interference between rotors and the higher the working pressure of the pump, the greater the starting torque of the pump. From the use point of view, the pump should be started after a long time of rest as much as possible; From the point of view of design and manufacture, the hardness and interference of rubber should be appropriately reduced, and coating materials with smaller friction coefficient of rotor and stator rubber should be selected. At the same time, it is very important to reduce the roughness of rotor and stator surfaces.

3.2. Influence of rotor speed
The rotational speed of the rotor determines the displacement of the screw pump. The higher the rotational speed of the rotor is, the greater the displacement will be. However, the higher the rotating speed, the greater the centrifugal force of the sucker rod, the more serious the bending vibration of the sucker rod, and the greater the friction between the sucker rod coupling and the inner wall of the tubing. At the same time, the lifting height will also decrease due to the increase of the loss along the way and the acceleration of the stator rubber wear. Therefore, the rotating speed of the rotor should not be too high, but should generally be less than 500r/min. At present, the rotating speed of the screw pump in the actual operation of our oilfield is generally below 160r/min.

3.3. Influence of viscosity
Because the screw pump is used to lift crude oil in practical application, and often because of lifting heavy oil, the working characteristics of the pump in the process of lifting will be very different from those when lifting clear water. On the one hand, the increase of viscosity reduces the leakage, which is beneficial to improve the volumetric efficiency and system efficiency of the pump; On the other hand, the increase of viscosity will increase the flow resistance, decrease the filling degree and lifting height of the pump, and decrease the volumetric efficiency and system efficiency of the pump. At the same time, the increased friction of the pump will increase the resistance torque. Therefore, in practical application, we should pay full attention to the influence of viscosity.

3.4. Influence of wax deposition in oil wells
The fluids pumped by screw pump are mainly oil, gas and water, among which crude oil is a multi-component mixture solution composed of various hydrocarbons, and the phase state of various hydrocarbons changes with the change of oil well pressure and temperature. Paraffin wax is the solid substance of alkane with 16 to 64 carbon atoms in crude oil, and its melting point is between 49°C and
Generally, wax contained in crude oil is in a dissolved state under reservoir conditions, but because the solubility of paraffin in oil decreases with the decrease of temperature, during the lifting process of fluid, with the gradual decrease of temperature, paraffin is continuously precipitated, and its crystal grows, gathers and deposits at a certain position on the pipe wall, which is called wax deposition phenomenon. The more wax content in crude oil, the more serious wax deposition. The impacts are: (1) With the increase of flow velocity in the tubing, the loss along the tubing increases, which increases the actual lifting head of the screw pump; (2) The rotating friction of sucker rod increases, and the load of sucker rod and ground drive system increases; (3) It is possible to suppress the pump, which will reduce the output, increase the energy consumption and increase the accident rate. The following lists the wax deposition data of several screw pump wells in actual production.

Table 1. Comparison of data of several wax deposition wells in actual production

| Serial number | Well No. | Before wax deposition | Slight wax deposition | More wax deposition | Remarks |
|---------------|---------|-----------------------|----------------------|--------------------|---------|
|               |         | Liquid production | Electric current | Liquid production | Electric current | Liquid production | Electric current |
| 1             | 6-1844  | 131                | 27                  | 122                | 30              | 107               | 34               |
|               |         |                      |                      |                    |                 | The current rise is relatively large |
| 2             | 5-173   | 98                  | 25                  | 91                 | 26              | 84                | 27               |
| 3             | 5-170   | 121                | 21                  | 117                | 22              | 109               | 23               |

Preventing wax deposition in oil wells is one of the main ways to ensure the long-term normal operation of screw pump production wells. Therefore, the technology of wax removal and plugging removal must be implemented in screw pump production wells.

Hot-washing wax removal technology is a mature technology widely used in plunger pump oil production, and it is also applicable to screw pump oil production. During hot washing, high-temperature hot washing medium is injected into the oil well for circulation. After circulating to a certain extent, the temperature in the well reaches the melting point of wax, and the wax gradually melts and returns to the ground along with the hot washing medium.

There are six main methods for regular hot wax cleaning in screw pump production wells:

3.4.1. Lift the rotor out of the stator to wash well. For small displacement screw pump, if the displacement of flushing fluid is large, the screw pump is easy to trip, the injection displacement is small, and the temperature cannot reach the melting wax temperature. In this case, the rotor should be lifted out of the stator, and hot water should be injected into the annulus of the oil casing for wax removal and well washing. After washing, lower the rotor into the stator to resume normal oil pumping. This method is generally used in screw pump wells which do not have hot washing process and can not implement chemical wax removal. However, crane equipment is needed and the cost is high.

3.4.2. Install well washing valve on the upper part of stator for hot washing. On the pipe string at the upper part of the stator, below the wax deposition point, install the well flushing valve. During well washing, hot water is injected into the annulus of oil pipe and under the action of hot washing pressure, the well washing valve is opened, so that hot water flows into the pipe string, and paraffin on the inner wall of oil pipe and the outer wall of sucker rod is melted away and taken away. However, the reliability of the cleaning valve in this cleaning process is poor.

3.4.3. Conventional circulating hot washing. For large displacement screw pump, hot water can be injected from the annulus of oil casing, and the screw pump runs normally, while pumping and washing. The hot water temperature should be gradually increased, and should not be too high at the beginning
(about 60℃ is advisable), otherwise, the melted wax block on the upper part of the tubing will sink to the bottom of the well to block the oil flow. In addition, the displacement of injected hot water should not be greater than the theoretical displacement of the pump, otherwise, the injection liquid will drive the screw pump to run and make the sucker rod trip. This method is not suitable for small displacement pumps because its hot washing capacity is limited by the pump's capacity, and its hot washing capacity is small, hot water circulation is slow and hot washing time is long.

3.4.4. Hot washing of hollow rotor screw pump. With the development of hollow rotor screw pump, large displacement and rapid hot cleaning and wax prevention technology have been realized.

Technological principle of well washing with hollow rotor

In this process, a well flushing valve is installed under the wax deposition point on the upper part of the hollow rotor, and the application of the well flushing valve can ensure that the screw pump does not need to stop for large displacement hot washing. During normal production, the hot wash valve seals the inner cavity of the hollow rotor under the action of its pre-tightening spring and oil pipe liquid column; During well washing, high-pressure and large-displacement hot water is injected from the annulus of the oil casing, one part of the washing fluid is pumped to the oil pipe by the pump itself, and the other hot washing fluid flows through the inner cavity of the hollow rotor and directly enters the oil pipe.

Quality requirements for hot washing of screw pump wells

For screw pump wells in normal production, it is mainly determined by the change of current, output and polished rod torque to determine whether the wax needs to be cleaned by hot washing. After determining the need for wax removal by hot washing, the data before and after well washing should be tracked and analyzed in order to judge the quality of well washing. The following table is a comparison of the data before and after hot washing of three wells.

| Serial number | Well No. | Wax deposition | After heat treatment | Remarks |
|---------------|---------|----------------|---------------------|---------|
|               |         | Liquid production | Electric current | Liquid production | Electric current |         |
| 1             | 6-1844  | 107            | 34                  | 129      | 26                |         |
| 2             | 5-173   | 84             | 27                  | 99       | 25                |         |
| 3             | 5-170   | 109            | 23                  | 119      | 21                |         |

By comparison, we can draw the conclusion that the hot washing of these wells is in good condition, the output and current can be restored to normal level after washing, the loss of fluid volume is saved, the energy consumption is saved, and the purpose of well washing is achieved.

After a long period of summarization and accumulation, we have summarized the quality requirements for hot washing:

A. the temperature of hot washing medium should not exceed 90℃.
B. hot wash outlet oil return temperature shall not be lower than 60℃, and stable for more than 40min.
C. the output is restored to the original production level, and the fluctuation is less than 10%.
D. The polished rod torque is restored to the polished rod torque value during normal production.
E. The current returns to the working current during normal production.

3.4.5. Chemical wax removal and prevention process. In most cases of oil well exploitation, the precipitation of paraffin crystal is almost inevitable, but there is a process from the crystallization of paraffin crystal to the deposition of wax on the pipe wall, which makes the crystal grow and aggregate. Therefore, it is also an important way to prevent wax deposition by adding chemical paraffin removal and prevention agents to prevent and reduce paraffin aggregation.
Chemical paraffin removal and prevention agents have certain influence on the stator rubber of screw pump, so chemical agents should be avoided from passing through the pump when chemical agents are used for paraffin removal and prevention. Therefore, the process of adding chemicals in hollow rod is mainly adopted. However, chemical paraffin removal and control agents with good compatibility with rubber can be directly added from the annulus of oil casing, and the dosing period depends on the wax content of oil well.

There are two schemes for dosing process, namely, continuous dosing and regular dosing.

3.4.6. Electric heating plugging removal process. In winter, the temperature is low, the freezing point of crude oil is high, and the wax content is high. If the shutdown time is long for some reason, the crude oil in the upper tubing (above the wax deposition point) will solidify, making it difficult or impossible to start the screw pump, so it needs to be unblocked before starting.

Cable heating unblocking is to run the movable heating cable in the hollow sucker rod, and the heat generated by the cable will reduce the viscosity and unblock the crude oil in the tubing after being electrified. As shown in the figure, when the plug is removed, the cable car lowers the cable into the hollow rod (filled with clear water) through the wellhead pulley, and when the cable descends to the depth below the wax deposition point, it is electrified, so that the heat released by the cable is transferred to the oil pipe through the hollow rod, thus heating up the crude oil in the oil pipe. During the heating process, measure the wellhead oil temperature regularly. When the oil temperature reaches above the freezing point of crude oil, pull out the cable and start the screw pump well, so as to achieve the purpose of plug removal.

4. Conclusions
To sum up, dealing with the factors affecting the pump efficiency of screw pumps will bring great benefits to oilfield production. In order to ensure the harmony and stability of enterprises, we should ensure safe production while improving production efficiency. Screw pump is dangerous, so we should avoid unnecessary personal injury accidents according to the operation requirements. Achieve: improve the safety awareness of all employees, change the concept of safety management, reduce the probability of accidents, and gradually improve production efficiency!

References
[1] Han Xiuting. Principle and application of screw pump oil production. Harbin Engineering University Press, 1998.
[2] Chen Taoping. Petroleum engineering. Beijing petroleum industry press, 2000.
[3] Xu Guomin. Problems and Countermeasures of Strong Base ASP Flooding [J]. Oil-gasfield Surface Engineering, 2008, (11): 70-71.
[4] Wei Yuhan. The development, tracking and adjustment method of ASP Flooding [J]. Journal of Yangtze University (Natural Science Edition), 2014, 13(11): 118-120.