Relief flow swirlers to control wax deposition formation inside downhole equipment

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Abstract. The present study describes problems of wax deposition formation on the surface of oil field equipment. In particular, the problem of wax deposition prevention inside tubing walls is considered. Wax prevention techniques and wax removal techniques were analyzed and the main advantages and disadvantages of these techniques were highlighted. The technique for controlling wax deposits by means of fluid swirl is proposed, which is carried out using a process module for controlling downhole deposits based on a flow swirl. Simulation flow modeling in the direct-flow swirler was performed. The simulation was carried out with the help of SolidWorks Flow Simulation program for different profiles of flow section, number of turns, and swirling pitch. An increase in temperature due to a fluid swirl and a significant pressure gradient in the wall layers of the tubing after the swirler were revealed.

1. Introduction

The current stage of world's oil and natural gas deposits exploitation can be characterized by an increase in the number of complicating factors. One of these factors is formation of asphalt-resin-paraffin and hydrate deposits (hereinafter referred to as deposits) on the surface of oil field equipment, in particular inside tubing and well equipment [1].

Due to formation and deposition of deposits the flow section of the tubing is reduced, a number of negative consequences arise; in particular, hydrocarbon production is significantly reduced as well as electricity consumption for their pumping is increased [2]. Oil field equipment fails more quickly, raw material production indicators deteriorate, productive pores of formation are blocked and its filtration characteristics deteriorate [3]. It is not uncommon for deposits to result in complete blockage of tubing passage area and shutdown of raw material production.

All these factors have an extremely negative impact on hydrocarbon production economy. Thus, it is obvious that controlling deposits formation inside wells is the most important task of oil and gas industry.

2. Techniques of controlling wax deposition formation inside downhole equipment

Deposits occur in adhesion to the surface of particles already formed in the flow or in formation and growth of crystals on the surface of the equipment [4], in particular on the peripheral zone of the tubing. The key factors affecting their formation are change in temperature gradient along tubing length and oil and gas flow velocity [5]. Techniques used to control deposits in oil field equipment involve two approaches: prevention of formation and removal of already formed formations (figure 1).

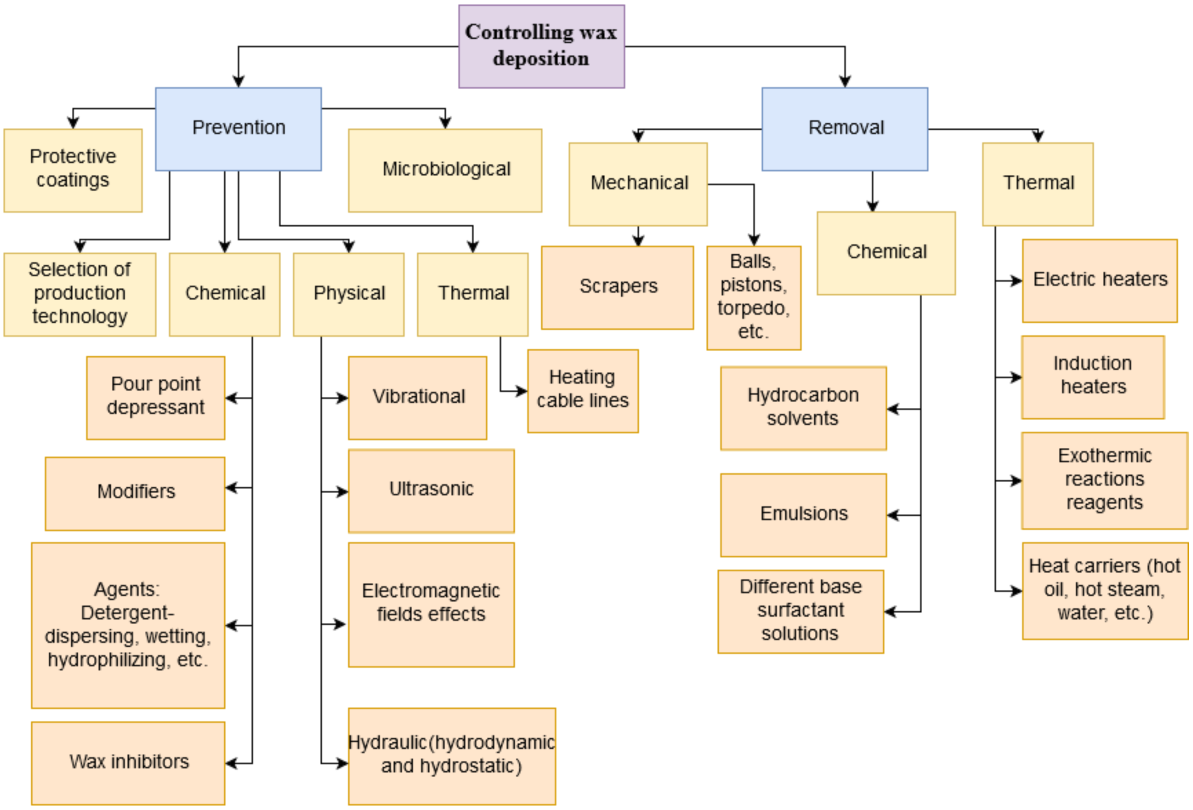

Figure 1. Wax deposition prevention and removal techniques.

Most modern techniques of preventing or removing deposits on pipe walls require shutdown of flow through the pipe as well as supplying external energy [6].

The technique of applying special coatings on a pipe wall is not effective as the coatings rather quickly can crack, be worn-out and carried away with the flow [7].

Application of physical techniques can cause destruction or self-screwing of tubing threaded connections, besides they are characterized by selection complexity of optimal processing conditions.

The use of chemical solvents to prevent and remove wax deposits can adversely affect oil and gas flow quality and lead to faster equipment corrosion.

Mechanical techniques of deposits removal consist in the use of special scrapers which often get stuck in the well and also scratch tubing walls that accelerates equipment failure.

One of the most promising techniques of wax deposition prevention is hydrodynamic actions on internal walls of tubing [8]. The main problem of existing hydrodynamic downhole equipment is high degree of flow section blockage of tubing string which creates high hydraulic resistances and therefore loss of fluid pressure in the well.

3. Developed technique of hydrodynamic impact on well wax deposits

In view of the above, the authors of this article developed the hydrodynamic technique of wax deposition formation preventing by means of fluid swirling [9].

Technique is characterized by the fact that when flow passes through the direct-flow swirler its transformation into pulsating turbulent flow with pressure fluctuations in peripheral zone occur and there is redistribution of flow rates.

When the flow is passing in the swirler an additional action is performed to redistribute flow swirling speed by successive involvement of flow layers starting from the boundary one when the flow is given additional swirling by the rotating swirler.

This results in flow pressure fluctuations affecting the tubing walls preventing the formation of deposits and contributing to the increase in flow temperature.

It should be noted that this method assumes that it is possible to determine in advance almost reliably the places of deposits formation in the tubing.

4. Process module for controlling well wax deposits

To implement the above technique the downhole process module with the direct-flow fluid flow swirler [9] was developed (figure 2).

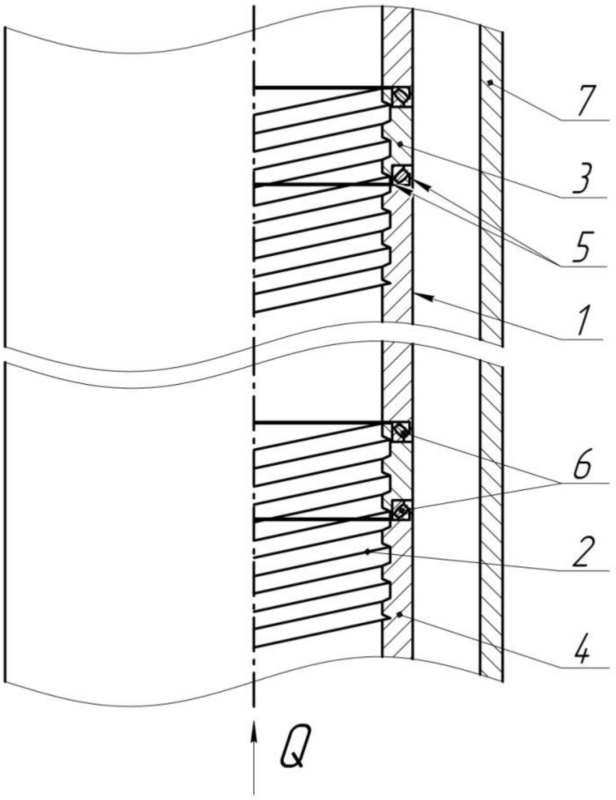

Figure 2. Process module for controlling well wax deposition: 1 – cylindrical body; 2 – relief; 3 – rotating part; 4 – stationary part; 5 – face; 6 – bearing; 7 – housing.

The process module for controlling well wax deposition (figure 2) is a hollow cylindrical body 1 with applied internal relief 2 and consists of alternating rotating 3 and stationary 4 parts. In faces 5 of the hollow cylindrical body 1 on the external side of rotating the part 3 and on the internal side of the part 4 there are annular sites for installation of support-centering bearings 6 (for example, conical roller bearings). If desired, the hollow cylindrical body 1 can be protected from external factors by the housing 7.

When the flow reaches the relief rotating parts, the speeds are redistributed from the axial one to the increasing angular speed, which results in deeper and more consistent involvement of fluid layers starting from the boundary layer resulting in a high pressure gradient and turbulent pulsations in the peripheral zone. The flow prevents the formation of deposits as the force of the tangential stresses is higher than the coupling forces between the deposits (paraffin carbon crystals) and the pipe surface.

The process module based on the direct-flow swirler, unlike, for example, flow vane swirlers, practically does not close passage area of the pipe and depends very little on the flow properties.

It should be noted that as for the swirlers partially closing the flow passage area of the pipe the efficiency of the flow swirling depends on the spooling profile, the pitch of location and the number of turnings [10].

5. Flow simulation in the swirler

In order to check operability and efficiency of the developed technique and device for controlling well wax deposition the authors of the article carried out the hydrodynamic simulation in SolidWorks Flow Simulation software module.

Initial data for oil and gas flow modeling through the direct-flow swirler are presented in table 1. The simulation was performed for different number of turns and spooling pitch of swirlers with rectangular, triangular, semicircular, trapezoidal and sinusoidal profiles. The working model of the swirler with trapezoidal winding profile is shown in Figure 3.

Table 1. Data are used for simulation.

Thread pitch, m	0.9
Swirler external diameter, m	0.073
Swirler inner diameter, m	0.062
Flow velocity, m/s	5
Total pressure, MPa	15
Formation temperature, К	350

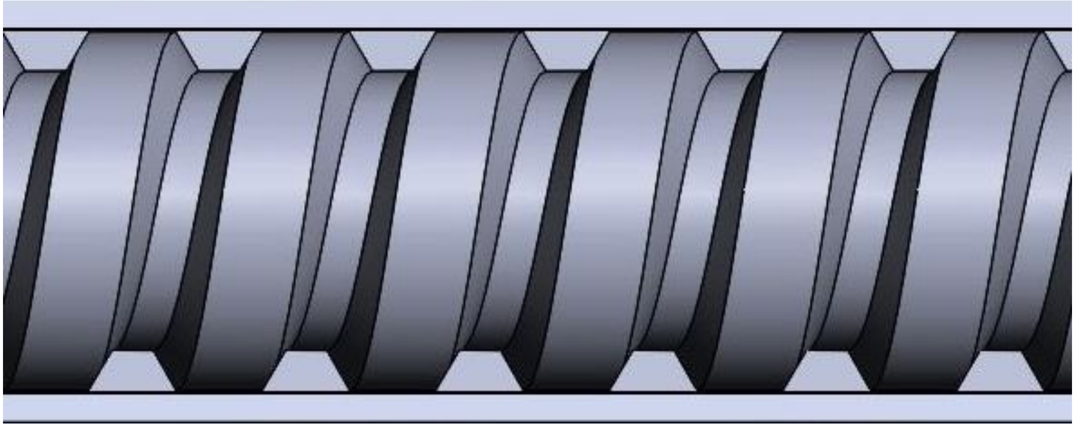

Figure 3. Swirler model with trapezoidal spooling profile.

6. Simulation result

The hydrodynamic simulation carried out in SolidWorks Flow Simulation software module made it possible to obtain data concerning the effect of the swirler profile, the spooling pitch and the number of turnings on the flow swirling.

It has been revealed that the swirlers with 30 revolutions are most effective. The maximum swirling value is observed in the trapezoidal profile device (figure 3) which leads to a high pressure gradient in the close region of the tubing after the process module to control well wax deposits. Diagram of swirling of the direct-flow swirler with the trapezoidal profile depending on trajectory length of oil and gas flow movement along its turns is presented in figure 4.

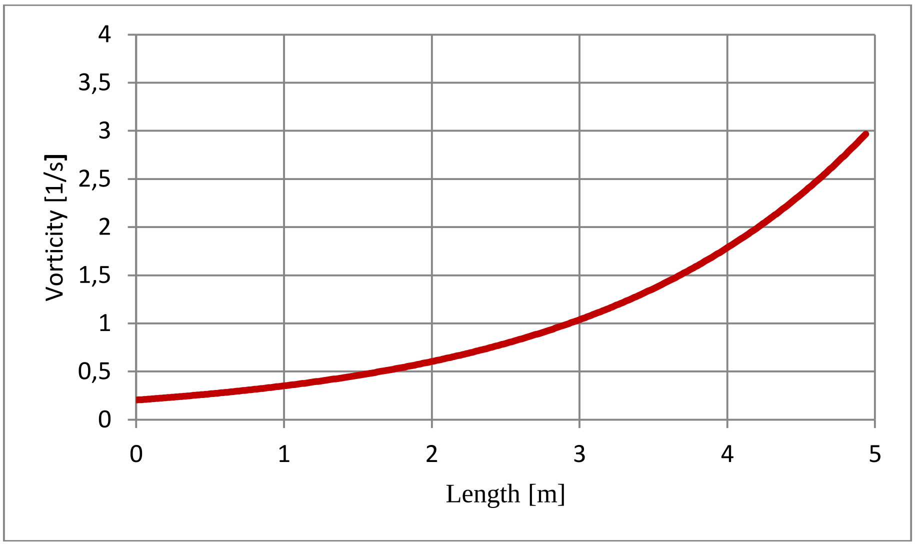

Figure 4. Dependence diagram of flow swirling for trapezoidal profile device on flow trajectory length.

Studies [11], [12] show that the increase in the temperature of the oil and gas flow positively affects the prevention of the deposits formation on the walls of the equipment. The authors of the article found out that the intensity increase of flow swirling intensifies heat generation in the system. Dependence diagram of flow temperature on flow trajectory length is shown in figure 5.

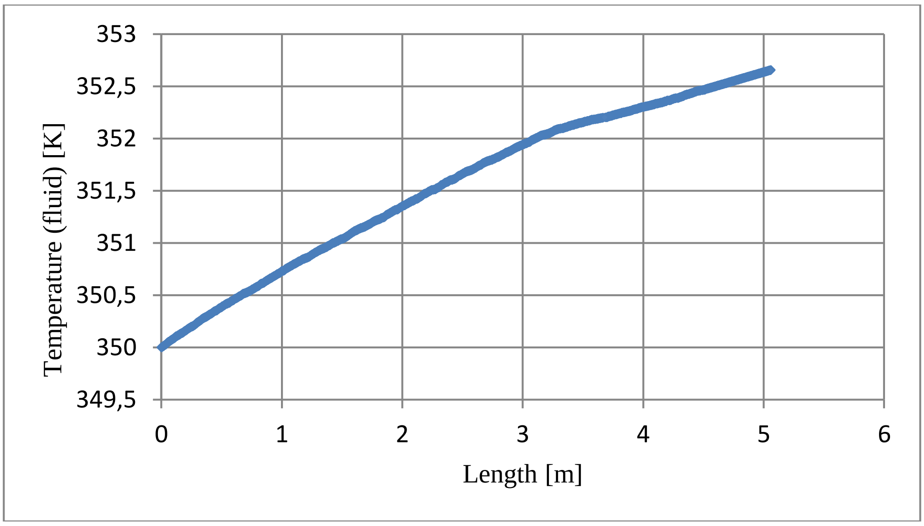

Figure 5. Dependence diagram of flow temperature for trapezoidal profile device on flow trajectory.

Taking into account the obtained diagrams it can be seen that the use of the developed module for controlling wax deposits based on the direct-flow swirler inside the tubing makes it possible to effectively swirl the oil and gas flow which works to prevent the formation and growth of wax deposits. In addition while using the module the temperature of the fluid flow increases and it prevents the formation and crystallization of solids. In particular, with the use of a connected chain of such modules a significant increase in swirling and flow temperature is possible. Thus, effectiveness of the proposed technique of preventing wax deposits formation inside the well and operability of the process module are visible. Further studies of the direct-flow swirlers are relevant, in particular, determination of their optimal parameters depending on well characteristics and produced raw materials, as well as experimental tests.

7. Conclusion

The main existing techniques for controlling the well wax deposits were analyzed, their major shortcomings were identified. The perspective of the hydrodynamic techniques for controlling the well wax deposits is shown. The technique of preventing the wax deposition formation developed by the authors and the process module comprising the direct-flow swirler based on this technique is set out. In SolidWorks software complex devices with different cross-section profiles, number of turns and swirling pitch were obtained. Using the oil and gas flow simulation in the Flow Simulation module the hypothesis was confirmed that the direct-flow swirlers can be effectively used in order to prevent the formation of deposits. It also revealed that it is advisable to use the trapezoidal profile swirler for better flow mixing as it has better swirling indicators and heat intensification indicators.

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