

# A Novel Automatic Phase Selection Device: Design and Optimization

Feng Zhang<sup>1,3</sup>, Haitao Li<sup>2</sup>, Na Li<sup>3</sup>, Nan Zhang<sup>2,\*</sup>, Wei Lv<sup>3</sup>, Xiaojiang Cui<sup>2</sup>

<sup>1</sup>China University of Petroleum (East China), Qingdao, 266580, Shandong, China

<sup>2</sup>State Key Laboratory of Oil and Gas Reservoir Geology and Exploitation, Southwest

<sup>3</sup>Petroleum University, Chengdu, 610500, Sichuan, China <sup>3</sup>Petroleum Engineering Research Institute of Shengli Oilfield, SINOPEC

\*Corresponding author e-mail: zhnorn@126.com.

**Abstracts.** At present, AICD completion is an effective way to slow down the bottom water cone. Effective extension of the period without water production. According on the basis of investigating the AICD both at home and abroad, this paper designed a new type of AICD, and with the help of fluid numerical simulation software, the internal flow field was analysed, and its structure is optimized. The simulation results show that the tool can restrict the flow of water well, and the flow of oil is less.

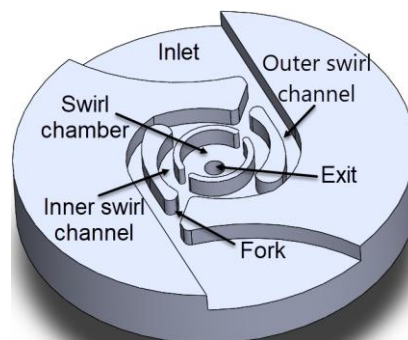
## 1. Introduction

At present, the horizontal well is an important technique for exploiting the edge and bottom water reservoirs and shallow reservoirs. The horizontal wells greatly increase the exposed area of oil reservoirs, thus improving the oil production efficiency. With the exploitation of oil fields, the shortcomings of horizontal wells have become increasingly prominent. For the moment, the horizontal and bottom water coning [1-4] is a major problem concerned by the major oilfields of the world. Inflow Control Device (ICD) and Autonomous Inflow Control Devices (AICD) is a new type of water control completion technology. ICD can reduce the period of hypertonic fluid production and control water coning according to producing an additional pressure drop. AICD is more intelligent than ICD because it can distinguish fluid based on the change of fluid properties or stream field. Because of the intelligence, AICD which has been widely used all over the world has a strong throttling effect on water while it has less throttling effect on oil. There are many AICD types designed by oil company and oil researchers [5-10]. For instance, in 2006, Crow [11, 12] and others designed a density sensitive valve based on the Archimedes principle. At the same year, Norway Petroleum Company [13,14] designed RCP (Rate Controlled Production) according to the principle of pressure balance; The Halliburton corporation designed the FD AICD (Fluid Diode) valve based on the diode principle; In 2014, Wang Xiaoqiu [15] of the China University of Petroleum designed a new AICD based on the Halliburton corporation's AICD; In this paper, a new type of AICD is designed based on flow channel split AICD, and its stream field, structure and fluid sensitivity are analyzed by using fluid numerical simulation software.



## 2. AICD Design

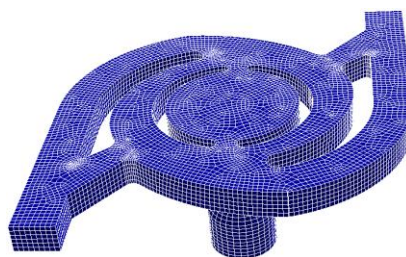
The Flow Control Valve(FCV) designed in this paper is shown in figure 1. The FCV is a rotating symmetrical structure, which consists of two inlet and one outlet. work area consists of a Y-shaped branch, outer swirl channel, inner swirl channel and swirl chamber. Due to the different physical parameters, the different liquid through the tool can produce different pressure drop, the tool use branch shunt and vortex role to realize the limitation on the fluid, so as to realize the recognition of the fluid. The flow area contains three branch bypass areas. The fluid flows into the FCV and the first shunt is generated at the Y structure. The branch flow through the branch enters the inner swirl channel, and the fluid of the main flow continues along the main flow path into the outer swirl channel. The fluid of the inner swirl channel flows into the swirl chamber through the branch flow. There are two branches at the end of the outer swirl channel, one of which is connected to the inner swirl channel and the other is connected with the swirl chamber. There is a narrow passage between the swirl chamber and the outlet.



**Figure 1.** Schematic of the FCV

## 3. The boundary conditions

Physical model and grid partition are shown in Figure.2. This model adopts hexahedral grid, which is more regular and more accurate. Two inlet boundary conditions are velocity-inlet and outlet boundary condition is outflow.



**Figure 2.** Physical model and grid partition

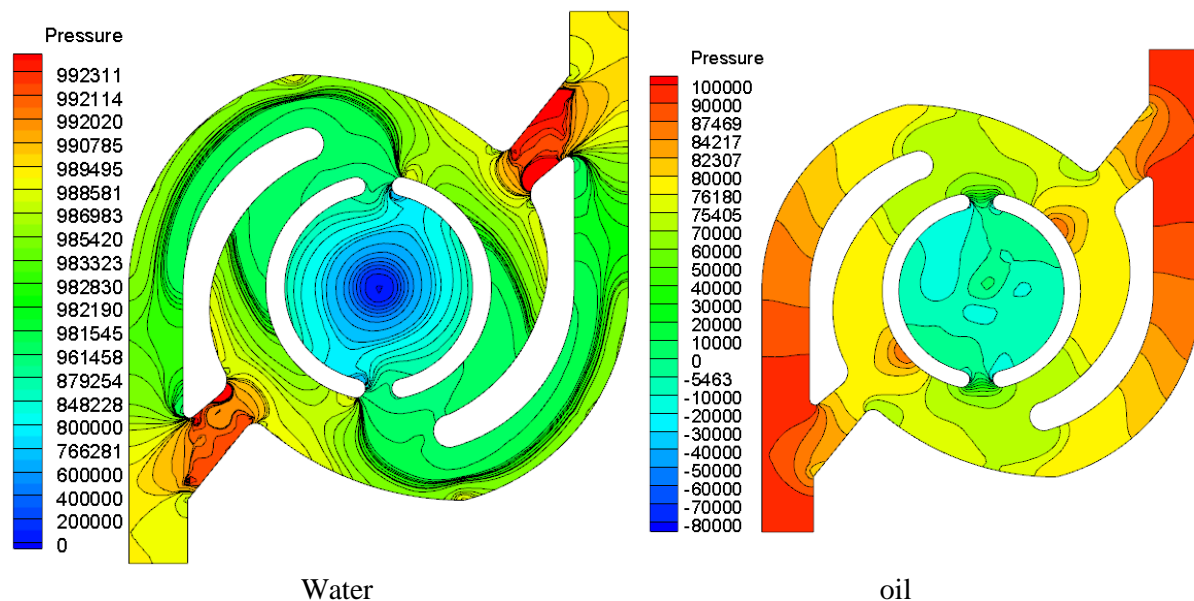
## 4. Simulation analysis

### 4.1. Comparative analysis of oil and water pressure field

Figure 3 is an oil-water pressure distribution in AICD while the flow rate of fluid is  $12\text{m}^3/\text{d}$ , and it is clear that the pressure drop of aqueous flow is mainly produced in the swirl chamber. Therefore, it is obvious that the swirl action in the swirl chamber has a great resistance to the flow of water. The contour shows that the branch pressure is larger than the main pressure at the Y type fork, and the flow of flowing directly into the swirl chamber has been replaced by forcing the fluid to enter the swirl chamber through the outer swirl channel. During this process more fluid will produce a pressure drop along the channel,

thus increasing the effect of flow resistance. In the swirl chamber, pressure gradient created mainly by swirl action is relatively large.

Comparing the pressure contour of water phase with oil phase, it can be concluded that the oil pressure drop is mainly produced at the outer swirl channel, so the main part of pressure drop has been created when the oil through the swirl channel. From Y fork, the pressure of branch channel is lower than main channel when oil through the Y type fork. It makes more oil get into the inner swirl channel according the fork. When the oil enters the swirl chamber from inner swirl channel, there is an over flow pressure drop, and the pressure drop is not obvious.



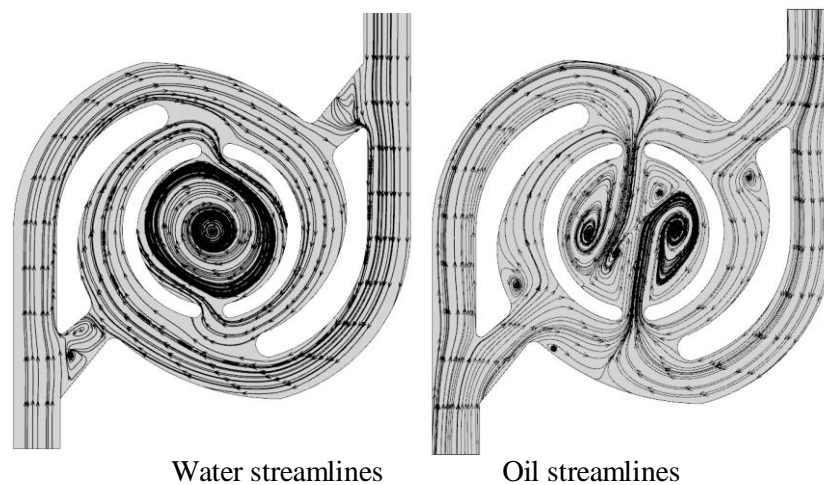
**Figure 3.** Contour of Static Pressure

#### 4.2. Analysis of speed field

In order to understand the movement mechanism of fluid in the valve, it is necessary to analyze the flow action of fluid which is directly related to the effect of valve. The following analysis is about the streamline of the fluid at different positions.

Figure 3 shows the flow of oil and water when they enter the valve respectively. There is a small vortex when water meet the Y branch and the vortex will cause a certain disturbance which will impede the water flowing into the swirl chamber by branch channel. The fluid of main channel will get into the inside valve according outer swirl channel and most of fluids will entry the inner swirl channel without entering the swirl chamber directly. The fluid at the end of the inner swirl channel which is impacted by the fluid from the outer swirl channel at the opposite side, will get into the swirl chamber and swirling.

There won't be whirl when oil meet Y type branch, because the viscosity of oil is heavier than water and the flow intensity is lower. So a portion of fluids will entry the swirl chamber according branch channel and other portion get into swirl chamber according inner swirl channel. The fluid passing the outer swirl channel will get into the swirl chamber directly because it is influenced by the branch channel at the other side. The turbulence created in the swirl chamber can effectively reduce the swirling flow of the fluid. Through the streamline comparison analysis, it can be seen that this valve can create a greater water flow distance and swirl effect, while for oil, it can reduce the flow distance and the swirl effect as much as possible.

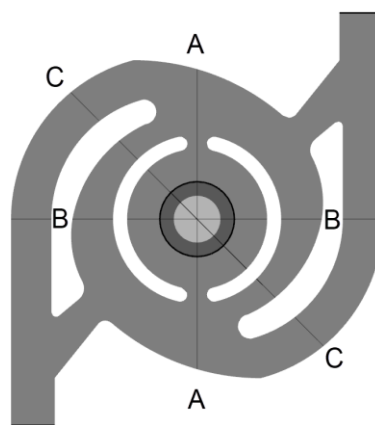


**Figure 4.** The distribution of flow field in the FCV

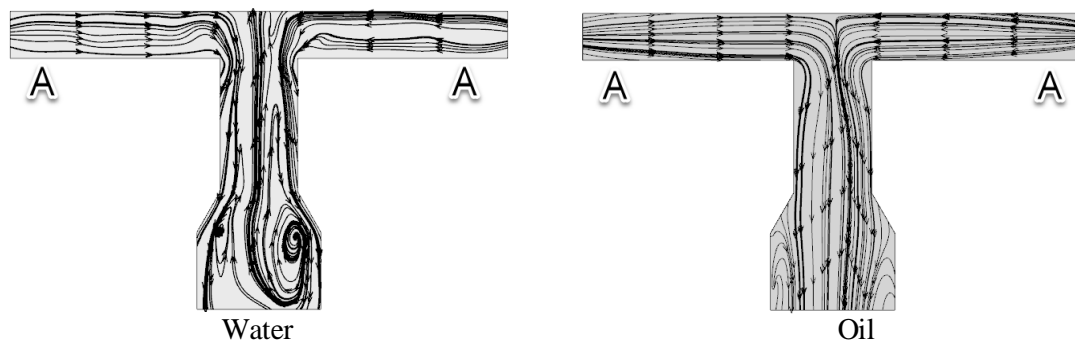
Figure 5 is a simplified model picture, then respectively intercepts three profiles along A, B and C three direction to analyze the flow of fluid. Figure. 6 is a streamline map of the A-A profile, as the section is toward the inlet of the swirl chamber, so it can be observed from the flow chart that the fluid is essentially flowing into the exit region along the radial direction. The whole flow process is relatively gentle, and there is turbulence only when the water through the outlet of the variable position where does the stirring happen. The existence of disturbances has impeded the flow of water.

Figure 7 shows the B-B profile, from the graph, there is turbulence in the swirl chamber when water pass this profile and the turbulence will impede whirl of water which decrease the energy used by whirl. The oil won't create any turbulence on the profile after entering the separation chamber, and the flow is relatively gentle. There will be turbulence when oil get through the inner swirl channel and the turbulence will impede and decrease the flow of oil in the inner swirl channel which can reduce the consumption of energy. The water also has an obvious disturbance when it get through the variable outlet.

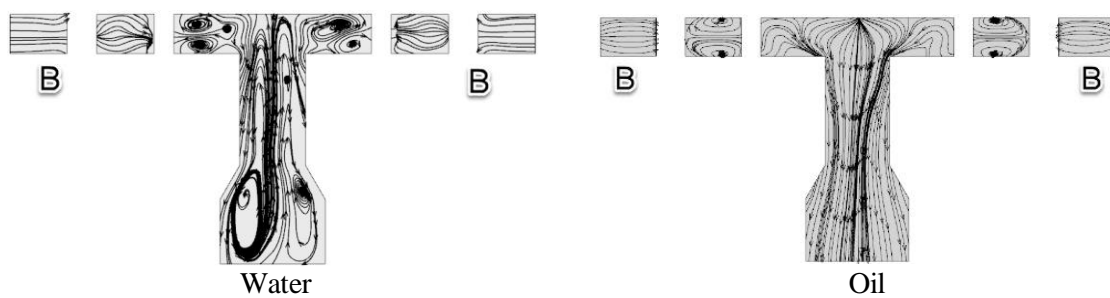
Figure. 8 is a streamline map of the C-C profile. By comparing Figure 6 and Figure 7, it can be observed that the flow in the outer swirl channel is different. There is turbulence in the outer swirl channel because the profile is in the bend position and compared to other locations, the flow is similar to that of the B-B profile.



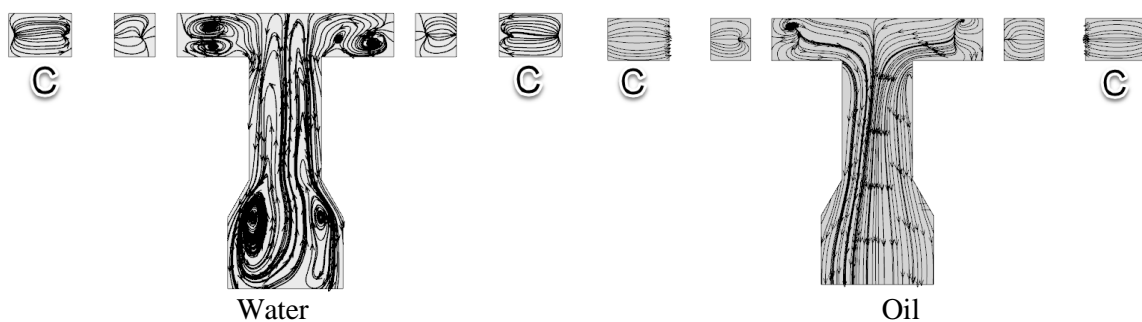
**Figure 5.** Schematic of section



**Figure 6.** The streamline of A-A section



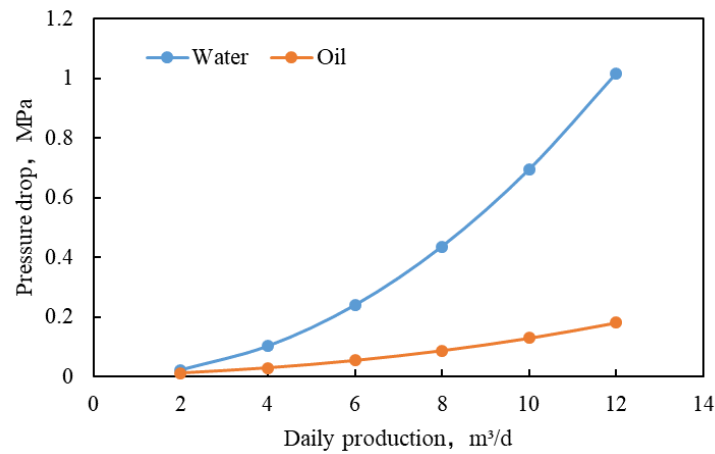
**Figure 7.** The streamline of B-B section



**Figure 8.** The streamline of C-C section

#### 4.3. Sensitivity analysis of oil-water flow

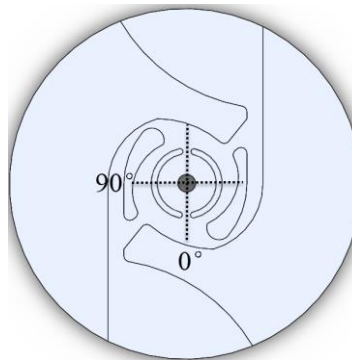
The effect of flow velocity on fluid pressure loss is relatively large, therefore, the oil and water overflow conditions are simulated in combination with the above structural design, mainly simulation the pressure drop of valve at the flow of 2, 4, 6, 8, 10 and 12m<sup>3</sup>/d. Through the pressure drop curve, it can be observed that the pressure drop of water is relatively large and the changing rate of pressure drop become more and more large. But the oil pressure drop is relatively small, and with the increase of flow rate, the changing rate of pressure drop is smaller. This curve shows that the tool is good for oil and water screening, and can play a great role in limiting water flow and releasing oil flow.



**Figure 9.** The pressure drop produced by the change of water and oil in daily production

#### 4.4. Structure optimization

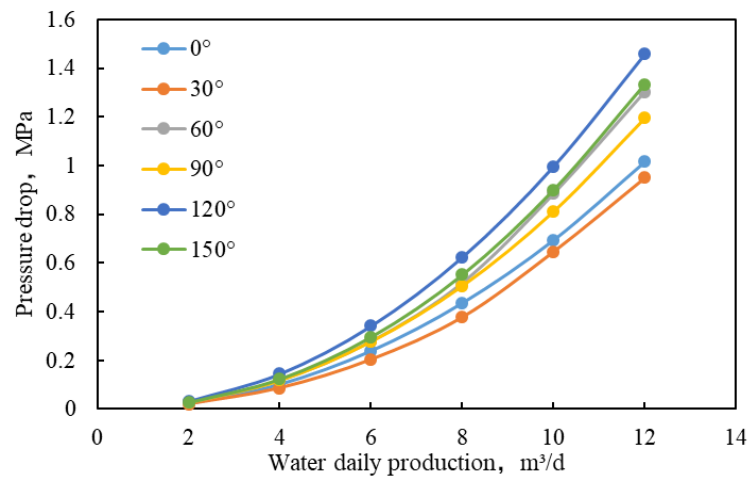
In order to improve the flow capacity of oil and reduce the flow capacity of water, it is necessary to optimize its structure. Because the water resistance is mainly generated in the swirl chamber, this paper will optimize the opening position of the swirl cavity inlet. Different open positions determine different flow modes, and the inflow mode has a great influence on the swirl movement. Mainly simulation the pressure drop of valve at the angle of 0°, 30°, 60°, 90°, 120° and 150°. The basic Angle transformation is rotated clockwise as shown in Figure 10. The pressure drop of the fluid flowing through the water control valve under different flow is measured.



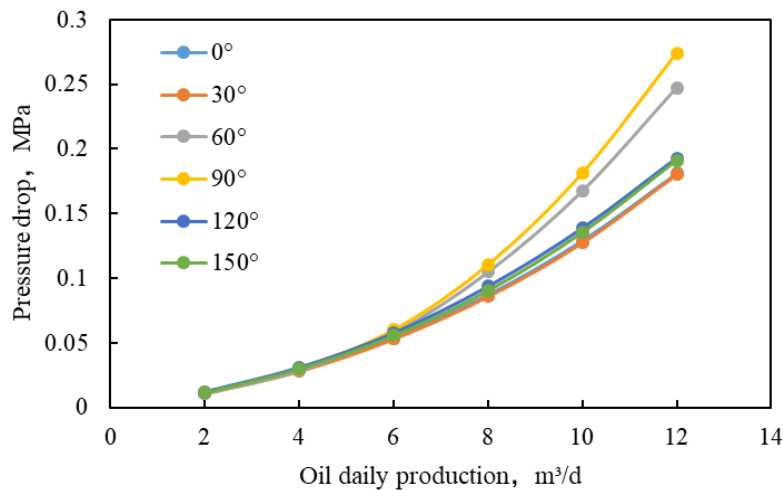
**Figure 10.** The schematic of angle setting

The pressure drop of water and oil from different angles and different flow conditions is shown in Figure 11 and Figure 12. By contrast can be seen that, with 120° design can make the water produces large valve pressure drop, but the oil valve pressure drop is not minimum values. The angle of oil producing minimum flow pressure drop is 30°, and the water flow pressure drop is also the smallest. Figure 13 is the difference of pressure drop produced by water and oil in the same condition. Through pressure difference can be seen that when the swirl chamber entrance by 120°, the oil and water flow pressure drop difference is the biggest of all.

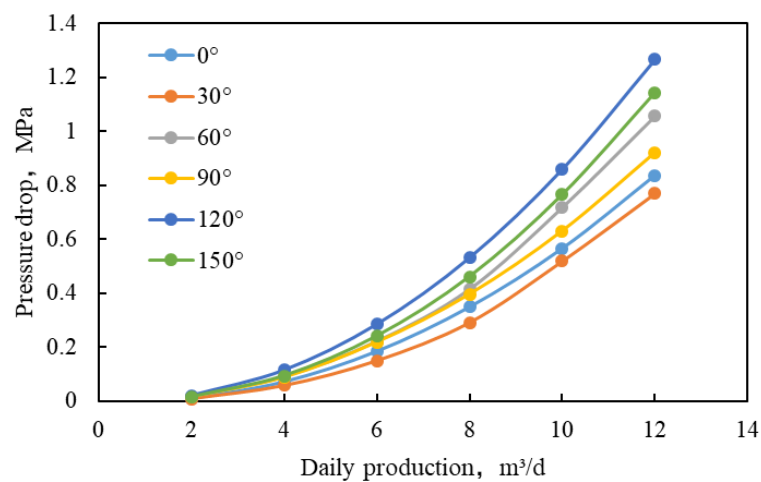




**Figure 11.** The pressure drop of the water



**Figure 12.** The pressure drop of the oil



**Figure 13.** The pressure differential of water and oil

## 5. Conclusion

Through the simulation of AICD, it can be seen that the tool can be used in the well to restrain the water. The numerical simulation of AICD in this paper can be seen that the y-type and swirl structure can be used to discriminate the oil and water. The simulation results show that the design of the y-shaped structure utilizes the flow characteristics of the fluid. The flow of water can produce vortices to stop water flow, and the flow of oil can play a good circulation. The design of swirl cavity can also play a good role.

It can be seen from the velocity field analysis that there are eddies in many places within the FCV. Most of these vortexes have a certain gain effect on the water control valve. The vortex in the swirl chamber has the opposite effect on the water control.

Swirl chamber entrance location optimization results show that when the swirl chamber entrance by 120 °, the pressure drop of oil and water flow difference value is the largest, water control effect is better.

## Acknowledgments

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