Comparison Of Development Effects For Two Different Combined Well Patterns With Horizontal Wells And Vertical Wells

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Abstract

In recent years, horizontal wells have been widely utilized in low permeability reservoirs of China. Normally horizontal wells are deployed combined with vertical wells, in which way effective injection-production well network system could be established. However, horizontal wells could be water injectors as well as oil producers and the same is true for vertical wells. The adoption of which kind of combined well pattern has been in dispute for a long time. In response to this issue, a novel physical simulation system is utilized to contrast the development effect of two well patterns with horizontal wells and vertical wells together. By comparing pressure gradient and flow velocity, the better scenario can be selected. If the horizontal well is not fractured, well pattern of horizontal wells as injectors with vertical wells as producers has a remarkable advantage. While the horizontal well is fractured, well pattern of horizontal wells as producers with vertical wells as injectors has a clear advantage. From another perspective to analyze the result, if an oilfield needs horizontal well to inject water for vertical wells, then the horizontal well is suggested not to be fractured. If an oilfield needs horizontal wells to produce much more oil with vertical injection wells, then horizontal wells with multiple hydraulic fractures could obtain better effect. As a rule of thumb, deployment of horizontal wells as oil producers is more common in oilfields.

Introduction

Application of horizontal wells and vertical wells combined is an effective technology to improve the development effect of low permeability reservoirs in China (Cai et al. 2009; Zeng et al. 2010). With respect to the combined well patterns (Cai et al. 2010; Xiong et al. 2012), there are two entirely different modes. One is setting horizontal wells as injectors and vertical wells as producers (HIVP), and the other one is on the contrary, i.e. horizontal wells as producers and vertical wells as injectors (HPIV). The adoption of which kind of combined well pattern has been in dispute for a long time and little literature involves research for this issue.

Large-scale slab model made of natural outcrop core is an effective tool to study seepage mechanism in low permeability reservoirs. In this paper, we present a novel physical simulation system to contrast the two approaches to optimize the more reasonable scenario.

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To carry out the slab model physical simulation experiment, several working procedures are essential, including natural outcrop screening, flat model fabrication, packaging, vacuum, water saturation, and flow field measurement. Detailed process of the large-scale slab model can be found in the following reference (Xu et al. 2012). The system of physical simulation has four sections: injecting system, natural outcrop slab, producing system and measuring system, as shown in **Figure 1**.

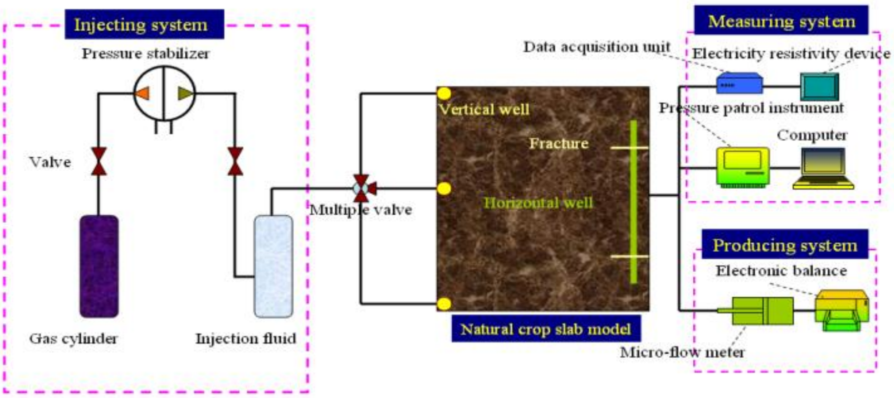

Figure 1—Flow diagram of physical simulation

In order to determine the better well pattern, horizontal well with fracture and without fracture are both considered, as shown in **Figures 2** and **3**. Pressure gradient distribution and flow velocity can be obtained by pressure patrol instrument and micro-flow meter respectively. According to Darcy Law, flow rate or flow velocity in porous media is proportional to the pressure gradient. In other words, the value or level of pressure gradient can reflect the degree of difficulty for displacement.

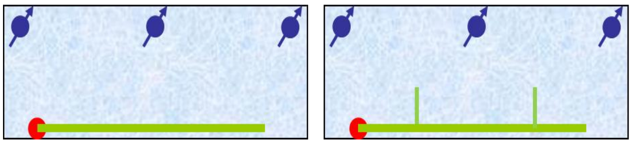

Figure 2—HPVI without fractures and with fractures

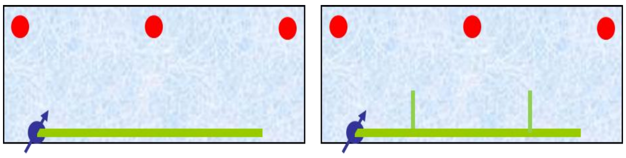

Figure 3—HIVP without fractures and with fractures

The size of the slab model is 0.4m×0.4m and the length of two fractures is 0.05 m. As shown in **Figures 4** and **5**, pressure gradient distribution of the two well patterns is provided when the displacement pressure difference is 30 KPa. Pressure gradient around injectors and producers is higher than the region between wells.

Also when the horizontal well is fractured, the pressure gradient nearby the fractures becomes higher. Low pressure gradient reveals high degree of difficulty for displacement, while high pressure gradient is the opposite.

While the horizontal well is not fractured, as a whole the pressure gradient of HIVP pattern is slightly greater than that of HPVI pattern, reflecting horizontal well as injectors has an advantage. While the horizontal well is fractured, the pressure gradient of HPVI pattern is significantly higher than that of HIVP pattern, reflecting horizontal well as produces has a clear advantage.

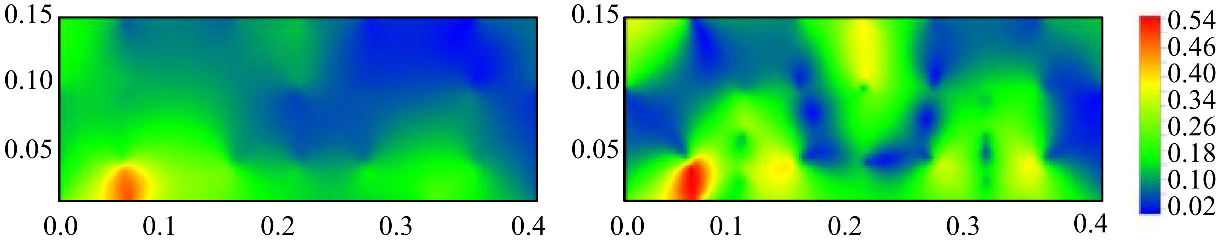

Figure 4—Pressure gradient distribution of HPVI without fractures and with fractures

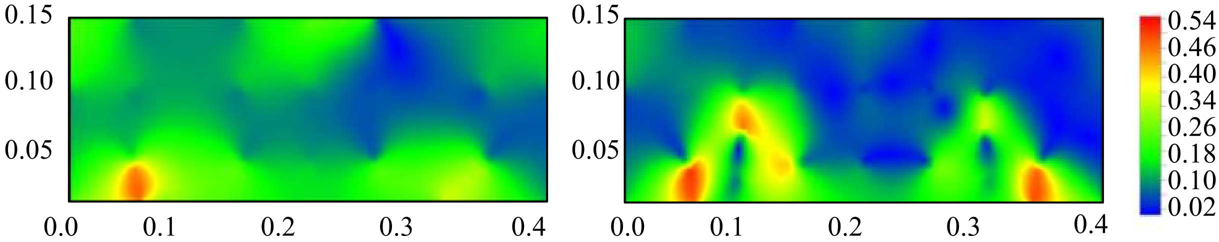

Figure 5—Pressure gradient distribution of HIVP without fractures and with fractures

As shown in **Figures 6** and **7**, the flow velocity of HIVP pattern is slightly greater than that of HPVI pattern, also reflecting horizontal well as injectors has an advantage when the horizontal well is not fractured. While the horizontal well is fractured, the flow velocity of HPVI pattern is significantly higher than that of HIVP pattern, also reflecting horizontal well as produces has a clear advantage after hydraulic fractured.

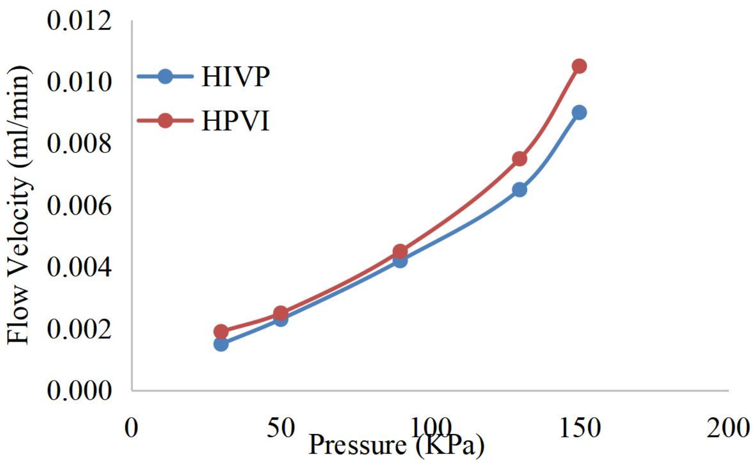

Figure 6—Flow velocity of HIVP and HPVI without fractures

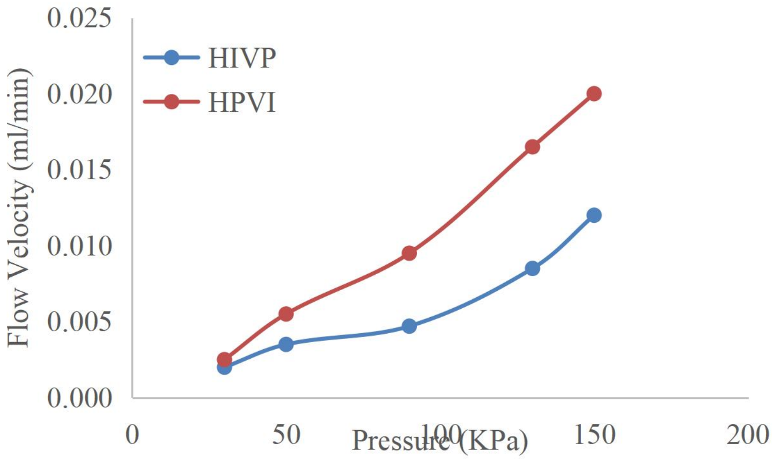

Figure 7—Flow velocity of HIVP and HPVI with fractures

Conclusions and Discussions

The present result may be useful for combined well pattern selection and adoption when horizontal wells are involved in the oilfield development. If the horizontal well is not fractured, well pattern of horizontal wells as injectors with vertical wells as producers could obtain better development effect. While the horizontal well is fractured, well pattern of horizontal wells as producers with vertical wells as injectors may result in better performance. From another perspective to analyse the result, if an oilfield needs horizontal well to inject water for vertical wells, then the horizontal well is suggested not to be fractured. If an oilfield needs horizontal wells to produce much more oil with vertical injection wells, then horizontal wells with multiple hydraulic fractures could obtain better effect. In general, deployment of horizontal wells as oil producers is more common in oilfields.

Acknowledgments

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Conflicts of Interest

The author(s) declare that they have no conflicting interests.

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