Analysis of hydraulic fracturing length and aperture on the production rate in fractured reservoir

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Abstract: Hydraulic fracturing operations are used mainly where the reservoir rock near the well is damaged or reservoirs with low permeability. In the fractured reservoir where the reservoir contains fractures and tracks, in order to connect them to each other, the rate of production should be increased. In this study, a hydraulic fracturing operation in fractured reservoir is investigated. 10 wells for this study with a different distribution of natural fractures are evaluated. Hydraulic fracturing operation in the wells with different length and aperture opening can be applied in any case; the impact of each of these two parameters can be evaluated on production. As we will see in reservoir with a low natural fracture, hydraulic fracture length should be having more and in reservoir with high density from natural fractures, hydraulic fracture height has an important role on the production rate.
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Introduction

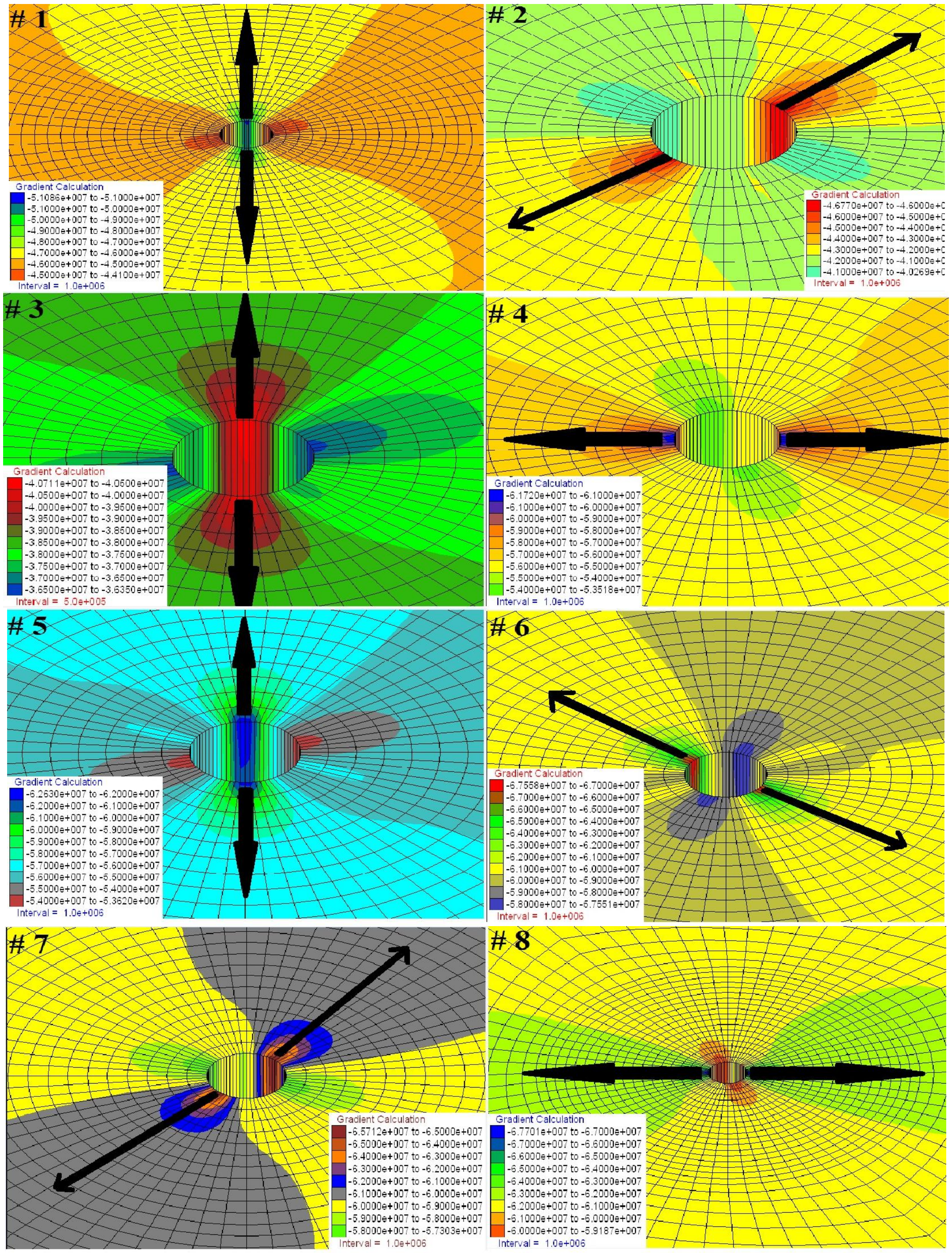
From the point of oil and gas engineering and exploitation of hydrocarbon reservoirs, increased productivity in the wells, especially in wells with low permeability or damaged wells is one of the main goals. Different ways to increase productivity of wells has been presented that can improve the performance of wells. The most important methods of improving productivity of wells, effect on the reservoir rock physics which is trying to improve the physical structure of reservoir rocks. Among the most important of these methods can be used to create artificial fractures in the reservoir rock. One common method to motivate the wells is creating artificial fractures and Proper use of this method can improve the permeability of reservoir rocks and thus can play an effective role in improving productivity of the wells. In hydraulic fracture, fractures from the wall are created to make the wells producing oil or gas.

The problem of crack deviation at natural cracks or faults has been widely investigated numerically (Zhang and Jeffrey 2006, 2008; Thiercelin and Makkhyu 2007). There are several numerical techniques that are proposed to model such complicated process, some of them are based on finite element method (Zhang and Ghassemi , 2010), others are based on combining analytical and numerical methods (Weng et al. 2011). However, a comprehensive analysis of how different parameters influence the fracture behavior has not been fully investigated to date. An understanding of the main physical criteria during the interaction of a hydraulic fracture with pre-existing discontinuities plays an important role in prediction of the propagation scenario (D. A. Chuprakov et al., 2010). Hydraulic fracture length and height are parameters that affect the operation of hydraulic fracturing. In reservoirs with different natural fracture from point of fractures density and their makeup which hydraulic fracture with which features be applied to be the best possible operating efficiency, it will be very important and efficient, as far as the economic discussion of the operations are heavily influenced. Therefore, these two parameters are essential to successful operation of hydraulic facture. In this study, two parameters in 10-well hydraulic fracture length and height indifferent natural crack density is studied. In each well, Hydraulic fracture with different length and height can be applied and the flow rate is checked at every stage of production. Here it is trying to influence the length and height of hydraulic fracture at fractured reservoir analysis and impact of each on the operations will be discussed.

Direction of hydraulic fracture

In terms of rock mechanics to create an artificial fracture in the rock can be expressed as: Each type of stone formation in general the amount of power (strength), which depends on rock structure, compaction of the cement stone. Forces that tend to hold the stones together are include Stress on the rocks and strength of stones. When the well is filled with fluid and the pressure of the fluid is left on the surface fluid pressure in the reservoir rock increased.

Hydraulic pressure should be applied equally in all directions. If the pressure is increased to the extent that the force of this pressure is created, impose any additional amount of pressure causes the rock fractures and gaps to be created. The extent of fractures with respect to the fluid pressure that is caused by fluid injection can be controlled. When a stone is placed under pressure the broken line is formed together with the main stress maximum principle maximum stress and minimum main stress is perpendicular. With the information from the field, the main stress distributions around the every 10 wells are studied and direction of forming the hydraulic fracture is given in Figure 1.



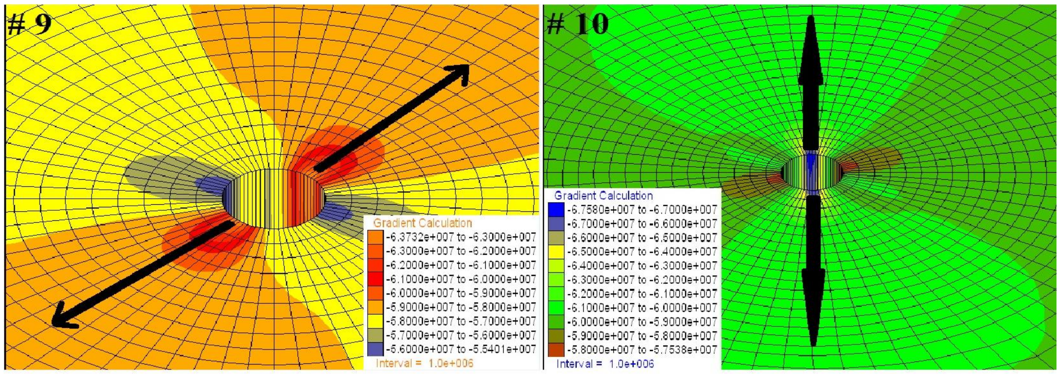


Figure1. Direction of forming the hydraulic fracture base on distribution of main stress around the wells

Model description

Block size for all wells in a block is 20 * 20 m that the Well is located in the middle of the block. With data from cores and logs Status of natural fractures around the wells are simulated with a distinct element code. The main point is that in this simulation only fractures that are connected at least with a more natural fracture is shown. In other words, if a natural fracture is not connected to any other fracture, it is not shown. After determining the direction of the hydraulic fracture, hydraulic fracturing operation with different length and opening is done in each well. All 10 wells in the study, fractures length of 2 meters started and in each stage, 2 meters long will be added to hydraulic fractures that block size is equal to the crack length reaches 20 meters. But height or aperture of hydraulic fracture in each well is almost a different choice. Schematic of the applied hydraulic fracture length of 20 meters in each well and Statuses of natural fracture around each hole can be seen in Figure 2. On the wall of well a group of nodes are defined to measure the flow of production. In this model it is assumed the flow source is only natural fracture of reservoir.

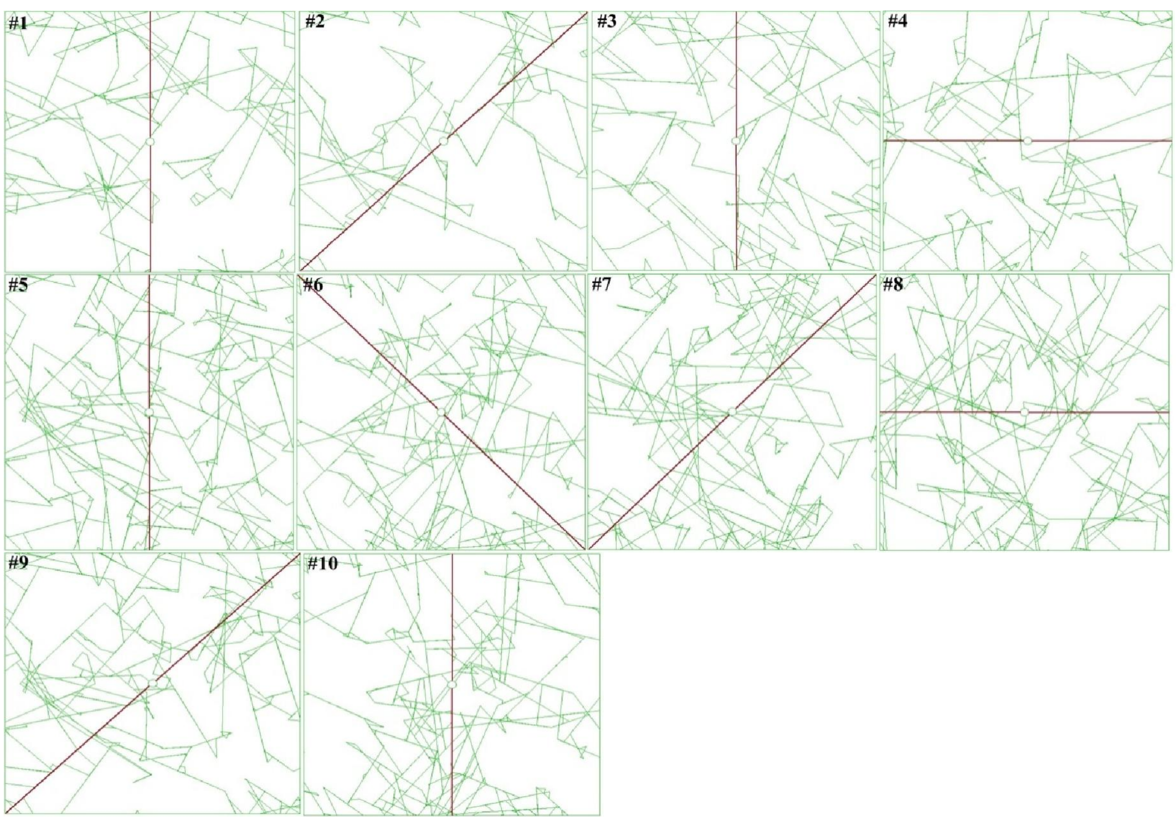


Figure 2. Natural fractures position around the wells and hydraulic fracture operation with 20 m long in wells

Analysis Results

Well #1, the hydraulic fracture is located in an area that high concentration of natural fracture are exist, but on other side we can see a few number of natural fractures. Since production is only from natural fractures that are connected to gather and finally connect to well, In this case the result is almost the most productive part of the fractures will be more connected to the wells that this matter can be seen in figure 3. In well #2, in some parts that near the well there is a small number of natural fractures but well away from the wall gradually becomes greater number of fractures. So, hydraulic fracture with low length and high height cannot increase the production. Better words, when the hydraulic fracture length is reduced in such an environment, the fracture created by adding height cannot affect, but when the length of hydraulic fracture will increase that reach to such an environment with high density, In this case add height can affect the production severely which is shown in figure 4. Hydraulic fracturing operation in well #3 will apply in direction that the distribution of natural fractures are same, and a few number of natural fractures disconnected by hydraulic fracture and connected to well. Production flow chart at well No. 3 when hydraulic fracture applied is given in Figure 5. As can be seen when the hydraulic fracture equal to 2, 4 and 6 meters, the production in different aperture is the same. If the area that these lengths of hydraulic fractures are located there considered carefully, Can be seen that the hydraulic fracture is located in a region almost intact virgin and increased to 6 meters in length practically does not interrupt the natural fracture. With increasing length of hydraulic fracture more normal fracture will connect to well. If the chart is accurate, this conclusion can reached that the length can play an important role. And production shows more sensitivity to length and after opening approximately 200 micrometers, with increased production of this parameter is almost constant.

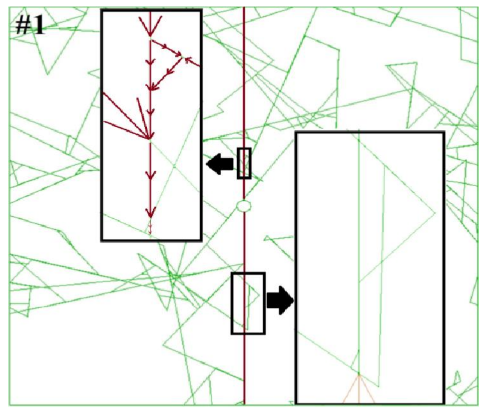


Figure 3. Current status between the natural fractures that connected to hydraulic fracture in the areas of reservoir in well #1

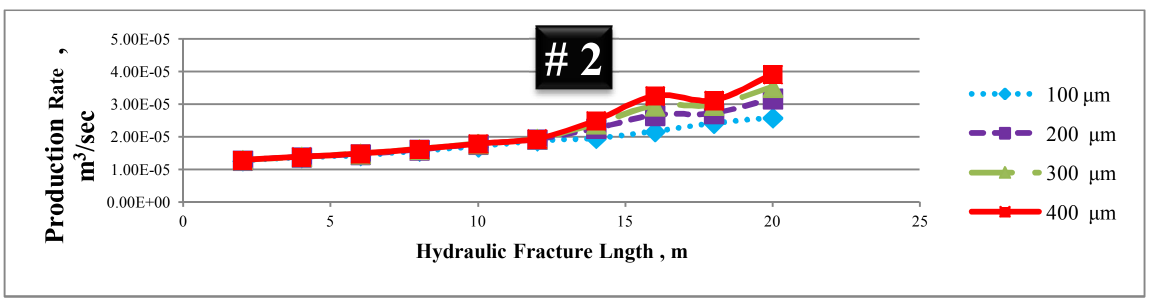


Figure4. Production flow rate in hydraulic fracture with different length and height in well #2

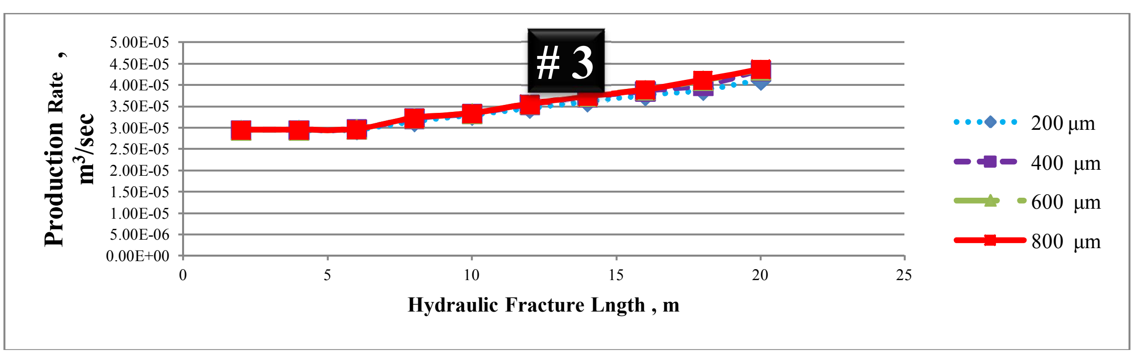


Figure5. Flow chart of production with different length and height of the hydraulic fracture in well #3

`Well #4 is established in the same situation, that mean the direction of hydraulic fracture in some area of reservoir will extended that a few number of natural fracture connected to that reservoir, therefore the length should be increased and so that because of that with increasing of natural fracture then hydraulic fracture reach the best results.

In well #5 we have the different situation, because this well is located in reservoir with many natural fractures. In such a situation by increasing the length of hydraulic fracture more natural fractures can connect to the well. Flow diagram of production of these wells (Figure 6) also shows this significant point that with increases of length and hydraulic fracture aperture production is also increase.

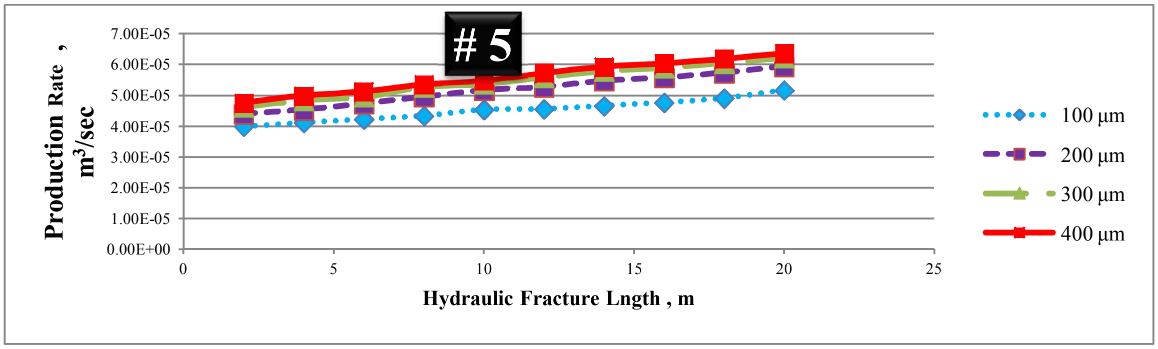


Figure6. Flow diagram of production varies with the length and height of hydraulic fracture in wells #5

In well #6 the density of natural fractures near the wells are numerous and in more distant areas is less. Figure 7 shows the Flow chart of the production in well #6 with applies of hydraulic fracture. In the hydraulic fracture with length of 4 m, because of no natural fracture related to hydraulic fracture thus Production is equal to the length of 2 m. When hydraulic fractures in the reservoir is extended Reach up to 12 meters long, effectively increasing the height of the fracture so that should not impact on production levels and is often ineffective. Expected with increasing of length due to more relationship natural fracture and hydraulic fractures the production should increases and this increase will be more with adding more apertures, but this is not. Perhaps it could be justified so that the hydraulic fracture with length of 12 m that are near the wells connect to well and on other hand these fractures are related to each other, is only part of its fluid exchange to Hydraulic fracture and other parts exchange in their fractures and may be in communication with nearby wells increase the production by themselves not by hydraulic fracture. Figure 8 shows that this phenomenon better. When the hydraulic fracture length exceeds 12 meters again increasing of aperture shows its influence and will affect the production. This effect can probably find a connection to the natural fractures in intervals that are located far away from well with hydraulic fractures.

In well #7 we have the same condition. In this well when the hydraulic fracture of fractures related to the well passes, in other mean, reaching over 12 meters long and when is connected to other natural fracture will have more effect on production. As can be seen in Figure 9, along with hydraulic fracture to 16, 18 and 20 meters and the aperture effect will be more. This is because the fracture in the non-connected and more wells are connected through a hydraulic fracture.

Wells 8 and 9 as wells 3 and 4 have similar condition however those more natural fractures are around this well and hydraulic fracture which expands in main direction makes more cuts. Thus both the length and the aperture can be effective in on this two production wells. In well no 8 when hydraulic fracture is near the well that full of natural fracture and also increase of height for fracture had no effect on production (figure10). But the point here is that it should be noted that when the hydraulic fracture is connected to high-density area (Higher than 12 meters in length) Add the fracture height, strongly enhances the production. In fact, because of relation between natural hydraulic fracture and natural fracture, adding height to the hydraulic fracture by high capacity of this natural fractures that are connected be compensated. Flow diagram of well no 9 express this fact that if the hydraulic fracture in order that expands, communicate with a large number of natural fractures, by Increase of hydraulic fracture length, height can be increased (Figure 11). When the gap length can be increased in such an environment, the increase in the production flow sensitivity is higher than the hydraulic fracture aperture.

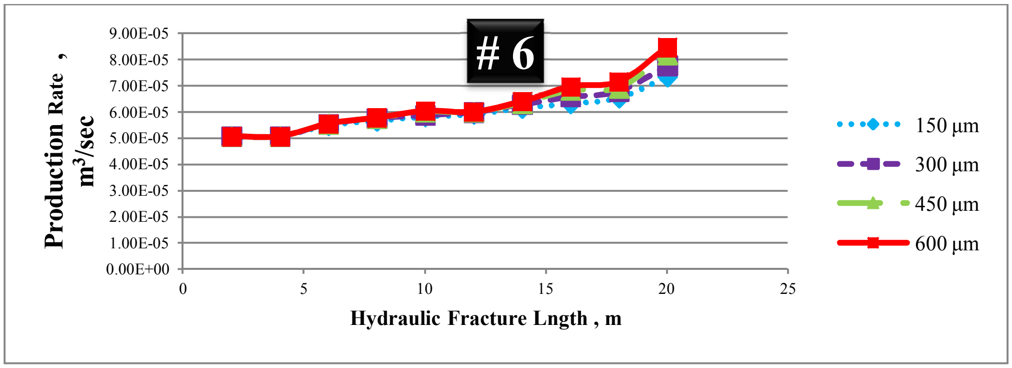


Figure7. Flow chart of production varies with the length and height of hydraulic fracture in well #6

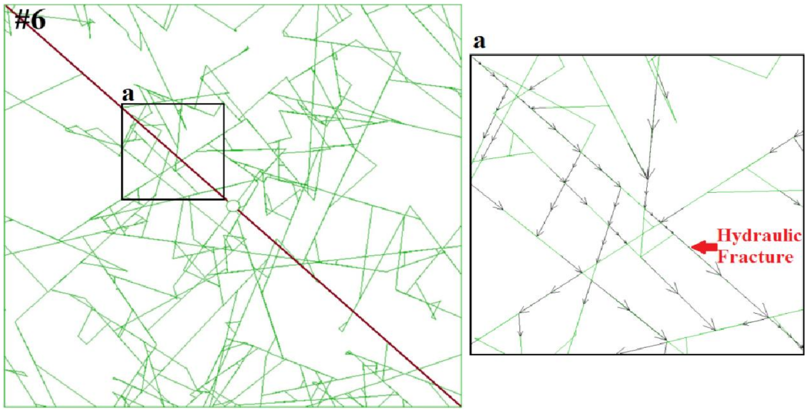


Figure 8. The status of flow between the natural fractures near the wells associated with hydraulic fractures in well #6

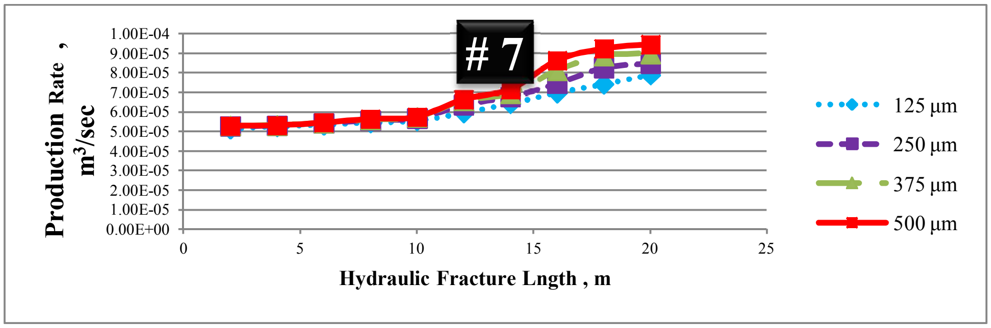


Figure9. Flow diagram of production varies with the length and height in hydraulic fracture of well #7

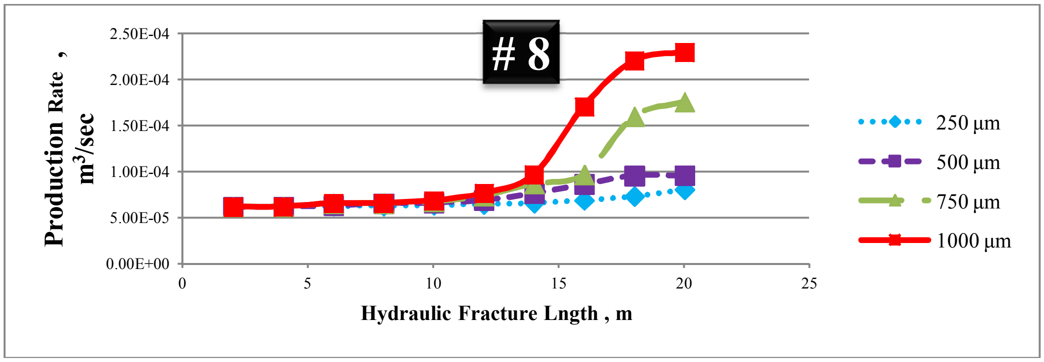


Figure10. Flow diagram of production varies with the length and height of hydraulic fracture in well #8

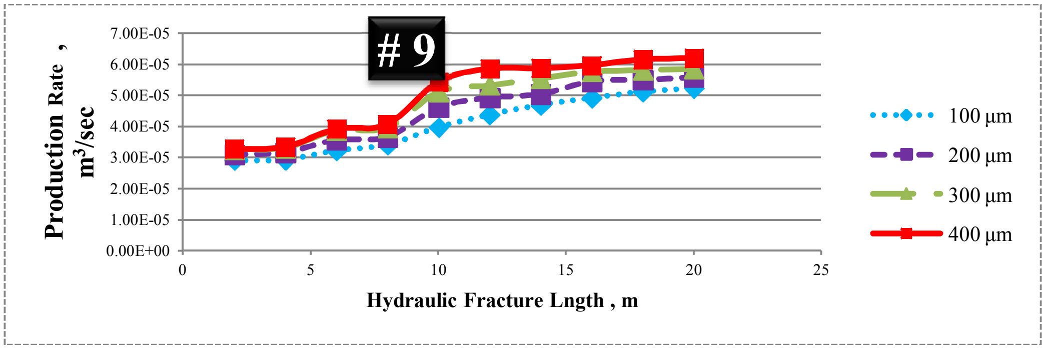


Figure11. Flow diagram of production varies with the length and height of hydraulic fracture in well #9

A hydraulic fracturing operation in the well #10 is such that the distribution of natural fractures in the both sides different. Flow diagram of the production of this well is given in Figure 12. When the hydraulic fracture connects to a large number of natural fractures that are far from the well, both length and aperture have effect on the production. During the 10-meter to the higher length, hydraulic fracture connection to the natural fractures become more production also increased due to increase of aperture and length. This phenomenon can be explained such that when a hydraulic fracture contact to the area with a large accumulation of natural fracture that are far from the well, Due to lack of communication or poor communication this fractures with each other and also with the wells, their current capacity are exchange with hydraulic fracture and this causes the increased aperture is offset by the exchange of high flow (Figure 13). Maybe if the other hydraulic fracture, that natural fracture in the low-density area expands, the high concentration of natural fractures indicate more sensitivity of production rate.

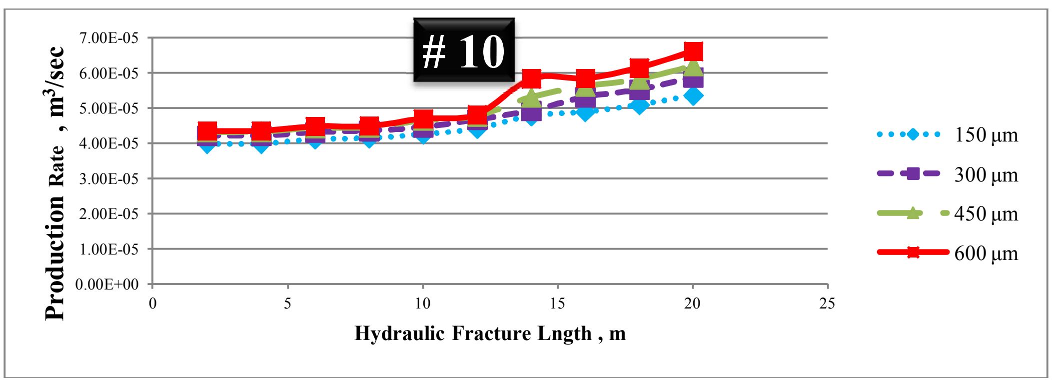


Figure12. Flow diagram of production varies with the length and height of hydraulic fracture in well #10

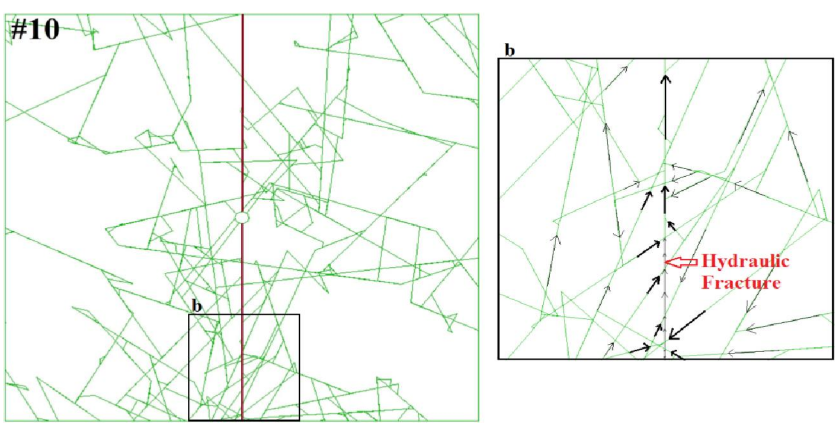


Figure13. Status of the natural fracture flow that far away the well with hydraulic fracture in well #10

If well #3 as well in orders that it hydraulic fracturing operation expands in that direction that lowest number of natural fractures are interrupted by hydraulic fractures I.e. the applied area hydraulic fracture with low density of natural fractures and Well #5 as well, with high density and nearly uniform in the hydraulic fracture is considered, so, sensitivity analysis can be performed in these two wells to check the length and height of hydraulic fracture on production rate. By coding in matlab software diagram of the two wells is given in Figure 14. Clearly, in well #3 the number of fractures in hydraulic fractures path are low, and also the length play an important role and adding in aperture to the fracture has very little effect on production. In well #5 the height of hydraulic fracture has more effect on production. These results show qualitative agreement with field results (e.g. Z. Zaho et al., 2005).

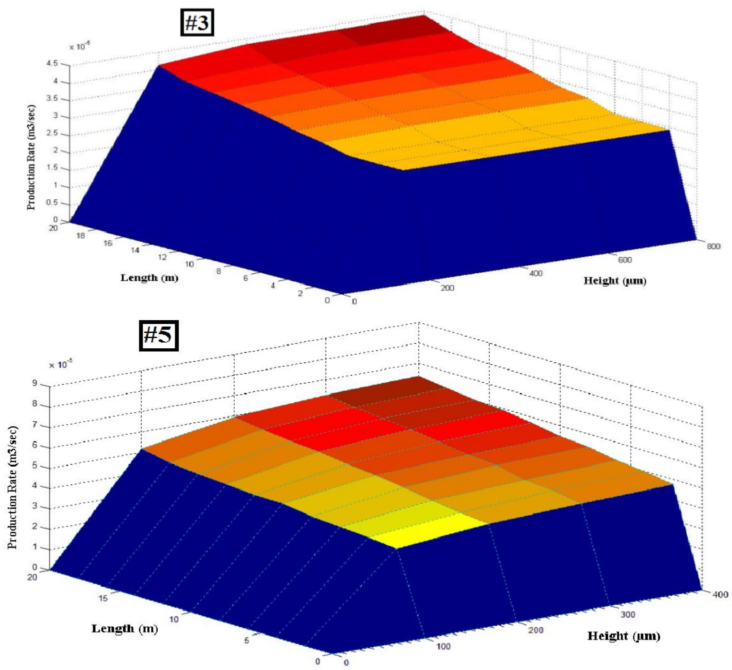


Figure14. Effect of hydraulic fracture length and height on production flow in wells 3 and 5

Conclusion

According to the performed analysis, obtained results can be summarized as the following:

- In fractured reservoirs, mainly if the hydraulic fracture expands in direction that more natural fractures will connect to well, in this case the efficiency will go up.
- In fractured reservoir with low natural fracture, the fracture must be applied with great length and by connecting greater number of natural fracture to well, the production will increase. And in this situation by adding to the height of hydraulic fracture practically will not be acceptable on production flow.
- In fractured reservoirs which have natural fracture with high density the hydraulic fracture must be apply with more conductivity in reservoir that it need more aperture in hydraulic fracture. In such a reservoir due to relation between natural fractures and conducted fractures, we can see more influx to fracture. And adding to the height of hydraulic fracture the flow capacity of this hydraulic will rises. That with this increase of capacity due to high flow exchange of natural fractures can be compensated.
- If the areas around the well contain many natural fractures expansion of hydraulic fractures in such an area would not be very successful and also low increase of production is due to length and add height to the hydraulic fracture has no effect on production.
- The most efficient mode of operation of hydraulic fracturing occurs when the hydraulic fracture can connect the natural fracture to well that are far from well. If these numbers of natural fractures are high or other hydraulic fractures that are far from the well have a contact with high density area, so increase in aperture can have extreme effect on production.

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