Selection Criterion and Economical Evaluation of Refracturing in Tight Gas-Condensate Reservoirs

Introduction

Hydrocarbon produced from unconventional and tight reservoirs became one of the primary sources of energy. However, unlike conventional reservoirs, unconventional reservoirs require unique recovery methods and operations. One and the most necessary these techniques is the hydraulic fracturing technique. Unconventional rocks are assumed to be tight, and hydrocarbons should be extracted by way of using massive hydraulic fracturing treatment to achieve commercial production (Glorioso and Rattia, 2012).

The commercial introduction of the hydraulic fracturing process to the petroleum industry was in 1949 (Coulter and Menzie, 1973). In addition, since the emergence of hydraulic fracturing technology, routine refracturing has been considered as the right choice for economically recovering reserves and boosting production rates (Howard and Fast, 1970). Moreover, refracturing of the existing wells represents an alternative to drilling new wells during an unfavourable economic climate (Conway et al. 1985).

Multistage fracturing is one type of stimulation methodologies that is applied to maximize the hydrocarbon production from unconventional reservoirs (usually shale formations). Sometimes initial completions are ineffectually performed. Some of the possible factors for ineffective initial completions can be considered as the various failure occurred in cementing, packers, and liners installation process.

Refracturing is a highly used technique when the particular well has a considerable resource that was not produced by the initial completion. Refracturing helps to access that significant number of hydrocarbons with low capital expenses compared with drilling new wells. The success rate of refracturing is extremely depended on various vital factors, including reservoir properties, and properties of previously formed fracture networks and reservoir-wellbore connectivity. The latter is somehow associated with the reorientation of the existing fractures (Tavassoli et al. 2013).

According to Howard and Fast (1970), around 35% of gas wells that underwent to hydraulic fracture were not successfully performed due to many reasons, which led them to refrac the formation. In addition, they mentioned that usually when the formation reacts with the first attempt of hydraulic fracture, it will react with retreatment, and the refracturing operation should be performed similarly to the first fracking job.

An example where refracturing becomes necessary is when the old proppant system has no adequate flow capacity for the reservoir (Coulter and Menzie, 1973). Therefore, Coulter and Menzie (1973) conducted laboratory tests to establish a technique of eliminating or changing the old proppant system in the fracture. They discussed and studied experimentally and economically two methods which are the practice of using high-viscosity fluids or high injection rates. They concluded that replacing an old proppant system by injection rate means or high-viscosity fluids is challenging since when the fracture is reopened, a large cross-sectional area open to flow exists above the proppant bed. However, closing this area can be achieved temporarily through using a diverting gel which allows the injection through the proppant system. Then, the proppant system below the diverting gel can be removed by higher injection rates. Also, the high flow rate underneath the diverting gel represents a benefit for the placement of a new proppant system. Using an intensely high viscosity fracturing fluid is the second technique. It increases the fracture widths, which allows the new proppant system to be placed and the old proppant system to settle.

During the refracturing operations, diverter is usually used along with fracturing fluid in order to divert or share the treatment in an equal manner for the parts of the well that had lack of the treatment. Balls are generally used in the purpose of diverting the treatment fluid (Senters et al. 2019).

Within the scope of the refracturing projects particulate diverters are used as well. These type of diverter materials depend on particle sizes variance to clean the perforations, which are fetching the fluid during the period of fracturing (Van Domelen, 2017).

Tavassoli et al. (2013) studied the optimal time of refracturing and well screening according to the well performances. They developed a detailed reservoir model to control shale-gas production, considering wells with initial fractures and refractured fractures. They have used two approaches in the model. CMG
simulator was utilized to build up a model of initial fractures, and the refracturing treatment in Barnett shale play and sensitivity analysis was performed and the influences of formation permeability, formation porosity and initial fracture conductivity on gas flow rate and cumulative gas production taking into account the refractured and non-refractured scenarios.

According to Hunter et al. (2015), Encana operating company performed refracturing job in this formation using the systematic candidate selection proposed by Schlumberger and as a result shale gas production increased by 27 times within the production period after refracturing for the first 30 days. Senters et al. (2019) worked on proposing a new diagnosing evaluation of the of refracturing techniques on Barnett shale. Optimization of the refracturing techniques, including bullhead refracturing considering diverter (different types of diversion) and with no diverter and mechanical isolation was analyzed.

Elbel and Mack (1993) work represents a special report regarding refracturing operation. They focused on the influences of formation pore pressure between the fractures. Tavassoli et al. (2013) stated that besides the mentioned necessary factor for the successful refracturing job, the timing for restimulation should be correctly chosen. Xu et al., (2017) described the main challenges of refracturing with chemical diverters, and they strongly advised to run more fracture modelling before conduct refracturing to obtain more reliable production result and for better understanding to what happens downhole. Basically, he validated a certain well by production history, matching real data from previous wells results in the same field to generate better estimation.

Sinha and Ramakrishnan (2011) proposed a novel screening technique for horizontal well refracturing using completion index, which considers the importance of completion features during refracturing operations.

Reese et al. (1994) have published a paper that talks about selecting cost-effective way of refracturing. Their study was about the economic results from the refracturing. They summarized their study when a refracturing operation occurs in a high permeable zone, it should enhance the fracture conductivity, whereas, in the low permeable zone, it helps to expand the fracture length. Furthermore, they highlighted that in tight formation, refracturing could be complicated and not economical as the treatment will be costly.

Hunter et al. (2015) proposed insights on the economical evaluation and systematic selection of candidates for the refracturing process in the Haynesville shale. They emphasized very important aspect while performing refracturing operation which is the cost of drilling and stimulation a new lateral is approximately 6-7 times expensive than refracturing in the aforementioned formation.

Indras and Blankenship (2015) discussed the economic aspects and the success rate of refracturing technique in three well-known shale formations in the United States, including Bakken, Haynesville and Barnett. The principal reason for applying the refracturing in the tight formations is to enhance and increase the production capability of the wells. This fracturing method allows the oil and gas companies to achieve high production rates by minimum capital expenditures since the drilling of the new wells in the tight formations costs much money to companies. However, as mentioned in this article, refracturing helps to get high Net Present Value (NPV) in Bakken and Haynesville formations while this method could not achieve long-term commercial achievement in some wells in Barnett formation because of the poor selection process of the wells for refracturing.

Method and/or Theory

A tight sandstone gas-condensate reservoir model, with a rectangular shape, is built using CMG-GEM simulator. The reservoir and fluid properties were taken from the literature with some modifications (Bagherzadeh et al. 2018). The reservoir is divided into 6250 grid cells with 25, 25, and 5 grids in x, y, and z directions, respectively. In addition, the grid size in x, y, and z directions are 240 ft, 240 ft, and 140 ft respectively. The model has an isotropic homogenous permeability.

Firstly, multistage hydraulic fracturing is introduced at the same date the well starts producing. It consists of 7 equally spaced fractures as shown in Figure 1. The sensitivity analysis is applied to study different scenarios by changing the parameters, including reservoir permeability and porosity, fracture width and half-length, cluster spacing and initial production rate.

The ultimate gas and oil recovery of each scenario in addition to the pressure drop curves were examined. Two scenarios obtained by changing a reservoir property (permeability) and a fracture
property (spacing) were selected for refracturing because they give the lowest recovery and the fastest pressure drop. Figure 2 shows how the decision was taking for refracturing in addition to a summary of the work done.

The selected two cases for refracturing from the previous section were examined. Refracturing was applied at different times to determine the optimum time for refracturing. The refracked cases were compared with each other. In addition, the initial fractured case (base case) was compared to the refracked cases to study the effect and significance of refracting in increasing the production rate and reducing the pressure drop.

In this part, the economic feasibility of the optimum scenario will be evaluated. Economic comparison between the refracturing job or drilling new well will be presented. For example, new vertical or horizontal will be drilled in the reservoir and the additional recovery obtained from this development in addition to other factors such as costs (e.g. Net Present Value), and time (e.g. Internal Rate of Return) will be compared to that of the refracturing completion.

---

**Figure 1** Introduced multistage hydraulic fracturing

**Figure 2** Flow chart showing how the decision was taking for refracturing

---

**Conclusions**

CMG-GEM was used to construct the fundamental reservoir model and reservoir models with hydraulic fracturing and refracturing. We researched various fracking scenarios for our reservoir model after the development and verification of the model. The impact of the various reservoir and fracture parameters has been studied bottomhole pressure, cumulative oil and gas productivity and hydrocarbon recovery. It was noticed that reservoir parameters were most influential on overall well performance. On the other hand, fracture parameters showed a positive and negative impact of well productivity.
Based on our simulation results for fracturing, we decided to apply refracturing to analyze its effect on well productivity by using the cases in which we noticed a relatively rapid production decline. We studied two cases, including very low permeability and fracture spacing, with a more dramatic decrease in well productivity. The results showed that applying refracturing after 2 years and 10 years respectively will be expected to result in higher cumulative hydrocarbon production. This tendency again tells us how important it is to choose proper timing for refracturing. Thus, we can conclude that applying refracturing in gas-condensate reservoirs with very low permeability yields a higher production.

Finally, according to our economic analysis, it was concluded that applying refracturing has a higher possibility to give a higher positive NPV and IRR than drilling a new well. Thus, the profitability is expected to be higher in refracturing than drilling a new well.

References