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Stimulation Of The Methane Production With The Use Of Changing Of The Rock Massif Physical Conditions

Mikhail Baev[1*], *Veniamin* Khyamyalyaynen[1], and *Aleksandr* Shevtsov[1]

[1] T.F. Gorbachev Kuzbass State Technical University, 650000, 28 Vesennyaya St., Kemerovo, Russia

Abstract. The commercial coalbed methane production success is majorly defined by the effectiveness of the use of special gas inflow stimulation methods. The necessity of using of such methods is subject to the aspects of searching and displacement of methane within the coal compound. The analysis of the ways of methane production stimulation from virgin coal formations is given. The description of the process of hydraulic fracturing (fracturing) as the most common stimulation method during the commercial coalbed methane production as well as its major advantages are presented. The present work provides data about the initiated laboratory research of sands collected from Kemerovo region deposits for the purpose of finding of the most prospective samples by means of anchoring of fractures. The prospectivity and ability to implement the hydraulic fracturing with the use of locally available sands acting as proppants are shown. The influence of the strain-stress state of the rock massif on the alteration of permeability and the necessity of its extension study with respect to different technological features of hydraulic fracturing is shown.

1 Introduction

Today's world economy is characterized with the high level of energy consumption. The development of fuel and energy complex and metallurgy, as well as oil processing and chemical industries is based on the wide using of different types of mineral resource produced from the earth interior. In the capacity of fuel and energy material, oil, natural gas and coal are the most widespread. Growing human demand on the abovementioned resource leads to the continuously increasing of its production. Gradual depletion or immense decreasing of reserves in accessible deposits culminated in higher complexity and the cost of production. Due to that, the one of prior tasks is the development of unconventional hydrocarbon resources, such as: heavy oil and oil sands (bituminous sand), coalbed methane, shale gas and oil, tight gas, gas hydrates and water dissolved gases. Coalbed methane (CBM) shows the number of differences from other unconventional resources.

At the present moment, the unique for Russia project for commercial methane production from the virgin coal seams is being implemented in Kemerovo region. The major issue of the commercial methane production, unlike the conventional natural gas production,

* Corresponding author: bma.gdk@gmail.com

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centers around the features of the methane storage within the coal bed. According to existing concepts, methane in coal deposits presents in different states. Upon that, up to 80-95% of the total volume consists of the tied methane, and its major volume is presented as the solution within the hard matter (sorbed methane). Along with this, in the natural conditions of occurrence of coal seams, the process of slow diffusion-induced transfer of methane through coal matter predominates, i.e. the gas transfer from the formation is extremely slow [1, 2]. These particular features of bedding and transfer of methane within the coal matter predetermine the necessity of using of special methods, such as: hydraulic fracturing (the fracking), caving, directional drilling, pneumatic and hydrodynamic impact, well's reactant treatment, wave exposure on the seam, injection into coal seams of helium, nitrogen and carbon dioxide, plasma impulse excitation, foam-nitrogen hydraulic fracturing and so on.

2 Materials and methods

For the effective implementation of stimulation methods the understanding of physical processes occurring within the rock massif is primarily required. Aside from that, the Kuzbass coalbed methane fields development process showed the necessity of methodological adaptation with respect to the features of exact deposits as well as optimizing of economical expenses for their implementation.

In the world's practice of wells performance stimulation, both conventional oil and gas deposits and commercial coalbed methane production, hydraulic fracturing (fracking) is widely used [1-4]. During the process of fracking the special technological fluid is injected into the seam under high pressure, enough for fractures to occur. At the next fracking stage grainy materials – proppants (propping agents or fixing materials) are added to the fracturing fluid. The proppant allocates in fractures and holds them open (wedging them) after the process is finished. As the result of fracking, the created system of fractures deeply penetrating into the seam allows, first of all, to enlarge the seam's surface area connected to the well (well's drainage area), among other things due to the creation of the connection with the natural fractures system not touched with the well. Second, wedged highly-permeable fractures act as the passage ways helping the migration of gas from the seam to the well. Almost in all the cases, the major portion of the production comes from the seam into fractures and after that into the well. And third, due to the increasing permeability conditions for effective underground water drainage are created, which allows to get the maximal possible depression on the coal seam with the aim of enabling the process of gas desorbing.

Consequently, the well performance is connected with the fractures geometry and their residual (effective) permeability. In the work [5] general factors affecting the geometry of fractures created after the fracking are described. Main factors affecting the residual permeability of fractures are subsurface conditions (rock pressure, mechanical properties of rocks, temperature) and proppant's features.

Subsurface conditions are best characterized with the stress-strain state of the examined rock massif. During the long period of geological time the rocks lying within the earth's crust, are exposed to many natural forces and factors. As the result of such impacts within the massif the natural stress-strain state is created. Any human impact (like construction of the well, fracking, well production or extraction of coal) leads to the alteration of the natural stress-strain state. The control of the stress-strain state of the rock massif or the formation properties as the result of the fracking is a quite complicated task. However, during the implementation of the fracking understanding of the stress-strain state allows to find the most prospective intervals for the fracking, as well as to control the fractures growth and to forecast their orientation. Even after the fracking and during the whole period of the well's operation the stress plays an important role for the underground fluid production affecting

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the reservoir properties. It is proved that the porosity and permeability of the rock massif are decreasing with the growth of the massif stress [6], which works greatly for coal.

The important task during the fracturing designing is the proper proppant selection, which can allow the necessary permeability of the wedged fracture. During the selection of the exact propping material it is necessary to take into account its major physical properties: the strength, grain size and granulometric texture, the quality (the presence of compounds, acid solubility), grain shape (spherical shape factor, roundness) and the consistency. The special emphasis is to be paid on the prevention of the closure of the fixed fractures and providing of the required permeability. As the proppant artificial ceramic materials and natural quartz sands are used. Most of the frackings, including the coalbed fracking, are done with the standard quartz sand sorted by size [1-4, 7-10]. This is largely due to its availability, relatively low price and applicability at different underground conditions. The sand shows quite high strength to stand the closure stress during the fracking of seams bedding at the depths up to 2400 – 2500 m. Coal seams currently used for coalbed methane production in Kuzbass are bedding at the depths up to 1350 m, thus the using of the sand during the fracking is a quite practical solution. Upon that, in order to decrease the proppant cost, the using of local sands is obviously practical. For that purpose it is necessary to prove the feasibility of its using for wedging the fractures during the methane production from virgin coal seams.

3 Results and discussion

Kemerovo region shows the rich material base of sands. There are nine explored foundry sand deposits (reserves are estimated 214 million tons), as well as three glass sand ones (144 million tons), six masonry sand ones (35 million m^3) and thirty deposits of the sand-and-gravel material (189 million m^3). Along that, there is a number of deposits not accounted for by the state balance sheet. Thus, the purpose of the present work is searching of natural sand deposits of Kemerovo region, which can be used as propping agents during the fracturing of coal seams. For research samples of twenty two sand and sand-gravel deposits of Kemerovo region, as well as three deposits of Tomsk region and two Altai Krai deposits have been collected.

As it was mentioned before, the permeability of fractures is directly connected with wells performance. Whereas there is a link between the permeability of the grain material and its porosity (cavernosity) – as a general rule, the permeability is higher with the higher porosity. One of the factors affecting the porosity is the homogeneity or the sorting of grains by size [11]. If the small-sized particles are mixed with bigger sand grains, the effective porosity (represented by the pores connected to each other) will gradually decrease. Thus, for wedging of fractures proppants of defined grades are used, i.e. properly sorted material. Along with that, the permeability of the wedged fracture is greatly influenced with the grains breaking down within the fracture caused by the compression strain. The breaking down intensity relies upon the grain size, its shape, invisible defects, temperature, chemical compound and so on. Grains breaking down leads to the alteration of granulometric texture of the proppant within the fracture and, consequently, to the decreasing of its porosity and permeability. Thus, during the selection of proppant it is necessary to take into account the ability of its grains to withstand the destruction.

The compound and physical properties of untreated sand have been investigated, which included the analysis of the presence of flour and clay particles, as well as granulometric texture and the modulus of size, density and cavernosity of the unwiped and wiped samples. Also, research of the treated sand based on the ISO 13503-12 standard [12] is done for defining of the density and cavernosity, as well as the crush resistance [13].

As for the permeability measuring of the wedged fracture, the following aspects should be taken into account. The residual (or effective) permeability of the wedged fracture within the coal seam can gradually differ from the initial proppant's permeability factor, provided by the supplier. This difference can be explained with the number of causes, such as physical-mechanical properties of coal and bedding properties of the coal seams. These causes are not fully taken into account in the standard method for measuring of the proppant's conductivity in accordance with ISO 13503-5 [14], while the information about its influence on the filterability of wedged fractures at coal seams is insufficient.

By that reason during the research of sands for measuring of permeability it is suggested to use the original laboratory unit developed in KuzSTU. Its major feature is working with samples manufactured from the material comparable to coal which are used instead of the standard laboratory samples of the sandstones [5]. First of all, research for measuring of the fracture's permeability factor wedged with the proppant of given permeability (i.e. measured by the standard unit) has been implemented. Such material is the ceramic aluminosilicate proppant Borprop of the fraction 20/40. The data of its permeability is given at the manufacturer's website. It allowed to compare the given official information with data obtained at the assembled laboratory unit with the use of samples prepared from the equivalent material. The experiment results are shown on the drawing 1.

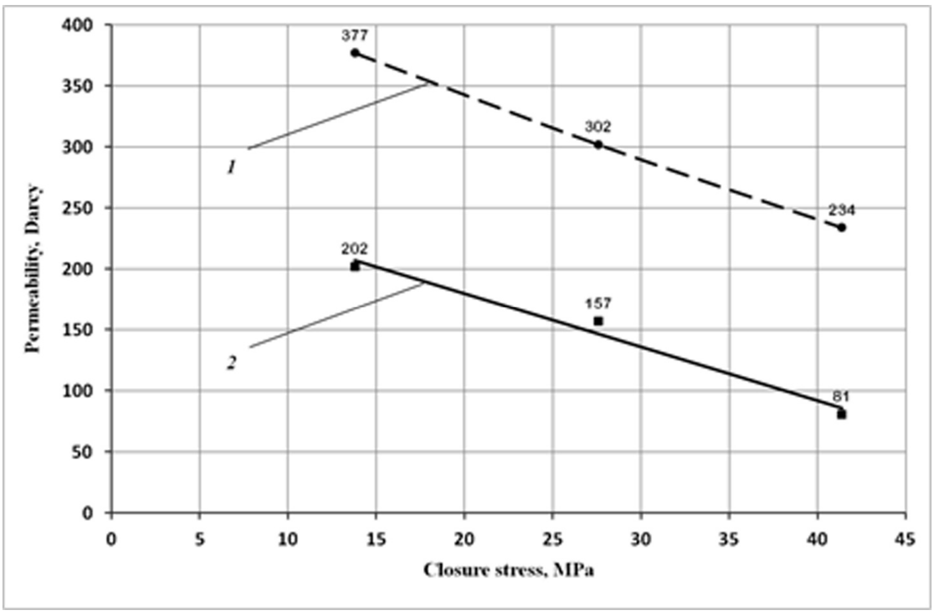

Fig. 1. Dependence of the permeability of the fracture wedged with Borprop 20/40 proppant on the closure stress: 1 – initial permeability; 2 – data obtained at the assembled laboratory unit.

The drawing shows that permeability of the wedged fracture in the coal seam is 2-3 times lower than the initial permeability. This fact shows the influence of coal seam properties on the residual permeability of the wedged fracture.

The world's practice of the strain-stress state's research is widely using the geomechanical modelling. The geomechanical model can be analytical, numerical or the physical one depending on the type of processing of data. The most handling are numerical models which are more accurate and more complex than analytical ones while the physical models are even more acute, however demanding more time and expenses. The key components of numerical models are: vertical stress, minimal horizontal stress, maximal horizontal stress and its direction, as well as the porous pressure and mechanical properties of the rock mas-

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sif. Among the existing methods of measuring of the strain-stress state (finite element method, finite difference, boundary element method and so on) the finite-element technique and the finite difference technique can be accentuated, which are used in the majority of today's software suites for engineering measurements. Upon that, the leading role is given to the finite element method, which is explained with the ability of creation of the geometry of any complexity, and the resulting granularity degree [15]. Thus, during the modelling of coal seams with fractures (the opening of which can reach the value of several millimeters) the achievement of results properly describing the actual stress distribution is impossible without getting of the proper degree of detalization.

Results of the geomechanical modelling of the rock massif on the example of Yerunakovsky geological and economic region of Kuzbass in form of the stress patterns are given on the drawing 2.

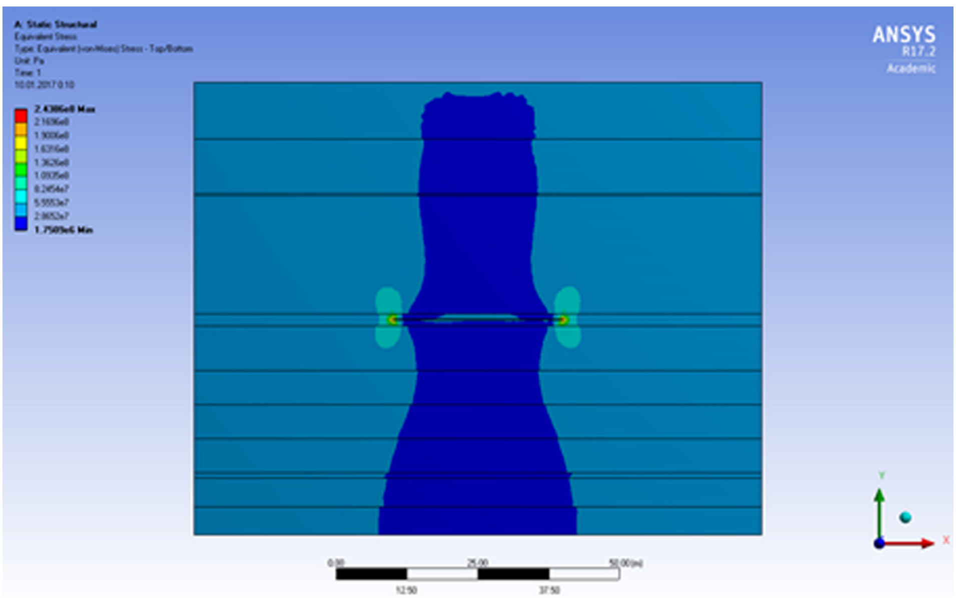

Fig. 2. Distribution of equivalent stresses around the coal seam with the horizontal hydraulic fracturing's resulting fracture of 30 m length and 10 cm opening.

Results show that fractures of the same geometry at different reservoir properties will lead to the different alteration of the natural strain-stress state. Consequently, the hydraulic fracturing requires the individual approach in each particular case.

4 Conclusions

Results of the abovementioned analysis of abstract theorems and research of the possibility of stimulation of coalbed methane production from the virgin coal seams prove the prospectivity of using and improving of the hydraulic fracturing technique with respect to the alteration of strain-stress state of the rock massif around the newly-created fractures. The using of local sand in Kuzbass as the proppant for hydraulic fracturing's resulting fractures appears to be prospective as well.

References

1. R. E. Rogers, K. Ramurthy, G. Rodvelt, M. Mullen, *Coal Bed Methane: Principles and Practices. 2nd ed*, 504 (Starkville, MS: Oktibbeha Publishing Co., 2007)
2. S. Schatzel, K. Aminian, *Coal Bed Methane: From Prospect to Pipeline. 1st ed*, 440 (San Diego, CA, Elsevier Inc., 2014)
3. M. J. Economides, R. E. Oligney, P. Valkó, *Unified Fracture Design: Bridging the Gap Between Theory and Practice*, 262 (Alvin, TX, Orsa Press, 2002)
4. M. J. Economides, T. Martin, *Modern Fracturing: Enhancing Natural Gas Production*, 509 (Houston, TX, Energy Tribune Publishing Inc., 2007)
5. M. A. Baev, Proceedings of the Taishan Academic Forum – Project on Mine Disaster Prevention and Control, 361(2014)
6. I. Palmer, J. Mansoori, SPE Reservoir Evaluation & Engineering, **1:6**, 539 (1998)
7. V. A. Hollub, P. S. Schafer. *A Guide to Coalbed Methane Operations*, 376 (Chicago, IL, Published by Gas Research Institute, 1992)
8. M. J. Economides, A. D. Hill, *Christine Ehlig-Economides. Petroleum Production Systems. 1st ed*, 624 (Upper Saddle River, NJ, Prentice Hall PTR, 1994)
9. F. Gray, *Petroleum Production in Nontechnical Language. 2nd ed*, 288 (Tulsa, OK, Penn Well Publishing Company, 1995)
10. M. J. Economides, K. G. Nolte, *Reservoir Stimulation. 3rd ed*, 856 (New York, NY, John Wiley & Sons Inc., 2000)
11. E. C. Donaldson. *Petrophysics: Theory and Practice of Measuring Reservoir Rock and Fluid Transport Properties. 3rd ed*, 976 (Waltham, MA, Gulf Professional Publishing, Elsevier Inc., 2012)
12. *ISO 13503-2:2006. Petroleum and natural gas industries – Completion fluids and materials – Part 2: Measurement of properties of proppants used in hydraulic fracturing and gravel-packing operations*, 28 (2006)
13. M. A. Baev, V. A. Khyamyalyaynen, Proceedings of the 8th Russian-Chinese Symposium , 330 (2016)
14. *ISO 13503-5:2006. Petroleum and Natural Gas Industries – Completion Fluids and Material.* **5**, 25 (2006)
15. M. D. Zoback, *Reservoir Geomechanics. 1st ed*, 461 (Cambridge, Cambridge University Press, 2010)