NUMERICAL MODELLING OF DRILL WELL PACKER BY USING FINITE ELEMENT METHOD

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ABSTRACT

Construction and operation of cone packer for small diameter drill wells is examined. Its advantages and disadvantages are analyzed. By using finite element method and ANSYS program is investigated stress- strain condition of the packing element of the packer. Matter of modeling is deformed condition of the cylindrical element for different drill well diameters and the intrusion of a cone stem in it. Occurring forces, stresses and deformations in packing element of the packer and at the border "packing element- drill well" are defined. Influence of basic constructive parameters and working conditions on serviceability of the packer are analyzed.

Prospecting drilling for minerals in general is in hard, strong rocks in which faulting structures are met very often. Abovementioned zones are usually presented by hydrothermally altered rocks and quartz layers with different degree of cavities. In such conditions if drilling is from the earth surface water losses occur, and if drilling is from underground, water inflow with 20 l/s rate and 2 MPa pressure are observed. Drilling from underground workings is additionally obstructed because of the fissuration and jointing of rock mass as a result of blasting. The classic way of drill well cement grouting (by pouring out cement grout into the well) as a matter of fact is ineffective because the low pressure of the grouting agent and as a result of it low penetration of the grout into fissures of rock mass. For obtaining better results from grouting in Department of Drilling, Oil and Gas a complex of units is elaborated (V. Arisanov, N. Tchervenakov and all, 1985, 1986,1988). The principal element of this complex of units are the two packers: cone packer (V. Arisanov, N. Tchervenakov, 1985) and cylindrical packer (N. Tchervenakov, V. Arisanov, 1986).

The structure of cone packer is shown on fig. 1. Its function is to insulate zone of grouting from upper- positioned drill well intervals, and by this way to permit to force grout under high pressure. Packer consists of back- pressure valve pos. 1, 2, 3, cone body 4, stopping washer 5, screw spindle 6, elastic packing element 7, pressing washer 8, washer 9, and combined upper adapter- safety adapter 10. The packing element diameter is some bigger of the drill well diameter (60 mm for drill well diameter 59 mm). Excluding washers 5 and 8 and upper adapter 10, diameter of all other elements of the packer are smaller of inner diameter of diamond core bit for the respective well, and for this reason they can be taken out as a core and used many times.

Cone packer must be screwed in lower part of drilling pipe and is descended to required depth into the well without any rotation. Because of the friction with the well wall during dropping down, the packing element rests immobilized. To operate the packer we slowly take up and rotate at the same time the drilling rods. The cone part of the body 4 enters into the opening of packing element, deforms it and press it more strong to drill well wall.



Figure 1. Cone packer

Friction force between the cone 4 and packing element 7 tends to move up the packing element 7, but against it is acting friction force between packing element 7 and well wall. Coming into packing element 7, cone 4 magnifies the friction force between cone and packing element, but in the same time deformation of packing element is increasing and respectively the force, pressing it to well wall is increasing too, i. e. we have

an autowedging effect. If the angle of cone is suitable, friction force between packing element and the well wall is always bigger than the friction force between the cone stem and packing element and packing element rests fixed to the rock. Turning right, screw spindle 6 is screwing into the body 4 and by pressing washer 8 additionally deforms packing element 7 and press it to well wall. Stopping washer 5 prevents packing element 7 from falling down. After putting the packer into action, we are forcing the grouting mix by using circulating drilling fluid pump. After finishing cement grouting, we are taking out the drilling rod from the well by turning it carefully left and in the same time easy lifting it up. As a result of this action. safety adapter 10 is unscrewed from screwing spindle 6. We are taking drill rod together with adapter 10 of the packer out of the well, and other packer elements rest in the well until cement hardens. By this way is prevented cement washing out and ensure high quality of grouting. After cement hardening we lower down diamond core drilling bit and drill again grouted interval. Because the outer diameter of back pressure valve 1, 2, 3, body 4 and screw spindle 6 are smaller than inner diameter of diamond core drilling bit, we take them out of the well as a core and after cleaning we could use them again. Stopping washer 5, packing element 7 and pressing washer 8 should be drilled with the diamond core drilling bit, that why they must be produced of easy drilling matter.

In known packer constructions for fixing the packer to well wall at predetermined depth cone jaws are used. In the abovedescribed construction this action is done by the packing element of the packer. For the purpose its outer diameter is bigger from the drill well diameter and the effect of autowedging occurs when the cone stem is entering into the packing element. This leads to a very simple construction of the packer. In the same time removal of jaws gives the possibility the greater number of details to be elaborated with enough small diameter and to be used as "drilled packer", i. e. to stay in the well until grout becomes hard, and after that to take them out and use them again. Letting the packer to stay in the well during cement hardening is guite effective when grouting zones are with abundant water inflow because it prevents cement grouting to be washed out or forced out from fissures of the rock. But this construction has some disadvantages, part of them removed from later constructions. One of the main disadvantages is if it is put into the well it can't be positioned at upper place, taken out or rotated, because this leads to put it in action. Because of the small difference between packing element diameter and well diameter it can't be used in cavernous zones because of the unavoidable enlargening of well diameter. But we must say that such zones are met not too often in prospecting drilling for minerals.

In this article modeling of packing element deformations of the packer are made during the time in its putting into action. For the purpose, by means of program ANSYS v.5.3 finite element method is used. Occurring forces and deformations of two main stages of packer putting into action are investigated:

- initial deformation of cylindrical packing element as a function of drill well diameter;

- packing element deformation during entering of cone stem into it.

For technologic reasons the packing element is divided into two separate elements. As an packing element is used cylindrical rubber sleeve with outer diameter 60 mm, inner diameter 31 mm and height 40 mm from the lower outer part on which chamfer 3 mm is made. Cylindrical part of the central stem is with a diameter of 30 mm. The angle of cone part of the body is 5°, the small cone diameter is 30 mm, the bigger one is 38 mm, and the height of the cone is 45 mm. For simplification of calculations axial symmetry of the model is used, and later is operated with radiuses. Cylindrical packing element body is divided to 200 finite elements with total sum of 241 nodes and elements type HYPER56 are used with parameters as follow: axially symmetric model, hyperelasticity, nonlinear large deformations. Moonev- Rivlin coefficients 0.8 and 0.2 MPa, temperature 20 deg and Poisson's ratio 0.49. For modeling the contact "packing element- rock" and "packing element- cone" type CONTAC26 elements with linear contact and Coulomb friction law were used. Friction factor is one of the basic parameters, which influence is investigated into the interval 0-0.5.

During first stage, preliminary deformation of packing element was investigated in function of drill well diameter and friction factor between well wall and packing element. This is of great Importance, because it is initial force that holds packing element 7 immobilized during cone stem 4 enters into it. Influence of the change of drill wall diameter from 60 to 59 mm was investigated (5 steps of 0.2 mm) for friction coefficient between the packer and well wall 0; 0.3; 0.5. Results of every step are saved in a file and for every node the information saved is as follows: node number, node coordinates X and Y, displacements on X and Y, vector sum of the displacements, stresses values for SXX, SZZ and SXY. In addition for every step two- dimension graphs with isograms of this parameters are saved. Of particular interest are this parameters for the surface of the packing element and for the contact "packing element - cone", that why they are saved as separate files. On fig. 2 is shown stress distribution into the packing element in radial deformation 0.5 mm (i. e. the packer is positioned in a 59 mm diameter drill well and friction coefficient between the packing element and well wall 0.3)

From fig. fig. 3, 4, and 5 could be seen distribution of radial stresses SXX on the contact "outer diameter of the rubber packing element- drill well". The influence of packing element radius decreasing is investigated in the interval from 0.1 to 0.5 mm, and it corresponds with the change of well diameter from 60 mm to 59 mm with a step of 0.2 mm. Modeling is made for friction factor on the contact "well wall- packing element" 0; 0.3 and 0.5.

From comparisons made is evident, that if friction factor in contact "packing element- rock" increases, compressive stress SXX between packing element and rock increases too. Higher stress concentration is typical for the lower part of the packing element, their values in its upper part are some lower, and the stress values are proportional to friction factor.

The explanation of the fact is as follows- the radial deformation of the packing element causes its longitudinal deformation. In lack of friction there is not anything to obstruct this longitudinal deformation and stresses of the packing element are relatively small. With the increasing of friction factor a friction force occurs and it obstructs the longitudinal deformation and that why radial stresses raise. Because



Figure 2. Radial stresses SXX into the packing element (radial deformation – 0.5 mm, friction coefficient 0.3)

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Figure 3. Radial stresses SXX on the contact "packing element- drill well" (radial deformation 0.1- 0.5 mm, friction factor with the rock 0)

packing element deforms comparatively symmetrically from the middle to the two ends, stresses from friction force are higher at the two ends of the packing element, and where the greatest longitudinal deformations are. This is evident and from fig. fig.6, 7 and 8 too. Investigations are made at friction factor between the packing element and rock 0; 0.3; 0.5. In presence of friction at the middle of the packing element it is clearly seen a zone, where friction force obstructs longitudinal deformations and with growth of friction factor this zone is magnifying.



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Figure 4. Radial stresses SXX on the contact "packing element- rock " (radial deformation 0.1- 0.5 mm, friction factor with the rock 0.3)

File: I51_3_01-05.DAT DR=0.1-0.5mm MU2=0.5





Next stage of packer putting into action is cone stem entering into the hole of cylindrical packing element. The stem causes radial deformations of the packing element, by pressing it to well wall and packer body. At the same time cone stem is trying to push up the packing element, and against it acts friction force between well wall and packing element. The most unfavorable case for putting packer into action is when friction factor between packing element and cone stem is maximal and friction force between the packing element and rock is minimal

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Fiure 6. Longitudinal deformations on outer diameter of the packing element (radial deformation 0.1- 0.5 mm, friction factor with the rock MU2=0)

i.e. we have minimal friction factor between packing element and rock and minimal preliminary packing element deformation. For such case investigations for zero packing element initial deformation DR=0, friction factor between packing element and cone stem MU2=0.3 and friction factor between packing element and rock MU3=0.3 are made. Cone stem has 40 mm total way up and it is divided into 10 steps of 4 mm.

On fig. fig. 9; 10; 11 are shown the radial stresses SXX in the packing element when cone stem has entered 8; 24; and 40 mm into it. On fig. fig. 12; 13; 14 vertical stresses SYY into the packing element at the same conditions are shown. The simulation of cone stem entering into cylindrical packing element shows stability of packer putting into action even in the most unfavorable conditions- near to zero initial deformation of the packing element and equal friction factor for the two contacts: packing element- rock and packing element-cone. Using the above- discussed method, 34 numerical experiments were made at different values of input parameters with 560 total steps of change of input parameters. Input parameters varied as follows:

- friction factor of packing element with the rock and with the cone stem- 0.3 and 0.5;

- initial deformation of the packing element- from 0 to 0.5 mm with 0.1 mm step i. e. it was simulated well wall diameter 59-60 mm;

vertical pass of the cone stem from 0 to 40 mm with a step of 4 mm;

rubber elasticity modulus 2; 4; 6 and 8 MPa.



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Figure 7. Longitudinal deformations on outer diameter of the packing element (radial deformations 0.1- 0.5 mm, friction factor with the rock MU2=0.3)

File: I51_3_01-05.DAT

DR=0.1-0.5mm MU2=0.5



Figure 8. Longitudinal deformations on outer diameter of the packing element (radial deformations 0.1- 0.5 mm, friction factor with the rock MU2=0.5)

The packer reacted safely for all combinations of input parameters. Construction discussed is tested in practice and it sowed definitely sure action.



Figure 9. Radial stresses SXX in packing element (cone stem pass DH=8 mm)



Figure 10. Radial stresses SXX in packing element (cone stem pass DH=24 mm)



Figure 11 Radial stresses SXX in packing element (cone stem pass DH=40 mm)



Figure 12. Longitudinal stresses SYY into the packing element (cone stem pass DH=8mm)



Figure 13. Longitudinal stresses SYY into the packing element (cone stem pass DH=24mm)

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Fig. 14. Longitudinal stresses SYY into the packing element (cone stem pass DH=40mm

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