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Satbayev University

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ИЗВЕСТИЯ

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IMPROVING THE DESIGN OF INCLINED WELLS AS THE BASIS FOR THE DEVELOPMENT OF HARD–TO-RECOVER HYDROCARBON RESERVES

Abstract. The basis for the extraction of hard-to-recover reserves (HTRR) of hydrocarbon raw materials (HM) are technologies for drilling cluster inclined wells. The importance of this approach lies in the fact that the development of HTRR qualitatively affects the growth of the capacity of the extractive and processing industries of the oil and gas complex. This article discusses the methodology for improving the design of cluster inclined wells, which allows to estimate the values of their parameters. This article provides a calculation scheme that allows estimating the values of the parameters of cluster of inclined wells according to the data on the coordinates of their wellheads. For high-quality planning and design of cluster inclined wells, it is necessary to develop (improve) methods for determining the main parameters of the profile, assess the influence of various factors on the choice of profile, which is important in the design of profiles, as well as the justification and selection of technical and technological solutions. Studies have shown that the process of controlling the drilling of a cluster of inclined wells includes a number of successive stages of determining the position of the drilled part of the wellbore in space, making decisions that ensure the orientation of the wellbore in a given direction, and their implementation.

Briefly, what has been noted is in the design of cluster drilling of wells, including the assessment and refinement of the coordinates of the wells, taking into account the relative position and distance from the wellhead, the target and the point of preventing the shafts from contacting. An appropriate algorithm is proposed for estimating rectangular coordinates. Using this algorithm, the geographic coordinates of the drilled wellhead and the target point are recalculated in accordance with the projection coordinates. At the same time, it is necessary to check the coincidence of the results of calculations of the geographical coordinates of each well with the values of geographical coordinates provided by the company, to assess the accuracy of the data when moving from one coordinate system to another, according to the scheme given in the article. All of the above stages can form a mathematical basis for setting the problem and developing software for controlling the curvature of the trajectories of wells drilled from well in the field considered in the future.

Key words: Extractive and processing industries, Inclined wells, drilling technology, cluster drilling, azimuth, coordinates, projection, trajectory, curvature, algorithm

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КӨЛБЕУ ҰҢҒЫМАЛАРДЫ ЖОБАЛАУДЫ ЖЕТІЛДІРУ-КӨМІРСУТЕГІ ШИКІЗАТЫНЫҢ АЛЫНУЫ ҚИЫН ҚОРЛАРЫН ИГЕРУДІҢ НЕГІЗІ

Аннотация. Көмірсутегі шикізатының (КШ) алынуы қиын қорларын (АЛҚҚ) өндірудің негізі –шоғырлы көлбеу ұңғымаларды бұрғылау технологиясы. Мұндай тұжырымның маңыздылығы сол, АЛҚҚ игеру мұнай-газ кешенінің өндіруші және өңдеуші салалары қуатының өсуіне сапалы түрде әсерін тигізеді. Бұл мақалада шоғырлы көлбеу ұңғымаларды жобалауды жетілдірудің әдісі олардың параметрлерінің мәндерін бағалауға мүмкіндік беретіндей етіп қарастырылады. Шоғырлы көлбеу ұңғымаларды сапалы түрде жоспарлау және жобалау үшін бейіннің негізгі параметрлерін айқындау әдістерін әзірлеу (жетілдіру), бейіндерді жобалау кезінде маңызды мәні бар бейінді таңдауға әртүрлі факторлардың әсерін бағалау, сондай-ақ техникалық-технологиялық шешімдерді негіздеу және таңдау қажет. Зерттеулер көрсеткендей, көлбеу ұңғымалар шоғырын бұрғылауды басқару процесі ұңғыманың бұрғыланған бөлігінің кеңістіктегі орнын

анықтау, ұңғыманың оқпанын белгілі бір бағытта бағыттауды қамтамасыз ететін шешімдер қабылдау және оларды жүзеге асыру бойынша бірқатар дәйекті кезеңдерді қамтиды.

Қысқаша айтқанда, ұңғымаларды шоғырлы бұрғылауды жобалау дегеніміз, ұңғымалардың координаталарын бағалау және нақтылауды олардың өзара орналасуы мен ұңғыманың сағасынан қашықтығын, оқпандардың жанасуын болдырмайтын мақсаттар мен нүктелерді ескере отырып жүзеге асыруды айтамыз. Тікбұрышты координаталарды бағалау үшін сәйкес алгоритм ұсынылады. Осы алгоритмді қолдана отырып, бұрғыланған сағаның және мақсатты нүктенің географиялық координаталары проекцияның координаттарына сәйкес қайта есептеледі. Айта кететін жай, әрбір ұңғыманың географиялық координаталарын есептеу нәтижелерінің компания ұсынған географиялық координаттар мәндерімен сәйкестігін тексерудің, сондай-ақ мақалада келтірілген схемаға сәйкес координаттардың бір жүйесінен екіншісіне ауысу кезіндегі деректердің дәлдігін бағалаудың қажеттігі. Аталған барлық кезеңдер, алдағы қарастырылатын кен орындарында шоғырлы алаңшалар арқылы бұрғыланатын ұңғымалардың траекторияларының қисаюын басқару үшін міндеттер қою және бағдарламалық қамтамасыз етуді әзірлеудің математикалық негізін құрауы мүмкін.

Түйін сөздер: өндіруші және өңдеуші салалар, көлбеу ұңғымалар, бұрғылау технологиясы, шоғырлы бұрғылау, азимут, координаталар, проекция, траектория, қисықтық, алгоритм.

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СОВЕРШЕНСТВОВАНИЕ ПРОЕКТИРОВАНИЯ НАКЛОННЫХ СКВАЖИН – ОСНОВА ОСВОЕНИЯ ТРУДНОИЗВЛЕКАЕМЫХ ЗАПАСОВ УГЛЕВОДОРОДНОГО СЫРЬЯ

Аннотация. Основой добычи трудноизвлекаемых запасов (ТРИЗ) углеводородного сырья (УС) являются технологии бурения кустовых наклонных скважин. Важность такого подхода заключается в том, что освоение ТРИЗ качественно влияет на рост мощности добывающих и перерабатывающих отраслей нефтегазового комплекса. В настоящей статье рассматривается методика совершенствования проектирования кустовых наклонных скважин, позволяющая оценить значения их параметров. Для качественного планирования и проектирования кустовых наклонных скважин необходимы разработка (совершенствование) методов определения основных параметров профиля, оценка влияния различных факторов на выбор профиля, что имеет важное значение при проектировании профилей, а также обосновании и выборе технико-технологических решений. Исследования показали, что процесс управления бурением куста наклонных скважин включает ряд последовательных этапов по определению положения пробуренной части ствола в пространстве, принятию решений, обеспечивающих ориентирование ствола скважины в заданном направлении, и их реализацию.

Вкратце отмеченное заключается в проектировании кустового бурения скважин, включающем оценку и уточнение координат скважин с учетом взаимного расположения и расстояния от устья скважины, цели и точки предотвращения соприкосновения стволов. Для оценки прямоугольных координат предложен соответствующий алгоритм. С применением данного алгоритма географические координаты пробуренного устья и целевой точки пересчитываются в соответствии с координатами проекции. При этом необходимо проверить совпадение результатов расчетов географических координат каждой скважины со значениями географических координат, предоставленными компанией, оценить точность данных при переходе от одной системы координат к другой, согласно приведенной в статье схеме. Все отмеченные этапы могут составить математическую основу для постановки задачи и разработки программного обеспечения управления искривлением траекторий скважин, бурящихся с кустовых площадок на рассматриваемом в дальнейшем месторождении.

Ключевые слова: добывающие и перерабатывающие отрасли, наклонные скважины, технология бурения, кустовое бурение, азимут, координаты, проекция, траектория, искривление, алгоритм.

Introduction. The development of HTRR plays an important role in the sustainable development of extractive and processing industries. They are additional sources in the total volume of HM. In this regard, the technology of drilling bush inclined wells is given great importance, since they form the basis of technical means for the development of HTRR. One of the main problems in drilling of inclined wells is the presence of following factors: increased friction with a complex profile, insufficient stability of the drill string and the need to build curvature, the complexity of the profile due to insufficient displacement from the wellhead to the opening point of the intended productive formation, finding the final from a technological point of view in the "non-preferred area" of drilling due to the high risks of getting complications in the coordinates of bottomholes. To improve the efficiency of drilling of cluster inclined wells, at different times, calculation schemes providing the step-by-step optimization of well profiles and projections based on the coordinates of their wellheads have been proposed and implemented. As a result of which reasonable, effective and economically justified technical and technological solutions have been developed (M.M. Fattakhovet.al, 2016; Muratov O.V. et.al). In the modern literature, a sufficient number of research results have accumulated on the issues of cluster drilling of inclined, branched-horizontal and horizontal wells. An analysis of the studies conducted in recent years has shown their consistency, where researchers from Kazakhstan, Russia and Azerbaijan continue to take an active part (Scherbakova A.V. et.al, 2019). The results of the generalization of these developments showed that, from the point of view of the well profile, they are divided into two conditional categories: "normal profile" and "complex profile". The latter of them is considered technically unrealizable, or implemented with unproductive time using a typical drilling tool.

It should be noted that in the process of cluster wells drilling, the technology and the strategy of drilling out the deposit may change. In some cases, it is possible to change the sequence of drilling, the purpose of wells, the method of their completion - both in terms of facilitating their construction, and obtaining more accurate geological information.

Experience shows that cluster drilling can significantly reduce the amount of work associated with construction and installation operations, reduce the amount of construction of roads, power lines and communications, simplify the maintenance of wells in operation, decrease the volume of transportation, etc.

Before drilling a particular well, geological information is usually obtained and analyzed, geomechanical models are built, if possible, taking into account the entire set of initial data, including data from previously drilled wells. At the same time, methods for selecting the coordinates of well bottoms based on calculations are used, taking into account the coordinates of their wellheads (Serapinas B.B et.al; Wenhao X.U. et.al, 2019; Liu X.Y. et.al, 2012), all this allows to make a reasonable choice of a drilling tool and other technical and technological solutions in the future. To optimize well profiles, both shifting the coordinates and changing the azimuth of the wellbore at the bottom of the well and at the point of entry into the formation, and considering the option of well drilling from neighboring cluster areas are possible.

Materials and methods. Thus, for high-quality planning and design of cluster inclined wells, it is necessary to develop (improve) methods for determining the main parameters of the profile, assess the influence of various factors on the choice of profile, which is important in the design of profiles, as well as in the justification and selection of technical and technological solutions.

In this regard, this article provides a calculation scheme that allows to evaluate the values of the parameters of cluster inclined wells according to the coordinates of their wellheads.

When developing and designing measures to prevent encounters and collisions of shafts that make up a cluster, as a rule, problems arise due to the incompatibility of the conditions for calculating the drilled route and software when designing the parameters of cluster wells.

The designs of the wells included in the cluster differ in the chosen coordinate system, the method of calculating the trajectory, the initial depth of the well, used when constructing the cluster of drilled wells. In this case, data on wells must be processed using data on previously drilled wells (Wenhao X.U. et. al). A number of researchers considered optimization technology for preventing collisions of a large group of wells.

So, in order to assess and clarify the coordinates of wells, the author consider the relative position and distance of the wellhead, the goals and points of prevention of shaft contact, and, as noted in the works of recent years, all this is the basis for the design of cluster drilling of wells. As it is known, the relative position and distance between two points on the earth can be determined by geographic coordinates and the depth of the vertical position. In this regard, the so-called Gauss-Kruger projections are built on the basis of geographical coordinates in (Wenhao X.U. et. al). Taking into account the recommendations of this work, the sequence of calculations can be represented using the block diagram shown in Figure 1.

Using this algorithm, the geographic coordinates of the drilled wellhead and the target point are recalculated in accordance with the projection coordinates. At the same time, it is necessary to check whether the results of calculating the geographic coordinates of each well coincide with the geographic coordinates provided by the company, to assess the accuracy of the data when moving from one coordinate system to another, according to the scheme shown in Figure 1. The flow chart also refers to the assessment and calculation of risks, which is carried out according to the experience accumulated to date (Khismetov T.V. et.al, 2006).

Results. To calculate and build a plan of cluster wells, it is necessary to take into account the position of their intakes on the platform. For this, a base well is selected, the intake of which is taken as the origin of the coordinate system. When calculating vertical and horizontal projections of any well from another platform, the initial coordinates are determined relative to the intake of the base well (Khismetov T.V. et.al, 2006; Gasanov I.Z. 2001). For this purpose, the intakes of all cluster wells are tied to the base wells. The well that should be drilled for the first time, by the first or second drilling rig, is taken as the base well (Fig. 2.).

When determining the current coordinates of any (second) well, one should take into account the coordinates of its intake A (X_A, U_A, Z_A) relative to the intake of the base (first) well B (X_0, Y_0, Z_0).

$$\begin{cases} X_A = h \cdot \cos\varphi_c \\ Y_A = h\sin\varphi_c \\ Z_A = Z_0 + \Delta Z_0 \end{cases} \quad (1)$$

where, ΔZ_0 – wellhead height difference, $h = \sqrt{a^2 + (\sum b_i)^2}$ – the distance between the intakes of drilling wells on a cluster, α – the distance between rows of wells on a cluster, b_i – the distance between the wellheads located in the same row.

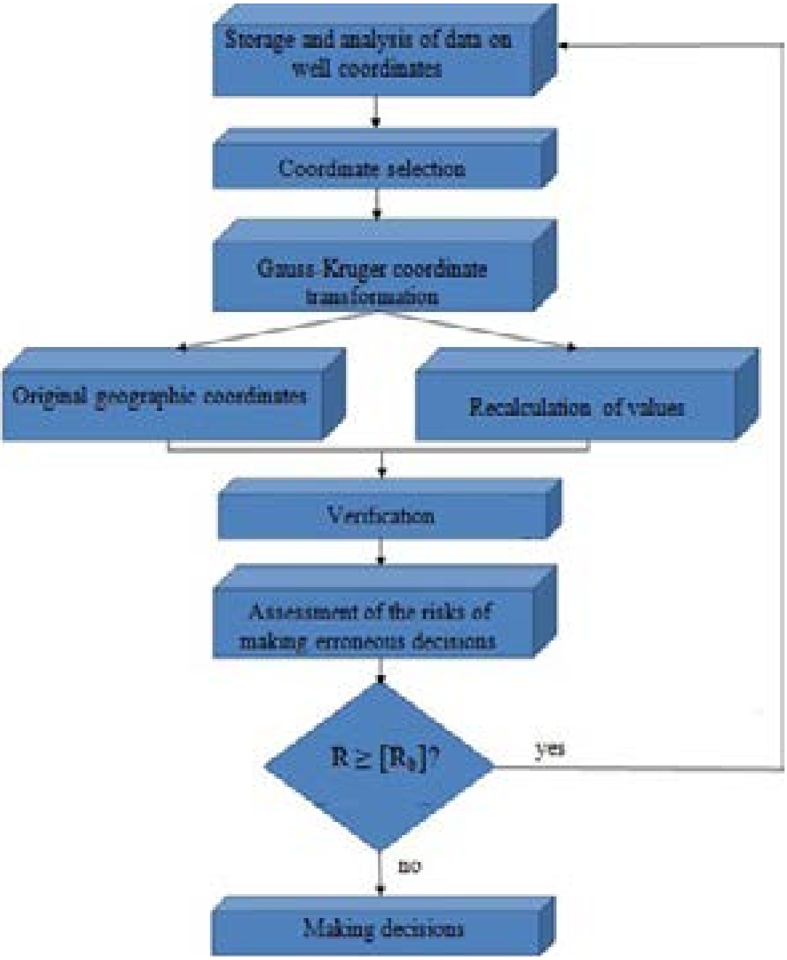

Fig.1 - Block diagram of decision making when refining the coordinate system.

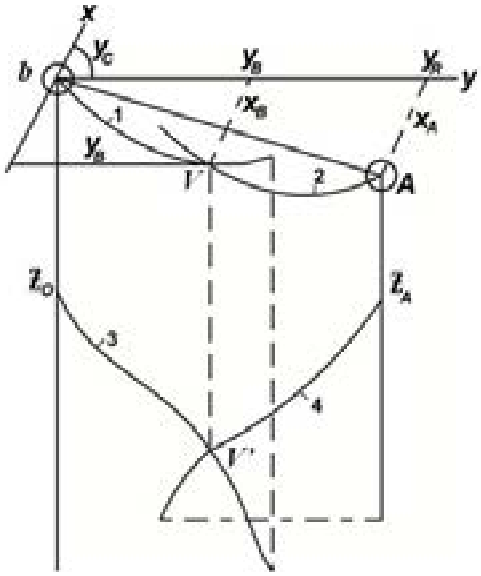

Fig. 2 - Scheme of convergence and meeting of cluster well shafts:
1, 2 - horizontal projections of two cluster wells,
3, 4 - vertical projections (profiles) of two cluster wells.

The azimuth of the installation ψ_i of the deflecting BHA (bottom hole assembly) for changing the azimuth $\Delta\varphi$ and the zenith angle $\Delta\alpha$ is determined by graphical or analytical methods. To determine the angle ψ_i graphically, it is necessary to construct a triangle ΔOAB (Fig. 3)

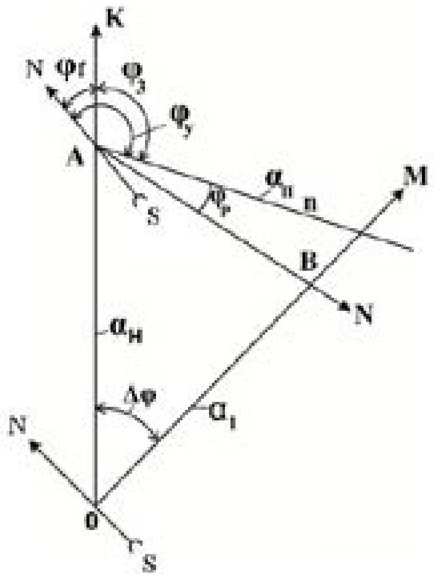

Fig. 3 - Scheme determining the drilling angle and setting the deflector.

For this purpose, from a certain point O in the direction of the actual well azimuth φ_f a segment OA is deposited, equal (on a certain scale) to the numerical value of the zenith angle α_f, at the beginning of drilling. Then, a line OM is drawn from the point O, forming an angle Δφ, with the segment OA, equal to the zenith angle α_e, which must be obtained while drilling after working with the deflector. The straight line AB drawn through points A and B shows the direction of action of the deflector relative to the actual azimuth of the well, and the angle BHA is equal to the angle φ_d, called the drilling angle. With this method, the azimuth of the deflector installation is determined by the formula:

$$\psi_i = \varphi_f + \varphi_d + \varphi_p \qquad (2)$$

where, φ_p – the angle of twist of the drill strings from the action of the reactive moment of the downhole motor, φ_f – the actual borehole azimuth at the beginning of drilling.

In an analytical way, the values of the drilling angle for the case of reduction, stabilization of the zenith angle and azimuth change are determined by the appropriate formula

$$\varphi_d = 180^0 + \operatorname{arctg}\frac{\sin\Delta\varphi}{\cos\Delta\varphi - tg\alpha_H/tg\alpha_k} \qquad (3)$$

For other purposes (tasks) of curvature, the angle values must be determined from the expression:

$$\varphi_d = 360^0 + \operatorname{arctg}\frac{\sin\Delta\varphi}{\cos\Delta\varphi - tg\alpha_H/tg\alpha_k} \qquad (4)$$

The spatial value of the zenith angle α_s and the length of the drilling interval ΔL required to obtain the required values of the zenith angle α_T and azimuth φ_T are determined by the formulas, respectively:

$$\alpha_\Pi = \alpha_T \frac{\sin\Delta\varphi}{\sin\varphi_z}, \qquad (5)$$

$$\Delta L = \frac{\alpha_\Pi}{i_0} \qquad (6)$$

where, i_0 – the rate of change in the zenith angle per 1 m of penetration, obtained when using this BHA to correct the trajectory of the wellbore axis.

Discussion. Theoretical studies and practical experience accumulated to date have shown that the process of controlling the drilling of a cluster inclined wells includes a number of successive stages of determining the position of the drilled part of the wellbore in space, making decisions that ensure the orientation of the wellbore in a given direction, and their implementation. Briefly, what has been noted is in the design of cluster drilling of wells, including the assessment and processing of the coordinates of the wells, taking into account the relative position and distance from the wellhead, the target and the point of preventing the shafts from contacting.

Conclusion. To estimate rectangular coordinates, an algorithm is proposed, according to which, at the initial stage, data on well coordinates are collected and analyzed, transformation of geographic coordinates into rectangular ones, verification, calculation of the azimuth of the whipstock installation, drilling angle, spatial value of the zenith angle, length of the interval necessary to obtain the required values of the zenith angle and azimuth, clarification of the deflector angle value depending on the received actual bottom hole coordinates and making technological decisions - correcting the wellbore trajectory, the decision to change the layout based on the results of comparing the actual and design well profile have been carried out. All of the above stages can form a mathematical basis for setting the problem and developing software for controlling the curvature of the trajectories of wells drilled in the cluster areas in the field considered in the future.

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