УДК 622.243.23

# УГОЛ ОРИЕНТАЦИИ ОТКЛОНЯЮЩЕГО ИНСТРУМЕНТА В СКВАЖИНЕ

# THE ANGLE OF ORIENTATION DEFLECTING TOOL IN THE WELL

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**Аннотация.** В статье описан графический метод определения угла ориентации отклоняющего инструмента в скважине и определения его пространственной кривизны.

**Ключевые слова:** кривизна скважины, ориентация инструмента, пространственная кривизна, оперативный контроль, полезные ископаемые, разведка скважин.

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**Annotation.** The article describes a graphical method for determining the orientation angle of a deflecting tool in a well and determines its spatial curvature.

**Keywords:** borehole curvature, tool orientation, spatial curvature, operational control, minerals, well exploration.

The drilling of inclined wells is usually carried out along a pre-designed profile on a vertical plane passing through the mouth and the design bottom. In this case, the intensity of the curvature is equal to the ratio of the difference in zenith angles at the end and at the beginning of any interval to the length of the same interval. Often, for certain reasons, the well axis has the shape of a spatial curve [1]. This occurs, as a rule, with the natural curvature of the well and the wrong orientation of the tool due to operator error [2]. As a result, the bottom hole moves away from the vertical plane. Therefore, to ensure the opening of the productive formation in the area provided for by the project, it becomes necessary to control the parameters of the curvature of the well.

Operational control or regulation of the curvature parameters is usually carried out by a layout with an orientable deflector, and, if necessary, by means of regulation of the zenith angle with a non-orientable layout [3]. The intensity of the change in angles most often depends on the angle between the plane of action of the whipstock passing through the top and bottom axis of the whipstock, or the direction and the vertical plane passing through the tangent drawn to the axis of the well. This angle is called the orientation direction angle.

To change the zenith angle of the well by Δα, the azimuth by Δφ with an oriented layout, the direction (azimuth) of the orientation of the deflecting tool is determined in two ways – graphical and analytical. The angle of orientation relative to the actual direction of the well is denoted by ψ and is called the drilling angle. To determine this angle graphically, we build a triangle OAO (Fig. 1).

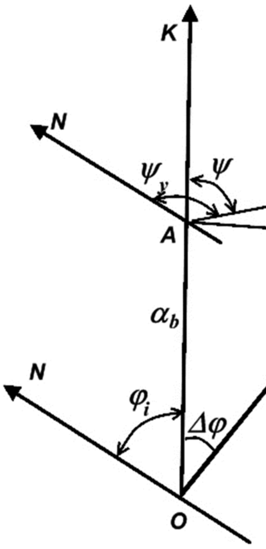

**Fig. 1** – Scheme for determining the orientation angle of the deflecting tool in the well

To do this, from an arbitrary point O, we draw a line OK in the direction of the actual well azimuth φ and mark on it with an accepted scale (for example, 10 = 5 mm) segment OA, equal in value to the zenith angle of the well α at the beginning of the run. Then, from the point O, we draw the line OM, which makes an angle equal in value to the change in azimuth at the end of the flight (Δφ) with the line OA. On the OA line, we mark the segment OB (OB = αs), equal to the zenith angle of the well at the end of the interval of work with an orientable assembly. Line AB shows the direction of action of the deflecting tool relative to the actual well azimuth (ψ = ∠KAV). The length of the line AB is equal in value to the spatial curvature of the well Δα, i.e. angle of spatial curvature multiplied by the accepted scale. The angle oriented relative to the north direction of the deflecting tool in the well is denoted ψ and is called the orientation or direction angle. If we assume that the angle of rotation of the drill pipes depends on the reactive moment of the downhole motor $\varphi_R$, then the angle of orientation of the whipstock will be determined based on the figure by the formula:

$$\psi_y = \varphi_i + \psi + \varphi_R. \tag{1}$$

The angles ψ and Δα can also be determined analytically in a simpler form. To do this, we write according to the sine theorem from ∆OAB:

$$\frac{\alpha_b}{\sin(\psi-\Lambda\varphi)} = \frac{\alpha_s}{\sin(180-\psi)}. \tag{2}$$

$$\frac{\Delta\alpha_f}{\sin\Lambda\varphi} = \frac{\alpha_s}{\sin(180-\psi)}. \tag{3}$$

Solving these expressions together, we get:

$$\frac{sin\ {}_{\Delta\varphi}}{\cos\Lambda\varphi-\frac{\alpha_b}{\alpha_s}}\ . \tag{4}$$

$$\Delta\alpha_f = \alpha_s\frac{sin\ {}_{\Delta\varphi}}{\sin\psi}. \tag{5}$$

The values of $\Delta\alpha_f$, based on the cosine theorem from ∆OAB, can be determined from the following equality:

$$\Delta\alpha_f^2 = \alpha_b^2 + \alpha_s^2 - 2\alpha_b\,\alpha_s cos\Delta\varphi$$

or

$$\Delta\alpha_f = \sqrt{(\alpha_s-\alpha_b)^2 + 4\alpha_b\alpha_s sin^2\frac{\Delta\varphi}{2}}. \tag{8}$$

Therefore, expression (8) can be written in a more simplified form:

$$\Delta\alpha_f = 2\sqrt{(\frac{\Delta\alpha}{2})^2 + \alpha_b\alpha_s sin^2\frac{\Delta\varphi}{2}}\ \text{deg/m}. \tag{9}$$

If we assume that $\alpha = \alpha_b = \alpha_{or} = \frac{\alpha_b+\alpha_s}{2}$,then we get:

$$\Delta\alpha_f = 2\sqrt{(\frac{\Delta\alpha}{2})^2 + (\alpha\, sin\,\frac{\Delta\varphi}{2})^2}\ \text{deg/m}. \tag{10}$$

Consequently, the spatial curvature can be calculated taking into account the orientation angle of the tool using formula (9), in other cases, i.e. when working with non-orientable layouts – according to the formula (10).

Knowing the increase in space of the zenith angle in a certain interval $\Delta\alpha_f$, one can determine the length of this interval using the following formula:

$$\Delta L = \frac{\Delta\alpha_f}{i_\alpha} = \frac{\alpha_s}{i_\alpha}\frac{sin\Delta\varphi}{sin\psi}, \tag{11}$$

where $i_\alpha$ – the intensity of the curvature when working with a deflecting layout; $\psi$ – drilling angle, selected depending on the purpose of the borehole curvature.

If it is necessary to reduce the zenith angle or keep it stable and change the azimuth, then the value of ψ is calculated by the formula:

$$\psi = 180 + arctg\frac{sin\Delta\varphi}{\cos\Delta\varphi-\frac{\alpha_b}{\alpha_s}}\ . \tag{12}$$

If it is necessary to increase the zenith angle and change the azimuth, then

$$\psi = 360 + arctg\frac{sin\Delta\varphi}{\cos\Delta\varphi-\frac{\alpha_b}{\alpha_s}}\ . \tag{13}$$

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