Research of Tunnel Directional Gamma Spectrum Measurement Method

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Abstract

A technical proposal of directional gallery gamma energy spectrum measurement is developed and demonstrated. the main tasks we will accomplish as follows: (1) According to the attenuation law of gamma ray in the shield, we calculate the transmittance range of the shielding body by using the least square fitting method, then we establish simulation model using MCNP, and we calculate the transmittance of the probe shield by the combination of simulation and theory. (2) The same rock face of gallery was measured by severally using gamma spectrometers with shielding substance probe and without it, then, by using difference of two times measurement, theoretical formula of net count that had been eliminate effects from ambient rock faces was acquired. (3) U, Th, K equations were established by using the instruments for calibration with five scale model of a given U, Th, K content. This proposal was preliminarily applied by utilizing datum of directional gamma energy spectrum measurement from tin ore of cuprum pit in tunnel 216 and tunnel 218 of the middle 225 and tunnel 216 and tunnel 218 of the middle 305 in Dachang Bureau of Mines in Guangxi.

Keywords

Directional Gallery, Spectrum Measurement, MCNP, Transmissivity, Instrument Calibration.

1. Introduction

Gamma energy spectrum measurement has been gradually developed in measuring mines, however, the technologies of gamma energy spectrum measurement which are applied to land, aviation and gallery still need to be improved, especially the technology of gallery gamma energy spectrum measurement [1]. Currently there are less researches into the technology of gallery gamma energy spectrum measurement at home and abroad, which work involved is not a lot, but from its importance in prospecting, calculating metal mineral deposits etc., latent capacity of the technology is very large. Gallery gamma energy spectrum measurement can become an efficient method of uranium mine prospecting for prospecting near surface uranium mine in the basin and forecasting possible developing areas of uranium mine in the depth of surface [2].

When gamma energy spectrum measurement is launched in the gallery, instrument probe not only receive gamma ray from the face measured, but gamma radiation from tunnel wall. If the jam from other unmeasured faces can't be removed, accurate data reflecting the measured face would not be obtained. In order to solve the influence from tunnel wall radiation on the measuring point, this paper offers a means of directional gallery gamma energy spectrum measurement based on using shielding material and cancelling shielding substance. This technical proposal plays an important role in outlining mineralization alteration zone of metal, stratigraphic division, exploration metal ore and nonmetallic ore.

2. Directional gallery gamma energy spectrum measurement

The plan of directional gallery gamma energy spectrum measurement is shown in Fig 1. Directional gallery gamma energy spectrum measurement is carried out to meter the same rock wall by using gamma spectrometry tools with shielding substance and without it. geting the gamma count rates[3] $I_{with\ shielding}$ and $I_{without\ shielding}$. where $I_{without\ shielding} = I_{rock} + I_{environment}$ and $I_{with\ shielding} = I_{rock} + \alpha I_{environment}$, $I_{环境}$ is the gamma count rate from surrounding environment and ∂ represents the transmissivity of shielding substance in technical proposal[4].

$$\nabla I = I_{without\ shielding} - I_{with\ shielding} = (1-\partial) I_{environment} \tag{1}$$

So

$$I_{environment} = \frac{I_{without\ shielding} - I_{with\ shielding}}{1-\partial} \tag{2}$$

And we can get that the gamma count rate of rock wall of measuring point I_{rock} is the function of $I_{with\ shielding}$ and $I_{without\ shielding}$.

$$I_{rock} = I_{without\ shielding} - I_{environment} = I_{without\ shielding} - \frac{I_{without\ shielding} - I_{with\ shielding}}{1-\partial} \tag{3}$$

If the value of ∂ is known, we can calculate the value of I_{rock}, according to the same principle, we can work out the contributing count rates of rock about U, Th and K.

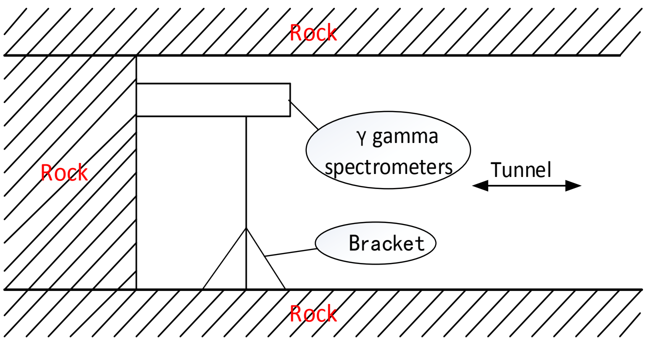

Fig. 1 System model of gallery gamma energy spectrum measurement

3. The transmissivity of probe shielding substance in the gamma spectrometer

3.1 Theoretical arithmetic of the transmissivity of probe shielding substance

According to material, thickness and transmission law on different energy gamma ray of shielding substance[5-7], by using maximum and minimum of distance penetrated of shielding substance, maximum ∂_{Max} and minimum $\partial_{\min}$ of transmissivity were worked out to obtain range of transmissivity of the shielding substance ($\partial_{\min}, \partial_{Max}$). Minimum of distance of shielding substance penetrated by gamma ray was linear distance which gamma ray vertically passed through in shielding substance, each thickness of shielding substance, and maximum distance was afocal.

According to absorption law of each shielding substance on gamma ray, the transmissivity of gamma ray in lead, stainless steel and aluminum could be obtained by using least square fitting. When gamma ray, 1.46MeV, 2.62MeV, 1.76MeV, passed through minimum distance, the result of transmissivity of each shielding substance fitted was shown as Table 1.

Table 1. Transmissivity of shielding substance when distance penetrated is minimum

Er(MeV)	1.46	2.62	1.76
The transmissivity of lead α_1	0.5451	0.6332	0.5892
The transmissivity of aluminium alloy α_2	0.6713	0.7851	0.7015
The transmissivity of stainless steel α_3	0.9319	0.9268	0.9266
Total transmissivity α	0.34	0.46	0.38

Total transmissivity and transmissivity fitted in this time was the maximum transmissivity . Transmissivity was minimum ($\alpha_{\min}=0$) when gamma ray pierced through infinitely long distance. In this way, range of transmissivity of shielding substance was obtained and shown as Table 2.

Table 2 .The range of transmission when gamma rays of different energy pass through the shield

Er(MeV)	1.46	2.62	1.76
Range of transmissivity	(0, 0.34)	(0, 0.46)	(0, 0.38)

3.2 Ensuring the transmissivity of probe shielding substance by MCNP simulation

The size of this model is shown as Fig 2 and structure and size of detector are given in Tab 3.

There are three kinds of normal sources of gamma ray simulated (1.46MeV,2.62MeV,1.76MeV), which are all single energy and circular column source. Gamma photon number simulated in each condition was five hundred million and detector used was F5a ring detector. The transmissivity of probe shielding substance could be ensured by using mothed of combining simulation and theory and result was shown as Tab 4.

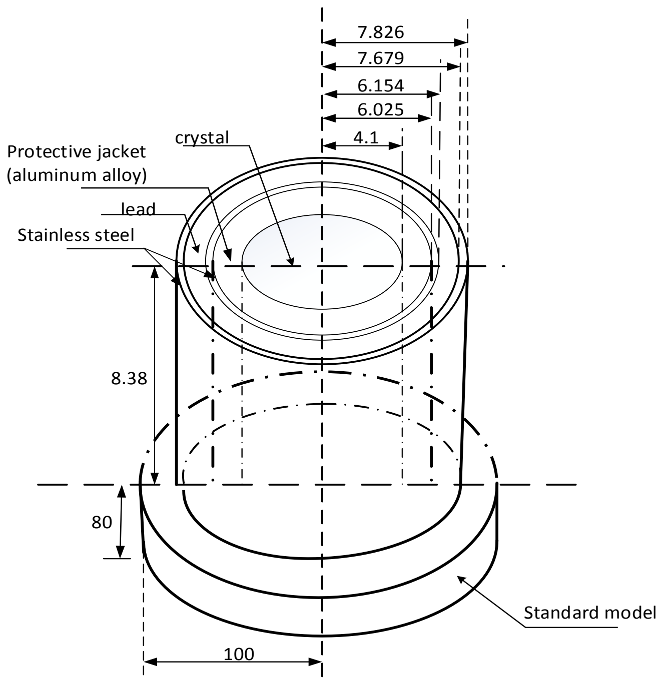

Fig. 2 The size of detector

Table 3. Structure and size of detector

Structure of detector with shielding substance	Size
Crystal (NaI(Tl))	High 8.38 cm, radius 4.1cm
Protective casing (aluminium alloy)	High 8.38 cm, thickness 1.925cm
Stainless steel (double-deck)	High 8.38 cm, thickness 2*0.129cm
Lead sheath	High 8.38 cm, thickness 1.543cm

Table 4. The transmissivity of different energy gamma ray penetrating shielding substance obtained by simulating

Er(MeV)	1.46	2.62	1.76
Transmissivity	0.2	0.24	0.22

4. Confirming content equations of U, Th and K

4.1 Graduationre of instrument

On the basis of the method of graduating instrument[8, 9], we could establish fifteen dial equations based on five models, including background model, uranium model, thorium model, kalium model and mixed model, which their contents of U, Th and K are given.

$$
\begin{aligned}
I_{\text{rock}\,i}^{U} &= a_1U_i + b_1Th_i + c_1K_i \\
I_{rock\,i}^{Th} &= a_2U_i + b_2Th_i + c_2K_i \\
I_{rock\,i}^{K} &= a_3U_i + b_3Th_i + c_3K_i
\end{aligned}
\tag{4}
$$

Among equations, U_i, Tu_i and K_i severally represent contents of U, Th and K given from five equations.severally represent five standard models. a_1~a_3, b_1~b_3, c_1~c_3 are coefficient of sensitivity.

Counting rates and contents of U, Th and K form the five models are shown as Table 5.

Table 5. contents of U, Th and K and counting rates

Model number	Net counting rate of rock			Content without background (given)		
	Peak of K	Peak of U	Peak of Th	K(%)	U(g/t)	Th(g/t)
Background model	0.00	0.00	0.00	0.00	0.00	0.00
Kalium model	8.39	0.76	0.53	4.28	2.54	5.5
Thorium model	20.22	17.41	35.04	0.38	6.56	368.81
Uranium model	40.45	39.61	0.52	0.05	189.63	3.48
Mixed model	25.40	20.60	18.45	2.29	59.94	181.46

If the datum from Table 5 are used in equations (4), the fifteen graduation equations would be obtained. The coefficient of sensitivity of instrument has been worked out by MATLAB and shown as Table 6.

Table 6. The coefficient of sensitivity

Ordinal	a	b	c
1	0.208083	0.0435066	-0.00182616
2	0.000998674	0.0949893	0.00117342
3	0.21194	0.0492302	1.77124

4.2 Establishing content equations of U, Th and K

Apply the coefficient of sensitivity in Table 6 to equations (4) and we can obtain content equations of U, Th and K:

$$
\begin{aligned}
U &= A_1I_{rock}^{U} + B_1I_{rock}^{Th} + C_1I_{rock}^{K} \\
Th &= A_2I_{rock}^{U} + B_2I_{rock}^{Th} + C_2I_{rock}^{K} \\
K &= A_3I_{rock}^{U} + B_3I_{rock}^{Th} + C_3I_{rock}^{K}
\end{aligned}
\tag{5}
$$

A_1~A_3, B_1~B_3, C_1~C_3 are conversion coefficient. conversion coefficient worked out by MATLAB is shown at Table 7.

Table 7. Conversion coefficient

Ordinal	A	B	C
1	4.80984	-2.20631	0.00642061
2	-0.0434738	10.5511	-0.00703473
3	-0.574318	-0.0292602	0.564004

Content equations of U, Th and K can be obtained by conversion coefficient in the Table 7:

$$\begin{aligned} U &= 4.80984 I_{rock}^{U} - 2.20631 I_{rock}^{Th} + 0.00642061 I_{rock}^{K} \\ Th &= -0.0434738 I_{rock}^{U} + 10.5511 I_{rock}^{Th} - 0.00703473 I_{rock}^{K} \\ K &= -0.574318 I_{rock}^{U} - 0.0292602 I_{rock}^{Th} + 0.564004 I_{rock}^{K} \end{aligned} \quad (6)$$

5. Conclusion

5.1 Confirmation of the feasibility of technical proposal

According to the graduation result of last chapter, the contents of U, Th and K of five graduation models can be worked out based on content equations of U, Th and K and are compared with the contents of U, Th and K to work out fractional errors. The results are shown as Table 8.

Table 8. The contents of U, Th and K and errors

Model number	Content			Content(given)			Fractional error(%)		
	U(g/t)	Th(g/t)	K(%)	U(g/t)	Th(g/t)	K(%)	U(g/t)	Th(g/t)	K(%)
Background model	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kalium model	2.548	5.54	4.276	2.54	5.5	4.28	0.31	0.71	-0.09
Thorium model	6.544	368.79	0.383	6.56	368.81	0.38	-0.25	-0.01	0.68
Uranium model	189.648	3.489	0.047	189.63	3.48	0.05	0.01	0.25	-5.25
Mixed model	58.544	193.63	2.05	59.94	181.46	2.29	-2.33	6.71	-10.48

According to fractional error requirement in checkout regulations, $eU \leq 7\%, eTh \leq 7\%, eK \leq 12\%$. From the confirmation result in Table 8, fractional errors meet the requirements in checkout regulations, so the technical proposal is feasible.

5.2 preliminary application of the feasibility of technical proposal

Datum of directional gamma energy spectrum measurement from tin ore of cuprum pit in tunnel 216 and tunnel 218 of the middle 225 and tunnel 216 and tunnel 218 of the middle 305 in Dachang Bureau of Mines in Guangxi were processed (Table 9).

Table 9. The datum of gamma energy spectrum measurement (average count)

Type model	Without Shielded			Shielded		
	I_U	I_{Th}	I_K	I_U	I_{Th}	I_K
Background model	0.932	0.65	2.745	0.672	0.4335	2.174
Kalium model	2.1256	1.5186	16.6884	1.5214	1.0476	11.7832
Thorium model	26.3112	54.9886	31.0884	19.6724	40.1036	24.1812
Uranium model	60.64	1.26775	62.70425	44.3048	0.9776	46.9156
Mixed model	30.8984	28.5334	39.9834	23.1474	21.1502	30.1782

According to $I_{rock} = I_{without\ shielding} - I_{environment} = I_{without\ shielding} - \frac{I_{without\ shielding} - I_{with\ shielding}}{1-\partial}$, net counting rate of the rock face from measuring point. Then the contents of U, Th and K from each measuring point could be ascertained according to content equations of U, Th and K established in the fourth section as shown in the Table 10.

Table 10. Net counting rate of the rock face from measuring point and the contents of U, Th and K

Type model	Net counting rate of the rock face			Content		
	I_U	I_{Th}	I_K	U(g/t)	Th(g/t)	K(%)
Background model	0.607	0.3651	2.0129	2.1269	3.8120	0.776
Kalium model	1.3704	0.8989	10.3997	4.6748	9.3513	5.0521
Thorium model	18.0127	35.4031	22.2330	8.6708	372.6019	1.1586
Uranium model	40.221	0.8860	42.4623	191.7745	7.3007	0.8234
Mixed model	21.2097	18.8187	27.4126	60.6712	197.4427	2.7291

6. Conclusion

This paper expounds technical proposal of directional gallery gamma energy spectrum measurement. The content includes: (1)The physical model of this technical proposal was established by using method of Monte Carlo imitate and the transmissivity of probe shielding substance could be obtained by using mothed of combining simulation and theory. (2) The same rock face of gallery was measured by severally using gamma spectrometers with shielding substance probe and without it, then, by using difference of two times measurement, theoretical formula of net count that had been eliminate effects from ambient rock faces was acquired. (3) graduation equations were established based on five normal graduation models given contents of U, Th and K and the coefficient of sensitivity and conversion coefficient were obtained by MATLAB to establish content equations of U、Th and K. (4) This proposal was preliminarily applied by utilizing datum of directional gamma energy spectrum measurement from tin ore of cuprum pit in tunnel 216 and tunnel 218 of the middle 225 and tunnel 216 and tunnel 218 of the middle 305 in Dachang Bureau of Mines in Guangxi.

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