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Benefit calculation to determine the mining and processing of low-grade ore of copper mine

铜矿山低品位矿石可采选效益计算方法

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1 Scope

The standard lays down the method of calculating the mining and processing benefit of low-grade ore at copper mines, the method of calculating the economic cut-off grade for the mining and processing of low-grade ore, and the method of converting the usable components associated with copper polymetallic ores.

It applies to the calculation of the mining and processing benefit of low-grade ore at copper mining enterprises working open-pit, underground, or combined open-pit and underground operations.

2 Normative references

After the usual wording on dated and undated references, the clause cites a single document, GB/T 13471-2008, Calculation and evaluation method for economic benefit of power-saving techniques.

3 Terms and definitions

3.1 copper mine: a production enterprise engaged in mining, beneficiation or heap leaching whose object is a single-metal copper ore or a copper polymetallic ore.

3.2 low-grade ore: ore lying between the boundary grade and the industrial grade, once the industrial indicators of the deposit have been fixed.

3.3 copper grade equivalent: where a copper polymetallic ore contains other usable components, the grades of those components are converted, by the profitability method, into an equivalent copper grade; the copper grade equivalent is the sum of the copper grade and the converted equivalent copper grades of the usable components.

3.4 financial evaluation of mining and processing project for low-grade copper mine: on the basis of the current national economic environment, such as interest and exchange rate levels and price levels, and of the fiscal and tax policy environment, the cost, expenditure, benefit and efficiency of a low-grade ore mining and processing project at a copper mine are examined and calculated in order to judge the financial soundness of the project. The English term is printed on the page without word spaces, as low-gradecoppermine.

4 Benefit calculation for the utilization of low-grade ore

4.1 General formula: formula (1) gives the net benefit of a unit weight of low-grade ore mined and processed at the mine. The symbols are given as follows. E1 is the net benefit of a unit weight of low-grade ore mined and processed, in yuan. The Greek letter alpha with subscript m may stand either for the average grade of the copper ore, written alpha m1, or for the copper grade equivalent, written alpha m2, in per cent. The Greek letter epsilon is the beneficiation recovery, in per cent. K is the current price, excluding tax, of the metal in the concentrate obtained after beneficiating a unit weight of low-grade ore, in yuan per tonne. The Greek letter rho is the mining dilution rate, including primary and secondary dilution, in per cent. The letter s is the sales tax and surcharge rate, in per cent. G is the government subsidy income, or the income from reduced or waived taxes and fees, for a unit weight of low-grade ore, in yuan. C is the direct cost of a unit weight of low-grade ore, in yuan. D is the depreciation and amortisation of fixed and intangible assets for a unit weight of low-grade ore, in yuan. I with subscript e is the selling, administrative, financial and other expenses of a unit weight of low-grade ore, in yuan. K with subscript w is the equity capital cost of a unit weight of low-grade ore, in yuan. T1 is the newly added environmental protection expense and investment for a unit weight of low-grade ore, in yuan.

4.1.1 Method of taking the beneficiation recovery: under 4.1.1.1, where the beneficiation recovery varies with the feed grade of the ore and is positively correlated with it, the recovery is determined by regression analysis of the production reports of the concentrator; formula (2) expresses the recovery as a linear function of the feed grade, in which a is the intercept and b the slope of the straight line, and formula (3) gives the feed grade of the ore, in per cent, from the average grade and the dilution rate. The constants a and b are obtained by regression analysis from the data of the concentrator production reports. Under 4.1.1.2, the recovery from a beneficiation test or the average recovery indicator of the plant may be taken directly as the beneficiation recovery, in which case the recovery is a constant.

4.1.2 Method of taking the grade of copper ore: under 4.1.2.1, for a single copper ore the average grade of the copper deposit is used as the basis of calculation and the grade is taken as alpha m1. Under 4.1.2.2, where a copper polymetallic ore contains other usable components, the ore body is normally delimited using the boundary grade indicator of the element copper, and the ore grade is taken as the equivalent grade indicator, that is the sum of the copper grade and the converted equivalent copper grades of the usable components. The first step is the calculation of the grade conversion coefficient of the associated usable components: the coefficient is computed by the profitability method, which takes into account both the prices of copper and of the associated usable components and the beneficiation cost factor. In formula (4) the coefficient f with subscript i converts component i into a copper grade, epsilon with subscript i is the beneficiation recovery of the associated useful component in per cent, H with subscript i is the current price of the associated useful component in the concentrate in yuan per tonne or yuan per gram, C with subscript i is the unit production cost of the associated component in yuan per tonne or yuan per gram, epsilon with subscript z is the beneficiation recovery of copper in per cent, H with subscript z is the current price of the main element copper metal in the concentrate in yuan per tonne, and C with subscript z is the unit production cost of the main component copper in yuan per tonne. The second step is the calculation of the copper grade equivalent by formula (5), in which alpha m2 is the copper grade equivalent in per cent and alpha m1 the average grade of the element copper in per cent.

5 Calculation of cost, benefit and economic cut-off grade for low-grade ore utilization at producing mines

5.1.1.1 Spare capacity at the concentrator: when the concentrator has spare capacity, the additional cost of treating one more unit weight of low-grade ore includes only the mining, ore haulage and beneficiation costs, and does not include any apportionment of the fixed expenses of the mine and of the concentrator. Formula (6) gives the direct cost required to mine and process a unit weight of low-grade ore as the sum of four terms: m1, which for an underground mine covers development, mining preparation, cutting, water supply and drainage, power supply, air supply, ventilation and mine workshop manufacturing costs, and for an open-pit mine covers stripping, water supply and drainage, power supply, waste rock haulage and mine workshop manufacturing costs, in yuan per tonne; m2, which for an underground mine covers stoping, ore drawing and hoisting costs and for an open-pit mine is the extraction cost, in yuan per tonne; m3, the ore haulage cost, in yuan per tonne; and p, the beneficiation cost, in yuan per tonne. Formula (7) then combines formulas (2), (3) and (6) with formula (1) to give the mining and processing benefit of low-grade ore when the concentrator has spare capacity.

5.1.1.2 Saturated capacity at the concentrator: when the capacity of the concentrator is saturated, treating one more unit weight of low-grade ore means that the same quantity of normal-grade ore will be treated later, the service life of the mine is extended, and the unit weight of low-grade ore mined and processed must therefore bear the corresponding fixed expenses. Formula (8) adds to the four terms of formula (6) the quotient of f1 by Q, where f1 is the depreciation and amortisation of fixed assets arising from the extension in time, in yuan, and Q is the production capacity of the concentrator, in tonnes per year. Formula (9) combines formulas (2), (3) and (8) with formula (1) to give the mining and processing benefit in the saturated case.

5.1.2 Calculation of the economic cut-off grade: under 5.1.2.1, when the concentrator has spare capacity the utilization of low-grade ore does not take up the production indicators of normal-grade ore, so it is enough for the net income to satisfy the condition that E1 in formula (7) be greater than or equal to zero; the value of alpha m3 corresponding to E1 equal to zero is called the economic cut-off grade and is computed by formula (10), in which U stands for the product of K, of one minus rho and of one minus s. Where the recovery from a beneficiation test or the average plant recovery indicator is used, the economic cut-off grade is computed by formula (11). Under 5.1.2.2, when the capacity of the concentrator is saturated the net benefit from using low-grade ore may be smaller than the net benefit from using normal-grade ore, but the service life of the mine is extended and the profit temporarily forgone can be recovered later from the normal-grade ore. From a dynamic economic point of view the deferred normal-grade ore has to be discounted, and at a discount rate greater than zero the future income shrinks after discounting; since mineral product prices and production costs show relatively stable long-term trends, the deferred normal-grade ore income may either gain or lose value. Using low-grade ore is worthwhile only when the net income obtained now from a unit weight of low-grade ore is greater than the difference between the net income obtained now from a unit weight of normal-grade ore and the discounted future income from a unit weight of normal-grade ore; when the two are equal, that is the economic cut-off grade for the utilization of low-grade ore. The present and future net incomes from a unit weight of normal-grade ore are written E2 and E3 and are related by formula (12); formula (13) then gives the economic cut-off grade and formula (14) gives it for the case where a test or average plant recovery is used. In the expressions that follow, the average grade of normal-grade and low-grade ore taken together is written as alpha m with an overbar, in per cent, K1 is the long-term average price of the metal in the concentrate in yuan per tonne, and n is the remaining service life of the mine in years. The text notes that, once the methods of taking prices, costs and