KINETICS OF ABRASIVE-REACTIVE WEAR OF MINERAL RAW MATERIALS IN MECHANOCHEMICAL REACTORS

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Kinetics of abrasive-reactive wear **(ARW)** of steel material of planetary ball mills "Mekhanobr", AGO-2 and EI2x150 in process of mechanically activated **(MA)** processing into nanocomposite powders of the following kinds of mineral are investigated:

[1,2] - natural quartz (obtaining of a magnetic composite);

[3] - ilmenite concentrate of the arm filters of titanium-magnesium manufacture and mixes of concentrate with coke (reduction of concentrate with obtaining of iron, rutile and anatase);

[1,4-8] - mixes of quartz and quartz glass with tenorite (opening with obtaining of copper-bearing composite), galena (with obtaining of lead-bearing composite), sulfur (obtaining of pyrite-bearing composite) and graphite (obtaining of cementite);

Diamond (obtaining of cohenite [9]) and a powder mix of diamond-graphite-copper (obtaining of high heat-conducting composite materials).

Kinetics of ARW were studied by two methods: weight, with accuracy of measurement of weight of drums and ball loading before and after experiments not less than 0.01 g; volumetric, on reaction of MA samples with an acid. The linear law of ARW increase (in terms of weight) from MA time is established at absence of phenomenon of self-lining of milling tools surfaces and power law of ARW at presence of the self-lining phenomenon with an exponent less then unity.

The data on ARW kinetics of mechanochemical reactors for the following systems have been obtained:

A) MA of quartz. Detailed conditions of MA of quartz in mill "Mekhanobr" with speed of relative impact of milling bodies W = 17 m/s are given in [1,2]. The volume of drums made V = 450 ml, radius of balls R = 0.5 cm, number N = 120, the relation of ball loading weight M to weight of quartz m was accepted equal 4 at M + m = 480 + 120 = 600 g. Time of MA varied from 5 up to 90 min. The amount of wear at 5 min, ARW (in grammes), has totaled 1.43, and at 90 min ARW(g) = 5.14. Thus the self-lining phenomenon of milling tools surfaces by MA quartz is observed. Kinetic curve of ARW is shown on fig. 1.

B) MA of ilmenite concentrate. Conditions of MA in mill " Mekhanobr " were: b1) relation M/m = 2 at M + m = 166.67 + 83.33 = 250 g; b2) M/m = 4, M + m = 200 + 50 = 250 g; b3) $M/(m+m_k) = 4$ at $M + m + m_k = 200 + 42.5 + 7.5 = 250$ g, where m_k - weight of coke. MA time varied from 15 up to 90 min. Amount of ARW at specified MA times for all cases did not exceed 1 g. At that the appreciable self-lining phenomenon of milling tools surfaces by MA materials was observed only in case (b3). ARW kinetics curves are shown on fig. 2.

C) Opening of galena (PbS) and tenorite (CuO) by ARW method [4,5]. MA was carried out in mill AGO-2 (W = 11 m/s, V = 140 ml, N = 400, R = 0.2 cm). Tenorite or galena in amount of 1.5 g were added in charges of crushed quartz glass (abrasive) taken in amount of 3 g. MA time varied from 15 up to 210 min. ARW during 60 min in the investigated systems has totaled about 1 g. Experiments have shown both similarity and essential difference in course of mechanochemical processes with participation of tenorite and galena. In both systems takes place ARW of milling tools with involving of iron nanoparticles in reducing reactions with formation of metal particles of lead or copper [1]. Self-lining of surfaces of milling tools takes place after even short-term (5 min) MA of systems with tenorite. On the contrary in system with galena the phenomenon of self-lining is completely absent. Kinetic curves of ARW for the investigated systems are shown on fig. 3.

D) ARW (mill AGO-2) in systems graphite (1.5 g) - quartz glass or quartz (3 g) [4-6] and sulfur (1.6 g) - quartz glass (3 g) [4-8]. MA time up to 135 min. ARW in the investigated systems has not exceeded 1.15 g. In both systems involving of iron nanoparticles in reaction with graphite and sulfur with formation of cementite (Fe_3C) and pyrite (FeS_2) takes place. Self-lining takes place during MA of systems with graphite and in system with sulfur the phenomenon of self-lining is absent. Kinetic curves of ARW for the investigated systems are shown on fig. 4.

E) ARW during MA of diamond [9] **and powder system diamond (1.3 g) - graphite (1.3 g) - copper (1.3 g)**. Mill AGO-2 with N = 400 for charge of diamond 2.85 g and with N = 150 for charge of diamond 1.75 g was used. Time of MA up to 120 min. During MA of diamond self-lining is almost absent, ARW reaches 1.6 g. For MA of system diamond - graphite - copper mill EI2x150 (V = 148 ml, R = 0.2 cm, N = 400) was used, see [10]. Time of MA up to 60 min. Self-lining is present. ARW has totaled about 3 g. Kinetic curves of ARW for the investigated systems are shown on fig. 5.

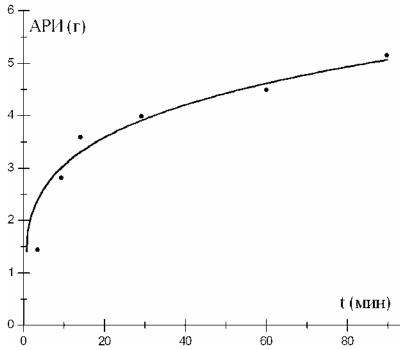

Fig.1. ARW kinetics under MA of quartz is described by expression: $K*t^n = 1.8*t^{0.23}$.

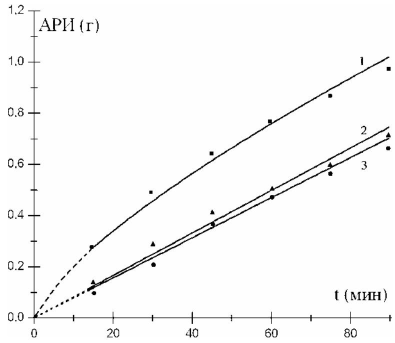

Fig. 2. ARW kinetics under MA of ilmenite: 1(b3), $0.038*t^{0.73}$; 2(b2), 0.083*t; 3(b1), 0.078*t.

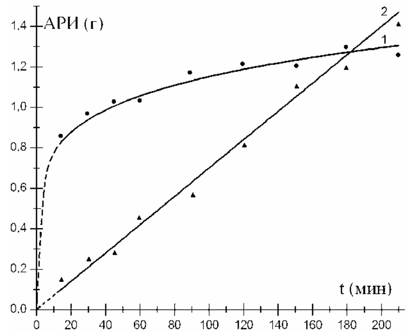

Fig.3. ARW kinetics under MA:
1) tenorite, $0.53*t^{0.17}$;
2) galena, 0.0070*t.

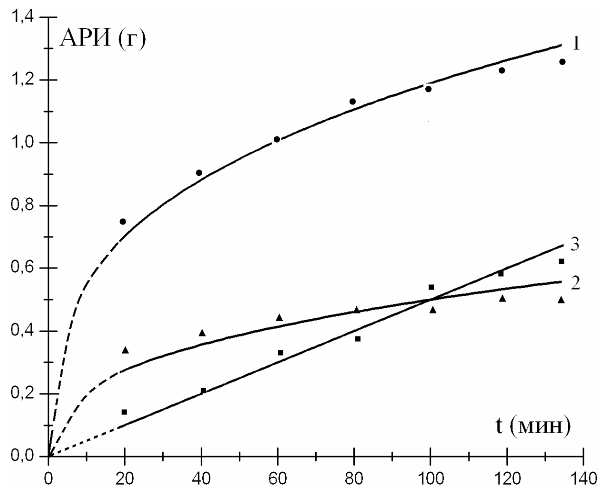

Fig.4. ARW kinetics under MA of systems:
1) quartz glass-graphite, $0.26*t^{0.33}$;
2) quartz-graphite, $0.091*t^{0.37}$;
3) quartz glass-sulfur, 0.0050*t.

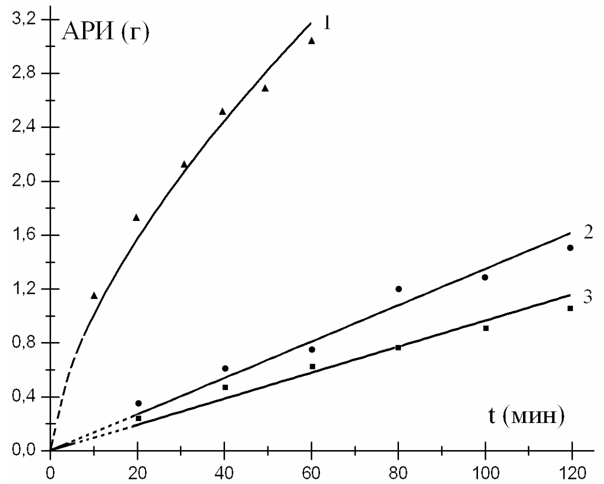

Fig.5. ARW kinetics under MA of systems:
1) diamond-graphite-copper, $0.23*t^{0.64}$;
2) diamond charge 2.85 g, 0.0135*t;
3) diamond charge 1.75 g, 0.0097*t.

Discussing the obtained data on ARW kinetics, let us pay special attention to a role of the phenomenon of self-lining of milling tools surface (internal walls of drum and ball loading) in course of mechanochemical processes [10], presence or absence of which is mentioned in the description of experiments. The experimental data unequivocally confirm, that the self-lining phenomenon of milling tools impeded their abrasive wear and, as consequence, course of mechanochemical reactions of activated sample with steel material of milling tools wear. Mathematical treatment of experimentally measured values of ARW(g) depending on MA time t (min) in various mills (fig. 1-5) gives the following empirical dependence: $ARW(g) = Kt^n$, where K is rate constant of abrasive-reactive wear of milling tools material, and n is an exponent. It is visible, that both rate constant (K, from 0.0050 g/min for MA sulfur-quartz glass system up to 1.8 $g/min^{0.23}$ for MA quartz), and exponent (n, from 0.17 for MA tenorite up to 1 for systems in which self-lining of milling tools surfaces does not take place) vary in wide enough numerical interval. On an example of tests on MA of diamond and ilmenite it is visible that K depends on activation conditions (n = 1): K = 0.0135 g/min for diamond charge 2.85 g and ball loading N = 400; K = 0.0097 g/min for diamond charge 1.75 g and N = 150; K = 0.0078 g/min for the relation of ilmenite weight m to weight M of ball loading m/M = 0.5; K = 0.0083 g/min at m/M =

0.25. On example of MA of mixes of tenorite and galena with quartz glass, and also mixes of graphite with quartz, graphite and sulfur with quartz glass executed in identical conditions of MA, it is visible, that values of K and n also essentially depend not only on nature and specificities of proceeding chemical reaction, but also on a phase state of an abrasive: $K = 0.53$ g/min^n and $n = 0.17$ for tenorite; $K = 0.0070$ g/min^n and $n = 1$ for galena; $K = 0.091$ g/min^n and $n = 0.37$ for a mix of graphite with quartz; $K = 0.26$ g/min^n and $n = 0.33$ for a mix of graphite with quartz glass; $K = 0.0050$ g/min and $n = 1$ for a mix of sulfur with quartz glass. It is established by us, that $n = 1$ for ARW processes proceeding without self-lining, and also it is shown, that the size n is connected to volume fraction of an abrasive material in activated mix for ARW processes with lining of milling tools surfaces:

$n = 1 - (V_a/V_0)$, where V_a is a volume of an abrasive, V_0 is total volume activated charge.

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