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CRUSHING KINETICS OF POLYMINERAL RAW MATERIAL

Based on a study of the strength characteristics of the main minerals of the oxidized ferruterous quartzites of two fields Skelevatskogo and Valyavkinskogo carried out research on the kinetics of formation of a class minus 0,074 (0,044) mm in case of a rod and ball grinding ore samples on 9 mineralogical varieties of hematite ore.

Problem and its connection with scientific and practical problems. The important condition of effective ore enrichment is the high degree of disclosing components allocated from it. Completeness of ore mineral disclosing is rather important for getting an iron concentrate with the minimal mass fraction of silica. Alongside with a high degree of ferriferous mineral disclosing it's also necessary the minimal formation fine dispersion slime ore fractions which enrichment efficiency is low and reduced in process of their fineness reduction. Besides that the surface of ore grains after ore pretreatment should be the purest, with absence of disperse particle fastening of nonmetallic minerals.

The analysis of researches and publications. Based on previous results of physical-mechanical property research of the oxidized ore mineral variety at their destruction by means of macro- and the micro deformations, the most competing operation variants of the oxidized iron ore intensive ore pretreatment are crushing in rod and spherical mills [1].

Problem statement. In iron-ore raw material pretreatment two basic stages were considered. The first one is ore piece destruction under action of the external force applied to set of initial raw material pieces. The second one is kinetics of -0,074 (0,044) mm class formation under condition of rod and spherical crushing of ore tests.

Material statement and results. For technological researches there have been submitted 200 ordinary tests of 9 mineralogical hematite quartzite versions of two deposits Skelevatskoe and Valyavkinskoe (tab. 1) which in the certain ratio make general test for technological researches on development of enrichment technology of KrDF oxidized ores (tab. 2).

Table 1

An ordinary test composition of hematite quartzit versions of Skelevatskiy and Valyavkinskiy deposits in incorporated tests

Incorporated tests		Deposits	
index	name	Skelevatskoe	Valyavkinskoe
1	2	3	4
1	Quartzit martite - ferruginous micaceous	Skl-9, Skl -14, Skl -39, Skl -74	Vlk -213, Vlk -214, Vlk -228, Vlk -235, Vlk -239, Vlk -258, Vlk -267, Vlk -288
2	Quartzit ferruginous micaceous martite	Skl -4, Skl -15, Skl -16, Skl -17, Skl -28, Skl -37, Skl -38, Skl -80, Skl -81, Skl -84, Skl -90, Skl -91, Skl -92, Skl -100	Vlk -208, Vlk -212, Vlk -220, Vlk -221, Vlk -223, Vlk -249, Vlk -253, Vlk -255, Vlk -257, Vlk -272, Vlk -295, Vlk -296
3	Quartzit ferruginous micaceous martite marshalited	Skl-5, Skl-6, Skl-12, Skl-20, Skl -21, Skl -30, Skl -45, Skl -46, Скл-56, Skl -76, Skl -77, Skl -78, Skl -89, Skl -93	Vlk -206, Vlk -215, Vlk -216, Vlk -245, Vlk -250, Vlk -259, Vlk -265, Vlk -280, Vlk -281
4	Quartzit martite	Skl -2, Skl -7, Skl -11, Skl -13, Skl -23, Skl -58, Skl -59, Skl -65, Skl -70, Skl -71, Skl -72, Skl -79, Skl -83, Skl -97	Vlk -238, Vlk -244, Vlk -252, Vlk -254, Vlk -256, Vlk -282, Vlk -284, Vlk -289
5	Quartzit martite marshalited	Skl -27, Skl -31, Skl -57, Skl -60, Skl -64, Skl -68, Skl -82, Skl -85, Skl -86, Skl -88, Skl -94	Vlk -201, Vlk -202, Vlk -203, Vlk l -204, Vlk -205, Vlk -217, Vlk -219, Vlk -227, Vlk -229, Vlk -243, Vlk -246, Vlk -266, Vlk -268, Vlk -271, Vlk -277, Vlk -300
6	Quartzit martite hetited	Skl -18, Skl -19, Skl -24, Skl -25, Skl -26, Skl -29, Skl -40, Skl – 42, Skl -43, Skl -44, Skl -47, Skl -48, Skl -49, Skl -50, Skl -53, Skl -54, Skl -55, Skl -62, Skl -63, Skl -87, Skl -95, Skl -98	Vlk -207, Vlk -209, Vlk -225, Vlk -230, Vlk -233, Vlk -247, Vlk -248, Vlk -261, Vlk -262, Vlk -274, Vlk -275, Vlk -285, Vlk -291, Vlk -298
7	Quartzit hematite dispersed - martite	Skl -8, Skl -34, Skl -35, Skl -36, Skl -41, Skl -51, Skl -52, Skl -99	Vlk -224, Vlk -234, Vlk -237, Vlk -240, Vlk -242, Vlk -251, Vlk -269, Vlk -286, Vlk -294, Vlk к-297, Vlk -299
8	Quartzit containing martite, magnetite	Skl -1, Skl -32, Skl -33, Skl -61, Skl -66, Skl -67, Skl -69, Skl -73	Vlk -210, Vlk -211, Vlk -218, Vlk -226, Vlk -231, Vlk -236, Vlk -273, Vlk -276, Vlk -278, Vlk -283
9	Schist and barren quartzit	Skl -3, Skl -10, Skl -22, Skl -75, Skl -96	Vlk -222, Vlk -232, Vlk -241, Vlk -260, Vlk -263, Vlk -264, Vlk -270, Vlk -279, Vlk -287, Vlk -290, Vlk -292, Vlk -293

Table 2

Material contents of incorporated version of hematite quartzite of Skelevatskoe and Valyavkinskoe deposits in general tests

Incorporated mineralogical hematite quartzite versions		Contents in general technological tests, mas.%
index	name	
1o	Martite ferruginous micaceous quartzit	2,18
2o	Ferruginous micaceous martite quartzit	11,40
3o	Ferruginous micaceous martite marshalited quartzit	8,36
4o	Martite quartzit	27,45
5o	Martite marshalited quartzit	24,60
6o	Martite hetitizate quartzit	10,31
7o	Quartzit hematite- martite and martite- hematite dispersed ("red lead ")	6,64
8o	Quartzit martite containing magnesite (weakly weathered)	4,50
9o	Schist and barren quartzit	4,56

According to results of the detailed geological - mineralogical researches which have been carried out in May - July 2013 under the leadership of prof. V.D. Evtehov, in structure of each incorporated version of the oxidized ferriferous quartzite there is allocated one or two leader integrated versions (on quantitative presentation in structure of the oxidized ferriferous quartzite deposits); others attached to it (to them) on the basis of mineralogical parameter affinity are in a quantitative sense considerably less representative and do not essentially influence on general characteristics of the incorporated versions in case of difference on some parameters from leaders.

Because the basic minerals of oxidized ferriferous quartzit of Skelevatskiy and Valyavkinskiy deposits are martite, ferruginous micaite, hetite, quartz, there have been investigated their strength characteristics resulted in tab. 3, 4, 5, 6, 7.

Table 3

Strength characteristics of oxidized ferriferous ore

Mineral variety	Strength properties			
	modulus of micro elasticity, E, 10^{10} Pa	micro-harshness, H, 10^9 Pa	elasticity factor, K, %	crushing load, P, $H*10^3$
Martite	10±0,6	7,1±0,5	42,1±0,4	0,21±0,02
Ferruginous micaite	9,5±0,6	6,9±0,4	41,2±0,4	0,20±0,02
Hetite	9,6±0,7	6,8±0,4	40,6±0,5	0,20±0,02
Quartzit	8,6±0,6	20,1±2,5	69,2±1,1	0,4±0,02

Table 4

Strength characteristics of oxidized ferriferous ore mineral sample at shearing test

Mineral variety	Strength properties	
	failure strain, $\sigma \cdot 10^3$ Pa	specific energy consumption, 10^3j/m^3
Martite	63	44,2
Ferruginous micaite	32	34,1
Hetite	48	56,3
Quartzit	77	60,6

Table 5

Strength characteristics of oxidized ferriferous ore mineral sample at crushing on bend

Mineral variety	failure strain, $\sigma \cdot 10^3$ Pa	modulus of elasticity, $E \cdot 10^{-3}$ Pa	specific energy consumption, 10^{-5}j/m^3
Martite	41,6	9,4	1,7
Ferruginous micaite	24,4	5,2	1,4
Hetite	31,8	8,0	1,6
Quartzit	54,9	16,0	2,5

Table 6

Physical-mechanical properties of oxidized ferriferous quartzite and dilution rock

Physical-mechanical properties	Material contents,%/ Mineral variety of oxidized ferriferous quartzite (see tab.2)								
	1	2	3	4	5	6	7	8	9
Density, t/m^3	3,88	3,22	3,31	3,58	3,27	3,16	3,24	3,41	2,81
Crushability, mdis/m^3	85,8	94,4	73,9	100	84,65	65,4	56,4	104,4	52,4
Solidity factor	10,2	11,9	9,8	11,0	10,6	10,9	6,3	14,3	8,2
Porosity	8,5	4,5	7,4	7,7	4,8	39,5	8,2	4,2	4,6

It is necessary to pay attention, that martit – iron micaite quartzite (version 1) is characterized relatively low porosity, crevice, high ability to splitting on lamination because of a plenty of parallel - scaly units iron micaite. Iron micaite - martit quartzite (the incorporated mineral version 2) is also characterized rather low porosity, crevice. The incorporated mineral version 3 and 5 are characterized flow ability, presence of fine-grained material precipitations from pit face; and for the incorporated mineral version 4 rather low porosity, crevice are characteristic**.** Martite hetited quartzite (the incorporated mineral version 6) differ by high porosity, fissuring, crevice, relatively high durability martite hetited quartzite in connection with filling interstices and cracks with hetit. For incorporated mineral version 7 it is typical rather low porosity, fissuring, crevice and rather low durability; and for the incorporated mineral version 8 it's typical low porosity, fissuring, crevice, the increased durability. Slates and barren quartzite are characterized by low porosity, crevice, fissuring.

Tables 7

Physical properties of ore(general test)

Material fineness, mm	Initial ore		Middlings SMS		Mill tailing SMS	
	Powder density, t/m^3	An angle of natural slide, degree	Powder density, t/m^3	An angle of natural slide, degree	Powder density, t/m^3	An angle of natural slide, degree
70-0	1,99	33,7				
10-0	1,92	36,4	2,22	34,5	1,72	34,3
Density,t/m^3	3,54		3,7		2,87	
Humidity	3,7		3,7			

Ore by mass of 1,8 kg (for a mill 40-A-Ml) and 8 kg (for mill MCZ-14) was crushed in ball and rod mills during various time (3, 8, 12, 17, 22, 27, 32, 37 min). According to results of screen fractionation of the crushed products size characteristics have been designed, on the basis of which necessary time for ore crushing up to determined size was determined (fig. 1-18). For the further researches time of crushing was 10 minutes. As the increment of - 0,044 mm class at crushing in ball mills is higher on the average 10-18 %, during ore preparation for researches the preference to crushing in a rod mill is given. Screen characteristic of the general test crushed up to 0,5-0 mm (62,5 % of a class - 0,07 mm) is resulted in tab. 8.

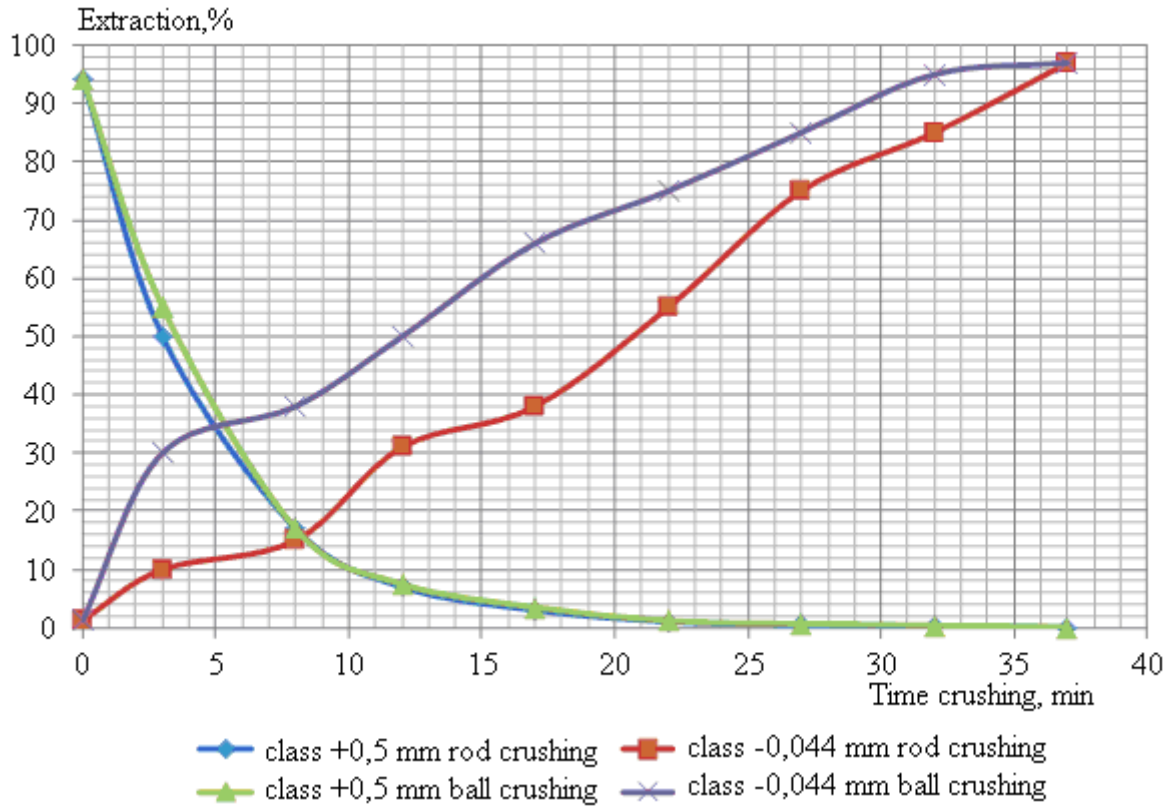

Fig. 1. Crushing kinetics of martite ferruginous micaceous quartzit of Skelevatskoe deposit (incorporated mineral variety 1) in rod and ball mills

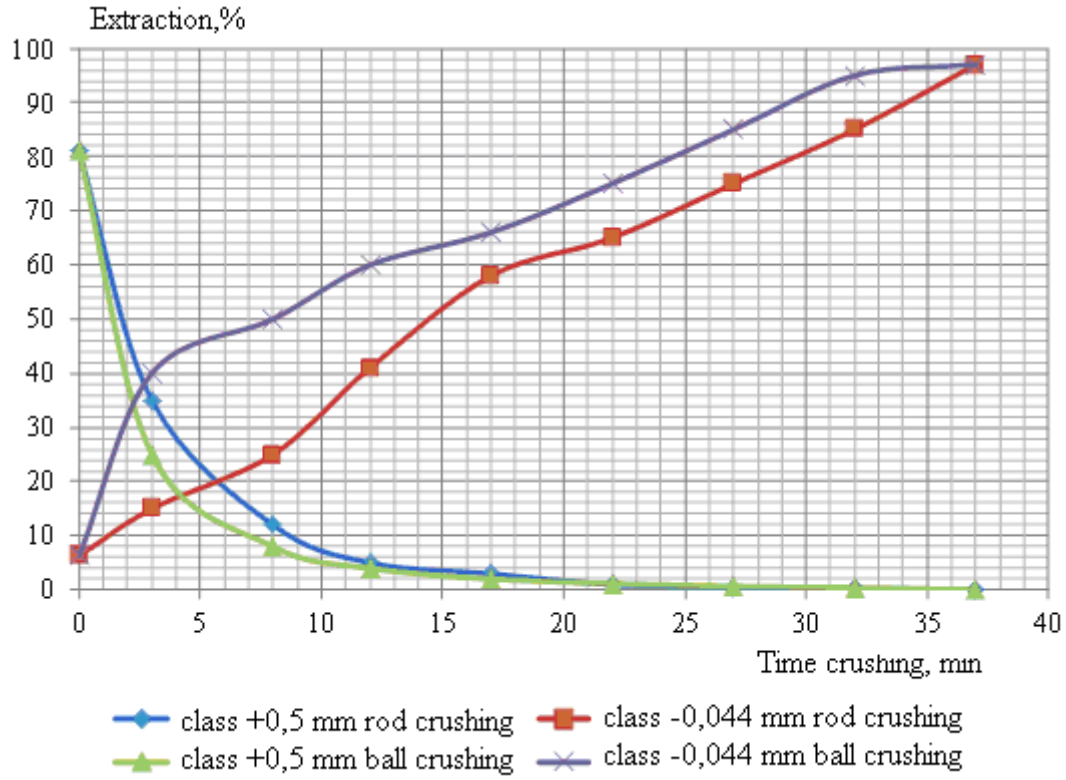

Fig. 2 Crushing kinetics of martite ferruginous micaceous quartzit of Valyavkinskoe deposit (incorporated mineral variety 1) in rod and ball mills

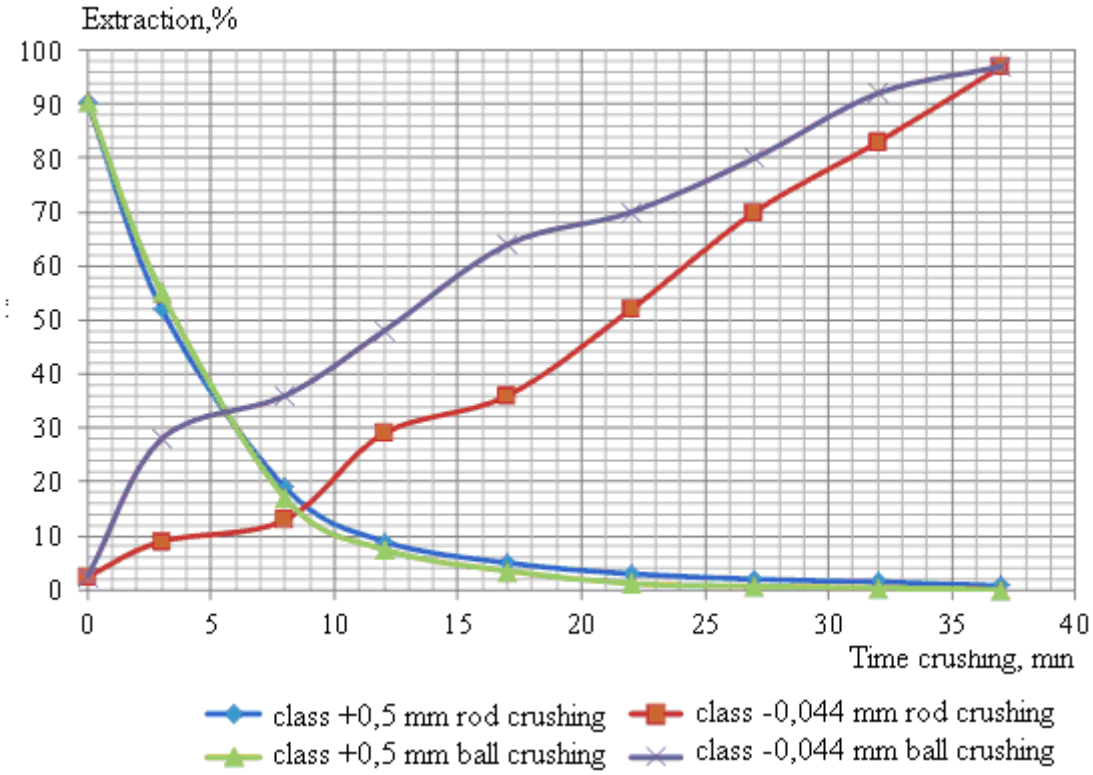

Fig. 3. Crushing kinetics of ferruginous micaceous martite quartzit of Skelevatskoe deposit (incorporated mineral variety 2) in rod and ball mills

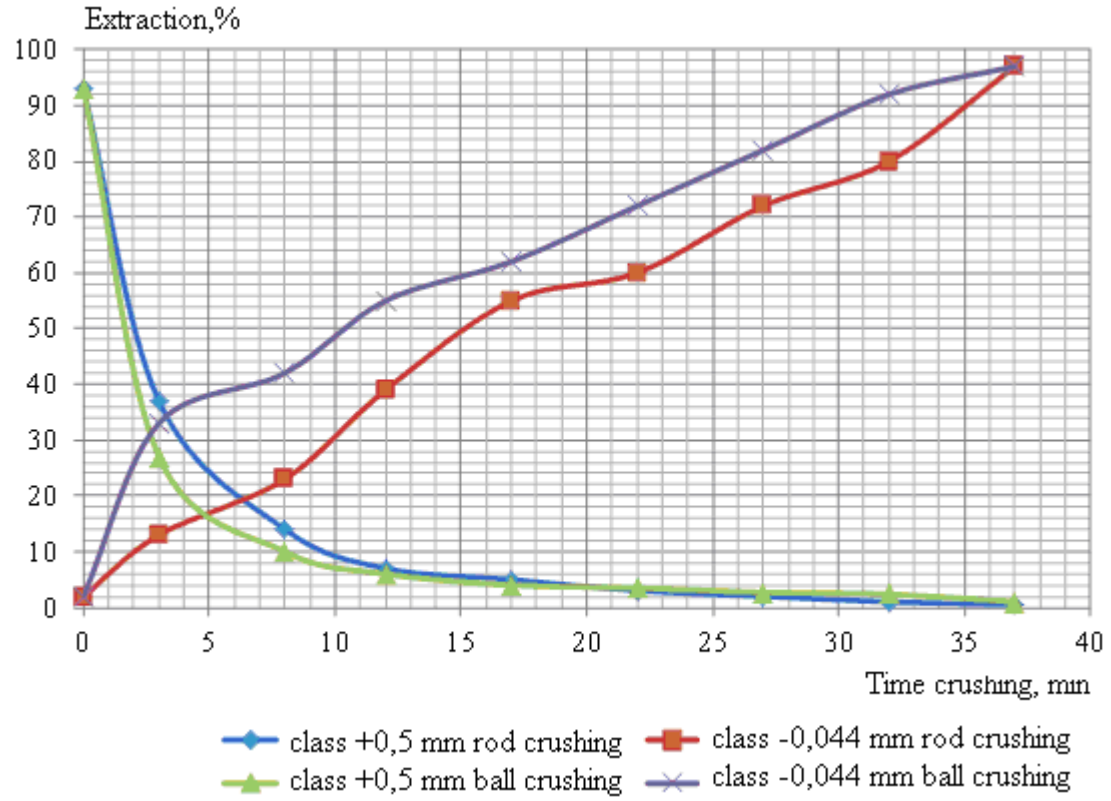

Fig. 4. Crushing kinetics of ferruginous micaceous martite quartzit of Valyavkinskoe deposit (incorporated mineral variety 2) in rod and ball mills

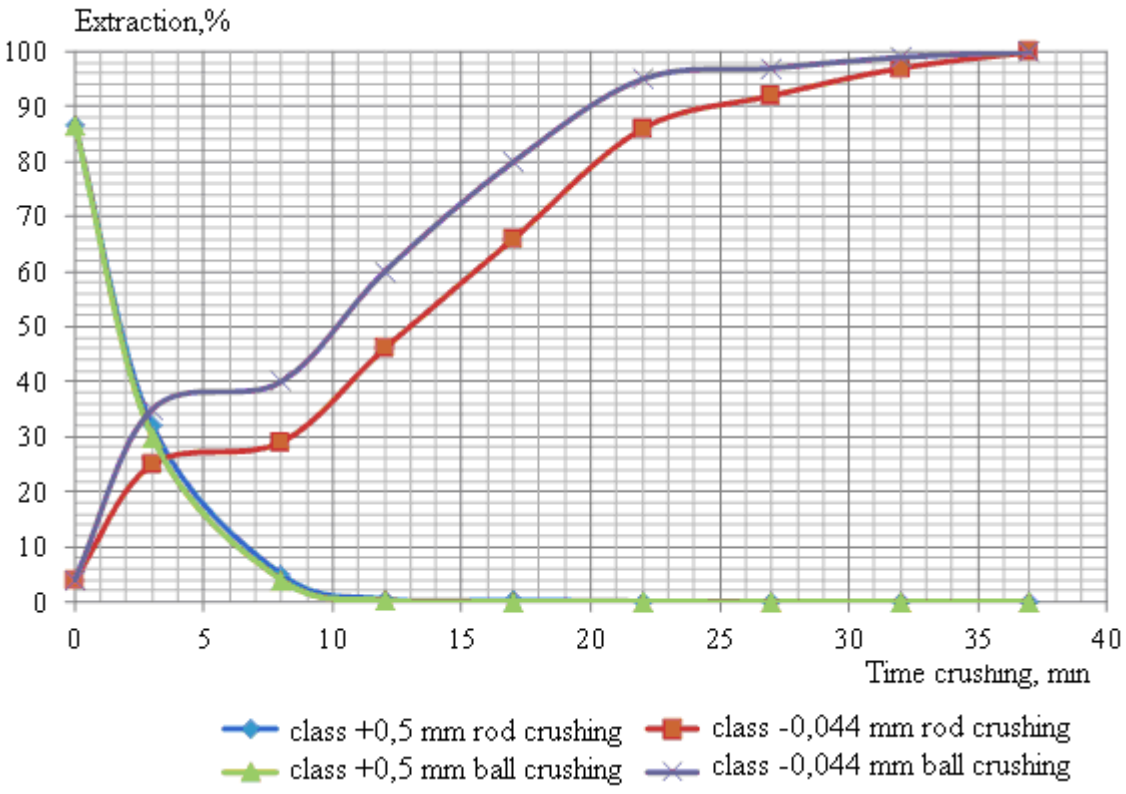

Fig. 5. Crushing kinetics of ferruginous micaceous martite marshalited quartzit of Skelevatskoe deposit (incorporated mineral variety 3) in rod and ball mills

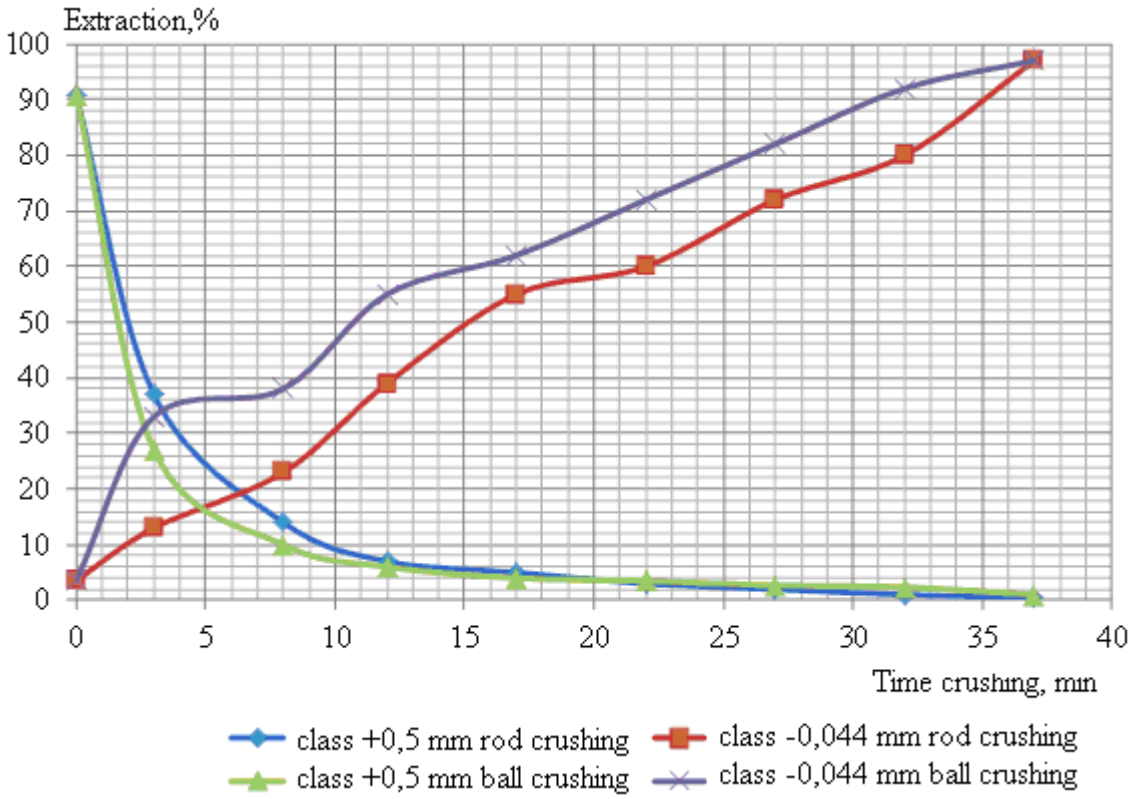

Fig. 6. Crushing kinetics of ferruginous micaceous martite marshalited quartzit of Valyavkinskoe deposit (incorporated mineral variety 3) in rod and ball mills

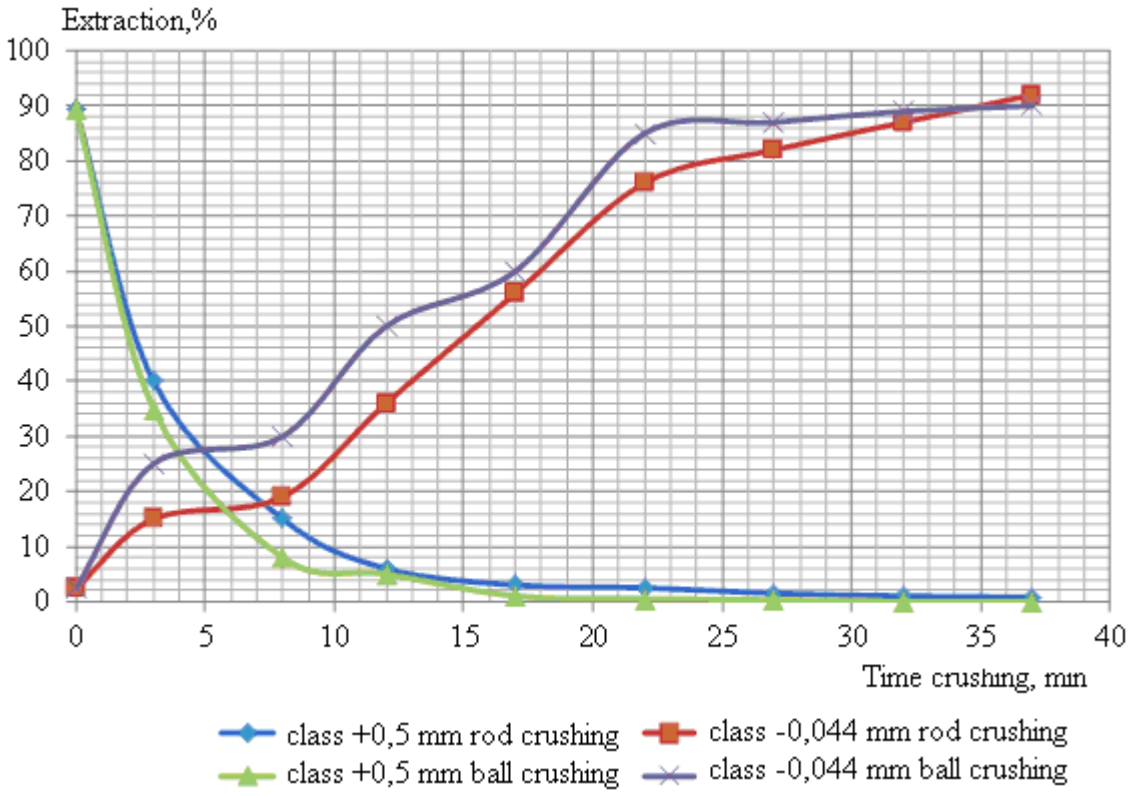

Fig. 7. Crushing kinetics of martite quartzit of Skelevatskoe deposit (incorporated mineral variety 4) in rod and ball mills

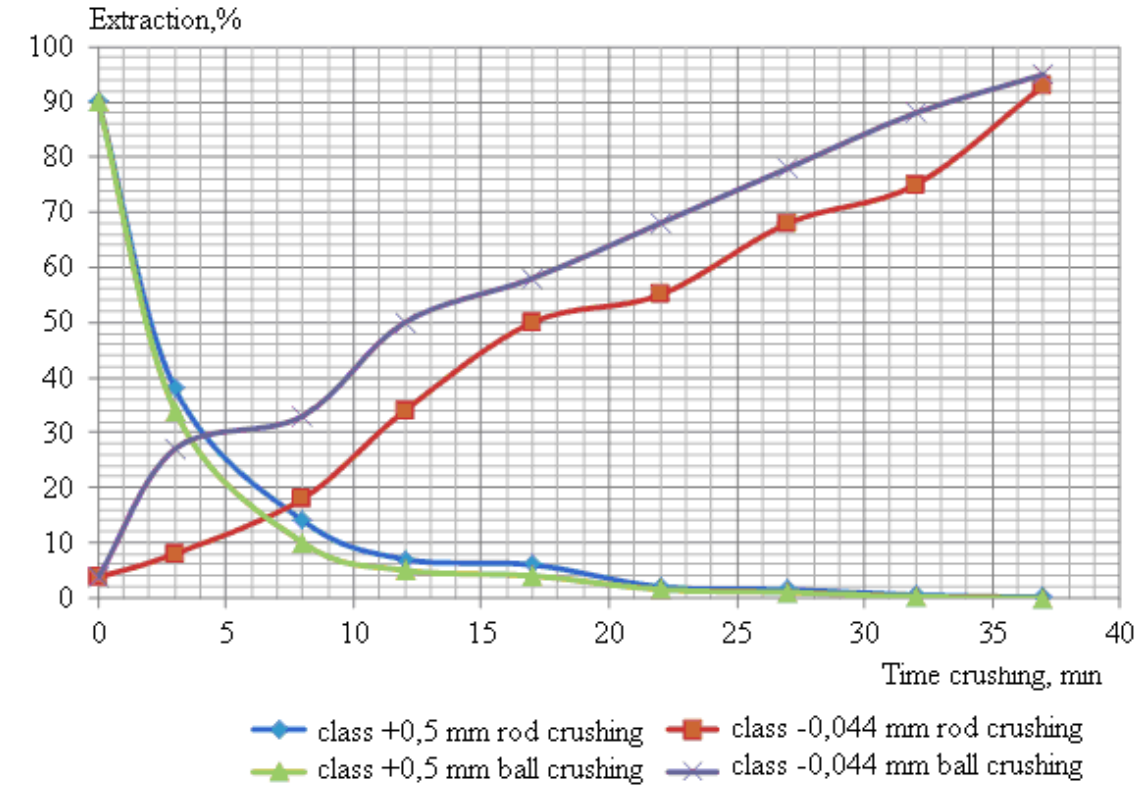

Fig. 8. Crushing kinetics of martite quartzit of Valyavkinskoe deposit (incorporated mineral variety 4) in rod and ball mills

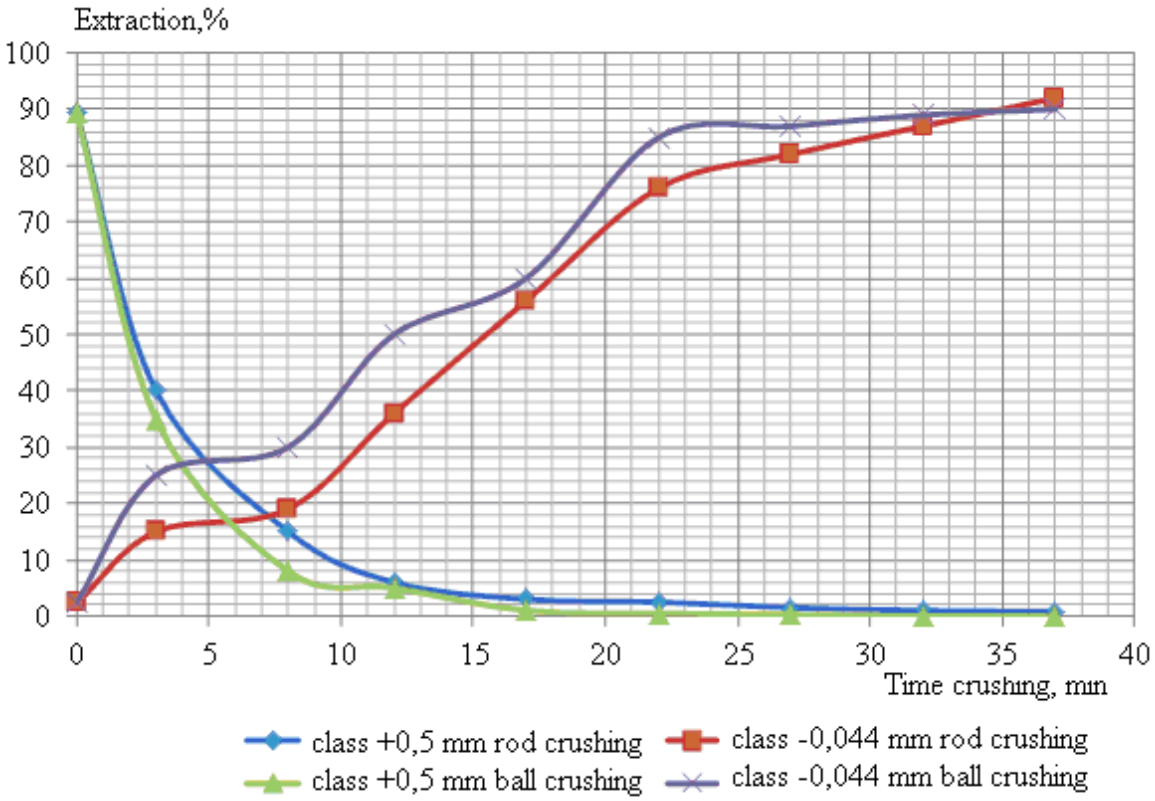

Fig. 9. Crushing kinetics of martite marshalited quartzit of Skelevatskoe deposit (incorporated mineral variety 5) in rod and ball mills

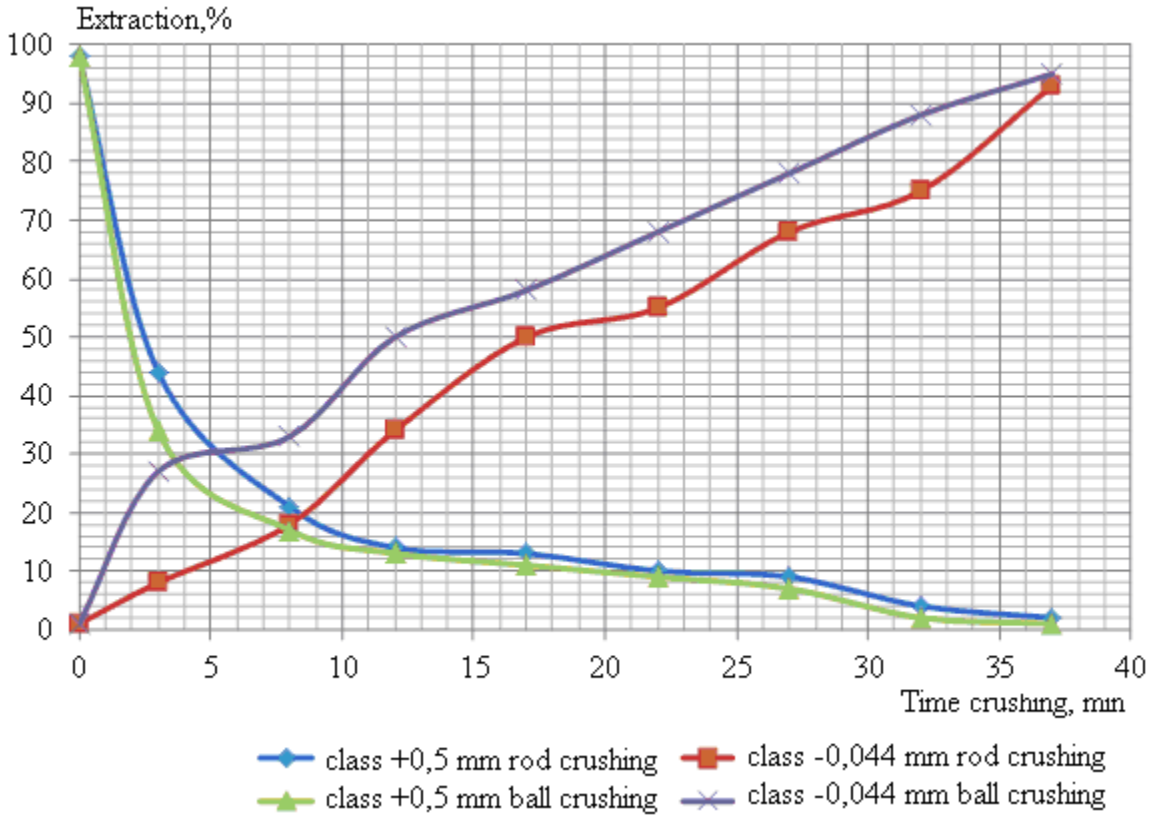

Fig. 10. Crushing kinetics of martite marshalited quartzit of Valyavkinskoe deposit (incorporated mineral variety 5) in rod and ball mills

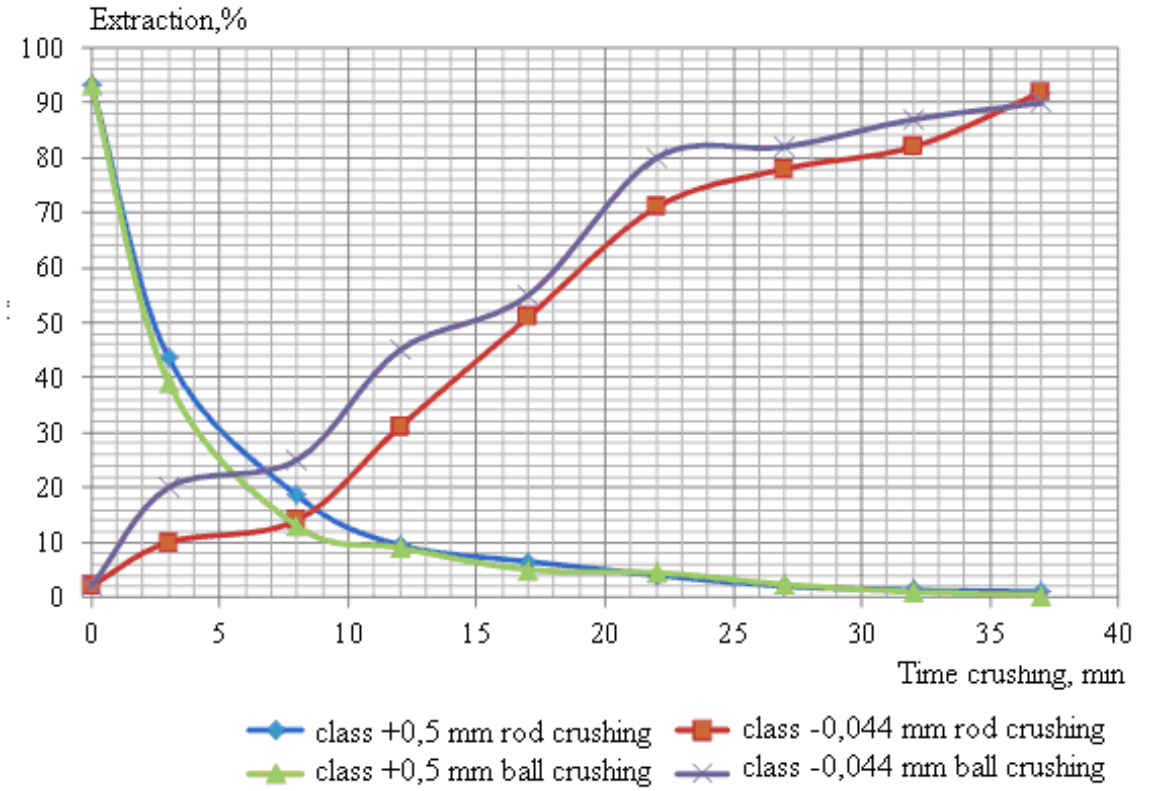

Fig. 11. Crushing kinetics of martite hetitizate quartzit of Skelevatskoe deposit (incorporated mineral variety 6) in rod and ball mills

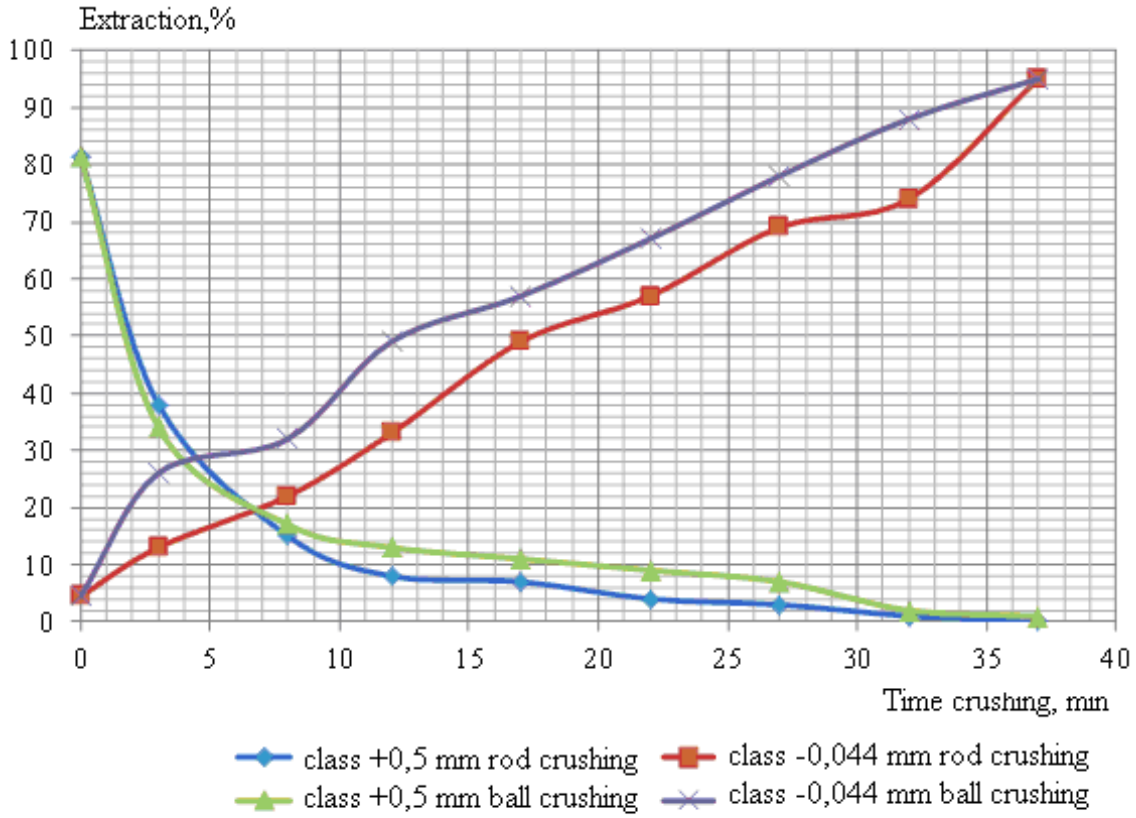

Fig. 12. Crushing kinetics of martite hetitizate quartzit of Valyavkinskoe deposit (incorporated mineral variety 6) in rod and ball mills

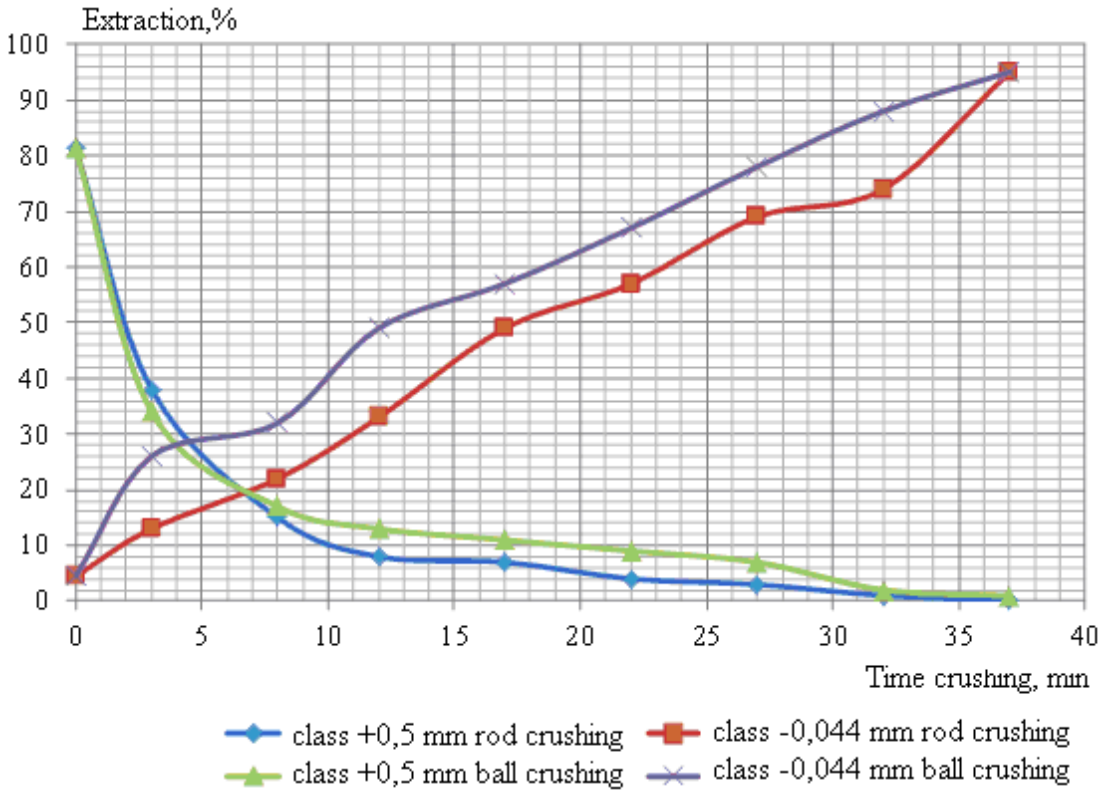

Fig. 13. Crushing kinetics of ferruginous quartzit hematite- martite and martite- hematite dispersed of Skelevatskoe deposit (incorporated mineral variety 7) in rod and ball mills

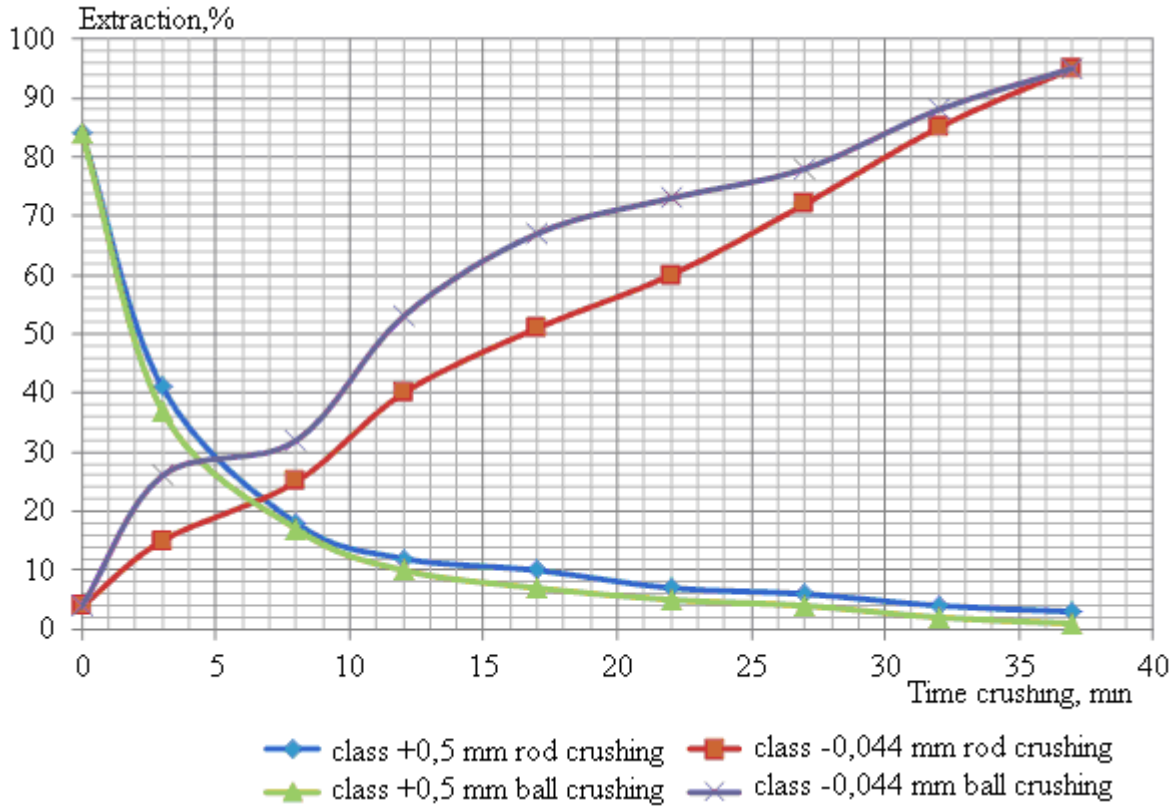

Fig. 14. Crushing kinetics of ferruginous quartzit hematite- martite and martite- hematite dispersed of Valyavkinskoe deposit (incorporated mineral variety 7) in rod and ball mills

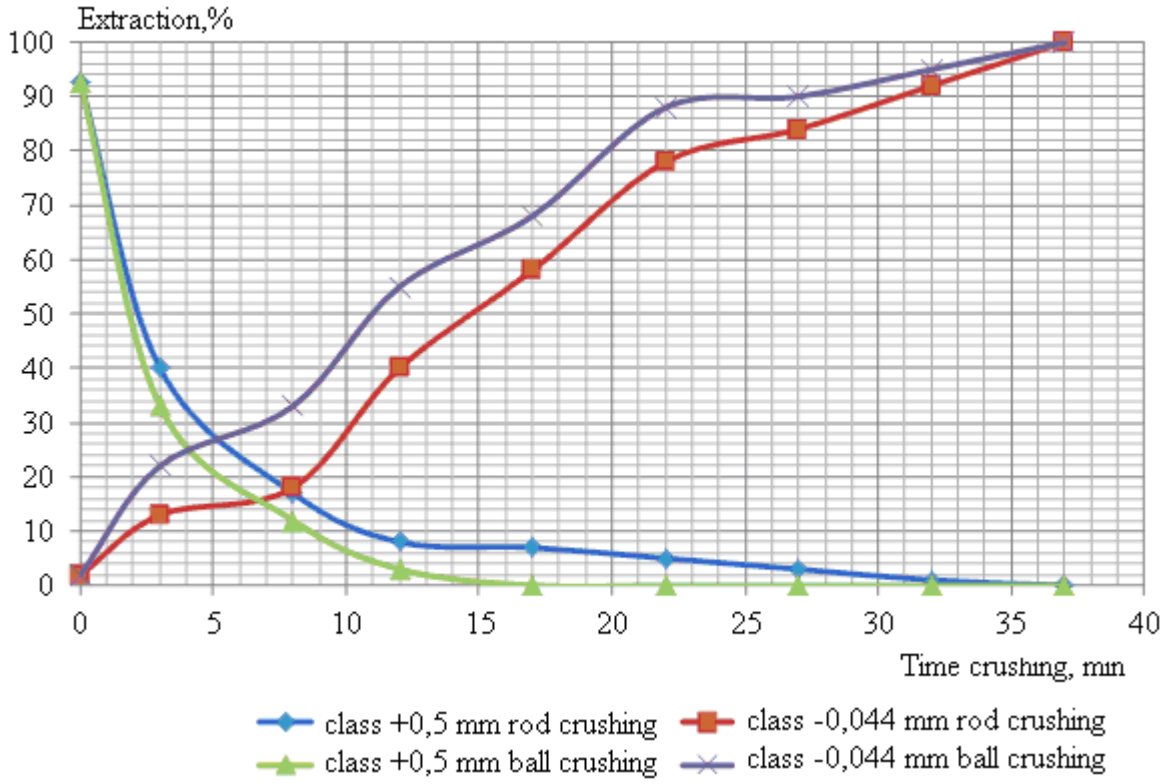

Fig. 15. Crushing kinetics of martite magnetite containing quartzit (weakly weathered) of Skelevatskoe deposit (incorporated mineral variety 8) in rod and ball mills

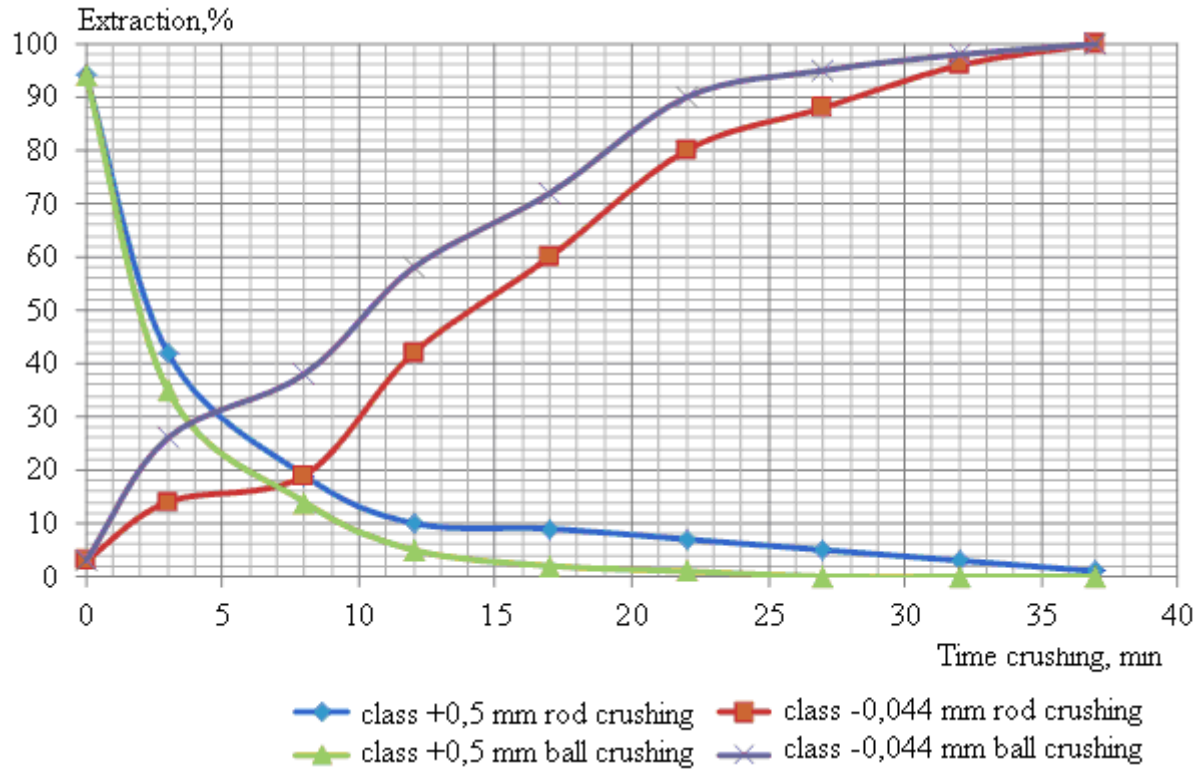

Fig. 16. Crushing kinetics of martite magnetite containing quartzit (weakly weathered) of Valyavkinskoe deposit (incorporated mineral variety 8) in rod and ball mills

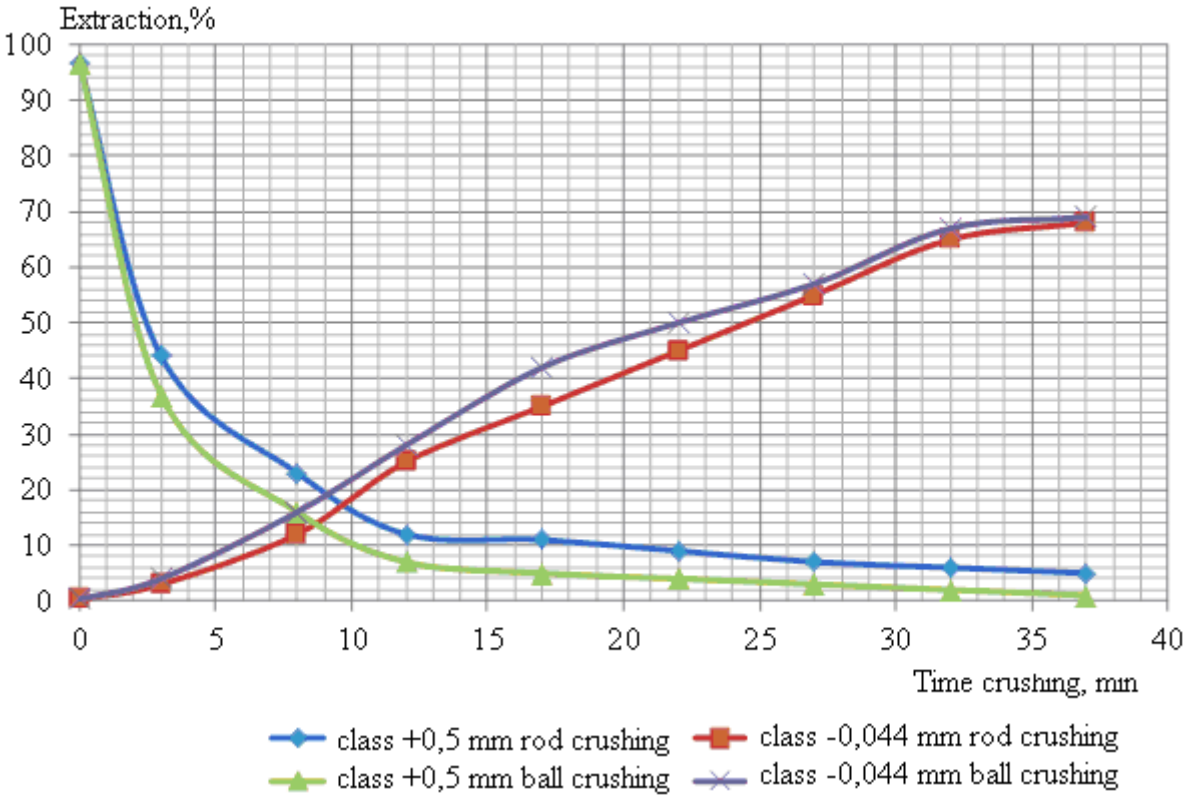

Fig. 17. Crushing kinetics of schist and barren quartzit of Skelevatskoe deposit (incorporated mineral variety 9) in rod and ball mills

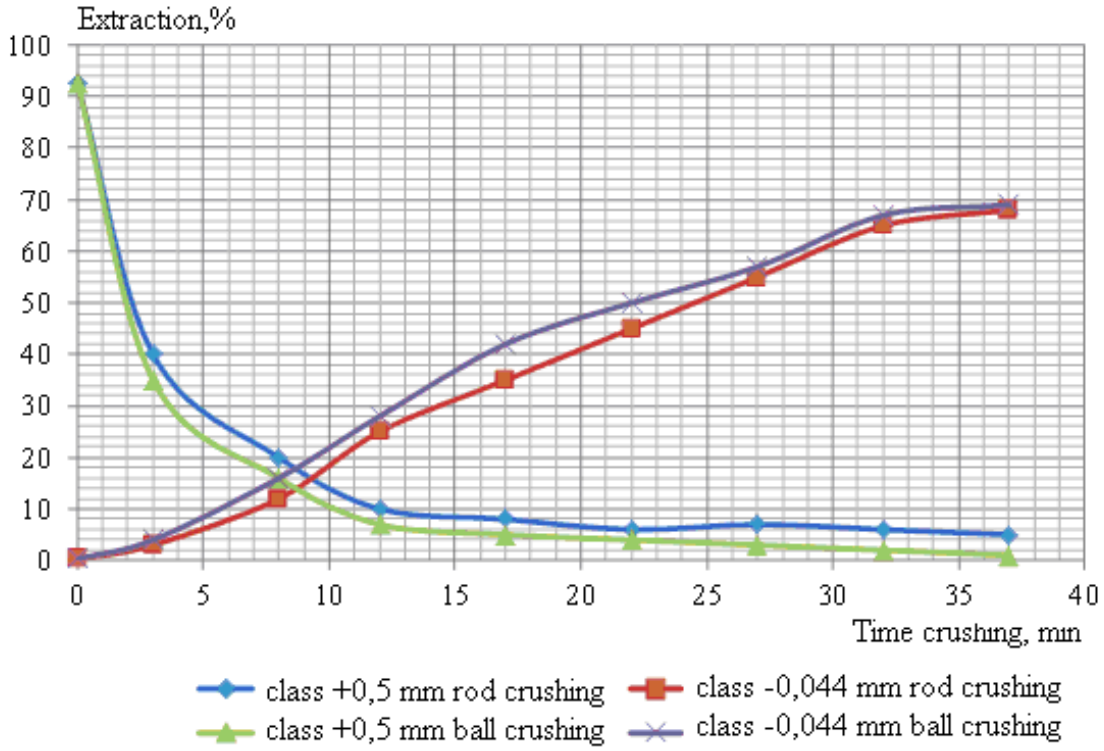

Fig. 18. Crushing kinetics of schist and barren quartzit of Valyavkinskoe deposit (incorporated mineral variety 9) in rod and ball mills

Table 8

Specific mill productivity according to new formed class in rod and ball mill with volume of 32 and 7 l (averaged data)

New formed class	Time of crushing			
	3	8	12	17
Rod crushing				
Initial ore				
-0,074 мм	1,427	0,887	0,747	0,638
-0,044 мм	0,739	0,459	0,387	0,33
Ball crushing				
Initial ore				
-0,074 мм	1,789	1,105	0,929	0,792
-0,044 мм	0,927	0,572	0,481	0,41

Conclusions and further research directions

1. Studying results of physical-mechanical properties of ore tests have allowed to relate the oxidized ores to a category of an average solidity ores, average crushability, to strongly abrasive materials with rather low porosity.

2. Crushing ore is recommended to carry out in two stages: the first one - up to 60-65 % of a class - 0,07 mm, the second - up to 90-95 % of a class - 0,044 mm.

3. At the first stage it is expedient to apply the rod mills working in an open crushing cycle.

4. For removal of dilution breeds from ore streams it is recommended predressing raw material by either a method of dry magnetic separation or jigging which expediency there will be shown by results of the further researches and technical economic calculations.

1. Справочник по обогащению руд. Подготовительные процессы / Под ред. Ю.Э. Аккермана, Г.Б. Букати, Б.В. Кизевальтера и др., 2-е изд., перераб. и доп. – М.: Недра, 1982. – 388 с.

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