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**ANALYSIS OF TECHNOLOGICAL POSSIBILITIES OF FERRIC RECOVERY BY
NON-CONVENTIONAL REDUCING AGENTS****P.Kh. Khayrullaev¹, U.B. Farmanov¹**¹*Tashkent State Technical University***Abstract**

The article discusses the results of the analysis of the technological possibilities of iron recovery of iron-containing concentrate by non-traditional restorers. The restoration of iron from its oxide compounds by direct gas recovery of iron-containing pellets with carbon monoxide is presented. The direct use of the secondary carbon monoxide available in the republic is shown in comparison with the application of complex process processes of carbon monoxide processing and production of intermediate products. It has been established that in order to fully recover iron oxides in the source raw material mass the technological cycle should be repeated several times. As a result, alloys of iron with other metals in iron ore concentrate are formed, as hydrogen is the ideal regenerator.

Key words: *monoxide, oxygenate, pelvis, regeneration, iron ore, exothermic reactions, magnetic separation, briquet.*

Today's demands on material resources make researchers and technologists strive to develop new high-efficiency yet environmentally sound technologies in the production of goods and products. At present, ferrous metallurgy does not meet such requirements. The domain method of iron production is quite "dirty" technology. Large amounts of gas emissions, wastewater and solid waste are generated.

The alternative to domain-based production is the method of gas direct recovery of iron-containing concentrates-pellets. The technologies in place in different parts of the world for direct recovery of iron-containing concentrates are quite different since in all cases the technological process is designed for the raw materials available in the country where production is well established. On the basis of the above, it is considered advisable to develop its own technology of direct recovery of iron-containing concentrates by a secondary gas reactor as opposed to the existing gas mixtures in the world practice.

Rich iron ore has an iron content of over 57%, silicon less than 8...10%, sulfur and phosphorus less than 0.15%. Rich iron ores are used for steel smelting in Martinov, converter production or for direct recovery of iron (hot briquettes iron). Poor and medium iron ore for industrial use must be pre-enriched. Unlike the domain technology, the proposed metal is not melted, but it is restored in the temperature range of 600-950⁰ C. In this case, the starting temperature of the stationary loading layer is determined at 650-750⁰ C. These leaking exothermal reactions to the complete combustion of carbon monoxide are perceptual: $\text{Fe}_2\text{O}_3 + \text{CO} \rightarrow \text{Fe} + \text{CO}_2 + 3900 \text{ Cal/mol}$. The equilibrium of reactions is shifted toward CO₂ formation.

The original material for the research was a technological sample selected by the Eastern Uzbekistan Geological Survey expedition. Before the enrichment, the original material was thoroughly mixed. The material composition of the products was studied through spectral and chemical analyzes. Before the enrichment process, the original raw material was subjected to chemical analysis. The results of chemical analysis of average samples of non-magnetic fractions are given in Table 1.

Table 1.

Results of chemical analysis of average ore samples

Component Name	Sample Contents, %		
	Not magnetic fraction 1	Not magnetic fraction 2	Not magnetic fraction 3
Silicon industry	40,92	42,6	40,4
Ferrum total	17,87	17,01	21,34
Ferrum sulfide	3,08	2,37	1,89
Oxides ferric (+2)	9,28	9,36	10,8
Titanium oxide	0,61	0,73	0,72
Glinosis	5,05	9,55	8,7
Calcium oxide	2,36	3,36	2,52
Magnesium oxide	3,79	5,45	5,65
Sulphur general	3,16	2,49	2,18
Sulphur SO ₃	0,28	0,24	0,19
Carbon oxide	2,0	2,46	2,46
Phosphorus	0,07	0,07	0,06
Arsenic	0,02	0,005	0,005
-H ₂ O	0,35	0,45	0,4
p.p.p.	4,45	5,8	5,0

Phase analysis of the original ore. The results of the phase analysis on the iron of the original ore, from which non-magnetic fractions were extracted, are given in Table 2. The analysis was carried out in the chemical laboratory of Opening Share Organization ``Ingichkka Enrichment Metal and Hard``.

Table 2.

Results of phase chemical analysis on iron

Forms of iron compounds	Content, %	Distribution of iron by mineral components, rel. %
Lightweight silicates (chlorite)	6,82	25,11
Magnetite	7,05	25,97
Carbonates	0,056	0,02
Iron hydroxide	2,58	9,5
Hepatitis	8,0	29,46
Hard-soluble silicates	not discovered	-
Sulfide	2,7	9,94
Total:	27,21	100

As shown in Table 2, the main part of the iron in the sample is associated with magnetite -25.97%, hepatitis -29.46% and light-soluble silicates (chlorite)-25.11 %. The smaller part of iron is made of sulfides - 9.94 and hydroxide - 9.5%. The source material was enriched with gravity, flotation and electromagnetic separations to obtain concentrate. Table 3 lists the results of the experiments of enriching a mixture of non-magnetic fractions on the concentration table.

Table 3.

Enrichment results on the concentration table

Products	Exit, %	Ferric content, %	Ferric extraction, %
Heavy fraction	26,0	40,0	59,43
Easy fraction	74,0	9,6	40,57
Source Material	100	17,5	100

Table 3 shows that a heavy fraction containing 40 % of the iron was obtained at the concentration table during the enrichment with a total extraction of 59.3 %. The results of the electromagnetic separation are given in Table 4.

Table 4.

Results of electromagnetic separation of heavy fraction

Products	Exit, %	Ferric Contents, %	Ferric Extraction, %	Current Power, A
Magnetic fraction	89,7	44,0	98,67	0,25
Non-magnetic fraction	10,3	5,17	1,33	
Ref. heavy fraction	100	40,0	100	

In the magnetic fraction chemical analysis determined sulfur, the content of which was 1.2-1.8%. Therefore, the magnetic fraction was floated to remove sulfide sulfur. Experimental works were carried out according to a simple scheme, including milking of the magnetic fraction and the main flotation.

In the Republic of Uzbekistan, there is no installation of iron from ore formations. The construction of a domain installation, which is obsolete today, is not in the interests of the republic. Copying of the technological process in operation at foreign objects, because they are not tied in projects to local ones, does not lead to expected results, as has already been the case in many cases in practice in the republic. Based on the above, within the framework of this scientific and technological development some technological parameters of direct recovery of iron-containing concentrate gaseous reactor - carbon monoxide of secondary origin, the potential of which is calculated in the republic in the amount of hundreds of millions of cubic meters. Besides, the technologies of underground and ground gasification of brown coal at the Angren field, which are being developed and proposed for implementation, can give such a quantity of carbon monoxide that can be successfully applied for the realization of promising environmentally sound technologies. A special place in the technology proposed for the study by the authors is the use of waste gas emissions as a regenerator of metallized pellets, consisting mainly of carbon monoxide produced as a result of methane conversion, which occurs in many chemical enterprises such as JV "Maksam-Chirchik", JSC "Navoiyazot", "Ferghana-nitrogen" etc. These gases are now being emitted into the atmosphere. It is considered advisable to use directly the secondary potential of carbon monoxide in the republic, instead of using complex process processes of carbon monoxide processing, with the production of intermediate products.

The reactor furnace regeneration of ferric oxides results from the chemical properties of carbon monoxide. At the same time, the process of ferric recovery takes place at a temperature

below the melting temperature and the final product of the process is a mixture of restored metal mass with slag. Therefore, the technological process continues until the receipt of the metal material. At first glance, the process being developed resembles the process of regeneration of iron ore concentrate using the Midrex method. It is supposed that the recovery mechanism is carried out according to a well-known scheme, which determines the physical and chemical properties of iron and its oxides: $3\text{Fe}_2\text{O}_3 + \text{CO} \rightarrow 2\text{Fe}_3\text{O}_4 + \text{CO}$; $\text{Fe}_3\text{O}_4 + \text{CO} \rightarrow 3\text{FeO} + \text{CO}_2$; $\text{FeO} + \text{CO} \rightarrow \text{Fe} + \text{CO}_2$.

As it is seen, in this case, hydrogen is not involved. However, it should be noted that it is necessary to strictly control the quality of the products of emission of the technological process of recovery, because the unreacted carbon monoxide must be oxidized to carbon dioxide. Particular rigidity of the technological process is caused by the need to ensure the absence of oxygen in the reaction zone. The presence of oxygen in the reducing gas mixture significantly reduces the efficiency of the technological process of reduction of iron oxides by carbon monoxide (Fig. 1).

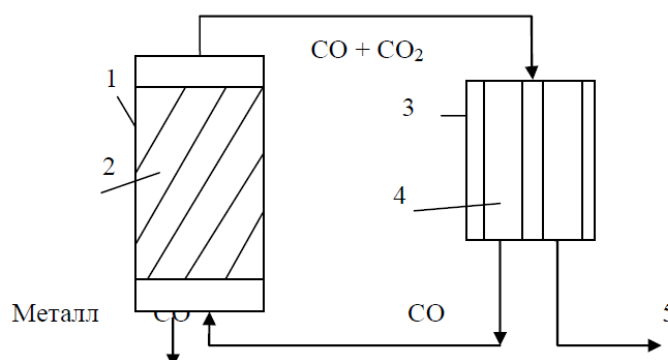


Fig. 1. Principal technological scheme of obtaining metals by ecologically clean method:

1. Reactor furnace; 2. Pellet; 3. Recovery department; 4. Restorer; 5. GTL installation - excessive amount of CO is directed to obtain synthesis gas or to obtain environmentally friendly energy carrier.

As a development of the above, there are possibilities of using excessive amounts of carbon monoxide as an external energy supply. Only in this case the flammable product does not return to the recovery mode. The reason for this is the presence of oxygen in the gaseous mixture.

Technological process of restoration of iron oxides by carbon monoxide should originate at the temperature mode not lower than 650-7500C. Otherwise, the process of gas-chemical synthesis with $\text{Fe}(\text{CO})_5$ formation proceeds instead of restoration. The technological process is carried out by restoration by carbon monoxide of pellets which are in a stationary condition. At the same time, the pellet surface has the possibility of contact with the reducing agent. It should be noted that the porosity of pellets favorably influences the degree of iron oxides recovery. The process with betonies does not affect the quality of the final product, as it takes place at the melted state of iron. And in case of gaseous reducing agent recovery, organic binders, like CMC reagent, are preferred, which influences the formation of tablets porosity, which simultaneously prevents iron pollution with silicon and aluminum. The technologies of direct reduction of iron-containing concentrates operating in different parts of the world differ from each other, as in all

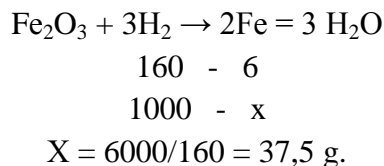
cases the technological process is developed for local raw materials. Based on this consideration, it is considered appropriate to develop its own technology of direct reduction on the basis of iron-containing concentrates from the Temirkon deposit as an alternative reducing agent of secondary origin. In this regard, the method of obtaining extrusion from powders enriched with ore mass with the use of water-soluble polymer - carboxyl methylcellulose - has been developed.

The estimated consumption of carbon monoxide for 1000 g of pure iron oxide is 525 g. If we take into account the concentration of iron oxide at 60 %, the estimated amount of carbon monoxide is 315 g for full recovery. It is necessary to take into account the oxidative catalytic property of iron oxide and therefore the supply of carbon monoxide should be in excess of 15 %. Other components of the ore mass may also be recovered.

The resulting reduction product is ground to a fraction below 0.125 mm and then subjected to magnetic separation. The results of the preliminary analysis show that the chemical composition is as follows: metallic iron of 62 % iron oxide of 28 %, mechanical admixture of 10 % for the complete reduction of iron oxides in the initial raw material mass the technological cycle should be repeated several times.

Note: Outgoing gas mixtures formed in the technological process of methane conversion have in their composition, in addition to monoxide, carbon dioxide, water vapor, hydrogen, methane, etc., which do not adversely affect the process of iron recovery. The presence of hydrogen and methane has a positive effect on the technological process.

The second option for iron ore concentrate recovery is a nitrogen-hydrogen mixture recovery technology based on the Chirchik-Maxam JV. The chemical scheme of the process is as follows:



Taking into account the concentration of hydrogen in the gas mixture at the level of 75% of the volume, the theoretical flow rate of gas flow is 50 g. It is necessary to take into account the additional hydrogen consumption for the recovery of other metal oxides contained in the iron ore concentrate.

In contrast to the reduction process with carbon monoxide, the nitrogen-hydrogen mixture recovery reaction takes place at significantly low temperatures; in the range of 450-480°C.

The results of the analysis lead to the conclusion that in the process of recovery alloys of iron with other metals are formed, which take place in the composition of iron ore concentrate, as hydrogen is an ideal regenerator.

Thus, the reduction reaction is effective only on the surface of solid ore particles, so a compromise between the raw materials (dusty or porous form) and the final product (sintered pellets, briquettes, "pumping", etc.) is needed.

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