PRODUCTION AND USE OF SYNTICOM®[1]

Guenrikh A. Dorofeev[2]

Summary: The purpose of the paper is to present the technology of production and use of a new cold metallic feedstock material for steelmaking called **Synticom** developed in Russia. The paper describes the production process of **Synticom**, which is a new material composed of pig iron and iron ore, in the simplest case, produced in pig machines, with low investment. It is expected that **Synticom** will replace with advantage the pig iron in the steelmaking burden. The paper shows the results of the use of this product in industrial scale in Russia, either in BOF vessels or in EAFs, as well as data about the use of **Synticom** in USA. It is described the various compositions of **Synticom**, indicating the most adequate type for each application. The paper lists the advantages of using **Synticom**, specially the high Carbon oxidation speed, due to the Oxygen contained in **Synticom**, when compared with pig iron.

Keywords: Synticom, pig iron

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[2] Engineer. Director of NPMP INTERMET-SERVICE, Tula, Russia.

PRODUCTION AND USE OF SYNTICOM®.

A new composite charge material for steelmaking - **Synticom**, has been developed, patented and is being produced in production quantities in Russia. It is basically comprised of the iron-carbon alloys and solid oxidants (ferric oxides). The material may additionally comprise carbonic materials, fluxes, alloying elements, reducing metals.

It makes it possible to replenish the list of already known types of metallic charge – scrap, cold pig iron, direct-reduced iron, hot metal, with one more stuff.

The name **Synticom** is an abbreviation from **synthetic composite of metal oxide.** From this appears that the developed charge is produced using the technique of initial original components synthesizing (solid oxidants, carbon, fluxes) and metallic component which basis is comprised of iron and carbon, for example, pig iron, or intermediate product recovered from hot metal after out-of-furnace treatment, or another iron-carbon melt.

Composition of the initial components, their known origin and heredity, absence of high-temperature phase transformations ensure **Synticom** to be a high-purity charge with known composition and origin.

General formula of **Synticom** looks like:

$[Fe]+(Fe_nO_m)+[C]+C_{free}+(Slag)+[R]_{Si, Mn, P, V, Ti, Cr, etc.}+R_{Si, Mn, P, V, Ti, Cr, etc}$

where [Fe] – basic (pivotal) element;

(Fe_nO_m) – ferric oxides;

[C] – melt-in carbon;

C_{free} – free carbon;

(Slag) – slag forming components (solid oxidants gob, special fluxes);

$[R]_{Si, Mn, P, V, Ti, Cr, etc.}$ – reducing elements dissolved in Fe;

$R_{Si, Mn, P, V, Ti, Cr, etc}$ – free reducing elements (not dissolved in Fe).

External view and cross section of Synticom pig are shown in Fig.1.

In the process of heat and melting-down, carbon and other elements containing in the pig iron or in the other iron-carbon melt are being oxidized by the oxygen from ferric oxides. It results in turning the metallic base of **Synticom** into steel or low-carbon Fe. After giving up oxygen the ferric oxides are reduced into Fe that comes into hot metal.

Possible degree of **Synticom** metallization is characterized by the special index of equivalent metallization:

$Y_{equivalent} = Y + 4.67[C] +2.33 [Si] + 4.58 [Mn] +2.58[P]$

where Y - initial degree of **Synticom** metallization;

[C], [Si], [Mn], [P] – concentration of elements in **Synticom** metallic base, % of weight.

Figures which stand before the concentration of elements are the coefficients which incorporate the stehiometry of reduction reaction of the ferric oxides by the corresponding elements.

Synticom is a material with the known and stable composition. The purity of composition for the filler is defined by the nature of ore deposit, and for the metallic base it is defined by the type of ore stuff, coke quality and kind of iron-carbon melt out-of-furnace treatment. As a rule **Synticom** is comprised of the metallic base derivable from ores, pellets, agglomerates from known ore deposit and oxide components from the same deposit. It ensures for extremely low contamination of the material with deleterious and undesirable elements as well as the stability of its composition.

Chemical composition and physical properties of **Synticom** as compared to traditional types of metallic charge are represented in tables 1 and 2.

Ferric oxides content may vary in a wide range – from 5% to 30% depending upon the **Synticom** specification and customer's demand. Grade of **Synticom** is determined by the part by weight of solid fillers in it – ferric oxides and other mineral components. Range of grades of **Synticom** comprises SK5, SK10, SK15, SK20, SK25 and SK30 grades. Admissible value of components variations in the batch of **Synticom** comes to $\pm$ 2.5%. Weight of pigs may vary from 8 to 40kg. The industry has already mastered the production of SK10, SK15 and SK20 grades of **Synticom**.

Average calculated composition of **Synticom** produced by Tulachermet JSC and Chusovskoy Metallurgical Plant is shown in tables 1 and 2. Cherepovets-based Severstal Metallurgical Works produces **Synticom** using agglomerates as a filler. Severstal uses **Synticom** instead of purchased steel scrap for making JF grades of steel in BOFs. Besides it is required by the necessity to speed up the slag forming. This plant faces this problem when making steels from low manganese pig iron.

The casting machines for cold pig iron production are used in the **Synticom** production process after their corresponding upgrade (Fig.2). Principle of production is based upon the mechanical mixture of the solid oxidants and other components of the filler with the pig iron melt in the casting machine moulds.

A set of optional equipment to upgrade casting machine includes:

- filler handling system;
- dosing apparatus for handling the filler into the moulds;
- system of pig iron melt supply into the moulds.

In the process of heat and melting-down of **Synticom** the following chemical reactions take place:

$(Fe_nO_m) + [Si] \rightarrow [Fe] + (SiO_2)$

$(Fe_nO_m) + [Mn] \rightarrow [Fe] + (MnO)$

$(Fe_nO_m) + [P] \rightarrow [Fe] + (P_2O_5)$

$(Fe_nO_m) + [C] \rightarrow [Fe] + \{CO\}$

$\{CO\} + {}^1/_2\{O_2\} = \{CO_2\}$

Fairly developed surface of contact of **Synticom** metallic base with ferric oxides and metallic base low melting temperature as well as the oxygen presence in the form of ferric oxides inside the volume of iron-carbon melt contribute to early beginning of the pig iron residuals oxidation, reduction of ferric oxides from the filler, active slag forming, continuous carbon monoxide release and its afterburning, intensive mixing of bath.

The above factors ensure extremely high rates of all reactions and their superimposition in time and space.

Basic physical and chemical reactions taking place in the process of heat and melting-down of grades of **Synticom** with different compositions are shown in Fig.3 and 4.

One should pay attention to the fairly high rates of carbon oxidation reaching the values of 0.25% C/min., as well as to the presence of two crests on the decarbonization curve corresponding to the temperature range of 1300^0C and 1600^0C. These specific values are not limiting. In the higher temperatures zone the rate of carbon oxidation reaches the value of 0.4-0.8% C/min., that exceeds this index for the converter baths.

Synticom composition and techniques of its production ensure the output of metallic charge with the preset qualities, considering the conditions of its further recast in the steel-making vessels of different types, including EAFs and BOFs. It allows to choose the grade, composition and properties of **Synticom** in regard to the peculiarities of specified vessel performance. Capability to adapt **Synticom** for the technological features of steel-making vessel allows to forecast its behavior during the heat and progress of whole heat with higher confidence.

Simultaneous presence of solid oxidants and reductants (carbon and other elements) in the **Synticom** and possibility of their proportions variation in wide ranges make it possible to change the oxidizing and reducing potentials of **Synticom** in the same way as it happens with the similar steel-making vessels oxidation power depending upon the blown oxygen, content of carbon in the charge, composition of metallic charge, power of degassing devices, status of furnace lining and other factors. From this point of view **Synticom** is a charge which oxidizing and reducing properties can be varied with respect to the vessel type, its oxidation power, thermal power and charge composition. Thus, the use of **Synticom** creates the necessary prerequisites for the optional control of the furnace oxidizing and reducing characteristics. In this way **Synticom** represents a class of materials with the certain thermal, physical and chemical properties which after bringing them into the vessel may change in this or that way the oxidizing and reducing characteristics of the system or to leave them as they are.

The same factors, the simultaneous presence in **Synticom** of solid oxidants and reductants in different proportions namely, as well as the temperature of heat allow to vary the share of carbon being oxidized by own oxygen coming from ferric oxides and gaseous oxygen blown into the bath (furnace).

Changes in proportions of oxidant and reductants shares and degree of carbon oxidation reaction progress (by the oxygen coming from ferric oxides and gaseous blowing) makes it possible to vary widely the energy properties of **Synticom** from cooling agent to energy carrier.

Cooling ability of **Synticom** with regard to scrap may vary in significant ranges from 0.85 to1.60, that is 2.0 times (Fig. 5).

Synticom with greater cooling ability is used as a cooling agent for the converter bath. **Synticom** with the low power inputs for its melting is expedient for use in the EAFs or in the BOFs processing cold pig iron (or to reduce the consumption of hot metal per 1 ton of steel).

To a certain extent **Synticom** comes as the analog of the capital scrap according to its thermophysical properties – density, bulk weight, heat conductivity, temperature conductivity, heat capacity. At the same time it differs essentially from the capital scrap by the following features:

- unit mass of the **Synticom** pigs (from 8 to 40kg) is much more less than of capital scrap fragments reaching 500-2000 kg;
- **Synticom** pigs are of the fixed size, weight, shape and properties;
- **Synticom** has a larger specific surface of heat referred to unit mass than capital scrap;
- melting temperature of **Synticom** metallic base is 230-380^{0}C lower than that one of scrap. It speeds up **Synticom** melting if compared to scrap;
- presence of the ferric oxides in **Synticom** ensures for oxidation of the pig iron particles in **Synticom** at low temperature – from the moment of beginning of **Synticom** metallic base melting, i.e. at 1150-1200^{0}C;
- continuous release of the carbon monoxide from the beginning of melting prevents the formation of the massive slabs from the **Synticom** in the liquid melt. These massive slabs may slow down the melt of the charge;
- carbon oxidation in **Synticom** takes place earlier than in scrap and proceeds significantly faster;
- use of **Synticom** instead of the capital scrap ensures for more expedient use of blown oxygen;
- unlike scrap, **Synticom** doesn't require the necessity of restrictions in electric input and reduces surges (more stable burning of arcs in EAFs);
- The possibility to use **Synticom** separately, as well as in combination with all the known types of charge, in any steel-making vessels and cast-iron machines – EAFs of different types, BOFs, open-hearth furnaces, when making various grades of steel – from ordinary to special alloyed ones is the proof of **Synticom** universal nature;

Synticom is a practically feasible charge:

- no additional measures are required for its transportation and storage;
- its use in steel-making doesn't require changes in vessels design;
- due to the fixed size, weight, shape and properties of **Synticom** prevent the development of any accidental processes when making steels;
- superimposition of the melting, oxidation of carbon and other impurities, slag forming, boiling and mixing, early and continuous carbon monoxide release in the process of heat, absence of the pre-forming of slag and warming the metal to 1560-1580^{0}C highlight the considerable advantages of **Synticom** as compared to known charges.

Synticom may be used in the charge for EAFs in any quantities right up to 60-100%, whereas the melting of 100% of cold pig iron or liquid hot metal in the EAF causes a number of technological problems.

Due to the use of **Synticom** in EAFs the share of the pure charge in the heat may be increased to the level of BOFs and it's possible to produce steels which are not inferior to the converter metal in purity.

Synticom may be also used in the EAFs together with hot metal, the share of which is usually limited to 30-40%. In this case the charge of the EAF may be by 100% comprised of the original material – hot metal and **Synticom**. This makes it possible to produce steels with extremely high purity which may be compared to the converter metal.

The ability of carbon to oxidize in the **Synticom** synchronously with its melting ensures the uniform oxidation of carbon in the course of heat excluding the peak nature of this reaction and peak gassing not acceptable for the EAFs because of design requirements. Thus, the use of **Synticom** in the EAFs creates future trends for widening the range of produced steels and improvement of their quality to the level of converter metal but without changes in the EAFs design. It raises the competitiveness of the electric furnace steel-making and promises new prospects by making possible the production of high-quality steel without presence of the hot metal in the charge.

As it was mentioned above, the cooling ability of **Synticom** may be varied in a wide range. This property of the **Synticom**-type materials makes them a perfect heat cooler in BOFs. The experience of tests in 160t and 350t BOFs shows that **Synticom** may be used both: together with scrap and under the total withdrawal of steel scrap from the charge.

Under the total substitution of the steel scrap for **Synticom** the charge of BOF heat is by 100% comprised of the original material – hot metal and **Synticom.** It allows to produce steels with the extremely low content of non-ferrous metals residuals and ensures for high and stable quality of the produced metal.

Use of **Synticom** with lower cooling ability than that one of scrap allows to decrease the share of hot metal in the charge to 69-70% without changes in converter design and other additional measures.

Change-over to the use of **Synticom** instead of cold pig iron removes all the restrictions from the use of the latter in BOF heat and allows to increase the share of cold pig iron in the form of **Synticom** to 25-31% instead of standard 5-7%. Developed and tested technology proves the practical feasibility of **Synticom** for the converter process.

Carbon oxidation in **Synticom** with the uniform and continuous release of carbon monoxide in the course of heat solves the problem which has not been cracked till the present moment – capability of CO afterburning into CO_2 and the increase of degree of furnace bath afterburning heat usage. Carbon in the **Synticom** starts to oxidize from the moment of material melting and its oxidation proceeds continuously in the whole course of the heat, including the phase when the major part of the charge is not melted down yet. It allows to increase the degree of CO afterburning into CO_2 and to increase the effectiveness of 1kg of carbon burning to 7.6 kWh instead of standard 2.9-3.3 kWh. Along with it, it increases the coefficient of energy used from CO afterburning into CO_2 from the value of 0.40-0.60 to the value of 0.75-0.90 in the EAFs. Thus, use of **Synticom** allows to improve the use of carbon as a fuel material in the EAFs without changes in their design. This is one of the most important advantages of **Synticom** before hot metal or cold pig iron, scrap or direct-reduced iron. This is of special importance for the heat in which the low-carbon semi-product obtained as a result of Si, P, S expulsion is often used as an initial charge. Under these conditions **Synticom** allows to improve thermal balance due to the better use of carbon as a fuel material.

Summing up the above, one may come to the conclusion that the carbon in **Synticom** is used with the maximum effectiveness as a fuel material and as a reducing material.

Some results of **Synticom** use in the BOFs are shown in Fig. 6-10.

Data concerning use of **Synticom** in EAFs are shown in tables 3-5.

Presented results confirm that **Synticom** improves the performance of both BOFs and EAFs.

Economic effectiveness of **Synticom** production is characterized by the following rates:

Conversion of 1 ton of pig iron into **Synticom** increases the **Synticom** charge yield to 1.111-1.429 t and this ensures output expansion by 11.1-42.9% depending upon the grade of **Synticom** (Fig.11).

Cost price of **Synticom** is lower than that one of pig iron and comes to 92.5-77.1% of cost price of pig iron used for **Synticom** production.

Economic indexes of **Synticom** may differ insignificantly depending upon certain features of the **Synticom** manufacturing company, however they do not change general evaluation of **Synticom** as a fairly efficient material.

Minimum price of **Synticom**, evaluated under the principle of the general cost of 1kg of Fe in **Synticom** and in the pig iron, comes to 90.9-97.0% of the pig iron price, i.e. it is lower than the price of pig iron by 3.0-9.1%. However, this price doesn't consider the effect obtained from the use of **Synticom** in steel-making. That's why the actual effectiveness of **Synticom** is higher. Economic indexes for the **Synticom** of various grades are shown in table 6.

Synticom is the most environment-friendly material if compared to known types of charge. In its original condition **Synticom** doesn't contain organic and mineral impurities, dust, moisture, foreign matters, it is explosion-proof and fire-safe, it doesn't evolve harmful gases in the course of transportation and storage.

Melting of the **Synticom** in the furnace and steel-making process with the use of **Synticom** is accompanied with the boiling of metal and slag, foaming of the latter, thus diminishing the evaporation of Fe, formation of nitric oxides NO_x, emanation and noise, and prevents the oxidation of Fe. The latter is one of the most important advantages of **Synticom**.

Synticom production lowers the influence upon environment because additional amount of charge obtained due to the ferric oxides input is not accompanied with the corresponding increase in consumption of coke, natural gas, oxygen and blowouts of waste gases and dust. Addition of the cold stuff into the hot metal in the course of **Synticom** production reduces to the minimum or totally excludes the necessity of cooling the obtained pigs of stuff with air and water and excludes kish formation. Taken together it makes **Synticom** to be a environmentally-friendly stuff .

Synticom may be considered as the first high-tech product in the field of charge materials. Its use in the steel production has great future. This is the first "smart" charge which is able to consider its future at its birth. The future for which it is specially produced!

The obtained data concerning the use of **Synticom** are the evidence of the fact that in the near future cold pig iron may give place to **Synticom-type** materials. It doesn't mean that pig iron is drawing to a close, but it means its new life in another status.

Synticom is very new as a material yet. It's just at the beginning of its way. But no doubts, in the course of time many of its capabilities will be revealed.

Synticom is an example of the steel metallurgy change-over to the usage of preliminary prepared charge materials adapted to the features of the certain steel-making vessels. This trend will take the future! Soon **Synticom** will be available in the market of metallic charge and the steelmakers will get new perfect material at their disposal.

Table 1

Chemical Composition of Synticom (produced at JSC "Tulachermet") and its general thermal properties.

№№	Chemical element or compound	SK10	SK15	SK20	Average	
					DRI OEMK	Pig iron
1.	Fe_{total}, %	89,7-93,0	88,1-91,6	87,5-90,1	90.0	94.5
2.	Fe_{met}, %	81,9-88,1	77,2-83,3	73,5-78,5	86.0	94.5
3.	Fe_2O_3, %	6,5-11,5	10,9-16,1	15,3-20,7	0.2	-
4.	FeO, %	0,1-0,3	0,2-0,4	0,3-0,5	8.5	-
5.	C, %	3,8-4,2	3,6-4,0	3,4-3,7	1.65	4.4
6.	Si, %	0,3-1,1	0,3-1,1	0,2-1,0	-	0.7
7.	Mn, %	0,1-0,4	0,1-0,4	0,1-0,4	-	0.1
8.	S, %	0,01-0,04	0,01-0,04	0,01-0,04	<0.01	<0.05
9.	P, %	0,03-0,06	0,03-0,06	0,03-0,06	<0.02	<0.1
10.	SiO_2, %	0,3-1,0	0,6-1,4	0,8-1,9	3.5	-
11.	CaO, %	0,1-0,4	0,1-0,4	0,1-0,5	-	-
12.	Cu+Cr+Ti+Sn+Pb,	0,01-0,02	0,01-0,02	0,01-0,02	<0.15	<0.2
13.	%	0,1-0,3	0,1-0,3	0,1-0,3	-	-
14.	Other impurities	1150-1250	1150-1250	1150-1250	1500	1150
	Meltdown, ^0C	6.33	6.06	5.80	3.2	6.8
	Specific density, t/m^3	3.20	3.10	2.90	1.80	3.3
	Apparent density, t/m^3					

Intermet – Service Composition

The calculated chemical composition of Synticom grades on the basis of carbon bearing semiproduct produced at the JSC "Chusovoy Metallurgical Plant" and iron-ore pellets from Kachkanarsky GOK.

Table 2

Chemical Composition of Synticom(produced at JSC "ChMP") and its general thermal properties.

№ №	Chemical element and compound	SK10P	SK15P	SK20P	Average	
					DRI OEMK	Pig iron
1.	Fe total, %	90,8-93,8	89,0-92,0	87,5-90,2	90.0	94.5
2.	Fe met, %	83,5-89,2	78,7-84,4	74,0-79,5	86.0	94.5
3.	Fe2O3, %	5,9-10,4	9,9-14,5	13,8-18,6	0.2	-
4.	FeO, %	0,3-0,6	0,5-0,8	0,7-1,0	8.5	-
5.	C, %	2,9-3,7	2,8-3,5	2,6-3,3	1.65	4.4
6.	Si, %	<0,1	<0,1	<0,1	-	0.7
7.	Mn, %	<0,1	<0,1	<0,1	-	0.1
8.	S, %	0,03-0,06	0,03-0,06	0,025-0,05	<0.01	<0.05
9.	P, %	0,035-0,06	0,035-0,06	0,03-0,05	<0.02	<0.1
10.	SiO2, %	0,3-0,63	0,5-0,9	0,7-1,13	3.5	-
11.	CaO, %	0,06-0,3	0,1-0,36	0,14-0,5	-	-
12.	V+Cr %	<0,2	<0,2	<0,2	-	-
13.	Other impurities	0,5-1,12	0,8-1,6	1,18-2,02	-	-
14.	Meltdown, ^{0}C	1150-1250	1150-1250	1150-1250	1500	1150
	Specific density, t/m^3	6.33	6.06	5.80	3.2	6.8
	Apparent density, t/m^3	3.20	3.10	2.90	1.80	3.3

Intermet – Service Use of Synticom in Steelmaking

TABLE 3

MAJOR RESULTS OF SYNTICOM use in 120-t EAF of DANARC-system at Moldova

Parameters of heats	Charge composition	
	Traditional technology, 100% steel scrap	**80% steel scrap + 20% Synticom SK17**
Number of heats analysed	**90**	**46**
Power-on time	**51,0**	**51,3**
Consumption of carburizer and coal powder, kg/t	**8,3**	**7,7**
Slag basicity ($CaO: SiO_2$)	**1,47**	**1,90**
Share of total iron in the slag	**22,8**	**18,1**
Electricity consumption, KWt/h per 1 t of steel	**431,6**	**420.2**
Yield, % of mass charge	**89,5**	**91,3**
Consumption of natural gas, refractory, lime, oxygen and electrodes was not varied.		

Intermet – Service **Use of Synticom in**

Steelmaking

THE MAJOR RESULTS OF SYNTICOM use in the 150-t EAF at Steel Dynamics Ins. (Butler,Ind.)

Parameters of heats	86 % of steel scrap + 14 % of solid pig iron (a conventional technology)	83 % of steel scrap + 17 % of Synticom SK17 (April, 1998.)	81,8 % of steel scrap + 8,5 % of solid pig iron+ 9,7 % of Synticom SK22 (September, 1998)
Number of heats analyzed	440	14	10
Power-on time, min	48,3	48.2	49,6
Fuel coke consumption in the charge, kg/Mt	11,3	14,7	15,3
Carbon powder consumption, kg/Mt	7.3	no data	8,8
Oxygen consumption, Nm^3/Mt	27,16	26,24	28,49
Oxygen content in steel, ppm	985	1096	1008
Carbon content in steel, ppm	29	28	27
Average electricity consumption, kWh/Mt	458,7	457,4	456,7
Average yield, % of charge mass	94,82	92,30	94,50

Consumption of natural gas, refractory, lime and electrodes were practically the same.

Intermet – Service Synticom®

Table 5. Comparisons of the basic heats parameters of the "standard" technology and trial heats in 60 t EAF of Kia-Steel

Type of technology	Metal charge	Average "power-on" time, min.	Average liquid steel output, %	Consumptions per 1 t. Of steel		Average koks consumption, kg
				Electricity, kWt	Injected oxygen, Nm^3	
"Standard" technology of Kia-Steel	100 % steel scrap	50-55	93,0	435-440	37-39	1600-1800
Trial heats using Synticom	80-89 % scrap and 11-20 % SK15-P	50	93,1	397	29	1212
Including the best result	80,4 % scrap and 19,6 % SK15-P	45	94,5	355,2	26	1005

Intermet – Service____________Composition

TABLE 6

Economic indexes	Pig iron used for **Synticom** production	Basic grades of **Synticom**			
		SK10	SK15	SK20	SK25
1. **Synticom** output per 1 ton of pig iron, t.	1.000	1.111	1.176	1.250	1.333
2. **Synticom** cost price in % to pig iron cost price.	100.0	92.5	88.7	84.8	81.0
3. **Synticom** price in % to the price of pig iron (acc. Fe_{gen}, not considering technological and consumer's properties.	100.0	96.9	95.4	93.9	92.4
4. Profit per 1 ton of **Synticom** in % to the profit per 1 ton of pig iron.	100.0	160.0	192.3	224.6	256.9