Experience in the use of tyres and organic components of municipal solid wastes in steel production

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Ferrous metallurgy is traditionally one of the most resource- and power-consuming branch of industry. It consumes up to 8 % of the world's energy resources. For example, in Japan 15 % of energy consumption falls to the share of ferrous metallurgy, in Germany – 10 %, in Great Britain, France, Italy – 7-8 %, in the USA – 4,5 %, in Russia – 9-10 %. Share of raw materials, fuel and energy resources in production price in traditional for Russia technological process of blast-furnace – converter is 66.6-73.1% whereas in the USA – 60.1 %, in Germany – 60.9 %, in Japan – 53.8 %, France – 61.7 %.

In the conditions of the settled mechanism of pricing in the industry, considerable decrease of material and energy recourses at steel melting in the converters is achieved with help of substitution of cast iron by scrap metal. It is well known [1] that specific power intensity, i.e. total primary energy inputs for cast iron equal to 23,8 MJ/kg, for scrap metal – 0,2 MJ/kg.

Nowadays energy-saving technologies are widespread. They allow to optimize thermal balance of the converter melting, decrease consumption of the liquid cast iron and increase the share of the processed scrap up to 35–40 % accordingly.

To the latest ones can be referred different methods of metal blow with afterburning of the effluent gas in the working space of the installation, scrap preheating with help of fuel-oxygen tuyere, additional tuyeres of the burners and wide use for heat carriers heating, first of all carbon-containing materials in lump or powder shape. But at the same time with the exception for cast-iron saving there is probable decrease of some technical and economic showings of the process, for example, metal quality, lining life and liquid yield of steel. Advanced solution of this problem is use of renewable types of energy resources including domestic garbage.

At the West Siberian Iron and Steel Plant (ZSMK) updated technologies of melting in converters are developed with use of elements of motor-vehicle tyres and solid domestic garbage as fuel elements [2, 3].

In the Table 1 the data about chemical composition and heat value of the carbon-containing materials recommended for use in the steel melting production are presented: coke, coals of different types, used tyres, conveyor belts and fuel

Table 1. Chemical composition and combustion value of solid fuel

Components	Humidity W_t^r, %	Concentration, % dry mass						Lowest combustion value, kJ/kg
		Ash level. A^d	C	H	O	N	S	
Coke	5.0	10.0	87.7	0.4	0.3	1.2	0.4	29 580
Coal, open-pit mine Mezhdurechenskiy	5.0-9.0	10.0	83.4	2.5	2.3	1.7	0.3	29 517
Coal, open-pit mine Bachatskiy	6.5-10.0	8.0	81.1	4.0	4.5	2.0	0.3	28 680
Coal, open-pit mine Yerunakovskiy	9.0-10.0	14.0	69.3	5.2	8.7	2.4	0.4	27 069
Rubber (used tyres, conveyor belts)	less than 1.0	2.5	85.0	8.2	2.4	0.4	1.5	37.025
Paper	less than 1.0	4.0	42.6	5.9	47.4	0.5	0.2	19 987
PE	less than 1.0	less than 1.0	91.5	8.0	0	0.5	0.1	39 680
PS	less than 1.0	less than 1.0	96.5	3.0	0	0.2	0	35 680
PET	less than 1.0	less than 1.0	55.0	4.0	41.0	0	0	22 677
Textile	less than 1.0	1.0-3.0	55.1	6.8	31.2	4.8	0.1	22 550
Wood	1.0	1.0	51.0	6.1	41.6	0.2	0.1	19 077

components of the Municipal Solid Waste (MSW) – paper, plastics waste (polyethylene PE, polystyrene PS, polythene terephthalate PET) and etc.

These data show that MSW in their chemical composition and technological value are close to the heat-carrying agents traditionally used in steel melting industry. At the same time MSW have some advantage over coal and coke because of its low humidity, and plastics (PE, PS, PET), textile, wood have a lower ash level (less than 1 %) in comparison with coals (8–14 %), coke (10.0 %) and rubber (2.5 %).

Melting technology in the converters with use of used tyres presupposes placing into converter for metal scrap at the stage of its prior heating with oxygen supply and burning of carbon containing materials of middle and small-sized automobiles. At the same time organic part of tyres burns down evolving a great amount of heat, the metal cord melts replacing the part of the metal scrap. Results of technical analysis of the organic part of the tyres are given above in Table 1. Factor of coal substitution by tyres is 1.5 t/t, i.e. combustion of 1 tonne of tyres equals in its heat effect to the combustion in the converter 1.5 t of coal. It is established that the highest possible efficiency and environmental safety of the converter process is provided by tyres consumption up to 2 kg/tonne. Technological work parameters of 160-ton converters with use of used tyres are given in the Table 2. Used tyres allowed to increase heat intake into the converter due to combustion value increase and improvement of the heat transmission conditions as a result of increase of jet luminous emittance while ash particles combustion that lead to the decrease of the total fuel consumption.

Tyres placing into the converter doesn't influence on the content of the dust in the gases emitted into the atmosphere. High temperature and excess oxygen in the converter furthered the complete combustion of the tyres and the products of their thermal decomposition that excluded the possibility of atmospheric air pollution with products of fuel partial combustion (soot, carbon monoxide, carbohydrates). Concentration of sulfur oxide in the emitted into the atmosphere gases within the recommended tyres consumption was not higher than during of the comparative experiments with use of coal without tyres addition.

As regards the use of combustible components of SDG as heat-carrying agents, then their sorting with separation of valuable components is necessary as well as briquetting in accordance with engineering procedure requirements.

For the pilot industrial researches pilot lots of solid fuel on the basis of organic components of MSW were produced:

1. Paper waste (pressed packs 0.6×0.8×0.8 m, 80 kg, tied up with steel wire);

2. PE waste (pressed packs 0.6×0.8×0.8 m, 150 kg, tied up with polypropylene tape);

3. PS waste (fragmentized material of 0.02 m size packed into the polypropylene sacks with propylene tape).

MSW has a lower humidity and ash level characterized by the absence of small items. Coefficient of thermo-technical substitution of coke MSW, representing ratio of magnitudes of low heat value, depends on their composition and vary from 0.67 (paper) to 1.32 (PE waste) t/t accordingly.

Table 2. Technological operating parameters of 160-ton converters with use of used tyres

Parameters	Developed technology	Conventional technology
Number of melts	100	100
Consumption, kg/t of liquid steel:		
cast iron	773.3	775.1
scrap	313.6	312.0
lime	53.7	54.0
used tyres	02.08.11	-
coal	14.02.11	18.05.11
Operation duration, min.:		
prior heat	01.05.19	01.06.00
refining	21.05.11	21.06.11
Total oxygen consumption, m^3 per melt	9703	9695
Cast iron consumption, %:		
Si	0.35	0.38
Mn	0.3	0.42
S	0.016	0,.16
P	0.17	0.16
Cast iron temperature, °C	1326	1330
Metal composition at the first turndown, %:		
C	0.13	0.10
Mn	0.16	0.15
S	0.020	0.020
P	0.015	0.016
Slag composition at the first turndown, %:		
FeO_{tot}	22.08.11	24.01.11
MgO	03.05.11	03.05.11
Slag basic capacity	03.07.11	03.06.11
Liquid metal yield, %	92.0	92.0

Particularly, coefficient of thermo-technical substitution of coal from Bachatskiy open-pit used at the present time in the melting industry of ZSMK with utilization of paper waste is – 0.7 t/t; PE waste – 1.36 t/t, PS waste – 1.24 t/t. Design factor of cast iron substitution by scrap with use of MSW is 3.0 and 5.85 for paper and PE waste accordingly.

Processing characteristics of pilot industrial melts in 350-ton converters with use of MSW are given in tables 3 and 4.

Table 3. Typical processing characteristics of work of 350-ton converters with use of MSW (variant 1)

Parameters	Comparative melts		Pilot melt
Melt number	456152	456153	456154
Steel grade	St 3ps	18G2S	18G2S
Cast iron consumption, kg/t	781.2	781.2	780.0
Scrap consumption, kg/t	341.2	259.7	250.9
Lime consumption, kg/t	46.8	50.6	42.06
Coal consumption, kg/t	6.1	6.6	6.1
Flux consumption, kg/t	8.4	14.8	12.2
MSW consumption, kg/t	-	-	4.5
Oxygen consumption for scrap heating, m^3/t	7.7	7.8	7.7
Oxygen consumption for refining, m^3/t	51.4	48.3	49.7
Oxygen consumption for melt, m^3/t	59.1	56.1	57.3
Scrap share in burden, %	30.4	24.9	24.3
Duration of scrap heating, min-sec	6-09	6-04	6-12
Duration of refining, min-sec	18-22	17-25	17-22
Cast iron composition, %:			
Si	0.44	0.50	0.44
Mn	0.43	0.40	0.47
S	0.016	0.015	0.017
P	0.09	0.09	0.10
Cast iron temperature, °C	1395	1395	1390
Steel temperature at the first turndown, °C	1620	1660	1705
Composition of finished steel , %:			
C	0.09	0.07	0.05
Mn	0.14	0.12	0.13
S	0.016	0.015	0.014
P	0.012	0.012	0.015

Table 4. Typical processing characteristics of work of 350-ton converters with use of MSW (variant 2)

Indexes	Comparative melt	Pilot melt
Melt number	456158	456159
Steel grade	35GS	18G2S
Cast iron consumption, kg/t	780,6	779,4
Scrap consumption, kg/t	324.1	257.8
Lime consumption, kg/t	51.6	58.2
Coal consumption, kg/t	7.5	3
Flux consumption, kg/t	17.4	15.1
MSW consumption, kg/t	-	8.8
Oxygen consumption for scrap heating, m^3/t	7.0	6.4
Oxygen consumption for refining, m^3/t	52.0	48.4
Oxygen consumption for melt, m^3/t	590	57.4
Scrap share burden, %	29.3	24.9
Duration of scrap heating, min-sec.	6-04	5-00
Duration of refining, min-sec.	18-22	17-22
Cast iron composition, %:		
Si	0.63	0.53
Mn	0.45	0.42
S	0.014	0.015
P	0.10	0.09
Cast iron temperature, °C	1435	1450
Steel temperature at the first turndown, °C	1630	1655
Composition of finished steel, %:		
C	0.10	0.09
Mn	0.16	0.16
S	0.015	0.015
P	0.015	0.014

Thus, while carrying out melts No. 456154 with utilization of MSW (18 packs with total mass 1.44 t) which were loaded into the furnace charge of converter with scrap during scrap heating was made an addition of coal from the scales. Duration of scrap heating was 6–12 min.

As it can be seen from the Table 3, the main processing characteristics of pilot and comparative melts according to variant 1 don't differ much. MSW consumption was 4.5 kg/t of steel. A higher temperature of steel at the turndown must be noted (1705 °C), whereas during the comparative melts it was 1620 °C and 1660 °C. At the same time pilot and comparative melts were carried out with the same coal rate – 6.1 kg/t of steel and the metal temperature at the turndown during pilot melts increased on average by 85 °C.

Thus, for example, according to the second variant (Table 4) MSW was loaded into the converter with separate scoop between two scoops with scrap. On average 2.81 t of MSW was loaded for a melt. Additional heat-carrying agent (coal) was practically not used (0.11 t), at the same time duration of scrap heating was reduced to the 5 min.

Data from table 4 shows that MSW consumption is 8.8 kg/t of steel. Melts were carried out practically without coal and the steel temperature at the turndown was 1655 °C that is 25 °C higher then the temperature at the comparative melts.

Thus, the results of carried out experimental melts showed that usage of used tyres and SDG on the basis of fuel components of MSW (paper, PE, PS etc.) can be utilized in the converter melt as an alternative heat-carrying agent that allows to decrease cast iron consumption and to increase considerably technical and economic processing characteristics. MSW loading into the converter with consumption up to 2.1 kg/t and tyres – 2 kg/t of steel doesn't worsen the metal quality. Metallurgy introducing into its technological processes MSW can get not only cheap fuel and economy due to the consumption decrease of traditionally used and constantly rising in price energy carriers but also a great chance to obtain public acknowledgement as environmental safe and mass MSW utilization enterprise.

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