ANALYSIS OF THE RECYCLING POSSIBILITIES OF FERROUS WASTE WITH SMALL GRANULATION IN CUPOLAS FURNACE

Cosmin MITITELU[1], Mircea HRITAC[2], Nicolae CONSTANTIN[3*], Elisa-Florina PLOPEANU[4], Adrian IOANA[5], Mariana CIURDAS[6], Cristian PANDELESCU[7]

In Romania there are stored over 250 million tons of ferrous waste resulting from industrial activity. In this paper, the authors carried out a technological design study and economic analysis elements in order to process and recover these wastes. The technological design considers both the technology used and the related thermo-technological equipment. The financial economic analysis and the elements of the technical feasibility study were carried out in three stages of the ash cast iron production flow for a recipe with 50% crusts and 50% self-fuel briquettes. From the stages of technological design and economic analysis, the paper presents the establishment of the investment need, the determination of the need for current production costs, the amortization and the profitability of the proposed investment.

Keywords: ferrous waste, coal coke, cast iron, steel, furnace, environment, economic analysis

1. Introduction

In Romania, there is no systematic and technologically based concern for using the potential offered by blast furnaces and cupolas furnaces in the direction of processing and recovery of waste of various kinds or origins [1], [2].

It is important to show that there is a historical basis for ferrous waste from different industrial sectors and for which there is currently no other recycling solution than processing in small capacity furnaces according to the model shown below.

Listed in table 1 are more waste existing in our country, with the potential to be recycled by the technology of cast iron in furnaces and cupolas furnace [2],[3],[4].

[1] University POLITEHNICA of Bucharest, Romania, e-mail: cosminmiti@yahoo.com
[2] SC CERMAX 2000, Bucharest, Romania, e-mail: m_hritac_cermax2000@yahoo.com
[3]* University POLITEHNICA of Bucharest, Romania, e-mail: nctin2014@yahoo.com
[4] University POLITEHNICA of Bucharest, Romania, e-mail: elisaplopeanu@yahoo.com
[5] University POLITEHNICA of Bucharest, Romania, e-mail: adyioana@gmail.com
[6] University POLITEHNICA of Bucharest, Romania, e-mail: ciurdasmariana@yahoo.com
[7] University POLITEHNICA of Bucharest, Romania, e-mail: pandelescuupb@yahoo.com

In the present current context, an amount of approx. 250 million tons of waste resulting from industrial activity stored in historical spoil tips. In Romania there is no concern for their processing and disposal, although they are sources of pollution for the environment.

The paper has based and evaluated the economic feasibility of creating a section of two furnaces that is designed to consume a significant amount of this range of waste of approx. 15,000 - 23,000 t / yr.

Multiplying such production modules as well as increasing the number of cupolas furnace in each section or increasing the useful workload can lead to an increase in the quantity of waste processed annually with multiple economic and environmental benefits.

2. Experimental

The economic analysis was performed for the recovery by smelting of iron and steel bark resulting from recoveries and adding 30 - 50% briquettes from ferrous oxide with ferrous waste in a section equipped with two cupolas furnace of de 600 mm Ø diameter.

The economic calculation was performed for a section with two furnaces that have an estimated annual output of 10800 tons of ingot cast iron. The furnaces have an estimated productivity of 1.1 - 1.2 t / h, and the raw material used consists of:

-cast iron and steel bark with a maximum size of 200 - 220 mm and a minimum of 30 mm with a degree of impurity between 75-85% with oxide materials;

-coke that can be coke used in castings or metallurgical coke used for care furnaces is recommended to place and use in the blast furnaces the fraction of more than 40 mm or introduced in the recipe for making briquettes at a cone <0.8 mm;

- briquettes from ferrous oxy-ferrous dusty waste recovered from dumps with a Fe content between 35 - 65% of maximum granulation 1 mm, limestone with granulation of minimum 30 mm and maximum 60.

- the final product obtained is liquid iron with foundry cast iron characteristics with Si> 0.8% but without a specific mark and limitations on the accompanying elements Cu, Pb, Ni.

- the delivery method is in ingots with a notch and a maximum weight of 15-17 kg;

- The whole range of raw materials of ferrous waste type that can be used by re-casting in cubicle type furnaces is presented in table 1.

The chemical analysis of these materials was performed by SC CERMAX 2000 Bucharest, in the laboratories of SC ICEM SA Bucharest.

Table 1

The range of waste possible to be recovered by recast in the cubicle [1].

Type of waste material	Chemical composition [%]										Val met. %
	Fe	Mn	SiO_2	Al_2O_3	CaO	MgO	Ti	Zn	Cu	Pb	
Dross	52.56	0.29	4.54	1.09	5,2	0. 71	0.03	0.58	0.005	0.15	55.7
CEA dust	31,1	3.51	3.71	0.87	12.55	2.19	0.07	28.49	0.28	7.1	25.5
A mixture of iron ore and furnace dust	44.7	0.41	8.44	2.02	4.05	1.4	0.05	0.085	0.017	0.01	41.43
Furnace sludge and steelwork	18.61	0.66	13.05	4.6	15.4	2.11	0.04	0.36	0.015	0.66	19.5
Furnace dust	23.91	0.48	13.93	4.5	13.35	2.19	0.05	0.47	0.017	0.07	23.64

For the continuous operation of the furnace cupolas furnace it is necessary that the dosing and loading operations in the skips be done mechanically and with electrical control for each operation [5].

Bunkers are required for each material used as raw material: coke, ferrous bark, limestone and ferrous powdery waste with a capacity to ensure the operation of the two cupolas furnace for 24 hours.

The capacity of the bunkers must be 60 tonnes for ferrous bark, 30 tonnes for coke, 10 tonnes for limestone and 3 bunkers of 25 tonnes each for powdered waste with iron oxides.

The loading of the bunkers of raw materials is done mechanized with tape or metal buckets manipulated with the crane.

The loading of the cubes is done with skips with the nominal capacity of 0.14 m^3 on the inclined plane on the beam at approximately 22-30 degrees with tilting through the side loading door.

Duration of the charging cycle on the charging unit: 6' – 7'35"

The dimensioning of the drive system is required to be done to ensure the effective duration of the loading cycle in 155 seconds (2'35 ") with a duration of climb - descent of the skip of 40".

The levels of automation of the loading dosing operations must be at the level of manual electrical control for each sequence of the cycle.

Any extraction and dosing solution are accepted if it does not involve increasing costs by increasing the level of automation.

It is required to design these operations so that it is performed by 6 people.

The equipment that is needed in the proposed technological flow is represented by the briquetting line of the ferrous powdered waste, two furnace cupolas furnace, a torpedo pot for cast iron storage and the cast iron installation.

The briquetting line for the ferrous powder waste consists of:

- Storage bunkers of at least 3 types of waste with the ability to ensure the operation of cubes at least 24 hours.

- Homogenizing mixer for a capacity of 3 t/h with function for humidification up to 8-10%, added binder which can be molasses and/or bentonite, homogenization degree of minimum 90%.

- The constructive variant chosen for continuous working mode is that with inclined rotary drum.

The material structure of the briquettes is binder: 5-7%; coke dust: 22%; dusty waste: the rest up to 100%.

- The briquetting press with operation contained the type with rollers and chambers for the formation of briquettes having the characteristics, briquetting capacity of 3.2 t / h, the size of the briquettes: 80 mm x 50 mm of ovoid shape, the density of the briquette: 3 - 3,5 g / cm3, bulk density: 1.7 - 1.9 t / m3.

- Storage space for lighters for 36 - 48 hours required storage to increase the hardness of lighters, with a volume of approx. 10 m^3.

The furnace cubes proposed in the technological flow have the following characteristics:

-working diameter: Ø 600 mm;

-2 rows of windscreens each 4 on level shifted to 900, inclined to 7-100;

-crucible with continuous cast iron drainage trap and slurry port with 25 - 30 l reservoir for liquid cast iron for controlling the level of cast iron in the crucible: 70-100 mm; for the control level of the slag in the crucible: 200 - 250 mm;

- the working solution with 2 furnace cupolas furnace, allowing both the normal cycle of the furnace cubicle operation and the time required for the revisions and repairs for each furnace cubicle.

The torpedo pot for cast iron storage must meet the following characteristics:

- must allow continuous collection of cast iron from the two furnace cupolas furnace and during tilting for casting of cast iron on the casting route;

- equipped with a CH_4 burner to maintain the cast iron temperature;

- pot capacity: 0.83 m^3;

- the thickness of the masonry and the refractories must satisfy the direction of minimum loss of temperature of the liquid iron - 2-row fire clay and ceramic fibber insulation as the shield;

-cast iron at maximum casting: 4,5 kg/s;

-manual tilting;

The cast-iron installation or the casting train must meet the following characteristics:

-The casting is done in cast iron or steel ingot with a capacity of 90 kg, arranged in 6 ingots with a notch.

-Weight of ingots / ingot: 6 x 15 kg / ingot

-Ingot caster weight: 320 kg

-Total ingots mounted on the train: 20 pieces.

-The length of the casting train: 13 m

-The length of the tread: 22 m

-Train drive variant with gearbox and cable drum.

-Simple push-button control located next to the torpedo pot with cast iron.

-Release of the ingot from the ingots casts it is machined with lateral tilting at an angle of 110° to the vertical.

-The working cycle of the casting train and the torpedo pot is 90 minutes.

-The ingots are handled manually after cooling.

The estimated general data of the production flow proposed in this paper are:

-maximum production capacity: 2.2 - 2.3 t / h / department

-annual production capacity: 10,000 - 12,000 t;

-electricity consumption: 1.9 - 2.1 MW / day pig iron;

-specific consumption of coke: 160 - 190 kg / t cast iron;

-specific consumption of bark: 1.25 - 1.35 kg / kg cast iron;

-specific consumption of limestone: 30 - 35 kg / t cast iron;

-specific consumption of ferrous waste powder in lighters 1.91 - 2.56 kg / kg/cast iron

-used personnel: 20 people

-working regime: 16 hours / day, 6 days / week in shifts of 8 hours.

The wastes from the manufacturing process are dust from the dry cyclone parachute protection system and wet scrubber, acid cubicle slag and brick and refractory concrete scraps [2], [7], [8].

3.Economic-financial analysis and the elements of the technical feasibility study:

The economic design and analysis were carried out in accordance with the general data of the production flow, taking as reference the following input data (estimated operating data):

-Annual average cast iron production: 10,800 t / cast iron

-Estimated productivity of each cubicle: 1,125 tonnes / h, for melting cast iron and steel with 50% briquettes from ferrous powdery waste, which can increase to 1.79 ~ 1.8 t / h for melting cast iron and recovered steel

-Operating time per department: 300 days / year

-Stopping time for recovery: 60 days / furnace cubicle / year

-Average daily production achieved: 36 t pig iron/day / department

- The maximum productivity of the section in the two-cubicle version and the melting of cast iron and steel bark with 50% briquettes from ferrous powdery waste is: 2.25 t cast iron / h.

The cast iron production flow for casting in pieces will be realized in 3 components, namely:

-The extraction flow of cast iron and steel slag from slag spoil tip;

-Flow of preparation and briquetting of ferrous powdered waste;

-Melt flow of waste in the bin for a recipe with 50% bark and 50% self-fuel briquettes

The investments required for the implementation of the presented technology are represented by:

Fixed assets investments 0 RON,

Construction and transformation: 260.000 RON,

Arrangement + Inventory: 12.000 RON

Production machines: 737.100 RON

Current assets:

-Initial supply of materials: 422.200 RON

-Claims: 0 RON

-Cash / bank liquidity: 150.000 RON

-Rent advance: 0 RON

-Total capital invested: 1.600.000 RON

Initial supply of materials for one month of operation:

-bark made to produce cast iron for 1 month

1,100 t cast iron / month x 1,15t bark / t cast iron x 52.50 RON = 66,410 RON

- coke required for 1 month of production:

1100 t.cast iron x 0.27 t k /t.cast iron x 1104.37 = 328,000 RON

-the required limestone for 1 month of production: 2020 RON

-fire clay brick: 15 t x 1.645 RON /t = 24.675 RON

Estimated expenses for transport: 11.760 RON

Total initial supply costs: 422.200 RON

Investment in the extraction line of cast iron and steel slag: 170.000 RON

Investment in the briquetting line: 197.500 RON

Total investment :2.280.000 RON

Investment recovery: 5 years = 60 months

Investment recovery: 3 years = 36 months

Amortization rate of the investment = 38.000 RON/month = 456.000 RON/ year

Amortization rate of the investment = 63.333 RON/ month = 760.000 RON / year

4. Results and discussions

The analysis of the economic efficiency of the operation of the projected cubicle section was carried out taking into account two operating variants, differentiated by the iron content of the load, namely with a content of Fe 48 - 50% first and with a content of Fe 35% second.

Investment: Section of 2 cupolas furnace of Φ 600 mm with a load of 50% cast iron and steel bark recovered from the steel slag dumps and 50% self-fuel briquettes made from ferrous oxide with ferrous waste recovered from the spoil tip. The general economic data of the operating version with loads containing iron content of 48-50%, are presented in table 2.

Table 2.

General economic data for operating variant 1[1]

- own funds investment [thousands of RON]	1.9 67.500
- investment from bank loans [thousands of RON]	0
- duration of study [years]	15
- profit tax [%]	16, 00
- VAT [%]	19
- average fuel price [RON/coke]	6.0 00
- technical coke with 10% humidity [RON/t]	105 0
- the duration of the investment [year]	1
- the share of the investment made from own funds [%]	100 ,00
- the duration of the investment recovery [years]	5

The general economic data of the operating version with loads containing iron content of 35% are presented in table 3.

Investment: Department of 2 furnace cupolas furnace of Φ 600 mm with a load of 50% cast iron and steel bark recovered from the steel slag dumps and 50% self-fuel briquettes made from ferrous oxide with ferrous waste recovered from the dumps.

The economic analysis considered the situation of using a wider range of ferrous oxide waste existing in the historical dumps [1, [2], [6] in order to achieve a higher consumption of these or to consume those with a higher impact of an environmental pollution.

Table 3

General economic data for variant 2 [1]

- own funds investment [thousands of RON]	1.9 67.500
- investment from bank loans [thousands of RON]	0
- duration of study [years]	15
- profit tax [%]	16, 00
- VAT [%]	19
- average fuel price [RON/coke]	6.0 00
- technical coke with 10% humidity [RON/t]	105 0
- the duration of the investment [year]	1
- the share of the investment made from own funds [%]	100 ,00
- the duration of the investment recovery [years]	3

This situation requires the use of a ferrous load and a lower metallurgical value, with a Fe content that will lead to the decrease of the economic efficiency of the technological flow by increasing the consumption, especially the coke and the decrease of the production of cast iron [1].

In order to determine the efficiency, limit up to which the economic agent can accept the decrease of the content of Fe, the consumption balance of the section was performed for, several variants of metallic loads [1].

It turned out that the minimum profitability limit is reached when using 50% of the load of briquettes containing 35% Fe.

For this situation, the recovery of the investment and the transition to profit is realized in year 5 after putting into operation a 10% discount rate.

The proposed technological variant for the recycling of industrial waste resulting from the iron and steel slag and powders with iron oxide content is an economically efficient solution for the situation where 50% of the load is used but cast iron and steel recovered with 85% Fe and 50% of powders from ferrous oxide wastes briquetted in the fuel version with 20% coke dust.

The investment recovery period is fast, 1 year for a 10% recovery rate and 3 years for a 25% recovery rate;

Short-term recovery of investment 1-3 years and a rate of return of approx. € 300,000 / year represents financial indexes higher than the level at which any bank accepts the loan for investments:

The technical data supporting this economic efficiency are:

- Reduced coke consumption, which accounts for 46.5% of total production costs;

- The low cost of the raw material that weighs in the economic balance only through the costs of its processing production;

The profitability limit is reached when using a lighter load with a Fe content of min. 35% for which the investment recovery is 5 years, with 10% discount rate.

The proposed solution is technically feasible and economically viable from the perspective of recycling a wide range of waste from which no other rainfall factors result to affect the environment.

4.Conclusions

From the results obtained in the design calculation and the economic technical analysis carried out [1], it is necessary to achieve an industrial objective in Călan - Deva - Hunedoara area on the site of one of the former steel companies [8], [9].

To begin with, it can have a processing capacity of 600 tons of cast iron and steel recovered from the slag and ca. 15,000 - 20,000 tons of ferrous oxide powder waste existing in the historical dumps derived from the activity of the steel companies.

The most feasible option is the financing of one of the economic agents with private capital in the area with profile. In this direction, they have partially developed this activity.

The margin of use of these wastes will depend on the minimum acceptance limit of a profit rate of approx. € 23,000 / and a period of recovery of the investment of approx. 7 - 8 years situation for which it can process waste of low metallurgical value, with a minimum of 35% Fe in order to offer a possibility of processing the waste for which there is no solution for this purpose [10].

The functioning of such an industrial objective that processes waste mainly requires the implementation of a waste management system from the double hypostasis, namely a waste processor for which it is necessary to ensure the environmental impact safety norms but also a secondary waste producer for which the evaluation is necessary. and their handling in accordance with the existing legal norms [11].

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