STREAMLINING TECHNOLOGIES FOR PROCESSING SCRAPS FROM ALUMINIUM ALLOYS

Mihai BUŢU[1], Constantin APOSTOL[2], Florin BUD[2], Alexandra TACHE[2], Dragoş Florin MARCU[1], Victor Florin JEFLEA[3], Constantin Domenic STĂNCEL[1*], Sebastian Titus DUMA[4*]

The aluminium waste recycling industry applies technical standards that impose certain characteristics on secondary raw materials - SR EN 13920 (1 ÷ 16), I.S.R.I. (Institute of Scrap Recycling Industries) and requirements from environmental standards. The quality of the raw materials has an overwhelming influence on the production costs and alloys obtained. With the low-temperature processing technology of aluminium alloy scraps, quality secondary alloys can be obtained at an advantageous production cost. By means of optical microscopy, SEM, EDS and thermodynamic calculations we highlighted the main oxidic compounds, resulting in the processing of low-temperature scraps in a pasty condition.

Keywords: Circular economy, SR EN 13920, ISRI, yield, low cost, efficiency, sustainable development

1. Introduction

The present paper aims to perform a technical-economic comparative analysis of the technologies used in the processing of aluminium scraps and the technology which uses a system of drying and immersion of the cargo in liquid aluminium vortex at high temperature.

"Circular Economy" is a generic term used for an industrial economy that is created in order to be effective and where the cycle of materials is of two kinds: the biological cycle, where the processes act so that the components re-enter the biosphere without negative effects and the second cycle is the technical one, where the components are used very efficiently and do not enter the biosphere [1].

The desiderate expressed by the circular economy can be divided into three stages:

[1] Faculty of Materials Science and Engineering, University POLITEHNICA of Bucharest, Romania, *corresponding author, e-mail: stancel.constantin@yahoo.com
[2] AS METAL COM SRL, Bucharest, Romania, E-mail: constantin.apostol@asmetal.ro
[3] Faculty of Economic Sciences, OVIDIUS University from Constanta, Romania, e-mail: jefleavf@yahoo.com
[4] Faculty of Mechanics, University POLITEHNICA of Timisoara, Romania, *corresponding author, e-mail: sebastian.duma@upt.com

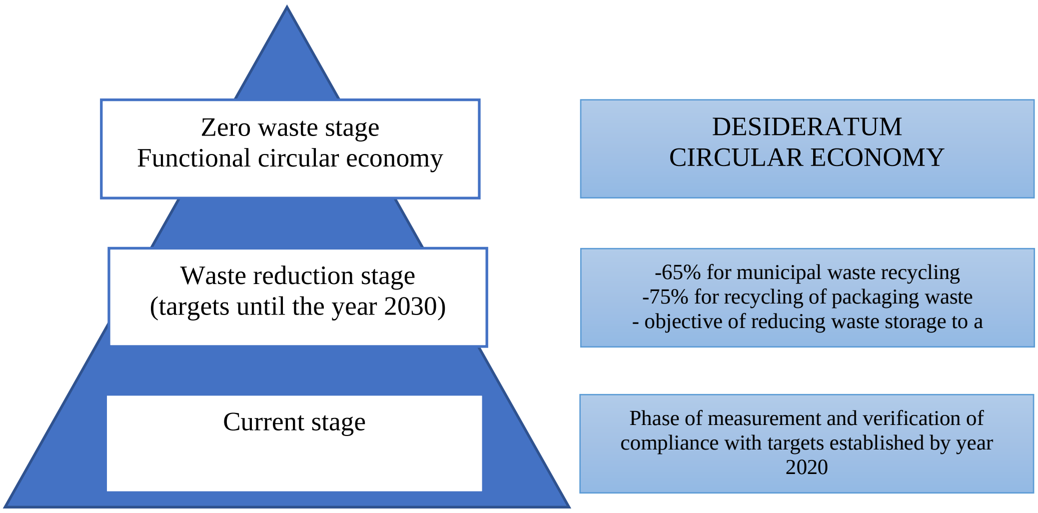


Fig. 1. Circular Economy Stages

"The legislative proposal promotes cooperation between industries, the waste generated by a process thus becoming secondary materials for others, through a simplified legal framework for secondary products and the cessation of waste status, creating more certainty for operators in those markets. Other measures promote the prevention of waste generation. A new eco-design work plan will promote energy efficiency and the possibility of recycling products through a number of measures, including new energy efficiency requirements" [2].

The principles expressed in the directives on the implementation of the circular economy accentuate the role of research and design activities that will guide production capabilities towards products with very high recyclability potential but also with solutions for the recycling of waste generated by the products still in use.

"*Circular economy* means a production and consumption system that generates as low a loss as possible. In an ideal world, almost anything would be reused, recycled or recovered in order to get other products. Redesigning products and production processes could help minimize waste and transform that unused part into a resource." [3].

A functioning market economy (as defined by the European Union) entails free trade in a competitive market. Environmental legislation is a restrictive legislation imposing controlled commercial channels in order to reduce the negative impact of waste on the environment, thus complicating the implementation of the concept of "waste as a raw material-economic income" versus "Pollutant waste – Economic cost".

Such an approach to industrial activities is a basic element in the development of sustainable economic models, through contributions to the improvement of environmental conditions, by framing technology within the ecological limits that the planet offers us.

The recycling of ferrous and non-ferrous metal waste is an industrial branch with a history that extends over many decades. It is a highly developed global industry and provides a significant part of the raw material needs of the manufacturing industries. Although metallic substances present in various typologies of waste have a high potential for recycling, it is increasingly difficult to separate them from waste (objects dumped by consumers).

“Secondary raw materials still represent only a small part of the production materials. There are important obstacles that hinder their takeover of the economy, such as, for example, uncertainty about their composition. Thus, the European Commission will launch activities to develop quality standards for secondary raw materials and will take steps to facilitate the legal carriage of waste between member states” [3].

Since 2009 ÷ 2011, the european legislation has created a legal framework that encourages the use of metal waste, facilitating their free movement. This new orientation foreshows the new circular economy concept. Terms like by-product, waste that ceases to be considered waste, define a new orientation of environmental policies. These were the first steps on the new vision by which waste is no longer a "burden" but become the resource of secondary raw materials with use in manufacturing, construction, etc.

With a direct impact on the recycling industries of metals we recall Regulation 333/2011 laying down the criteria for determining the conditions under which certain types of waste no longer constitute waste under Directive 2008/98/EC of the European Parliament and of the Council, applicable to post-consumer metal waste (end-of-life products) as well as the communication from the Commission to the Council and the European Parliament on the interpretative communication on waste and by-products applicable to production residues (Waste obtained from the manufacture of a product).

The legislation in force defines the waste as “any substance or object which the holder throws or intends or is required to dispose of” [6, 7] and aluminium wastes as “metal wastes consisting mainly of aluminium and aluminium alloys” [8].

This new european legislation in the year 2011 apparently simplifies the route of secondary raw materials in aluminium by the occurrence of the sub-product criterion applicable to residues in the production and non-waste applicable to post-waste consumption. In theory, significant amounts of metal that are traditionally regarded as waste and subject to environmental restrictions, now have the possibility of circulating in accordance with market economy perceptions and the free trade territory of the European Union.

In practice, the implementation of this legislation was seen with restraint by national environmental authorities that did not create the levers needed to implement these new development possibilities. This retention is explained by the fact that the recycling industry does not have a strict reference in environmental legislation. It would have been desirable that the Ministry of Environment, the Ministry of Industries and the Ministry of Finance, together with the National Body of Standardization in Romania (ASRO), the Romanian Accreditation Association (RENAR) and the professional associations in the field ensure a legislative context that harmonises the specific terms of each area so as to create the necessary coherence for this complex activity.

Like any industry, the aluminium waste recycling industry also refers to technical standards that require these secondary raw materials certain characteristics to make it possible to re-enter them in the industrial cycle. At the european level, we are talking about SR EN 13920 standards from 1 to 16. The requirements of these industrial standards overlap with the requirements of environmental standards by creating a double conditionality on the recycling industry. IF technical standards refer to the qualitative conditions of aluminium waste, environmental standards refer to quantities and their provenance. In the context of global economic globalisation, we have identified a new reference, namely the American Standard ISRI (Institute of Scrap Recycling Industries).

2. Experimental technique

The experiments were designed to determine how to process aluminium scraps at low temperatures (580 ÷ 620ºC/853.15 ÷ 893.15 K, for EN AB 46100 alloy), to achieve the highest possible extraction of useful elements [10].

Thus, it has proved necessary to develop guidelines, task-books, that harmonize both the requirements of industry standards and the requirements of environmental standards, thus facilitating the operative decisions that a recycler must take in the framework of its activity.

The elaboration and implementation of these task-books took place in the framework of AS METAL between 2013 and 2017, such a task-book is presented below.

TEENS

SEGREGATED (HOMOGENEOUS) ALUMINUM BORINGS AND TURNINGS

1. **ISRI-SCRAP SPECIFICATIONS CIRCULAR:**

TEENS - SEGREGATED ALUMINUM BORINGS AND TURNINGS - Shall consist of aluminum borings and turnings of one specified alloy. Material should be free of oxidation, dirt, free iron, stainless steel, magnesium, oil flammable liquids, moisture and other non-metallic items. Fines should not exceed 3% through a 20 mesh (U.S. standard) screen.

- Industrial wastes (industrial residues): - Industrial byproducts (industrial residues); - Wastes.
- Scrap (processed waste).

2. **STANDARD**: SR EN 13920-12
3. **EUROPEAN WASTE CATALOGUE AND HAZARDOUS WASTE LIST –** valid from 18th of December 2014:

- **12 01 03 –** ALUMINUM WASTES FROM SHAPING AND PHYSICAL AND MECHANICAL SURFACE TREATMENT OF METALS AND PLASTICS ***CODE APPLICABLE ONLY FOR ORIGINAL WASTE PRODUCERS/COLLECTORS)***
- **19 12 03** – ALUMINUM WASTES FROM THE MECHANICAL TREATMENT OF WASTE (FOR EXAMPLE SORTING, CRUSHING, COMPACTING, PELLETISING) NOT OTHERWISE SPECIFIED ***(CODE APPLICABLE ONLY FOR RECOVERABLE)***.

4. **CHEMICAL COMPOSITION**

- Turning from only one type of alloy must have the CHEMICAL COMPOSITION established in contract;
- The chemical composition is determined after reception.

5. **EXEMPLES:**

- Scrap from debarking, turnings, milling, punching of thick sheets, extruded profiles, molded parts, etc.

6. **QUALITY CONDITIONS**

6.1. With impurities: moisture and greases maximum 5%;
6.2. Homogeneous (according with SR EN 573 – 3:2009 – within the same series);
6.3. Metal yield minimum 90% (required metal yield) after drying and removal of free iron
6.4. If the quality of wastes complies the condition of paragraph 6.1 and the supplier is certified according with Regulation no. 333/2011, the wastes can be purchased as waste which has ceased to be waste; in this case, the waste will be accompanied by the Statement of Conformity in accordance with the model set out in Annex III of Regulation mentioned above;
6.5. Material containing more than 10% iron and/or magnesium free, stainless steel or containing highly flammable compounds will not constitute a good delivery. To avoid a dispute, material should be sold on the basis of tests done in accordance with EN 13920 – 1.

7. **CHARACTERISTICS:**

7.1. The scrap must be not oxidized and for the delivered weight are applied the following:
   - 0% (mass fraction) for magnetic iron;
   - 5% (mass fraction) for moisture and oils;
   - 3% (mass fraction) for small particles passing through 20 mesh screen, after drying.

The total of impurities mentioned must not exceed 5% mass fraction.

7.2. The scrap shall be free of foreign materials;
7.3. The presence of any impurities listed in 7.1 and 7.2 are subject to agreement between buyer and seller;
7.4. The scrap must be free of hazardous materials (any wastes which have one or more hazardous properties provided in Annex no. 4 of Law no. 211/2011);

8. **LOGISTIC CONDITION**

- Bulk;
- Big bags;
- Briquetted.

9. **PICTURES**

Bulk

Briquetted

3. Experimental results and their interpretation

Thermodynamic studies have led to the selection of 9 reactions that may take place between the metal bath and the reaction products from the combustion of methane/oxygen gas [11]. as can be inferred from the analysis by electronic microscopy and analysis EDS shown in Figs. 2 and 3.

$$2Al + 3H_2O(g) = Al_2O_3 + 3H_2(g) \quad (1)$$
$$2Al + 3CO_2(g) = Al_2O_3 + 3CO(g) \quad (2)$$
$$2Al + 1{,}5O_2(g) = \mathbf{Al_2O_3} \quad (3)$$
$$2Mg + O_2(g) = \mathbf{2MgO} \quad (4)$$
$$2Mn + O_2(g) = 2MnO \quad (5)$$
$$2Al_2O_3 + 2Mg + O_2(g) = 2MgAl_2O_4(ia) \quad (6)$$
$$Ca + 2Al + 2O_2(g) = \mathbf{CaAl_2O_4(ia)} \quad (7)$$
$$Ca + 2Al + 4CO_2(g) = CaAl_2O_4(ia) + 4CO(g) \quad (8)$$
$$Mg + 2Al + 4CO_2(g) = MgAl_2O_4(ia) + 4CO(g) \quad (9)$$

It is noted that, from a thermodynamic point of view, the most probable reactions are those with the formation of aluminium, magnesium oxides and the complex oxide $CaAl_2O_4$ (spinel) as can be seen from Table 6. The variations of the Gibbs Free Energy for reactions (1) ÷ (9) and Fig. 8.

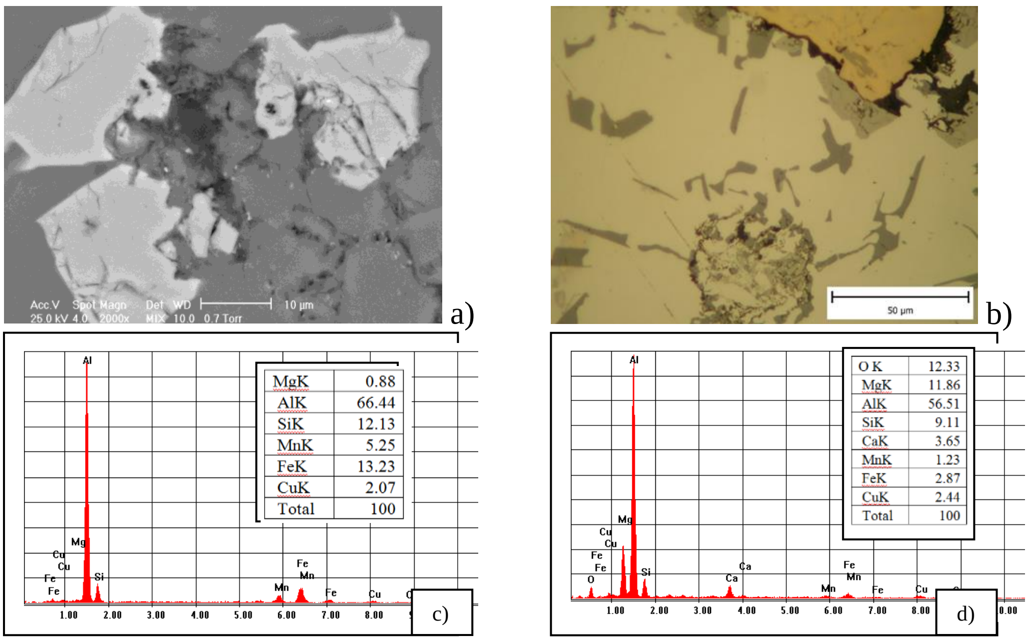


Fig. 2. Analysis by optical microscopy (a) electronic (b) and EDS analysis with the chemical composition of dark grey filiform compounds (c) and large grey compounds (d)

The activation energy of the reactions

The dependencies of the reaction speed constants (6) ÷ (9) of temperature are represented in Figs. 3 ÷ 6 and can be calculated with the equation of Arrhenius:

$$K = A\exp(-Q/RT) \qquad (10)$$

where: A represents the frequency factor;
Q is the activation energy of the reaction, kJ/mol;
R is the universal gas constant;
T is the absolute temperature, K.

Al_2O_3: $\Delta G^0_{823} = -1417\ kJ \rightarrow \Delta G^0_{983} = -1367\ kJ$
MgO: $\Delta G^0_{823} = -1026\ kJ \rightarrow \Delta G^0_{983} = -991\ kJ$
$CaAl_2O_4$: $\Delta G^0_{823} = -1828\ kJ \rightarrow \Delta G^0_{983} = -1695\ kJ$

Through logarithm, the following results:

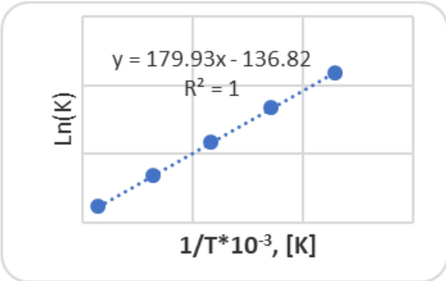
$$\ln K = \ln A + (1/T)(-Q/R) \qquad (11)$$

The variation in the parameters of the speed constant in relation with temperature, for the reactions 6 ÷ 9, are shown in tables 1 ÷ 4.

Table 1

Variation of thermodynamic parameters according to the temperature for the reaction (6)

T, K	ΔG, kJ	k	ln k	1/T, K^{-1}	1/T*10^{-3}, K^{-1}
823.150	-559.395	3.166E+035	81.743	0.00121485	1.21485
843.150	-536.879	1.834E+033	76.592	0.00118603	1.18603
863.150	-514.203	1.319E+031	71.657	0.00115855	1.15855
883.150	-491.369	1.161E+029	66.924	0.00113231	1.13231
903.150	-468.380	1.234E+027	62.380	0.00110724	1.10724
923.150	-445.235	1.566E+025	58.013	0.00108325	1.08325
943.150	-421.576	2.239E+023	53.766	0.00106028	1.06028
963.150	-397.767	3.749E+021	49.676	0.00103826	1.03826
983.150	-373.813	7.283E+019	45.735	0.00101714	1.01714



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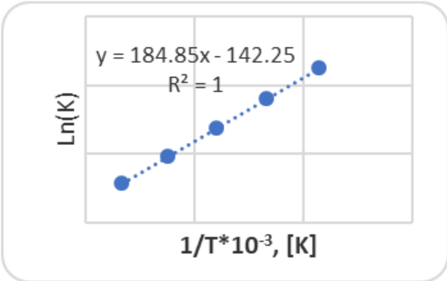


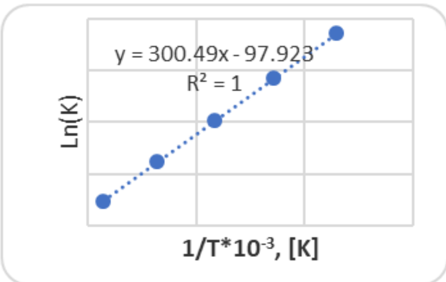
b)

Fig. 4. Dependencies of the reaction speed constants (6) of temperature,
for the two intervals: a) 823.15 – 903.15 K; b) 903.15 – 983.15 K

Table 2.

Variation of thermodynamic parameters according to the temperature for the reaction (7)

T, K	ΔG, kJ	k	ln k	1/T, K^{-1}	1/T*10^{-3}, K^{-1}
823.150	-1827.937	1.012E+116	267.112	0.00121485	1.21485
843.150	-1811.770	1.785E+112	258.469	0.00118603	1.18603
863.150	-1795.525	4.651E+108	250.216	0.00115855	1.15855
883.150	-1779.201	1.742E+105	242.327	0.00113231	1.13231
903.150	-1762.800	9.160E+101	234.776	0.00110724	1.10724
923.150	-1746.323	6.615E+098	227.543	0.00108325	1.08325
943.150	-1729.544	6.247E+095	220.578	0.00106028	1.06028
963.150	-1712.461	7.583E+092	213.864	0.00103826	1.03826
983.150	-1695.306	1.199E+090	207.414	0.00101714	1.01714



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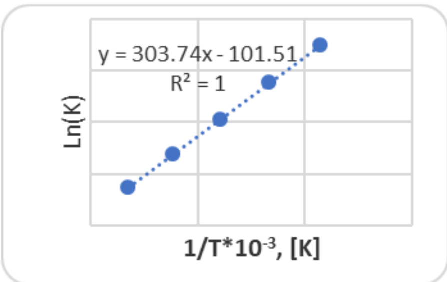


b)

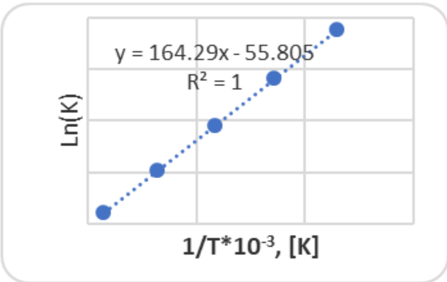
Fig. 5. Dependencies of the reaction speed constants (7) of temperature,
for the two intervals: a) 823.15 – 903.15 K; b) 903.15 – 983.15 K

Table 3.

Variation of thermodynamic parameters according to the temperature for the reaction (8)

T, K	ΔG, kJ	k	ln k	1/T, K^{-1}	1/T*10^{-3}, K^{-1}
823.150	-983.886	2.752E+062	143.773	0.00121485	1.21485
843.150	-974.731	2.462E+060	139.056	0.00118603	1.18603
863.150	-965.491	2.709E+058	134.546	0.00115855	1.15855
883.150	-956.167	3.614E+056	130.230	0.00113231	1.13231

903.150	-946.761	5.774E+054	126.093	0.00110724	1.10724
923.150	-937.272	1.092E+053	122.125	0.00108325	1.08325
943.150	-927.477	2.349E+051	118.286	0.00106028	1.06028
963.150	-917.370	5.701E+049	114.567	0.00103826	1.03826
983.150	-907.186	1.595E+048	110.991	0.00101714	1.01714



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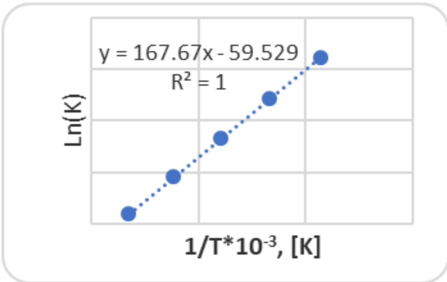


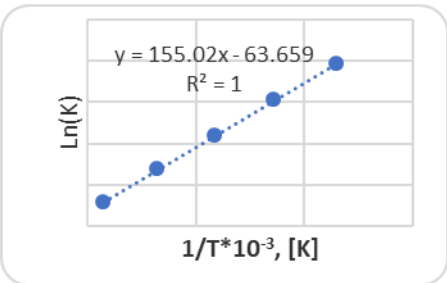
b)

Fig. 6. Dependencies of the reaction speed constants (8) of temperature,
for the two intervals: a) 823.15 – 903.15 K; b) 903.15 – 983.15 K

Table 4.

Variation of thermodynamic parameters according to the temperature for the reaction (9)

T, K	ΔG, kJ	k	ln k	1/T, K^{-1}	1/T*10^{-3}, K^{-1}
823.150	-853.085	1.376E+054	124.659	0.00121485	1.21485
843.150	-842.621	1.608E+052	120.209	0.00118603	1.18603
863.150	-832.074	2.281E+050	115.954	0.00115855	1.15855
883.150	-821.445	3.882E+048	111.881	0.00113231	1.13231
903.150	-810.735	7.828E+046	107.977	0.00110724	1.10724
923.150	-799.945	1.850E+045	104.231	0.00108325	1.08325
943.150	-788.667	4.814E+043	100.583	0.00106028	1.06028
963.150	-777.079	1.403E+042	97.047	0.00103826	1.03826
983.150	-765.415	4.675E+040	93.646	0.00101714	1.01714



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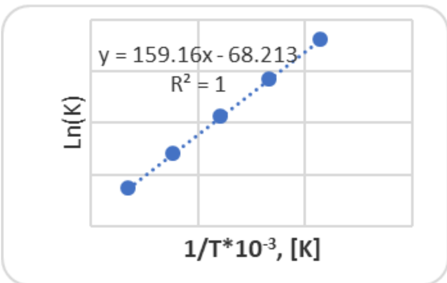

b)

Fig. 7. Dependencies of the reaction speed constants (9) of temperature,
for the two intervals: a) 823.15 – 903.15 K; b) 903.15 – 983.15 K

For the reactions (6) ÷ (9), for temperature intervals 823.15 – 903.15 K (550 – 630°C) and 903.15 – 983.15 K (630 – 710°C), the resulting values for the frequency factors (A) and for the activation energies (Q) are shown in – table 5.

Table 5.

The variations of the activation energies (Q) for reactions (6) ÷ (9)

Reaction	Temperature, K	ln A	A	-Q/R	Q, kJ/mol
6	823.15 - 903.15	179.93	5.192568	-136.82	1.13759
	903.15 - 983.15	184.85	5.2195446	-142.25	1.182737
7	823.15 - 903.15	300.49	5.705414	-97.923	0.814181
	903.15 - 983.15	303.74	5.7161720	-101.51	0.8440048
8	823.15 - 903.15	164.29	5.101633	-55.805	0.463991
	903.15 - 983.15	167.67	5.1219977	-59.529	0.4949538
9	823.15 - 903.15	155.02	5.043554	-63.659	0.529293
	903.15 - 983.15	159.16	5.0699099	-68.213	0.5671569

Table 6.

The variations of the Gibbs Free Energy for reactions (1) ÷ (9)

T, K	ΔG1, kJ	ΔG2, kJ	**ΔG3, kJ**	**ΔG4, kJ**	ΔG5, kJ	ΔG6, kJ	**ΔG7, kJ**	ΔG8, kJ	ΔG9, kJ
823	-810	-824	**-1417**	**-1026**	-649	-559	**-1828**	-984	-853
843	-807	-824	**-1411**	**-1022**	-646	-537	**-1812**	-975	-843
863	-804	-824	**-1405**	**-1017**	-643	-514	**-1796**	-965	-832
883	-801	-824	**-1399**	**-1013**	-640	-491	**-1779**	-956	-821
903	-799	-824	**-1393**	**-1009**	-637	-468	**-1763**	-947	-811
923	-796	-824	**-1386**	**-1005**	-634	-445	**-1746**	-937	-800
943	-792	-846	**-1380**	**-1000**	-631	-422	**-1730**	-927	-789
963	-789	-846	**-1373**	**-995**	-628	-398	**-1712**	-917	-777
983	-786	-846	**-1367**	**-991**	-625	-374	**-1695**	-907	-765

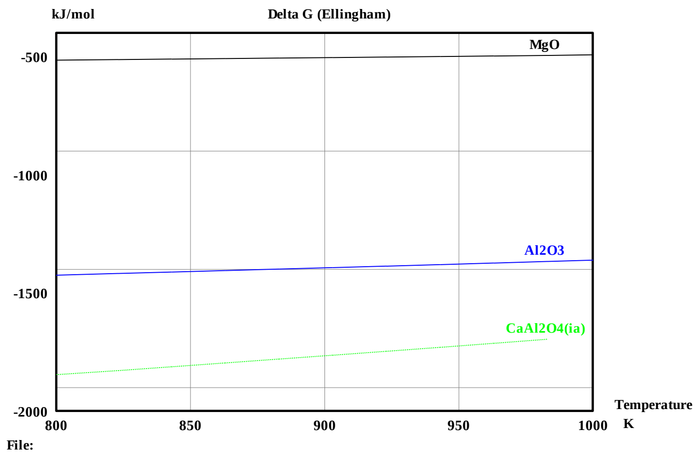

Fig. 8. Ellingham diagram ΔG_T^0 for the formation of Al_2O_3, MgO and $CaAl_2O_4$ (ΔG3, ΔG4, ΔG7)

4. Comparative analysis of economic performance

For a proper interpretation of the data on the economic performance of the processing technology we have studied, a brief description of how data has been collected in the 2016 - 2018-time interval as well as the description of certain parameters characteristics of the material that has been processed using this technology. We will also briefly analyse other factors that can influence economic performance.

Over the years 2016-2018, a quantity of 5820.3 tonnes was monitored using the methods of determination described in SR EN 13920-1 as a sampling method for obtaining a probe of material characteristic of each consignment of goods received in AS METAL COM SRL company.

For the determination of the qualitative parameters of the sample taken, ovens were used to determine the emulsion content (humidity), vibration separation system of the fine fraction (0.71 mm), successive weighing for the determination of the mass ratio, as well as the creep samples carried out on the crucible laboratory furnaces to determine the melting yield of the metal as well as its chemical composition, performing on the samples of the spectral analysis.

The creep samples were made using a part of the sample taken as it is, the other creep sample being carried out with the resulting material after performing the emulsion removal operations (drying in the oven), eliminating the fine fraction (sifting), removing particles/iron parts using a magnet.

This last creep sample, according to the standard it belongs to, must have a melting yield of about 90%. The result obtained will be compared with the reference in the standard but also with the result of the first creep sample in order to estimate the influence that the content of impurities may have in obtaining the expected economic performance.

Industrial reality is different from what is considered a normality of production systems designed to work in a certain way. Aluminium scraps, as a result of cutting-edge processing operations, in theory, must be collected selectively (on chemical compositions) and stored in specially equipped spaces for the leakage (recovery) of the excess emulsion. Compliance with these requirements would facilitate the recycling of these production residues. Unfortunately, of the quantities present in the market, below 30% correspond to these requirements.

As a rule, the material is mixed (uncertain chemical composition), and impurities not only with emulsions (being present and other types of residues: scum, slags, etc.). As such, the recycling industry had to find solutions to enable this waste stream to be processed. Obviously, the costs of these solutions are fundamental in order to have economic efficiency and competitiveness in the specific competitive market.

Theoretical calculation of combustion losses for the processing of scraps in a pasty state (a) versus scraps processed using a system of drying and immersion of cargo in liquid aluminium vortex at high temperature (b).

Table 6.

Theoretical calculation of combustion losses

Technical solution	Metal	Q	t melt	t f	ɣ	Processing temperature	Kt	T overheating	**τ** (per tonne scraps)
(a)	Al scraps	1674,7	660	2400	2,394	580	0,00473	0	1,43
(b)					2,350	720	0,01886	140	0,4

Fig. 8. Theoretical values of losses

A_{tot} is the total coefficient representing the sum between two ratios: the ratio between the heat of metal oxide formation (Q, KJ/mol O_2) and the density of metals at melting temperature ($ɣ, g/cm^3$) and the ratio between melting temperature + overheating temperature (T_{mo}, ^oC) and its boiling temperature (T_b, ^oC). [12]

$$A_{tot} = \frac{Q}{ɣ} + \frac{T_{mo}}{T_b} \rightarrow \begin{cases} A_1 = 699.78 \\ A_2 = 712.94 \end{cases} \quad (12)$$

Q - the heat of metal oxide formation, (kJ/mol O_2);
T_{mo} – melting temperature + overheating temperature, (^oC);
T_b – boiling temperature, (^oC);
τ – melting time, (h);
O_c – overheating coefficient;
ɣ - metal density (g/cm^3).

$$Y = O_c * A_{tot} * \tau \rightarrow \begin{cases} Y_1 = 4.73\% \\ Y_2 = 5.38\% \end{cases} \quad (13)$$

Following the monitoring carried out, with respect to the losses by processing in the chamber furnace of the scrap aluminium in a pasty state, both bulk and briquetted, resulted in the next values.

Table 7.

Recorded losses after monitoring the scrap processing

The material used for monitoring	2016			2017			2018		
	Processed Quantity (t)	Melting Yield (%) Liquid	Burning Loss (%) Slag	Processed Quantity (t)	Melting Yield (%)	Burning Loss (%)	Processed Quantity (t)	Melting Yield (%)	Burning Loss (%)
Bulk scraps	2229,12	90,55	9,45	2039,98	90,39	9,61	1951,29	90,35	9,65
Briquetted scraps	416,13	94,92	5,08	455,28	95,07	4,93	196,99	94,95	5,05

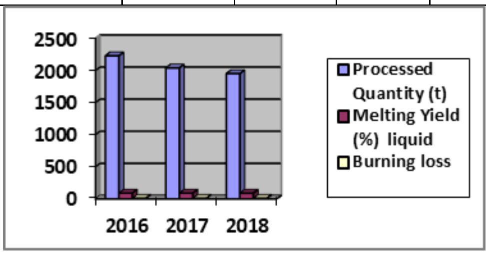

Fig. 9. Graphic Representation of losses in the case of bulk scraps

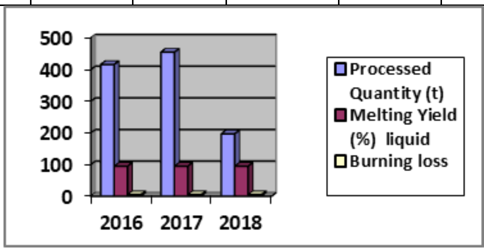

Fig. 10. Graphic Representation of losses in the case of briquetted scraps

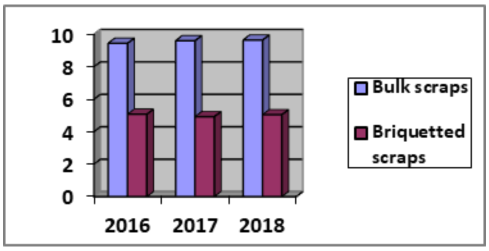

Fig. 11. Comparative analysis of combustion losses

Comparing the monitoring carried out we see that the combustion losses in the case of briquetted aluminium scraps are lower than the combustion losses of bulk aluminium, both processed in a pasty state.

This is due to the increase in temperature when inserting the bulk aluminium scrap with a high emulsion content in the melting furnace.

The combustion of the emulsions by injecting oxygen using the WEBASTO system has two effects, namely the heating of the refractory mantle but also the emergence of a slight phenomenon of overheating of the metal bath. If The quantities successively loaded are large, by default the quantities of the emulsion are large and their combustion will yield an excess of heat that will lead to an increase in the temperature of the metal bath, the pasty state not maintained.

The phenomenon of overheating of the material will appear, implicitly decreasing recovery yield.

In order to optimise the process, in terms of energy efficiency and minimisation of combustion losses, it is recommended that the scraps used to be passed through a centrifugal installation or a briquetting installation so that the amount of emulsion to be in as low a percentage as possible.

It is noted that the resulting combustion loss in the case of briquetted and processed aluminium scrap is very close to the theoretical loss calculated for this type of processing

The average productivity of the projected installation is 8 tonnes/h of which 4 tonnes/h the processing capacity of aluminium scraps using the vortex system. The metal recovery yields (eject index) calculated after the discharge of the slag, are between 88 and 93%.

Table 8.

Consumptions specific to the processing plant with decoter and bicameral furnace 65 tonnes equipped with electromagnetic pump and vortex system (LOTUS)

Installation	Burner power KW	Specific natural gas consumption KWh/t	Specific natural gas consumption €/t	Installed power KWh	Specific power consumption KWh/t	Specific electricity consumption €/t
Decoter	3000	369	10.33	68	10	0.95
65 tonnes bicameral furnace (LOTUS)	4000	645	18.06	242	30	2.85
Total consumption		1014	28.39	310	40	3.80

*The value of 645 KWh/tonne indicated by the manufacturer is related to a productivity of about 8 tonnes/h, of which 4 tonnes is a load of scraps. If we only load scraps the energy consumption would double.

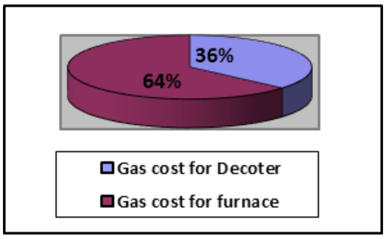

Fig. 12. Gas cost structure

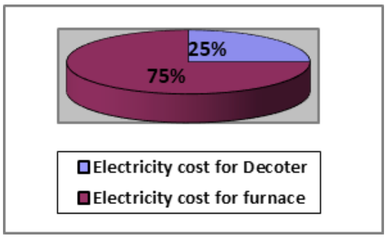

Fig. 13. Electricity cost structure

Table 9.

Consumption specific to processing plant scraps with oven 13 tonnes with oxy-fuel combustion system

Specific natural gas consumption	Specific natural gas consumption €/t	Specific oxygen consumption	Oxygen/t price	Oxygen/t value	Power consumption	Specific electricity consumption €/t
886 KWh/t	24.81	173 m^3/t	0.152	26.30	5 KWh/t	0.48

Table 10.

Value comparison between the consumptions of the aluminium scraps processing plants

Installation	Specific natural gas consumption, €/t scraps	Specific Power Consumption, €/t scraps	Specific Oxygen consumption, €/t scraps	Total consumption, €/t scraps
Decoter	20.66	1.9	0	**63.38**
65 tonnes bicameral furnace	36.12	8.7		
13 tons furnace	24.81	0.48	26.30	**51.59**

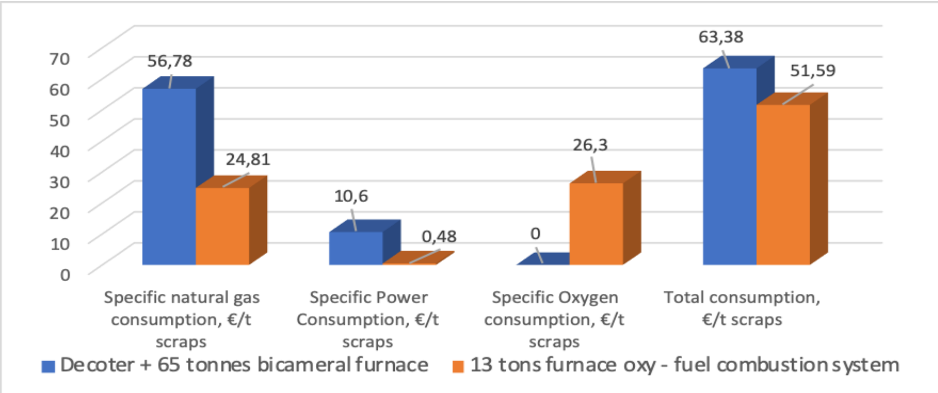

Fig.14 Value comparison between the consumptions of the aluminium scraps processing plants

5. Conclusions

From the point of view of yield, the briquetted scrap allows the reduction of losses by combustion and, implicitly, a 4.65% increase in the melting yield.

A phenomenon, which may affect the economic performance, expected from correct determinations carried out by the methods described above, is the storage of this material for a longer period. Once produced, the scrap, due to its geometric features that favour the process of converting aluminium to aluminium oxide, will lose its initial expected performance in the reception process. Subsequent recovery processes will no longer have the expected yield.

The melting yield/eject index is the most important parameter, bearing in mind that the value obtained by selling products resulting from the recycling industry's activity more than 70% is the cost of raw materials. The remaining 30% being allocated to the direct or indirect costs of the production process, the financial costs (interest, commissions, etc.) and a profit margin necessary for any economic activity.

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