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Synthesize of the ɣ- Al_2O_3 (Alumina) from Aluminium Dross by Using Chemical Method

Bilgehan Tunca*
Zahit Alüminyum San. Tic. A.Ş., Adana-Turkey,
**Corresponding Author: b.tunca@zahit.com.tr*
ORCID: 0000-0001-5826-1949

Merve Özcan
Zahit Alüminyum San. Tic. A.Ş., Adana-Turkey,
ORCID:0000-0003-3772-2229

ABSTRACT
Aluminium metal is an energy-storing metal due to its ability to be recycled with a wide range of uses. Also aluminium is a relatively light metal with a specific density of 2.7 g/cm3 compared to metals such as steel, nickel, brass, and copper. It is aimed to obtain of the alumina material from the dross by chemical methods. There is a certain amount of aluminium material in the dross formed in the liquid metal surface during melting process. Dross which is called 'semi-product' contain metallic aluminium (Al) and alumina (Al_2O_3). Aluminium dross is a mixture of free metal and non metal substances such as aluminium oxide and salts. Dross revulation machine was designed with diffent model within the scope of the study. Optimal design which was obtained lower amount of metallic aluminium and alumina was decided. Then experimental process was performed after machine design. The alumina (Al_2O_3) synthesize from dross by using chemical method with certain temperature, pressure and time. The dross was treated with 30% NaOH at 185 ° C for 2 hours under 4-5 Atm pressure. It was performed chemical analysis tests of recycled dross. Also the analysis was performed for determination ɣ-Al_2O_3.
KEYWORDS: *Alumina (Al_2O_3), Aluminium Dross, Billet Casting*

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I. INTRODUCTION

Aluminium and its alloys have an increasing use in the industry. Their lightness, easy formability and superior mechanical properties attract great attention in different industry. The properties of thermal conductivity, non-flammable, inflammable, weldable also provide significant advantages as the engineering material. Aluminium casting alloys having high strength, high corrosion resistance, excellent mechanical properties, high thermal conductivity and especially low density (2,7 gr/cm^3), are widely used in different areas with different purpose. In addition, aluminium is a metal with a great energy saving potential due to its very high rate of recyclability [1]. The aluminium casting process has an impact on physical properties, surface quality and smoothness of billet. However the dross which is formed in the molten metal surface affect negatively quality of casting during melting process [2]. Also the dross which is called semifinished product contain metallic aluminium about that 30 % - 50%. Aluminium is produced in the same method all over the world. Aluminium production takes place in two stages. One of them alumina (Al_2O_3) is obtained from bauxite ore by the Bayer method. In the second stage, aluminium is obtained from alumina by electrolysis [3]. Aluminium dross of process is one of the most challenging issue because of its toxic structure. The dross generated from molten metal is generally remelted with salts to recover residual metal values [4]. Aluminium is chemically very active material. Molten aluminium quickly forms aluminium oxide [5]. Factors such as high temperature, long waiting time, turbulence, alloy of liquid metal determine the rate and amount of oxides [6]. Dross is a mixture of aluminium oxide, carbide, nitride, various salts and other melting products [7]. This formation which mixes in aluminium metal cause to impureness during processing with liquid metal. Also it causes to metal loss with the liquid aluminium which it captures. It is impossible which remove of the dross formation by thermodynamically. Also measures can be taken to reduce dross [8].

II. MATERIAL AND METHOD

2.1. Casting Process

Aluminium alloys which are produced by casting are named according to the elemental composition.
6063 and 6951 Aluminium alloy casting process was performed in this stage. Also the chemical composition is given in Table 1.

Table 1. 6063 and 6951 Aluminium alloy chemical composition

	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
AA6063	0,47	0,25	0,05	0,02	0,50	0,01	0,01	0,02
AA6951	0,46	0,59	0,18	0,05	0,51	0,02	0,11	0,01

There are two kinds of Al dross, including primary (white) and secondary (black) dross. The former is produced in the primary Al production and the latter is generated in the secondary smelters, where Al scraps are also recycled together with primary Al raw feed. In primary aluminium metal production, alumina is firstly manufactured with processing bauxite ore through Bayer digestion process. Then, alumina is electrochemically converted to metallic aluminium via Hall-Héroult process [9] Secondary slag arises from scrap melting. Effective mixing of molten aluminium metal directly affect the acceleration of the kinetic reaction and the heat transfer and mass transfer in the aluminium melting and alloying stage. Although this mixing reaction was performed with the help of secondary tools. by manuel.The mixing process of molten liquid metal was performed with a kinetic reaction in rotary furnaces. It has been found that the temperature difference is high at the lower and upper points of the molten aluminium metal in the melting furnace. Manual reaction which is used in reverbere furnaces is one of the most important parameters that negatively affect the liquid metal thermal homogeneity. These conditions negatively affect the homogeneity of the molten metal and constitute a negative input quality in other processes following melting. Thus the temperature difference between upper and lower molten metal will be increased the thermal insulation layer which is called dross is formed [10]. Also Figure 1 shows stages of dross extraction and processing in the production process.

Figure 1. Stage of dross extraction and processing

2.2. Mechanical Design

First of all it was determined that the particle size of the dross should be as small as possible in order to obtain aluminium. Thus the equipment design and design revisions was performed in this stage. The dross was put into the rotating tambour which is driven by an electric motor. The aluminium parts and the dust will be seperated from each other by using iron ball. And then the dust will be withdrawn from tambour by means of a fan. The dusts drawn will first be collected in the cyclone, then the finer ones will be collected in another bunker. All the dust dross could not be absorbed by the cyclone because of formation of dead zones due to the geometry of the tambour. For this reason, designs related to the tambour geometry was performed and a conical tip design and manufacturing has been realized. Figure 2 shows design of dross evaluation machine.

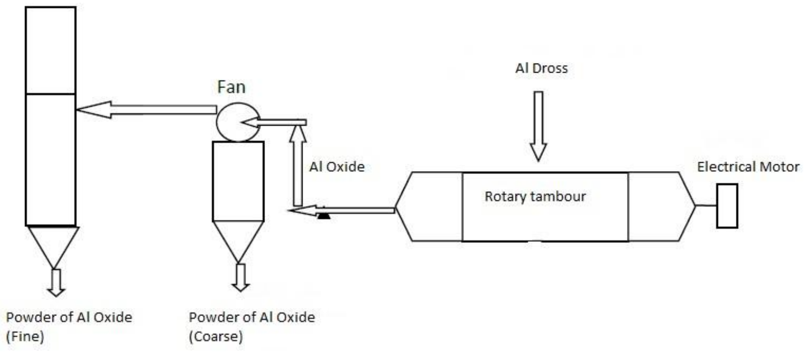

Figure 2. Design of dross evaluation machine

The addition of 3-stage bunker (second) and the geometry revision (conical type design, third design) was performed in order to increase the efficiency of the machine. Also these results which belong to geometry revision are given results and discussion. Thus the optimal design of the dross evaluation machine was determined in the light of the experiments. Figure 3 shows the conical type design and 3-stage bunker.

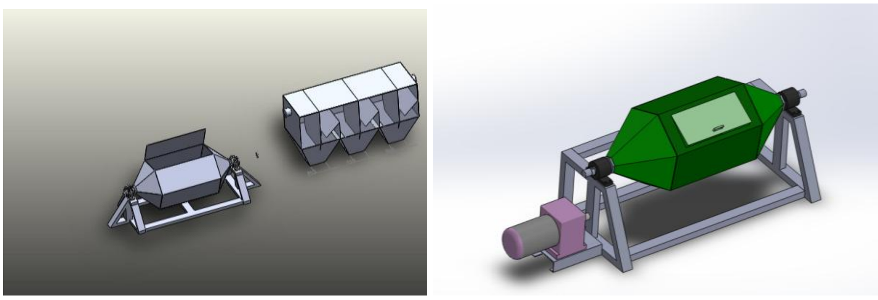

Figure 3. Revision design of dross evaluation machine

2.3. Experimental Design

Figure 4 shows experimental design and the chemical reaction was performed.

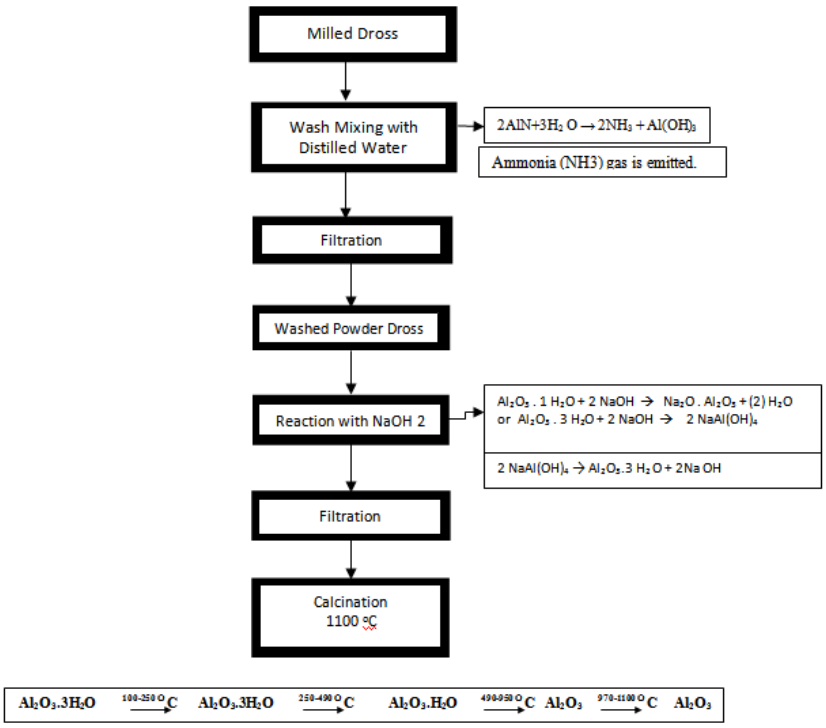

Figure 4. Experimental design of chemical reaction

2.4. Experimental Study

First experiment of alumina material aimed to be obtained from dross by chemical methods have been started. Alumina production was achieved with the Bayer Process. The basic principle of the process is to treat the material in the form of alumina hydrates with hot NaOH solution for a certain period of time to dissolve Al_2O_3 into sodium aluminate. The dross was washed with pure water in the laboratory environment. The dross was treated with 30% NaOH at 185 ° C for 2 hours under 4-5 Atm pressure. The experimental setup is illustrated Figure 5.

Figure 5. Experimental study with chemical reaction

$$Al_2O_3 . 1\ H_2O + 2\ NaOH \rightarrow Na_2O . Al_2O_3 + (2)\ H_2O$$

or

$$Al_2O_3 . 3\ H_2O + 2\ NaOH \rightarrow 2\ NaAl(OH)_4 \qquad \text{(Equation 2)}$$

The alumina trihydrate precipitated mixture was separated by vacuum filters and washed and cleaned of caustic. The experimental setup is illustrated Figure 6. The reaction is given equation 3.

Figure 6. Experimental study with filter

$$2\ NaAl(OH)_4 \rightarrow Al_2O_3.3\ H_2\ O + 2Na\ OH$$

Alumina trihydrate which is completely free of solution was calcined at 600-1100 in the ash furnace. The alumina trihydrate first gradually transformed into alumina which is the non-hygroscopic. Figure 7 shows calcination process. After the calcination process, the XRD result of the obtained alumina is shown in Figure 9.

Figure 7. Experimental study with calcination

III. RESULTS AND DISCUCCIONS

3.1. XRF and XRD Analysis

Dross dust of different particle sizes were obtained in the bunkers. The metallic aluminium and the alumina (Al_2O_3) concentration in the dross was analyzed. The elemental composition of dross after the casting process is given Table 2.

Table 2. Chemical composition of dross

	Aluminium (Al)	Alumina (Al_2O_3)
First Design	36.63 %	43.6 %
Second Design/ Third bunker	30.8 %	39.5 %
Third Design/Tambour	24.6 %	38 %
Third Design/First bunker	21.8 %	39 %
Third Design/Third bunker	19.5 %	32 %

Also its observed that the lower amount of metallic aluminium (Al) and alumina (Al_2O_3) was obtained last designed. The first dross evulation machine was designed with bump of the tambour edge and one cyclone. It was obtained that lower amount of the aluminium because of formation of dead zones due to the geometry of the tambour. Also it was observed that the amount of the metallic aluminium from dross is 36.63 %. Thus the revision was performed for dross evulation machine. This revision was called design second with 3 bunker in this study. Also its obtained that the distinction of the particle size from big to smaller with this second design. Finally the third design which has a conical was performed. Its aimed to decrement of grinding time. Its obtained that the amount of metallic aluminium was 24.6 % in tambour and 21.8 % in first bunker and then 19.5 % in third bunker. Also elemental composition analysis are given with different stage in Figure 8. Then Figure 9 shows XRD analysis.

No.	Component	Result	Unit	Det. limit	El. line	Intensity	w/o normal
1	B2O3	19.2	mass%	0.28474	B -KA	2.9902	29.3851
2	CO2	13.5	mass%	0.17529	C -KA	4.4910	20.6926
3	N	2.17	mass%	0.10359	N -KA	0.9340	3.3107
4	F	0.378	mass%	0.08128	F -KA	0.0948	0.5776
5	Na2O	4.45	mass%	0.01925	Na-KA	29.4540	6.8008
6	MgO	5.25	mass%	0.01681	Mg-KA	82.1342	8.0140
7	Al2O3	43.6	mass%	0.02110	Al-KA	1539.5397	66.5536
8	SiO2	2.41	mass%	0.00425	Si-KA	52.6715	3.6867
9	P2O5	0.0577	mass%	0.00132	P -KA	3.1350	0.0882
10	SO3	0.636	mass%	0.00191	S -KA	29.9132	0.9721
11	Cl	2.57	mass%	0.00783	Cl-KA	82.5352	3.9327
12	K2O	0.126	mass%	0.00176	K -KA	5.0239	0.1920
13	CaO	4.26	mass%	0.00440	Ca-KA	173.7260	6.5069
14	TiO2	0.526	mass%	0.00582	Ti-KA	7.3841	0.8035
15	Cr2O3	0.0188	mass%	0.00247	Cr-KA	0.9599	0.0287

a) Alumina ratio of the first design

No.	Component	Result	Unit	Det. limit	El. line	Intensity	w/o normal
1	B2O3	9.62	mass%	0.35283	B -KA	1.2049	12.2982
2	CO2	16.6	mass%	0.17275	C -KA	5.6517	21.2756
3	N	2.76	mass%	0.15156	N -KA	0.8212	3.5259
4	F	0.426	mass%	0.08505	F -KA	0.0794	0.5442
5	Na2O	2.20	mass%	0.01681	Na-KA	11.0689	2.8186
6	MgO	5.61	mass%	0.01365	Mg-KA	69.4796	7.1742
7	Al2O3	39.5	mass%	0.01880	Al-KA	1073.0311	50.5297
8	SiO2	2.91	mass%	0.00464	Si-KA	49.4614	3.7205
9	P2O5	0.128	mass%	0.00195	P -KA	5.7921	0.1637
10	SO3	1.41	mass%	0.00278	S -KA	54.5333	1.8056
11	Cl	2.56	mass%	0.00754	Cl-KA	66.1230	3.2775
12	K2O	0.0781	mass%	0.00223	K -KA	2.6169	0.0998
13	CaO	13.1	mass%	0.00702	Ca-KA	428.0619	16.7714
14	TiO2	1.50	mass%	0.00977	Ti-KA	13.5313	1.9233
15	V2O5	0.0059	mass%	0.01021	V -KA	0.2215	0.0076

b) Alumina ratio of the second design

No.	Component	Result	Unit	Det. limit	El. line	Intensity	w/o normal
1	B	6.97	mass%	0.12027	B -KA	2.6775	8.0425
2	C	6.04	mass%	0.06927	C -KA	5.1513	6.9697
3	N	4.16	mass%	0.19397	N -KA	0.9885	4.7982
4	O	33.2	mass%	0.18488	O -KA	10.4468	38.2708
5	F	0.471	mass%	0.07893	F -KA	0.0931	0.5434
6	Na	4.24	mass%	0.01313	Na-KA	29.6483	4.8896
7	Mg	4.42	mass%	0.00879	Mg-KA	87.5933	5.1059
8	Al	24.6	mass%	0.01021	Al-KA	1166.2550	28.4428
9	Si	1.65	mass%	0.00216	Si-KA	51.6753	1.9081
10	P	0.0773	mass%	0.00085	P -KA	6.8290	0.0892
11	S	0.672	mass%	0.00109	S -KA	54.9488	0.7754
12	Cl	5.62	mass%	0.01060	Cl-KA	120.0920	6.4842
13	K	0.0915	mass%	0.00181	K -KA	2.8676	0.1056
14	Ca	5.95	mass%	0.00410	Ca-KA	216.6633	6.8626
15	Ti	0.618	mass%	0.00546	Ti-KA	8.4683	0.7134

c) Metallic aluminium ratio of the third design (tambour)

No.	Component	Result	Unit	Det. limit	El. line	Intensity	w/o normal
1	B	8.29	mass%	0.12103	B -KA	3.2263	9.4851
2	C	6.03	mass%	0.07695	C -KA	4.7502	6.8937
3	N	3.13	mass%	0.21454	N -KA	0.7112	3.5810
4	O	32.4	mass%	0.17578	O -KA	10.0566	37.0844
5	F	0.502	mass%	0.08785	F -KA	0.0988	0.5741
6	Na	5.33	mass%	0.01389	Na-KA	37.0191	6.0971
7	Mg	3.89	mass%	0.00809	Mg-KA	74.7067	4.4437
8	Al	21.8	mass%	0.00956	Al-KA	1022.1114	24.9546
9	Si	2.13	mass%	0.00238	Si-KA	68.7818	2.4343
10	P	0.0744	mass%	0.00087	P -KA	6.7234	0.0851
11	S	0.787	mass%	0.00120	S -KA	65.6975	0.9001
12	Cl	7.46	mass%	0.01224	Cl-KA	159.9663	8.5318
13	K	0.0958	mass%	0.00174	K -KA	2.8950	0.1096
14	Ca	5.94	mass%	0.00405	Ca-KA	208.5181	6.7899
15	Ti	0.820	mass%	0.00573	Ti-KA	10.8679	0.9382

d) Metallic aluminium ratio of the third design (first bunker)

No.	Component	Result	Unit	Det. limit	El. line	Intensity	w/o normal
1	B	3.15	mass%	0.10945	B -KA	1.1652	3.4608
2	C	7.35	mass%	0.05667	C -KA	7.9759	8.0891
3	N	3.00	mass%	0.20070	N -KA	0.6669	3.3023
4	O	41.4	mass%	0.21082	O -KA	11.8879	45.5185
5	F	0.337	mass%	0.07628	F -KA	0.0550	0.3708
6	Na	1.82	mass%	0.01229	Na-KA	10.7020	1.9976
7	Mg	3.44	mass%	0.00735	Mg-KA	61.0587	3.7863
8	Al	19.5	mass%	0.00874	Al-KA	861.7933	21.3928
9	Si	1.52	mass%	0.00209	Si-KA	48.9330	1.6772
10	P	0.0635	mass%	0.00082	P -KA	5.7803	0.0699
11	S	0.675	mass%	0.00107	S -KA	57.0412	0.7425
12	Cl	2.97	mass%	0.00752	Cl-KA	66.6325	3.2662
13	K	0.0877	mass%	0.00183	K -KA	3.0498	0.0964
14	Ca	12.2	mass%	0.00554	Ca-KA	469.6167	13.4154
15	Ti	0.926	mass%	0.00933	Ti-KA	10.8369	1.0190

e) Metallic aluminium ratio of the third design (third bunker)

Figure 8. Elemental composition with different stage

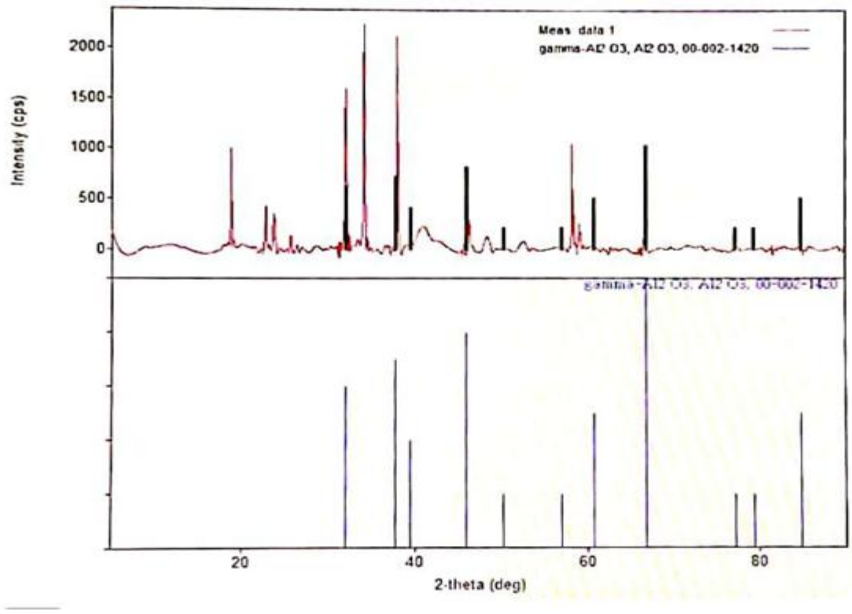

Figure 9. XRD result after calcination process

IV. CONCLUSIONS

The aimed of the production alumina (Al_2O_3) from dross which come out molten metal during melting process. Dross revulation machine was designed with diffent model within the scope of the study. Optimal design which was obtained lower amount of metallic aluminium and alumina was decided. Then experimental process was performed after machine design. The alumina (Al_2O_3) synthesize from dross by using chemical method. The experimental study was performed using by dross which come from molten metal during melting process. The obtained dross was chemical reaction with 30 % NaOH with 185 ^{0}C temperature, 4-5 atm pressure during 2 hours. The filtration, calcination were performed after chemical reaction. Alumina trihidrat which was cleaned from solution was calcinated with 100-110 ^{0}C in the ash furnace. Alumina trihidrat which was cleaned from damp. Then the dross was analyzed for determination of the alumina (Al_2O_3). Finally its observed that the ɣ-Al_2O_3. Another study which was aimed to obtain alumina from secondary aluminium dross performed by Allahverdi A. and Mahinroosta M.,. The various parameters of dross particle size, leaching time, leaching temperature, acid concentration were performed in this study. Also its reported that synthesis and characterization of high crystalline activated-alumina (gama) nanopowder from secondary aluminium dross [11].

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