

PROCESSING METHOD AND DROSS DUST FRACTIONS PROPERTIES IN THE CONFAL Inc.

Ing. Jan Sedo

Development and realization workplace of raw materials extracting and treatment, Faculty of Mining, ecology, process control and geotechnology, Technical University of Kosice

Abstract

Dross processing and its dust non-melting fractions is an important area for the producers of this type of waste and also for the products consumers. It is possible to produce the products from the waste. The Confal Inc. company creates its own production process, which is more economically advantageous in comparison with the previous used method. To handle this process, it offers promising future prospects for small companies which are so far from the major processors of dust dross. To contribute to the protection of the environment in any form, it is the responsibility of each producer and consumer.

Keywords: Dross, non-melting fractions, Confal Inc., environment, economically effective process

Introduction

Dust fractions from aluminum dross treatment are the environmental burden of any company operating in this sector. Their physical and particularly chemical properties are among the wastes that need extra attention. On the other hand, the same properties include them to the position of possible chemical substances source used in other industries. The processing companies within Europe are concentrated in Western Europe, especially in Germany.

There are concentrated the largest production capacity of aluminum and its alloys, waste from melting. Therefore there is also concentrated the treatment of dust fractions from dross. All companies use technology of soluble components leaching, as they process dross from salt rotary kilns.

It is the predominant process for aluminum waste melting. Brine and after its drying a salt is a by-product which is returning to the suppliers and black mud with various content of Al_2O_3 is used as a source of Al_2O_3 for other industries. It is supplied with varying purity. The way of dust fractions

delivery of dross for treatment is for a small company as Confal Inc. in its geographical position economically impassable.

Passive land filling is for a company with environmental principles unacceptable and also it is economically inefficient solution. Therefore, the company has begun to focus on research of dust fractions recovery of dross in their own conditions, finding the way to create the products and disposal of gaseous products in an environmentally sound way.

Energy content of the material is also significant. Its combination of attributes under Confal Inc. conditions it belongs to the position of non-hazardous (other) waste with the possibility of subsequent industrial exploitation. Treatment technology without leaching of soluble components is significantly different from the established methods, but economically preferable. Therefore, the research addresses this issue in an integrated production process level.

1. Dross pre-treatment from melting and purchase:

It has been considered, that there are efficient dross with metal content of minimum 50 % for the melting without pre-treatment based on the long-term monitoring of the melting results. Other dross, except of dross from the rotary furnace, it is essential to carry out pre-treatment in terms of melting. In terms of the products from dross dust fractions, it is considered the production of semi-finished products. In total, it is produced about 100 tons of dust fractions from purchased dross and about 180 tons of dust fractions from the dross rotary furnace within a period of one month. In total, about 280 tons of less than 0.8 mm grain size is the amount that is available for secondary production. Technological scheme of pre-treatment of doses (production of semi-finished products for the secondary production) is shown on Fig. 1.

The process consists of a basic sorting, sieve sorting and logistics. Compact pieces with visually (long-term experience with metal content evaluation is essential) convenient metal content are being sorted for production. The remainder will be smashed into pieces below 200 mm by hydraulic hammer and the self-designed hammer crusher will crush the broken pieces.

The metal dust non-metallic fractions are released from small metal skeletons by pulse energy of hammers and by mutual particle collisions. The speed of particles is reduced by intensive suction of the crusher chambers through a maze (metallic parts entrained by air stream fall back into the crusher). Dust grain size of 0.05 to 0.8 mm is separated in a cyclone; the fractions of 0.05 mm are collected on a filter tissue and both fractions fall through the rotary feeders to the big-bags. Crushing and evaluating of the

outcomes is carried out on each delivery, including accumulated dose deliveries of own production (the dose of own production is about 25 tons).

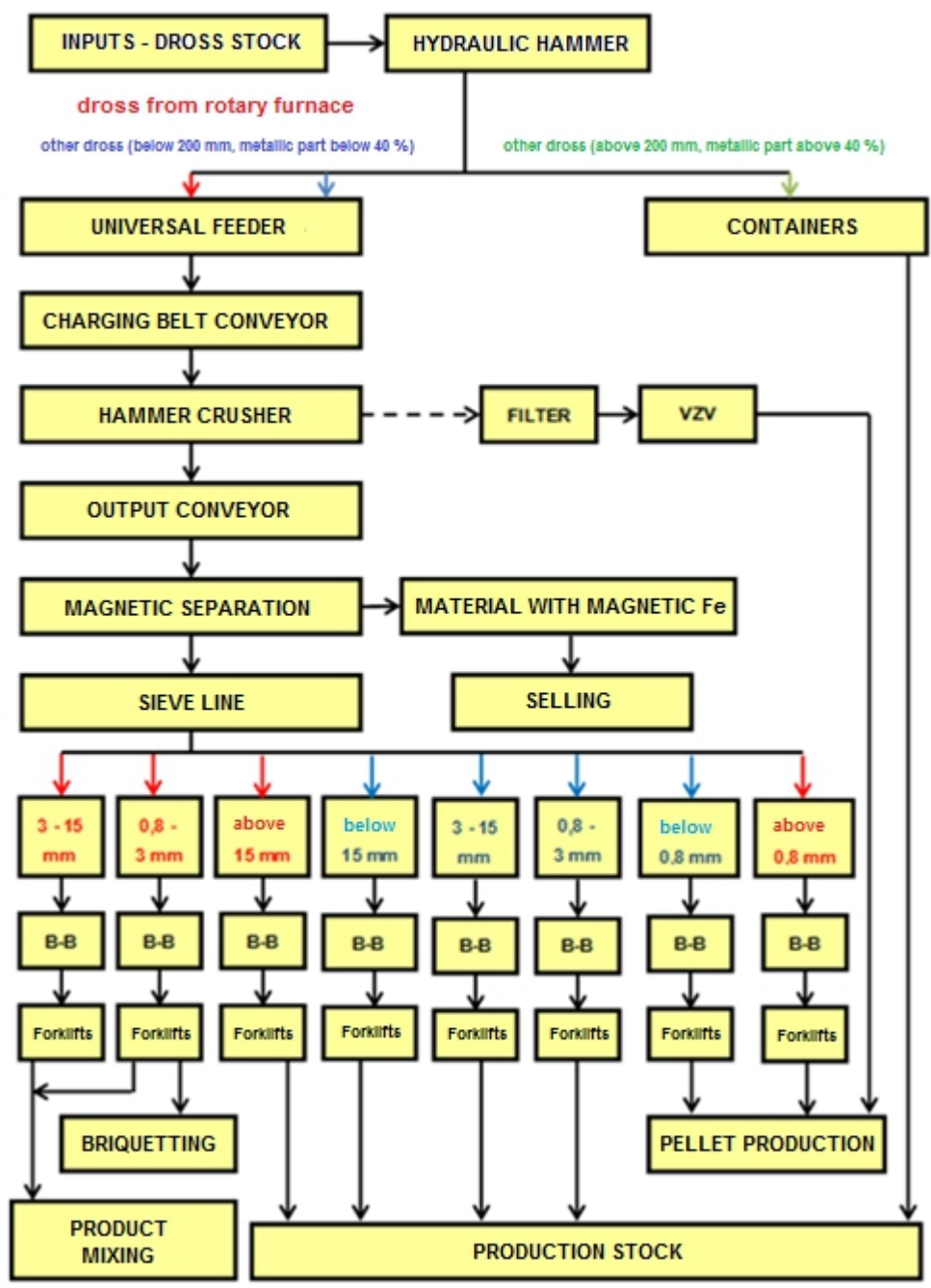


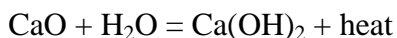
Fig. 1 Technological scheme of the dross pre-treatment

2. Market demands for the products and their properties:

Currently, the secondary production of the Confal Inc. produces the intermediate products from dross dust fractions in pilot conditions for mixed and pressed products of the steel industry. Granulation with acceptable logistic and technological properties of intermediate products to comply with environmental requirements for the operation is a priority of the operation.

Before starting research and pilot production, the following requirements based on market research has been created for the end products:

- maximum 16 % of permissible fractions content below 1 mm is in the product at client's acceptance procedure. It means that it is necessary to produce intermediate products without fraction of below 1 mm. For technological and commercial logistics, a reserve up to 10 % must be remained as intermediate products are chafed and they create dust during mixing;
- in the synthetic slag for ladle metallurgy, granules have to reduce the viscosity of CaO and intensify its desulfurization ability to the value up to 5 points (0.005 %) in special steels for the electrical industry and eliminate scabs from the ladles. This preparation must terminate its activity within 5 minutes after pouring of a melt from the converter to the ladles. After 5 min, the ladle is conveyed into the vacuum station for refining;
- preparation for converting for the scabs removal from converter throat;
- the preparations must not cause oversized fumigation. The level of fumigation is limited by a sharpness of control cameras. During ladles transport for the next operations, fumigation is inadmissible;
- preparations must not have a negative impact on the life of ladle linings and converters;
- residual moisture must not exceed 0.6 %, since CaO is a highly active substance and with a small quantity of moisture it reacts according to the reaction:



The intensity of the reaction depends on the amount of moisture. The small amount of moisture even from the air will cause gradual decomposition of the CaO into the dust. Therefore, it is necessary to transport lime just before mixing with residual temperature of 60-70°C after burning and immediately after mixing the mixture to transport to the customer by the same means to the nitrogen stabilized silo.

2.1 Definition of granular product strength properties

Granular products made from dross dust fractions must have mechanical properties that do not define measurable physical quantities by customers. The strength requirements are given by time limit of decomposition of granules in the slag. Before the granules are used in products, they must withstand technology logistics load (transport in spiral conveyors, mixing, and pneumatic transport).

After the tests in operation, I verified that if the granules have satisfactory strength properties for sufficient resistance to logistics burden (removal of the granules from the customer's product is a guaranty that they have already overcome the logistics burden), they are limited by decomposition time in the slag and are controlled by customer using simple test of free fall onto a hard surface. If a granule of medium-size (diameter of approximately 8 mm) free falls from a height of about 2 m on a smooth concrete surface and if it is not decomposed into more than 2 pcs, or is not decomposed at all, strength is satisfactory. Measuring of the hardness on the laboratory meter found that the strength shall have at least a value, corresponding to the burdensome strength of 120-130 N at a pressure on the granule. This auxiliary rule can check strength in operating conditions.

3. Production methods of the products from dross dust fractions in the world:

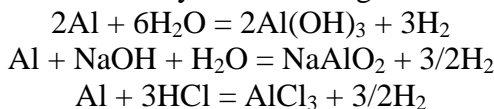
Volumes of the processed dross dust fractions of the major processors are ten thousand tons per month. Such quantities come from many sources, especially alloy manufacturers and are mainly formed in salt rotary kilns, as this melting technology is the most widespread at recycling companies. Other dross with high metal content is treated either by originator or is a valuable business article. They are finally sent to the salt rotary kilns of other processors of Al waste.

Salt factories around 0.3-0.4 used in the world determine the content of soluble salts in the dust particle dross. At initial mechanical separation of metal-bearing fraction, oxide particles bound to the salt are released from metal skeletons by impact energy. Thus, most of the salt enters to the dust fraction and it increases its concentration in the dust.

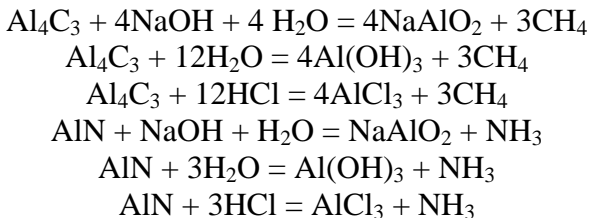
Salt factor is the ratio of melting salt to the non-metal part of charge (impurities, oxides). If a salt factor is 0.3, it can be assumed that 30 % of the dross is salt. Conventional dross of salt rotary furnaces content about 20-25 % of metallic aluminum in the form of separable alloys, or in the form of very finely dispersed particles of maximum 0.5 mm after initial crushing. To minimize the loss of metal, an autogenous crushing is used in order to crush dross of salt rotary furnaces. Metal extraction is generally 8-11 %. 8-18 % of non-melting metal residue is in the dust fraction. Taking into account these

facts, salt content increases by about 33.3 % in the dust fractions at the salt factor of 0.3; at salt factor 0.4 by 44.4 %.

This salt percentage at the residual content of fine (maximum 0.8 mm) metal aluminum practically excludes a direct processing of dust fractions without removing of soluble components. Therefore, salt dross processors use pressure leaching of soluble components (Bayer method, Fig. 2) and by their transferring to an aqueous solution (liquor) it remains insoluble residue (black mud) consisting of 60-70 % Al_2O_3 , and other insoluble substances (SiO_2 , MgO and others). To increase the pressure in the reactor of 0.6 bar, constant mixing and increased temperature from the exothermic reactions results in a favorable time course of leaching approximately 1 hour. In the initial phase, hydrogen is formed by the following reactions:



A smaller amount of gases (methane and ammonia) arises from carbides and nitrides by these reactions:



Due to the presence of As, P, Sb and S in dross dust fractions, a small amount of AsH_3 , PH_3 , SbH_3 , H_2S as additions of mixed gas can be created. The resulting gas mixture is highly explosive because hydrogen is predominant in the mixture and its composition is in the range of 85-95 % H_2 , 4-10% CH_4 , up to 1% NH_3 .

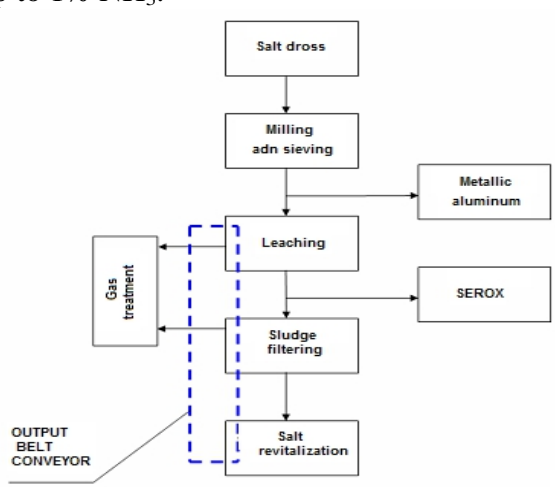
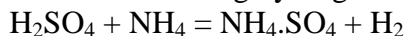


Fig. 2 Bayer method scheme used in ALSA Developing Hannover

The scheme is well known and is practically identical to all processors. Compared to the past, there are differences in the products portfolio and the gas treatment method. The publication of the patent No.US4732606 in Germany solves the neutralization of ammonia in 1988. To the related works belong No.DE3137950A1, EP0075971A2, EP0075971A3, EP0075971B1 with the same author team that deal with gas treatment, crystallization of salts NaCl and KCl from the leach and placing the residues in the caverns. The procedures for industrial use of black mud as a source of chemical substances based on Al₂O₃ have been solved only after 1988.

The gases are in the first step filtered through aqueous solution of sulphuric acid H₂SO₄. The company ALSA stated a concentration of sulphuric acid by about 10 %. In this solution, the binding of ammonia from gases is happened which reacts with solution of sulphuric acid to form ammonium sulphate NH₄.SO₄ and releasing hydrogen H₂.



In an aqueous solution of sulphuric acid, the concentration of ammonium sulphate is gradually increasing and the amount of a reactive sulphuric acid is decreasing. When concentration of ammonium sulphate increases by 30 % in the solution, it is necessary to revitalize this chemical liquid filter - adding acid or to replace a solution.

Gases, devoid of ammonia and also enriched with hydrogen are further passed to the concentration and final combustion. The gases escaping from the leaching process consist mainly of hydrogen, methane, ammonia and water vapor. The steam is condensed in liquid filter; proceeding gas is then freed from the residual water vapor in the condenser. Dry gases are captured with active charcoal and are combusted. The problem is their concentration. In this gas mixture hydrogen prevails. The lower explosion limit is 4.1 % in the mixture with air; the upper explosion limit is at 88% level of hydrogen. This wide range results in the need for system tightness and thorough monitoring of the gas composition.

As running chemical reactions are exothermic and capable to heat up the leaching mixture to 150°C temperatures, it is not necessary to add another considerable amount of energy for reactor heating. Energy is created by combustion of gases and is used for energy balancing of leaching process and partially for salt brine heating as well as black mud drying.

The leachate is basically contaminated salt which is returned to suppliers or sold after it is revitalized and further leached and after evaporation of water. In practice it is more complicated as salt brine takes a lot of space, it creates lakes of saturated solution of salt in water at all manufacturers. Maximal solubility of NaCl in water is 358.6 g/1000 ml of water at ambient temperature 20°C and even at 100°C it is only 390.2 g/1000 ml of water. Potassium chloride has solubility from 341.9 g/1000 ml to 562 g/1000 ml at

ambient temperature of 100°C. However, melting salts (e.g. montanal) contain approximately 66 % of NaCl and cca 31 % of KCl. It causes a great usage of water and energy for water evaporation. The specific heat capacity of water is 4186 J.kg⁻¹.K⁻¹ which is the highest value of all common substances and thus the evaporation of water is very energy consuming.

As mentioned above, dross dust fractions contain cca 33.3 % of salt at salt factor 0.3 and 44.4 % of salt at salt factor 0.4. If we consider an average value of 38.85 % and the solubility of salt NaCl and KCl in water, we can see that the content of salt from 1 ton of dross dust fractions can be dissolved in approximately 1 m³ of water. There are approximately 90000 tons of dross dust fractions at yearly manufactured amount of 100000 tons of dross after metal separation, which are intended for leaching and therefore approximately 90000 m³ have to be vaporized yearly. For illustration, this amount represents a 9 ha lake with average water depth of 1 m, with 18–19 cm thick salt layer left on the bottom of the lake according to measured weights of both main components.

3.2 Determining conditions for dross dust fractions treatment in Confal Inc., without leaching the soluble components

Confal Inc., is a small recycling company in European scale for aluminum waste with yearly treatment amount approximately 13000 tons of waste. Company's geographical location is economically disadvantageous for cooperation with manufacturing companies in the field of dross dust fraction treatment. Therefore, the company concentrated on internal possibilities of dross dust fraction treatment. The melting technology using low salted melting in rotary furnace with a salt factor of 0.2 to max. 0.23 creates appropriate possibilities for own treatment and recovery of dross dust fractions by a dry method without leaching the soluble components. Company's own treatment method means environmentally advantageous solution.

Passive landfill on dumps is expensive and it is conflict with environmentally conceived manufacturing in Confal Inc., company. Logistics of treatment at other manufacturers which are open to the market is economically unprofitable because of their location in Germany. Manufacturers in Poland are not opened to cooperation in this field. They protect their technologies and formulas as they have many year traditions in this area (Hermex) and the market competition is very strong. In Central Europe there is much greater production of dross dust fractions than the steel market can accept in the form of preparation. Therefore, the perspective way to succeed in competition is to concentrate on the most complex parameters i.e. the highest quality.

In Confal Inc., two dross types are on the output from melting process. The melting process outputs are always identical as the whole volume of inputs goes through identical technological processes independently from dross and waste to treat. Small differences emerge in chemical composition of metallic aluminum always contained in the dust. This fact is negligible from product's point of view. A good possibility to identify inputs is positive for dust fraction treatment process creation. An internal pilot project carried out in 2010 to 2011 showed that the knowledge of input parameters enables to create very specific intermediate products with good reproducibility and products for steel industry. Principally the accurate balance is a very important part of the overall process for reproducibility and stability of output quality. The relative representation of qualities according to reactivity with water and grain size creates conditions for process optimization and for physical control parameter determination for sophisticated dust fraction treatment in secondary production.

It is possible to make targeted process parameter control and efficient physical and chemical process control aid during production to ensure final product parameters according to the market requirements by the possibility to identify the inputs in Confal Inc., company. Monthly amounts of undersize fractions of less than 0.8 mm are approximately 280 tons, which gives approximately 3000 tons yearly as January and December are shorter months. By this amount, Confal Inc., company differs significantly from any other company that treat tens of thousands tons yearly. With relative small amounts, it is not possible to calculate with cost demanding chemical technological processes of wet treatment technologies. The aim is to place all generated fractions into products by their appropriate combination and by dry technology without leaching the soluble components so that any waste is dumped. If we consider the amount of soluble components in dross fractions from rotary furnace and the relative representation of final dust fractions (180 rotary furnace, 100 tons the rest), it is possible to achieve concentrations of soluble elements below the limit by treatment mixture combination. The overall production process is focused on products for steel industry.

4. Physical and chemical parameters of dust dross fractions produced in the Confal Inc.:

In conditions of Confal Inc, company there is a limit value 0.8 mm for dust fractions. Grain size above 0.8 mm is meltable and is returned into the melting process as it contains approximately 40 % of metallic content. This data was verified by melting experimental tests in scorifier furnace with batch capacity of 150 kg under flux.

4.1 Grain size analysis, cohesiveness and chemical composition

For grain size analysis, a laboratory sieve separator of 300 mm in average and with 6 sieves was selected as seen in Table 1. Graphs may be seen in Fig. 3. It can be seen, that finer fractions predominate in fractions from filter and rougher fractions from cyclone. The sample No. 1 with 500 g weight is a representative sample generated by heaping from 20 kg of dust separated by filter. The collection was made evenly from 5 full big-bags. The sample No. 2 with 500 g weight was created similarly from dust separated by cyclone. Digital laboratory weight devices were used to measure the weights with weighing capacity of 0.1–5000 g. Specific weights were determined for all fractions by pycnometer using spirit as an internal fluid, that does not develop any gases and thus it does not change volume. They are in the range of 2.39 to 3.72 g/cm³. A significant dispersion is caused by significantly higher content of metallic particles in rougher fractions. Bulk weight is different too, the fraction from filter has a value of 910 kg/m³, the fraction from cyclone has a value of 1050 kg/m³. The bulk weights were determined by cases with volume 1.1 m³ at upper edge. Big-bags were replaced by weighted cases under filter and cyclone. After they were filled, the surface was levered carefully by slat without ramming and cases were weighted. Bulk weights were calculated for 1 m³ of both fractions. Long-term operational experiences show that the occurrence of dust from filter and from cyclone has the ration of 3:1. The results of sieve analysis can be seen in Table 1.

Table 1 Sieve analysis of dust

Sieve, mesh size [mm]	Samp. No. 1 filter share [%]	Samp. No. 2 cyclon share [%]	Density [g/cm ³]	Notice
0,5	3,35	29,70	3,72	oversize fraction
0,18	16,85	24,50	2,92	oversize fraction
0,12	10,05	18,30	2,84	oversize fraction
0,10	7,10	6,70	2,65	oversize fraction
0,08	7,20	3,30	2,65	oversize fraction
0,05	9,95	8,00	2,65	oversize fraction
Pod 0,05	45,50	9,50	2,39	undersize fraction

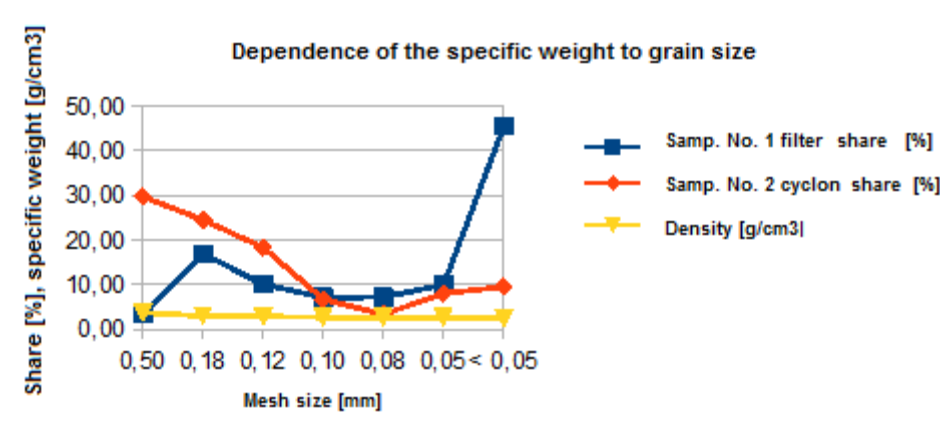


Fig. 3 Sieve analysis of dust with fraction under 0,8 mm

The cohesion expresses the flow parameters of dusts. Dust fractions can be named as particular materials because they have been created by disconnection of compact material. Particular materials consist of particles which have their shapes, surface segmentation, porosity, internal friction between particles in volume, external friction e.g. at stack walls, cohesiveness which expresses flow parameters of dust materials. Flow parameters describe the Hausner ratio (HR) with bulk volume weight of not compressed and compressed particular material.

$$HR = P_{ssg}/P_{nsg}$$

Dust materials are divided into these groups:

- HR < 1,25 - Geldart group A (freely flowing dusts),
- HR > 1,25 - Geldart group C (cohesive dusts),
- 1,25 < HR < 1,4 - A/C (semi-cohesive dusts).

It takes a high priority to include disposable material for the most optimal treatment (granulation) method. To exclude humidity influence two dust samples from filter and cyclone have been gradually dried with weight approximately 1 kg at temperature 110°C during 90 minutes in chamber laboratory furnace LAC. After cool down not-compressed and compressed bulk weights have been measured according to the appropriate method. Test results are shown in Table 2. Hausner ratio shows that the dust from filter (HR = 1,542) is cohesive and the dust from cyclone (HR = 1,306) is semi-cohesive. This classification is important for treatment device design.

Table 2 Hausner ratio

Sample	Non-compressed bulk weight [kg.dm ⁻³]	Compressed bulk weight [kg.dm ⁻³]	Hausner ratio [HR]
Dust from filter	0,903	1,392	1,542
Dust from cyclone	1,045	1,365	1,306

Found Hausner ratios result the fact that it is a dust type which hardly falls apart by itself and has the tendency to create vaulting in stack. Therefore it is necessary to subordinate the construction of technological logistical resources to it.

The average chemical composition can be seen in Table 3. It differs from ordinary dross from salty meltdown by a lower content of metallic aluminum. It is not possible to compare other parameters as references show composition of untreated dross and not only the composition of dust fraction with pellets sized under 0.8 mm.

Table 3 Average chemical composition of dross dust fractions

Smp.	Al ₂ O ₃	Al _{kov}	Na	K	Cl	F	SiO ₂	Fe	Cu	Zn	Mg		
1	61,9	7,77	1,63	1,72	2,90	0,70	3,22	1,50	0,38	0,69	2,00		
2	60,0	8,71	1,70	1,75	3,36	0,55	4,21	2,30	0,62	0,23	1,83		
3	61,0	8,23	1,71	1,68	3,00	0,74	3,98	2,05	0,47	0,54	2,30		
	Ti	Mn	Pb	Sn	Ni	Sb	Ba	As	C	S	N	P	
1	0,16	0,18	0,18	0,04	0,03	0,1	0,07	0,03	2,29	0,19	0,82	0,03	
2	0,18	0,19	0,22	0,05	0,06	0,06	0,05	0,02	2,24	0,10	1,45	0,01	
3	0,19	0,21	0,25	0,03	0,05	0,05	0,06	0,03	2,30	0,35	2,03	0,05	

Conclusion:

Basic assumptions have been made for continuous granulation technological production line construction by researching the parameters of dust fractions of dross produced by Confal Inc., company. This process is another step in development programme of Confal Inc., company. A basic pilot granulation production line is available nowadays in which physical – chemical processes are verified find out the most suitable parameters for process control. The aim is to achieve continually working production line. Pellets will be final products with consumer required physical – chemical parameters after they leave the production line.

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