

“Material-treatment installation and method for the use of a material-treatment installation”

[01] Worldwide, the negative environmental impacts of waste disposal are receiving increasing attention. Proper waste disposal requires large areas of land, which are limited in certain urban areas or on islands. The waste can also have adverse environmental impacts, including impacts on groundwater, as chemicals and heavy metals contained in the waste can contaminate the groundwater. However, waste can have negative impacts on the environment not only in landfills, but also through incomplete separation and processing for reuse as potential secondary materials in various industrial applications.

[02] The present invention relates to a method for separating non-ferrous metals from bottom ash, so-called slag, from waste incineration installations, which functions as a subsystem of a comprehensive slag processing process.

[03] The separation of non-ferrous metals by means of an eddy-current separating device is known from the prior art. This method is also used in the processing of slag originating from a waste incineration installation. After the slag is removed from the incineration furnace, it consists substantially of mineral slag particles and various metals. After removal, before feeding it into a slag treatment installation, the slag is usually stored to reduce its moisture content. To date, there is no globally standardized method that can process the mineral slag fraction and the metals with sufficient quality so that these products meet the legal requirements of different countries for the reuse of both materials.

[04] In typical slag processing methods, larger particles of the size order > 300 mm and large iron scrap particles are usually separated in a first step. Afterwards, the slag is separated into different fractions in a separating device, for example using a sieve. After these processes, in a third step, the fractions obtained are further separated into ferrous fractions and slag particles with magnetic properties.. It is important to notice that these process steps can also be carried

out in a different arrangement depending on the system. However, regardless of the order, they must be carried out before the process step of separating the non-ferrous metals from the mineral slag fraction takes place. The separation of non-ferrous metals is usually carried out using an eddy-current separating device, and is a crucial factor for the economic returns of the operator of the slag processing installation, having a significant impact on the profitability of the installation. In the separation technology for waste incineration slag, the goal is to recover as many non-ferrous metals as possible with high purity. Usually, 70-90% of all non-ferrous metals can be separated using one or two eddy-current separating devices connected in series per fraction. An important disadvantage of the known process is that only a certain proportion of the non-ferrous metals present in the slag can be separated in an economically viable manner if a certain non-ferrous metal quality is to be guaranteed. To further increase the separation, additional eddy-current separating devices or similar methods are required. Since the absolute amount of non-ferrous metals separated off decreases after the separation of each additional eddy-current separating device, further eddy-current separating devices are not used to this day, as the cost-effectiveness of the additional eddy-current separating devices is not guaranteed.

[05] However, the non-ferrous metals that are not separated off limit the reuse of the mineral slag fraction in various industrial applications such as base layer creation for road construction, cement production or ceramic manufacturing. The heavy metals and aluminium in the remaining mineral slag fraction still pose obstacles to its full integration as a secondary material on a global scale. The release of heavy metals or oxidation of the aluminium particles can lead to environmental pollution or reduction in material quality.

[06] With the ever-decreasing landfill volumes for non-recyclable materials and the efforts to reuse secondary resources in the fight against climate change, the use of mineral slag after the separation of ferrous and non-ferrous metal fractions is gaining in importance.

[07] The elimination of the mineral slag fraction in landfills can also have economic potential

for operators, since, depending on the country and specific landfill disposal, high landfill costs can be saved by reusing the mineral slag fraction. Thus, the additional increase and improvement of the separation of non-ferrous metals can also create additional economic potential for the operator.

[08] The underlying object of the described invention is therefore to propose a material-treatment installation and a method that allows to further increase the separation efficiency of the contained non-ferrous metals from the bottom ash of a waste incineration installation in various slag fractions. The aim is to separate the non-ferrous metals and the remaining mineral slag fraction in such a way as to ensure that sustainable reuse of both end products as secondary material.

[09] The invention relates to a subsystem of a slag-treatment installation with an eddy-current separating device, which has an inlet for a slag fraction, an outlet for a mineral slag fraction and an outlet for a non-ferrous metal fraction, and a method for the treatment of slag from waste incineration installations with an eddy-current separating device integrated into a closed-loop process in which the slag is separated into a mineral slag fraction and a non-ferrous metal fraction through several cycles.

[10] Such devices and methods are designed to ensure a particularly high separation efficiency of the non-ferrous metal fraction from the mineral slag fraction in a particularly high purity.

[11] The object of the invention is therefore to propose a material-treatment installation and a method for providing particularly pure material products from slag already freed from ferrous particles; a mineral slag fraction and non-ferrous metals. This is achieved using a closed-loop process, which increases separation efficiency without the need to integrate additional eddy-current separating devices.

[12] The object of the invention is solved with a material-treatment installation having the features of claim 1.

[13] Advantageous further embodiments are the subject of the dependent claims.

[14] The method according to the invention could be carried out continuously if properly adjusted. Preferably, it is carried out as a batch process, wherein the batch is preferably fed to the eddy-current separating device at least twice. The material-treatment installation has two storage containers. A first storage container serves to store incoming slag and is provided upstream of the eddy-current separating device. The second storage container is provided in the return line for the mineral slag fraction. The material to be separated is fed to the eddy-current separating device for the first time as untreated slag and for the second time as the mineral slag fraction of the material not separated off in the eddy-current separating device. This loop can be repeated indefinitely before the material is removed from the loop.

[15] The two storage containers are necessary to guarantee a flawless batch principle. Without storage, one would have to calculate how much material can effectively fit in the loop. If untreated slag is fed into the loop, it could happen that at some point the mineral slag fraction has already been processed once with the eddy-current separating device and is fed back towards the eddy-current separating device. If untreated slag is still being pumped from the first storage container into the loop, the amount to be processed increases until the closed loop system eventually reaches its maximum separation capacity and the eddy-current separating device is overloaded. Hence, installing two storage containers of the same size ensures that there is enough space for the material in the loop. The eddy-current separating device typically has the lowest throughput of the individual components in the loop, making it the bottleneck.

[16] The return line normally consists of various transport systems which convey the mineral slag fraction into the second storage container. A combination of vibratory conveyor systems, conveyor belts or bucket elevators is normally used.

[17] The mineral slag fraction loop includes a material removal outlet. The material can be conveyed from the system via this material removal outlet during each cycle. It is advantageous

if the material removal outlet is located in the return line of the mineral slag fraction. This allows a batch of material to be removed from the system after being separated off by the eddy-current separating device. The material removal outlet can be, for example, a reversing chute, a switching valve, or a hinged box with two outlets.

[18] To improve the separation efficiency of the non-ferrous metals, one or a plurality of further eddy-current separating devices can be provided between the outlet for the mineral slag fraction and the return line. The separated off non-ferrous metals from the respective eddy-current separating devices are then combined.

[19] The eddy-current separating device and at least one further eddy-current separating device preferably include an eddy-current separator. There are various types of eddy-current separators. The basic variations relate primarily to the eccentric or concentric magnetic drum, the number of magnets inside the magnetic drum, the working width, and whether the separation peak, which separates the non-ferrous metals from the mineral slag fraction, is adjustable. Additionally, the settings of the eddy-current separator also have an influence on the separating efficiency of the non-ferrous metals. The throughput amount of the incoming slag, the speed of the conveyor belt in the eddy-current separator, the separation peak position and the rotational speed of the rotating magnetic drum can be adjusted. In an eddy-current separator with an eccentric magnetic drum, the position of the magnets within the drum can also be varied.

[20] The eddy-current separator method is based on the repulsive property caused by the electrical conductivity of individual particles, which is induced by a variable magnetic field of the eddy-current separator. The electrical conductivity of the particles is crucial for the strength of the particle repulsion. However, the successful separation of non-ferrous metals in the slag industry depends on a complex interaction between electrical conductivity, density of the material, particle size and geometry of the individual particles.

[21] For example, aluminium particles, which have a low density and high electrical

conductivity, are strongly repelled and have a distinct trajectory, which makes separation easy. In contrast, lead has a high density and low electrical conductivity, which weakens the trajectory and makes separation difficult.

[22] Other factors also play a role. Flat particles can experience greater air resistance during their trajectory, which weakens the trajectory itself and makes separation more difficult. Small particles have a lower repulsion due to their size, which can also lead to a weakening of the trajectory and thus make successful separation more difficult. Even the orientation of the particles in space influences the separation when they enter the magnetic field.

[23] Therefore, the setting of an eddy-current separator is not determined by a calculation formula, but is based on empirical data. The choice of particle size range, which are led together through the same eddy-current separator, also determines the separation efficiency.

[24] The aim of an eddy-current separator is usually to separate all non-ferrous metals from a mineral slag fraction. This results in a compromise: separating more non-ferrous metals leads to an increased presence of mineral slag particles in the non-ferrous metal fraction. On the other hand, separating fewer non-ferrous metals means that there are fewer mineral particles in the non-ferrous metal fraction, but more non-ferrous metals remain in the mineral slag fraction. It should be noted that due to the highly heterogeneous properties of the non-ferrous metals to be separated, a single eddy-current separator is not sufficient to separate off all non-ferrous metal particles with high purity. To achieve a high separation efficiency of the non-ferrous metals, it is therefore advantageous to process the slag with a plurality of eddy-current separators in series. This is because non-ferrous metal particles that have an unfavourable arrangement in the first separating device and are not separated off may have a more favourable arrangement in a second or subsequent separating device and can therefore be successfully separated. Increasing the number of separating devices thus increases the probability that the non-ferrous metals are favourably positioned to be separated off in one of the separating devices.

[25] The number of loops to be completed before the material is conveyed out via the material removal outlet can be determined by means of two principles: through a predefined number of loops or through a fill level sensor in the first storage container. According to the second principle, a batch of material can be processed in the loop until the sensor signals that the first storage container with new slag has reached its maximum capacity. The sensor then signals that the batch in the loop must be conveyed out of the system so that a new batch of untreated slag can be conveyed into the loop. This leads to optimized utilization of the material-treatment installation. With fluctuating material inflow of untreated slag being conveyed into the first storage container, the closed loop process can be utilized to its maximum extent. Thus, different batches can be processed with a varying number of loops.

[26] It is advantageous if a feed silo and a vibratory conveyor are integrated into the closed-loop process upstream of the first eddy-current separating device. The feed silo and the subsequent vibratory conveyor enable a metered and constant conveyance of the material to the eddy-current separating device. Only one vibratory conveyor is integrated upstream of each further eddy-current separating device connected in series, in order to guarantee a constant conveyance.

[27] To further optimize the separation off of non-ferrous metals, it is advantageous to change the position of the separation peak of the eddy-current separator, which separates the non-ferrous metals from the mineral slag fraction, depending on the cycle. This is because the non-ferrous metal content in the mineral slag fraction decreases after each cycle, and thus the separation process of the non-ferrous metals from the mineral slag fraction behaves differently.

[28] In order to guarantee a high quality of the two main fractions, it is advantageous to provide a system downstream of the outlet of the eddy-current separating device for the non-ferrous metals, such as a switching valve, which can convey the separated-off non-ferrous metals into two different lines. The switching valve allows a separation peak position to be set in the final

cycle, which separates as many remaining non-ferrous metals as possible from the mineral slag aggregates. If a complete separation of the non-ferrous metals is to be achieved in the final cycle, a larger quantity of mineral slag particles in the separated-off non-ferrous metal fraction must be accepted as impurities in this cycle. To ensure that this separated quantity does not reduce the high quality of the previously separated non-ferrous metals, a third fraction can be generated by actuating the switching valve. This third fraction contains the separated-off non-ferrous metals from the final cycle, processed using the eddy-current separating device. This third fraction can be further separated off in addition to the non-ferrous metal fraction and the mineral slag fraction. In the case of a plurality of eddy-current separating devices connected in series, only the last eddy-current separating device connected in series has a switching valve for the separated-off non-ferrous metal fraction. The switching valve is integrated into the system before the merging of the separated-off non-ferrous metals from the eddy-current separating devices.

[29] It is also advantageous, if the previous processing system did not separate ferrous and magnetic particles, that this separation process is carried out within the described closed-loop system. The separation of the ferrous and magnetic materials must take place upstream of the eddy-current separating device. Ferrous and magnetic materials can negatively affect the process of separating non-ferrous metals and damage the magnetic drum in the eddy-current separating device. If the separation of ferrous materials for this material fraction has not yet taken place, it is advantageous to install a magnetic separator in the line between the outlet of the first storage container and upstream of the inlet of the feed silo. In this process, the ferrous and magnetic particles are separated off upstream of the eddy-current separating device.

[30] The lines between the two storage containers and the feed silo or magnetic separator usually consist of a combination of discharge units located immediately downstream of the storage containers, as well as vibratory conveying systems, conveyor belts or pipelines that

transport the slag to the feed silo or magnetic separator.

[31] In view of the overall system, there are substantially two products to be addressed: the mineral slag fraction, which is mostly in the loop, and the non-ferrous metals, such as aluminium, copper, silver, gold, lead, zinc, tin and palladium, which are separated off from the mineral slag fraction by the eddy-current separating device. The mineral slag fraction is the predominant fraction relative to its quantity.

[32] Advantageous embodiments are shown in the figures and are described in more detail below. Identical elements sometimes have the same reference numerals. Figures show the following:

- Figure 1 shows a flowchart of a simple device with a switching valve for the separated-off non-ferrous metal fraction from the last loop,
- Figure 2 shows a flowchart with an extension of a second eddy-current separating device,
- Figure 3 shows a flowchart as in Figure 2, which is extended with further eddy-current separating devices,
- Figure 4 shows an extended flowchart based on the flowchart shown in Figure 1 for a material-treatment installation,
- Figure 5 shows a flowchart as in Figure 1, which is extended with a magnetic separator.

[33] In the material-treatment installation 1 shown as a flowchart in Figure 1, slag 2 is conveyed into the first storage container 3. As soon as the first storage container 3 with slag 2 has reached its maximum capacity, the first cycle begins. The untreated slag 4 is conveyed via the outlet of the first storage container 5 via a line 6 from the first storage container 3 to the feed silo 7. The untreated slag 4 is conveyed from the feed silo 7 by a vibratory conveyor 8 towards the inlet 27 of the eddy-current separating device 9. In the eddy-current separating device 9, the untreated slag 4 is separated off for the first time. The eddy-current separating device 9 has an outlet 10 for the mineral slag fraction 11 and an outlet 12 for the non-ferrous metal fraction 13. The

mineral slag fraction 11 is conveyed by means of the primary return line 14 into a second storage container 15. During the separation of the untreated slag 4 with the eddy-current separating device 9, no mineral slag fraction 11 is conveyed from the second storage container 15 by means of the line 16 towards the feed silo 7. Once the entire material batch of untreated slag 4 has been conveyed from the first storage container 3, the conveyance of additional untreated slag 4 towards the feed silo 7 is stopped. Once the entire batch of untreated slag 4 from the first storage container 3 has been separated off using the eddy-current separating device 9, a new cycle begins. The mineral slag fraction 11 is conveyed from the second storage container 15 by means of outlet 29 and line 16 towards feed silo 7. Depending on the amount of slag 2 flowing into the first storage container 3, a certain number of cycles can be carried out via the eddy-current separating device 9. As soon as the first storage container 3 with new slag 2 reaches its maximum capacity, the mineral slag fraction 11, which is in the loop, is conveyed out of the system by means of the material removal outlet 17. Once the entire processed mineral slag fraction 11 has been removed from the loop via material removal outlet 17, new untreated slag 4 is conveyed from the first storage container 3 towards feed silo 7. Now a new batch begins with new untreated slag 4, which is separated using the eddy-current separating device 9. The conveyance from the two storage containers 3, 15, as well as the unloading of the mineral slag fraction 11 from the system are coordinated during operation. Additionally, this flowchart shows a switching valve 18 downstream of the outlet 12 for the non-ferrous metal fraction 13 of the eddy-current separating device 9. Before the final cycle of a batch starts, the switching valve 18 for the separated-off non-ferrous metal fraction 13 of the eddy-current separating device 9 can be switched to discharge this separated-off non-ferrous metal fraction 19 from the final cycle separately.

[34] The material-treatment installation shown in Figure 2 as a flowchart shows an extension by an additional vibratory conveyor 31 and an additional eddy-current separating device 20

downstream of the outlet 10, which separates the mineral slag fraction 11 again with an eddy-current separating device 20 from additional non-ferrous metals 13 before the mineral slag fraction 11 is then conveyed by means of the primary return line 14 into the second storage container 15. The separated-off non-ferrous metal fractions 13 from the two eddy-current separating devices 9, 20 are combined after separation. Additionally, this flowchart shows a switching valve 18 downstream of the outlet 12 for the non-ferrous metal fraction 13 of the eddy-current separating device 20. Before the final cycle of a batch starts, the switching valve 18 for the separated-off non-ferrous metals 13 of the eddy-current separating device 20 can be switched to discharge this separated-off non-ferrous metal fraction 19 from the final cycle separately.

[35] In the flowchart shown in Figure 3, the installation shown in Figure 2 is extended with further vibratory conveyors 32, 33 and eddy-current separating devices 21, 22. For this purpose, downstream of the outlet 10 for the mineral slag fraction 11, the installation has a plurality of further vibratory conveyors 32, 33 and further eddy-current separating devices 21, 22, which again separate the mineral slag fraction 11 from non-ferrous metals 13 before the mineral slag fraction 11 is then conveyed by means of the primary return line 14 into the second storage container 15. The separated-off non-ferrous metal fractions 13 of all eddy-current separating devices 9, 20, 21, 22 are combined after separation off. In this flowchart shown, the last eddy-current separating device 22 connected in series downstream of the outlet 12 for the non-ferrous metal fraction 13 has the switching valve 18.

[36] In a case where the desired number of loops for separating off the non-ferrous metals 13 from the untreated slag 4 or the mineral slag fraction 11 is not achieved, the material-treatment installation 1 can be extended as shown in Figure 4. By extending the installation shown in Figure 1 through an identical parallel system, the number of loops for the incoming slag 2 can be doubled. The slag 2 is split or halved before it reaches the first storage container 3. Part of

the slag 2 is conveyed into the first storage container 3 of the left system 23, the other part is conveyed into the first storage container 3 of the right system 24. The slag 2 is then separated off as illustrated in Figure 1.

[37] In a case where the ferrous and magnetic slag 25 has not yet been separated off upstream of the material-treatment installation 1, the material-treatment installation 1 can be extended with a magnetic separator 26. In the flowchart shown in Figure 5, the installation shown in Figure 1 is extended with a magnetic separator 26. The magnetic separator 26 is integrated into the line 6 between the outlet of the first storage container 5 and the feed silo 7. This produces the untreated slag 4, which is conveyed towards feed silo 7, and a ferrous and magnetic slag fraction 25, which is discharged from the system.

[38] In general, the material-treatment installation 1 has two strategies for increasing the separation-off efficiency of the non-ferrous metals. Either the material-treatment installation is extended as shown in Figures 2 and 3 with one or a plurality of additional eddy-current separating devices 20, 21, 22 connected in series. Or the amount of slag 2 is halved by an additional parallel system, as shown in Figure 4, in order to halve the filling rate of the first storage container 3. Thus, a slag batch in the loop has twice as much time and can therefore double the number of cycles. These two strategies can also be combined.

List of reference numerals:

1	material-treatment installation
2	slag
3	first storage container
4	untreated slag
5	outlet of the first storage container
6	line from the first storage container to the feed silo
7	feed silo
8	vibratory conveyor
9	eddy-current separating device
10	outlet for a mineral slag fraction
11	mineral slag fraction
12	outlet for a separated-off non-ferrous metal fraction
13	non-ferrous metal fraction
14	primary return line
15	second storage container
16	line from the second storage container to the feed silo
17	material remove outlet

18	switching valve
19	non-ferrous metal fraction from the final cycle
20	further eddy-current separating device
21	further eddy-current separating devices
22	further eddy-current separating devices
23	left system
24	right system
25	ferrous and magnetic slag
26	magnetic separator
27	inlet of the eddy-current separating device
28	inlet to vibratory conveyor
29	outlet of the second storage container
30	mineral slag discharged from the system
31	further vibratory conveyor
32	further vibratory conveyors
33	further vibratory conveyors

Claims

1. Material-treatment installation (1) for separating non-ferrous metals (13) from slag (2) with an eddy-current separating device (9),
 - which has an inlet (27) for untreated slag (4) or a mineral slag fraction (11),
 - an outlet (10) for a mineral slag fraction (11) and
 - an outlet (12) for a separated-off non-ferrous metal fraction (13),

characterized in that

 - a first storage container (3) is provided upstream of the inlet (27) for untreated slag (4)
 - with an outlet (5) for untreated slag (4) from the first storage container (3),
 - a line (6) from the outlet (5) to the inlet (27) of the eddy-current separating device (9) and
 - a primary return line (14) from the outlet (10) for the mineral slag fraction (11) to a second storage container (15),
 - which has an outlet (29) and a line (16) from the outlet (29) to the inlet (27) of the eddy-current separating device (9).
2. Material-treatment installation according to one of the preceding claims, *characterized in that* a material removal outlet (17) for the mineral slag fraction (11) is provided in the primary return line (14) upstream of the second storage container (15).
3. Material-treatment installation according to one of the preceding claims, *characterized in that* a vibratory conveyor (8) is provided upstream of the inlet (27) of the eddy-current separating device (9).
4. Material-treatment installation according to one of the preceding claims, *characterized in that* a feed silo (7) is provided upstream of an inlet (28) of the vibratory conveyor (8).

5. Material-treatment installation according to one of claims 2 to 4, *characterized in that* a further vibratory conveyor (31) and subsequently a further eddy-current separating device (20) are provided between the outlet (10) for the mineral slag fraction (11) and the material removal outlet (17).
6. Material-treatment installation according to one of claims 2 to 4, *characterized in that* a plurality of further vibratory conveyors (32, 33) and further eddy-current separating devices (21, 22) are provided between the outlet (10) for the mineral slag fraction (11) and the material removal outlet (17).
7. Material-treatment installation according to one of claims 4 to 6, *characterized in that* a magnetic separator (26) is provided between the outlet (5) for the untreated slag (4) and the inlet of the feed silo (7).
8. Material-treatment installation according to one of the preceding claims, *characterized in that* a switching valve (18) is provided downstream of the outlet (12) for the separated-off non-ferrous metal fraction (13).
9. Method for the use of a material-treatment installation (1) according to one of the preceding claims, *characterized in that* the material is treated in a batch process and the slag (2) is fed to the eddy-current separating device (9) at least twice.
10. Method according to claim 9, *characterized in that* during the treatment of the untreated slag (4) the slag (2), from which no non-ferrous metals (13) have yet been separated off, is stored in the first storage container (3).
11. Method according to one of claims 9 or 10, *characterized in that* a batch of untreated slag (4) is removed from the loop after a certain number of cycles in the material-treatment installation (1) and then a new batch of slag (2) is fed from the first storage container (3) to the feed silo (7) via the outlet (5).
12. Method according to one of claims 9 to 11, *characterized in that* a material batch is

conveyed in the loop system until the inflowing slag (2) has reached a predefined fill level of the first storage container (3).

13. Method according to one of claims 9 to 11, *characterized in that* depending on the amount of inflowing slag (2) in the first storage container (3) per unit of time, the number of cycles of the respective slag batch in the material-treatment installation (1) can be varied.
14. Method according to claims 9 to 13, *characterized in that* the peak position of the eddy-current separating device (9) for the separation of the non-ferrous metal fraction (13) is changed after at least one and preferably after each cycle.
15. Method according to one of claims 9 to 14, *characterized in that* the slag originates from a waste incineration installation and has a moisture content of less than 5 wt% by weight.
16. Method according to one of claims 9 to 18, *characterized in that* the slag fractions to be processed have particle sizes smaller than 100 mm.
17. Use of the material-treatment installation (1) according to one of claims 1 to 8 for the treatment of bottom ash from a waste incineration installation.