No. 12.0

Briquetting of Metallurgical Residues to be Returned to the Material Cycle

Dr.-Ing. Ulrich Hirsch
Maschinenfabrik Köppern GmbH & Co. KG

1. Introduction

Metallurgical processes frequently produce substances that due to their degree of fineness are unsuited for further use. Using such materials for landfilling or similar purposes often is not economical and/or made difficult as a result of statutory provisions. Using roller presses for briquetting or compaction processes enables a product of defined size to be obtained so that its inherent resources can be further utilized.
Via a feeder system the material to be briquetted is introduced into the space above two counter rotating rollers. When passing through the roller gap the material is compacted and formed into product. Two processes are described here: Briquetting and compaction. Both methods aim at yielding a product of defined shape and size. By the briquetting process agglomerates of uniform shape are produced in cavity-sunk congruent moulds, examples of such products are egg-shaped coal briquettes and HBI. The process may also be employed for crushing purposes, an application which shall not be discussed here in more detail. Fig. 1 shows various products of the different applications.
For compaction work either smooth or - to improve material intake properties - profiled pressing tools are used. A strip of uniform material thickness is thus generated - the so-called sheet - which may subsequently be crushed to attain the desired final grain size. Fields of use include the compacting granulation of fertilizers or the production of sheets made of aluminum chips.

Fig. 1: Roller press application fields

2. Fundamentals of the Briquetting Process

Roller press technology is more than 150 years old now. The simple still highly effective underlying operating principle has not changed. Nevertheless, innovative development has taken place in machinery and process technology, in finding new applications and making use of new materials. Fig. 2 gives an overview of various fields of use in metallurgy.

2.1. Mechanical Equipment

A roller press consists of the following main assemblies

- Press frame
- Floating and fixed rollers
- Main drive
- Material feeder equipment
- Hydraulic pressurizing system

In Fig. 3 a roller press with standard frame and double output shaft drive system is compared to a press comprising a hinged frame and planetary gear units. The press frame accommodates the floating and fixed rollers as well as hydraulic equipment and housing. Applying the hinged frame design the head ends can be hinged down so that the rollers can be removed from the front. Standard press types are of simplified design and provided with a hinged frame top part.

Aluminum dust and chips	Iron oxide	Steel mill dusts
Brass dust and chips	Lead oxide	Concentrated tin
Chromium ore	Mill scale	Waelz oxide
Coke/petroleum coke	Molybdenum oxide	Zinc oxide
Electrode material	Nickel ore	Sponge iron, hot/cold
Converter dust, cold/hot	Nickel powder	Copper concentrate

Fig. 2: Various metallurgical materials processed by roller presses

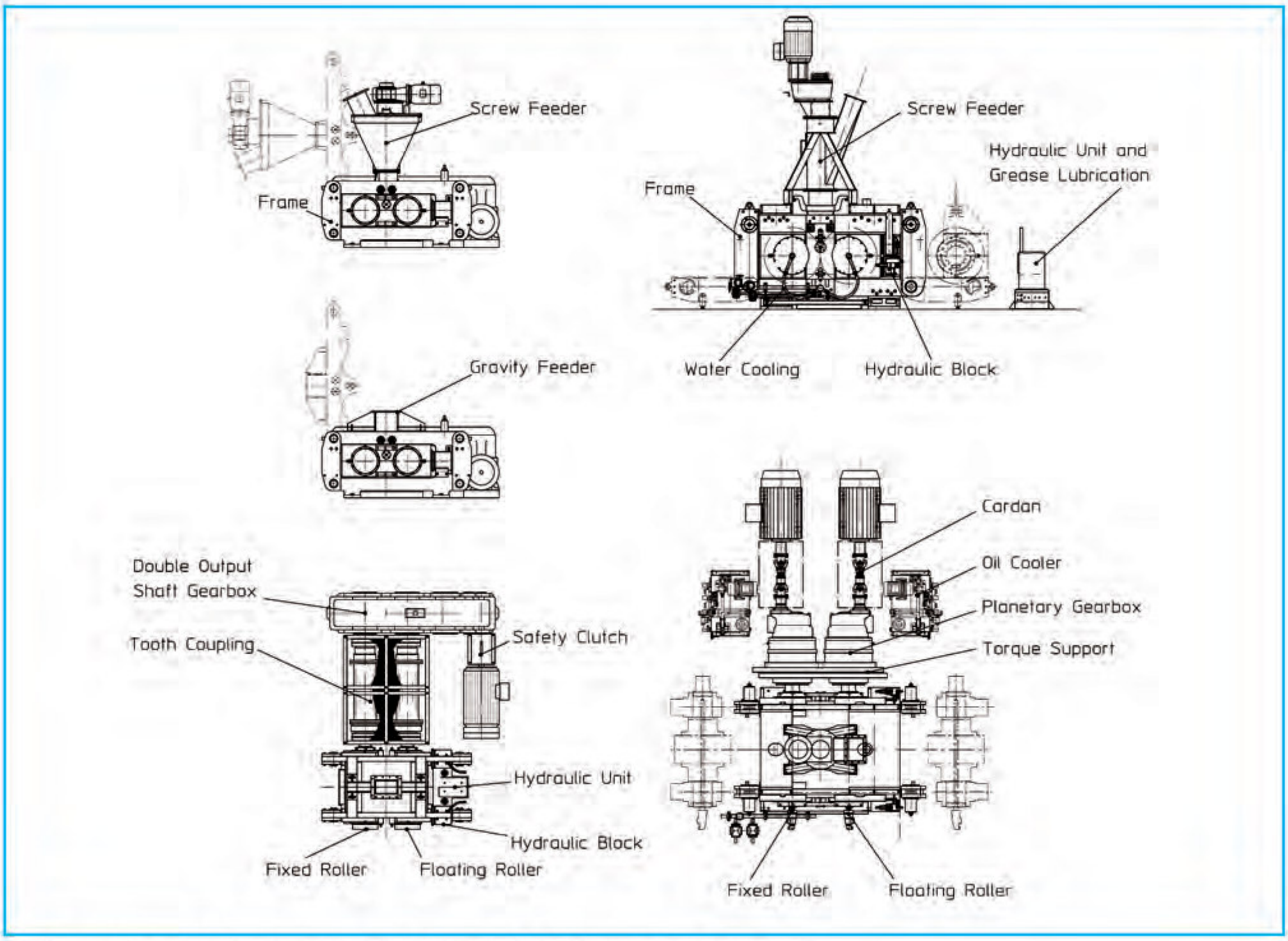

Fig. 3 Left-hand - Roller press with standard frame and double output shaft drive system
Right-hand - Roller press comprising a hinged frame and planetary gear units.

The rollers carrying the pressing tools may be of solid construction, or fitted with tires or segments (refer to Fig. 4). The surface is designed to meet specific requirements and suited for the feed to be processed. Briquetting moulds of different shape and size can be provided as well as smooth or profiled surfaces for compaction and comminution purposes. Various technical solutions are available adapted to the respective feed and equipment type. In the interest of maximum service life and minimum expense the materials used must be sufficiently wear resistant. Solutions in this respect are designed to meet the relevant application needs. The materials and treatment methods applied here (hardening, tempering etc.) are tailored to the needs of customers.

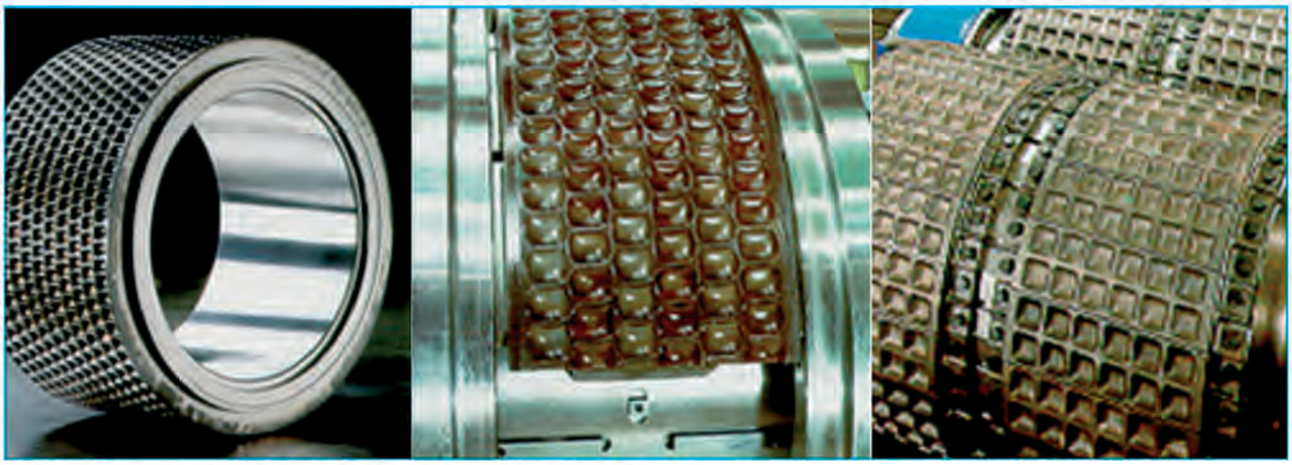

Fig. 4 Various press tools (from left): Tire, segments, strip segments

The main drive in conjunction with the hydraulic pressurizing system enables the operation of floating rollers and the use of rollers having different diameters. The pressing tools can be refurbished and then put to use again. Briquetting requires the moulds to be synchronized so that a double output shaft driver with tooth couplings is used for this purpose. For compaction and crushing applications the rollers are powered individually via planetary gear units.

Feed is introduced to the plant either via a screwfeeder or gravity-type feeder. Which is to be used depends on the flow and mould-filling characteristics.

Roller press categories are based on the relevant bearing size. The smallest type features a total pressing force of 400 kN, while the largest press manufactured so far has a pressing force of 19,100 kN. Equipment weights vary between 2 and 400 tons. Governing factors that determine machine type selection are attainable peripheral speed, specific pressing force requirements, and mould size. Moreover, the design of pressing tools and material feeders are also important selection criteria.

2.2. Binders

A number of substances can be converted into product of adequate strength without having to add a binding agent. Such materials include burnt lime, salts, sponge iron and magnesite. Bonding in this case is achieved as a result of quite different phenomena:

- *Van-der-Waals forces,*
- *mechanical linkage,*
- *forging,*
- *plasticization under pressure.*

According to Reichmann /1/ binders are categorized into seven groups:

- *Thermoplastic binders (e.g. pitch, bitumen, plastics, waxes, resins)*
  Typical example is hard coal briquetting using pitch or bitumen. Raising the temperature of the material to be pressed and the binder causes the binder's viscosity to be lowered to the extent that each individual particle of the briquetting material is duly coated with binder. After the material has cooled down strong, tenacious links will form.
- *Mortar binders (e.g. lime mortar (set with or without CO_2), gypsum, cement)*
  As a result of a chemical reaction crystals form that attach to the surface of the briquetting material. Disadvantageous in this context is that green strength properties are poor and relatively high binder volumes are needed. Using (hydrated) lime post-cured in a CO_2 containing atmosphere is certainly of interest provided the briquetting material has a certain lime content (steel mill residues).
- *Glucosidic binders with water (e.g. starch, molasses, lignosulfonate)*
  Molasses in combination with hydrated lime probably is the most commonly employed binder. Calcium saccharates will form under pressure yielding excellent green strength properties. Mortar forming through CO_2 will then improve the setting behaviour.
- *Non-glucosidic organic solutions (e.g. bakelite, polymers)*
- *Inorganic solutions (e.g. water glass, phosphoric acid)*
- *Clayey binders (e.g. bentonite)*
- *Fibrous binders (e.g. cellulose fibers, paper fluff)*

2.3. Equipment Design and Process Technology

The feed used is more or less of natural origin which means significant physical property fluctuations may be encountered even if similar materials are involved (e.g. as determined by chemical analysis). Initial tentative trials can be conducted with small volumes and using a piston-type press. Suitable binder combinations can be examined and pressing force requirements determined in this manner. Basically, it is recommendable that the design of the equipment and pertinent plant be verified by conducting trials on roller presses.

A pilot plant on a semi-commercial scale is available (see Fig. 5). Aside from two roller presses having roller diameters of 1000 mm and 650 mm there are also mixers, crushers, screens and further peripheral devices that enable various processes to be simulated.

Hot briquetting tests of up to approx. 850 °C can be carried out as well.

Fig. 5 Köppern pilot plant. Roller press of size 52/10 (left), press 52/6,5 (right)

All such trials aim at

- optimizing feed characteristics (blend, binder, moisture, recycle etc.)
- determining briquetting parameters such as torque, pressing force, speed
- selecting the suitable feeder equipment
- determining product parameters such as output, density, strength properties
- examining recycling potentials
- selecting additional equipment (e.g. crushers, screens)

In terms of diameter the existing roller presses reflect average supply range equipment so that a design based on trials can be safely and risklessly implemented when systems have to be scaled up or down.
Likewise, process technological fundamentals can be determined for the planned briquetting systems. Moreover, material flow data are determined and ancillary equipment units selected, for example mixers, screens or crushers. Fig. 6 shows a detailed process flow diagram established on the basis of comprehensive trials; Fig. 7 is a display screen of the plant control system.

3. Application Examples

Using roller presses for the treatment of residues is explained below by way of examples. A comprehensive discussion would doubtlessly go beyond the scope of this paper all the more so because fluctuations are constantly experienced in this field with new applications emerging ever so often. Fig. 8 indicates the pressing forces needed for various roller press applications. They range from abt. 25 kN/cm for the briquetting of steel mill residues with binder to 140 kN/cm for aluminum. The pressing force to be exerted for a given material rises as a function of the roller diameter and mould size.

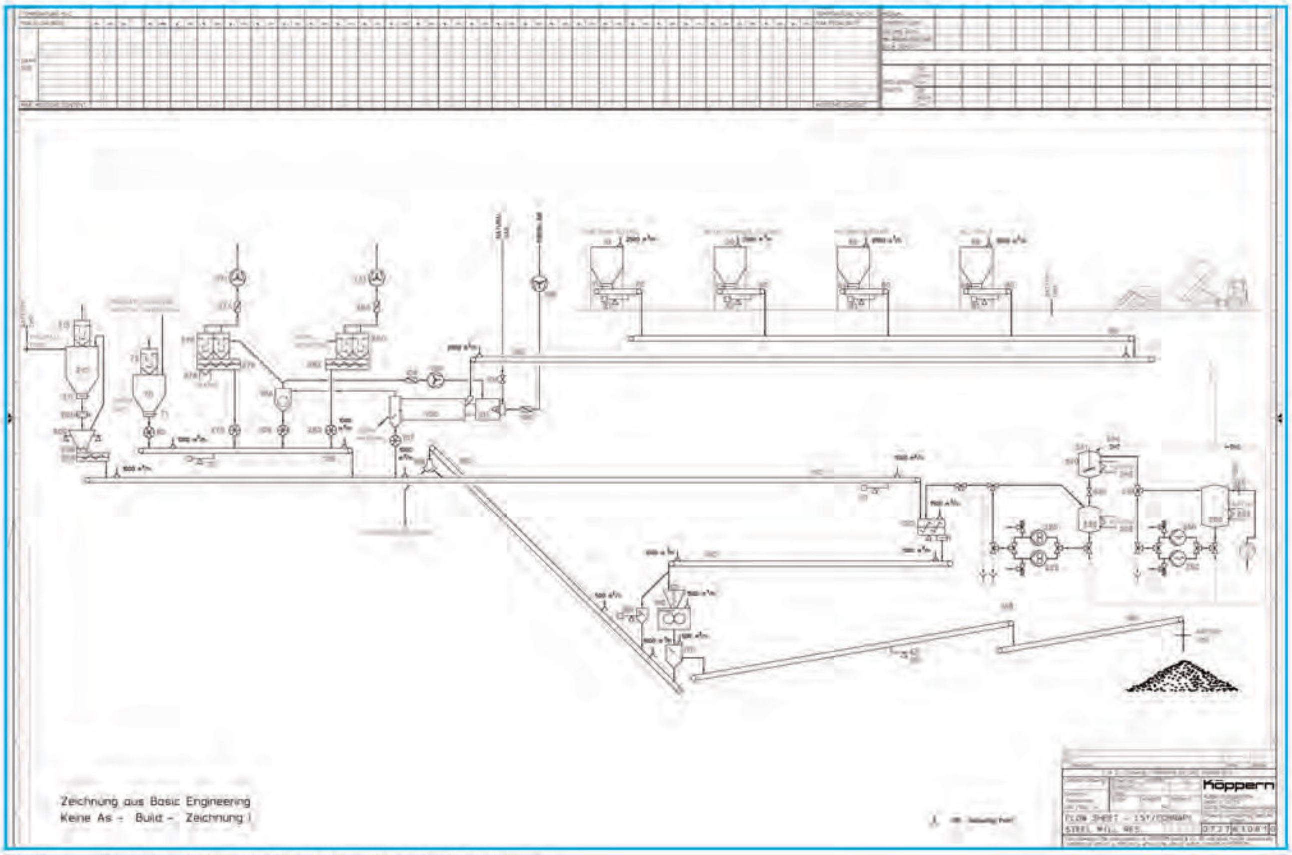

Fig.6 Flowsheet showing the briquetting of mill residues

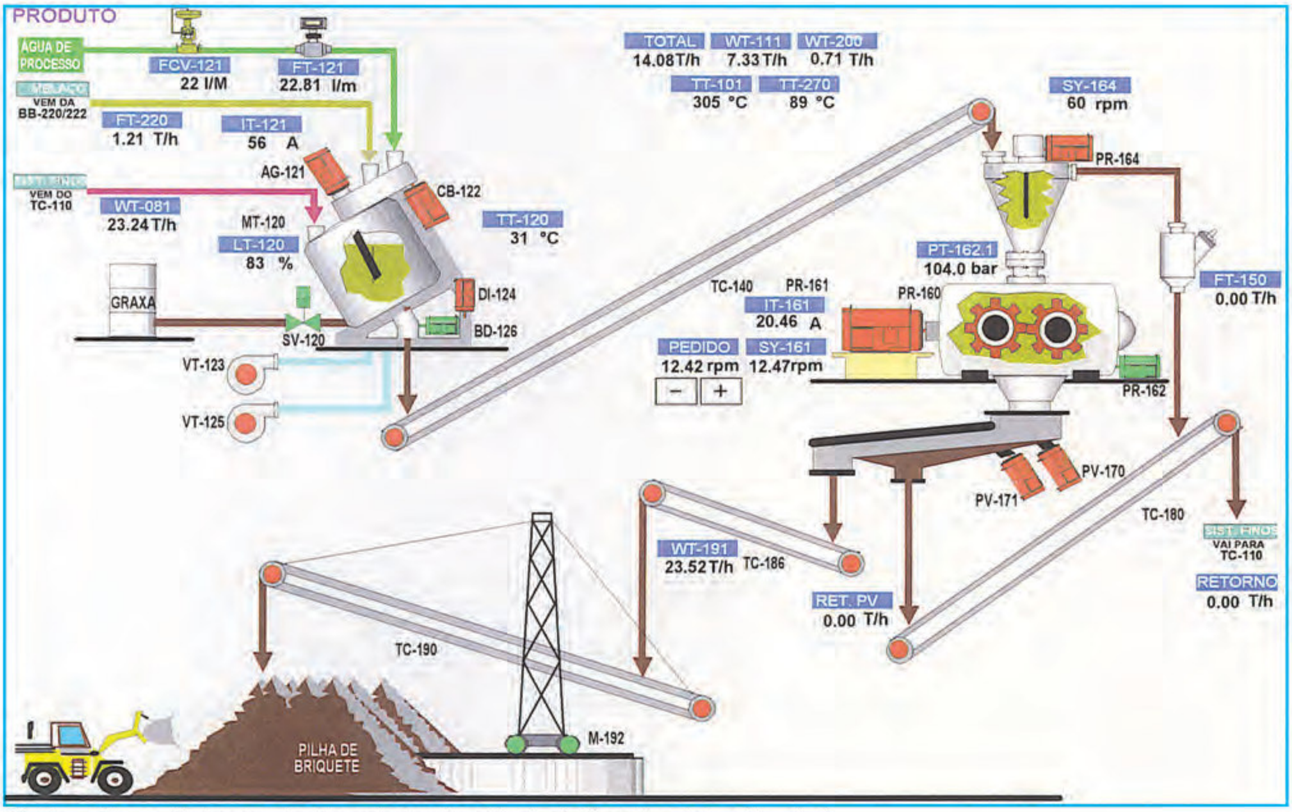

Fig. 7 Screen display showing the control system of a steel mill residues briquetting plant

3.1. Steel Mill Residues

The range of residual substances found in steel mills is almost unimaginable and, moreover, they vary tremendously in terms of volume and composition. Briquetting allows a great variety of residues to be processed. There are limits with respect to the oil and water content and regarding downstream processes. It is basically possible to tailor a briquetting plant to the specific needs of the steel mill and still offer the capability of processing a broad feed range.

Basically, there are two processes that can be applied, i.e. the cold or hot briquetting process. In case the residual substance contains metallic iron this may be used as binder after having been heated to temperatures above 550 °C. Some references are available regarding the hot briquetting of converter dust obtained from dry dust separation. Such dust contains CaO in amounts of up to 30 %. Binders on water basis can only be applied if adequate provisions have been taken (increased expenditure) because slaking the lime will lead to undesirable and difficult to control reactions. Hot briquetting will leave the metallic iron and CaO contents unchanged which offers considerable benefits for the converter process.

"Wet" feed materials are fully oxidized and hydrated and may be briquetted with binders being used. The contents of oil (separating agent) and water (incompressible) must be limited. Admissible contents vary depending on size distribution and feed. Usually, molasses and hydrated lime are used as binding agent. These materials are readily available at reasonable prices. The dosing procedure is unproblematic. Moreover, this binder system tolerates feed fluctuations to some degree. A steel mill has provided briquetting capability of approx. 25 t/h for residual material to be fed to the blast furnace.

An important aspect is the service life of the briquetting tools. Steel mill residues may contain substances of highly abrasive nature (e.g. pig iron, iron oxide, quartz). Comprehensive experience backed by relevant basic investigations is available so that specific technical solutions can be offered to clients.

3.2. Grindings

The quantity, nature and composition of grindings to be handled vary greatly. Furthermore, there are chips of brass, bronze and copper stemming from drilling and milling operations. Generally speaking,

all these residues are suitable for a briquetting treatment after drying and/or deoiling, either with or without a binder depending on the respective material. The challenge in this case is a logistic one. Compared to the throughput capacity of a roller press the volumes arising here are rather marginal. Major manufacturers may produce quantities in the range of 500 t/a. Moreover, producers are scattered across the whole country.
The briquetting plant must be capable of processing a broad range of materials. Since storage, preparation, binder dosing etc. require a certain expenditure in terms of equipment a through-put of 5-10 t/h is needed from an economical viewpoint. On the other hand, the relatively constant costs incurred are to be seen in comparison to variable earnings that can be expected through receipts from taking on the material for processing and from selling the resulting metal products and recovered cooling lubricants. By skillfully selecting the chips and grindings accepted for processing there will be a certain margin.

3.3. DRI Fines

Fines ranging between 6 and 30 % will arise when iron ore is directly reduced in a shaft furnace. Feeding these fines to an electric arc furnace is not always feasible so that they have to be briquetted using a binding agent. Usually, the binding system employed for this purpose is water glass with hydrated lime. Alternatives (sulfite lye, molasses) of equivalent quality are available.
For the cold briquetting of sponge iron specific pressing forces in the range of between 100 and 120 kN/cm are required, with similar forces to be applied during the hot briquetting process (HBI). Cold briquetting combines the "forging" phenomenon known from hot briquetting in the absence of a binding agent with the "glueing" action taking place during cold briquetting. The product density is around 4 g/cm^3 with typical tonnages ranging between 20 and 40 tons per hour /2/, /3/.

3.4. Reduction in the Rotary Hearth Furnace

One of the mill residues recovery variants frequently discussed in recent times is to reduce the material via the rotary hearth furnace. The original approach involves the reduction of iron ore with coal. This process is capable of generating metallic iron by separating volatile constituents such as zinc and lead so that it is considered beneficial to make use of residual

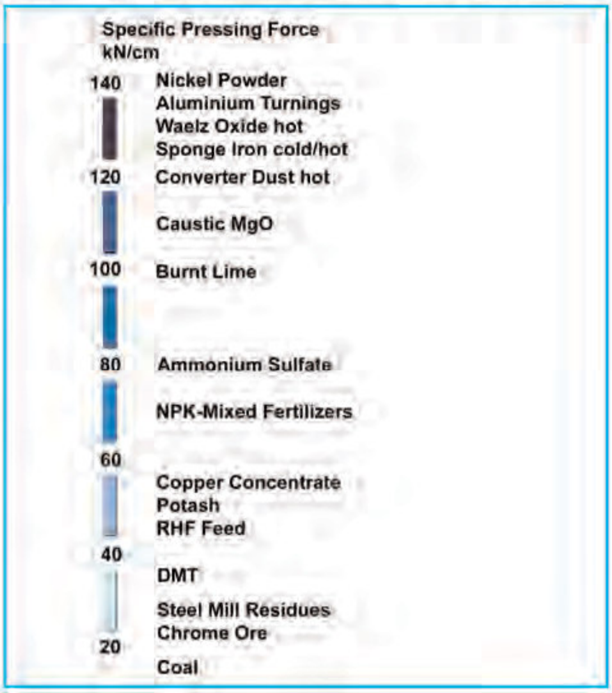

Fig. 8 Pressing force requirements for various applications

materials. Size-enlarged material is needed for the rotary hearth. Using a pelletizing system means that certain granulometric requirements must be met that limit the feed selection. Plant owners have substituted the pelletizing by a briquetting operation because handling the green pellets and distributing them on the hearth could not be solved satisfactorily.
Producing briquettes with binders out of the feed employed here does not present problems. What is challenging in this context is that high-temperature resistant reducible briquettes must be produced with the amount of binding agents to be kept to a minimum. This objective was achieved based on extensive basic investigations including verification on an industrial scale. Meanwhile, the plant has been taken into operation and performs to the satisfaction of the client. The output from the rotary hearth is subjected to hot briquetting with a view to increasing the density to around 4.5 g/cm^3 and improving size enlargement in an endeavor to optimize the melting operation. Such briquettes may also be sold to satisfy scrap replacement needs.

3.5. Aluminum Chips

Aluminum chips, foil remnants or treated beverage cans generally have a low bulk density (about 0.25 kg/l) so that they are less suited for direct feeding into the melting process. Moreover, fed-in volumes are low and losses due to oxidation are to be expected.

As needed by the residue type a pretreatment such as crushing, deoiling, drying is carried out. These residues are coarsely grained as a rule. Briquetting this material would produce briquettes quite firmly joined which would make it impossible to separate them. The compaction process yields an endless strip of material cut into pieces of defined length. The density of the sheet ranges between 2.3 and 2.5 g/cm³. Fig. 9 shows granulated aluminum foil and a sheet produced from it. The specific pressing force required is between 120 and 140 kN/cm. The high compression ratio makes it necessary to include a screwfeeder in the press design. The capacity of equipment built so far ranges between 2.75 and 4 t/h.

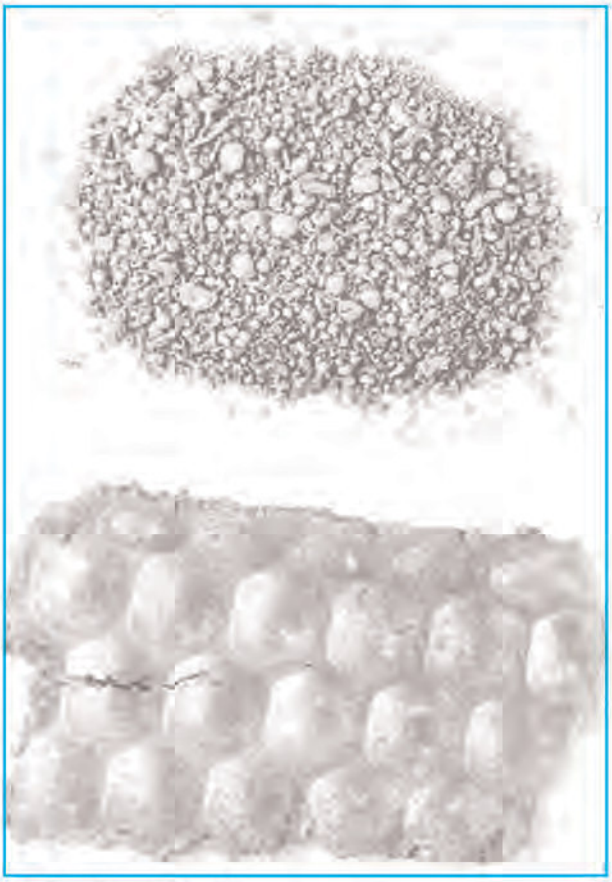

Fig. 9 Compaction of aluminum

4. Summary

The use of roller presses returning residual material into the production cycle has been discussed by way of practical examples. It appears that a wide range of materials can be processed. The technology described here has a long tradition in this field and has proven its worth many times. The design of machinery and equipment is highly flexible and can be tailored to the specific requirements of customers. Know-how, systems and equipment needed for the investigation and development of machinery, processes and tools are available. New fields of application open up again and again as a result of continuing development work performed in close cooperation with customers.

5. Literature

/1/ Reichmann, F.: "Bindemittel und ihre typischen Verwendungen", interne Köppern-Schrift

/2/ Rieschel, H. Dr.: "Gegenwärtiger Stand der Eisenschwammbrikettierung unter Berücksichtigung der Bindemittelauswahl", Stahl und Eisen, Heft 24, 1980

/3/ Rieschel, H. Dr.: "Über die Brikettierung von Eisenschwamm", Fachberichte Hüttenpraxis, Heft 12, 1977

Maschinenfabrik KÖPPERN
GmbH & Co. KG
Königsteiner Str. 2
45529 Hattingen
fon +49 (2324) 207-0
fax +49 (2324) 207-207
mail: info@koeppern.de
www.koeppern.de

02/2015