Main Types of the Briquetting Technologies in Ferrous Metallurgy

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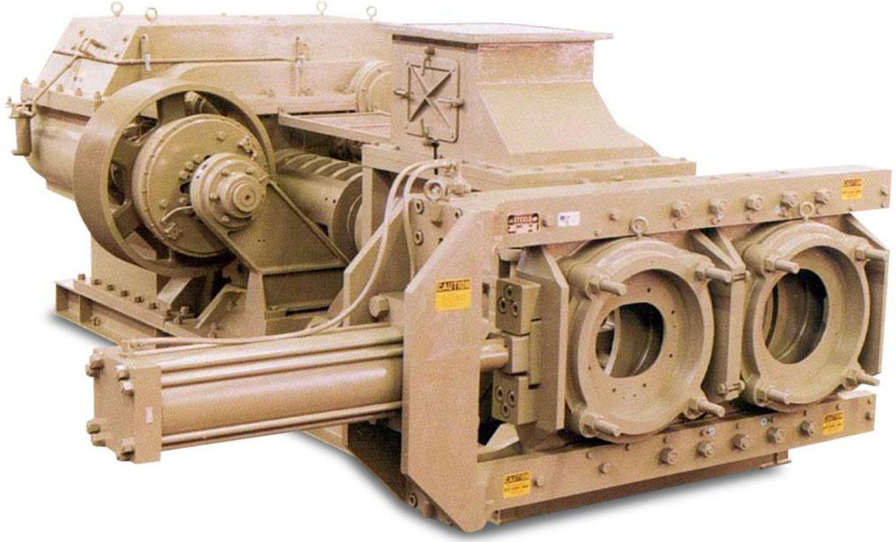
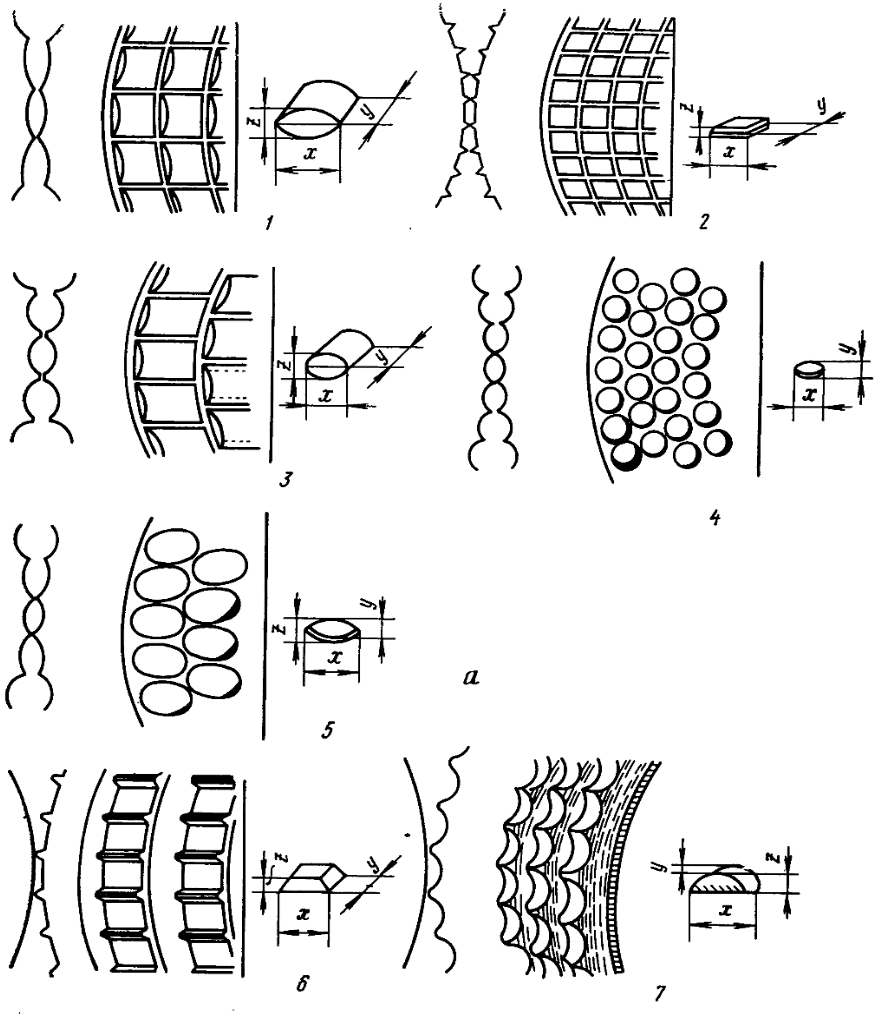


Roller-Press Briquetting

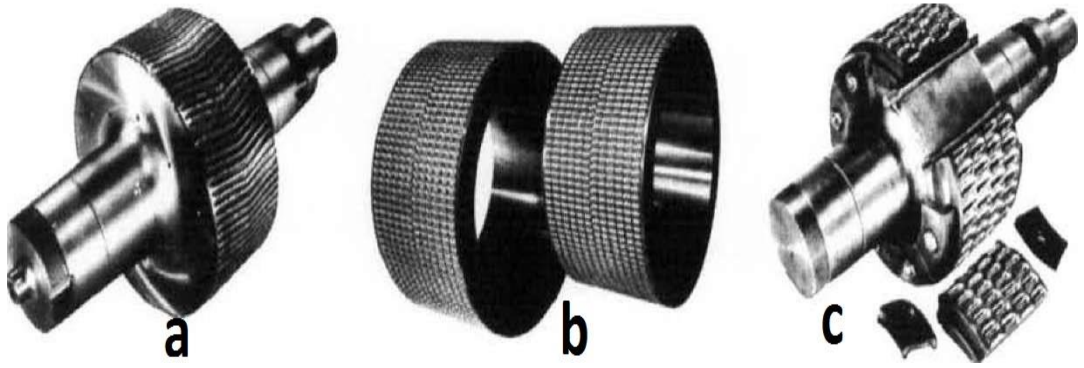
- The principle of operation of such presses is that the briquetted mixture is fed into the gap between two rolls rotating towards each other, on the surface of which symmetrically located cells in the form of semi-briquettes are arranged in a checkerboard pattern.
- During the rotation of the rolls, there is a convergence of cells, the capture of the material and its sealing compression.
- The briquetted material is subjected to bilateral compression, which contributes to a more uniform distribution of its density by volume.
- Then, as the rolls rotate, the cells diverge, and the briquette drops out of the cell under its own gravity.

Roller-Press Briquetting



Different types of cells of the roller press sleeves

The shape and size of the roller briquettes, determined by the geometry of the cells of the sleeves, are important for the processes of storage, transportation and subsequent metallurgical processing.



Designs of rolls of roller presses: a - one-piece solid roll; b - sleeve rings; c – segmented roll.

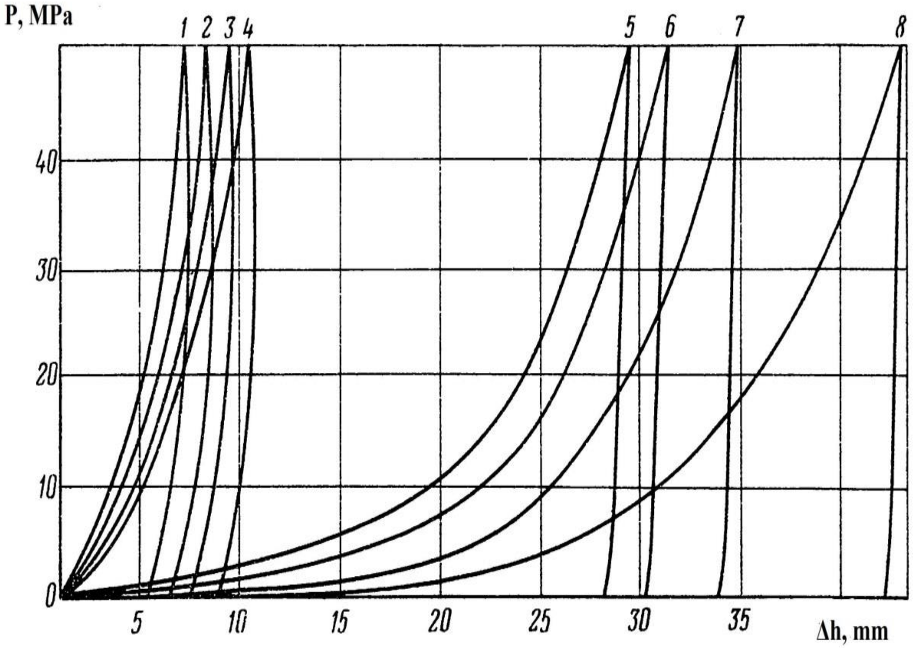
Roller-Press Briquetting

- The processes occurring in the briquetted mass in a roller press can, to a certain degree, be described by methods of the general pressing theory.
- The compaction process can be divided into three stages.
  - The first stage is the reorientation of particles without changing their shape and size.
  - In the second stage, the deformation of the soft and the destruction of brittle particles of material take place.
  - At the last stage, plastic changes in the structure of the material occur, and its compaction occurs.
- The strength of briquettes produced in this way depends on several factors:
  - the particle size and component composition of the briquetted material,
  - the magnitude of the applied pressing force;
  - the moisture of the charge;
  - the duration of the pressing process;
  - the shape and size of the cells of the sleeves and friction coefficients.

Roller-Press Briquetting

- The factor limiting the effectiveness of compaction is the presence of air, which is **"trapped"** inside the material during compression and is released after the external pressure ceases.
- The amount of pressed air can be **30-70%** of the initial volume of air in the material. To avoid this phenomenon, it is necessary to ensure maximum **removal of air from** the briquetted mixture.
- Air removal can be facilitated by a reduction in the rate of material compression itself, facilitating the release of air from a decreasing pore space.
- During **vibropressing and in stiff vacuum extrusion** the removal of air from the briquetted mass is an important component of the technology and is achieved by displacing the air as a result of high-frequency vibrations in the vibropress and the complete removal of air from the stiff extruder's working chamber.
- The maximum particle size for roller briquetting usually does not exceed **5-6 m**m.
- Multi-fractionality is a factor favoring briquetting efficiency, since in this case the space between large particles is filled with smaller particles, which contributes to the displacement of air from the material.

Roller-Press Briquetting

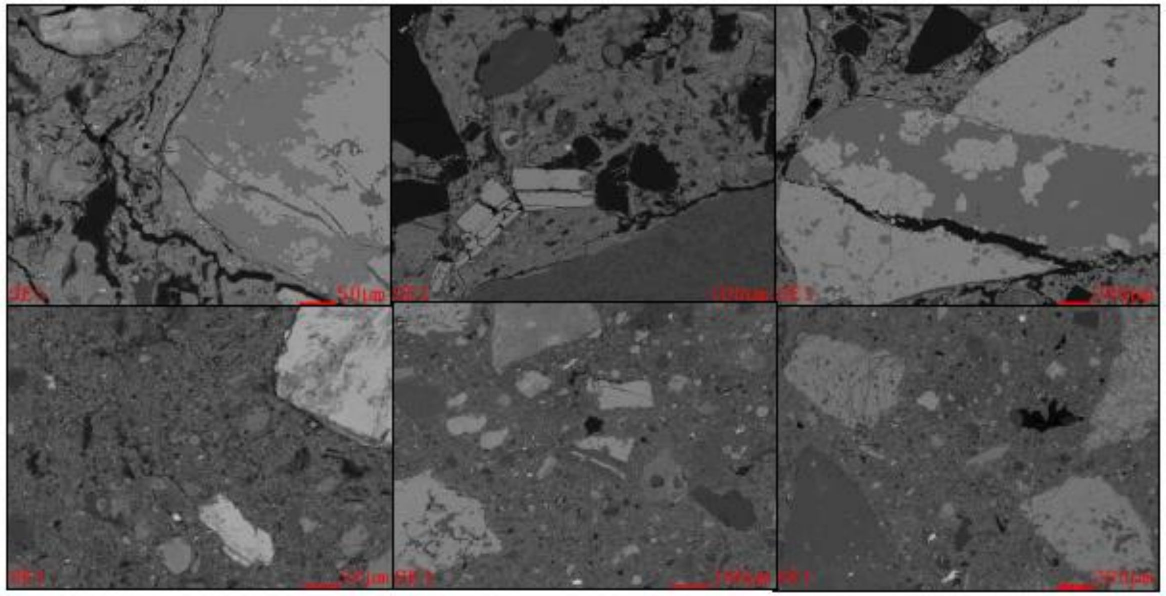


The degree of compaction of the mixture with coal and peat components depending on the compression load (1-4 - manganese ore fines and coal in proportions of 70:30, 60:40, 50:50 and 40:40 respectively; 5-8 - manganese ore fines and peat in proportions of 70:30, 60:40, 50:50, and 40:40, respectively

When briquetting multicomponent mixtures, one should also consider the difference in the manifestation of the elastic-plastic properties of the individual components, leading to a significant difference in the degrees of compaction. Figure illustrates the degree of compaction of roll briquettes based on manganese ore fines with the addition of various carbon-containing materials (coal or peat). It is seen how significantly the degree of compaction of the mixture varies depending on the physical-mechanical properties of the components of the mixture.

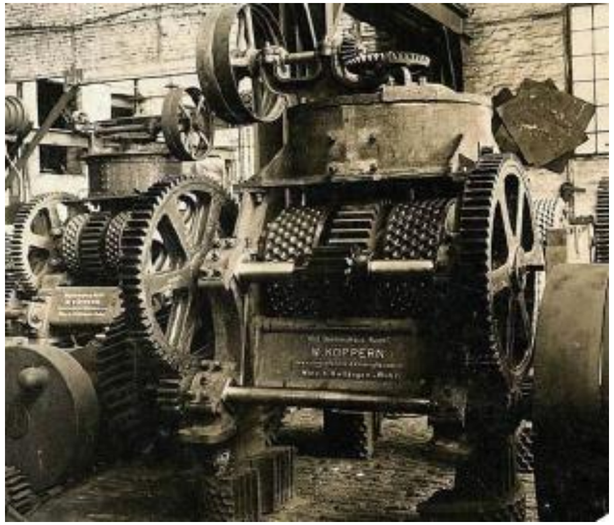
Roller-Press Briquetting

- The structure of the material pressed in the rollers undergoes changes due to elastic and irreversible deformation, destruction of the particles of the pressed material and the formation of cracks in it (at pressures above 10 MPa).
- Figure shows the structure of a **roller-pressed briquette** (manganese ore fines -47.6%, dust of the gas cleaning system - 38.1%, coal - 9.5% and lignosulfonate as a binder – 4.8%) in comparison with the structure of **extrusion briquette** (manganese ore fines -66 %, gas cleaning dust - 28%, cement -5% and bentonite -1%). As a result of high pressure (up to 100 MPa), the briquette structure is characterized by the presence of many large cracks and low porosity. The occurrence of such cracks may be due to elastic expansion after the finished briquette leaves the cells, which leads to a decrease in its strength.



Roller-Press Briquetting

- A feature of roller briquetting is the limitation on the **moisture content** of the charge material (not higher than **5-10%**).
- Roller presses in ferrous metallurgy allow briquetting a wide class of natural and anthropogenic materials with a range of bonding materials. However, restrictions on the moisture content of the briquetted charge create difficulties in using Portland cement, which has become widespread, as a binder. The required proportion of cement in the mass of the briquette can reach 8-12%, which is comparable with the content of this binder in the vibropressed briquettes, but two times higher than that required in stiff extrusion briquettes.
- The strength of the briquettes is significantly affected by the duration of the pressing process. For example, the duration of pressing for rolls with a **diameter of 1.1 m** at a frequency of rotation of **8-11** revolutions per minute is only **0.29-0.38** seconds. Exposure of the briquette under pressure allows not only more fully to force out the air from the narrowing pore space without the formation of pressed "air pockets", but also to reduce the amount of elastic deformations that can lead to its softening. The increase in pressing time is achieved by restrictions on the speed of rotation of the rolls. For iron ore briquettes, usually no more than **6-8** revolutions of rolls per minute are recommended



Roller-Press Briquetting. Main Producers. Köppern

- One of the largest manufacturers of roller presses used for briquetting natural and anthropogenic raw materials in the steel industry, is the company **Köppern**, which since **1950** supplied 450 roller presses for cold briquetting and 143 presses to produce hot briquetted iron. Figure shows one of the company's first roller presses, used in the **1920s** for coal briquetting and a modern briquette press.
- An important design feature of the company’s roller presses is that the gap between the rolls is controlled automatically by a hydraulic station depending on the requirements of a process, which ensures that the entire feed material passes through the gap between the rolls under the same process conditions.

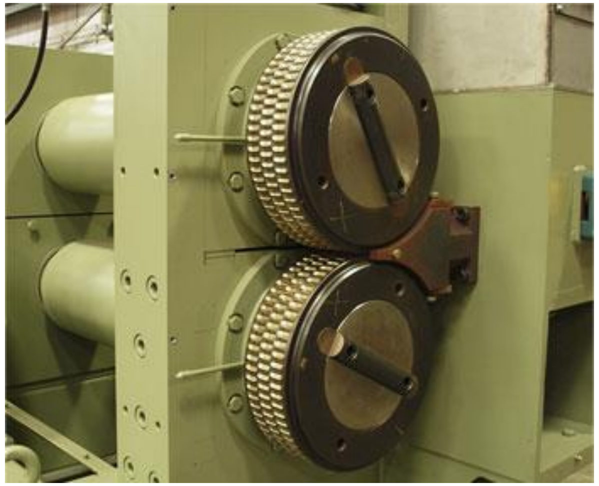
Roller-Press Briquetting. Main Producers. Köppern

- Köppern is also known for its work in improving durability of materials used in the construction of roller presses.
- Cells of sleeves for the formation of briquettes are manufactured by electrochemical processing technology (**ECM –Electro Chemical Machining**) since 1965. Electrochemical treatment consists in removing the metal from the surface of the workpiece by electrolytic dissolution to achieve the desired shape and size.
- Köppern has also developed the **HEXADUR® anti-wear system** - the patented technology to produce briquetting sleeves with high-wear-resistant metal-powder surface - **RESIDUR®**.
- The design of the rolls consists of two parts: the base (core) of the roll and the wear-resistant band fixed on the base by means of a shrink fit, which makes it possible to reuse the core of the roll at the end of the life of the band. Figure presents for comparison the degree of wear for the same time of operation of fragments of the regular sleeve and a sleeve made using the RESIDUR® technology.

Roller-Press Briquetting. Main Producers. Köppern

- The company's experience in briquetting hot plastic materials, high performance presses (up to 100 tons per hour), their reliability and high wear resistance of sleeves led to the fact that today Köppern is the world leader in hot briquetting technology.
- The Köppern roller briquetting technology allows to convert sponge iron directly after it exits the direct reduction reactor at a temperature of 750 ° C into a form that is more convenient for transportation and storage - into hot briquetted iron (**HBI**). Such pressing makes it possible to effectively prevent the occurrence of pyrophoric sponge iron during its transportation and storage, due to compaction and reduction of porosity.

Roller-Press Briquetting. Main Producers. Komarek.



- Komarek, a Köppern group of companies, is also the largest producer of roller briquetting presses.
- The company has been on the briquetting market for more than a century, starting, like Köppern, with coal briquetting.
- Since **1968**, the company has put on the market more than **600** presses for briquetting, pelletizing and compaction in more than 40 countries of the world.
- For the first time, Komarek began to use segment bandages with replaceable elements

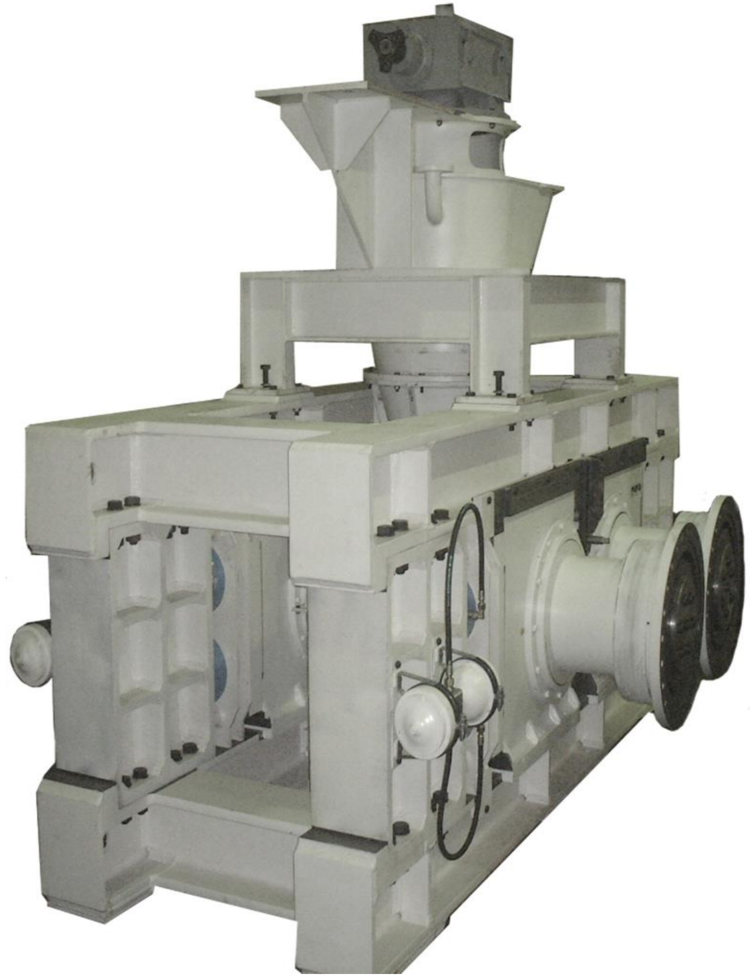
Roller-Press Briquetting. Main Producers. Komarek.

- The maximum capacity of Komarek presses is 54 tons of briquettes per hour (Model DH 500- 28x2). This model is designed for coal briquetting.

- For briquetting metal oxides, ore fines and sludges, press Komarek DH500 with a capacity of up to 45 tons per hour is used. The design features of this press consist in:
    - the use of continuous or segment bandages,
    - in the vertical flow of the charge by gravity or using a screw feeder,
    - in the vacuum deaeration of the fine powder components of the charge, which, as we noted above, is very important for roller briquetting,
    - the use of engines with the ability to control the speed of rotation of the rolls and the screw,
    - in the use of materials from resistant alloys, etc.

- Roll diameter 710 mm, roll width 229-508 mm, pressing force up to 3000 kN. The drive power of the rolls 200 kW, the drive feeder 22 kW. Press weight - up to 33 tons

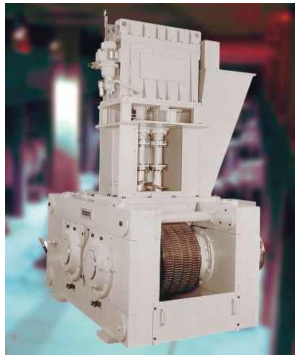
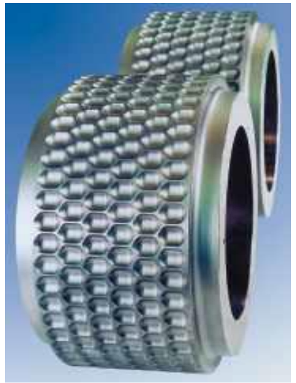
Roller-Press Briquetting. Main Producers. Euragglo.



- In 2001, Komarek acquired a controlling stake in EURAGGLO, which is currently the European division of Komarek.
- The maximum productivity of roller presses EURAGGLO reaches 65 tons per hour (model E92).
- The model is designed for briquetting at medium and high pressures. The pressing force - 4200 kN, roll diameter 1200 mm, width - 300-460 mm, roll power drive 500 kW.

Roller-Press Briquetting. Main Producers. Hosokawa-Bepex.

- Hosokawa-Bepex is one of the largest manufacturers of roller briquetting presses. For briquetting with the use of high pressure, roller presses of the MS series are used, suitable for processing also abrasive and hot materials.
- A special feature of the design of Hosokawa-Bepex presses is the possibility of their work in an inert gas atmosphere, as, for example, when working with materials that require the exclusion of contact with oxygen. In this case, the casing of the roller presses of the MS series are made in a gas-tight version.
- The surface of the rolls can be smooth, profiled or with grooves. For presses of the MS series there are rolls suitable for a variety of applications (segmented, for highly abrasive materials and high temperatures; with an external sleeves, for moderately abrasive materials and temperatures up to 450 ° C; solid rolls).
- The pressing force of presses of the MS series is in the range from **360 to 6000 kN**. Roll diameters - from 300 to 1100 mm.

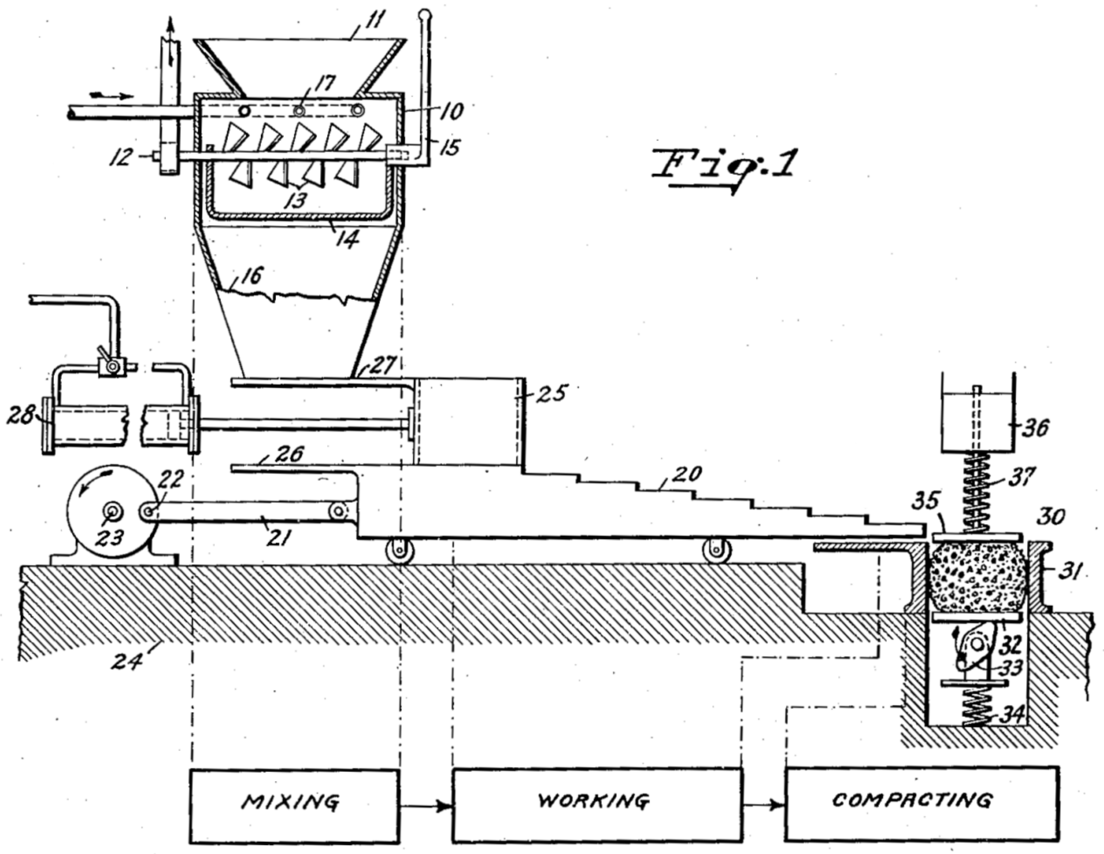



Roller-Press Briquetting. Main Producers. Sahut-Conreur.

- The largest French manufacturer of roller presses for briquetting coal and ore concentrates is Sahut-Conreur, one of the oldest briquette companies in the world.
- The roller presses of this company have been used for briquetting since **1860**.
- The performance of modern roller presses companies from 500 kg to 100 tons of briquettes per hour. The pressing force reaches values of 10-50 kN per linear centimeter of roll width. The roll diameter is 250 - 1400 mm. The presses are equipped with a system of hydraulic compression of the rolls and a system for automatically controlling the frequency of their rotation.
- As well as Köppern, Sahut-Conreur produces briquetting roller presses for hot briquetting.
- The company is also the developer of the patented concept of "cold briquetted iron and carbon" (Cold Briquetted Iron and Carbon, CBIC). The raw material for such briquetting is the so-called cold direct reduced iron and carbon. The largest producer of such iron is Iran. The method proposed by Sahut-Conreur serves the same purpose as Köppern presses for hot briquetting - passivating pyrophoric sponge iron.

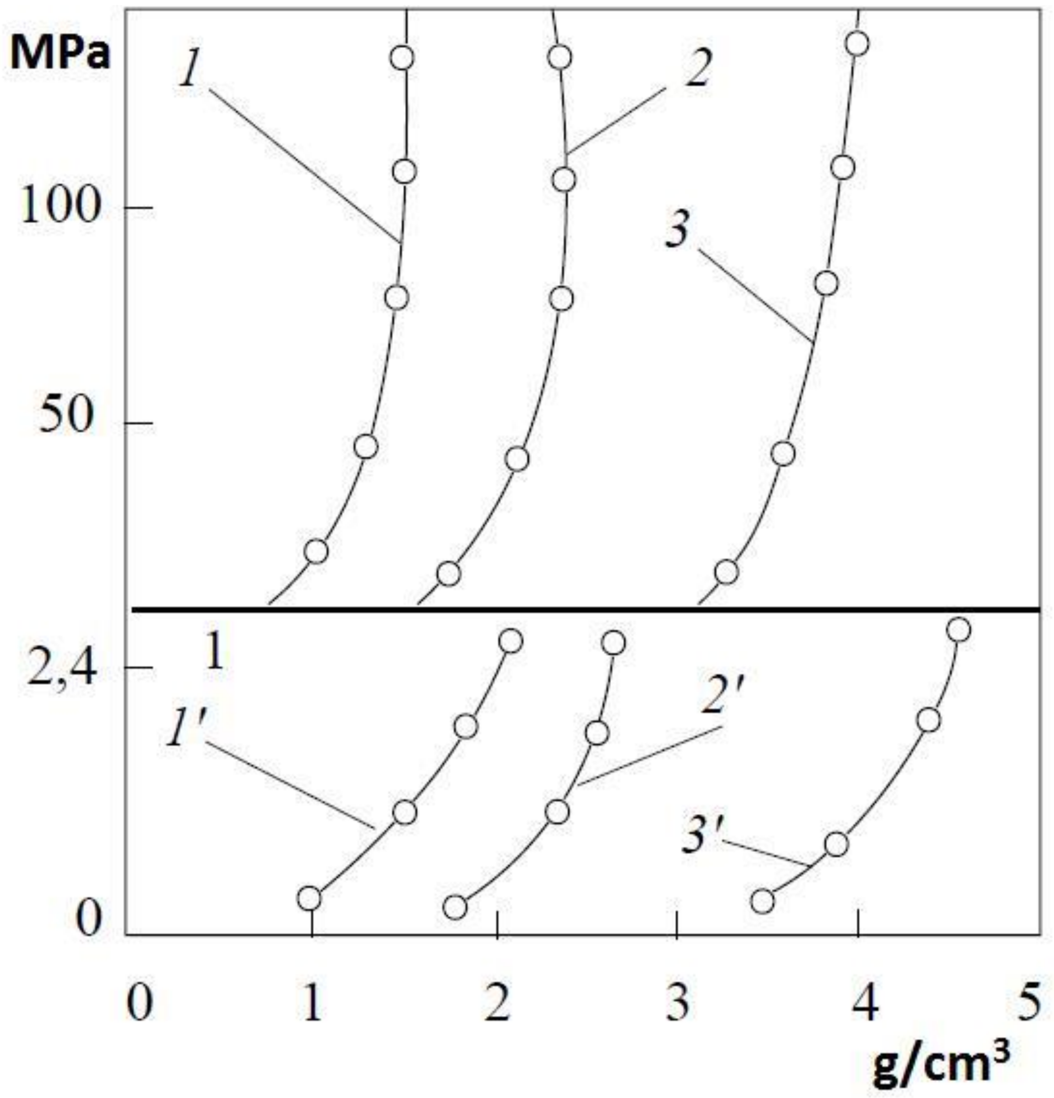
Vibropressing Briquetting

- The possibility of using vibrations for agglomeration was known as early as 1902.
- Vibration was used in the United States in the production of concrete, and in 1927 in France a patent was issued for a method of vibrating concrete compaction.
- In the same year, a method for producing agglomerated masses using vibration was patented in the USA.



Vibropressing Briquetting

- The very first experience in powder metallurgy at the end of the 40s of the last century showed that the use of vibration when filling powder into a mold or in the process of compaction allows significantly reducing the required pressure and homogenizing the distribution of its density by volume.
- It was found that when vibrations with a frequency exceeding 50 Hz, the bonds between the particles in the compacted dry powder are destroyed and the internal friction in the compressible mass sharply decreases, which facilitates the convergence of particles and compaction of the mixture.
- In this case, a higher degree of compaction is achieved at lower load values than during compression.



Comparison of the degree of compaction of the material during static pressing (1-3) and vibropressing (1’-3’). 1, 1’ - boron carbide; 2, 2’ - silicon carbide; 3,3’ – titanium carbide

Vibropressing Briquetting

- The process that occurs when vibration is applied to a formable mass containing gel phases is the so-called **"thixotropy"** - a decrease in viscosity (liquefaction) under mechanical action and thickening in state of rest.
- Manifestations of thixotropy underlie the process of vibration compaction of concrete. Under the influence of vibration, the cement gel transforms into a sol, simplifying the movement (convergence) of solid aggregate particles under the action of its own gravity, which leads to compaction of concrete.
- Similar processes take place during briquetting with the use of cement binder, when, due to the reversible transformation of a cement gel into sol when exposed to vibration, at the stages of its liquefaction, particles of the briquetted charge approach each other under the action of their own gravity, which contributes to compaction of the briquette, and the air displaced by the approaching particles is released on the surface of the compressible mass in the form of bubbles.
- The thixotropy of the gel and the reduction of internal friction due to the oscillatory movements of the particles caused by vibration lead to the fact that the briquetted mass acquires some properties of the liquid, which simplifies the molding.

Vibropressing Briquetting

- It is clear that thixotropy plays a key role in vibropress briquetting.
- It is no coincidence that almost all known vibropressing briquette factories use cement as a binder. That is why the moisture content of the charge components plays an important role in briquetting with vibropressing. Its quantity should be enough to preserve the properties of the cement gel and for further hydration hardening of the cement.
- Usually its content in the briquetted mixture is limited to 5-8% by weight of the briquette. The cycle of vibratory compaction lasts less than 30-40 seconds, which is obviously not enough for the cement to “set”.
- As a result, newly formed vibropressed briquettes have a very low mechanical strength, which does not allow them to be transported and stacked like roll briquettes or BREX.
- Therefore, the equipment of the vibropressed briquetting factories include special mechanisms to transport and accumulate finished products on pallets.
- In addition, to speed up the curing of briquettes, their “steaming” is used - heat and moisture treatment at a temperature of **70-95 ° C** in an atmosphere of saturated steam. Movement of moisture and steam in a briquette that has not yet become strong may lead to its softening.

Technology of Vibropressing, Transportation, Heat Treatment and Storage of Briquettes

- The process of vibropressing consists of several stages.
- The pallet is mounted on the vibrating table.
- The briquetted mixture prepared in the mixer with the addition of a binder is poured into a replaceable mold tooling - a matrix.
- Next, the mixture is compressed by the punch, a kind of “mirror” reflection of the matrix, ideally entering it exactly like a piston in a cylinder, and the vibration of the whole unit is turned on.

Technology of Vibropressing, Transportation, Heat Treatment and Storage of Briquettes

- The duration of the vibration cycle is 15-40 seconds.
- At the end of the molding cycle, the vibration is automatically turned off, the pressure in the hydraulic system decreases, the matrix rises, and the formed briquettes remain on the process pallet.
- The appearance of the briquetting vibropress is shown in Figure.

Technology of Vibropressing, Transportation, Heat Treatment and Storage of Briquettes

- The low strength of freshly formed briquettes does not allow them to be delivered to the zone of curing by the conveyor.
- Preserving the integrity of freshly formed briquettes requires special measures. Briquettes are transported, remaining on technological pallets.
- Pallets with freshly formed briquettes along the conveyor are fed to a special hoist drive, from where a stack of pallets is delivered to the heat treatment zone.

Technology of Vibropressing, Transportation, Heat Treatment and Storage of Briquettes

- After accumulating the required number of pallets on the pallet stacker, they are removed and further transportation to the heat treatment chamber is carried out by an automatic stacked cart moving along the rails.
- It is possible to transport a stack of pallets to the heat treatment zone and with the help of a transborder consisting of transfer and dispensing carts, which ensures the accuracy of the installation of pallets in the heating chambers.
- The duration of heat treatment can reach 24 hours or more. The temperature in the chamber is **70-95 ºC**. The cost of heat treatment chambers can exceed **20%** of the cost of equipment and engineering costs.

Technology of Vibropressing, Transportation, Heat Treatment and Storage of Briquettes

- After heat treatment, the briquettes on the pallets are moved to the stacker and further using a hydraulic pusher to the finished product conveyor for further unloading to the warehouse or loading onto a vehicle.
- The pallets freed from briquettes are returned to the vibropress.
- With a briquette line capacity of up to **130 thousand tons** of briquettes per year, the number of formable pallets can exceed **one million pieces**. The cost of technological pallets may exceed the cost of the vibropress itself.
- In general, the cost of special mechanisms and devices for automatic lines of vibropressing, allowing ensuring the preservation of raw briquettes intact until delivery to the heat treatment chambers and the return of pallets can **double the cost of vibropress**. In the absence of automation of these procedures, the capacity of the briquetting plant will be **not exceeding a few tons per hour**. The cost of automation can be up to **50% of the cost of the vibropress**.
- In connection with the specifics of vibropressing, the productivity of a vibropress is usually understood as the number of units of products produced during an hour or eight-hour shift. First of all, productivity depends on the degree of automation, which affects the rate of removal of pallets with raw briquettes from the working area.
- Equipment productivity essentially depends on the sizes and volume of briquettes. Therefore, the performance is sometimes offered to compare the number of pallets filled in a certain period. According to the results of operation of the known automated vibropress briquette factories, their productivity does not exceed **20-30 tons** of briquettes per hour.

Technology of Vibropressing, Transportation, Heat Treatment and Storage of Briquettes

The size of briquettes is **60-100 mm**; the most widely used form is a hexagonal prism. Such a size of vibropressed briquettes can lead to their "**bridging**" when unloaded into the bunker. The smaller the size of the briquette produced, the lower the performance of the vibropress.

Technology of Vibropressing. Main Producers

- The largest manufacturers of equipment for the production of briquettes by the method of vibropressing are the companies **Hess and Masa** (Germany).
- Hess supplies to the vibration molding market a series of **MULTIMAT** concrete molding machines, which can also be used for briquetting in ferrous metallurgy.
- The machine MULTIMAT RH 2000-3 MA is shown at the Figure.

Hess concrete forming machine MULTIMAT RH 2000-3 MA

Technology of Vibropressing. Main Producers

- The dimensions of the technological pallet are 1400x1300 mm, the area of molding is 1300x1250 mm, the cycle time is 10 seconds.
- The productivity of the machine in the production of paving stones (10x20x6 cm) is 352 m2 of such coverage per hour.
- A special feature of Hess vibropresses is the patented VARIO TRONIC vibrosystem, which allows to set vibration parameters (frequency and amplitude) individually for each type of vibration and achieve optimal compaction using eight vibrators, with minimal wear on equipment components.
- The company supplies the market with automatic briquetting lines, which, in addition to vibropresses, include special devices for transporting pallets with raw briquettes to the heat treatment area and finished briquettes to their shipment points to consumers (pallet conveyors, storage hoists, transborder, multiformes, cameras for heat treatment, briquette dumpers, etc.).
- Figures depict the components of the technological vibration lines of the company Hess, designed to transport and accumulate pallets for heat treatment.



Technology of Vibropressing. Main Producers

- Masa manufactures high-performance XL 9.1 and XL 9.2 stone-forming machines.
- The productivity of the machine XL 9.2 reaches 2938 m3 of rectangular paving slabs with dimensions of 200x100x80 mm, with the standard size of the technological pallet 1400x1300 mm.
- The company supplies complete briquetting lines on a turnkey basis.
- The main equipment, as well as Hess, includes special devices and mechanisms ensuring the safety of raw briquettes until delivery to the heat treatment chambers for curing

Stiff Vacuum Extrusion Briquetting Technology

- Extrusion is a process used to create objects with a fixed cross section profile. The material is pushed through the die of the desired cross section. This method has found a great distribution in the industry of the production of ceramic bricks. Vacuum is maintained in the working chambers of modern brick-making extruders, which contributes to achieving greater uniformity and density of the product. Stiff vacuum extrusion (SVE) technology is applied in the production of ceramic bricks in **64** countries around the world, including the United States, Britain, Germany, South Korea, and South Africa. The world's largest brick factory in Saudi Arabia produces a million bricks per day using SVE technology.
- In accordance with brick industry terminology, the word "stiff" is used to describe the process of extrusion, which is carried out at pressures ranging from **2.5 to 4.5 MP**a and moisture contents ranging from **12-18%**.

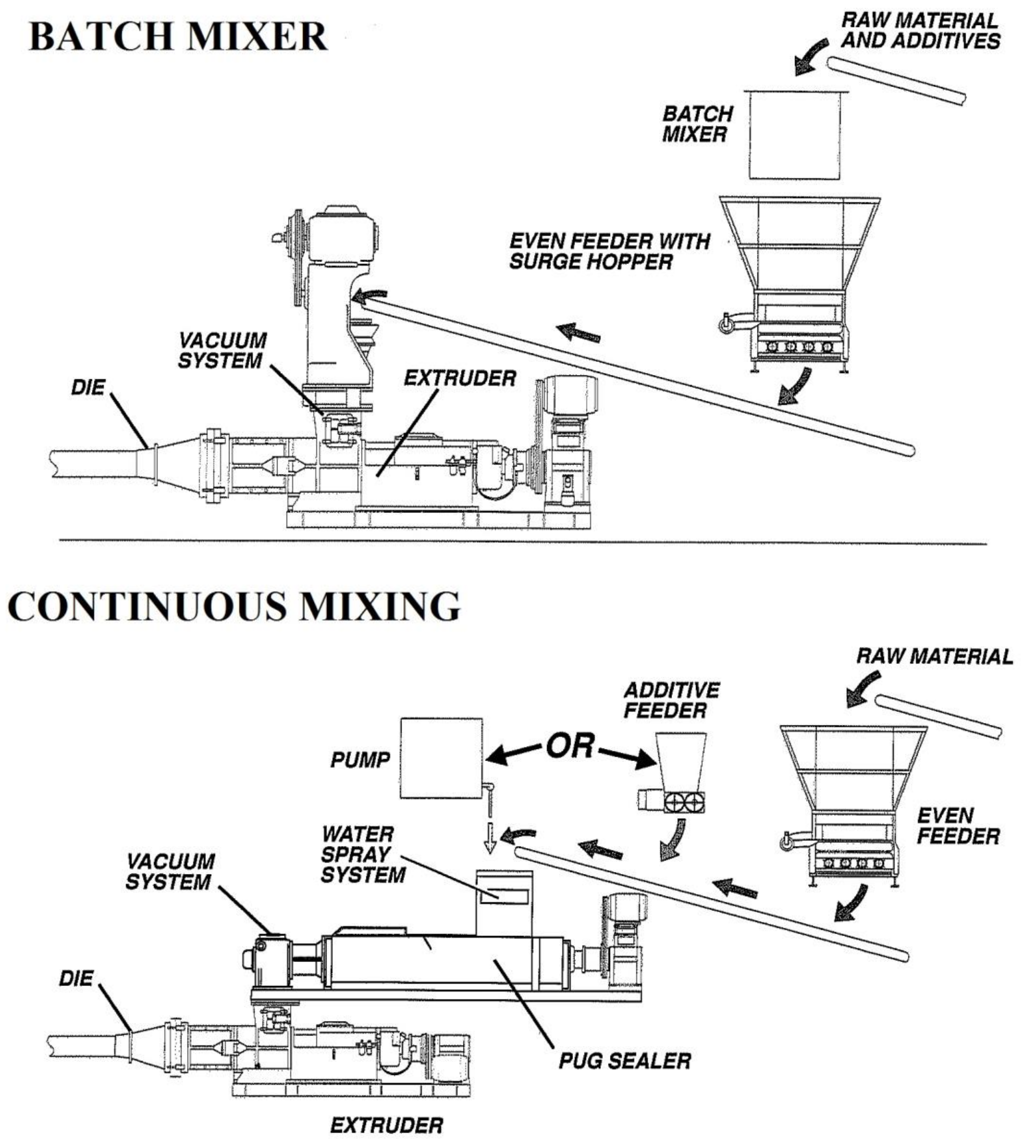
Type of extrusion	Low-pressure extrusion	Medium-pressure extrusion	High-pressure extrusion	
Designation used in structural ceramic industry	Soft extrusion	Semi-stiff extrusion	Stiff extrusion	
Extrusion moisture, % on dry	10-27	15-22	12-18	10-15
Extrusion pressure, MPa,	0,4-1,2	1,5-2,2	2,5-4,5	Up to 30

Stiff Vacuum Extrusion Briquetting Technology

- Unlike a roller-press and vibropress briquetting, shear stress plays an important role in SVE agglomeration. Shear stress occurs when the mixture is processed in the screw feeder, in pug mills, and then in the extruder.
- Based on a comparison of coal briquette porosity values in various pressing options (compression and its combination with torsion), it was found that more dense briquettes (less porous) are formed in the combined pressing option (under identical values of applied pressure).
- With full compression, a significant proportion of energy is expended on the elastic deformation of the particles themselves, while, in the presence of shear stress, the convergence of particles on the surface forces activation distance is more effective.
- In full compression of close-packed particles, each particle only comes into contact with its immediate neighbors and is subjected to compression load.
- Under shear stress, the particles of the adjacent layers are subjected to abrasion due to contact with irregular surfaces, which can lead to crushing, the opening up of new surfaces, and, hence, to an increase in the number of contacts between particles of the mixture.

Stiff Vacuum Extrusion Briquetting Technology

Typical layouts of the SVE briquetting line



Stiff Vacuum Extrusion Briquetting Technology

The mixture of raw materials is fed by a front loader to a Steele E Series Even feeder (Figure), equipped with wear-resistant spiral cast-iron auger elements made of a chromium alloy.

Stiff Vacuum Extrusion Briquetting Technology

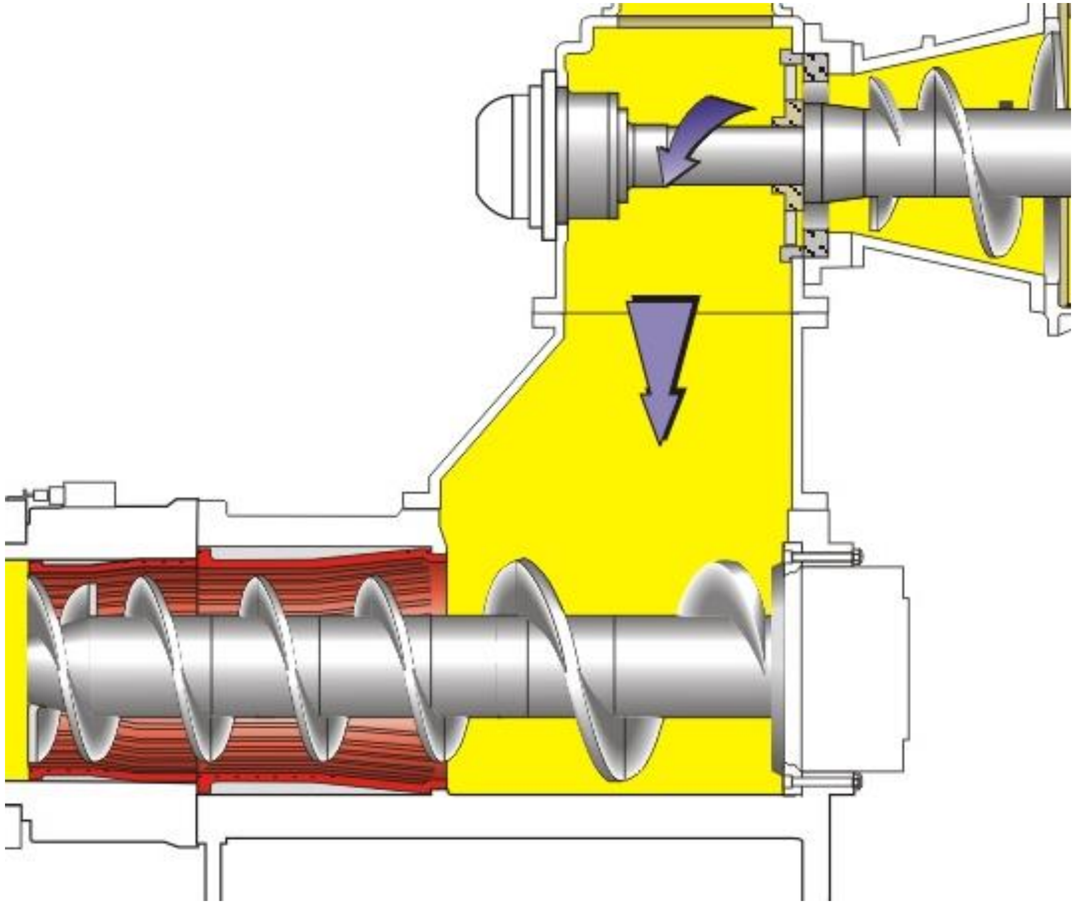
- Next, the prepared mixture with added binder and plasticizer is fed for mixing in the pug sealer.
- The line can also contain primary open pug-mill.
- The pug sealer consists of a large open part and the sealing node. The open part consists of a trough and blades for mixing.
- The blades are fastened to the steel rod shaft by bolted clamps, making it possible to rotate the blades to adjust the angle at which the processing takes place and, thereby, change the machine's performance.
- The pug sealer is combined in a single unit with the extruder and is positioned above it.

Stiff Vacuum Extrusion Briquetting Technology

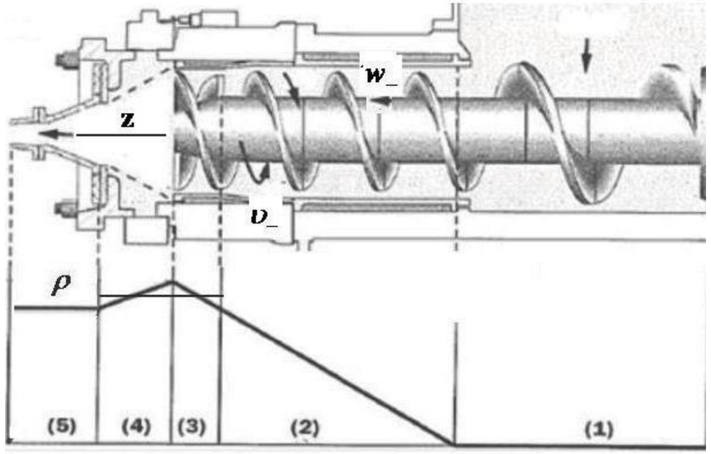
- The mixture enters the vacuum chamber partially agglomerated and due to the high vacuum inside the chamber the pieces of the mixture immediately crumble into isolated particles, which fall on the blades of the auger.
- It is known that air adsorbed by the surface of particles of plastic material in the form of polymolecular layers held by van der Waals forces slows down their wetting with water, prevents the mass from being evenly compacted, contributes to an increase in elastic deformations during plastic molding, forming delamination as well as micro-cracks.
- Filling the pores, the air also prevents the penetration of moisture into them, separates the particles of the mass, acting as a leaner.
- Vacuum leads to the removal of air from the pores and promotes closer contact of the particles.

Stiff Vacuum Extrusion Briquetting Technology

- The vacuum is maintained throughout the working volume of the extruder up to the die.
- The pressure of the vacuum is at least 100 mm Hg (in absolute value).
- The combination of mechanical pressure and vacuum in the working extruder chamber helps to remove almost all compressible air from the material before densifying,
- In addition, as is well known, the vacuum slightly decreases the viscosity of the cement paste, which facilitates its uniform distribution in the briquetting mass and improves its interaction with water.
- This circumstance in combination with a higher density of the briquetting mass, due to the removal of air from it, leads to a decrease in the consumption of cement binder.



Stiff Vacuum Extrusion Briquetting Technology



- Due to rotation of the auger blades in the working chamber of the extruder, formable mass performs translational and rotational motion, which is slowed by the walls.
- Stages of densifying in the working zone of the extruder.1 – conveying, 2 – densifying, 3 – metering, 4 – pressure distributing, 5 – die.
- In the conveying zone, material is loose and moves along the barrel without densification. Bulk density remains unchanged. Zone 2 is the densifying region where the loose material is compacted. In zone 3, metering is achieved by way of the special geometry of the wings of the point auger. Zone 4 serves the purpose of distributing the pressure generated by the metering zone more evenly over the die, thus tending to yield a more even flow through it.
- In zone 5, the brex are squeezed out of the holes in the die, which completes the process of their formation.

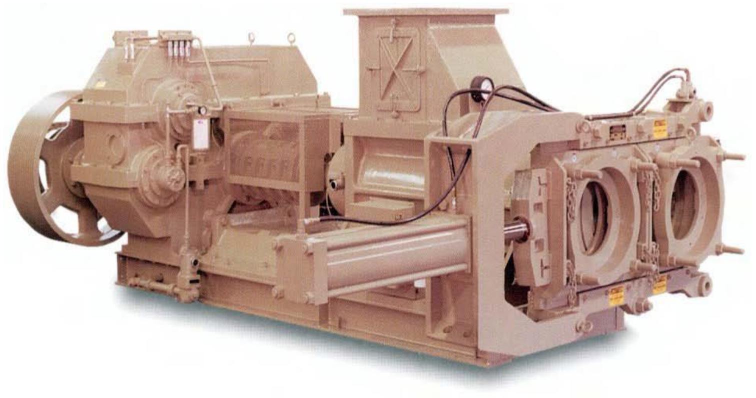
Stiff Vacuum Extrusion. Main Equipment

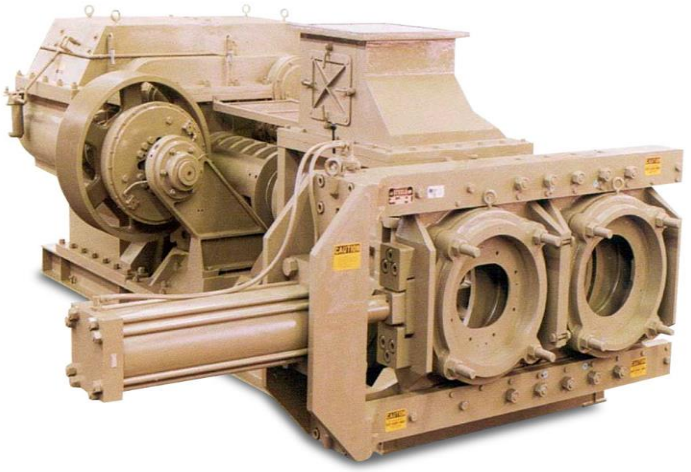
- The first successful attempts to deaerate the mixture before it was fed to an extruder were made in the USA in 1920, and from 1932 such a procedure was used in Europe. The first stiff extrusion experience also took place in the USA at the end of the 19th century and was associated with **J.C.Steele & Sons, Inc.** founded in **1889**. But for the first time on an industrial scale, stiff extrusion was implemented in England in **1960**, and then in Germany in **1967** by **Haendle**, which today is part of the J.C.Steele & Sons, Inc. group of companies. It is the company Haendle has combined vacuum and stiffness of the mixture in extrusion.
- J.C.Steele & Sons, Inc. Is the creator of the modern Stiff Vacuum Extrusion technology and the world's largest supplier of extruders for stiff extrusion.
- As noted above, shear stress plays a significant role in SVE. It is this effect that the briquetted by this method is subjected to at all stages of agglomeration, starting with feeding and mixing in so-called even feeders “J.C.Steele & Sons, Inc.”.
- The company manufactures feeders with two, four and eight augers. Solid augers only serve the mixture, and the split augers, in addition to the feed, carry out loosening, grinding and crushing. The performance of uniform feeders from **30 t / h to 200 t / h**. Knives pugs made of alloy with 28% of chromium.

Stiff Vacuum Extrusion. Main Equipment

- J.C.Steele & Sons, Inc. produces several extruder types with different capacities.
- The smallest rated output of this company's extruders is **5 tons per hour** (extruder **HD-10**). The actual performance is determined by the density of the briquetted mass.
- In the range of capacities from **20 to 50 tons per hour**, the company supplies the **25th and 45th** series Steele extruders.

Stiff Vacuum Extrusion. Main Equipment





- Extruder Steele 75 allows to produce up to **54 tons** of briquettes per hour.
- The company's most high-performance extruder is the Steele 90 extruder, designed for production of **80-90** tons per hour. The 45, 75 and 90 series extruders can be equipped with a hydraulic die change mechanism that performs this procedure almost instantly.
- All units and parts of the machines are designed for significant overloads, especially bearings and powerful shafts made of one-piece forging. All elements of the extruder body, the vacuum chamber and the pug mill assembly are molded from ductile iron. In the design of the extruder and the vacuum chamber of the clay mill, welding is not used. All parts in contact with the processed metal are made of 28PC alloy (28% chromium and other alloying additives.)
- Extruders and pug mills are designed for a long service life (30 years or more) and are characterized by ease of maintenance and operation.

Stiff Vacuum Extrusion.

Company	Country	Extruder (quantity)	KTY	Purpose
Bethlehem Steel (1994-1997)	USA	Steele 25	80	BF
Suraj PL (2011)	India	Steele 25	100	BF
Steelmaking Company*(2010)	NDA	Steele 25 (1) + Steele 90 (2)	1000	BF
NLMK (2019)	Russia	Steele 45 (3)	700	BF
CAP Steel (2018)	Chile	Steele 25	100	BF
J.C.Steele&Sons/TMS (2017)	USA	Steele 25	100	BF
BHP Billiton (1997)	Columbia	Steele 90 (3)	700	RKEF, Ferronickel
Vale (2014)	Brazil	Steele 90 (3)	700	RKEF, Ferronickel
Ferro Alloys Co. (2017)	NDA	Steele 45	200	Ferromanganese
JSC CHEMK (2018)	Russia	Steele 45	200	SiMn
JSC Kazchrome (2017)	Kazakhstan	Steele 25	80	Ferrochromium
BREXTIME (2019)	Ukraine	Steele 90	200	Ferronickel

CONCLUSIONS

- **The methods of roller pressing, vibropressing and stiff extrusion are most widely used for briquetting natural and anthropogenic materials.**
- **Moisture limits for roller briquetting require retrofitting of briquetting lines with dewatering and/or drying areas and limit the use of cement binder.**
- **Production of roller briquettes is characterized by the formation of up to 30% of recycled waste in the form of small fractions of the briquetted mixture.**
- **Maintaining the operational capacity of roller presses is associated with the need to purchase and replace expensive parts, as they wear out.**
- **The share of roller briquettes, in cases of their use in the charge of modern blast furnaces, is limited to several tens of kilograms per ton of iron. In this case, the required strength of the briquettes is achieved due to the increased consumption of the binder.**

CONCLUSIONS

- **In addition to the actual formation of briquettes, the vibropressing briquetting technology also includes techniques for ensuring the integrity of raw briquettes by transporting them on pallets to a heat and moisture chamber.**
- **This requires the organization of a complex system for transporting briquettes from the vibrating table to the hardening chamber, from the chamber to the production warehouse and returning the pallets to the vibrating table, which increases the cost of briquettes and reduces the reliability of the briquetting line.**
- **The disadvantage of the vibropressing technology is the directly proportional dependence of the line capacity and the inversely proportional dependence of the cost price and the recoverability of the briquettes on their size. Large hexagonal briquettes in cross section (60x60x60 mm and more) make it difficult to unload them from bunkers when loaded into blast furnaces because of bridging.**
- **The metallurgical properties of vibropress briquettes satisfy the requirements of the blast furnace process (except for their size) and can be considered as components of the blast furnace charge, but the high content of cement binder increases their cost and adversely affects the viscosity of the primary slags.**

CONCLUSIONS

- **The results of the operation of the SVE factories for the agglomeration of lateritic nickel ores and dust of the aspiration systems to produce ferronickel showed the possibility of achieving high levels of productivity of briquetting lines at low capital costs.**
- **The results of the operation of the SVE factories for the agglomeration of BF production fine materials confirms the economical feasibility of using extruded briquettes (BREX) in the BF charge.**
- **The capacity of SVE and good metallurgical properties of BREX allows to consider this technology as a possible alternative for sintering.**
- **The results of a comparative analysis of the technical and economic indicators of the modern industrial briquetting technologies allow quite reasonably to choose the SVE technology as the main technology of briquetting anthropogenic and natural raw materials used in the processes of extractive metallurgy of ferrous metals.**

THANK YOU FOR ATTENTION!