THE SELECTED DESIGN AND OPERATING PARAMETERS OF BRIQUETTING PRESSES AND LINES FOR THE TREATMENT OF SCRAP METAL AS CHARGE TO STEEL FURNACES

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Abstract

The processing of scrap metal as charge in steel furnaces is a relatively broad area, where many different processes and technologies are applied. One of these technologies is waste metal briquetting technology. This technology is mainly used to process swarf from chip machining, which is a relatively valuable raw material as long as the required purity of its chemical composition is maintained. The machines on which this technology is implemented are called briquetting presses. These briquetting presses can process metal chips resulting from the machining of machine parts made of various metallic materials. According to the mechanical properties of the metal chips material, for the processing of which the briquetting press is designed, the individual structural nodes of the briquetting press are designed. The manufacturers of briquetting presses do their best to meet the demands and requirements of customers who want to use these presses in their plants. For the perfect function of the briquetting press the quality of the design is therefore crucial. The aim of this article is to introduce the reader to the main types of briquetting presses for the processing of metal chips as well as the method of determining selected design parameters important for the design of briquetting presses and lines.

Keywords: steel scrap, steelmaking, briquetting press, design, charge for steelmaking furnaces

1. INTRODUCTION

The idea of compressing metal waste to achieve a greater specific gravity was probably taken from a similar technique used for compressing some agricultural products. If we are compressing or pressing metal waste in order to achieve a higher specific gravity, then the technology of baling [1] or briquetting can be used. Both of these technologies do not allow for subsequent sorting. This means that the material to be processed must be sorted prior to compression in a compression chamber. This pre-sorting must guarantee the chemical purity of the treated waste. The faggoting technology is suitable for sorted scrap with the size of individual pieces in the order of tens of centimetres to units of metres. On the other hand, the briquetting technology processes sorted metal waste with the size of individual pieces in the order of millimetres to units of centimetres. Briquetting technology is also used for non-metallic materials such as sawdust and wood shavings, pulverized coal, biomass, paper, etc [2]. As far as metal waste is concerned, briquetting technology is mainly used for the processing of chips from chip machining. The briquetting of ferrous and non-ferrous metal chips is used, e.g., for metal particles from grinding sludge and dedusting gases, scales, the dust fractions of ores or ferroalloys.

This article aims to provide information about this technology of iron waste processing, specifically about selected types of presses, their advantages and the possibility of determining some design parameters of briquetting presses and lines. The information could help potential users of metal waste briquetting technology to orientate themselves more quickly on the subject and on the offers of briquetting presses and lines manufacturers.

2. SELECTED TYPES OF BRIQUETTING PRESSES AND THE ADVANTAGES OF BRIQUETTING

In general, different types of briquetting presses are used in practice, based on different pressing principles [3]. If we focus on the briquetting of metal chips, then we encounter almost exclusively hydraulically driven presses. In most cases, briquettes made of metal chips have the shape of a cylinder with the largest diameter of about 20 cm and approximately the same height [4]. The specific gravity of briquettes, made from ferrous metal chips, is often above the value of 5,000 kg·m^{-3}. When pressing such briquettes, the briquetting press must exert a pressure of up to 500 MPa [5]. The most powerful briquetting presses for the production of briquettes from metal chips include presses with a non-moving and moving press die. Presses with a non-movable pressing die are equipped with two pressing rollers that press "against each other" (**Figure 1**).

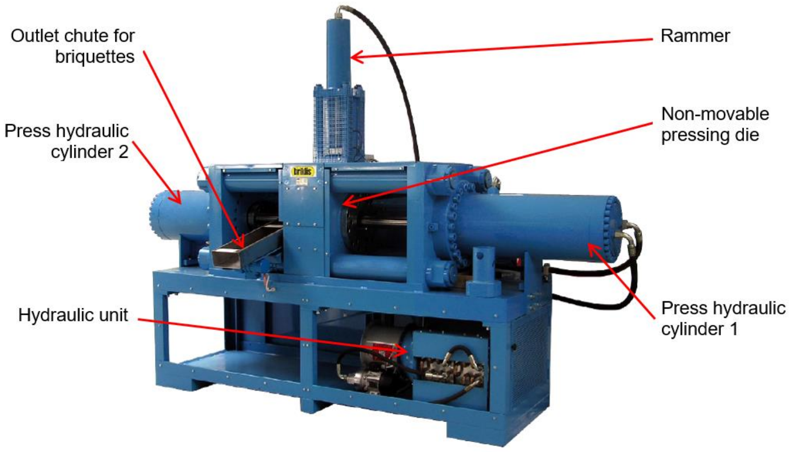
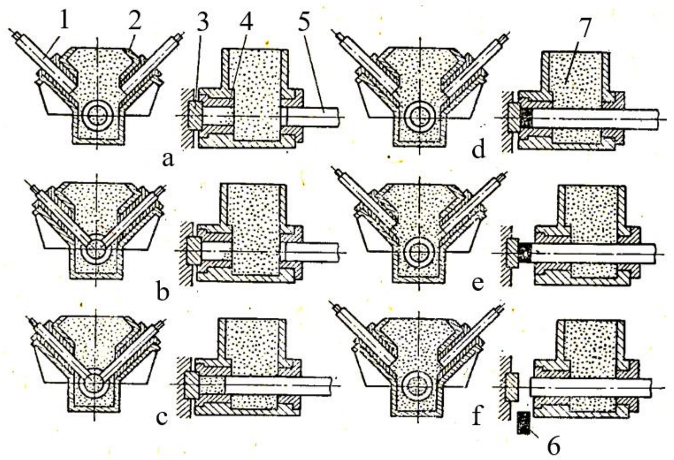


Figure 1 An example of a briquetting press with a non-movable press die [6]

Presses with a movable pressing die are equipped with one pressing cylinder that presses against a fixed pressing pad. The different stages of briquetting (pressing) a briquette on a hydraulic briquetting press with a single hydraulic press cylinder and a movable pressing die are shown in (**Figure 2**).



1…rammer, 2…rammer guide, 3…press mat, 4…pressing die, 5…punch, 6…briquette, 7…metal chips

Figure 2 Individual stages of briquetting (pressing) briquettes on a hydraulic briquetting press with a single hydraulic cylinder and a movable pressing die [7]

The mobility of the pressing die is used in the "e" and "f" phase when it is necessary to press the finished briquette out of the pressing die. In these two phases, the pressing die is moved away from the pressing pad to a distance slightly greater than the height of the briquette, and then the press roller punch presses the finished briquette out of the pressing die space.

The major advantages of briquetting include:

- reducing the volume of waste and increasing its specific weight,
- a reduction of storage and handling costs,
- a reduction of melting loss during steel furnace charging,
- returning the expensive coolants and lubricants that contaminate the chips back into circulation (production process).

3. THE THEORETICAL RELATIONSHIP BETWEEN THE PRESSURE ON THE PUSHER AND THE PRESSURE ON THE BOTTOM OF THE PRESSING CHAMBER

The determination of the force load on the briquetting press structure is absolutely necessary for the correct dimensioning of its individual structural nodes. Below is an example of the calculation of the pressure acting on the bottom of the press chamber depending on the pressure exerted by the press pusher. If we know the area of the push rod, then we can also calculate the force of the hydraulic cylinder acting on the push rod. And from the known value of the pressure on the press pusher, it is possible, for example, in the case of a press with a moving pressing die, to determine the pressure acting on the press mat, i.e. the force load on the structure of the press chamber bottom and other related structural nodes.

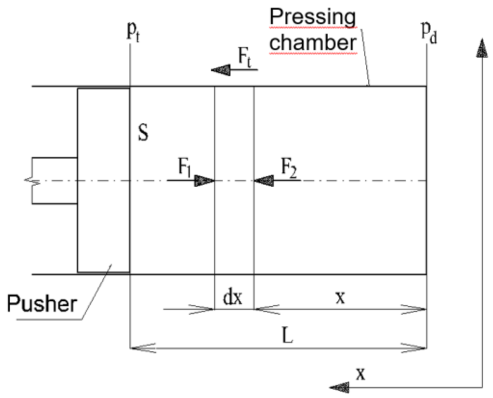


Figure 3 Calculation schematic diagram (Pressing chamber, Pusher)

Calculation conditions:

- the pressed material is homogeneous
- the coefficient of friction between the material to be pressed and the surface of the pressing chamber and the coefficient of proportionality between p_x and p_y are not dependent on coordinates

The equation of force equilibrium on a displaced element (**Figure 3**) of width dx has the form

$$(p_x+dp_x).S - p_x.S=k.p_x.O.f.dx \qquad (1)$$

Where:

S	area of the press pusher	(m^2)
p_x	pressure on the press pusher at a distance **x** from the bottom of the press chamber and in the direction of the **x**-axis	(Pa)
p_y	pressure on the side wall of the compression chamber at a distance **x** from the bottom of the compression chamber and in the **y**-axis direction	(Pa)
p_d	pressure on the bottom of the press chamber (start of the coordinate system)	(Pa)

p_t	pressure on the pusher of the press	(Pa)
O	circumference of the pressing chamber cross-section	(m)
f	coefficient of friction between the material to be pressed and the surface of the pressing chamber (f = 0.2 to 0.25) [8]	(1)
dx	width of the extruded element in the pressing chamber	(m)
k	coefficient of proportionality between p_x and p_y (k = 0.3 to 0.4) [8]	(1)
F_t	frictional force acting against the movement of the pusher	(N)
L	the distance of the pusher surface from the bottom of the pressing chamber	(m)

After adjusting equation (1) the final relationship between the pressure on the pusher and the pressure on the bottom of the press chamber is given by

$$p_t = p_d . e^{k\frac{O}{S}f.L} \quad \text{(Pa)} \tag{2}$$

4. THE THEORETICAL DEPENDENCE OF THE MAXIMUM CONTENT OF UNDESIRABLE LIQUIDS IN THE BRIQUETTE ON ITS SPECIFIC GRAVITY

From the steel furnace operation point of view, the rupturing of the briquette when it is charged into the furnace can be a problem. The briquette rupturing effect is caused by the excessive content of unwanted liquids in the briquette (some sources refer to briquette moisture). These unwanted liquids are made up of various cooling and lubrication fluids used in the machining process. In the furnace area, where the temperature is more than 1,000 °C the briquette heats up very quickly and thus also the undesirable liquids contained in it. Heating the liquids in the briquette increases their pressure until the briquette ruptures violently. The individual parts of the torn briquette hit the working lining layer and thus reduce its durability, which has a negative effect on operating costs. For this reason, the various operating fluids used in the machining process when processing chips from chip machining are considered an undesirable impurity that contaminates the chips themselves as well as waste from the machining process. Normally contaminated steel chips contain about 4 weight percent of unwanted liquids, but often much more. The briquettes must contain less than 2 weight percent of the following undesirable liquids to prevent the rupture of the briquettes in the working space of the furnace.

Even if the pressures on the pusher during briquette pressing reach up to 500 MPa in some cases and some of the unwanted liquids leak out of the briquette, there is still enough space inside the briquette to accommodate more than two weight percent of the unwanted liquids. For this reason, it is necessary to reduce the volume of unwanted liquids in the chips below 2 weight percent before the actual pressing. This can be ensured by centrifuges used in practice and the justification for their use can be proven using a simple calculation.

The weight percentage of unwanted liquids **p** can be expressed as

$$p = \frac{M_{nk}}{M_b}.100 = \frac{V_{nk} \cdot \rho_{nk}}{V_b \cdot \rho_b}.100 \quad (\%) \tag{3}$$

Where:

M_{nk}	weight of unwanted liquids	(kg)
M_b	weight of the briquette	(kg)
V_{nk}	volume of unwanted liquids	(m^3)
V_b	weight of the briquette	(m^3)
ρ_{nk}	specific weight of unwanted liquids	($kg \cdot m^{-3}$)
ρ_b	specific weight of the briquette	($kg \cdot m^{-3}$)

To determine the ratio V_{nk}/V_b , we can use the following equation

$$\rho_b.V_b = (V_b - V_{nk}).\rho_m + V_{nk}.\rho_{nk} \tag{4}$$

Where:

ρ_m specific weight of the briquette material (kg·m^{-3})

After further adjustment and substituting the selected values of the specific gravity of unwanted liquids (e.g. r_{nk}=900 kg·m^{-3}) and briquetted material (for steel chips 7,850 kg·m^{-3}) we obtain an expression for the weight percentage of unwanted liquids as a function of the specific gravity of the briquette

$$p = \left(\frac{1016{,}575}{\rho_b} - 0{,}1295\right).100 \quad (\%) \tag{5}$$

Graphical representation of the formula (5) is displayed in (**Figure 4**).

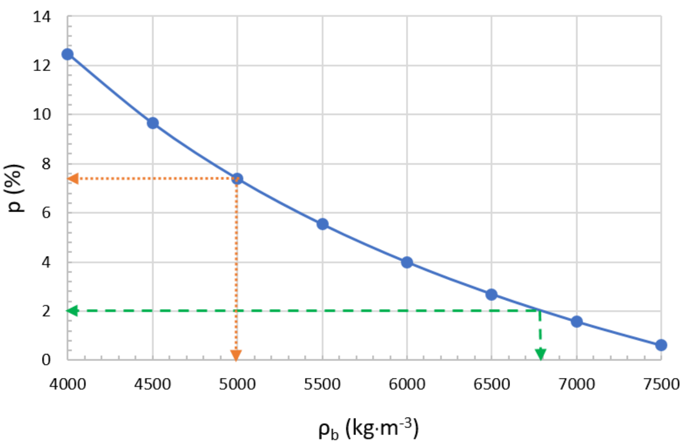


Figure 4 Dependence of the weight percentage of unwanted liquids **p** depending on the specific weight of the briquette $\mathbf{r_b}$

The volume increase coefficient for briquettes ranges from 1.1 to 1.2. In other words, this means that if we want the briquette to have a specific gravity after extrusion from the pressing chamber 5,000 kg·m^{-3}, it has to be pressed to specific gravity in the pressing chamber of 5,500 to 6,000 kg·m^{-3}.

From the graph (**Figure 4**) it can be seen that even if we press the briquette in the pressing chamber to the specific gravity of 6,000 kg·m^{-3}, there is still enough room to hold 4 weight percent of unwanted liquids. In order for the briquette to contain less than two weight percent of unwanted liquids, we would have to compress the briquette in the pressing chamber to a specific gravity just below 7,000 kg·m^{-3}, which is currently difficult to achieve using standard means of operation. It follows that the chips must be freed from unwanted liquids before the briquetting (pressing) process. Centrifuges that are able to reduce the volume of unwanted liquids in the chips below two percent by weight have proven to be the best in practice.

In the briquetting line, there are several devices placed in a series, which are connected by means of an inter-operational transport [9]11]. As a rule, a chip crusher is included first, in which the chips are crushed to a size of around three to five centimetres. The crusher is followed by a centrifuge, in which unwanted liquids are separated from the chips. These can then be regenerated and returned to the production process. After the centrifuge, it is advisable to place, for example, a magnetic separator, which in the case of ferromagnetic metals separates the metal chips from any non-ferromagnetic impurities. Last in the line is the briquetting press, which is usually equipped with a hopper and a dosing device for precise dosing of the briquetted material.

5. CONCLUSION

Briquetting technology is nowadays one of the technologies for the treatment of scrap metal and the preparation of charge for steel furnaces. Briquetting is carried out on a machine called a briquetting press. When transforming briquetted metallic waste with a bulk weight of 0.1 to 0.6 $t \cdot m^{-3}$ into a compact briquette shape with a specific weight of up to 5 $t \cdot m^{-3}$, it is necessary to overcome the forces that arise from the deformation of the material to be compacted, the friction of the material acting against each other and the friction of the material against the walls of the briquetting press chamber. All of these forces are difficult to be defined. In this paper, a theoretical relationship between the pressure on the pusher and at the bottom of the pressing chamber was derived, including a calculation showing that even if we press the briquette in the pressing chamber to a specific gravity of 6,000 $kg \cdot m^{-3}$ there is still enough free space to accommodate 4 weight percent of unwanted liquids. This is effectively an argument for the use of centrifuges, which are able to reduce the volume of unwanted liquids in the dimensionally treated chips to below two percent by weight before the briquetting process.

The aim of this article was mainly to provide information on the possibility of determining some design parameters of briquetting presses. This information should make it easier for potential users of briquetting technology to find their way around the technical parameters of briquetting presses and the lines that are listed in the manufacturers' catalogues.

REFERENCES

[1] KOVÁŘ, L., NOVÁKOVÁ, E., KOSTECKÝ, V., PRAVDA, Š., ŠEBESTA, R. Selected design parameters of baling presses for the treatment of steel scrap as a charge for steelmaking furnaces. In: *32nd international conference on metallurgy and materials – METAL 3* Ostrava: Tanger Ltd.,2023, pp. 108-113.

[2] OLADEJI, J. T. Theoretical Aspects of Biomass Briquetting: A Review Study. Journal of Energy Technologies and Policy. 2015, vol 5, pp. 72-80.

[3] INEGBEDION, F., ISHIOMA, T. Design and Fabrication of a Briquetting Machine. *Journal of Energy Technology and Environment.* 2022, vol. 4(1), pp. 11-20.

[4] Metso EtaBriq - Briquetting Press. 2024. [viewed: 2024-02-05]. Available from: https://www.environmental-expert.com/products/metso-etabriq-briquetting-press-155669

[5] RUF Briquetting Systems.*Metal Briquetting Press*. 2024. [viewed: 2024-02-05]. Available from: https://www.ruf-briquetter.com/metal-briquetting/

[6] Briklis. *HLS metal* [online]. 2024. [viewed: 2024-02-05]. Available from: https://www.briklis.sk/briketovacie-lisy-na-kov/hls-metal

[7] GREBENIK, B.M.et all: *Mechaničeskoje oborudovanije elektrostaleplavilnych i ferosplavnych cechov.* Kijev, golovnoje izdatělstvo, 1980. 255 s.

[8] LEVIN, M. Z.: *Mechaničeskoje abarudovanije staleplavilnych cechov*. Kijev – Doněck 1985. 168 s.

[9] SÝKORA, M., JAITNER A., VESELÝ O., CHOCHOLÁČ A.: *Výrobní stroje a zařízení pro zpracování odpadu*. Interní učební text. VŠB - TU Ostrava, FS, kat. 344. Ostrava 1996

[10] KMEC engineering. *How to build the briquette production line*. 2024. [viewed: 2024-04-05]. Available from: https://www.woodbriquetteplant.com/news/176.html

[11] ENERPAT. Metal Chips Briquetting Press Line. 2024. [viewed: 2024-04-05]. Available from: https://www.enerpatrecycling.com/Metal-Chips-Briquetting-Press-Line-pd47869590.html?gad_source=1&gclid=EAIaIQobChMIqL3u143MhwMVfLGDBx3TYS0tEAAYASAAEgLr6PD_BwE