BALING – TECHNOLOGY FOR THE PREPARATION OF CHARGES INTO STEELMAKING FURNACES

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Abstract

Even in the production of steel, the quality of the final product depends on the quality of the raw material used for its processing. One of the raw materials that is put into steelmaking furnaces is also steel scrap. The purity of steel scrap is one of the main indicators of its quality, which in turn affects the quality of the final product leaving the steelmaking furnace, i.e. the quality of the liquid steel melt. Various technologies are currently used for the preparation and treatment of steel scrap used as charges for steelmaking furnaces. Baling technology is one of the most widely used technologies for scrap treatment nowadays. However, this technology has its pros and cons. The presented article will inform readers about the main characteristics of this technology, including a description of the three most widely used axial baling presses, used for the production of the biggest and heaviest faggots that serve as a charge for steel furnaces.

Keywords: Metal scrap, metal scrap treatment, baling, bale, charge for steelmaking furnaces

1. INTRODUCTION

Baling is, nowadays, a very widespread technology used for the treatment of metal waste (scrap). It is mainly used for the relatively light baling metal waste of ferrous or non-ferrous metals. Baling is carried out on a device (machinery) called a baling press. The input raw material for baling presses is loose metal waste, the output product of the baling press is the so-called bale. Bales made from steel waste serve as a charge into steelmaking furnaces. In the conditions of the Czech Republic, these are mainly oxygen converters, electric arc furnaces and tandem furnaces.

The advantage of this technology is its low production costs, practically the lowest in comparison with the other commonly used technologies. This deals with the treatment of scrap metal, such as its shearing, crushing and briquetting.

One shortcoming of this technology is the need for the subsequent inspection of the bales and their contamination, which is quite difficult to provide. Copper and tin are considered to be particularly hazardous elements in steel waste. This is also why bales with smaller dimensions (the cross-section) are currently preferred than they were in previous periods. Smaller bales have a relatively large specific surface area $m^2.kg^{-1}$ and visual inspection of their contents is more effective [1]. However, small bales, unlike the bigger ones, have larger production costs $CZK.kg^{-1}$. The highest quality bales are the ones produced from 'new' waste, which is created directly in some production (e.g. cuts from sheet metal pressing shops), as there is a high purity guaranteed. The aim of the presented article is to provide important information about this technology of iron scrap preparation, including a description of the two most widespread types of baling presses. The information should serve potential users of baling technology for quick orientation in the given issue.

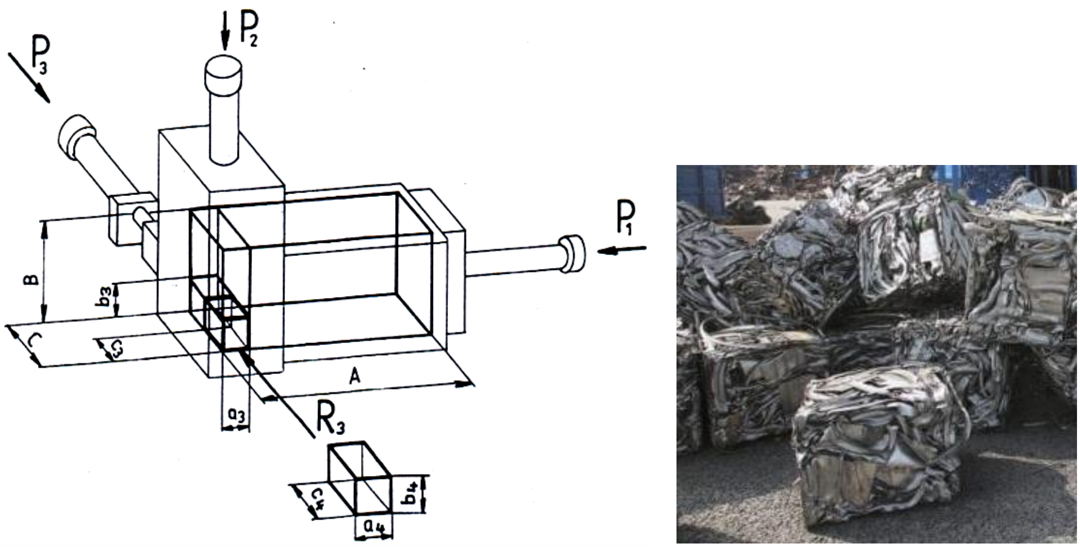
2. MATERIALS SUITABLE AND UNSUITABLE FOR BALING

Suitable (baleable) material consists mainly of sheet metal cuttings or eventually discarded structures from weaker profiles up to the strength of 450 MPa. Using conventional baling presses up to a specific pressure of 10 to 30 MPa on the pusher of the last pressing operation, it is possible to advantageously form a sheet of the grade 11, thin-walled steel structure or sheet metal waste with a 15 to 30 % weight fraction of long (soft) steel chips. When baling light steel waste, the pressure on press pushers used is exceptionally up to 40 MPa.

Materials that cannot be used for baling include whole sheet metal sheets (sheet metal sheet layers cannot be effectively deformed), hollow vessels of an unknown content, objects with an unauthorized wall thickness and with high material strength, electric motors (a high copper content), radioactive material, etc. [2]. Small steel cuts cannot be used for baling (with an area of square centimetre units), created, for example, by the perforation of sheet metal strips in press shops. These tiny punches worsen the cohesion of a bale, they fall out and jam in the joint between the pusher and the walls of the pressing box. It is also not possible to use steel chips or ropes for baling. The reason for this is the poor cohesion of the bale already when it is pushed from the baling press and the high bale suspension value, which can ultimately lead to the complete disintegration of the bale [3].

3. BALE DIMENSIONS, SHAPE, SIZE AND DENSITY REQUIREMENTS

Baling presses are intended for pressing light and large steel waste, or eventually non-ferrous metals. If we are talking about a baling press with a vertical prepress, then the pressing box has a dimension A x B x C, (**Figure 1**) into which the waste for baling is loaded, whereby using a gradual, in this particular case, a three-stage (triaxial) pressing reduces the size of A to a_3, B to b_3 and C to c_3. The mentioned type of press has three pressing parts P_1, P_2, P_3 , where the last part of the pressing process causes a response of R_3 pushing on the door.



A B

Figure 1 Diagram of the baling process on a baling press with a vertical precompress – A [1], bale is product of baling technology – B [6]

For the processing of small size metal waste, baling presses with two-stage (biaxial) pressing are used, where e.g. B = b_3 or with a single-stage (uniaxial) pressing, where B = b_3 and at the same time C = c_3. Designs of presses with two-way repressing are also known, where R_3 = P_3, presses with the lid covers of the pressing box or with a sliding wall, presses with bale being tilted from the pressing box, or with a crane mechanism for their removal. Presses with an octagonal bale profile were also manufactured and presses with bale extrusion provided by pressure rollers were tested. Bale with a prism cross-section (**Figure 1**) can be described using the pusher sizes of the last pressing operation (P_3) a_3 x b_3 and its finished length in the press box c_3, which tends to be variable for the diversity (size and orientation) of the waste on the feed into the baling press, and due to various loading weights G of the waste fed. Bale dimensions can be also measured outside the press box (dimensions a_4, b_4, c_4). The average density of the bale in and out of the pressing box is given by the expression

$$\rho_3 = \frac{G}{a_3 . b_3 . c_3} > \rho_4 = \frac{G}{a_4 . b_4 . c_4} \quad . \tag{1}$$

where:

$\rho_{3,4}$ – specific weight of the bale in the press box (index 3) and outside the press box (index 4) ($kg.m^{-3}$),

G – bale weight (kg),

$a_{3,4}$ - bale width in the press box (index 3) and outside the press box (index 4) (m),

$b_{3,4}$ - bale height in the press box (index 3) and outside the press box (index 4) (m),

$c_{3,4}$ - bale length in the press box (index 3) and outside the press box (index 4) (m).

The average density, also known as compactness, which is a contractual designation for the specific weight of the bale ρ_4 is calculated from the weight of bale G and its dimensions outside the press box. When a bale is pushed out of the pressing box, it is enlarged by a flexible deformation, and this flexibility is approx. 4 to 6 % in length and about 15 % in volume. For processing new sheet metal waste from pressing shops, for example from car manufacturing companies, baling presses with forces needed for each pressing operation are designed up to 3.15 MN, where the bale profile dimensions are 300 mm x 300 mm or 400 mm x 400 mm, and the bale lengths range from 200 mm to 600 mm. Requirements from the customers for the bales to be approximately the same length even when they are repressed to full force, are solved in pressing shops by weighing sheet metal cuts before they are feed into the pressing box – the same weight of the dose for each bale must be observed. The bale density ρ_4 is achieved from 3,000 to 3,500 $kg.m^{-3}$.

In large treatment plants (former plants called Kovošrot = scrap metal plants, or in their successor companies), large baling presses are used in the Czech Republic, with max. forces of any of the pressing operation ranging from 4 MN to 12.5 MN. Bales then have a cross-section from 500 mm x 500 mm for a press with the tonnage of 4 MN and up to 800 mm x 800 mm for a press with the tonnage of 12.5 MN, the length of bales is up to 2,000 mm. The bale density ρ_4 can be from 2,000 $kg.m^{-3}$ to 3,000 $kg.m^{-3}$. Small baling presses of a tonnage around 1 MN are also used for pressing a bale of 300 mm x 300 mm with a length of up to 600 mm. These presses are mainly used for the treatment of suitable waste concerning non-ferrous metals. The latest trend of recent years is to use movable baling presses with a tonnage of approx. 1.4 MN placed onto trailers with bales reaching 500 mm x 800 mm and with a length of up to 1000 mm, with a bale density ρ_4 = 1,500 $kg.m^{-3}$ to 2,500 $kg.m^{-3}$. Bale purchaser requirements for their average density vary widely, as some require the density of a bale to be such that the bale can withstand transportation and does not fall apart, and some demand the highest possible density.

4. TRIAXIAL BALING PRESSES AND THEIR MAIN PARTS

When converting the original metal waste with a density from 0.1 $t.m^{-3}$ to 0.6 $t.m^{-3}$ into a compact bale of a density from 2 $t.m^{-3}$ to 3.5 $t.m^{-3}$, it is necessary to overcome the forces arising from

- the deformation of the pressed material,
- the displacement of the compressed parts on the top of others,
- the displacement of the pressed scrap along the press walls

All these forces depend on the amount, type and orientation of the scrap loaded into the baling press. Even if a batch of the same homogenous scrap and weight is fed (for example, metal waste from sheet metal pressing shops), the resulting bales will be of different lengths and, therefore, of different densities. When pressing amortization scrap under comparable conditions, the dispersion of density is roughly in the range of ±25 %.

In practice, baling presses use usually press scrap in one, two, or three directions of mutually perpendicular axes [4]. The latest group is the most often one used for the production of bales charged into steelmaking furnaces [5], [6], [7]. Practically, there are two different designs of presses in this group. These are presses with a vertical precompress **Figure 2** and presses with a horizontal precompress **Figure 3**.

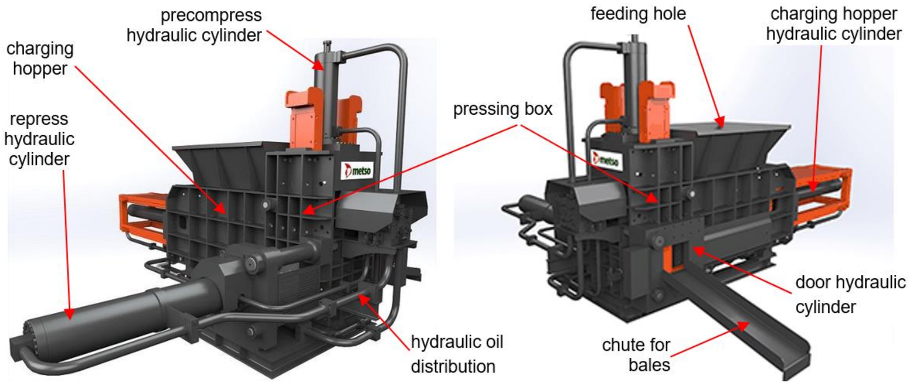


Figure 2 Scheme of a triaxial baling press with a vertical precompress [8]

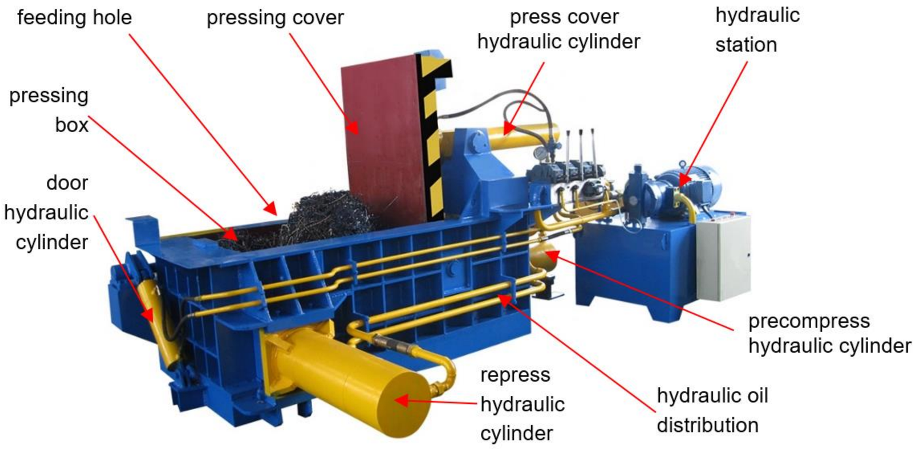


Figure 3 Schematic diagram of a triaxial baling press with a horizontal precompress [4]

Charging hopper moves scrap from the loading area into the pressing box. It consists of a loading trough, in which the pusher of the hopper moves. According to the specific design, the front wall of this pusher forms either one wall of the pressing box, i.e. presses the scrap to one dimension of the bale, or just moves the scrap to the pressing box.

Feeding hole is an opening intended for loading the scrap to the press. For the press illustrated in **Figure 3** the dimensions are given by the size of the pressing box with an open cover, for presses according to **Figure 2** it is given by the width of the charging hopper with the pusher and the length that the pusher travels.

Pressing box is the space of the press in which the scrap is formed into the final shape of the bale. Some walls of the pressing box are movable. The number and position of movable walls is determined by the baling press design.

Tilting hopper allows the preparation of the loading batch during the pressing period. It is located above the feeding hole so that after tilting the waste scrap chutes into the space of the pressing box. Feeding the scrap into the tilting hopper also allows the very rough sorting of the scrap before pressing it. After releasing the feeding hole, the scrap is tilted and chuted into the space of the hopper with the pusher, respectively into the pressing box.

Precompress is the name of the penultimate pressing operation, in which the scrap is pressed to the bale cross-section with a length corresponding to the width of the pressing box. The ability of the precompress to fill the designated space with a sufficient amount of scrap is given by the size of the bale and thus the performance of the press. For the proper work of a press, travel of the precompress to achieve the required size of bale is determinative. In other words, the precompress pusher must reach the given position (location), otherwise it is not possible to proceed with another pressing operation. Technically, it is possible to remove incorrectly pressed bales, but basically these are considered to be rejects.

Repress is the last pressing operation when the bale is pressed to the final length. The termination of pressing is due to the increase in pressure in the hydraulic circuit and reaching the predetermined value. In other words, the pusher of the repress reaches the maximum force that it is capable of developing. When the pressure is reached, bale pressing is finished. The finished bale is then moved out of the pressing box by the pusher. The full power of the press is available to push the bale out.

Door closes the pressing box on the opposite side to the repress. By opening the door, it is possible to push out the finished bale from the press.

Pusher is a rectangular or square body that moves inside the press in a straight line, is in contact and forcefully acts on the pressed metal waste, and is driven by a hydraulic cylinder of individual pressing operation stages. The triaxial baling press with a vertical prepress in **Figure 2** is equipped with three pushers – a charging hopper with pusher, precompress and repress.

Press cover represents for presses with a horizontal precompress, as in **Figure 3,** the first pressing operation, when the waste in the pressing box is compressed to the height of the bale by this press cover. The following two pressing operations, i.e. precompress and repress, are done by means of pushers.

5. FACTORS INFLUENCING THE PRESS DESIGN

The design of the baling press is mainly influenced by the following factors:

- the quantity of available scrap suitable for baling,
- the required bale cross-section, sometimes even the density of a bale,
- scrap thickness, or eventually proportional representation of the scrap thicknesses,
- the dimensions of the processed scrap,
- the purity and condition of the scrap.

For the economical operation of baling technology, a sufficient amount of scrap suitable for baling is essential. For the smallest presses, it is necessary to have around 6,000 t of light scrap per year, for large machines to have a quantity of about 100,000 t per year. If a certain specific cross-section of the bale and hourly output are required, the dimensions of the press are this way specified, and also dimensioning for the hydraulic drive is determined. If a specific cross-section of a bale is not required, a larger cross-section is preferred, with regard to the press performance. The cross-section of the bale has a very significant impact on the performance of the press. Scrap thickness is the biggest limitation to baling technology. Scrap with a maximum wall thickness of about 12 mm can be processed. However, scrap of such a thickness can be processed only on large baling presses. It is recommended that scrap with a maximum wall thickness should account for a maximum of 20 % of the batch. The rest of the batch must consist of scrap with a lower thickness (about 50 % of scrap with up to its half thickness). The fed scrap should not exceed the dimensions of the feeding hole designed for a given baling press. Additional enlarging of the feeding hole is very costly. So, it is always necessary to choose between the possibility of purchasing a larger press and thus obtain a resulting higher performance at increased purchasing costs or introducing increased costs for the pre-treatment of the scrap. When designing a press, it is necessary to consider not only the largest dimensions of the scrap, but also its smallest dimensions. If the thickness of the smallest scrap is comparable to the clearance between the press wall and the pusher, or it is necessary to press scrap of a size comparable to e.g. coins, it is necessary to line all surfaces in contact with the scrap using grooved sheets to prevent pushers get stick inside the pressing box. Despite these measures, the coins will not be fully pressed into the bale and after pushing a bale out of the press, the part of the smallest scrap will fall off the bale, but the press will be not damaged. Within a project, the designer and contractor must remember to consider these weight losses. Scrap able to be baled, especially amortization scrap, is the largest source of impurities polluting steel. An impurity in steel is considered to be anything that is not intentionally added to steel to achieve the required steel properties, or for other reasons. It is, therefore, clear that material suitable for baling are those that are unpolluted, homogenous, and preferably with a known chemical composition, so that alloying elements from scrap can be used in creating the steel chemical composition.

6. CONCLUSION

The technology of metal scrap processing by bailing is one of the most economical methods of preparing a charge for steelmaking furnaces [8]. When using this technology, it is very important to ensure, above all, the purity of the feedstock – processed scrap. This can be achieved by consistent sorting, i.e. by removing all undesirable impurities. The baling operation is carried out on a machine called a baling press. The feedstock for the baling press is loose pure metal waste scrap, and the output product leaving the baling press is the so-called bale. The largest baling presses process metal waste acting in three perpendicular axes. Bales produced this way can reach a specific weight up to 3,500 kg m^{-3} and the cross-section of a bale can be (height x width) approx. 800 mm x 800 mm.

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