SELECTED DESIGN PARAMETERS OF BALING PRESSES FOR THE TREATMENT OF STEEL SCRAP AS A CHARGE FOR STEELMAKING FURNACES

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Abstract

The preparation of the charge for steelmaking furnaces is a key area from the point of view of the quality of the produced steel. One of the most important components of the charge is the treated steel scrap (in general, you can say metal waste). Technologies such as shearing, crushing and briquetting are currently used to treat steel scrap. Among the most widespread and, at the same time, the most economical technologies for the treatment of steel scrap is the baling technology, which can be described as the pressing of steel scrap, which takes place in the direction of three axes at most and that axes are perpendicular to each other. This technology is realized by means of so-called baling presses. The design of the individual structural nodes of the baling press itself has a significant influence on the correct way of charge adjusting when using baling technology. The presented article will inform readers about the possibilities of determining selected design parameters of the baling press.

Keywords: Steel scrap, steelmaking, baling press, design, charge for steelmaking furnaces

1. INTRODUCTION

The idea to compress light and bulky scrap in several directions to achieve a greater specific weight was taken from a similar technological process used for pressing agricultural products, such as jute, wool, and similar materials. The process of pressing light metal scrap into bales to achieve a higher specific weight is called baling. This technology has a positive effect on transport costs, the way of charging the steelmaking furnaces and thus the course of the metallurgical process itself. Baling is a technology that eliminates the possibility of subsequent sorting. The chemical purity of the scrap is determined by the possibility and efficiency of the preliminary sorting process. Baling is used to process mainly homogenous materials, preferably of the same composition, from which impurities, adversely affecting the quality of the steel produced, are removed [1]. The efficiency of the pre-sorting process depends on the work organization and machinery provided by the scrap yard. If these parameters do not reach the required level, the bales may have a higher content of undesirable impurities, which can in turn affect the quality of the melt. This implies that baling technology is best suited for materials with known chemical composition and for scrap grades where contamination is not anticipated [2].

This article aims to present important information concerning the technology of iron scrap preparation, specifically about the possibility of determining some design-construction parameters of the baling presses. This information could help potential users of scrap metal baling technology to get orientated much faster in the issue and the offers of baling press manufacturers.

2. DESIGN CALCULATIONS

If we want to use baling technology, it is advisable to first determine the basic design parameters of the baling press. As far as customer requirements are concerned, in most cases the following parameters are required for a particular baling press:

- bale cross-section S (m^2),
- annual occurrence of baling scrap Q (t).

In some cases, these parameters are supplemented by additional requirements, such as:

- bale weight G (t).
- the specific weight of the finished bale ρ_b ($kg.m^{-3}$).

The bale weight is usually specified when the baling press is equipped with weighing and dosing devices. Therefore, if we do not consider the weight of the bale, then we take into account the cross-section of the bale, the annual occurrence of the baling scrap and the specific weight of the finished bale.

2.1 The determination of forces for individual pressing operations

From the required or selected specific weight, we determine the appropriate specific pressure, and we determine the magnitude of the force F_{ro} needed for the hydraulic press cylinder according to the relationship below.

$$F_{ro} = S\ p \tag{1}$$

where: F_{ro} - the force of the hydraulic cylinder for the repressing operation (MN),
p - pressure on the repressing pusher for the required specific weight of the bale (MPa).

If the required specific weight of the bale is not specified, it must be determined with regard to the specific pressure on the pusher of the last pressing operation - repressing. For the designed specific weight of the bale, it is necessary to determine the amount of force for the repressing. For these purposes, we have the so-called contract curve (**Figure 1**), which indicates the dependence of the specific weight of the bale ρ_b on the specific pressure of the press finish pusher **p**.

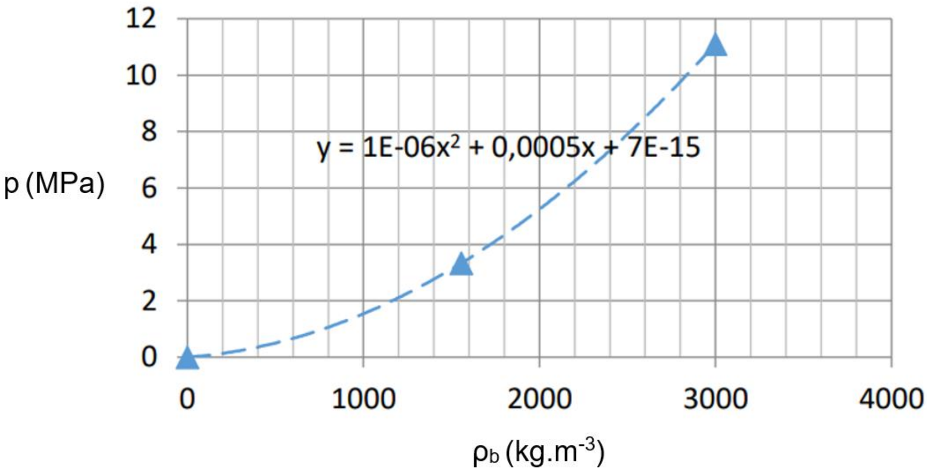

Figure 1 Example of the so-called contract curve [4]

For example, a baling press with folding hoppers marked as CPS630 produced by ŽĎAS,a.s. has, according to the catalogue data, pressure for a pusher needed for repressing approx.17MPa, and a baling press with a CPB400 folding cover cca16MPa [3].

Depending on the power of the repressing, it is possible to size the required forces for the remaining pressing operations, both regarding the scrap pressing itself and with regard to the effect of the side forces acting during the pressing operation.

For baling presses designed to process the baling scrap of various thicknesses, sizes and forms, the hydraulic cylinder force applied to the pre-pressing operations should be $F_{po} \geq F_{ro}$.

F_{po} = (1÷1.3) F_{ro} (MN) (2)

Lower pre-pressing forces F_{po} are selected for baling presses designed for the treatment of homogenous baleable scrap, mostly equipped with weighting and dosing equipment (e.g., sheet metal press operations), and the bales have the length **l** of no more than twice the side of the bale **a**, so here applies that l ≤ 2.a.

For such presses, it is possible to choose

F_{po} = (0.6÷0.8) .F_{ro}. (MN) (3)

For the strength of the hydraulic cylinder for the folding hopper or press cover $F_{pc,}$ it is possible to apply a relationship

F_{pc} = (0.3÷0.5) F_{ro} (MN) (4)

and the force of the hydraulic cylinder door F_d can be determined from the relationship

F_d = (0.2÷0.4) F_{ro} (MN) (5)

For the hydraulic cylinder of the door, cover and folding hopper, the speed of piston rod movement is recommended to reach approximately 0.5 $m.s^{-1}$, so that the performance of the hydraulic drive is economically efficient [5].

The contract curve gives only one specific weight value. However, in practice, the specific weight value shows a variance in the range of approx. ±25 %. The contract curve, therefore, represents a kind of mean value of the specific weight of the bale. To determine the performance of the baling press, the contract value of the specific weight ρ_{cv} should be considered the upper limit ρ_{max} and the lower limit ρ_{min} is obtained after subtracting the anticipated variance

$\rho_{max} = \rho_{cv}$ ($t.m^{-3}$) (6)

$\rho_{min} = 0{,}75\ .\ \rho_{cv}$ ($t.m^{-3}$) (7)

2.2 The determination of baling press performance

To determine the amount of compressed scrap per hour, two extreme representatives of the produced bale are usually selected. The minimum bale is assumed to be in the shape of a cube and the maximum bale has a length of approximately 65% width of the compression chamber **K**, which is e.g. for a baling press equipped with a folding hopper (or a so-called vertical prepress offered by the company ŽĎAS, within the range of CPS products) CPS l = 0.9 to 1.96 m, and presses with a folding cover (or a horizontal prepress, offered by ŽĎAS in the range of CPB) which is CPB l = 1.0 - 2.6 m, according to the size of the press [7], [6]. According to the already determined force required for the repressing operation $F_{ro,}$ the size of the press can be determined, and then it is possible to define the size of the press and then the extreme values of the bale volume V_{min} and V_{max} with its dimensions in m^3

$V_{min} = S^{1,5}$ (m^3) (8)

$V_{max} = S \cdot 0{,}65 \cdot K$ (m^3) (9)

When calculating the bale weight, we consider ρ_{max} for minimum bale volume $V_{min,}$ and for maximum bale volume V_{max} we consider ρ_{min}. Then we determine the extreme bale weight values in tons G_{min} and G_{max}. To determine the output per hour for the press stated in the number of bales pressed per hour, denoted as **n**, we consider the arithmetic mean G_{am} for both weights G_{min} and G_{max}. If the baling press will work in a two-shift operation, then its annual working time is about 2,500 hours. The required output per hour for the press Q_H in tons per hour is then determined as the ratio of value **Q** and figure 2,500.

From the known output per hour Q_H and the bale weight G_{am} then we can divide them and determine the number of bales per hour **n**, which must be pressed by the baling press to process the required amount of scrap **Q** within a year.

Taking into account the time required to press one bale, it may be provided that if the value **n** lies within the recommended range of values, then these requirements can be met by a suitable (efficient) choice of parameters for a hydraulic drive. It is recommended that if the number of bales is less than approx. 25, either the annual occurrence of the baleable scrap **Q** shall be reassessed, or the bale cross-section **S**. If the number of bales exceeds approx. 60 (in case of heavy bales), then it is possible to change the bale cross-section **S** or use a larger number of baling presses so that the number of bales per hour does not exceed the maximum recommended value.

If bales of specified weight are required by the customer, the press must be equipped with a weighting and loading device and the dispersion of bale weight is then determined only by weighing them. In this case, the calculations are simplified, since in these cases we can consider that $\rho_{max} = \rho_{min} = \rho_{cv}$ and the bale weight is the value given as **G**.

3. DIMENSIONS OF THE PRESS CHARGING CHAMBER

The mass of the bale G_{am}, which is taken as the basis for determining the performance parameters, is calculated with a certain allowance which includes the estimation of the charge size weight by the press operator. To determine the size of the charging chamber, the parameters of the average bale G_{ab} are used, given by the ability of the press to compress the loaded batch of the scrap charge. It can be therefore assumed that the ratio of the maximum and minimum weight of the estimated and weight scrap batch is given by the value of the number three, whereas in practice it is more likely that a bigger charge will be dosed [5]. The weight of the average bale is then given by the following equation

$$G_{ab} = 2G_{min} \quad \text{(t)} \qquad (10)$$

where $G_{min} = S^{1.5} \cdot \rho_b$ (t) (11)

Provided that the specific weight of the scrap suitable for baling is within the range of 100 ÷ 600 [kg.m^{-3}], the volumes determined below for V_{min} and V_{max} correspond to the volume of the average bale at a given specific weight of the scrap

$$V_{min} = \frac{G_{ab}}{0,6} \quad (\text{m}^3) \qquad (12)$$

$$V_{max} = \frac{G_{ab}}{0,1} \quad (\text{m}^3) \qquad (13)$$

The charging chamber volume (**Figure 2**) can be designed so that the chamber accommodates the volume of the scrap corresponding to the mean of the two defined volume extremes V_{min} and V_{max}. When charged with lighter scrap, the batch will exceed the volume of the press, but as this scrap is light, it can be easily pressed into the pressing chamber using the folding cover. When pressing the lightest types of scrap, it is possible to proceed in such a way that the first batch of loaded scrap is adjusted in height by the folding cover to obtain the height of the bale, pressed using a prepress to about half of the prepress stroke, and subsequently, the pusher of the prepress is returned, the folding cover opened and a second dose is loaded. The volume of the charging chamber V_{cc} is then determined by the expression

$$V_{cc} = \frac{V_{min} + V_{max}}{2} \quad (\text{m}^3) \qquad (14)$$

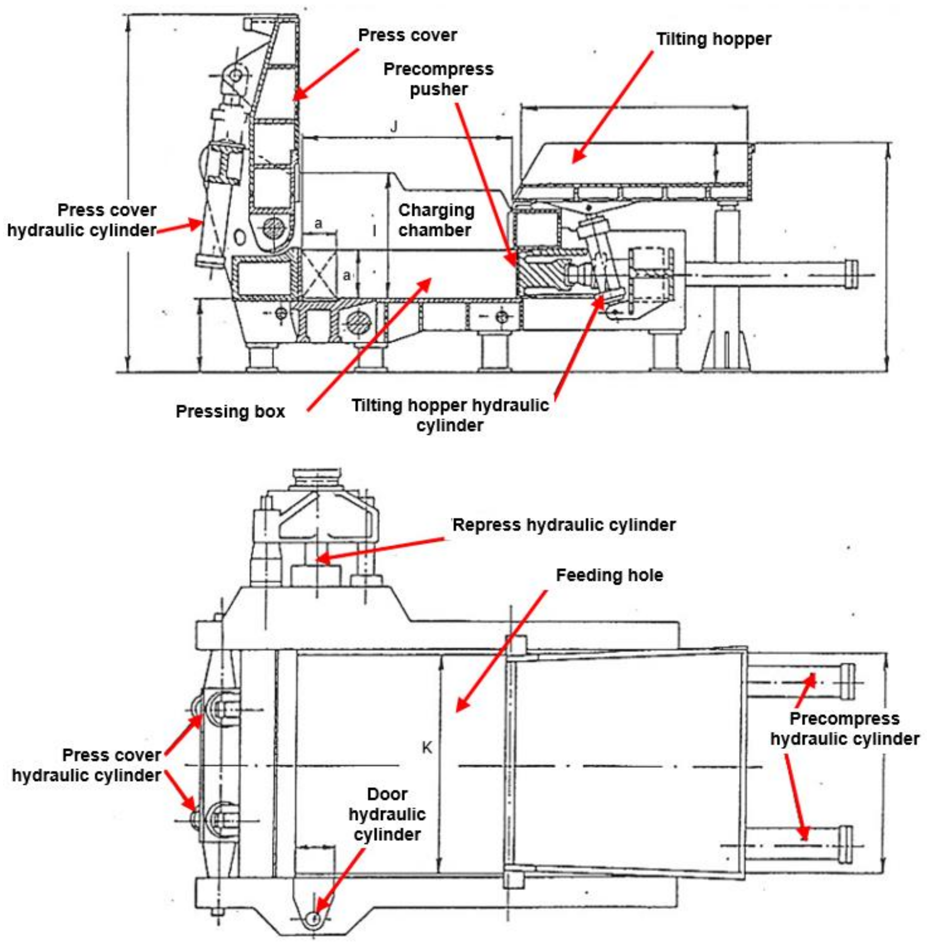

Figure 2 Schematic diagram of a baling press with a folding cover [5]

The shape of the bale cross-section is in most cases considered to be square, and so the length of the side **a** can be determined from the equation

$$a = \sqrt{S} \qquad \text{(m)} \tag{15}$$

The height of the charging chamber **l** in **Figure 2** can be determined using the relationship l = (2÷2.3).a.

From the known height **l** and volume V_{cc} for the charging chamber, we can calculate the area needed for the charging space S_{cs}

$$S_{cs} = \frac{V_{cc}}{l} \qquad \text{(m}^2\text{)} \tag{16}$$

The width of the charging chamber **K** can be obtained using the expression

$$K = \sqrt{\frac{S_{cs}}{(1.3 \div 1.2)}} \qquad \text{(m)} \tag{17}$$

The length of the charging chamber (loading space) **J** must be chosen depending on the width of the charging chamber width **K,** according to

$$J = K \cdot (1.1 \div 1.3) \qquad \text{(m)} \tag{18}$$

The necessary stroke of the hydraulic cylinder for the precompress is then

$$s_p = J - a \qquad \text{(m)} \tag{19}$$

4. CONCLUSION

Nowadays, baling technology is one of the most widespread and, at the same time, the most economical technologies for the treatment of metal scrap and the preparation of charges for steelmaking furnaces. Baling is carried out on a device called a baling press. When converting a baleable metal scrap with a loose weight from 0.1 to 0.6 t m^{-3} into a compact bale with a specific weight of 2 - 3.5 t m^{-3}, it is necessary to overcome the forces that arise from the deformation of the compressed material, the friction of this material rubbing one after another, and rubbing the compressed scrap against the walls of the press chamber. All these forces are very difficult to be defined, due to the considerable diversity of the scrap. They are dependent on the quantity, type and orientation of the scrap charged into the press. These conditions are practically different for each baling dose [5], [8]. The main task of designers is to design baling presses capable of pressing metal scrap into bales dealing with their diverse properties. The aim of this article was to provide information about the possibility of determining some design parameters for baling presses. This information should help potential users of baling technology to get well-oriented in the technical characteristics of baling presses offered in the catalogues of their manufacturers.

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