BRIQUETTING OF CHIPS FROM NONFERROUS METAL

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Abstract. The paper presents pieces of knowledge obtained at chips briquetting at metal cutting. For briquetting the functional model of the briquetting press of our own construction was used. Experiments were carried out using eight chips types obtained at three different cutting methods and five different nonferrous metal alloys. By the evaluation of the measured values the relations between the briquettes volume density and the briquetting pressure and between the force needed for the briquette destruction and the briquetting pressure were obtained. It was proved that the briquettes volume density depends very much on the material which the briquettes are made from. Next influences (cutting method, chips size) are less meaningful. From the point of view of the relation between the destruction force and the briquetting pressure it was found that the resistance to crushing of briquettes made from copper alloys was minimal, the resistance to crushing of briquettes made from aluminium alloys was major and the resistance to crushing of briquettes made from zinc alloys was the highest.

Keywords: metal cutting, chips, briquetting, briquettes properties.

Introduction

At the relative motion of the cutter edge and the workpiece the cut off material is plastic deformed and creates the chips. The chips volume is evaluated using the chips volume change coefficient W, which is calculated as the ratio of the unpressed chips volume to the cut off metal volume. The chips volume depends on the cutting conditions – e.g., on the machined material, geometry of the tool etc. Chips are the scrap, which is necessary to remove from the place of cutting. Therefore, it is the endeavor to minimize the value of the volume change coefficient (e.g., by the use of the chip-former). In practice its values vary in the large range – from 3 to 600. One of the possibilities of the chips utilization is the briquetting.

Advantages and disadvantages of briquetting

Briquetting is the pressure moulding of small grained materials into regular shapes - briquettes. Briquettes are mostly of cylindrical shape. But they are made in the form of stones with corner fillet or hexagonal prism, too. Briquetting is used for metallic as well for nonmetallic materials. The coal briquettes, made by briquetting of coal dust, are widely known. In the last years the power-producing use of ecological briquettes from wood waste increases.

The greatest preference of briquetting is the considerable volume reduction of the treated materials (Figure 1).

Fig. 1. **Chips before and after briquetting**

It makes possible or easy the handling and the subsequent utilization of metallic and nonmetallic scrap. Usually nonferrous materials are utilized by power production (combustion), metallic scrap is metallurgical utilized (as material). After briquetting the transportation costs of both material groups expressively decrease. The disadvantage of briquetting is the necessity of the suitable plant acquisition and the lack of information which concerns this method.

Briquetting of metallic scrap

The standard ČSN 42 0030 engages in steel and cast iron scrap problems of purchase, grading, testing, storage, supply, records, control, transport sampling and checking. The same problems of nonferrous metals and their alloys are solved by the standard ČSN 42 1331.

In the standard ČSN 42 0030 the briquettes from steel chips are presented as the type 38. The following requirements are demanded for briquettes: the volume density over 4500 $kg \cdot m^{-3}$, the smear and moisture content is subtracted from the delivery weight. Briquettes from cast iron chips are presented as the type 08. The requirements are analogous: the volume density over 4500 $kg \cdot m^{-3}$, 1 % of oil is allowed. In the standard ČSN 42 1331 the briquettes are presented as the type 176 – machine briquetted material; form, size and weight according to the used plant. With regard to different properties of nonferrous metals the demands concerning the volume density are not presented.

Contemporary a row of inland and foreign producers offer their products. Briquettes made using their presses are very different in form, size and weight – from small of 30 mm diameter and about 0.1 kg weight to big ones of 200 mm diameter and about 30 kg weight (see Figure 2).

Fig. 2. **Briquettes from steel and brass chips**

Materials and Methods

For tests the chips resulting from the cutting operations of five different alloys from non-ferrous metals (AlSi10, AlSi9, CuZn35, CuSn10 and ZnAl4Cu1) by use of three cutting technologies (turning, milling, sawing) were collected.

Briquetting was carried out using the functional press model of the own design. The universal tensile testing machine ZDM 5 of maximum force F_{max}=500 kN was the force source for briquetting. The press model was located between its pressure plates. Using the maximum force and the piston diameter of 40 mm the briquetting pressure was next to 400 MPa. The above presented arrangement makes it possible to study the properties of briquettes, made under wide pressure range. Using firm presses this study is impossible.

At the tests the charges of the same weight were prepared from each of the tested materials. The chips were poured into the pressing chamber, closed by the piston and loaded using various forces (from 50 to 500 kN). After removing from the press the briquettes were weighted, their volume measured and using this data the volume density was calculated. For the judgment of strength, which was necessary for the successive handling, the plate loading test (Figure 3) and compression test were used. The tests confirmed the hypothesis, that for briquettes compactness the plate-loading test is critical (the compression test was problematic and further this test was not used).

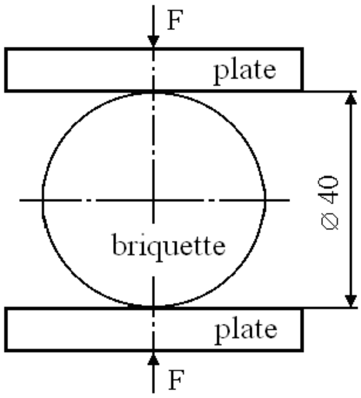

Fig. 3. **Schematic representation of briquette test: plate-loading test**

Results and Discussion

The plate-loading test results of briquettes from the chosen non-ferrous metals are presented in two following diagrams. Figures 4 and 5 represent the briquettes density – briquetting pressure relationship of the tested chips from non-ferrous metals. Figure 6 presents the relationship between the forces (reduced to the briquette unit length of 40 mm) needed for the briquettes destruction and the briquetting pressure.

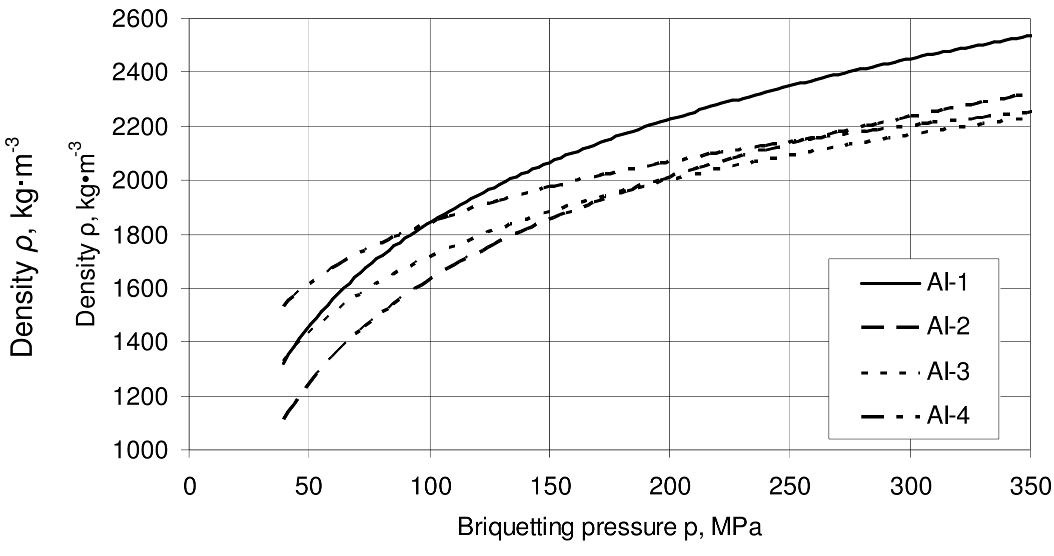

Fig. 4. **Relationship between the briquettes density and the briquetting pressure at the aluminium alloys briquetting**

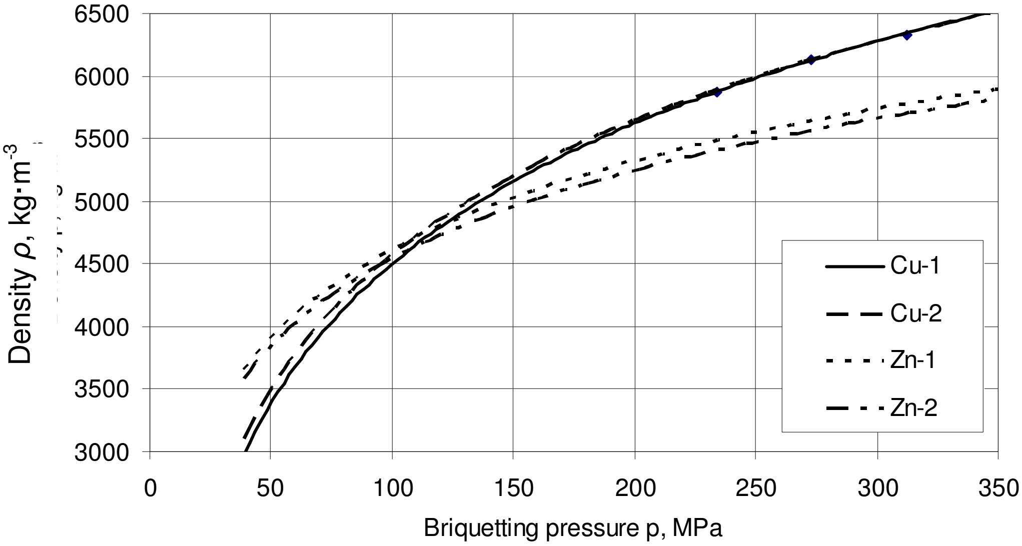

Fig. 5. **Relationship between the briquettes density and the briquetting pressure at the copper and zinc alloys briquetting**

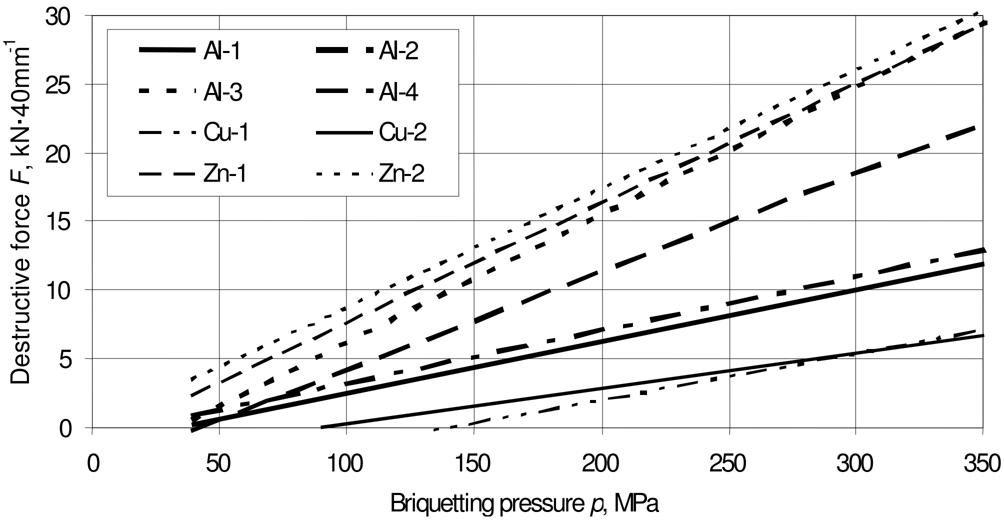

Fig. 6. **Relationship between the destructive force and the briquetting pressure at the non-ferrous metals briquetting**

Using the program EXCEL the measured values (Figures 4, 5 and 6) were interlaid. The equations of regression curves are presented in Tab. 1 (for the relation volume density – briquetting pressure) and in Table 2 (for the relation destruction force – briquetting pressure). In this place it is necessary to remind that the diagrams and equations are valid only in the tested range.

Table 1

Relation volume density - working pressure

Briquetted material	**Sample mark**	**Equation of regression ρ=*f* (*p*)**	**Determination coefficient R^2**
Al alloy (AlSi10) – turning	Al-1	$\rho = 553.3 \cdot \text{Ln}(p) - 705.5$	0.991
Al alloy (AlSi10) – milling	Al-2	$\rho = 552.8 \cdot \text{Ln}(p) - 916.5$	0.985
Al alloy (AlSi9) – turning	Al-3	$\rho = 412.8 \cdot \text{Ln}(p) - 185.5$	0.980
Al alloy (AlSi10) – sawing	Al-4	$\rho = 329.2 \cdot \text{Ln}(p) + 325.6$	0.996
Cu alloy (CuZn35) – milling	Cu-1	$\rho = 1615.9 \cdot \text{Ln}(p) - 2939.4$	0.998
Cu alloy (CuSn10) – sawing	Cu-2	$\rho = 1556.6 \cdot \text{Ln}(p) - 2598.2$	0.997
Zn alloy (ZnAl4Cu1) – turning	Zn-1	$\rho = 1024.2 \cdot \text{Ln}(p) - 102.5$	0.995
Zn alloy (ZnAl4Cu1) – milling	Zn-2	$\rho = 1018.3 \cdot \text{Ln}(p) - 147.4$	0.989

Table 2

Relation destruction force - briquetting pressure

Briquetted material	Equation of regression $F = f(p)$	Determination coefficient R^2
Al alloy (AlSi10) – turning	$F = 37.3 \cdot p - 1231.5$	0.975
Al alloy (AlSi10) – milling	$F = 71.9 \cdot \mathrm{p} - 3157.1$	0.969
Al alloy (AlSi9) – turning	$F = 92.9 \cdot p - 3170.7$	0.963
Al alloy (AlSi10) – sawing	$F = 38.8 \cdot p - 741.8$	0.983
Cu alloy (CuZn35) – milling	$F = 33.7 \cdot p - 4720.1$	0.963
Cu alloy (CuSn10) – sawing	$F = 25.4 \cdot p - 2290.9$	0.987
Zn alloy (ZnAl4Cu1) – turning	$F = 87.2 \cdot p - 1111.7$	0.981
Zn alloy (ZnAl4Cu1) – milling	$F = 86.6 \cdot p - 35.9$	0.979

From the results it follows that at all tested materials the volume density and destruction force increase with the increasing briquetting pressure.

At briquettes from non-ferrous metals the comparison of the test results with the standard is not possible. Wide assortment of in practice used non-ferrous metals and their alloys are the reason. But the ratio of the briquettes density to the same compact material density offers itself to the possibility of evaluation, analogously as it is used for evaluation of briquettes made from steels and cast irons (according to CSN 42 0030). For this comparison intention the density of steel 7850 $kg \cdot m^{-3}$ and the density of cast iron 6800 $kg \cdot m^{-3}$ were taken into consideration. With respect to the standard CSN 42 0030 it is possible to state that the steel and cast iron briquettes density is about 0.57-0.66 of the compact material density. Then the briquettes density from aluminium and its alloys must be of about 1650 $kg \cdot m^{-3}$, from copper and its alloys of about 5200 $kg \cdot m^{-3}$ and from copper and its alloys of about 4400 $kg \cdot m^{-3}$ regardless of the process technology.

These parameters were reached at the following briquetting pressures: at Al alloys about 70 to 105 MPa, at Cu alloys about 150 MPa, at Zn alloys about 85 MPa. Keeping these conditions the briquettes of satisfactory properties were obtained. Nevertheless, the authors of this paper assume that in practice rather higher briquetting pressures should be used (of 10 to 22 %). Using the above mentioned briquetting pressures for the destruction of briquettes of 40 mm diameter and 40 mm length the force of 2100 to 5200 N for Al alloys, of 350 to 1500 N for Cu alloys and of 6300 to 7300 N for Zn alloys is necessary. The next briquetting pressure increase contributed no doubt to the density mild increase, but the briquettes mechanical properties increase was expressively slower. Therefore, it is possible to say that the above described process is applicable for the prognosis of non-ferrous chips briquetting conditions.

Conclusions

1. The paper contains the laboratory test results of chips briquetting. The chips were made from chosen alloys of non-ferrous metals. The functional model of briquetting press of the own design was used. By means of this press the relationships density – briquetting pressure and destruction force – briquetting pressure were determined.
2. The tests were carried out using eight chip sorts resulted from turning, milling and sawing of two different aluminium alloys, two different copper alloys and one zinc alloy. For evaluation the plate-loading test, for the force inducing the universal tensile testing machine were used. The test results are presented in form of diagrams and tables.
3. The test results confirmed the authors' hypothesis that for non-ferrous metals briquetting it is possible to take over the numerical ratio of the chips density to the compact material density for ferrous materials, the value of which is about 0.6.

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