11th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2007, Hammamet, Tunisia, 05-09 September, 2007.

MAIZE COBS PROCESSOR – PREPARATIONS FOR ITS USE AS A FUEL

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ABSTRACT

In agricultural regions of Serbia, especially in the Province Vojvodina, Serbian part of Pannonia plane, maize is most significant crop. Almost all small and majority of medium farms apply harvesting by use of picker-husker. First after natural drying and threshing of grains, maize cobs are residual biomass available for energy use.

Modern farmers need more comfort and advanced heating facilities, e.g. boilers with automatic feeding. The objective was to develop processor for maize cobs crushing. The cobs should be so sized to enable feeding by use of charging screw, commonly used for wood chips. This will enable, after adjustment of combustion technique, use of serial produced boilers and feeding equipment. The following prerequisites have been set up: the processor has to be low-cost type, and produced granulation should fulfil demands similar to these defined for wood chips used as a fuel.

Using previous experience with similar material the prototype based on cylinder with spirally positioned knives, stationary comb type knife counter and under-sieve has been selected and designed. The effects of stationary knifes, RPM of cylinder, different under-sieve openings and distance of sieves to rotated knife trajectory has been tested, and crushed maize cobs analyzed.

The results showed that this processor can be successfully used for crushing of maize cobs for it use as fuel in boilers with crew conveyor, commonly used for wood chips. The fuel flow, due to lower density of crushed maize cobs, should have about 1.5 times bigger volume. The capacity of processor overcomes need of one user. It can supply enough fuel for four to five consumers.

Keywords: solid biomass, maize cobs, crushing

1. INTRODUCTION

Biomass is traditionally used in rural areas in the countries of the Pannonia plane as a fuel for household heating and other purposes. In the Serbian part of the Pannonia plane, Province Vojvodina, maize is the major crop. Most of small and medium farms, owning two thirds of arable land, use picker-husker for maize harvest. The harvested maize ears without husks are dried naturally in traditional maize drying bins. After drying and shelling of grains, dry maize cobs are available as residues in farm yard. The calorific value of dry mater is about 17 MJ/kg, as for the other crop residues. Yield of maize cobs is 12 to 20% compared with grain yield, with the same moisture content. This biomass is very interesting as a fuel for household heating. Advanced and progressive farmers expect from heating facility to be more comfortable, while the society expects higher efficiency and lower pollutants emission [1]. This was the motivation for the development of a continuous feeding boiler like the model which is used for wood chips combustion.

The maize cobs have to be prepared, i.e. crushed for this purpose. The following demands should be fulfilled:

1. The maize cobs length should be reduced so as to enable transport, combustion chamber feeding, by screw elevator, used for wood chips or similar.

2. The maize cobs may not be too intensive crushed to generate small particles, under 2 mm, whose are not suitable for controlled combustion. Ideal length is 1-1.5 of maize cob diameter.
3. The processor, crusher, should be simple, inexpensive, with high capacity that should enable user to prepare, within one hour fuel needed for two or more days.

As the base for size reduction were used requirements defined for wood chips in Austrian standard ONORM M 7133 [2], and draft of European ones [3].

The objective of the project was to develop processor-crusher, and to optimize working parameters in order to fulfill defined demands. This should enable testing and improvement of already used wood chips boilers.

2. MATERIAL AND METHODS

The developed processor –crusher, is presented in Figure 1. It consists of rotating cylinder –1 with spirally placed knifes made of steel band, three spirals with 9 knifes. Two comb-like stationary knifes, ten knifes in total, –2, have a role of counter knifes. Beneath the cylinder there is a sieve –3, whereby the distance to the knife top trajectory –d is adjustable. The drive –4 consists of 1.5 kW electromotor and a belt transmission. Maize combs are fed into the hopper –5, and crushed on their way out through outlet hopper –6. The cylinder diameter of the tested prototype was 500 mm as was the width.

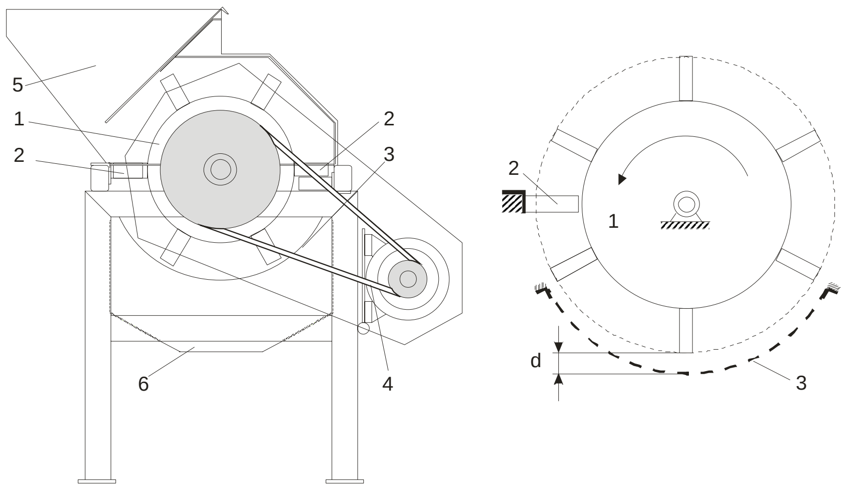

Figure 1. Developed processor for crushing of maize cobs
1– cylinder with spirally positioned knifes, 2– comb like stationary knifes, 3– sieve, 4– drive, 5– feeding hopper, 6– outlet hopper

The cobs of three mostly grown maize hybrids in the region were used for the crushing test. All were air dried with the 12% average moisture content.

The following parameters have been varied:

1. crushing effects with two or one frontally mounted counter knifes (position –2 in Figure 1),
2. cylinder –1 rotation per minute, using frequency converter, the values
3. sieve opening, 25, 30 and 35 mm, and
4. sieve distance to rotated knifes –d, 10, 20 and 30 mm.

The crushed material was analyzed by sieving in plane sieve machine using sieve openings 2, 3.6, 6, 10, 16, 25 and 40 mm, i.e. R10 relation according to [4]. The material in size groups was weighed using 0.1 g scale balance, and the results presented in a log-normal distribution diagram according to [5]. For the sieve openings less than 10 mm the average size was used as the representative value, and for larger sieve openings the representative size was estimated by manual measurement of the samples.

After linearization of the gained points, the results, cumulative mass frequency, the representative particle size distribution line was derived using regression analysis. The median, standard deviation, content of undersized, less than 2 mm particle, and oversized, over 40 mm were recorded and

analyzed. Criteria for crushing evaluation were to achieve as small as possible content of undersized and oversized particles.
The material flow, continues or interrupted, was obtained and evaluated.
The density of crushed maize cobs was tested using cylindrical vessel of 0.3 m diameter and 1 m height. The mass of filled in adequate sized maize particles was measured and density calculated. The average value of ten measuring is used as representative.

3. RESULTS AND DISCUSSION

The best crushing results have been achieved using following parameters:

1. Better results have been achieved if both stationary counter knifes were used. Using counter knifes lot of cobs were only partially crushed, and using only one knife the share of oversized particles was over 8%.
2. The best result concerning sizing of particles and material flow was achieved using RPM in the range 480 to 600.
3. Only by the use of under sieve opening 35 mm enables acceptable share of under- and oversized particles. Additional testing without the under sieve resulted in a high share of oversized particles by all other testing parameters.
4. The under sieve distance of 20 mm gave best results for all other parameters. Smaller distances led to material flow interruption or even blocking. Increased distance resulted in a higher share of oversized or even uncrushed cobs.

Figure 2 shows particle size distribution of crushed maize cobs using suitable parameters drawn as a solid line on a log-normal distribution grid. The normally used distribution parameters median and standard deviation were not used here, but the share of undersized and oversized particles. For the presented distribution both stationary counter knifes were used, cylinder RPM was 600, under sieve opening 35 mm, and sieve distance 20 mm.

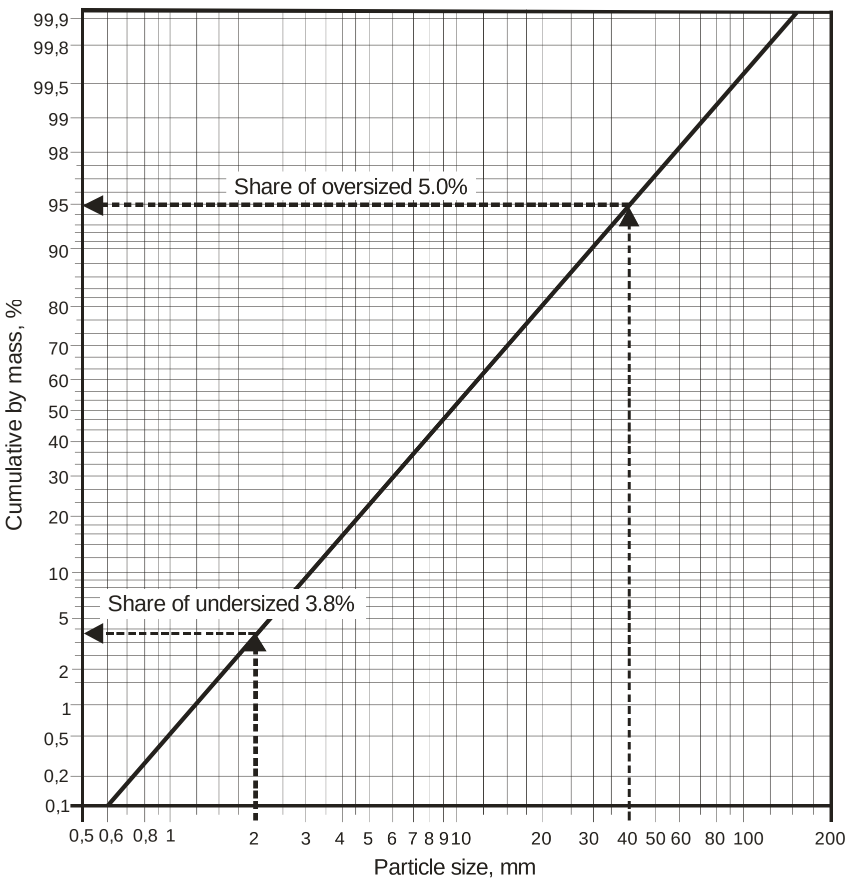

Figure 2. Particle size distribution, best results, drawn as a solid line on a log-normal distribution grid

The share of oversized particles was around 5%, and undersized 3.8%. Similar result has also been achieved for the cylinder RPM 480, but the share of oversized particles was around 7%, and of undersized less than 2%. Both distributions fulfill requirement demands of group G 50 according to Austrian, and group P45 according to draft of European standard for wood chips particle size distribution. It was recorded that smallest part of crushed maize cobs belongs to “lightest” material parts. This could cause the problem in combustion chamber due to their high air flow resistance, and, at least during ignition phase, these parts could be transported by air stream to the chimney.
The average density of the most conveniently crushed material was 190 kg/m^3, which is almost more than double than that of uncrushed cobs –105 kg/m^3. The average value of wood chips density is 290 kg/m^3. This means, the flow volume of maize cobs should be about 1.5 times higher for the same mass. This should be taken into account by adjusting the screw elevator capacity, i.e. control.
Practical testing of screw elevator ability to feed the material to the combustion chamber required some slight changes in elevator parameters. Namely, cob particles caused from time to time inclination between auger edges and tube, blocking the drive. This should be overcome by reducing the auger diameter or using larger tube diameter. Increased distance shall reduce the deformation of cob particles and strength in the same time.
The capacity of the processor has only been measured preliminarily. It amounted to 300 kg per hour. This can satisfy requirements of at least three families.

4. CONCLUSIONS

Developed simple maize cobs processor –crusher, can fulfill user demands. The simple design of crusher with cylinder with three rows of spirally arranged knifes and two stationary comb-like knifes showed good result of crushed cobs using 35 mm opening of under sieve, distance to rotated knifes 20 mm and RPM or cylinder in range 480 to 600.
According to share of under- and oversized particles achieved particle distribution fulfill the demands defined in Austrian and European standards for wood chips.
The material can be transported, i.e. fed to combustion chamber by common screw elevator after slight redesign.
Capacity of the tested prototype is sufficient to fulfill the needs of three families, but it can be easily increased by enlarging cylinder width.
Future development should be oriented toward adequate design of combustion chamber and boiler, in order to adapt them to specific characteristics of maize cobs as a fuel.

5. REFERENCES

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Acknowledgement: The paper is result of Eureka project E 3414, *Multifuel-polygeneration for distributed heating and cooling applications*, financed by the Ministry of Science and Environment Protection of Republic of Serbia.