Prosimy cytować jako: Inż. Ap. Chem. 2012, 51, 5, 216-218

Józef Flizikowski[1], Kazimierz Bieliński[1], Maciej Nowicki[2]

e-mail :fliz@utp.edu.p

[1]**University of Technology and Life Sciences, Bydgoszcz**

[2]**PANASONIC Polska**

Research and development of plastic wastes grinding in recycling

Introduction

Grinding of carriers, products, waste and recyclates plays important role in the mechanical engineering [*Flizikowski, 2011a; Flizikowski, 2011b; Flizikowski, 2011c*]. The grinding processes result is a reduction of dimensions of material, corresponding to the desired size distribution, while increasing the product surface area. The grinding process is used for minerals, plastics, grain, biomass, municipal waste, etc. Each material has different properties (e.g. brittleness, elasticity, viscosity, humidity, fat content) resulting from its structure and storage conditions, which depending on the expected fineness creates various demand with respect to energy needed to fulfil the specified objective of the grinding process.

Aim of the work: The active research, development, monitoring, automatic, intelligent optimization of the grinding process is aimed, above all, at best relations, elements, effects and inputs such as energy, environmental.

In the case of biomaterials, of prime importance are relations between the digestibility effect of the grinding process of eg. grain and energy used to produce the effect [*Bieliński and Flizikowski, 2007*].

In the case of multi-particle materials, energy biomass, polymer plastic waste, depending on the primary purpose of the grinding process, it is essential to achieve satisfactory relations between the obtained particle-size homogeneity of the feed material, energy performance and efficiency, and the necessary energy consumption [*Bieliński, 2011*].

Research methodology

The research into energy-related, environmental and economic efficiency of the grinding in recycling processes is intended to identify the directions of the engineering and organizational efforts to build and operate an optimal machine design that will ensure lower energy consumption, increase capacity, improve relations in the environment, and above to obtain good (satisfactory) properties of the final product. Requirements of the ground material recipients as its particle size composition and energy characteristics largely depend on the intended use of the product.

The grinding process is described by a number of indicators such as : efficiency, reliability, outcome, product quality. Each indicator requires different sources of information.

In the grinding engineering, there are three main groups of objects:

- material that is considered in three states:
  – at input,
  – during mechanical processing,
  – at output,
- machine, as a functional system that may include:
  – drive motor (motors),
  – mechanical gear,
  – grinding unit,
- process considered with respect to categories related to:
  – energy,
  – cost-efficiency,
  – environmental aspects,
  – organisational aspects,
  – time,
  – social aspects.

The above shows that grinding is a multi-stage process that requires detailed knowledge on properties of specific groups of objects: the material, the functional unit and the grinding process itself.

Grinding process indicators. In the case wastes of biomaterials, the energy-related indicators that significantly affect the grinding process include [*Bieliński and Flizikowski, 2007*]:

– total energy of fracture propagation,
– crack stress,
– crack resistance,
– load during collision and cutting,
– collision duration,
– digestibility of organic material, performance ratio of ground product incineration,
– relation of dimensions before and after the grinding process,
– increase of specific surface area.

Many theoretical works known as theories have been published on the subject including theories by: *Griffith, Behrens, Rumpf, Schonert, Kerlin, Flizikowski*.

Fig. 1 shows a schematic diagram showing variables, constants and disruptions taken into account during active monitoring of the grinding process.

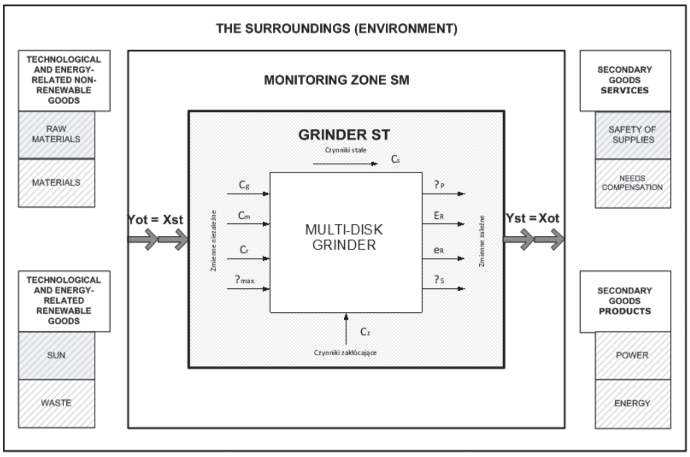

Fig. 1. General diagram of elements and relations between the grinding system (ST), the environment (OT), the monitoring zone (SM = SG) (boundary zone)

Active monitoring of waste grinding processes in recycling, constitutes a higher level of the capacity to use information from monitoring to achieve the principal objectives of the process implemented. Usually, the objective relates to an improvement of energy, economic and ecological efficiency of the analysed process. Thus, when searching for effective innovative activities related to the process and development activities related to designing grinders, it is necessary to link the idea of monitoring and the principal objective of the process.

Strategy of development

Choosing an active monitoring as development strategy of technical recycling objects, must take into account models and objectives, for example, the highest efficiency of the grinding process and final product quality (e.g. optimal) [*Bieliński and Flizikowski, 2007*]:

$$o_e = f(P_o, P_e, P_s, P_{od}, E_j, O_{nq}) \quad (1)$$

Prosimy cytować jako: Inż. Ap. Chem. 2012, 51, 5, 216-218

where:
P_o – initial potential,
P_e – effectively used/lost potential,
P_s – ineffectively lost potential,
P_{od} – potential recovered from technology or the surroundings,
E_j – unit energy consumption,
O_{nq} – low quality product, waste, loss, defect operations etc.

As a result of the development of modern technologies, active monitors, optimization numerical methods (statistical and deterministic) have displaced previously used analytical methods. The principle of operation of deterministic methods is to aim at the optimum value by using appropriate algorithms. The best results are obtained by an effective combination of both methods.

The technical system (ST) includes the grinding unit (Fig. 2) connected directly by a drive shaft or through the gear to an electric motor (motors).

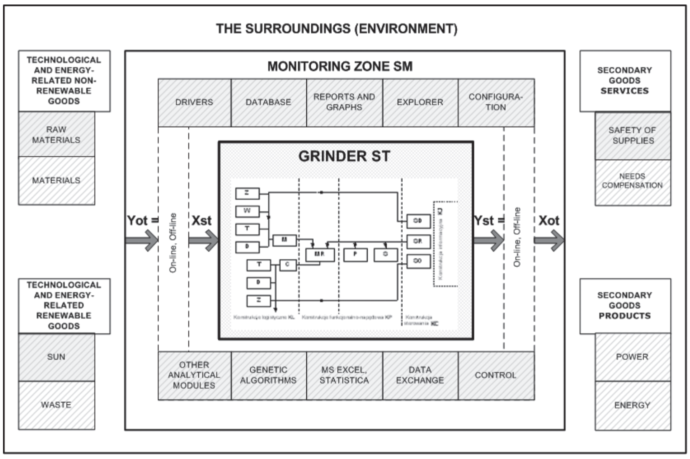

Fig. 2. Detailed diagram of elements of and relations between the grinding system (ST), the environment (OT), the extended monitoring zone (SM = SG) (boundary zone)

Each drive motor is equipped with a dedicated inverter that controls its operation. The technical system also includes physical quantity measurement units and necessary systems:
– for material transport and feeding,
– wiring systems (power supply, measurement, control, data transmission, safety, visualization and alarm),
– ground material collection, transport and packing system.

The boundary zone (SG) is made up of programmes, algorithms, executive units, modules of active monitoring system (SM) used to identify, acquire, analyse, verify and exchange data and to configure the system, control inverters of motors that drive the grinding unit. This zone also consists of modules and tools used to analyse data that supplements the monitoring system, such as image identification, *Genetic Algorithms, MS EXCEL, STATISTICA*.

Reference values must also be defined for further analysis and standard and custom reports on test results must be pre-defined, for those interested in achieving the highest efficiency of the grinding and recycling processes.

Fig. 3 shows a monitored multi-hole multi-disc grinder with a control cabinet [*Tomporowski., 2011*].

Five discs are driven by five independent three-phase electric squirrel-cage motors – power $P = 1.4$ kW, $\cos\varphi = 0.8$, $\eta_n = 74\%$, IP55. Torque from electric motors is transferred onto the grinding unit by gear with a cogbelt (Fig.3).

The grinding unit is integrated with a 16 dm^3 loading tank fitted with a screw feeder for ground material – DSK 07 (*Hydrapress*) that supplies material into the grinding unit with continuously regulated capacity of 20 kg/h. The regulation of capacity is possible within a range of 0÷100% of maximum feeder capacity. The DSK feeder is fitted with a RS485 communication interface and *Modbus* communication protocol that enables active monitoring, control of capacity and data reading from registers of memory of the device controller as well as storage of the data in a database of the application that manages the monitoring system.

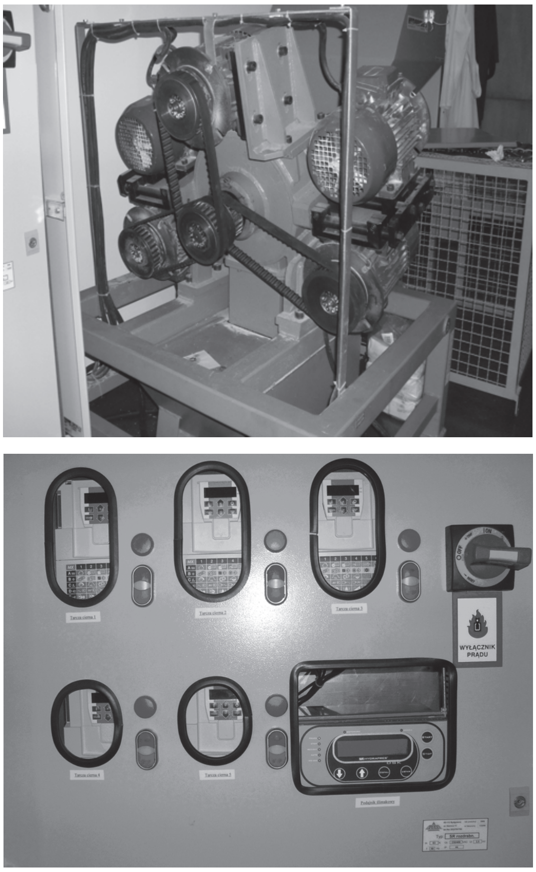

Fig. 3. Station for operational characteristics active monitoring in development strategy of a multi-disc grinder design optimisation ($x^* \in \Phi$) and control cabinet of drive motors and feeders

Each of the electric motors is controlled by a dedicated inverter – *pDrive MX 600 4V2.0 (Va Tech)*. *pDrive* frequency converters are used in a wide range of power of drive systems from 0.7 kW to 800 kW, 500–690 V, 50/60 Hz. Each inverter is fitted with RS485 communication interface and *Modbus* communication protocol that enables acquisition of data and sending control signals. Inverters and the feeder controller with their associated accessories and wiring system elements are installed in SR 230/400 V 63A IP44 control cabinet (Fig. 3).

The research and development test station is also equipped with a direct measurement system for measuring energy consumption in form of three-phase EAP meter and fitted in a separate cabinet together with over current protection units in the power supply system. The *EAP (POZYTON)* meter uses RS485 communication interface and IEC 1107 communication protocol that enables remote reading of the power and electricity load profile of the tested process.

PCD1 (SAIA) physical parameters recorder is also used to record:
– changes of temperature in a few measurement points,
– material and air humidity,
– mass of material before and after the granulation process and screening.

To ensure simultaneous data reading from all inverters, so-called Nport 5630 units has been used – a multi-port 16*RS485/Ethernet converter (*MOXA*) installed in a 19” cabinet together with recording devices and a PC. The converter has also been connected to data transmission paths from: the controller of DSK feeder, EAP electricity meter and PCD1 recorder of the following physical parameters: temperature, level, weight and humidity. For synchronizing local system clocks with the reference real-time clock, NTP service (*Network Time Protocol*) of *MS Windows* has been used.

Results and development directions

Visualisation, results of the waste grinding processes in recycling coming from active monitoring are fundaments for development strategy. The first step of strategy: effectively and ineffectively used/lost potential. Fig. 4 shows results of measurement energy potential lost, as temperature before (*Twe*) ineffectively changing in product after (*Twy*) grinding process and in the surroundings temperature (*Tot*) in the function of time of multi-disc grinding process.

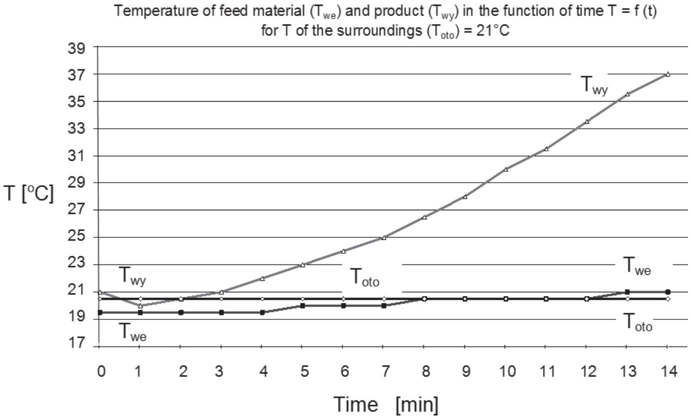

Fig. 4. Temperature of the surroundings T_{ot}, product T_{wy} (low quality product) and feed material T_{we} in the function of grinding time, $T_{oto} = 21^{\circ}C$

Fig. 5 shows effectively changes in unit energy consumption in the function of changes in the size of gap between disc 1 and 2 of the grinding unit.

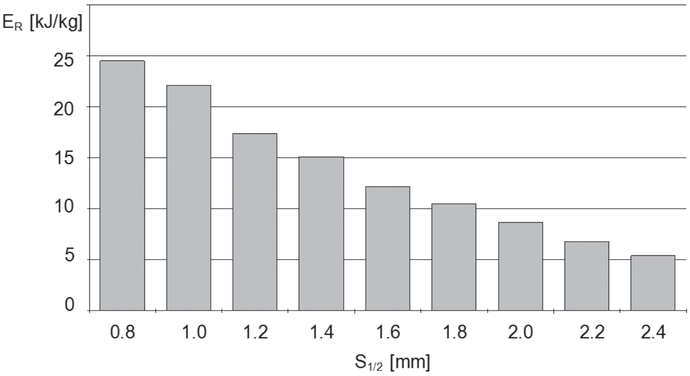

Fig. 5. Changes of unit energy consumption E_R in the function of changes in the size of gap $S_{1/2}$ between disc 1 and 2 of the grinding unit

Fig. 6 shows effectively changes of productivity of the ground material, fraction $0.5 < f < 1.5$ and Fig. 7 – the energy efficiency of the biomaterials grinding process in the function of changes in the size of the gap between disc 1 and 2 of the grinding unit.

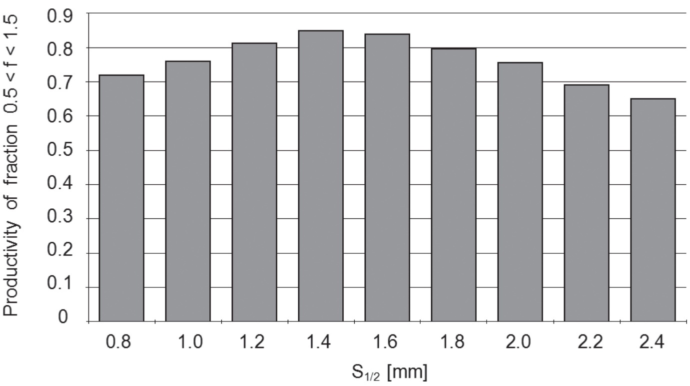

Fig. 6. Changes of productivity of fraction $0.5 < f < 1.5$ in the function of changes in the size of the gap between disc 1 and 2 of the grinding unit

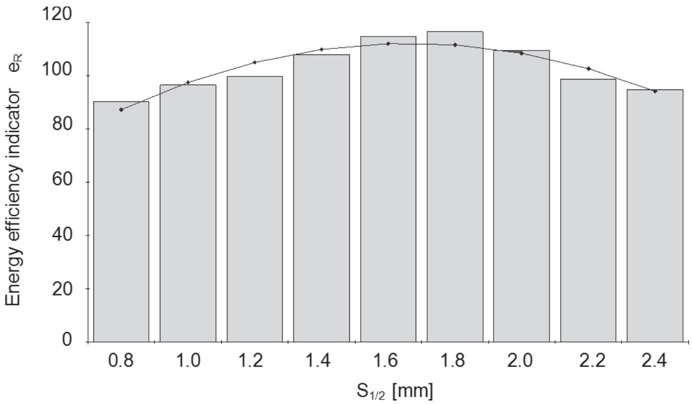

Fig. 7. Changes of energy efficiency in the function of changes of gap between disc 1 and 2 of the grinding (unit effectively used potential)

The influence of changes in the size of the gap on the effectively energy efficiency indicator for the specific biomaterial wastes has been described with the following equation of non-linear regression:

$$e_R = 19{,}72 + 111{,}03s - 33{,}35s^2, \quad \text{for} \quad R^2 = 0{,}869 \qquad (2)$$

The sought value of the energy efficiency indicator of the process e_R [*Flizikowski, 2011a, 2011b, 2011c*] is development strategy obtained for specific design features of the grinding and driving unit and movement features of the grinding elements. Consequently, the sough value of e_R indicator may be described as follows:

$$e_R = e_R(C_{kx}, C_{Rx}) \qquad (3)$$

where:

C_{kx} – active monitoring, sought design features of the grinding and driving unit,

C_R – active monitoring, sought features of movement of grinding elements

Conclusions

Relationships (2) and (3) are general solutions to the problems consisting in finding the best grinder design in terms of the waste (material) and the process (grinding and recycling).

The selection of design features (C_{kx} C_{Rx}) of the multi-disc grinding unit for which the effectively and ineffectively used/lost potential estimators: energy efficiency of the process (e_R) reaches maximum values or the energy demand (E_R) of the process reaches minimum values is a solution to the problem $x^* \in \Phi$ (that belongs to a permissible set).

BIBLIOGRAPHY

Bieliński K.S. and Flizikowski J.B., 2007. *System aktywnego monitorowania obiektów technicznych*. XXI Międzynarodowa Konferencja Naukowo-Techniczna: „Ekologiczne i energooszczędne budownictwo”. EKOMILITARIS, pp. 24-35. Wyd. BEL Studio, Warszawa

Flizikowski J.B., 2011a. Research and development of polymer materials grinders in the direction of increasing energy efficiency of recycling processes. *Przetwórstwo tworzyw*, 3(141)/17, 128-131

Flizikowski J. B., 2011b. Intelligent grinding system. *Inż. Ap. Chem.* 50, nr 3, 22-23

Flizikowski J. B. (2011c). Levels of inteligent grinding system. *Inż. Ap. Chem.* 50, nr 3, 24-26

Niederliński S., 1987. *System i sterowanie*. PWN, Warszawa

Tomporowski A., 2011. Structure development of biological material shredders. Part I and II (in Polish). *Inż. Ap. Chem.* 50, nr 3, 75-78

This work was financially supported by the Polish National Centre for Research and Development in 2010-2013.