Prosimy cytować jako: Inż. Ap. Chem. 2011, 50, 3, 22-24



**Józef FLIZIKOWSKI**

**e-mail: fliz@utp.edu.pl**

**Department of Production Technology and Engineering, Faculty of Mechanical Engineering, University of Technology and Life Sciences, Bydgoszcz**

# Intelligent grinding system

## Introduction

By definition, the intelligent grinding/comminuting system is integrated, focused on the process objective: an increase of specific surface area of the product and the degree of comminution; on the energy consumption minimum – as an environmental objective; on self-regulation – in the area of efficiency; on a multi-level and dependent structure – elements and relations in the system. Therefore, it corresponds to the evolutionary model of an integron, introduced into biological sciences by Jacob and adapted for technical sciences, in the construction and use of integrated grinding machines by *Flizikowski* [6].

The intelligence of the grinding system is based on the use of strategic genetic algorithms [11, 12] to contemplate structural solutions (of the machine and material), also complete the process [12], primarily of regulation and compensation (dynamic control) – depending on the state of the objective function: the quality of product; effectiveness of the comminution; harmlessness of the system to the environment, fed material/product, the border area and the system itself [4].

The aim of the work is to use the intelligent system to improve operating parameters in respect of efficiency, the degree of comminution (an increase of specific surface area), effective work (total energy) of the comminution and relation of the same to stresses and plastic strains [7, 8, 10, 13, 14, 15, 16]. The genetic research algorithms used so far, based on the effectiveness of the objective function, have been aimed mainly at optimization of the design of the process system [1, 2, 6, 8, 10].

## The model of the system and the analysis

On the basis of principles of the intelligent grinding strategy, objective functions (1), models are distinguished containing information related to:

- Quality – structure (the quality of machine design and fed material) and the parameters of the grinding system (IS);
- Effectiveness of operation – strength quality of the product (load necessary to warp, alteration of plastic strain in the ground section (double increase of specific surface area), resulting in the effectiveness of the process of grain division), the compliance of the structure with the optimum comminution (IW);
- Harmlessness – of a technical system and the ground product to the environment, the fed material, the border area, and themselves – when fulfilling (the function of) objective λ (ISW).

In the general case, the function of the objective fulfilment has the following form [1]:

$$\lambda = \lambda\ [\mathrm{IS, IW, ISW}] \quad (1)$$

The general equation covering (optimizing) complexity of the parameters of quality, effectiveness, harmlessness of elements, relations, control, duration of the grinding process, has the following form [1, 4]:

$$L(\overline{H},\overline{E},\overline{R},\Theta,t) = P(\overline{s},\overline{z},\Theta,t-t_0) \quad (2)$$

where:

$\overline{H}$ – parameters of the process/product as sought after solutions (required states, objectives, unknown), output values (effectiveness, quality, harmlessness, environmental friendliness),

$\overline{E}$ – parameters of internal elements (features of mechanical structures, grains, features of carriers, materials – waste),

$\overline{R}$ – parameters of relations between internal elements (interrelations between elements),

$\Theta$ – time,

$t_1 - t_0$ – time,

$\overline{s}$ – control,

$\overline{z}$ – disturbance.

### *Analysis of the model*

The left side of the equation (2) (the model of an intelligent development of the system) describes properties of the grinding process, its physical features, specific for each class of actions. Those properties depend on features of elements $E1, E2$ , ..., $Em$, relations between these elements $R1$, $R2$ , ..., $Rn$, and are functions $\Theta$ and $t$ (time of operation and dynamic process). Unknowns are elements of the set of parameters H as input values, on which optimization, the evaluation of energy/mechanical development and the evaluation of the overall efficiency of the system depend - effectiveness, efficiency, power consumption and type, unit power consumption etc.

The right side of the equation (2) describes the internal and external interference. It may depend on the form of intelligent influence – control by means of signals from set $\overline{s}$ (variables of tool movement – actively supported), interaction $\overline{z}$ – interrelations between elements: product – machine – technological process – conditions – the environment – e.g. stresses, comminution strains that cause compensatory processes.

### *The main problem*

The main scientific/research problem has been formulated as a question: What conditions related to design, materials and control of special mills ($W_{kms}$) used for grain, polymer and fibre materials ($m_{zg}$) are necessary for optimum comminution state ($SP_{rbr}$)?

The scope of the work includes modelling, a description of an analysis of quasi-cutting modulus for grain, granules and a description of a research case involving an intelligent grinding system (ISR).

### *Ground material $m_{zg}$*

The tests were conducted with grain, polymer granules and fibre granules (Tab.1).

Table 1. Parameters of grain, polymer granules and fibre granules

| Item | Type of material | Moisture content, % | Weight of 1000 grains, g |
|---|---|---|---|
| 1. | Triticale (maize) | 10.5 (8.6) | 34.16 (281.10) |
| 2. | Granules – PE-LD | 8.6 | 81.10 |
| 3. | Granules with wood fibres | 9,4 | 68,50 |

### *Design conditions $W_{kms}$*

RWT-5:KZ multi-disc grinder was used for quasi – cutting. The grinder is fitted with five (or seven – RWT-7:JA) discs mounted coaxially in a vertical arrangement (each disc is driven by a separate motor and transmission). The difference in linear velocity of holes, grinding edges in adjacent discs is a sought feature of the movement of the process structure. The discs have cylindrical holes and they differ in a number and size of holes, a number of hole rows and diameters of holes arrangement in a disc.

### *Operational parameters, objectives of the grinding process $SP_{rbr}$*

Requirements: high effectiveness, harmlessness and high quality of ground product. The grinding process, to put it simply [10], may be

Prosimy cytować jako: Inż. Ap. Chem. 2011, 50, 3, 22-24



regarded effective, when the technical efficiency and the degree of comminution increase and load and the energy necessary for comminution strains – decrease. This leads to determination of specific criteria of process optimization related to [10]:

1. effective efficiency, $k_w = W_t$,; $W_t$ means process efficiency,
2. effective degree of comminution, $k_n = n$; $n$ – degree of comminution,
3. effective maximum loads, $k_R = 1/R_{max\,sr}$; $R_{max\,s\,r}$ – an average value of permanent strain stresses, for maximum comminution load,
4. effective energy $k_E = 1/L_r$; $L_r$ – the value of energy (or effective work for comminution strains).

When harmlessness of the grinding process and quality of the product are not considered, the overall index of the effectiveness of the system operation, process completion (for a given fed material) is as follows:

$$k = k_w k_n k_R k_E \tag{3}$$

If machine and process no. I are more effective than machine and process no. II, then $k_I > k_{II}$.

***Monitoring parameters*** $\boldsymbol{SP_{rbr}}$: of required comminution states (Fig. 1), is a precondition for getting to know and intelligent programming of the dynamics of operational parameters of the grinding process. The basic, IT structure of the system including the database uses a special programming and control interface that enables a connection of an external genetic algorithm to an *ERCO.Net* application driver [4]. The driver (communication controller) enables acquisition of data from measurement instruments, transmits the signal that controls linear velocity and direction of disc rotation according to the genetic algorithms. Groups of data may be exported to analytical IT tools such as *MS EXCEL, STATISTICA*.

An existing *MS SQL* database of the *ERCO.Net* system was used. For the purpose of the monitoring system, the following were also created:

– communication controller (driver) for the control of *pDrive* inverters,
– register of data recorded by each inverter – files (oscillograms),
– programming interface of data exchange from and to *ERCO.Net* system
– extended configuration of the analytic module based on the genetic algorithm, enabling the compensation of parameters of the grinding process,
– a file of exchange of data from *PSI-GAD* application [3] to *ERCO.Net* system,
– data export to *MS EXCEL*.

All applications were installed on a PC used as the server. An access to the server from other computers is possible via a dedicated internal Ethernet network at the *Engineering Systems and Environmental Protection Unit*.

The system was equipped with:

– five motors that drive five discs of the grinder, type *SLh 90L*-4/2; 3.4 W; cos φ = 0.8 *(INDUKTA),*
– a set of five independent pDrive inverters with RS485 interface that can be used to read data and to control the motors *(VATECH)*,
– a feeder of the ground material *DSK (HYDRAPRESS)* with *RS 485* interface,
– electric energy meter, type *EAP (POZYTON)* with *RS 485* interface.

In order to provide simultaneous reading of data from each inverter, a multiport *RS485/Ethernet* converter (N-port) was used. The very same N-port is used to read the *EAP* electric energy meter. The next port enables communication with the controller of the *DSK* feeder. Data is transmitted from the *PCD1* recorder. The diagram shows the basic principle of an intelligent grinding system, used in the target structure. The basic design/structure (Fig.1) includes an object layer, a data concentration and registration layer, a computer and data transmission layer, and application layer including a database and a genetic application managing the system.

An object layer consists of motors that drive grinder discs and a system for power electronic control and measurement of physical parameters [4].

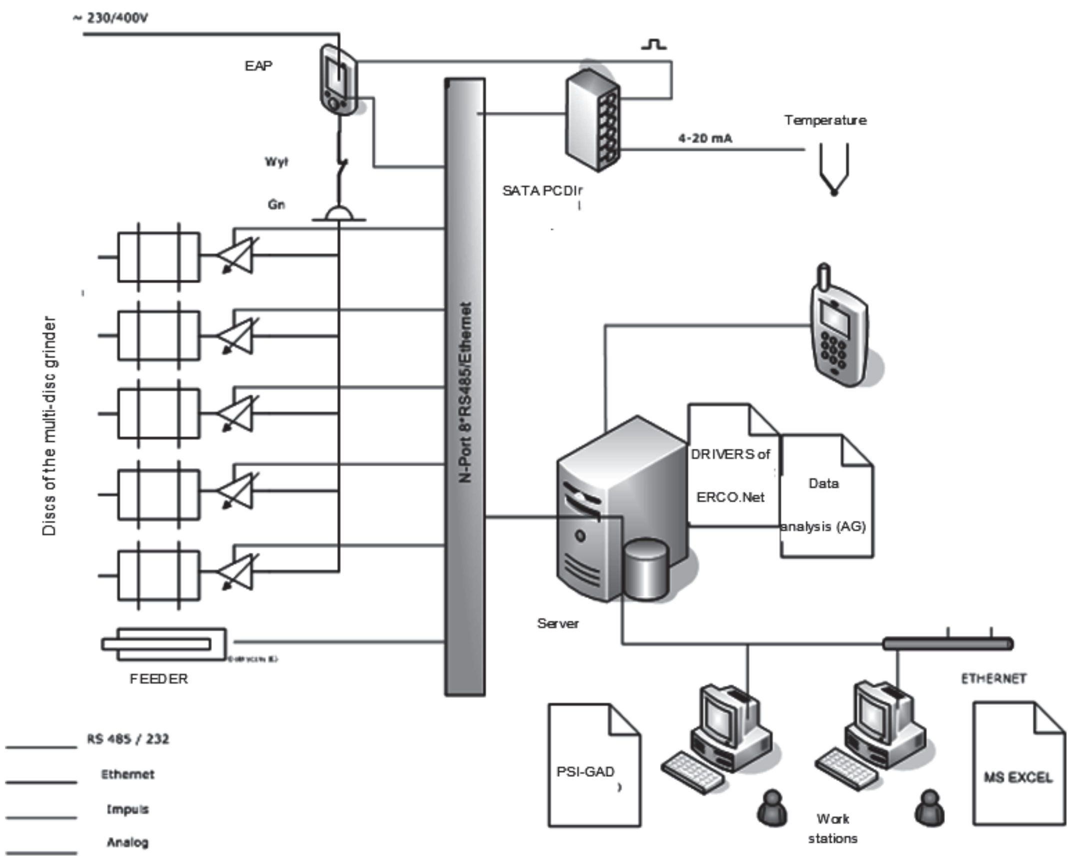


Fig. 1. A schematic diagram of an intelligent grinding system (ISR) used for grain materials ensuring target quality of product, energy effectiveness of the process and harmlessness of the system [4]

Prosimy cytować jako: Inż. Ap. Chem. 2011, 50, 3, 22-24



The machine – 5-disc grinder is controlled by a system of pDrive inverters, installed in control cabinet SR 230/400V 63A IP44, with the controller of the DSK material feeder. The genetic algorithm enables identification of: product quality in technology; control based on product quality indicators; actual state of effectiveness of mechanical processing and harmlessness of the energy system effects (in $CO_2$ emission equivalent units: 960.2 $MgCO_2$/GWh of saved electric energy) and switching to a higher effectiveness level and a lower emission of harmful gases.

## Summary

Procedures, based on the monitoring algorithm, were used to support innovation of creative activities, i.e. environmentally friendly actions, that is those actions that produce specific positive quality and environmental results in the energy-related, clean, mechanical processing of grains of biomaterial and other grain materials.

Technologies and activities lead to standards described as: clean processes, high quality materials and products, effective use of energy in operations, and energy saving. For the purpose of rough evaluation and compensation of grinding system operational parameters, the basic criteria of eco-innovation were applied: energy consumption, material consumption, operational efficiency and effectiveness.

### REFERENCES

[1] *S. Ziemba, Wł. Jarominek, R. Staniszewski*: Problemy teorii systemów. Ossolineum PAN, Wrocław 1980.
[2] *L. Powierża,:* Zarys inżynierii systemów bioagrotechnicznych. Część I. ITEE, Radom 1997.
[3] *J. Flizikowski:* Rozprawa o konstrukcji. ITEE, Radom 2002
[4] *J. Flizikowski:* Projekt implementacji inteligentnego systemu wspomagania konstrukcji młynów specjalnych, Min.NiI Warszawa, ATR Bydgoszcz, AGH Kraków 2005.
[5] *Rada Ministrów RP:* Polityka energetyczna Polski do 2030 roku, Warszawa 2009.
[6] *J. Flizikowski:* Plastic devices for Energy Engineering. NANOENERGY, Tapis Rouge, Paryż 2008.
[7] *J. Sidor:* Badania, modele i metody projektowania młynów wibracyjnych. Rozprawy-Monografie nr 150, Wyd. AGH Kraków 2006.
[8] *G. Szala i inni:* Analiza energochłonności technologicznego ścinania ziaren zbóż. Grant Min. NiI Warszawa, UTP Bydgoszcz 2007.
[9] *A. Kaleta, J. Wojdalski:* Przetwórstwo rolno-spożywcze. Wybrane zagadnienia inżynieryjno-produkcyjne i energetyczne. Warszawa 2007
[10] *Zawada J. (red):* Wprowadzenie do mechaniki maszynowych procesów kruszenia. Wyd. ITE, Radom-Warszawa 2005.
[11] *D. E. Goldberg:* Algorytmy genetyczne i ich zastosowanie. WNT, Warszawa 2003
[12] *W. Tarnowski:* Problemy Eksploatacji, **77**, nr 2, 17 (2010).
[13] *A. Lisowski (red.):* Efekty działania elementów wspomagających rozdrabnianie roślin kukurydzy a jakość kiszonki. Wyd. SGGW, Warszawa 2009.
[14] *A. Janowicz:* Problemy Eksploatacji, **77**, nr 2, 149 (2010).
[15] *J. Świątkowski, J. Flizikowski:* Inż. Ap. Chem. 49, nr 5, 111 (2010).
[16] *J. Flizikowski:* Recykling 1(109), 8 (2010).

***The research financed by the funds of the National Centre for Research and Development in 2010/2013 as a development project.***