Control system of multi-disc mill with a new structural solution

W Kruszelnicka, A Tomporowski, J Flizikowski and R Kasner

University of Science and Technology in Bydgoszcz, Faculty of Mechanical Engineering, Al. Prof. S. Kaliskiego str., no. 7, 85-793 Bydgoszcz, Poland

E-mail: weronika.kruszelnicka@utp.edu.pl

Abstract. The study presents the issues involved in control and monitoring of functional characteristics of the process of grinding, on the example of a multi-disc mill, designed according to a new solution. The authors' original system for control and monitoring of the mill operational parameters has been presented. The aim of this work is to develop a methodology for integration of the control, process and logistic modules of a multi-disc mill designed for industrial purposes. The structure of the control and monitoring systems has been analyzed. The structure was used for tests of the mill operational parameters whose results were used for evaluation of the mill operation.

1. Introduction

The research on control and intelligent grinding systems has been taking place for fifteen years, and the methodology of integrated and intelligent systems innovation and life cycle management has been used in some studies of the environmental impact of products, services and processes, by Polish scientists (eg, Kłos Z. [1], Flizikowski J. [2], [3] and others [4–10]). The process conditions, grinding engineering, also the form and further processing of products have a significant impact on sustainable economic development and its postulated states, among others, energy and ecological efficiency of industry [11–13]. One aspect of involved in energy-environmental efficiency improvement is a search for new alternative energy sources and the pursuit of actions aimed at improving the efficiency of the processes with an emphasis on lowering energy consumption and environmental harm [14–16].

The need to undertake the issue of intelligent monitoring and control of grinding characteristics is due to insufficient descriptions of the grinding process quality, not many effective technological solutions, and the lack of satisfactory ways to increase energy and environmental indicators and product quality for further energy use [17–19]. Grinding process is characterized by high energy consumption, low efficiency, low effectiveness, and unfavorable grain size distribution characteristics – hence, monitoring of operational parameters such as power consumption, disc speed, rotational speed, etc. seems to be important [20–22].

The processes and functions connected with recording and calculation of data play more and more important role in the research on development of mills and grinders for grainy and fragmentary materials. Calculation systems perform required computing, mathematical operations, e.g. summation, multiplication, exponentation, root extraction, differentiation, solution of equations, and use procedures based on statistical analyses [23], [24]. In machines, processing systems calculation blocks can perform several functions.

In the light of the above, the aim of this study is to develop a methodology for integration of the following modules: machinery, control, process, and logistic ones as well as evaluate and document functional and operational state of the drive and control systems of a multi-disc multi-hole mill for fragmentary materials grinding.

2. Developed system of control and monitoring

2.1. Characteristics of new multi-disc mill

The analyzed object consists of (Figure 1):

- body from aluminium profiles,
- output basket,
- working unit (discs),
- motoreductor (transmission and collar motor),
- dump basket.

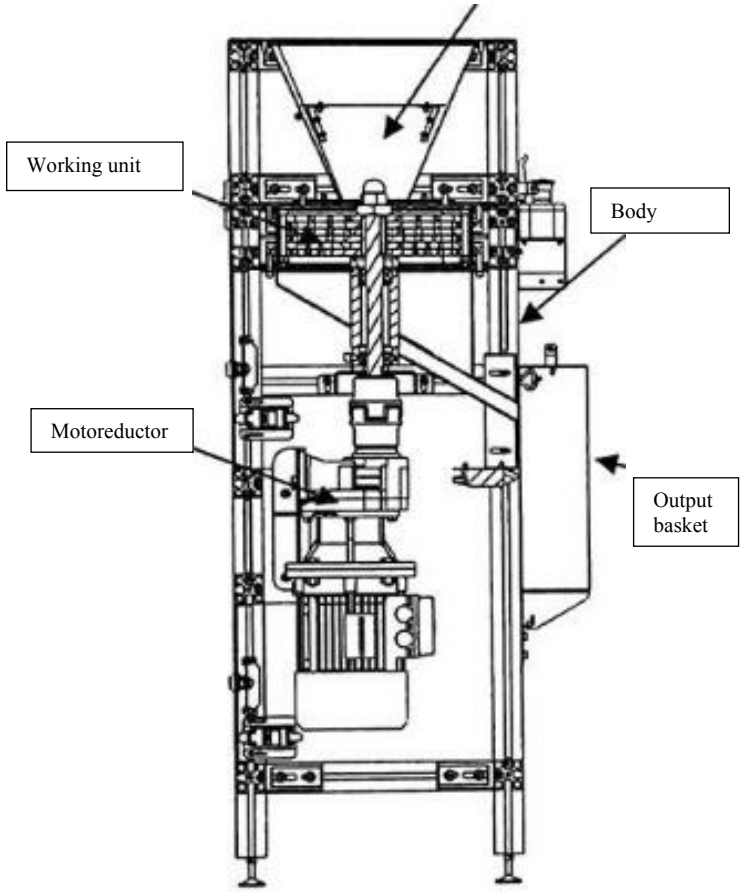

Figure 1. Cross-section of the analyzed multi-disc grinder

The mill is powered by independent drives with frequency converters SK 500E 1.5 kW. The operation principle of the device is similar to typical structural solutions of multi-disc grinders. The feed material falls continuously from the chargé into the machine. Movable discs, set into rotational motion, comminute the material through quasi-cutting in the contact zone with permanent disc. After grinding the material falls into the output basket, where it is collected from. Technical specification of the mill is presented in Table 1.

Table 1. Technical data of PS.02 grinder

Parameter	Quantity
Diameter od discs (mm)	Ø200
Number of movable discs – fixed on the shaft (pcs.)	3
Number of fixed discs – mounted to the (pcs.)	3
Thickness of discs (mm)	10
Gap between discs (mm)	0.3 – 0.4
Number of the rotor holes (rev./min)	700
Motoreductor	MOTOVARIO HR041U, motor N = 1.1 kW
Number of the motor revolutions (rev./min)	1400
Total weight (kg)	160

The working unit of the analyzed device consists of three pairs of comminuting alternately positioned plates, starting with fixed disc (Figure 2). Fixed discs are mounted to the housing by means of a screw, whereas movable discs are set on the rotor shaft. The diameters of holes of successive disc pairs decrease.

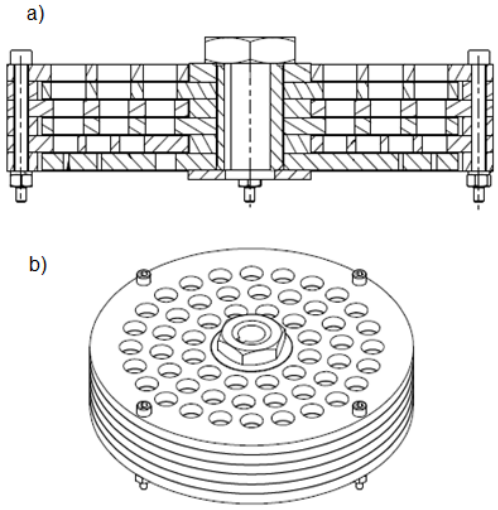

Figure 2. Working unit of a multi-disc grinder:
a) cross-section, b) isometric projection

2.2. Characteristics of the control system

The system is designed to control the drive unit of the process system and to record operational parameters of the analyzed mill. It consists of the following elements (Figure 3 and Figure 4):

- Set of computers with installed laboratory software LabView 2014
- System of data acquisition and control LabJack
- Set of frequency converters of Nord company

Extension of the control system with the above indicated elements provides multi-disc grinders with improvement in functional characteristics in terms of: power demand, specific energy consumption and efficiency, as compared to earlier used grinders.

The control system includes:

- Processing -calculation unit with a keyboard, monitor with software: Windows 8.1, LabView 2014 and dedicated software in LabView language,
- server of series ports RS232 enabling communication with frequency converters according to MOD BUS protocole,
- module of WT control and acquisition,
- control box with a set of frequency converters (Figure 2).

Figure 3. Stand for monitoring of functional characteristics of multi-disc grinding: a) control-monitoring system, b) multi-disc mill

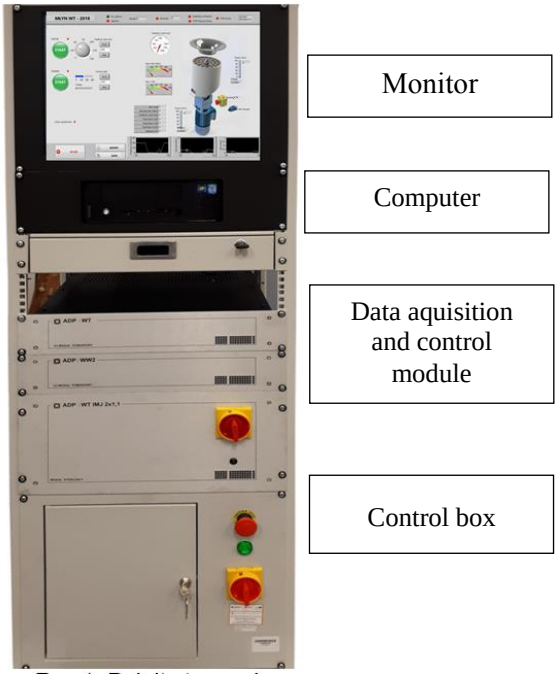

Figure 4. Control and measuring system

Measurement control software operating in LabView environment allows to control of drives through frequency converters in on-line mode which enables smooth adjustment of rotational speed (Figure 5). The software has the function of timer. Graphic visualization of the measured main and auxiliary processes parameters is also possible as well as their archiving.

User /operator of the system obtains:

- Voltage [V],
- Phase U current [A],
- Phase V phase [A],
- Phase W phase [A],
- Speed [rev./min],
- Torque [Nm],
- Power [kW],
- Temperature 1 [ºC],
- Temperature 2 [ºC].

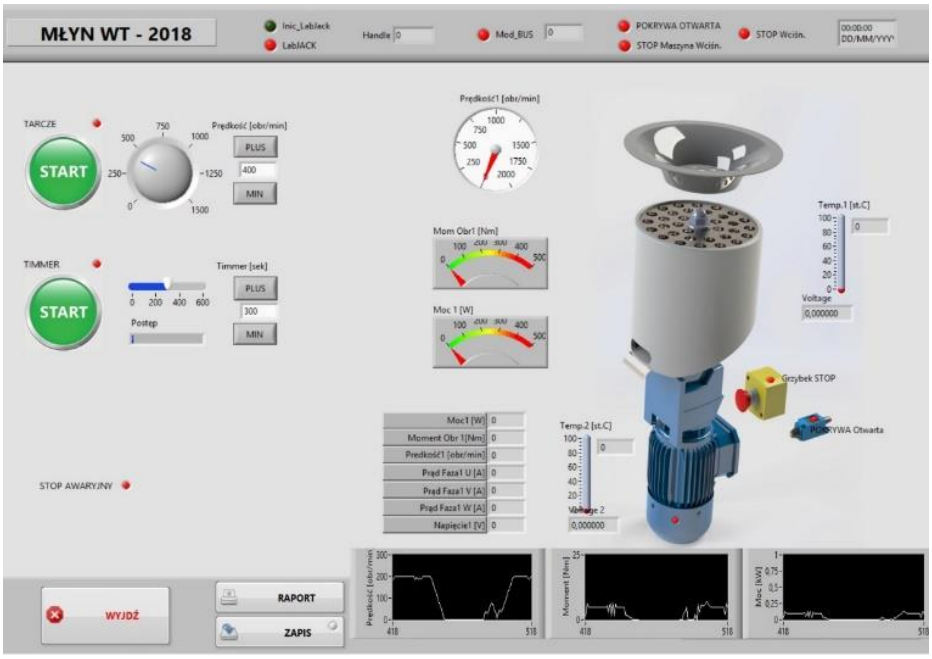

Figure 5. Control-reading panel

The above parameters for control and measurement results are currently recorded in xls file. Additionally, outprint of current control parameters and measurement results is possible.

3. Research results

After development of the control system, particular characteristics of the analyzed multi-disc mill operation were analyzed in order to verify the system operation correctness and assessment of the new structural solution of the disc mill. Rice were used as the feed material.

In Table 2 there are results of tests of monitored operational parameters for both analyzed grain types.

Table 2. Presentation of tests results

Parameter	rice				
Rotational speed n (rev/min)	500	600	700	800	900
Mean power P (kW)	0.98	1.22	1.67	1.94	2.10
Enrgy consumption E (kJ)	55.73	67.31	103.26	147.30	211.32
Time t (s)	66.70	62.20	79.50	79.00	110.50
Torque M_o (Nm)	18.70	19.40	22.80	23.60	24.00
Mass of the comminuted material (kg)	2.42	2.35	2.07	2.27	1.90
Product yield Q (kg/s)	0.04	0.04	0.03	0.03	0.02
Specific energy consumption E_j (kJ/kg)	23.03	28.64	49.88	64.89	111.22
Dimension of the comminuted grains d_{80} (mm)	1.98	1.93	1.92	1.91	1.89
Fineness degree λ_{80}	1.11	1.14	1.15	1.15	1.16

Results of rice comminution showed that along with an increase in the disc rotational speed the power consumption increased as well as energy consumption. Energy consumed for n=900 rev/min

was almost 4 times higher than for the lowest rotational speed of discs n=500 rev/min. It has a significant influence on economic aspects connected with grinding of materials. The same situation applied specific energy consumption, which was proportional to the assigned speed of discs. Speed increase by 400 rev/min (from n=500 rev/min to n=900 rev/min) resulted in almost 5 time higher specific energy consumption. Both energy consumption and specific energy consumption were similar for low discs speeds (n=500-600 rev/min). Product yield connected with the comminuted material mass and comminution time decreased along with increasing speed of discs. It was nearly 2 times lower for the highest rotational speed than for n=500 (rev/min). In the case of product yield, it assumed the highest value for speed n=600 rev/min.

4. Summary and conclusion

The path of formal procedure was used in implementation of the compatibilization process, proposing an original methodology of research and special development of grinding of materials such as plastics, grainy materials biomaterials, and polymers. At the stage of integration of the functional-working systems of a hole-disc mill, the following generalizations were formulated:

- The results of compatibilization of the process and control systems of the analyzed device for comminution of grainy, polymer and biological materials are used, after statistical and substantial analysis, are used for local and coordinative optimization of the process. Original optimization method corresponds to current standards and assumptions of an intelligent system of granulation. The research method for local and coordinative optimization of grinding includes: creation of a measuring system for optimization and providing the basis for milling with the use of simulation and visualization methods,
- In terms of current advancement in construction of special mills and intelligent granulation system , the results of research on compatibilization are precious and innovative contribution to development of grainy materials engineering, design and operation of grinders on the national scale.

Comminution of rice depending on an increase in the rotational speed of the grinder working unit, was featured by:

- significant increase in specific energy consumption,
- growth in the power consumption,
- drop in production yield,
- similar degree of finenes,
- apropriate percentage number of comminuted particles in the range 0.5-2,0mm.

Acknowledgment

Scientific work financed by the budget resource for science in 2017-2021, as a research project under the “Diamentowy Grant” program.

References

[1] Kłos Z and Koper K 2017 Proposal of environmental aspects assesment of products, *Izvestiya Journal of Varna University of Economics* **61**(1) 36–48

[2] Flizikowski J, Piasecka I, Kruszelnicka W, Tomporowski A and Mroziński A 2018 Destruction assessment of wind power plastics blade, *Polimery* **63**(5) 381–386

[3] Tomporowski A, Flizikowski J, Kasner R and Kruszelnicka W 2017 Environmental Control of Wind Power Technology, *Rocznik Ochrona Środowiska* **19** 694–714

[4] Anastasi G, Corucci F and Marcelloni F 2011 *An intelligent system for electrical energy management in buildings*, 11th International Conference on Intelligent Systems Design and Applications, Cordoba, Spain, November 22-24, pp 702–707

[5] Bhinge R, Biswas N, Dornfeld D, Park J, Law K H, Helu M and Rachuri S 2014 *An intelligent machine monitoring system for energy prediction using a Gaussian Process regression*, 2014 IEEE International Conference on Big Data (Big Data), Washington, DC, USA, October 27-

30, pp 978–986
[6] Tomporowski A, Flizikowski J, Wełnowski J, Najzarek Z, Topoliński T, Kruszelnicka W, Piasecka I and Śmigiel S 2018 Regeneration of rubber waste using an intelligent grinding system, *Przemysł Chemiczny* **97**(10) 1659–1665
[7] Sallese L, Grossi N, Tsahalis J, Scippa A and Campatelli G 2016 Intelligent Fixtures for Active Chatter Control in Milling, *Procedia CIRP* **55** 176–181
[8] Piasecka I, Tomporowski A, Flizikowski J, Kruszelnicka W, Kasner R and Mroziński A 2019 Life Cycle Analysis of Ecological Impacts of an Offshore and a Land-Based Wind Power Plant, *Applied Sciences* **9**(2) 231
[9] Mannheim V 2014 Examination of Thermic Treatment and Biogas Processes by LCA, *Annals of the Faculty of Engineering Hunedoara - International Journal of Engineering* **12**(2) 225–234
[10] Mannheim V and Siménfalvi Z 2012 Determining a priority order between thermic utilization processes for organic industrial waste with LCA, *WIT Transactions on Ecology and the Environment* **163** 153–166
[11] Flizikowski J, Tomporowski A, Kasner R, Mroziński A and Kruszelnicka W 2019 Machinery Life Cycle Efficiency Models for their Sustainable Development, *System Safety: Human - Technical Facility - Environment* **1** 363–370
[12] Davé A, Salonitis K, Ball P, Adams M and Morgan D 2016 Factory Eco-Efficiency Modelling: Framework Application and Analysis, *Procedia CIRP* **40** 214–219
[13] Johnson N W 2013 Review of Existing Eco-efficient Comminution Devices, http://www.ceecthefuture.org/wp-content/uploads/2013/02/Blils-review-ofEco-eff-devices.pdf?dl=1
[14] Kruszelnicka W, Tomporowski A, Flizikowski J, Kasner R and Cyganiuk J 2019 Basis of Biomass Grinders Sustainable Designing, *System Safety: Human - Technical Facility - Environment* **1** 542–549
[15] Caiado R G G, de Freitas Dias R, Mattos L V, Quelhas O L G and Leal Filho W 2017 Towards sustainable development through the perspective of eco-efficiency - A systematic literature review, *Journal of Cleaner Production* **165** 890–904
[16] Fuerstenau D W and Abouzeid A-Z M 2002 The energy efficiency of ball milling in comminution, *International Journal of Mineral Processing* **67**(1-4) 161–185
[17] Kruszelnicka W, Flizikowski J and Tomporowski A 2018 Auto-monitoring system of grainy biomass comminution technology, *IOP Conf. Ser.: Mater. Sci. Eng.* **393** 012076
[18] Pomffyova M 2017 Monitoring and management of technology processes, *International Journal of Economics and Management Systems* **2** 248–253
[19] Remes A, Karesvuori J, Pekkarinen H and Jämsä-Jounela S-L 2006 Integrated approach to monitoring and control of mineral grinding Processes, *IFAC Proceedings Volumes* **39**(14) 124–129
[20] Tomporowski A, Flizikowski J and Kruszelnicka W 2017 A new concept of roller-plate mills, *Przemysł Chemiczny* **96**(8) 1750–1755
[21] Bayram M and Öner M D 2007 Bulgur milling using roller, double disc and vertical disc mills, *Journal of Food Engineering* **79**(1) 181–187
[22] Kruszelnicka W, Bałdowska-Witos P, Kasner R, Flizikowski J, Tomporowski A, Rudnicki J 2019 Evaluation of emissivity and environmental safety of biomass grinders drive, *Przemysł Chemiczny* **98**(9) 1494-1498
[23] Abdellahi M, Bahmanpour M and Bahmanpour M 2014 The use of artificial bee colony algorithm to speed up the nanopowders synthesis during high energy ball milling, *Powder Technology* **264** 61–70
[24] Ghayour H, Abdellahi M and Bahmanpour M 2016 Optimization of the high energy ball-milling: Modeling and parametric study, *Powder Technology* **291** 7–13