# Modeling and diagnosing of grinding system

# Моделювання та діагностика технологічної системи шліфування

# Моделирование и диагностика технологической системы шлифования

Supervisor – Doctor of Science, professor of the mechanical engineering technology department

Vasily Larshin, Василь Петрович Ларшин

Student Zhang Yunxuan, Чжан Юньсюань

*Технологічна система шліфування представлена у вигляді об'єкта управління, що має параметри входу, стану і виходу. У свою чергу, до складу цього об'єкта управління входять відповідні підсистеми оброблюваної заготовки, шліфувального круга і правлячого інструменту (алмазні ролики). Запропонований системний підхід є необхідною умовою для моделювання і діагностики технологічної системи шліфування з урахуванням взаємовпливу зазначених підсистем. Бібліографія, яка наведена в кінці статті, відображає окремі аспекти прийнятого в статті підходу.*

***Ключові слова:*** *об'єкт управління, проектування системи, моделювання, математична модель, алгоритм управління, модель системи управління, температура шліфування.*

*Технологическая система шлифования представлена в виде объекта управления, имеющего параметры входа, состояния и выхода. В свою очередь, в состав этого объекта управления входят соответствующие подсистемы обрабатываемой заготовки, шлифовального круга и правящего инструмента (алмазные ролики). Предложенный системный подход является необходимым условием для моделирования и диагностики технологической системы шлифования с учетом взаимовлияния указанных подсистем. Приведенная в конце статьи библиография отражает отдельные аспекты принятого в статье подхода.*

***Ключевые слова:*** *объект управления, проектирование системы, моделирование, математическая модель, алгоритм управления, модель системы управления, температура шлифования.*

*A grinding system is represented as a control object with input, state, and output parameters. In turn, this control object includes the corresponding subsystems of the workpiece to be ground, the grinding wheel and the dressing tool (diamond rollers). The proposed system approach is a necessary condition for modeling and diagnosing of the grinding system, taking into account the mutual influence of these subsystems. The bibliography given at the end of the paper reflects some aspects of the approach adopted in the paper.*

***Key words**: control object, system design, modelling, mathematical model, control algorithm, control system model, grinding temperature.*

## 1. Introduction

In accordance with the Systems engineering (theory of technical systems) one of the important initial stages of a system development is an adequate representation of the system from the concept stage to the running one. The system design includes its description, modelling and simulation, which may be represented in the respective formats: verbal description (text) in ordinary languages, graphical representations (block diagram, graphs), special signs systems (e.g., programming languages), mathematical model, a timing diagram, the combined method, etc. Selecting an appropriate way of the system representation depends on the purpose of the study. If the purpose is to create conditions to ensure the desired course of a process, when the process is the developing system, then it should be said of the system operation and control algorithm. In this case the technical system is being developed in the form of a control system model.

## 2. Literature Review

In this modelling (versus simulation) the system is a mathematical abstraction that is taken as a model of a dynamic phenomenon which represents the dynamic phenomenon in terms of mathematical relations. Such a system is characterized by the input ***u***, state ***x*** and output ***y*** (Fig.1, a) [1].

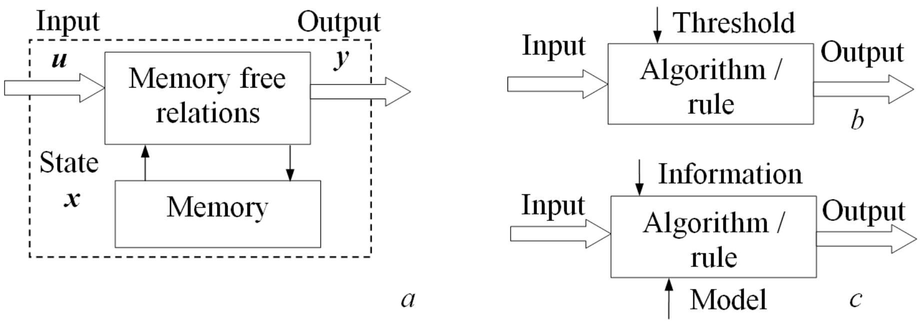


Fig.1 – Representation of the grinding system based on "input-state-output" model (a) [1] and those for decision making without (b) and with (c) a model [2].

The input ***u*** in the form of a set of time functions (e.g., in time domain) is the external forces (input variables) which are acting upon the grinding process that represents the dynamic phenomenon mentioned. The state ***x*** is a form of the system state-space representation, which with the input affects the output ***y***. The output y in similar form is the measures of the grinding process result, i.e. output quantities belonging to the ground part (part accuracy, surface finish and surface integrity).

A basic characteristic of any dynamic phenomenon is its behavior at any time and whether or not the behavior is traceable not only to the presently applied forces (input variables) but also to those applied in the past. A dynamic phenomenon (process) may or may not possess a memory depending on whether or not the effect of past applied forces is stored. In this connection the state x of the system is a vector function of time (e.g., in time domain) as well as both the input u and output y. In grinding it may be corresponding signals like those of grinding forces ***F*** in Newtons, temperature ***T*** in Celsius or acoustic emission ***AE*** in RMS quantities.

Similarly, the system approach have been taken by H.K. Tönshoff et al [2] to explain a strategy of decision making while interpreting a process monitoring in grinding without (Fig. 1, *b*) and with (Fig. 1, *c*) a process model. There are two approaches for the decision making. Firstly, the distinctive values of the processed signals are to be compared with a predetermined threshold in order to identify the status of the grinding process by means of preparing a process database (memory stored). This approach is the preferred choice for sensor signals used to interpret output quantities. Secondly, a model based identification approach may be when various kinds of physical or empirical models are employed which utilize known relationships (Fig.1, *c*). As a result, the calculated value is compared with a threshold in order to evaluate the process. This approach is the preferred choice for the sensor signals used to monitor the process quantities which are equal to the system state ones. Because of its complexity and significance, the model based identification approach involves understanding the process model (don't confuse with the grinding system model). In this connection the methods for process modelling are of great impotence as they are in decision making.

### 3. Research Methodology

Methods for process modelling discussed further. Besides, the model definition mentioned above another term to explain the "model" may be as follows: a model is the abstract representation of a manufacturing process which serves to link causes and effects [2]. That is why the description of the correlation of different quantities of a real system to correspond to a modeled system is the dominant task of process models. In grinding, the dependences of settings on process quantities such as grinding forces ***F***, temperature ***T***, and acoustic emission *AE* as well as on output quantities such as surface roughness and surface integrity (surface layer quality like grinding burns and residual stresses) may be mapped too on the basis of F. Klocke' representation [3]. Taking into account this representation, a model of technological grinding system can be represented as follows

(Fig. 2). The model consists of the following state parameters: $\boldsymbol{Q'_w}$, $\boldsymbol{V'_w}$, $\boldsymbol{F}$, $\boldsymbol{T}$, $\boldsymbol{AE}$, where $\boldsymbol{Q'_w}$ is the specific material removal rate in $mm^3/(s\cdot mm)$, $\boldsymbol{V'_w}$ is the specific material removal in $mm^3/mm$.

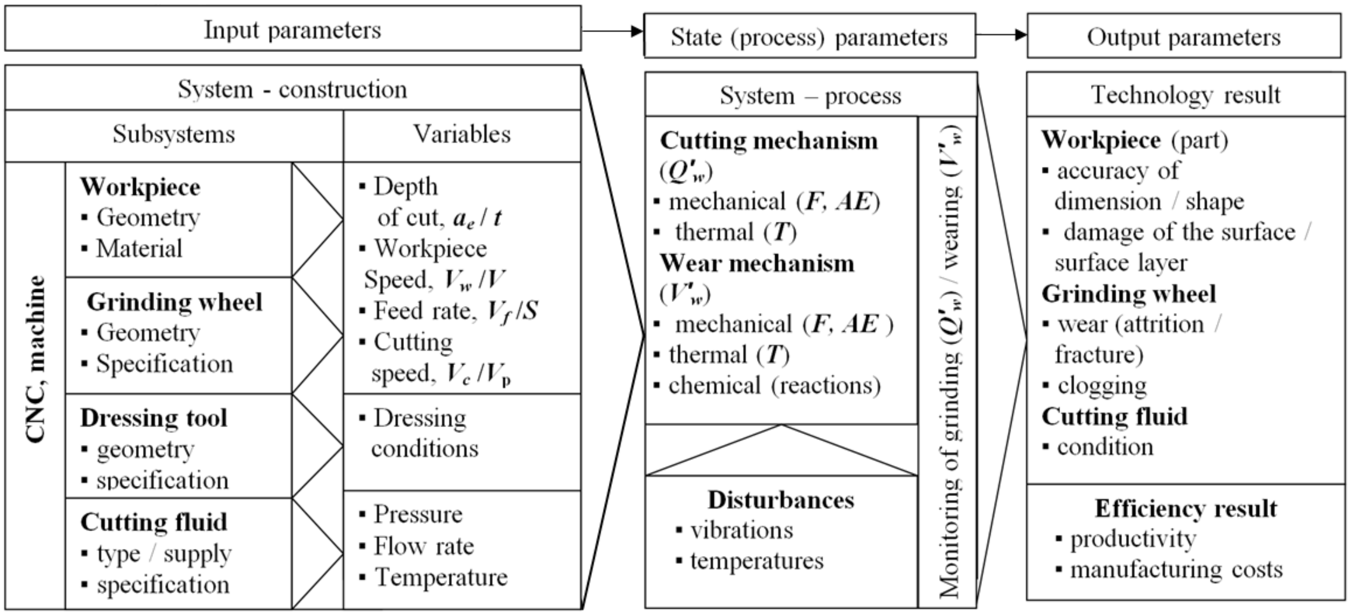


Fig. 2. Grinding system model (in fractional notations the input variables are listed in overseas [3] and domestic designations).

## 4. Results

1. In the paper a methodology for studying the grinding system as a control object having an input (grinding parameters, part to be ground parameters, grinding wheel parameters), a state (grinding forces and temperature, acoustic emission. etc.) and an output (part accuracy parameters, surface finish and surface integrity after grinding) is represented. The methodology includes the new approaches (theoretical-and-probabilistic, frequency, etc.), as well as the modeling, optimization, and control methods and working techniques [4-7].

2. Further studying of three-, two- and one-dimensional solutions of the differential equation of thermal conductivity has been developed and the following conditions for the use of an analytical one-dimensional solution for determining the grinding temperature are found: the dimensionless rate of the thermal source (Peclet number) must be not less than four; the thermal flux must be averaged over at least three areas of the contact zone in the profile grinding [8-12].

3. Based on the Ni-DAQ$_{mx}$ data acquisition system and Ni-LabVIEW software, an automated system of scientific research is developed to increase the efficiency of collecting and processing experimental data both in on-line and off-line modes [13-15].

4. The bibliography given at the end of the paper reflects some aspects of the approach adopted in the paper.

## 5. Conclusions

1. The grinding temperature is one of the factors limiting the performance of the profile grinding operation; therefore the temperature information is used to optimize the grinding parameters during both the production and production preparation stages.

2. The grinding temperature is conventionally determined either theoretically or experimentally, on the basis of the mathematical models of the temperature field and by means of using the sensors for direct and indirect measurements, respectively. The physical essence of temperature modeling and simulation has been revealed; it consists in using a vector model of the temperature field and naturally takes into account the geometric shape of the surface being ground.

## 6. Acknowledgement

This work was carried out under the state (Ukraine) budget theme of the Odessa National Polytechnic University (2018-2021, registration number: 0118U004400)

## Reference

1. Freeman Herbert (1965) Discrete-time systems: an introduction to the theory / Herbert Freeman. – New York: J. Wiley. - 241 p.

2. Tönshoff, H. K. (2002) Process monitoring in grinding / H. K. Tönshoff, T. Friemuth, J. C. Becker. – CIRP Annals – Manufacturing Technology. – Volume 51, Issue 2. - PP. 551-571.

3. Klocke Fritz (2009) Manufacturing Processes 2: Grinding, Honing, Lapping / Fritz Klocke. – Berlin: Springer. - 433 p.

4. Lishchenko, N. & Larshin, V. (2019) Grinding Temperature Model Simplification for the Operation Information Support System, Scientific Journal Herald of Advanced Information Technology, Odessa, Ukraine, Publ, Science and Technical, Vol. 2, No. 3, - PP. 197-205. DOI: 10.15276/hait.03.2019.3.

5. Lishchenko, N. & Larshin, V. (2019) Temperature Models for Grinding System State Monitoring, Applied Aspects of Information Technology, Odessa, Ukraine, Publ, Science and Technical, Vol. 2, No. 3, pp. 216-229. DOI: 10.15276/aait.03.2019.4.

6. Lishchenko, N. & Larshin, V. (2019) “Comparison of Measured Surface Layer Quality Parameters with Simulated Results”, Applied Aspects of Information Technology, Odessa, Ukraine, Publ, Science and Technical, Vol. 2, No. 4, - PP. 304-316. DOI: 10.15276/aait.02.2019.5.

7. Larshin, V. & Lishchenko, N. (2019) Education Technology Information Support, Scientific Journal Herald of Advanced Information Technology, Odessa, Ukraine, Publ, Science and Technical, Vol. 2, No. 4, - PP. 317-327. DOI: 10.15276/hait.04.2019.8.

8. Larshin, V. & Lishchenko, N. (2020) Detecting Systematic and Random Component of Surface Roughness Signal, Scientific Journal Herald of Advanced Information Technology, Odessa, Ukraine, Publ, Science and Technical, Vol. 3, No. 2, - PP. 61-71. DOI: 10.15276/hait.03.2019.3.

9. Larshin, V. & Lishchenko, N. (2020) Intermittent grinding temperature modeling for grinding system state monitoring Applied Aspects of Information Technology, Odessa, Ukraine, Publ, Science and Technical, Vol. 3, No. 2, - PP. 58-73. DOI: 10.15276/aait.02.2020.3.

10. Larshin V. P., Lishchenko N. V. (2020) Complex-shaped parts grinding technology information ensuring. Applied Aspects of Information Technology. Odessa, Ukraine, Publ, Science and Technical, Vol.3 No.4: - PP. 246–262. DOI: 10.15276/aait.04.2020.3.

11. Larshin V. P., Lishchenko N. V., Babiychuk O.B., Piteľ Ján (2021) Virtual reality and real measurements. Applied Aspects of Information Technology. Odessa, Ukraine, Publ, Science and Technical; Vol.4 No.1: - PP. 24–36. DOI: 10.15276/aait.01.2021.2

12 Lishchenko N.V., Larshin V.P. (2019) Profile Gear Grinding Temperature Determination. Lecture Notes in Mechanical Engineering. Proceedings of the 4th International Conference on Industrial Engineering. - PP. 1723–1730.

13. Lishchenko N. V., Larshin V. P. (2020) Temperature Field Analysis in Grinding. Lecture Notes in Mechanical Engineering. Advances in Design, Simulation and Manufacturing II. - PP. 199–208.

14. Lishchenko N. V., Larshin V. P. (2020) Gear-Grinding Temperature Modeling and Simulation. Lecture Notes in Mechanical Engineering. Proceedings of the 5th International Conference on Industrial Engineering. - PP. 289–297.

15. Larshin V., Lishchenko N., Lysyi O., Uminsky S. (2021) Intelligent Numerical Control of Profile Grinding. In: Ivanov V., Trojanowska J., Pavlenko I., Zajac J., Peraković D. (eds) Advances in Design, Simulation and Manufacturing IV. DSMIE 2021. Lecture Notes in Mechanical Engineering. Springer, Cham. https://doi.org/10.1007/978-3-030-77719-7_21