

SUMMARY

of the PhD Thesis on the Specialty «6D070400 - Computer Science and Software Engineering» A.Z. Bigaliyeva «Development of a software package for intelligent control of the fine grinding technological process»

The dissertation work is devoted to improving the efficiency of the technological process of extracting valuable components using an intelligent control system in turbulent shredders.

Topicality of the research

The accumulation of man-made waste in Kazakhstan began in the middle of the XIX century and is currently accumulating.

The existing and widely used methods in non-ferrous metallurgy for processing slags, tailings of enrichment introduce significant energy consumption and low recoverability of the metal, as well as the requirements for environmental protection do not meet the modern requirements of a comprehensive energy-saving technology for processing mineral raw materials.

Heap leaching is one of the most widely used technologies in Kazakhstan. This technological process is prohibited for use in many countries due to its particular danger to the environment.

The way out of this situation is to develop an environmentally friendly technology using modern mechanochemistry.

The raw material base for the implementation of the proposed technology is historical and modern products in the form of slurries, slags, overburden, off-balance ores in dumps and warehouses. For the conditions of the Kazakhmys copper corporation, depending on the type of copper ore, the share of related components in the total cost is from 24% to 50% or in monetary terms \$80...\$ 120 per ton, excluding the cost of copper. In the case of the organization of its own production for the processing of man-made waste in the cost of raw materials will be zero. The cost of the extracted metal, taking into account production costs, will be approximately in the range of \$ 200 - \$ 250 per ton.

The method of direct extraction of metal from ore and man-made raw materials consists in ultrafine grinding (the order of 80 ... 125 micrometers of the mineral component). With the subsequent air and magnetic classification of the grinding medium with the separation of the metal and mineral components.

In all technologies, the main operation that determines the entire subsequent course of the technology is the fine or even ultra-fine grinding of the raw material.

Thus, the task of developing algorithms for controlling the process of fine grinding, ensuring the improvement of the quality of grinding, is relevant.

The development of computer technologies determines the possibility of practical use of regulators for controlling specialized mechanical devices.

The problem with using classical controllers is that it is not always possible to represent input and output data based on the expert's knowledge and experience in the control logic.

An effective solution is to use fuzzy controllers as the control of the actuators. Fuzzy controllers have the ability to work with rapidly changing, complex dynamic processes, to take into account incomplete and ambiguous information about the process.

The controls must be «intelligent» and provide high accuracy with a simple and inexpensive hardware implementation.

The dissertation work is a result in the formation of the theory and practical methods for the synthesis of intelligent control systems for grinding in turbulent grinders. The implementation of the process control was performed using the Arduino Mega 2560 microcontroller based on Fuzzy Logic.

The aim of the research – improving the efficiency of the technological process of extracting valuable components using an intelligent control system.

Research objectives:

- to investigate the influence of architectural features of shredders on the technological process of extracting valuable components;
- to develop a control system that takes into account the features of the turbulent chopper architecture and complex nonlinear thermomechanical processes in the medium under study;
- to develop a software model of an intelligent control system and conduct numerical simulation;
- to develop and implement a microcontroller software and hardware complex using fuzzy logic for experimental research.

Research methods

The tasks set in the dissertation work are solved on the basis of artificial intelligence technologies. The methods of classical set theory and formal logic were used. Modeling, research and verification of the algorithms being developed, the formulation of research and experiments were carried out using mathematical packages MatLAB, Fuzzy Logic Toolbox, programming languages C /C++.

Verification of the theoretical positions and adequacy of the models developed in the dissertation work was carried out using computer modeling on a PC and experimental studies on experimental stands.

Statements for the defense:

- the results of the study of the influence of architectural features of industrial shredders on the technological process of extracting valuable components;
- hardware and software complex of the developed intelligent control system.

Scientific outcomes:

- the influence of architectural features of shredders on the technological process of extraction of valuable components is investigated;
- an intelligent control system of the shredder has been developed, taking into account the architecture features, based on fuzzy logic in the MATLAB environment, and its technical and operational characteristics have been investigated;
- a microcontroller software and hardware complex using fuzzy logic for experimental research has been developed and implemented.

The scientific novelty:

- an intelligent control system for a turbulent rock shredder has been developed;
- an intelligent software package has been developed in the MATLAB environment;
- a microcontroller software and hardware complex using fuzzy logic is implemented.

Practical significance of the research outcomes in this work lies in the fact that thanks to the development, testing and implementation of a software package for intelligent control of the technological process of fine grinding, it became possible to improve the quality of grinding.

Personal contribution of the PhD student consists in direct participation in the formulation of research tasks, obtaining initial data, in conducting the main volume of theoretical and experimental research set out in the dissertation work, analyzing and processing the results of the work in the form of scientific publications and reports at scientific conferences.

Approbation of the thesis outcomes:

1. Seminar of doctoral students of the Department «Computer and software engineering».
2. Seminar of the ITMO University Megafacultet of Computer Technologies and Management, Russian Federation, Saint Petersburg, 2019.
3. VIII Congress of Young Scientists (St. Petersburg, 2019). Diploma in the category «Best report».
4. International Scientific and Technical Conference of Young Scientists of BSTU named after V. Sh. Shukhov (Belgorod, 2019).
5. «Научная сессия ТУСУР-2020» XXV International Scientific and Technical Conference of Students, Postgraduates and Young Scientists (Tomsk, 2020).

Publications:

- **publications in publications included in the scientometric databases**

Scopus

1. Вопросы управления процессом тонкого помола в планетарной мельнице // Вестник Санкт-Петербургского университета. Прикладная математика. Информатика. Процессы управления. – 2020. Т. 16, Вып. 3. – С. 277-292 (База данных Scopus).

– articles published in scientific journals recommended by the KKSON of the Ministry of Education and Science of the Republic of Kazakhstan:

1. Расчёт степени помола сырья с применением компьютерных технологий ANETR5 на примере планетарной мельницы // Университетінің еңбектері – Труды университета. – 2018. – №4. – С. 139-144.
2. Разработка и моделирование оптимального контроллера LQG для управления процессом помола // Вестник КазНУ. – 2019. – №6. – С. 526-533.
3. Математическая модель процесса помола в планетарной мельнице

// Университетінің еңбектері – Труды университета. – 2020. – №1. – С. 148-153.

4. Построение фильтра Калмана для восстановления недостающей информации о состоянии процесса помола в планетарной мельнице // Университетінің еңбектері – Труды университета. – 2020. – №2. – С. 133-138.

5. Синтез LQG регулятора для интеллектуального управления технологическим процессом тонкого помола // Вестник Национальной инженерной академии Республики Казахстан. – 2020. – №4. – С. 21-27.

– **publications published in the proceedings of international conferences:**

1. Бигалиева А.З. Расчёт степени помола сырья с применением прикладного программного обеспечения ANETR5 на примере планетарной мельницы. // Технический журнал «Автоматизация. Современные технологии». – 2019. – №2. – С.155-160.

2. Бигалиева А.З., Лисицына Л.С. Интеллектуальные системы управления для неопределённых ситуаций управления // Сборник тезисов докладов конгресса молодых ученых. Электронное издание. - [2019, электронный ресурс]. - Режим доступа: <https://kmu.itmo.ru/digests/article/674>, своб.

3. Бигалиева А.З. Разработка экспертной системы по управлению технологическим процессом на основе нечёткой логики // Сборник докладов «Международная научно-техническая конференция молодых ученых БГТУ им.В.Ш.Шухова», г.Белгород. – 2019. – С.2868-2873.

4. Бигалиева А.З. Интеллектуальное управления технологическим процессом тонкого помола // Сборник избранных статей научной сессии ТУСУРа по материалам XXIV Международной научно-технической конференции студентов, аспирантов и молодых ученых «Научная сессия ТУСУР-2019». – 2019. – С.104-106.

5. Атанов С.К., Бигалиева А.З. Интеллектуальное управление технологическим процессом тонкого помола LQR регулятором // Материалы докладов Международной научно-практической конференции «Электронные средства и системы управления». – 2019. – С.61-63.

6. Бигалиева А.З., Мурых Е.Л. Вопросы управления процессом помола с применением фильтра Калмана // Сборник избранных статей научной сессии ТУСУРа по материалам XXV Международная научно-техническая конференция студентов, аспирантов и молодых ученых «Научная сессия ТУСУР-2020». – 2020. – С.18-21.

7. Бигалиева А.З. Определение значения внутримельничного заполнения шарами и акустический анализ // Материалы Международной научной конференции «Теоретические и прикладные вопросы математики, механики и информатики». – 2019. – С.126-127.

– **certificate of state registration for the object of copyright:**

1. Computer program: Интеллектуальное управление технологическим процессом тонкого помола. Certificates on entering information into the State register of Rights to objects protected by copyright No. 5042 of 27.08.2019.

2. Computer program: Интеллектуальное управление технологическим процессом тонкого помола. Certificates on entering information into the State

register of Rights to objects protected by copyright No. 15286 of 18.02.2021.

– **implementation act:**

2 acts of implementing the software «I Интеллектуальное управление технологическим процессом тонкого помола».

On the topic of the dissertation, 13 papers were published, reflecting the main results of the work, including 1 publication in publications included in the scientometric databases Scopus, 5 publications in journals from the list of KKSOn, 7 publications in peer-reviewed Russian scientific journals and proceedings of international conferences. There is two acts on the implementation of the results of the dissertation and two certificates of state registration of rights to the object of copyright.

Volume and structure of the thesis:

The dissertation consists of an introduction, three sections, a conclusion and a list of references. The volume of work is 68 pages, includes 41 figures, 8 tables, 3 appendices. The list of sources used contains 81 titles.

The introduction presents the scientific apparatus of the research, the rationale for the relevance of the research, the degree of its study in theory and practice, defines the purpose, objectives, object and subject of the research, reveals the scientific novelty, theoretical and practical significance of the work, defines the research methods, presents the provisions submitted for defense, the personal contribution of the author, the list of publications and approbations of the results of the work.

Section 1 includes an analysis of the problem of processing man-made mineral formations. The analysis of existing ways of controlling the technological process of grinding is given. The device and the principle of operation of a turbulent shredder are considered.

Section 2 includes the basic principles of building intelligent systems in a fuzzy environment. Theory of fuzzy sets. Development of the regulator structure based on fuzzy logic. The construction of fuzzy logic in the MATLAB system is considered.

Section 3 The hardware and software complex for controlling the technological process of fine grinding based on Arduino is considered.

In conclusion, the results of the study are summarized, the main conclusions are formulated, confirming and proving the truth of the provisions submitted for defense.

The appendix presents practical research materials.

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