

International periodic scientific journal

—ONLINE

www.moderntechno.de



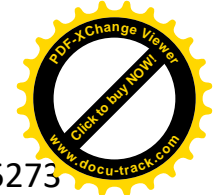
Indexed in
INDEXCOPERNICUS
(ICV: 95.33)

MODERN ENGINEERING AND INNOVATIVE TECHNOLOGIES

Heutiges Ingenieurwesen und
innovative Technologien

Issue №18
Part 1
December 2021

Published by:
Sergeieva&Co
Karlsruhe, Germany



ISSN 2567-5273
DOI 10.30890/2567-5273

Editor: Shibaev Alexander Grigoryevich, *Doctor of Technical Sciences, Professor, Academician*

Scientific Secretary: Kuprienko Sergey, *PhD in technical sciences*

Editorial board: More than 240 doctors of science. Full list on pages 4-5

UDC 08

LBC 94

DOI: 10.30890/2567-5273.2021-18-01

Published by:

Sergeieva&Co

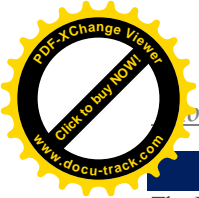
Lußstr. 13

76227 Karlsruhe, Germany

e-mail: editor@modern techno.de

site: www.moderntechno.de

Copyright
© Authors, 2021



About the journal

The International Scientific Periodical Journal "Modern Technology and Innovative Technologies" has been published since 2017 and has gained considerable recognition among domestic and foreign researchers and scholars.

Periodicity of publication: Quarterly

The journal activity is driven by the following objectives:

- Broadcasting young researchers and scholars outcomes to wide scientific audience
- Fostering knowledge exchange in scientific community
- Promotion of the unification in scientific approach
- Creation of basis for innovation and new scientific approaches as well as discoveries in unknown domains

The journal purposefully acquaints the reader with the original research of authors in various fields of science, the best examples of scientific journalism.

Publications of the journal are intended for a wide readership - all those who love science. The materials published in the journal reflect current problems and affect the interests of the entire public.

Each article in the journal includes general information in English. The journal is registered in INDEXCOPERNICUS.

Sections of the Journal:

Library of Congress Classification Outline	Sections
Subclass TJ / TJ1-1570	Mechanical engineering and machinery
Subclass TK / TK1-9971	Electrical engineering.
Subclass TA / TA165	Engineering instruments, meters, etc. Industrial instrumentation
Subclass TK / TK5101-6720	Telecommunication
Subclass TK / TK1-9971	Electrical engineering. Electronics. Nuclear engineering
Subclass TN / TN1-997	Mining engineering. Metallurgy
Subclass TS / TS1950-1982, TS2120-2159	Animal products., Cereals and grain. Milling industry
Subclass TS / TS1300-1865	Textile industries
Subclass TK / TK7800-8360	Electronics
Subclass T / T55.4-60.8	Industrial engineering. Management engineering
Subclass T / T351-385	Mechanical drawing. Engineering graphics
Subclass TA / TA1001-1280, Subclass TL / TL1-484, Subclass TE / TE1-450, Subclass TF / TF1-1620	Transportation engineering, Motor vehicles. Cycles, Highway engineering. Roads and pavements, Railroad engineering and operation
Subclass TH / TH1-9745	Building construction
Subclass T / T55-55.3	Industrial safety. Industrial accident prevention
Additional sections	<i>Innovative economics and management, Innovations in pedagogy, Innovative approaches in jurisprudence, Innovative philosophical views</i>

Requirements for articles

Articles should correspond to the thematic profile of the journal, meet international standards of scientific publications and be formalized in accordance with established rules. They should also be a presentation of the results of the original author's scientific research, be inscribed in the context of domestic and foreign research on this topic, reflect the author's ability to freely navigate in the existing bibliographic context on the problems involved and adequately apply the generally accepted methodology of setting and solving scientific problems.

All texts should be written in literary language, edited and conform to the scientific style of speech. Incorrect selection and unreliability of the facts, quotations, statistical and sociological data, names of own, geographical names and other information cited by the authors can cause the rejection of the submitted material (including at the registration stage).

All tables and figures in the article should be numbered, have headings and links in the text. If the data is borrowed from another source, a bibliographic reference should be given to it in the form of a note.

The title of the article, the full names of authors, educational institutions (except the main text language) should be presented in English.

Articles should be accompanied by an annotation and key words in the language of the main text and must be in English. The abstract should be made in the form of a short text that reveals the purpose and objectives of the work, its structure and main findings. The abstract is an independent analytical text and should give an adequate idea of the research conducted without the need to refer to the article. Abstract in English (Abstract) should be written in a competent academic language.

The presence of UDC, BBK

Acceptance of the material for consideration is not a guarantee of its publication. Registered articles are reviewed by the editorial staff and, when formally and in substance, the requirements of the journal are sent to peer review, including through an open discussion using the web resource www.sworld.education

Only previously unpublished materials can be posted in the journal.

Regulations on the ethics of publication of scientific data and its violations

The editors of the journal are aware of the fact that in the academic community there are quite widespread cases of violation of the ethics of the publication of scientific research. As the most notable and egregious, one can single out plagiarism, the posting of previously published materials, the misappropriation of the results of foreign scientific research, and falsification of data. We oppose such practices.

The editors are convinced that violations of copyrights and moral norms are not only ethically unacceptable, but also serve as a barrier to the development of scientific knowledge. Therefore, we believe that the fight against these phenomena should become the goal and the result of joint efforts of our authors, editors, reviewers, readers and the entire academic community. We encourage all stakeholders to cooperate and participate in the exchange of information in order to combat the violation of the ethics of publication of scientific research.

For its part, the editors are ready to make every effort to identify and suppress such unacceptable practices. We promise to take appropriate measures, as well as pay close attention to any information provided to us, which will indicate unethical behavior of one or another author.

Detection of ethical violations entails refusal to publish. If it is revealed that the article contains outright slander, violates the law or copyright rules, the editorial board considers itself obliged to remove it from the web resource and from the citation bases. Such extreme measures can be applied only with maximum openness and publicity.



Editorial board

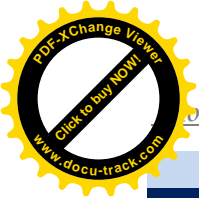
Averchenkov Vladimir Ivanovich, Doctor of Technical Sciences, Professor, Bryansk State Technical University, Russia
 Angelova Polya Georgieva, Doctor of Economic Sciences, Professor, Economic Academy D A Tsenova, Svishtov, Bulgaria, Bulgaria
 Animica Evgenij Georgievich, Doctor of Geographical Sciences, Professor, Ural State University of Economics, Russia
 Antonov Valerij Nikolaevich, Doctor of Technical Sciences, Professor, National Technical University of Ukraine "Kiev Polytechnical Institute", Ukraine
 Antrapceva Nadezhda Mihajlovna, Doctor of Chemical Sciences, Professor, National University of Life and Environmental Sciences of Ukraine, Ukraine
 Ahmadiyev Gabdulah Malikovich, Doctor of Veterinary Sciences, Professor, Kazan (Volga) Federal University, Russia
 Bazheva Rima Chamalovna, Doctor of Chemical Sciences, Professor, Kabardino-Balkarian State University named after H M Berbekov, Russia
 Batyrgareeva Vladislava Stanislavovna, Doctor of Law, Research Institute for the Study of Crime Problems named after academician V V Stashisa NAPRN of Ukraine, Ukraine
 Bezdenzheniy Tatjana Ivanovna, Doctor of Economic Sciences, Professor, St Petersburg State University of Economics, Russia
 Blatov Igor Anatolevich, Doctor of Physical and Mathematical Sciences, Professor, Volga State University of Telecommunications and Informatics, Russia
 Burda Aleksey Grigorevich, Doctor of Economic Sciences, Professor, Kuban State Agrarian University, Russia
 Buharina Irina Leonidovna, Doctor of Biological Sciences, Professor, Udmurt State University, Russia
 Bushueva Inna Vladimirovna, Doctor of Pharmaceutical Sciences, Professor, Zaporizhzhya State Medical University, Ukraine
 Bykov Yuriy Aleksandrovich, Doctor of Technical Sciences, Professor, Moscow State University of Railway Engineering, Russia
 Velichko Stepan Petrovich, Doctor of Education, Professor, Kirovograd State Pedagogical University named after Vladimir Vinnichenko, Ukraine
 Vizir Vadim Anatolevich, Doctor of Medical Sciences, Professor, Zaporizhzhya State Medical University, Ukraine
 Vozhegova Raisa Anatolevna, Doctor of Agricultural Sciences, Professor, Institute of Irrigated Agriculture of the National Academy of Agrarian Sciences of Ukraine, Ukraine
 Volgireva Galina Pavlovna, Candidate of Historical Sciences, assistant professor, Perm State University, Russia
 Voloh Dmitriy Stepanovich, Doctor of Pharmaceutical Sciences, Professor, A A National Medical University Pilgrim, Ukraine
 Vorozhbitova Aleksandra Anatolevna, Doctor of Philology, Professor, Sochi State University, Russia
 Gavrilenko Nataliya Nikolaevna, Doctor of Education, assistant professor, Peoples' Friendship University of Russia, Russia
 Georgievskij Gennadiy Viktorovich, Doctor of Pharmaceutical Sciences, senior scientific employee, SE "Ukrainian Scientific Pharmacopoeia Center for the Quality of Medicines", Ukraine
 Getman Anatolij Pavlovich, Doctor of Law, Professor, National Law University named after Yaroslav the Wise, Ukraine
 Gilev Gennadiy Andreevich, Doctor of Education, Professor, Moscow State Industrial University, Russia
 Goncharuk Sergej Mironovich, Doctor of Technical Sciences, Professor, Russia
 Granovskaya Lyudmila Nikolaevna, Doctor of Economic Sciences, Professor, Kherson State Agrarian University, Ukraine
 Grebneva Nadezhda Nikolaevna, Doctor of Biological Sciences, Professor, Russia
 Grizodub Aleksandr Ivanovich, Doctor of Chemical Sciences, Professor, SE "Ukrainian Scientific Center for the Quality of Medicines", Ukraine
 Gricenko Svetlana Anatolevna, Doctor of Biological Sciences, assistant professor, Ural State Academy of Veterinary Medicine, Russia
 Gudzenko Aleksandr Pavlovich, Doctor of Pharmaceutical Sciences, Professor, Lugansk State Medical University, Ukraine
 Demidova V G., candidate of pedagogical sciences, assistant professor, Ukraine
 Denisov Sergej Aleksandrovich, Doctor of Agricultural Sciences, Professor, Russia
 Dorofeev Andrej Viktorovich, Doctor of Education, assistant professor, Bashkir State University, Russia
 Dorohina Elena Yurevna, Doctor of Economic Sciences, assistant professor, G V Russian University of Economic Plekhanova, Russia
 Ermagambet Bolat Toleuanovich, Doctor of Chemical Sciences, Professor, Director of the Institute of Coal Chemistry and Technology LLP, Kazakhstan
 Zhovtonog Olga Igorevna, Doctor of Agricultural Sciences, Institute of Water Problems and Land Reclamation NAAS, Ukraine
 Zaharov Oleg Vladimirovich, Doctor of Technical Sciences, Professor, Saratov State Technical University, Russia
 Zubkov Ruslan Sergeevich, Doctor of Economic Sciences, assistant professor, Nikolaev Interregional Institute for Human Development of the Higher Educational Institution "University of Ukraine", Ukraine
 Irzhi Hlahula, Doctor of Geological and Mineralogical Sciences, Professor, FLKR - T Bati University, Zlín, Czech
 Kalajda Vladimir Timofeevich, Doctor of Technical Sciences, Professor, Tomsk State University, Russia
 Kalenik Tatjana Kuzminichna, Doctor of Biological Sciences, Professor, Far Eastern Federal University, Russia
 Kantarovich Yu L., Ph D in History of Arts, Odessa National Music Academy, Ukraine
 Kapitanov Vasilij Pavlovich, Doctor of Technical Sciences, Professor, Odessa National Maritime University, Ukraine
 Karpova Nataliya Konstantinovna, Doctor of Education, Professor, South Federal University, Russia
 Kafarskij Vladimir Ivanovich, Doctor of Law, Professor, Director of Science Center of Ukrainian Constitutionalism, Ukraine
 Kirillova Elena Viktorovna, Doctor of Technical Sciences, assistant professor, Odessa National Maritime University, Ukraine
 Kirichenko Aleksandr Anatolevich, Doctor of Law, Professor, Ukraine
 Klimova Natalya Vladimirovna, Doctor of Economic Sciences, Professor, Kuban State Agrarian University, Russia
 Knazeva Olga Aleksandrovna, Doctor of Biological Sciences, assistant professor, Bashkir State Medical University, Russia
 Kovalenko Elena Mihajlovna, doctor of philosophical science, Professor, South Federal University, Russia
 Kovalenko Petr Ivanovich, Doctor of Technical Sciences, Professor, Institute of Water Problems and Land Reclamation of the National Academy of Agrarian Sciences of Ukraine, Ukraine
 Kokebaeva Gaihatulbek Kekenovna, Doctor of Historical Sciences, Professor, Al-Farabi Kazakh National University, Kazakhstan
 Kondratov Dmitriy Vyacheslavovich, Doctor of Physical and Mathematical Sciences, assistant professor, Russian Academy of National Economy and Public Administration under the President of the Russian Federation, Russia
 Kopej Bogdan Vladimirovich, Doctor of Technical Sciences, Professor, Ivano-Frankivsk National Technical University of Oil and Gas, Ukraine
 Kosenko Nadezhda Fedorovna, Doctor of Technical Sciences, assistant professor, Ivanovo State University of Chemical Technology, Russia
 Kostenko Vasilij Ivanovich, Doctor of Agricultural Sciences, Professor, Ukraine
 Kotlyarov Vladimir Vladislavovich, Doctor of Agricultural Sciences, Professor, Kuban State Agrarian University, Russia
 Kochiney Yuriy Yurevich, Doctor of Economic Sciences, assistant professor, St Petersburg State Polytechnical University, Russia
 Kravchuk Anna Viktorovna, Doctor of Economic Sciences, Professor, Academy of the State Press Service, Ukraine
 Kruglov Valerij Mihajlovich, Doctor of Technical Sciences, Professor, Moscow State University of Railway Engineering, Russia
 Kuderin Marat Krykbaevich, Doctor of Economic Sciences, Professor, PSU named after S Toraiyrov, Kazakhstan
 Kurmaev Petr Yurevich, Doctor of Economic Sciences, Professor, Uman State Pedagogical University named after Pavel Tychnya, Ukraine
 Kuhar Elena Vladimirovna, Doctor of Biological Sciences, assistant professor, Kazakh Agro Technical University S Seifullina, Kazakhstan
 Lapkina Inna Aleksandrovna, Doctor of Economic Sciences, Professor, Odessa National Maritime University, Ukraine
 Latygina Natalya Anatolevna, Doctor of Political Science, Professor, Kiev National University of Trade and Economics, Ukraine
 Lebedev Anatolij Timofeevich, Doctor of Technical Sciences, Professor, Stavropol State Agrarian University, Russia

Lebedeva Larisa Aleksandrovna, candidate of psychological sciences, assistant professor, Mordevian State University, Russia
 Lipich Tamara Ivanovna, doctor of philosophical science, assistant professor, Belgorod State University, Russia
 Lomoto Denis Viktorovich, Doctor of Technical Sciences, Professor, Ukrainian State Academy of Railway Transport, Ukraine
 Lyalkina Larisa Vladimirovna, Doctor of Philology, assistant professor, Russian Academy of National Economy and Public Administration under the President of the Russian Federation, Russia
 Lyalkina Galina Borisovna, Doctor of Physical and Mathematical Sciences, Professor, Perm National Research Polytechnic University, Russia
 Majdanyuk Irina Zinovievna, doctor of philosophical science, assistant professor, National University of Life and Environmental Sciences of Ukraine, Ukraine
 Makarova Irina Viktorovna, Doctor of Technical Sciences, Professor, Kazan (Volga) Federal University, Russia
 Maksin Viktor Ivanovich, Doctor of Chemical Sciences, Professor, National University of Life and Environmental Sciences of Ukraine, Ukraine
 Malahov A V., Doctor of Physical and Mathematical Sciences, Professor, Ukraine
 Matveeva Anna Vasilevna, Doctor of Sociology, assistant professor, Altai State University, Russia
 Melnik Alyona Alekseevna, Doctor of Economic Sciences, assistant professor, Kiev National University of Technology and Design, Ukraine
 Milyaeva Larisa Grigorevna, Doctor of Economic Sciences, Professor, Biysk Technical Institute (branch) "Altai State Technical University named after I I Polzunova", head of the department of business economics, Russia
 Mishenina Tatjana Mihajlovna, Doctor of Education, Professor, Kryvyi Rih State Pedagogical University, Ukraine
 Mogilevska I M., candidate of pedagogical sciences, Professor, Ukraine
 Moiseykina Lyudmila Guchaevna, Doctor of Biological Sciences, Professor, Kalmyk State University, Russia
 Morozov Aleksey Vladimirovich, Doctor of Agricultural Sciences, Professor, Kherson State Agrarian University, Ukraine
 Morozova Tatjana Yurevna, Doctor of Technical Sciences, Professor, Moscow State University of Instrument Engineering and Computer Science, Russia
 Nefedeva Elena Eduardovna, Doctor of Biological Sciences, assistant professor, Volgograd State Technical University, Russia
 Nikolaeva Alla Dmitrievna, Doctor of Education, Professor, Northeast Federal University named after M K Ammosova, Russia
 Orlov Nikolaj Mihajlovich, Doctor of Science in Public Administration, assistant professor, Academy of Internal Troops of the Ministry of Internal Affairs of Ukraine, Department of Operational Conquest of the BB, Ukraine
 Otepova Gulmira Elubashevna, Doctor of Historical Sciences, Professor, Pavlodar State Pedagogical Institute, Kazakhstan
 Pavlenko Anatolij Mihajlovich, Doctor of Technical Sciences, Professor, Poltava National Technical University Yuri Kondratyuk, Ukraine
 Parunkyan Vaagn Emilevich, Doctor of Technical Sciences, Professor, Priazov State Technical University, Ukraine
 Patyka Nikolaj Vladimirovich, Doctor of Agricultural Sciences, Professor, National Scientific Center "Institute of Agriculture of NAAS", Ukraine
 Pahomova Elena Anatolevna, Doctor of Economic Sciences, assistant professor, International University of Nature, Society, and Man "Dubna", Russia
 Pachurin German Vasilevich, Doctor of Technical Sciences, Professor, Nizhny Novgorod State Technical University R E Alekseeva, Russia
 Pershin Vladimir Fedorovich, Doctor of Technical Sciences, Professor, Tambov State Technical University, Russia
 Piganov Mihail Nikolaevich, Doctor of Technical Sciences, Professor, Samara State Aerospace University named after academician S P Queen, Russia
 Polyakov Andrej Pavlovich, Doctor of Technical Sciences, Professor, Vinnitsa National Technical University, Ukraine
 Popov Viktor Sergeevich, Doctor of Technical Sciences, Professor, Saratov State Technical University, Russia
 Popova Taisiya Georgievna, Doctor of Philology, Professor, Peoples' Friendship University of Russia, Russia
 Rastrygina Alla Nikolaevna, Doctor of Education, Professor, Kirovograd State Pedagogical University named after Vladimir Vinnichenko, I Shevchenko, Krupytskyi, Ukraine
 Rebezov Maksim Borisovich, Doctor of Agricultural Sciences, Professor, Russia
 Reznikov Andrej Valentinovich, Doctor of Economic Sciences, assistant professor, Moscow State Technological University "Stankin", Russia
 Rokochinskij Anatolij Nikolaevich, Doctor of Technical Sciences, Professor, National University of Water Resources and Environmental Management, Ukraine
 Romashenko Mihail Ivanovich, Doctor of Technical Sciences, Professor, Institute of Water Problems and Land Reclamation of the National Academy of Agrarian Sciences of Ukraine, Ukraine
 Rylov Sergej Ivanovich, PhD in Economics, Professor, Odessa National Maritime University, Ukraine
 Savaleva Nelli Aleksandrovna, Doctor of Economic Sciences, Professor, Sochi State University, Russia
 Safarov Artur Mahmudovich, Doctor of Philology, Senior Lecturer, Russia
 Svetlov Viktor Aleksandrovich, doctor of philosophical science, Professor, Petersburg State University of Railway Engineering, Russia
 Semencov Georgij Nikiforovich, Doctor of Technical Sciences, Professor, Ivano-Frankivsk National Technical University of Oil and Gas, Ukraine
 Sentyabrev Nikolaj Nikolaevich, Doctor of Biological Sciences, Professor, Volgograd State Academy of Physical Culture, Russia
 Sidorovich Marina Mihajlovna, Doctor of Education, Professor, Kherson State University, Ukraine
 Sirota Naum Mihajlovich, Doctor of Political Science, Professor, State University of Aerospace Instrumentation, Russia
 Smirnov Evgenij Ivanovich, Doctor of Education, Professor, Yaroslavl State Pedagogical University named after K D Ushinsky, Russia
 Sokolova Nadezhda Gennadevna, Doctor of Economic Sciences, assistant professor, Izhevsk State Technical University, Russia
 Starodubcev Vladimir Mihajlovich, Doctor of Biological Sciences, Professor, National University of Life and Environmental Sciences of Ukraine, Ukraine
 Stegnij Vasilij Nikolaevich, Doctor of Sociology, Professor, Perm National Research Polytechnical University, Russia
 Stepenko Valerij Efremovich, Doctor of Law, assistant professor, Pacific State University, Russia
 Stovpce Olexsandr Vasilovich, Doctor of Philosophy, assistant professor, Odessa National Maritime University, Ukraine
 Stovpce Vasil Grigorevich, Candidate of Philology, assistant professor, Odessa National Maritime University, Ukraine
 Strelcova Elena Dmitrievna, Doctor of Economic Sciences, assistant professor, South Russian State Technical University (NPI), Russia
 Suhenko Yuriy Grigorevich, Doctor of Technical Sciences, Professor, National University of Life and Environmental Sciences of Ukraine, Ukraine
 Suhova Mariya Gennadevna, Doctor of Geographical Sciences, assistant professor, Gorno-Altai State University, Russia
 Tarariko Yuriy Aleksandrovich, Doctor of Agricultural Sciences, Professor, Ukraine
 Tarasenko Larisa Viktorovna, Doctor of Sociology, Professor, South Federal University, Russia
 Testov Boris Viktorovich, Doctor of Biological Sciences, Professor, Tobolsk Integrated Scientific Station, Ural Branch of the Russian Academy of Sciences, Tobolsk, Russia
 Tokareva Natalya Gennadevna, Candidate of Medical Sciences, assistant professor, Medical Institute FSBEI HE "Moscow State University named after NP Ogarev, Russia
 Tolbatov Andrej Vladimirovich, candidate of technical sciences, assistant professor, Sumy National Agrarian University, Ukraine
 Tonkov Evgenij Evgenievich, Doctor of Law, Professor, Law Institute of the National Research University Belgorod State University, Russia
 Trigub Petr Nikitovich, Doctor of Historical Sciences, Professor, Kazakh
 Tungushbaeva Zina Bajbagusovna, Doctor of Biological Sciences, Kazakh National Pedagogical University named after Abay, Kazakhstan
 Ustenko Sergej Anatolevich, Doctor of Technical Sciences, assistant professor, Nikolaev State University named after V O Sukhomlinsky, Ukraine
 Fateeva Nadezhda Mihajlovna, Doctor of Biological Sciences, Professor, Tyumen State University, Russia
 Fatyhova Alevtina Leontevna, Doctor of Education, assistant professor, Bashkir State University (Sterlitamak branch), Russia
 Fedorishin Dmitro Dmitrovich, Doctor of Geological and Mineralogical Sciences, Professor, Ivano-Frankivsk National Technical University of Oil and Gas, Ukraine



...otova Galina Aleksandrovna, Doctor of Education, Professor, Novgorod State University, Russia
 Fedyanina Lyudmila Nikolaevna, Doctor of Medical Sciences, Professor, Far Eastern Federal University, Russia
 Habibullin Rifat Gabdulhakovich, Doctor of Technical Sciences, Professor, Kazan (Volga) Federal University, Russia
 Hodakova Nina Pavlovna, Doctor of Education, assistant professor, Moscow City Pedagogical University, Russia
 Hrebina Svetlana Vladimirovna, Doctor of Psychology, Professor, Pyatigorsk State Linguistic University, Russia
 Chervonij Ivan Fedorovich, Doctor of Technical Sciences, Professor, Zaporizhzhya State Engineering Academy, Ukraine
 Chigirinskaya Natalya Vyacheslavovna, Doctor of Education, Professor, Volgograd State Technical University, Russia
 Churekova Tatyana Mihajlovna, Doctor of Education, Professor, Russia
 Shajko-Shajkovskij Aleksandr Gennadevich, Doctor of Technical Sciences, Professor, Chernivtsi National University Y Fedkovich, Ukraine
 Shapovalov Valentin Valerevich, Doctor of Pharmaceutical Sciences, Professor, Kharkov Medical Academy of Postgraduate Education, Ukraine
 Shapovalov Valerij Vladimirovich, Doctor of Pharmaceutical Sciences, Professor, Kharkiv Regional State Administration, Ukraine
 Shapovalova Viktoriya Aleksseevna, Doctor of Pharmaceutical Sciences, Professor, Kharkov Medical Academy of Postgraduate Education, Ukraine
 Sharagov Vasiliy Andreevich, Doctor of Chemical Sciences, assistant professor, Balti State University "Alecu Russo", Moldova
 Shevchenko Larisa Vasilevna, Doctor of Veterinary Sciences, Professor, National University of Life and Environmental Sciences of Ukraine, Ukraine
 Shepitko Valerij Yurevich, Doctor of Law, Professor, National Law University named after Yaroslav the Wise, Ukraine
 Shibaev Aleksandr Grigorevich, Doctor of Technical Sciences, Professor, Odessa National Maritime University, Ukraine
 Shishka Roman Bogdanovich, Doctor of Law, Professor, National Aviation University, Ukraine
 Sherban Igor Vasilevich, Doctor of Technical Sciences, assistant professor, Russia
 Elezovich M Dalibor, Doctor of Historical Sciences, assistant professor, Pristina University K Mitrovica, Serbia
 Yarovenko Vasiliy Vasilevich, Doctor of Law, Professor, Admiral G I Maritime State University Nevelsky, Russia
 Yacenko Aleksandr Vladimirovich, Professor, Institute of Maritime Economics and Entrepreneurship, Scientific Research Design Institute of the Marine Fleet of Ukraine, Ukraine
 Evstropov Vladimir Mikhailovich, Doctor of Medical Sciences, Professor, Russian Customs Academy, Russia
 Kononova Alexandra Evgenievna, PhD in Economics, docent, Pridneprovsk State Academy of Civil Engineering and Architecture, Ukraine
 Svitlana Titova, PhD in Geography, docent, Taras Shevchenko National University of Kyiv, Ukraine
 Tatarchuk Tetiana, PhD in technical sciences, NU "Zaporizhzhya Polytechnic", Ukraine
 Chupakhina Svitlana Vasyliivna, PhD in pedagogical sciences, docent, Vasyly Stefanuk Precarpathian National University, Ukraine
 Boiko Ruslan Vasiliovich, PhD in Economics, docent, Khmelnytsky National University, Ukraine
 Voropayeva Tetiana Sergiivna, PhD in Psychology, docent, Taras Shevchenko National University of Kyiv, Ukraine
 Zakhareenko Natalia, PhD in Economics, Priazov State Technical University, Ukraine
 Kirkin Oleksandr Pavlovich, PhD in technical sciences, docent, Priazov State Technical University, Ukraine
 Kyianovskiy Aleksandr Moiseevich, PhD in Chemistry, docent, Kherson State Agrarian University, Ukraine
 Tharkahova Irina Grigorevna, PhD in Economics, docent, Adyge State University, Russia
 Vitroviy Andriy Orestovych, PhD in technical sciences, docent, Ternopil National Economic University, Ukraine
 Khodakivska Olga, Doctor of Economic Sciences, senior research assistant, National Research Center "Institute of Agrarian Economics", Ukraine
 Shatkovskiy Andrii, Doctor of Agricultural Sciences, Institute of Water Problems and Melioration of the National Academy of Agrarian Sciences of Ukraine, Ukraine
 Katerynchuk Ivan Stepanovych, Doctor of Technical Sciences, Professor, National Academy of the State Border Service of Ukraine named after Bohdan Khmelnytsky, Ukraine
 Goncharenko Igor Vladimirovich, Doctor of Agricultural Sciences, Professor, National University of Bioresources and Nature Management of Ukraine, Ukraine
 Gornostaj Oryslava Bogdanivna, PhD in technical sciences, docent, Lviv State University of Life Safety, Ukraine
 Stanislavchuk Oksana Volodymyrivna, PhD in technical sciences, docent, Lviv State University of Life Safety, Ukraine
 Mirus Oleksandr-Zenovij Lvovich, PhD in Chemistry, docent, Lviv State University of Life Safety, Ukraine
 Nashynets-Naumova Anfisa, Doctor of Law, docent, Boris Grinchenko Kyiv University, Ukraine
 Kyselov Iurii Olexandrovych, Doctor of Geographical Sciences, Professor, Uman National University of Horticulture, Ukraine
 Smutchak Zinaida Vasyliivna, Doctor of Economic Sciences, docent, Flight Academy of the National Aviation University, Ukraine
 Polenova Galina Tikhonovna, Doctor of Philology, Professor, Rostov-on-Don State University of Economics, Russia
 Makeeva Vera Stepanovna, Doctor of Pedagogical Sciences, Professor, Russian State University of Physical Culture, Sports, Youth and Tourism, Russia
 Bunchuk Oksana, Doctor of Law, docent, Yurij Fedkovich Chernivtsi National University, Ukraine
 Gladukh Ievgenii, Doctor of Pharmacy, Professor, National University of Pharmacy, Ukraine
 Benera Valentyna, Doctor of Pedagogical Sciences, Professor, Taras Shevchenko Regional Humanitarian-Pedagogical Academy of Kremenets, Ukraine
 Demyanenko Natalia, Doctor of Pedagogical Sciences, Professor, Taras Shevchenko Regional Humanitarian-Pedagogical Academy of Kremenets, Ukraine
 Makarenko Andriy Viktorovich, PhD in pedagogical sciences, docent, Donbass State Pedagogical University, Ukraine
 Kharkovliuk-Balakina Natalia, PhD in biological sciences, docent, State Institution "Institute of Gerontology of the National Academy of Medical Sciences of Ukraine", Ukraine
 Chushenko Valentina Mykolajivna, PhD in pharmaceutical sciences, docent, National Pharmaceutical University, Ukraine
 Malinina Nina Lvovna, doctor of philosophical science, docent, Far Eastern Federal University", Russia
 Brukhansky Ruslan Feoktistovich, Doctor of Economic Sciences, Professor, Western Ukrainian National University, Ukraine
 Zastavetska Lesya Bogdanovna, Doctor of Geographical Sciences, Professor, Ternopil National Pedagogical University named after V Gnatyuk, Ukraine
 Kalabaska Vira Stepanivna, PhD in pedagogical sciences, docent, Uman State Pedagogical University named after Pavel Tychnina, Ukraine
 Kutishchev Stanislav Nikolaevich, Doctor of Physical and Mathematical Sciences, Professor, VSTU, Russia
 Pikas Olha Bohdanivna, Doctor of Medical Sciences, Professor, National Medical University named after A A Bogomolets, Ukraine
 Shepel Yuri Alexandrovich, Doctor of Philology, Professor, Oles Honchar Dnipro National University, Ukraine
 Kuris Yuri Vladimirovich, Doctor of Technical Sciences, Professor, Zaporizhzhya National University, Ukraine

Kalinichenko Irina Alexandrovna, Doctor of Medical Sciences, Professor, Sumy State Pedagogical University named after A S Makarenko, Ukraine
 Kagermazova Laura Israevna, Doctor of Psychology, Professor, Chechen State Pedagogical Institute, Russia
 Kravchenko Olena Ivanivna, Doctor of Pedagogical Sciences, assistant professor, Luhansk National Taras Shevchenko University, Ukraine
 Redkous Vladimir Mikhailovich, Doctor of Law, Professor, Institute of State and Law of the Russian Academy of Sciences, Russia
 Evstropov Vladimir Mikhailovich, Doctor of Medical Sciences, Professor, Russian Customs Academy, Russia
 Kononova Alexandra Evgenievna, PhD in Economic Sciences, assistant professor, Pridneprovsk State Academy of Civil Engineering and Architecture, Ukraine
 Svitlana Titova, PhD in Geography, assistant professor, Taras Shevchenko National University of Kyiv, Ukraine
 Tatarchuk Tetiana, PhD in Technical Sciences, Zaporizhzhya Polytechnic, Ukraine
 Chupakhina Svitlana Vasyliivna, PhD in Pedagogical Sciences, assistant professor, Vasyly Stefanuk Precarpathian National University, Ukraine
 Boiko Ruslan Vasiliovich, PhD in Economic Sciences, assistant professor, Khmelnytsky National University, Ukraine
 Voropayeva Tetiana Sergiivna, PhD in Psychology, assistant professor, Taras Shevchenko National University of Kyiv, Ukraine
 Kirkin Oleksandr Pavlovich, PhD in Technical Sciences, assistant professor, Priazovskiy State Technical University, Ukraine
 Kyianovskiy Aleksandr Moiseevich, PhD in Chemistry, assistant professor, Kherson State Agrarian University, Ukraine
 Tharkahova Irina Grigorevna, PhD in Economic Sciences, assistant professor, Adyge State University, Russia
 Vitroviy Andriy Orestovych, PhD in Technical Sciences, assistant professor, Ternopil National Economic University, Ukraine
 Khodakivska Olga, Doctor of Economic Sciences, senior researcher, National Research Center "Institute of Agrarian Economics", Ukraine
 Shatkovskiy Andrii, Doctor of Agricultural Sciences, Institute of Water Problems and Land Reclamation of the National Academy of Agrarian Sciences of Ukraine, Ukraine
 Katerynchuk Ivan Stepanovych, Doctor of Technical Sciences, Professor, National Academy of the State Border Service of Ukraine named after Bohdan Khmelnytsky, Ukraine
 Goncharenko Igor Vladimirovich, Doctor of Agricultural Sciences, Professor, National University of Bioresources and Nature Management of Ukraine, Ukraine
 Gornostaj Oryslava Bogdanivna, PhD in Technical Sciences, assistant professor, Lviv State University of Life Safety, Ukraine
 Stanislavchuk Oksana Volodymyrivna, PhD in Technical Sciences, assistant professor, Lviv State University of Life Safety, Ukraine
 Mirus Oleksandr-Zenovij Lvovich, PhD in Chemistry, assistant professor, Lviv State University of Life Safety, Ukraine
 Belotserkovets Vladimir Viktorovich, Doctor of Economic Sciences, Professor, National Metallurgical Academy of Ukraine, Ukraine
 Lopuch Protr Stepanovych, Doctor of Geographical Sciences, Professor, Belarusian State University, Belarus
 Shvets Iryna Borysovna, Doctor of Arts, Professor, Vinnytsia State Pedagogical University named after M Kotsyubynsky, Ukraine
 Morozov Oleg Viktorovich, Doctor of Historical Sciences, assistant professor, University of Customs and Finance, Ukraine
 Vykhrusch Vira Olexandriivna, Doctor of Pedagogy, professor, National University "Lviv Polytechnic", Ukraine
 Okhrimenko Viacheslav Mykolaiovich, PhD in Technical Sciences, assistant professor, Kharkiv University of Municipal Economy named after A M Beketova, Ukraine
 Podchashynskiy Yurii Olexandrovych, Doctor of Technical Sciences, professor, Zhytomyr Polytechnic, Ukraine
 Bilyavych Halyna Vasyliivna, Doctor of Pedagogy, professor, Vasyly Stefanuk Precarpathian National University, Ukraine
 Hurin Ruslan Serghiyovych, PhD in Pedagogical Sciences, assistant professor, South Ukrainian National Pedagogical University named after K D Ushinsky, Ukraine
 Sukhominov Anatolii Ivanovich, PhD in Technical Sciences, assistant professor, Far Eastern Federal University, Russia
 Popova Julia Mikhailivna, Doctor of Economic Sciences, assistant professor, Poltava State Agrarian University, Ukraine
 Kononenko Mykhailo Mykhaylovych, PhD in Public Administration, assistant professor, Poltava raionna glad, Ukraine
 Muliar Volodymyr Ilyich, Doctor of Philosophical Science, Professor, Zhytomyr Polytechnic, Ukraine
 Yefimova Olha Mykolajivna, PhD in Pedagogical Sciences, Senior Lecturer, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Ukraine
 Khymai Natalia Ihorivna, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Ukraine
 Zariivna Oksana Tymofiyivna, PhD in Pedagogical Sciences, assistant professor, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Ukraine
 Shalova Natalia Stanislavivna, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Ukraine
 Mitina Lubov Sergiivna, PhD in Philology, assistant professor, Kharkiv State Academy of Culture, Ukraine
 Suiima Irina Pavlivna, PhD in Philology, Oles Honchar Dnipro National University, Ukraine
 Medynska Tetiana Igorivna, PhD in Economics, assistant professor, Rivne State Humanitarian University, ORCID 0000-0001-6838-6403, Ukraine
 Vekua Oksana Vitalevna, PhD in Philology, assistant professor, Taras Shevchenko National University of Kyiv, Ukraine
 Shilo Zhanna Stepanivna, PhD in Economics, assistant professor, National University of Water Resources and Environmental Management, ORCID 0000-0002-2669-6734, Ukraine
 Chiladze Georgiy Bidzinovich, Doctor of Law, Professor, University of Georgia, Georgia
 Kolomiets Tetiana Vyacheslavivna, PhD in Philosophy, National Medical University named after A A Bogomolets, ORCID 0000-0002-5335-7789, Ukraine
 Fonar Liudmyla, PhD in technical sciences, Odessa National Polytechnic University, ORCID 0000-0002-7478-6742, Ukraine
 Melnyk Marharyta, PhD in technical sciences, assistant professor, Odessa National Polytechnic University, ORCID 0000-0003-0619-7281, Ukraine
 Cuznetov Alexandru Serghei, PhD in Law, assistant professor, Moldavian State University, ORCID 0000-0002-2738-5620, Moldova
 Yelnikova Mariia, PhD in political science, National Pedagogical University named after M P Dragomanov, ORCID 0000-0001-9250-4684, Ukraine
 Pysmenna Olena, PhD in Law, assistant professor, Donetsk National University named after Vasily Stus, Ukraine
 Knyazeva Maryna Vladislavovna, Kharkiv National University V N Karazin, Ukraine
 Khara Maryna Volodymyrivna, PhD in technical sciences, assistant professor, SHEE "Priazov State Technical University", Ukraine
 Nikolaienko Iryna Volodymyrivna, PhD in technical sciences, assistant professor, SHEE "Priazov State Technical University", Ukraine
 Malinovskiy Yuriy Alexandrovich, PhD in technical sciences, assistant professor, OSB "Kryvyi Rih Professional College of the National Aviation University", Ukraine
 Andrii Tkachuk, PhD in technical sciences, assistant professor, State University "Zhytomyr Polytechnic", Ukraine
 Shablii Tetiana Petrivna, PhD in Medical Sciences, assistant professor, Odessa National Medical University, ORCID 0000-0003-3114-3728, Ukraine
 Zaichukivska Oksana Vasulivna, PhD in Economics, assistant professor, NUVGP, ORCID 0000-0002-8792-9204, Ukraine



УДК 631.31:621.791.75

**APPLICATION OF WEAR-RESISTANT COATINGS TO INCREASE
RESOURCE OF WORKING BODIES OF GRINDING MACHINES****НАНЕСЕННЯМ ЗНОСОСТІЙКИХ ПОКРИТЬ ДЛЯ ПІДВИЩЕННЯ
РЕСУРСУ РОБОЧИХ ОРГАНІВ ҐРУНТООБРОБНИХ МАШИН**

Paladiychuk Yu. B. / Паладійчук Ю. Б.

s.t.s., as.prof / к. н. т., доцент

ORCID: 0000-0003-4257-9383

Telyatnuk I. A. / Телятник І. А.

*master's degree / магістр**Vinnitsia National Agrarian University, Vinnitsia, Academic str. 54, 21008**Вінницький національний аграрний університет, Вінниця, вул. Академічна 54, 21008*

Abstract. *Intensive compaction of the soil, which is caused by the use of modern powerful tractors with high weight and the presence of higher working speeds, and as a result reduces the service life of tillage equipment. Difficult weather conditions cause an increase in the load on the working bodies of tillage machines (plowshares, cultivator paws).*

The article considers the problem of restoring the resource of the working bodies of tillage machines by applying wear-resistant coatings. The types of wear and the impact of abrasive materials on the working bodies of tillage machines are analyzed. Determined optimal materials and methods to increase the wear resistance of the working bodies of tillage machines. Features of formation of a metallization covering which is reflected in its structure and character of defects which can differ in the sizes, density, morphology and orientation are considered. The dependence of the properties of coatings on the alloying system of the material is substantiated. Equipment and materials for coating are given.

Taking into account the received information, conclusions were made and the analysis of the technology of applying wear-resistant coatings for the restoration of the resource of the working bodies of tillage machines was carried out.

Key words: *tillage equipment, maintenance, tillage, metallization, surfacing, flux - cored wire, arc metallization, spraying.*

Formulation of the problem

The annual need of Ukraine's agriculture in working bodies for plows and other tillage machines is quite significant and cannot be estimated numerically. To maintain the efficiency of agricultural machinery, a significant number of spare parts are produced annually.

During tillage (plowing, cultivation) the energy intensity of the process increases sharply due to blunting of the working bodies due to abrasive wear [3].

The working bodies of tillage machines are exposed to shock-abrasive nature of wear, which occurs due to contact with soil particles and stones. Depreciation is influenced by concomitant factors such as: mechanical composition of the soil; humidity; hardness; material structure; pressure and speed of relative movement of soil on a surface of working bodies of tillage machines.

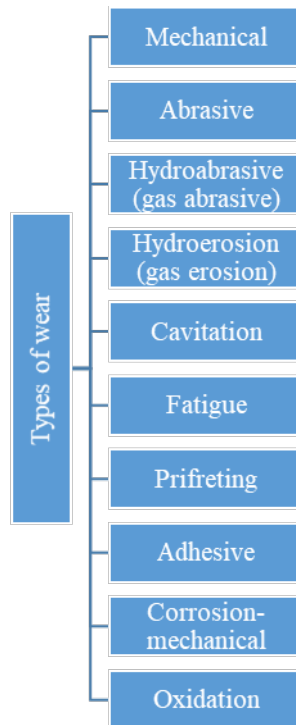
Table 1 shows an approximate classification of the characteristics of the variety of wear processes, which are the result of complex processes on the surface layer of the metal during wear, differences in conditions and modes of operation of friction pairs.

Abrasive wear is the main type of contact interaction during external friction.

Abrasive wear is present during the work of connections of working bodies of agricultural and other machines, which is the main factor that limits the technical characteristics and resource of machines, mechanisms and equipment [4].

This type of wear accounts for 50 to 80% of failures of the working bodies of machinery, including construction, road, transport, agricultural, livestock machinery and feed production [3].

Table 1. Classification of types of wear.



Abrasive particles such as quartz (HV 10.5-12.5 GPa) and feldspar (HV 6.5-7.2 GPa) are present in the soil. The presence of these minerals, based on sandy and loamy soils, explains the rapid wear of working bodies. Figure 1, 2 shows the characteristic wear profile of the working bodies of tillage machines.



Figure. 1. - Working bodies of tillage machines [4].

The manufacture of working bodies of tillage machines (plowshares, cultivator paws, harrow discs) should have increased requirements for the material, methods of improving wear resistance, manufacturing technology [4-5].

Abrasive wear is divided into four types:

1. destruction of material by cutting;
2. destruction of material by separation (brittle destruction);
3. destruction of the material by repeated deformation of the microvolumes of the surface layer (tiring destruction);
4. polydeformation process of destruction of materials (joint manifestation of the three above-mentioned destructions, including destruction as a result of re-riveting) [3].

Humidity, mechanical structure of the soil, the speed of relative movement and other factors affect the abrasive wear of the working bodies of tillage machines [3-6].

The abrasive content of the so-called quartz sand in the soil has the main effect on the abrasive wear of the working bodies of tillage machines. In addition to abrasive, which scratches or removes chips from the surface of the working bodies of tillage machines, the rate of wear is affected by the moisture present in the soil, which has a certain pH acidity. With increasing soil moisture and abrasive fraction (0.25 - 1.00 mm) the amount of wear increases by 25-50%.

Abrasive wear prevails over other types of wear, if the hardness of the abrasive exceeds the hardness of the material of the working body of tillage machines.



Figure. 2. The shape of the working body of the cultivator [4].

The purpose and objectives of the study

Restoration of the resource of working bodies of tillage machines due to the application of wear-resistant coatings.

To achieve this goal you need to solve the following tasks:

Analyze the types of wear and the impact of abrasive materials on the working bodies of tillage machines;

Determine the optimal materials and methods to increase wear resistance;

Taking into account the received information, draw conclusions and analyze the technology of applying wear-resistant coatings to increase the life of the working bodies of tillage machines.

Materials and methods to increase wear resistance

Increasing the wear resistance of the working bodies of tillage machines in agricultural engineering is due to:

- use of wear-resistant material and multilayer rolled metal;
- development of constituent working bodies;
- heat and thermochemical treatment;
- surfacing and spraying of wear-resistant materials.

When choosing a method of hardening depending on the type of soil should take into account not only technological and economic indicators, but also the need to implement the effect of self-sharpening of working bodies.

The essence of the effect of self-sharpening is the selective wear of the inhomogeneous cross-section of the blade, which retains the desired shape and cutting properties of the working body [4,5-7].

The production of trapezoidal bimetallic ploughshare with a two-layer rolled part of the blade made of steel H6F1 (lower layer) and L-53 (upper layer), allows to increase the service life and provide a self-sharpening effect. These plowshares have a longer service life, but to restore them requires the manufacture of specialized equipment for processing metals by pressure [4].

One of the most common technological operations for hardening is heat treatment. Due to heat treatment, the hardness of the metal for steel 45 is HRC 40-46, and for steel 65G and alloy steels - HRC 55-61. Wear resistance of such working bodies is less in comparison with the details made of special materials, but at application of such working bodies on loamy soils self-sharpening is not observed [6].

Wear of cultivator paws with induction hardening (width of the hardening layer - 8-10 mm, HRC 48-52) for the season will be 30 mm, while not ensuring the quality of processing [6].

The use of laser heat treatment to strengthen the working bodies 1.5 times reduces wear compared to bulk hardening. Laser surfacing with PS-14-60 + 6% B4C alloy reduces wear by 1.7-1.8 times compared to induction hardening [4].

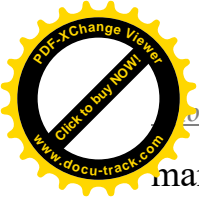
It is possible to increase wear resistance of details of cars at the expense of a surfacing.

Surfacing materials are self-protective flux-cored wires of the PP-AN170 type (PP-AN170M), provide the formation of a welded layer with a hardness of HRC 60-65.

Optimal wear resistance and self-sharpening is determined by adjusting the geometry of the deposited layer (height, depth, surfacing step), as well as the ratio of hardness of the deposited areas and the base metal in the range of 1.5: 1.0; 1.0: 1.0 [7].

Composite materials are mainly obtained by powder metallurgy. In addition, there are other methods, such as the method of direct introduction of the filler into the liquid metal or alloy before bottling. In the latter case, ultrasonic treatment of liquid melt is used to clean grease and other contaminants, improve wetting of parts with liquid metal and evenly place them in the matrix.

The use of composite materials (strong, plastic base - wear-resistant coating), meets the criterion of "price-quality" and is the best for strengthening the working bodies of tillage machines. In the manufacture of large batches of working bodies of tillage machines, strengthening technologies must be used at the stage of



manufacture. Technologies to increase the resource must meet certain requirements: the type of production, be productive, economical and provide a given thickness and durability of coatings.

The method of gas-thermal spraying allows to provide long service life of working bodies, to reduce time of carrying out works on strengthening and to reduce their cost.

The process of gas-thermal spraying is as follows: the material is sprayed in the form of powder or wire is fed into the heating zone; the gas sprays the heated particles and gives them acceleration in the axial direction; in the heating zone when feeding the wire, the spray gas disperses the molten material, and it also performs the function of heating; the particles entering the surface have a high collision velocity, thus forming strong interatomic bonds and creating conditions for the adhesion of the unfolded material by activating the surface contact [4-7].

Classification of methods of gas-thermal spraying by type of energy used and heat source.

By type of energy are divided into:

- ✓ gas-electric, which use electricity:
- ✓ gas-flame methods, where thermal energy is generated by the combustion of combustible gases.

The following types of heat sources are used to heat the sprayed material:

- arc;
- plasma;
- gas flame.

Spraying methods are divided into types:

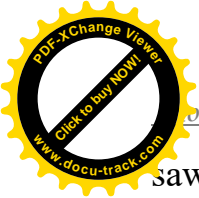
- arc metallization;
- plasma spraying;
- gas-flame spraying;
- detonation-gas spraying.

The first two methods belong to gas-electric, the last - to gas-flame [4,5-7].

The energy utilization factor of the supplied energy, the utilization factor of the sprayed metal, productivity, quality of coatings and the cost of their application determines the effectiveness of gas-thermal spraying methods. The predominant method of gas-thermal spraying in terms of thermal efficiency, productivity and cost of coatings is arc metallization.

When using arc metallization, the share of energy supplied goes directly to the heating and melting of the powder material, allows to increase the effective heating efficiency up to 60%. Low heat losses are due to the physical characteristics of the process.

The process of arc metallization occurs by spraying the wire into the arc burning between it and the powder, which is transported by gas, and the formed particles are accelerated and when they hit the surface form a coating. High thermal efficiency of arc metallization is due to the direct transfer of energy from the arc to the wire. The share of the introduced thermal energy from the arc going to the melting of the powder material is 60-70%, which is 7-10 times more than for other methods of gas-thermal spraying. Productivity of arc metallization is rather big - to 18 kg / h at steel



sawing. The price of wire is 2-3 times cheaper than powders used for other methods of gas-thermal spraying.

The level of strength depends on the volume composition of the hardening phase, the uniformity of its placement, the degree of dispersion and location between the particles. According to Orovan's formula, the shear resistance increases with decreasing distance between the particles:

$$\sigma = Gb / l \quad (1)$$

where G is the shear modulus; b is the interatomic distance; l is the distance between the particles.

Combustion of alloying elements in the applied material and saturation of powder metal with gases from the atmosphere in the combustion zone of the arc are physico-chemical features of the process of arc metallization, which makes it difficult to obtain quality coatings. Equipment for the process of arc metallization is characterized by a wide spray angle, up to 70° , low 0.5-0.6, the utilization factor of the metal, reducing the concentration of alloying elements and excessive oxides in the coating.

Activated arc metallization equipment designed to eliminate these shortcomings, which differs from the typical in that it uses combustion products (propane-air mixture) as a gas conveyor [9].

Expensive nickel-based alloy powders are materials for the application of wear-resistant coatings in plasma spraying and arc metallization [4]. For arc metallization, economically alloyed Fe-Cr-B type iron-based flux-cored wires have become widespread, which, unlike solid wires, make it easier to obtain wear-resistant coatings of the required alloying system, which is necessary to vary the coating composition at different wear modes.

Coatings of these flux-cored wires increase the wear resistance of steels by 2-5 times and make the method of arc metallization predominant when sprayed on the working bodies of agricultural machinery [5].

The greatest danger is wear on the mechanism of internal friction, with high contact loads and the presence of shocks. For coatings, it is probably due to the occurrence and development of microcracks in oxide films. Oxide films and even larger pores can contribute to the exfoliation of metal by the mechanism of internal friction, increasing the rate of mechanical wear of the metal coating.

Therefore, it is necessary to consider the peculiarities of the formation of metallic coatings and methods of improving the technology of their application, to ensure wear resistance of coatings during impact and abrasive wear, typical of operating conditions of working bodies of tillage machines [4, 8].

The main results of the study

The metallization coating is formed from layered elements formed by high-speed impact on a cold surface, which subsequently leads to solidification of the particles. The particles melt to a plastic state and are evenly distributed on the surface. The contact of the particles with each other occurs after their engagement on an uneven surface.

During spraying, the particles are oxidized, which leads to the formation of an oxide film, which enters the coating. Oxide film falling on the coating has a negative

effect on it:

1. prevents the diffusion of particles;
2. reduces the strength of adhesion;
3. reduces the hardness of the coating.

On the last sprayed layer the fraction in the form of dust of the molten material or its oxides and adsorption of gases will be put.

High velocity during spraying leads to spreading and crystallization of particles in contact with the previously applied surface, which causes defects, cavities, microcavities filled with gas.

Overheating of particles leads to their evaporation and settling in the vapor phase [5, 9].

Formation of the resulting coatings, which are formed from unmelted particles, oxides, pores, thin plates connected to each other or welded areas, or by "setting" formed during crystallization and curing.

The coating has a lower strength and density than the base material, because the welded areas do not fill the entire contact area between the applied particles.

In the seed coating there are boundaries between layers and particles, which determine the strength of adhesion between the coating and the substrate:

1. cohesion;
2. layered boundaries;
3. the boundary between the layer and the particles. [4-9].

The adhesive strength of the coating can be determined by the following mechanisms:

- mechanical adhesion of the applied parts to the surface of the substrate or with pre-deposited particles;
- activation energy, when the heat from the applied particle will be enough to form the required amount of heat on the surface of the material or pre-applied particle for diffusion of mutual remelting. This will cause the presence of chemical reactions in the area of the particle and the substrate, ie the metallurgical bond;
- the presence of van der Waals forces, when the physical interaction between the particles and the base is formed as a result of the convergence of atoms at a distance of the order of the size of atoms.

Summarizing the different estimates of the contribution of each type of connection, we can conclude that usually the share of metallurgical connection is small, otherwise the resistance to rupture of the coating is close to that of the source material [6-9].

Thus, the processes occurring in the two-phase flow affect the properties of the coatings and the features that determine the sprayed material will be:

- change in the composition of the particles of the sprayed material in interaction with the environment;
- high rate of crystallization and deformation upon impact of particles;
- the nature of the contacts between the particles in the coating.

The strength of the coating is ensured by adhesion and is characterized by the following mechanisms:

- the applied parts of the mine must be in mechanical adhesion to the surface of

the substrate or with a pre-deposited layer;

- the presence of a metallurgical bond indicates the presence of chemical reactions in the area of the particle and the substrate, which leads to the diffusion of mutual remelting;

- physical interaction between particles and the base as a result of the convergence of atoms at a distance of the order of the size of atoms, indicates the presence of van der Waals forces in this process.

The properties of the applied coating are influenced by the processes occurring in the two-phase flow. The features of the sprayed material include: the ability to change the composition of particles when interacting with the environment; at impact of particles there is a fast crystallization and deformation; the nature of the contacts between the particles in the coating.

The structure and nature of defects reflects the peculiarities of the formation of the metallization coating and differs in size, density, morphology and orientation.

In the study of metallization coating on the example of steel 30X13 descriptive composition of the sprayed layer. It has very thin alternately arranged wavy layers of white and gray-blue, which are hardened metal and oxides. The presence of metal and oxides indicates the presence of areas of mixed structure. Individual metal particles have a more rounded shape and globular, in turn, the pores have a globular and disc-shaped [10].

Insufficient layer-by-layer wetting of the droplets is the cause of the formation of disc-shaped pores that form between the layers. Globular pores occur as a result of insufficient filling of the hardening layer.

Etching of the samples made it possible to detect the rate of development, on thin layers of metal development occurred faster than in thicker layers and large particles. The high content of chromium in the structural components causes poor digestion compared to light areas.

Layer-by-layer chemical analysis of coatings sprayed with a DM apparatus showed that the content of elements is almost the same in the depth of the sprayed layer, but in the spraying process they burn out compared to the original content [10].

To determine the influence of the composition of the atmosphere of the transport gas on the peculiarities of the formation of the metallization coating, samples were taken using different metallization options. The serial device EM-14 became the basis for comparison. The ADM-10 apparatus uses the products of combustion of the propane-air mixture for spraying.

Assuming that the rounded metal particles got into the coating already in the cured state, with a particle size of less than 30 μm . Therefore, the coatings obtained by spraying in air have a rough inhomogeneous structure with elongated pores and large particles.

The use of propane-air medium made it possible to obtain a coating with a thinner structure, pores and voids are much smaller and they are smaller. The structure has a small amount of oxides, and oxide films are thinner. Therefore, when using an ADM device using propane-air environment, the resulting coatings are better.

Studies using a reducing atmosphere obtained with the use of propane-air environment have shown that the microhardness of coatings is much higher. There is a decrease in the porosity of the coatings and increase the microhardness in the various structural components is 6-12%. The increase in the porosity of the coatings, the increase in the number and size of the oxide layers, is due to the oxygen contained in the transport gas. Increasing the porosity reduces the cohesive strength, because the pores are voids with zero strength.

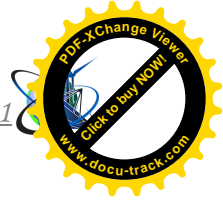
Physico-chemical features of the DM process are associated with the difficulty of obtaining quality coatings. This is due to the combustion of alloying elements in the applied material, and the saturation of the powder metal with gases from the atmosphere in the combustion zone of the arc. Typical DM equipment is characterized by a wide spray angle, up to 70° , low, 0.5-0.6, the utilization factor of the metal, reducing the concentration of alloying elements and excessive oxides in the coating.

To eliminate these shortcomings, activated arc metallization (ADM) equipment has been developed, which differs from the typical one in that combustion products (propane-air mixture) are used as a gas conveyor. In ADM devices, the spray angle is 10 degrees, the utilization factor of the material reaches 85%, particle velocity - 140-200 m / s, the degree of oxidation of the steel coating - 2.1-2.9%, porosity - 2%. On average, the level of parameters is 40% higher in comparison with both domestic and foreign DM installations [7, 25-26].

Expensive nickel-based alloy powders are used as materials for the application of wear-resistant coatings in PN and DP [6]. Economically doped Fe-Cr-B iron-based flux-cored flux-cored wires (DM) have become widespread for DM, which, unlike solid wires (SP), makes it easier to obtain wear-resistant coatings of the required alloying system, which is necessary to vary the coating composition in different modes. wear. Coatings from the specified PP [7, 25-26] provide increase in wear resistance of steels in 2-5 times and advantages of DM at spraying on working bodies of agricultural machines.

It should be noted that at high contact loads and the presence of shocks the greatest danger is wear on the mechanism of internal friction. For coatings, it is probably due to the occurrence and development of microcracks in oxide films. Oxide films and even larger pores can contribute to the exfoliation of metal by the mechanism of internal friction, increasing the rate of mechanical wear of the metal coating. Oxide films formed during spraying play a dual role. On the one hand, it is one of the hardest components of the coating structure, its microhardness is 5-6 GPa. On the other hand, oxides are a fragile part of the structure, characterized by low adhesion to other components. Therefore, for each type of coating there is an area of optimal oxide content. Taking into account the above, it is necessary to consider the peculiarities of the formation of metallic coatings and methods of improving the technology of their application, to ensure wear resistance of coatings during impact and abrasive wear, typical of operating conditions of tillage machines [6-9].

Comparing the coating sprayed with EM-14 without the use of a restorative atmosphere with the coating applied by ADM-10, it was found that the resistance of coatings and impact abrasion increases several times with decreasing oxidation of



droplets, and as a result - oxidation of the coating.

Tests of materials 10HGSA, 45G, 50HFA, 30X13 showed that the coating of steel 30X13 has the best results: wear resistance is 2-5 times higher than coatings of other materials; there is a released martensite and structural transformations in it will be accompanied by compressive stresses favorable for operating loads.

Subsequently, a sample of active arc metallization coatings made of 30X13 solid wire was adopted as a reference for testing the wear resistance of coatings.

Therefore, to improve the properties of coatings, it is necessary to create a protective atmosphere, especially in the combustion zone of the arc, as well as alloying of powder metal elements - deoxidizers, this will reduce the amount of oxide film on the particle surface [4,8-9].

Dependence of coating properties on the material alloying system

The choice of the doping system of the sprayed material, through the simulation of the process of oxygen supply to the sprayed particles makes it possible to obtain the required amount of oxides in the metallization coating and the required indicators of its properties. Technological parameters of arc metallization should be optimized according to an independent criterion that determines the performance of coatings during operation. The adhesive strength of coatings is a criterion in the conditions of impact and abrasive wear, which shows their ability to resist peeling from the base.

When estimating the dependence of the properties of coatings on the composition of the sprayed material, the model of particle oxidation in arc metallization, presented in [4, 9-10].

The works describe the process of arc metallization, consisting of three zones, which differ in the interaction of the sprayed metal with oxygen in each zone. The first stage describes the behavior of the metal at the end of the electrode. The second stage characterizes the metal in the combustion zone of the arc. The third stage describes the flight of drops over the spraying distance.

Equipment and materials for coating

Installation of active arc metallization ADM-10, designed for wear-resistant and anti-corrosion coatings of wire materials by thermal spraying. The installation is operated in the conditions for which the products are designed in category 3, in accordance with GOST 15150-69.

The installation works from a three-phase alternating current network with a voltage of 380/220 V, frequency 50 Hz. The operation requires the presence of compressed air, propane, and welding power supply with a rigid characteristic of VDU-506.

The process of melting wires with an electric arc and spraying molten metal with a high-speed jet of transport gas is the basis of the installation.

The installation works as follows:

1. voltage is applied to two wires that act as electrodes;
2. wires at a constant speed enter the spray head of the metallizer, where as a result of the convergence between them there is an electric arc and melting;
3. transport gas (compressed air and propane) blows the particles of molten metal from the ends of the wires, picks them up, accelerates to high speed and provides delivery to the surface of the workpiece.

When spraying PP in typical modes, the alloying elements burn out and saturate the metal sprayed with oxygen from the atmosphere. The diversity and complex nature of the relationship of parameters that determine the possibility of obtaining high-quality coatings, make it appropriate to use the method of experiment planning [9,10]. Using the method of experiment planning, it is possible to investigate the influence of technological parameters of ADM on the properties of metallic coatings with PP and perform their optimization.

To perform the installation work requires a summary:

- compressed air;
- propane;
- voltage from the welding power supply.

In the study of coatings were used: solid wire brand 30X13 FeC-Cr doping system and flux cored wire of the base Fe-Cr-B doping system of different brands: 45X13P10CI Fe-Cr-B-C-Y doping system; 40X18P10C5I alloying system Fe-Cr-B-Si-Y; 40X18P5Ю5CI alloying system Fe-CrB-Al-Y with a diameter of 2.0 mm (table 2).

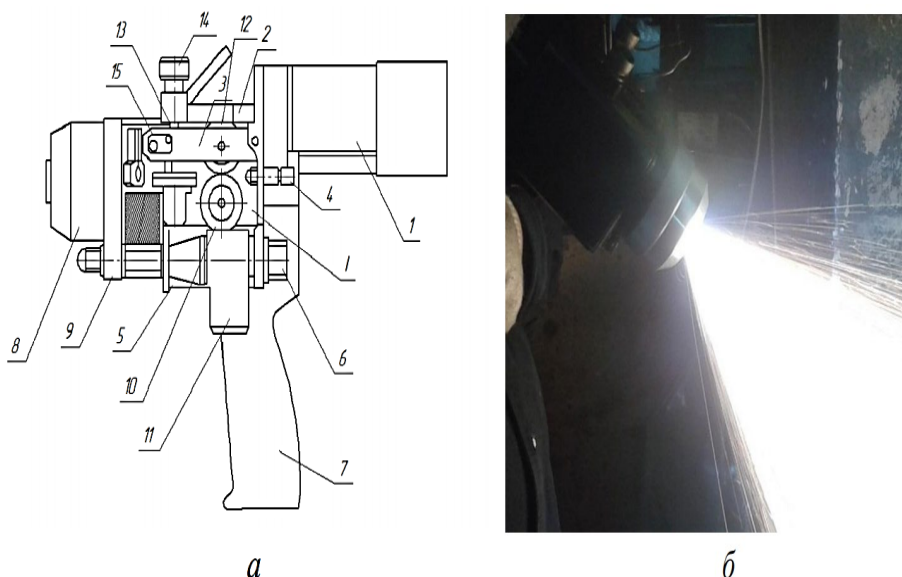
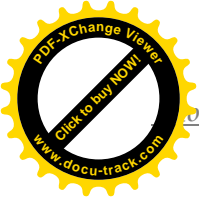


Figure 3. - General view of the metallizer: a - metallizer device; b - installation in operation; worm reducer - I; electric motor - 1; bracket of the mechanism of pressing of rollers - 2; levers - 3; front and rear guides - 4; crankcase tray - 5; power lines - 6; handle - 7; spray head - 8; plate - 9; feed rollers - 10; crane - 11; clamping rollers - 12; springs - 13; nuts - 14; levers - 15 [10].

Table 2.

Estimated chemical composition of the wires used.

Brand of wires	Mass fraction of elements, %						
	C	Cr	B	Al	Si	Y	Fe
СП 30X13	0,16-0,25	12-14	-	-	До 0,6	-	Basic
ПД 45X13P5CI	0,6	13	5	0,2	1	1	Basic
ПД 20X11P5C5I	0,2	11	5	0,2	4,5	1	Basic
ПД 20X11P5Ю3CI	0,2	11	5	3	1	1	Basic



During the process of arc metallization using the ADM-10 installation, auxiliary equipment was used:

- cassettes with electrode wire;
- device for installing cassettes, which eliminates the possibility of touching the wires when unwinding to avoid short circuits;
- compressed air network;
- propane network (cylinder).

The coating was sprayed on the surface of plates made of steel 40 according to GOST 1050-88, the thickness of the coating is 2.5 mm. Surface preparation of samples for coating was carried out in accordance with GOST 9.304.

Before spraying the surface of the plates was degreased with acetone according to GOST 2768-84. The surface was blown with compressed air and jet-abrasive treatment. The air temperature during the preparation of the surface for spraying was carried out was not lower than plus 5 ° C in order to exclude moisture condensation on the samples.

The coating was applied no later than 2 hours after jet-abrasive treatment using the installation of activated arc metallization ADM-10.

The samples for research were cut on an EDM CHARMILLES CUT 20 EDM machine from plates with sprayed activated arc metallization coating.

Preparation of micro- and macro-sections of samples for research of structure, physical-mechanical and operational properties of samples of coverings was carried out with use of nitric acid (HNO₃) - GOST 4461-77, ethyl technical alcohol (C₂H₅OH) - GOST 18300-87, distilled water (H₂O). GOST 6709, paste GOI № 2 (TU 6-18-36) and diamond paste NOM 60/40 (GOST 25593).

Results of optimization of arc metallization modes

Tables 3 and 4 show the results of determining the modes of arc metallization by planning an experiment on the criterion of maximum adhesive strength of flux coated wire coatings 20H11R5Yu3SI, which determines their ability to resist peeling under operating conditions of the working bodies of tillage machines.

Table 3.

Estimation of statistical significance of coefficients *.

Factors	Beta	<i>t</i> (3)	<i>p</i> – level
<i>I</i> , A	0,55	8,78	0,005
<i>U</i> , B	0,07	1,38	0,287
<i>T</i> , MM	0,73	12,59	0,002
<i>S</i> , MM	-0,4	-5,05	0,018

* *Beta* - regression coefficient; *p* - level of significance; *t* - Student's criterion.

The linear regression equation is adequate to the experimental data according to Fisher's test. All coefficients of the regression equation, except for the determining influence of the arc voltage, are statistically significant according to the Student's t-test for a given p-level of significance.

Table 4.

Assessment of the adequacy of the linear model *

Factor	SS	cc	MS	F	p
I, A	90,64	1	89,06	78,06	0,004
U, B	2,18	1	2,14	1,84	0,267
T, MM	184,16	1	184,16	159,45	0,001
S, MM	28,95	1	29,95	25,20	0,015
Error	3,46	3	1,16		
Total SS	308,33				

* SS - the sum of squares; cc - degree of freedom; MS - root mean square; F - Fisher's test; p - level of significance.

The dependence of the adhesive strength of the coating on the parameters of DM can be estimated by the results of regression analysis:

$$y = 0,52x_1 + 0,74x_3 - 0,34x_4 \tag{2}$$

where x_1 is the arc current, A; x_3 - coating thickness, mm; x_4 - spray distance, mm

The obtained results were performed using surface graphs (Fig. 4 and 5).

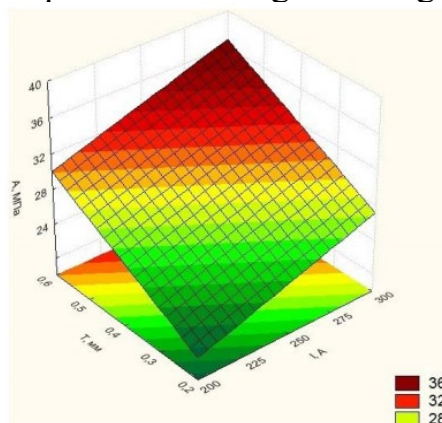


Figure 4. - Graph of the surface for the factors of arc current and coating thickness.

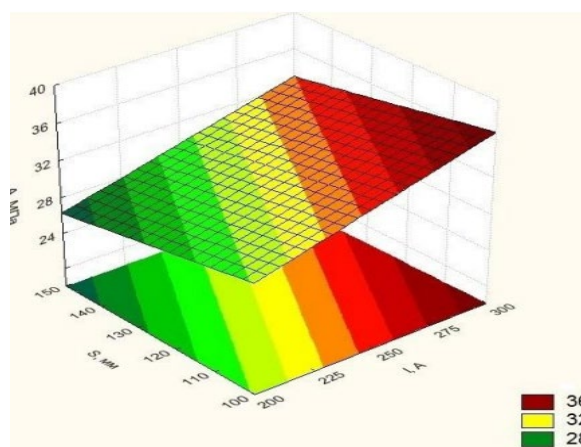
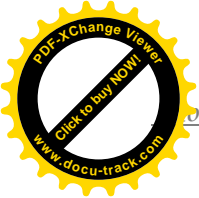


Figure 5. - Graph of the surface for the factors of arc current and spray distance.



Analysis of these data allows us to conclude that the adhesion of metallic coatings increases with increasing thickness, arc current, as well as reducing the spraying distance (in order to reduce the effect of factors), the effect of arc voltage is statistically significant.

In DM, an increase in the arc current leads to an increase in particle temperature, the development of interaction in the contact "particle-substrate" and increase the adhesive strength of the coating. Increasing the arc voltage, despite the increase in particle temperature, leads to a decrease in the utilization rate of the metal particles and its burnout by increasing the arc length [4], which probably causes little effect of this factor on the adhesion of the metal coating. The regularities obtained in this work coincide with the data of other authors [3, 4]. In DM, the specific energy expended on melting, overheating and evaporation of the metal, with increasing arc power increases, and therefore increases the temperature of the sprayed particles. Increasing the temperature of the sprayed particles in turn leads to increased adhesion strength, density and surface development of the resulting coatings.

When choosing the mode, you should strive for the minimum values of arc voltage without violating the stability of the process, and the power required to overheat the sprayed particles to set by changing the current [7].

To optimize the technological parameters of arc metallization by the criterion of maximum strength of sprayed coatings used the method of steep ascent, table 4 [7].

As a result, the optimal parameters of arc metallization of powder wire coatings 20X11P5IO3CI were determined: $I = 320 \pm 15$ A; $U = 34 \pm 1.5$ B; $S = 0.7 \pm 0.05$ mm; $L = 95 \pm 5$ mm, this metallization coating was the most durable, so it can be stated that it has the highest adhesive strength.

Table 5.

Optimization of arc metallization modes by steep ascent.

Characteristic	Factor		
	x_1, A	x_3, MM	x_4, MM
Zero level x_{i0}	300	0,8	100
Variation interval Δx_i	50	0,2	25
Coefficient b_i	0,54	0,75	-0,30
The product $b_i \Delta x_i$	27	0,15	7,5
Step h_a when changing the base factor x_i на 10	10	0,054	2,778
Rounding the variation step	10	0,05	2,8
State variable	Steep growth		
\bar{y}	310	0,65	97,2
36,97	310	0,65	97,2
42,76	320	0,7	94,4
31,18	330	0,75	91,6

The results of experimental studies

The obtained metallization coatings (Figure 7) have a lamellar-porous structure characteristic of gas-thermal spraying methods, where light areas are a metal base formed from droplets of molten metal, and dark ones are a layer of oxides formed by oxidation of droplets at the spraying distance. The coatings are characterized by a significant uneven alloy of individual sprayed particles with each other. Probably, the microheterogeneity of the coating structure is due to the presence of refractory boron-containing components in the PP.

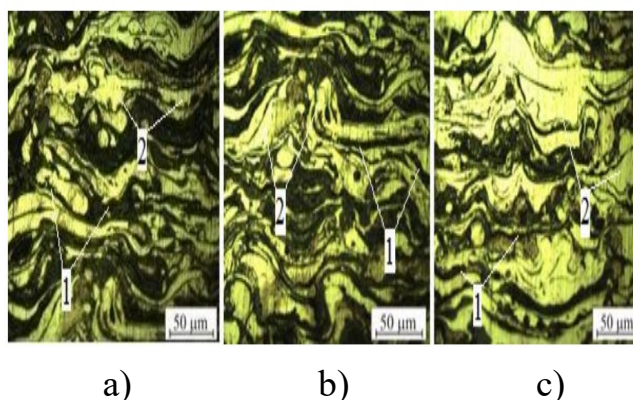


Figure 6. - Structure on cross sections of coatings:

a - flux-cored wire 45X13P5CI; b - flux-cored wire 20X11P5C5I; in - flux-cored wire 20X11P5IO3CI 1 - oxide films; 2 - metal.

Coatings made of flux-cored wire 20X11P5IO3CI (Figure 6, c) have less microheterogeneity, their structure is thinner, less oxide films, and they are smaller, which is probably due to the lower degree of oxidation of the coatings.

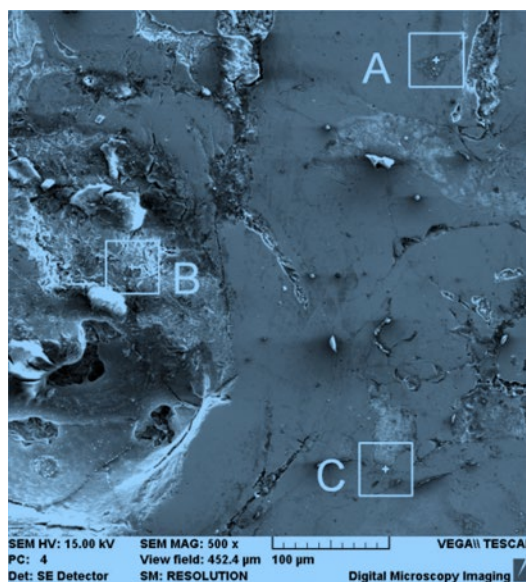
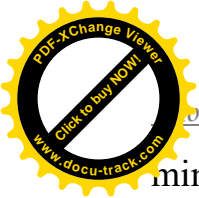


Figure 7. - Microstructure of the coating with flux-cored wire 20X11P5IO3CI: A, B, C - areas of the microstructure with different composition.

It was previously noted that oxide films promote the exfoliation of metal by the mechanism of internal friction, increasing the rate of mechanical wear of the coating. Favorable microstructure of the coating of flux-cored wire 20H11R5Yu3SI with a



minimum amount of oxide films in the end may cause high performance of its physical and mechanical and operational properties.

According to the results of determining the porosity of the coating of flux-cored wire 45H13R5SI maximum pore size is 24.2 μm, minimum - 1.2 μm, while the number of pores up to 10 μm is estimated at 92.8%, the area of these pores is 69.7%, volume - 46.7% (table 6).

Table 6.

Distribution of coating time with flux-cored wire 45X13P5CI by size, area and volume.

<i>D</i> , MKM	0,-2	2-4	4-6	6-8	8-10	Σ
<i>n</i> ,%	30,0	43,5	12,0	4,4	1,8	91,7
<i>A</i> ,%	5,4	22,6	19,8	13,12	9,8	70,72
<i>V</i> ,%	1,12	8,3	12,92	12,4	11,56	46,3

Table 7.

Distribution of coating time with flux-cored wire 20H11R5S5I by size, area and volume.

<i>D</i> , MKM	0,-2	2-4	4-6	6-8	8-10	Σ
<i>n</i> ,%	30,2	42,5	12,8	5,5	2,3	93,3
<i>A</i> ,%	5	20,8	17,9	14,8	11,8	70,3
<i>V</i> ,%	1,01	8,5	11,75	13,8	14,1	49,16

The coating with PP 20X11P5IO3CI differs in the greatest uniformity of distribution of microhardness on thickness that is explained by uniform distribution of strengthening phases in firm solution and smaller degree of oxidation that leads to decrease in thickness of an oxide layer. Boron components in the coating cause high hardness, which is one of the main factors affecting wear resistance. As a result of determining the wear resistance of the fixed abrasive it was found that the greatest weight loss are coatings with PP 45H13R5SI, and the smallest - coatings with PP 20H11R5Yu3SI, while the wear resistance of coatings with PP 20H11R5Yu3SI is 3.58 times higher than the wear resistance of coatings with SP 20X13 and times higher than 28MnB5 steel samples.

Table 8.

The number of pores up to 10 μm.

<i>D</i> , MKM	0,-2	2-4	4-6	6-8	8-10	Σ
<i>n</i> ,%	31,8	43,9	13,5	5,7	2,8	97,7
<i>A</i> ,%	5,3	21,7	18,9	15,9	12,7	74,5
<i>V</i> ,%	1,15	8,8	12,7	14	13,9	50,55

For the coating of flux-cored wire 20H11R5S5I the maximum pore size is 27.7 μm , the minimum - 1.2 μm , while the number of pores up to 10 μm is estimated at 92.5%, the area of these pores is 69.4%, the volume - 47.9% (table 7). For the coating of flux-cored wire 20X11P5IO3CI the maximum pore size is 28.3 μm , the minimum - 0.5 μm , while the number of pores up to 10 μm is estimated at 96.2%, the area of these pores is 72.2%, the volume - 49.8% (table 8).

The number of large pores with sizes larger than 10 μm for coatings of flux-cored wire 45X13P5CI, 20X11P5C5I, 20X11P5IO3CI is estimated at 2.2; 2.5 and 2.6%, which suggests their insignificant role in reducing the resistance of coatings to impact and abrasion. fine-porous structure of coatings indicates the stability of the process of spraying flux-cored wire. The lowest porosity is in the coating with flux-cored wire 20X11P5IO3CI (2.8%), and the highest - in the coating with flux-cored wire 45X13P5CI (3.5%).

Conclusions

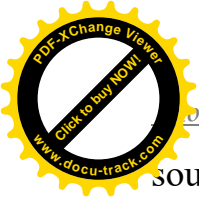
Thus, the introduction of gas-thermal spraying technology to strengthen the working bodies of tillage machines, allows to reveal the influence of the composition of sprayed materials and modes of their application on the process of spraying oxidation coatings, which determines their physico-mechanical and operational properties, in particular work of working bodies of tillage machines.

During the study, it was found that the dependence of physical and mechanical and operational properties of metallic coatings of flux-cored wires from their alloying system. The microhardness of 20X11R5Yu3CI flux coated coatings is 1.35 times higher on average, the porosity is 1.45 times lower, and the wear resistance is 1.15 times higher than for 60X13P5CI flux coated coatings. Metallographic studies have shown that the structures of metallization coatings of flux-cored wires 60X13P5CI, 20X11P5C5I, 20X11P5IO3CI differ.

Operational studies of loosening paws coated with flux-cored wire 20X11P5IO3CI showed that the relative wear resistance of reinforced plowshares was 2.18-2.66 times, for double-sided bit - 1.97-2.45 times relative to the serial, due to high physical performance - mechanical and operational properties of metallic coatings. The technological process of arc metallization of wear-resistant coatings of flux-cored wire 20X11P5IO3CI has been developed, which allows to increase the wear resistance of working surfaces by loosening cultivator legs and their resource by 1.8 times.

References

1. The market of agricultural machinery of Ukraine through the eyes of its dealers: website. URL: <http://www.agroprofi.com.ua/statti/1726-rynok-silhosptekhniky-ukrayiny-ochyma-yiyi-dyleriv> (access date 01.10.21)
2. E. Posviatenko, N. Posviatenko, R. Budyak, L. Shvets, Y. Paladiichuk, P. Aksom, I. Rybak, B. Sabadach, V. Hryhorychen. Influence of a material the technological factors on improvement of operating properties of machine parts by reliefs and film coatings. Eastern-European Journal of Enterprise Technologies. 2018. № 5/12 (95). ISSN 1729-3774. P. 48-56.
3. Shkilov OV The state of the material and technical base of agriculture and the



sources of its renewal. O.V. Schools. Formation and implementation of state policy for the development of material and technical base of the agro-industrial complex in Ukraine. - K.: IAE УААН, 2003. - С. 398–40

4. Machinery market 2020: will there be a tractor in the field: website. URL: <https://agroportal.ua/ua/views/blogs/rynok-tekhniki-2020-budet-li-traktor-v-pole/> (access date 04.10.21)

5. Nepochatenko AV The influence of the level of wear of the machine-tractor fleet on the main performance indicators of agricultural enterprises. A.V. Непочатенко, В.А. Непочатенко. Economics and management of agro-industrial complex: coll. Science. work. - Bila Tserkva, 2012. - Issue. 9 (97). - S. 9—12.

6. Y. Paladiichuk. Desining the structures of solid-alloy elements for broaching the holes of significant diameter based on the assessment of their strength Eastern-European Journal of Enterprise Technologies. 2020. № 3. (7-105), P. 57-65 (Scopus), SNIP.

7. Dobrovolsky, AG Abrasive wear resistance of materials: a reference guide. A.G. Dobrovolsky, P.I. Кошеленко. Kyiv: Tehnika, 1989. 128 p.

8. Sidashenko OI Repair of machinery and equipment: Textbook. for ed. OI Sidashenko, OA Naumenka. - H. : "Miskdruk", 2010. -744 p.

9. Iron-based coatings arc-sprayed with cored wires for applications at elevated temperatures. B. Wielage, H. Pokhmurska, M. Student, V. Gvozdeckii, T. Stupnyckyj, V. Pokhmurskii. Surface & Coatings Technology. 2013. 220. P. 27–35

10. Budko, S.I. Methods of increasing the efficiency of strengthening the parts of ploughshare-dump plows by arc surfacing with hard alloys: author's ref. dis. ... cand. tech. Science. SPb., 2009. 20 p.

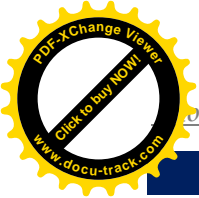
Анотація. Інтенсивне ущільнення ґрунту, що спричинене застосуванням сучасних потужних тракторів із великою вагою та наявністю у них більших робочих швидкостей, і як наслідок зменшується термін експлуатації ґрунтообробної техніки. Складні погодні умови викликають збільшення навантаження на робочі органи ґрунтообробних машин (леміші плуга, культиваторні лапи).

У статті розглядається проблема відновлення ресурсу робочих органів ґрунтообробних машин за рахунок нанесенням зносостійких покриттів. Проаналізовано види зношування та вплив абразивних матеріалів на робочі органи ґрунтообробних машин. Визначинні оптимальні матеріали та методи підвищення зносостійкості робочих органів ґрунтообробних машин. Розглянуто особливості формування металізаційного покриття, що відображається в його структурі та характер дефектів, які можуть відрізнятися за розмірами, щільності, морфології і орієнтації. Обґрунтованно залежність властивостей покриттів від системи легування матеріалу. Наведенно устаткування і матеріали для нанесення покриттів.

З врахуванням отриманої інформації, зробленні висновки та проведений аналіз технології нанесення зносостійких покриттів для відновлення ресурсу робочих органів ґрунтообробних машин.

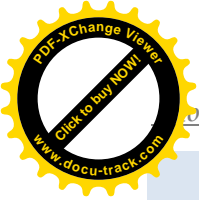
Ключові слова: ґрунтообробна техніка, технічне обслуговування, обробіток ґрунту, металізація, наплавка, порошковий дріт, дугова металізація, напилення.

Статья отправлена: 10.12.2021 г.
Паладийчук Ю.Б., Телятник И.А.



Expert-Peer Review Board of the journal

Abdulveleva Rauza Rashitovna, Orenburg State University, Russia
Antoshkina Elizaveta Grigorevna, South Ural State University, Russia
Artyuhina Marina Vladimirovna, Slavic State Pedagogical University, Ukraine
Afinskaya Zoya Nikolaevna, Moscow State University named after M.V. Lomonosov, Russia
Bashlaj Sergej Viktorovich, Ukrainian Academy of Banking, Ukraine
Belous Tatyana Mihajlovna, Bukovinian State Medical Academy, Ukraine
Bondarenko Yuliya Sergeevna, PSU named after T.G. Shevcheckko Department of Psychology, Ukraine
Butyrskij Aleksandr Gennadevich, Medical Academy named after S.I. Georgievsky, Russia
Vasilishin Vitalij Yaroslavovich, Ivano-Frankivsk National Technical University of Oil and Gas, Ukraine
Vojcehovskij Vladimir Ivanovich, National University of Life and Environmental Sciences of Ukraine, Ukraine
Gavrilova Irina Viktorovna, Magnitogorsk State Technical University named after G.I. Nosov, Russia
Ginis Larisa Aleksandrovna, South Federal University, Russia
Gutova Svetlana Georgievna, Nizhnevartovsk State University, Russia
Ivanova Svetlana Yurevna, Kemerovo State University, Russia
Ivlev Anton Vasilevich, Magnitogorsk State Technical University named after G.I. Nosov, Russia
Idrisova Zemfira Nazipovna, Ufa State Aviation Technical University, Russia
Iliev Veselin, Bulgaria
Kirillova Tatyana Klimentevna, Irkutsk State Transport University, Russia
Kovalenko Tatyana Antolevna, Volga State University of Telecommunications and Informatics, Russia
Kotova Svetlana Sergeevna, Russian State Vocational Pedagogical University, Russia
Krestyanpol Lyubov Yurevna, Lutsk State Technical University, Ukraine
Kuhtenko Galina Pavlovna, National University of Pharmacy of Ukraine, Ukraine
Lobacheva Olga Leonidovna, Mining University, Russia
Lyashenko Dmitrij Alekseevich, National Transport University, Ukraine
Makarenko Andrej Viktorovich, Donbass State Pedagogical University, Ukraine
Melnikov Aleksandr Yurevich, Donbass State Engineering Academy, Ukraine
Moroz Lyudmila Ivanovna, "National University" "Lviv Polytechnic" "", Ukraine
Muzylyov Dmitrij Aleksandrovich, Kharkov National Technical University of Agriculture named after Petr Vasilenko, Ukraine
Nadopta Tatyana Anatolievna, Khmelnytsky National University, Ukraine
Napalkov Sergej Vasilevich, Nizhny Novgorod State University named after N.I. Lobachevsky, Russia
Nikulina Evgeniya Viktorovna, Belgorod State National Research University, Russia
Orlova Anna Viktorovna, Belgorod State National Research University, Russia
Osipov Viktor Aveniurovich, Tyumen State University, Russia
Privalov Evgenij Evgrafovich, Stavropol State Agrarian University, Russia
Pyzhyanova Nataliya Vladimirovna, Ukraine
Segin Lyubomir Vasilovich, Slavic State Pedagogical University, Ukraine
Sergienko Aleksandr Alekseevich, Lviv National Medical University named after Daniil of Galitsky, Ukraine
Sochinskaya-Sibirceva Irina Nikolaevna, Kirovograd State Technical University, Ukraine
Sysoeva Vera Aleksandrovna, Belarusian National Technical University, Belarus
Tleuov Ashat Halilovich, Kazakh Agro Technical University, Kazakhstan
Tolbatov Volodimir Aronovich, Sumy State University, Ukraine
Tolbatov Sergij Volodimirovich, Sumy National Agrarian University, Ukraine
Hodzhaeva Gyulnaz Kazym kyzy, Russia
Chigirinskij Yulij Lvovich, Volgograd State Technical University, Russia
Shehmirzova Andzhela Muharbievna, Adygea State University, Russia
Shpinkovskij Aleksandr Anatolevich, Odessa National Polytechnic University, Ukraine



CONTENTS

Mechanical engineering and machinery

Машиностроение и машиноведение

<http://www.moderntechno.de/index.php/meit/article/view/meit18-01-005> 6

FEATURES OF CHIP FORMATION MECHANISM, MORPHOLOGICAL AND STRUCTURAL PROPERTIES OF SHAVINGS AND POWDER FROM ALUMINUM BRONZE

Morozov A.S./Морозов А.С.

<http://www.moderntechno.de/index.php/meit/article/view/meit18-01-045> 13

APPLICATION OF WEAR-RESISTANT COATINGS TO INCREASE RESOURCE OF WORKING BODIES OF GRINDING MACHINES

НАНЕСЕННЯМ ЗНОСОСТІЙКИХ ПОКРИТЬ ДЛЯ ПІДВИЩЕННЯ РЕСУРСУ РОБОЧИХ ОРГАНІВ ГРУНТООБРОБНИХ МАШИН

Paladiychuk Yu. B. / Паладійчук Ю. Б., Telyatnik I. A. / Телятник І. А.

Engineering instruments, meters, etc. Industrial instrumentation

Приборостроение, метрология и информационно-измерительные приборы и системы

<http://www.moderntechno.de/index.php/meit/article/view/meit18-01-078> 31

ISSUES OF IMPROVING THE AIR-GAS CONTROL QUALITY AT COAL ENTERPRISES OF UKRAINE

ПИТАННЯ ПІДВИЩЕННЯ ЯКОСТІ АЕРОГАЗОВОГО КОНТРОЛЮ НА ВУГІЛЬНИХ ПІДПРИЄМСТВАХ УКРАЇНИ

Smirnov A. M. / Смірнов А. М., Mineev S. P / Мінєєв С.П.

Motronenko D.V. / Мотроненко Д.В., Makarenko R.V./Макаренко Р.В.

Telecommunication

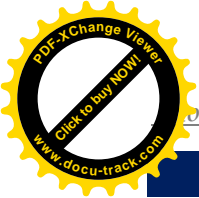
Радиотехника и связь

<http://www.moderntechno.de/index.php/meit/article/view/meit18-01-040> 45

COMPARATIVE ANALYSIS OF MANYPARAMETRIC NYQUIST SIGNALS

СРАВНИТЕЛЬНЫЙ АНАЛИЗ МНОГОПАРАМЕТРИЧЕСКИХ СИГНАЛОВ НАЙКВИСТА

Sukachov E. A./ Сукачев Э. А., Bykov R. G./ Быков Р. Г.



<http://www.moderntechno.de/index.php/meit/article/view/meit18-01-015> 49

PROSPECTS OF USE OF SULFUR CLEANING PLANTS ON LARGE POWER PLANTS

ПЕРСПЕКТИВИ ВИКОРИСТАННЯ СІРКООЧИСНИХ УСТАНОВОК НА ЕЛЕКТРОСТАНЦІЯХ ВЕЛИКОЇ ПОТУЖНОСТІ

Sheleshei T.V. / Шелешей Т.В., Bednarska I.S. / Беднарська І.С.

Mayer L. / Майєр Л., Piatachuk V. S./ П'ятачук В.С.

<http://www.moderntechno.de/index.php/meit/article/view/meit18-01-024> 56

DEVELOPMENT AND INTRODUCTION OF ENERGY SAVING TECHNOLOGIES INTO THE MUNICIPAL SECTOR IN ORDER TO INCREASE THE LEVEL OF ENERGY EFFICIENCY

РОЗРОБКА ТА ЗАПРОВАДЖЕННЯ ЕНЕРГООЩАДНИХ ТЕХНОЛОГІЙ У КОМУНАЛЬНИЙ СЕКТОР З МЕТОЮ ПІДВИЩЕННЯ РІВНЯ ЕНЕРГОЕФЕКТИВНОСТІ

Hlushchenko O.L. / Глущенко О.Л., Rybalchenko R.A. / Рибальченко Р.А.

Mining engineering. Metallurgy

Металлургия и материаловедение

<http://www.moderntechno.de/index.php/meit/article/view/meit18-01-010> 60

THE INFLUENCE OF SPATIAL POSITION ON THE FORMATION OF DEFECTS IN LASER WELDING

ВПЛИВ ПРОСТОРОВОГО ПОЛОЖЕННЯ НА УТВОРЕННЯ ДЕФЕКТІВ ПРИ ЛАЗЕРНОМУ ЗВАРЮВАННІ

Bernatskyi A.V./Бернацький А.В., Lukashenko V.A./Лукашенко В.А., Siora O.V./Сіора О.В.,

Sokolovskyi M.V./Соколовський М.В., Shamsutdinova N.O. / Шамсутдінова Н.О.

<http://www.moderntechno.de/index.php/meit/article/view/meit18-01-034> 68

ADSORPTION EQUILIBRIUM OF WATER VAPOR DURING PAPER ACCLIMATIZATION

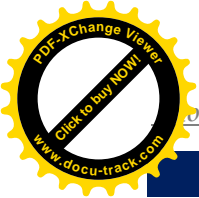
АДСОРБЦІЙНА РІВНОВАГА ВОДЯНИХ ПАРІВ ПРИ АКЛІМАТИЗАЦІЇ ПАПЕРУ

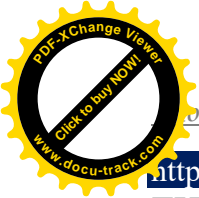
Babanska L.O. / Бабанська Л.О., Morozov A.S. / Морозов А.С.

<http://www.moderntechno.de/index.php/meit/article/view/meit18-01-051> 74

COMPOSITE BASED ON A SYSTEM OF COPOLYMER - ZEOLITE

Liubov Melnyk, Yevpak Victoria

**Animal products. Cereals and grain. Milling industry****Технология продовольственных продуктов**<http://www.moderntechno.de/index.php/meit/article/view/meit18-01-011> 79**STATE CONTROL, MEDICAL-BIOLOGICAL, TECHNOLOGICAL ASSESSMENT OF GMO FOOD PRODUCTS***ДЕРЖАВНИЙ КОНТРОЛЬ, МЕДИКО-БІОЛОГІЧНА, ТЕХНОЛОГІЧНА ОЦІНКА ЗА ГМО ХАРЧОВИХ ПРОДУКТІВ**Prylipko T.M. / Приліпко Т.М., Bukalova N. V. / Букалова Н.В.
Bogatko N. M. / Богатко Н. М.*<http://www.moderntechno.de/index.php/meit/article/view/meit18-01-049> 85**PROSPECTS OF IMPLEMENTATION OF ADDITIONAL CULINARY PRODUCTS TECHNOLOGIES IN HOTEL AND RESTAURANT BUSINESS***ПЕРСПЕКТИВИ ВПРОВАДЖЕННЯ АДИТИВНИХ ТЕХНОЛОГІЙ КУЛІНАРНОЇ ПРОДУКЦІЇ В ГОТЕЛЬНО-РЕСТОРАННОМУ БІЗНЕСІ**Razkevych V. / Разкевич В.Ю., Pushka O. / Пушка О.С.
Miroshnik Yu. / Мирошник Ю. А.*<http://www.moderntechno.de/index.php/meit/article/view/meit18-01-060> 92**HEMATOLOGICAL PARAMETERS OF PARASITOLOGICAL EXAMINATION OF FISH***ГЕМАТОЛОГІЧНІ ПОКАЗНИКИ ПАРАЗИТОЛОГІЧНОГО ДОСЛІДЖЕННЯ РИБИ**Prylipko T.M. / Приліпко Т.М., Bukalova N. V. / Букалова Н.В.
Lyasota V.P. / Лясота В.П.*<http://www.moderntechno.de/index.php/meit/article/view/meit18-01-065> 97**RESEARCH OF IN VITRO DIGESTION OF OAT BREAD***ДОСЛІДЖЕННЯ ПЕРЕТРАВЛЮВАНOSTІ ВІВСЯНОГО ХЛІБА В УМОВАХ IN VITRO**Sylchuk T.A. / Сильчук Т.А., Riznyk A.O. / Різник А.О.
Tsyurulnikova V.V. / Цирульнікова В.В.*<http://www.moderntechno.de/index.php/meit/article/view/meit18-01-072> 102**PRODUCTION AND BIOLOGICAL EVALUATION OF WINTER WHEAT VARIETIES RECOMMENDED FOR GROWING IN THE FOREST-STEPPE ZONE***ГОСПОДАРСЬКО-БІОЛОГІЧНА ОЦІНКА СОРТІВ ПШЕНИЦІ ОЗИМОЇ РЕКОМЕНДОВАНИХ ДЛЯ ВИРОЩУВАННЯ У ЛІСОСТЕПОВІЙ ЗОНІ**Voitsekhivskiy V. / Войцехівський В., Kodola R. / Кодола Р.
Bashta O. / Башта О., Poltoretskyi S. / Полторецький С.
Orlovskiy M. / Орловський М., Muliarchuk O. / Мулярчук О.
Balitska L. / Балицька Л., Yushkevich M. / Юшкевич М.*



<http://www.moderntechno.de/index.php/meit/article/view/meit18-01-073>

107

THE IMPACT OF TECHNOLOGICAL MEASURES ON GROWTH SURVIVAL OF PLANTS OF WINTER INTERMEDIATE CROPS DURING THE WINTER PERIOD

ВПЛИВ ТЕХНОЛОГІЧНИХ ЗАХОДІВ ВИРОЩУВАННЯ НА ВИЖИВАНІСТЬ РОСЛИН ОЗИМИХ ПРОМІЖНИХ КУЛЬТУР ВПРОДОВЖ ЗИМОВОГО ПЕРІОДУ

Svystunova I. / Свистунова І., Poshkrebnov V. / Пошкребньов В.

Poltoretskyi S. / Полторецький С., Yaremchuk L. / Яремчук Л.

Lashuk S. / Лашук С.

<http://www.moderntechno.de/index.php/meit/article/view/meit18-01-076>

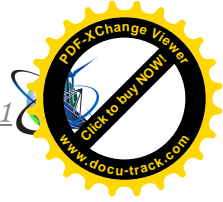
112

INFLUENCE OF BERRIES' ANTIOXIDANT ACTIVITY ON STORAGE OF CURD MASS WITH HIGH-FAT CONTENT

ВПЛИВ АНТИОКСИДАНТНОЇ АКТИВНОСТІ ЯГІД НА ЗБЕРІГАННЯ СИРКОВОЇ МАСИ З ПІДВИЩЕНИМ ВМІСТОМ ЖИРУ

Пушечна Т.В. / Pshenychna T.V., Грек О.В. / Grek O.V.,

Шиманюк І.В. / Shimanyuk I.V.



International periodic scientific journal

MODERN ENGINEERING AND INNOVATIVE TECHNOLOGIES

Heutiges Ingenieurwesen und
innovative Technologien

Indexed in
INDEXCOPERNICUS
high impact factor (ICV: 95.33)

Issue №18
Part 1
December 2021

Development of the original layout - Sergeieva&Co
Articles published in the author's edition

Signed: December 30, 2021

Sergeieva&Co
Lußstr. 13
76227 Karlsruhe
e-mail: editor@moderntechno.de
site: www.moderntechno.de



With the support of International research
project SWorld
www.sworld.education

