ISSN 2518-1483 (Online), ISSN 2224-5227 (Print)

2025 • 1



«қазақстан республикасы ұлттық ғылым академиясы» рқб БАЯНДАМАЛАРЫ

ДОКЛАДЫ роо «национальной

РОО «НАЦИОНАЛЬНОИ АКАДЕМИИ НАУК РЕСПУБЛИКИ КАЗАХСТАН»

REPORTS

OF THE ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN

PUBLISHED SINCE JANUARY 1944

ALMATY, NAS RK

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫНЫҢ БАЯНДАМАЛАРЫ

ЖҰРЫНОВ Мұрат Жұрынұлы, химия ғылымдарының докторы, профессор, ҚР ҰҒА академигі, ҚР ҰҒА РҚБ президенті м.а., АҚ «Д.В. Сокольский атындағы Отын, катализ және электрохимия институтының» бас директоры (Алматы, Қазақстан) https://www.scopus.com/authid/detail.uri?authorId=6602177960

Редакция ұжымы:

КАЛИМОЛДАЕВ Максат Нұрәділұлы, физика-математика ғылымдарының докторы, профессор, КР ҰҒА академигі (Алматы, Қазақстан) https://www.scopus.com/authid/detail.uri?authorId=56153126500

ӘДЕКЕНОВ Серғазы Мыңжасарұлы, химия ғылымдарының докторы, профессор, ҚР ҰҒА академигі, «Фитохимия» халықаралық ғылыми-өндірістік холдингінің директоры (Қарағанды, Қазақстан) https://www. scopus.com/authid/detail.uri?authorId=7006153118

РАМАЗАНОВ Тілекқабыл Сәбитұлы, физика-математика ғылымдарының докторы, профессор, ҚР ҰҒА академигі, әл-Фараби атындағы Қазақ ұлттық университетінің ғылыми-инновациялық қызмет жөніндегі проректоры, (Алматы, Қазақстан) https://www.scopus.com/authid/detail.uri?authorId=6701328029

ЭБИЕВ Руфат, техника ғылымдарының докторы (биохимия), профессор, Санкт-Петербург мемлекеттік технологиялық институты «Химиялық және биотехнологиялық аппаратураны оңтайландыру» кафедрасының меңгерушісі, (Санкт-Петербург, Ресей) https://www.scopus.com/authid/detail.uri?authorId=6602431781

ОЛИВЬЕРО Росси Сезаре, PhD (химия), Калабрия университетінің профессоры (Калабрия, Италия) https:// www.scopus.com/authid/detail.uri?authorId=57221375979

ТИГИНЯНУ Ион Михайлович, физика-математика ғылымдарының докторы, академик, Молдова Ғылым Академиясының президенті, Молдова техникалық университеті (Кишинев, Молдова) https://www.scopus.com/ authid/detail.uri?authorId=7006315935

САНГ-СУ Квак, PhD (биохимия, агрохимия), профессор, Корей Биоғылым және биотехнология ғылыми-зерттеу институты (KRIBB), өсімдіктердің инженерлік жүйелері ғылыми-зерттеу орталығының бас ғылыми қызметкері, (Дэчон, Корея) https://www.scopus.com/authid/detail.uri?authorId=59286321700

БЕРСІМБАЕВ Рахметқажы Ескендірұлы, биология ғылымдарының докторы, профессор, ҚР ҰҒА академигі, Л.Н. Гумилев атындағы Еуразия ұлттық университеті. (Астана, Қазақстан) https://www.scopus.com/authid/detail. uri?authorId=7004012398

КАЛАНДРА Пьетро, PhD (физика), нанокұрылымды материалдарды зерттеу институтының профессоры (Рим, Италия) https://www.scopus.com/authid/detail.uri?authorId=7004303066

БОШКАЕВ Қуантай Авғазыұлы, Ph.D. Теориялық және ядролық физика кафедрасының доценті, әл-Фарабиатындағы Қазақ ұлттық университеті (Алматы, Қазақстан), https://www.scopus.com/authid/detail. uri?authorId=54883880400

Бүркітбаев Мұхамбетқали, химия ғылымдарының докторы, профессор, ҚР ҰҒА академигі, (Алматы, Қазақстан) https://www.scopus.com/authid/detail.uri?authorId=8513885600

QUEVEDO Hernando, профессор, Мексика ұлттық автономиялық университеті (UNAM), Ядролық ғылымдар институты (Мехико, Мексика), https://www.scopus.com/authid/detail.uri?authorId=55989741100

ЖҮСІІ́ПОВ Марат Абжанұлы, физика-математика ғылымдарының докторы, теориялық және ядролық физика кафедрасының профессоры, әл-Фараби атындағы Қазақ ұлттық университеті (Алматы, Қазақстан), https://www. scopus.com/authid/detail.uri?authorId=6602166928

КОВАЛЕВ Александр Михайлович, физика-математика ғылымдарының докторы, Украина ҰҒА академигі, Қолданбалы математика және механика институты (Донецк, Украина), https://www.scopus.com/authid/detail. uri?authorId=7202799321

ТАКИБАЕВ Нұрғали Жабағаұлы, физика-математика ғылымдарының докторы, профессор, ҚР ҰҒА академигі, әл-Фараби атындағы Қазақ ұлттық университеті (Алматы, Қазақстан), https://www.scopus.com/authid/ detail.uri?authorId=24077239000

ХАРИН Станислав Николаевич, физика-математика ғылымдарының докторы, профессор, КР ҰҒА академигі, (Алматы, Қазақстан), https://www.scopus.com/authid/detail.uri?authorId=6701353063

ДАВЛЕТОВ Аскар Ербуланович, физика-математика ғылымдарының кандидаты, доцент, ҰЯЗУ МИФИ әл-Фараби атындағы Қазақ ұлттық университеті (Алматы, Қазақстан), https://www.scopus.com/authid/detail. uri?authorId=6602642543

ӘБІШЕВ Медеу Ержанұлы, физика-математика ғылымдарының докторы, профессор, ҚР ҰҒА академигі, (Алматы, Қазақстан) https://www.scopus.com/authid/detail.uri?authorId=26530759900

ЭБІЛМАГЖАНОВ Арлан Зайнуталлайұлы, химия ғылымдарының кандидаты, Д.В. Сокольский атындағы "Отын, катализ және электрохимия институты" АҚ Бас директорының бірінші орынбасары, (Алматы, Қазақстан), https://www.scopus.com/authid/detail.uri?authorId=57197468109

«Қазақстан Республикасы Ұлттық ғылым академиясының баяндамалары»

ISSN 2518-1483 (Online), ISSN 2224-5227 (Print)

Меншіктеуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» Республикалық қоғамдық бірлестігі (Алматы қ.).

Акпарат агенттігінің мерзімді баспасөз басылымын, ақпарат агенттігін және желілік басылымды қайта есепке қою туралы ҚР Мәдениет және Ақпарат министрлігі «Ақпарат комитеті» Республикалық мемлекеттік мекемесі **31.01.2025 ж.** берген № **КZ31VPY00111215** Куәлік.

Тақырыптық бағыты: физика, химия.

Мерзімділігі: жылына 4 рет.

http://reports-science.kz/index.php/en/archive

© «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ, 2025

ДОКЛАДЫ НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК РЕСПУБЛИКИ КАЗАХСТАН

Главный редактор:

ЖУРИНОВ Мурат Журинович, доктор химических наук, профессор, академик НАН РК, и.о. президента РОО НАН РК, Генеральный директор АО «Институт топлива, катализа и электрохимии им. Д.В. Сокольского» (Алматы, Казахстан) https://www.scopus.com/authid/detail.uri?authorId=6602177960

Редакционная коллегия:

КАЛИМОЛ/ДАЕВ Максат Нурадилович, доктор физико-математических наук, профессор, академик НАН РК (Алматы, Казахстан), https://www.scopus.com/authid/detail.uri?authorId=56153126500

АДЕКЕНОВ Сергазы Мынжасарович, доктор химических наук, профессор, академик НАН РК, директор Международного научно-производственного холдинга «Фитохимия» (Караганда, Казахстан), https://www.scopus. com/authid/detail.uri?authorId=7006153118

РАМАЗАНОВ Тлеккабул Сабитович, (заместитель главного редактора), доктор физико-математических наук, профессор, академик НАН РК (Алматы, Казахстан), https://www.scopus.com/authid/detail.uri?authorld=6701328029 АБИЕВ Руфат, доктор технических наук (биохимия), профессор, заведующий кафедрой «Оптимизация химической и биотехнологической аппаратуры», Санкт-Петербургский государственный технологический институт (Санкт-Петербург, Россия), https://www.scopus.com/authid/detail.uri?authorld=6602431781

ОЛИВЬЕРО Росси Чезаре, доктор философии (PhD, химия), профессор Университета Калабрии (Калабрия, Италия), https://www.scopus.com/authid/detail.uri?authorId=57221375979

ТИГИНЯНУ Ион Михайлович, доктор физико-математических наук, академик, президент Академии наук Молдовы, Технический университет Молдовы (Кишинев, Молдова), https://www.scopus.com/authid/detail. uri?authorId=7006315935

САНГ-СУ Квак, доктор философии (PhD, биохимия, агрохимия), профессор, главный научный сотрудник, Научно-исследовательский центр инженерных систем растений, Корейский научно-исследовательский институт бионауки и биотехнологии (KRIBB), (Дэчон, Корея), https://www.scopus.com/authid/detail. uri?authorId=59286321700

БЕРСИМБАЕВ Рахметкажи Искендирович, доктор биологических наук, профессор, академик НАН РК, Евразийский национальный университет им. Л.Н. Гумилева (Астана, Казахстан), https://www.scopus.com/authid/ detail.uri?authorId=7004012398

КАЛАНДРА Пьетро, доктор философии (PhD, физика), профессор Института по изучению наноструктурированных материалов (Рим, Италия), https://www.scopus.com/authid/detail.uri?authorId=7004303066 БОШКАЕВ Куантай Авгазыевич, PhD, преподаватель, доцент кафедры теоретической и ядерной физики, Казахский национальный университет им. аль-Фараби (Алматы, Казахстан), https://www.scopus.com/authid/ detail.uri?authorId=54883880400

БУРКИТБАЕВ Мухамбеткали, доктор химических наук, профессор, академик НАН РК, (Алматы, Казахстан) https://www.scopus.com/authid/detail.uri?authorId=8513885600

QUEVEDO Hernando, профессор, Национальный автономный университет Мексики (UNAM), Институт ядерных наук (Mexuko, Mekcuka), https://www.scopus.com/authid/detail.uri?authorId=55989741100

ЖУСУПОВ Марат Абжанович, доктор физико-математических наук, профессор кафедры теоретической и ядерной физики, Казахский национальный университет им. аль-Фараби (Алматы, Казахстан), https://www. scopus.com/authid/detail.uri?authorId=6602166928

КОВА.ЛЕВ Александр Михайлович, доктор физико-математических наук, академик НАН Украины, Институт прикладной математики и механики (Донецк, Украина), https://www.scopus.com/authid/detail. uri?authorId=7202799321

ТАКИБАЕВ Нургали Жабагаевич, доктор физико-математических наук, профессор, академик НАН РК, Казахский национальный университет им. аль-Фараби (Алматы, Казахстан), https://www.scopus.com/authid/ detail.uri?authorId=24077239000

ХАРИН Станислав Николаевич, доктор физико-математических наук, профессор, академик НАН РК (Алматы, Казахстан), https://www.scopus.com/authid/detail.uri?authorId=6701353063

ДАВЛЕТОВ Аскар Ербуланович, кандидат физико-математических наук, доцент, Филиал НИЯУ МИФИ Казахский национальный университет им. аль-Фараби (Алматы, Казахстан), https://www.scopus.com/authid/ detail.uri?authorId=6602642543

АБИШЕВ Медеу Ержанович, доктор физико-математических наук, профессор, академик НАН РК, (Алматы, Kaзахстан), https://www.scopus.com/authid/detail.uri?authorId=26530759900

АБИЛЬМАГЖАНОВ Арлан Зайнуталлаевич, кандидат химических наук, первый заместитель генерального директора АО «Институт топлива, катализа и электрохимии им. Д.В. Сокольского», (Алматы, Казахстан), https://www.scopus.com/authid/detail.uri?authorId=57197468109

Доклады Национальной академии наук Республики Казахстан»

ISSN 2518-1483 (Online), ISSN 2224-5227 (Print)

Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы).

Свидетельство N°KZ31VPY00111215 о повторной регистрации периодического печатного издания информационного агентства, информационного агентства и сетевого издания, выданное Республиканским государственным учреждением «Комитет информации» Министерства культуры и информации Республики Казахстан 31.01.2025

Тематическая направленность: физика, химия.

Периодичность: 4 раза в год.

http://reports-science.kz/index.php/en/archive

© РОО «Национальная академия наук Республики Казахстан», 2025

REPORTS

 $2025 \bullet 1$

OF NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN

Editor-in-Chief:

ZHURINOV Murat Zhurinovich, Doctor of Chemical Sciences, Professor, Academician of NAS RK, Acting President of RPA NAS RK, General Director of JSC "Institute of Fuel, Catalysis and Electrochemistry named after D.V. Sokolsky" (Almaty, Kazakhstan) https://www.scopus.com/authid/detail.uri?authorId=6602177960

Editorial Board:

KALIMOLDAYEV Maksat Nuradilovich, Doctor of Physical and Mathematical Sciences, Professor, Academician of NAS RK (Almaty, Kazakhstan), https://www.scopus.com/authid/detail.uri?authorId=56153126500

ADEKENOV Sergazy Mynzhasarovich, Doctor of Chemical Sciences, Professor, Academician of NAS RK, Director of the International Science and Production Holding "Phytochemistry" (Karaganda, Kazakhstan), https://www.scopus. com/authid/detail.uri?authorId=7006153118

RAMAZANOV Tlekkabul Sabitovich, (Deputy Editor-in-Chief), Doctor of Physical and Mathematical Sciences, Professor, Academician of NAS RK (Almaty, Kazakhstan), https://www.scopus.com/authid/detail. uri?authorId=6701328029

ABIEV Rufat, Doctor of Technical Sciences (Biochemistry), Professor, Head of the Department of Optimization of Chemical and Biotechnological Equipment, St. Petersburg State Technological Institute (St. Petersburg, Russia) https:// www.scopus.com/authid/detail.uri?authorId=6602431781

OLIVIERO Rossi Cesare, PhD (Chemistry), Professor at the University of Calabria (Calabria, Italy), https://www. scopus.com/authid/detail.uri?authorId=57221375979

TIGINYANU Ion Mihailovich, Doctor of Physical and Mathematical Sciences, Academician, President of the Academy of Sciences of Moldova, Technical University of Moldova (Chisinau, Moldova), https://www.scopus.com/authid/ detail . uri ? authorId = 7006315935

SANG SU Kwak, PhD (Biochemistry, Agricultural Chemistry), Professor, Chief Scientist, Research Center for Plant Systems Engineering, Korea Research Institute of Bioscience and Biotechnology (KRIBB), (Daecheon, Korea), https:// www.scopus.com/authid/detail.uri?authorId=59286321700

BERSIMBAYEV Rakhmetkazhi Iskenderovich, Doctor of Biological Sciences, Professor, Academician of NAS RK, L.N. Gumilyov Eurasian National University (Astana, Kazakhstan), https://www.scopus.com/authid/detail. uri?authorId=7004012398

CALANDRA Pietro, PhD (Physics), Professor, Institute for the Study of Nanostructured Materials (Rome, Italy), https://www.scopus.com/authid/detail.uri?authorId=7004303066

BOSHKAEV Kuantai Avgazvevich, PhD, Associate Professor, Department of Theoretical and Nuclear Physics, Al-Farabi Kazakh National University (Almaty, Kazakhstan), https://www.scopus.com/authid/detail.uri?authorld=54883880400

BURKITBAEV Mukhambetkali, Doctor of Chemical Sciences, Professor, Academician of NAS RK, (Almaty, Kazakhstan) https://www.scopus.com/authid/detail.uri?authorId=8513885600

OUEVEDO Hernando, Professor, National Autonomous University of Mexico (UNAM), Institute of Nuclear Sciences (Mexico City, Mexico), https://www.scopus.com/authid/detail.uri?authorId=55989741100

ZHUSUPOV Marat Abzhanovich, Doctor of Physical and Mathematical Sciences. Professor of the Department of Theoretical and Nuclear Physics, Al-Farabi Kazakh National University (Almaty, Kazakhstan), https://www.scopus. com/authid/detail.uri?authorId=6602166928

KOVALEV Alexander Mikhailovich, Doctor of Physical and Mathematical Sciences, Academician of NAS of Ukraine, Institute of Applied Mathematics and Mechanics (Donetsk, Ukraine), https://www.scopus.com/authid/detail. uri?authorId=7202799321

TAKIBAEV Nurgali Zhabagaevich, Doctor of Physical and Mathematical Sciences, Professor, Academician of NAS RK, Al-Farabi Kazakh National University (Almaty, Kazakhstan), https://www.scopus.com/authid/detail. uri?authorId=24077239000

KHARIN Stanislav Nikolaevich, Doctor of Physical and Mathematical Sciences, Professor, Academician of NAS RK, Kazakh-British Technical University (Almaty, Kazakhstan), https://www.scopus.com/authid/detail. uri?authorId=6701353063

DAVLETOV Askar Erbulanovich, Candidate of Physical and Mathematical Sciences, Associate Professor, Branch of NRNU MEPhI Kazakh National University named after Al-Farabi (Almaty, Kazakhstan), https://www.scopus.com/ authid/detail.uri?authorId=6602642543

ABISHEV Medeu Erzhanovich, Doctor of Physical and Mathematical Sciences, Professor, Academician of NAS RK,

(Almaty, Kazakhstan), https://www.scopus.com/authid/detail.uri?authorId=26530759900 ABILMAGZHANOV Arlan Zainutallaevich, PhD in Chemistry, First Deputy Director General of JSC "Institute of Fuel, Catalysis and Electrochemistry named after D.V. Sokolsky", (Almaty, Kazakhstan), https://www.scopus.com/ authid/detail.uri?authorId=57197468109

Reports of the National Academy of Sciences of the Republic of Kazakhstan.

ISSN 2518-1483 (Online), ISSN 2224-5227 (Print)

Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty).

The certificate of registration of a periodical printed publication in the Committee of Information of the Ministry of Information and Social Development of the Republic of Kazakhstan No.KZ31VPY00111215 issued 31. 01. 2025 Thematic scope: physics and chemistry.

Periodicity: 4 times a year.

http://reports-science.kz/index.php/en/archive

© National Academy of Sciences of the Republic of Kazakhstan, 2025

REPORTS OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN ISSN 2224-5227 Volume 1. Number 353 (2025), 64–77

https://doi.org/10.32014/2025.2518-1483.324

UDC 532.542, 532.135

U.K. Zhapbasbayev¹, G.I. Ramazanova^{1*}, M.A. Pakhomov², 2025. ¹Satbayev University, Almaty, Kazakhstan; ²Kutateladze Institute of Thermophysics SB RAS, Novosibirsk, Russia. E-mail: gaukhar.ri@gmail.com

TURBULENT FLOW OF VISCOPLASTIC FLUID IN A PIPE WITH SUDDEN EXPANSION

Zhapbasbayev Uzak Kairbekovich – doctor of technical sciences, professor, Scientific and Production Laboratory "Modeling in Energy", Satbayev University, Almaty, Kazakhstan; E-mail: uzak.zh@mail.ru, https://orcid.org/0000-0001-5973-5149;

Ramazanova Gaukhar Izbasarovna – candidate of physical and mathematical sciences, leading researcher, Scientific and Production Laboratory "Modeling in Energy", Satbayev University, Almaty, Kazakhstan; E-mail: gaukhar.ri@gmail.com, https://orcid.org/0000-0002-8689-9293;

Pakhomov Maksim Aleksandrovich – doctor of physical and mathematical sciences, professor, chief researcher, Kutateladze Institute of Thermophysics, Siberian Branch of the Russian Academy of Science, Novosibirsk, Russia; E-mail: akhomov@ngs.ru, https://orcid.org/0000-0002-8127-3638.

Abstract. The article examines the non-isothermal turbulent flow of a yield-stress viscoplastic fluid in a pipe with a sudden expansion. The effective molecular viscosity approach is employed to represent the rheological model of the yield-stress viscoplastic fluid. To perform a thorough calculation of the undeformed region of the viscoplastic fluid, the Papanastasiou regularization method for the effective molecular viscosity formula is applied.

Numerical simulations are conducted to analyze the velocity, temperature, and turbulent kinetic energy distributions. The results indicate significant differences in the flow structure between Newtonian and non-Newtonian fluids. In the case of Newtonian fluids, a recirculation region with negative velocities is observed downstream of the sudden pipe expansion, forming a characteristic end vortex. However, for viscoplastic fluids, this vortex structure is absent due to the yield stress effects, which suppress secondary flow formation.

The heat transfer characteristics along the pipe surface are also investigated. It is found that the distributions of heat flux for turbulent Newtonian and non-Newtonian fluids exhibit qualitative similarities, although quantitative differences arise due to the fluid's rheological properties. The study provides insight into the complex behavior of viscoplastic fluids under turbulent conditions and can be beneficial for engineering applications involving pipeline systems, heat exchangers, and energy transport processes. **Keywords:** non-isothermal turbulent flow, viscoplastic fluid, yield stress, RANS, sudden expansion

Acknowledgments

This work was supported by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant number AP23486543 for 2024-2026)

Ұ.Қ. Жапбасбаев¹, Г.І. Рамазанова^{1*}, М.Ф. Пахомов², 2025.

¹ Сәтбаев университеті, Алматы, Қазақстан; ²РҒА СБ С.С. Кутателадзе атындағы Жылуфизика институты, Новосибирск, Ресей. E-mail: gaukhar.ri@gmail.com

КЕНЕТТЕН КЕҢЕЮІ БАР ҚҰБЫРДАҒЫ ТҰТҚЫР-ПЛАСТИКАЛЫҚ СҰЙЫҚТЫҚТЫҢ ТУРБУЛЕНТТІК АҒЫНЫ

Жапбасбаев Узақ Қайырбекұлы – техника ғылымдарының докторы, профессор, «Энергетикадағы модельдеу» ғылыми-өндірістік зертханасы, Қ.И. Сәтбаев атындағы Қазақ ұлттық зерттеу техникалық университеті, Алматы, Қазақстан, E-mail: uzak.zh@mail.ru, https://orcid.org/0000-0001-5973-5149;

Рамазанова Гаухар Ізбасарқызы – физика-математика ғылымдарының кандидаты, жетекші ғылыми қызметкер, «Энергетикадағы модельдеу» ғылыми-өндірістік зертханасы, Қ.И. Сәтбаев атындағы Қазақ ұлттық зерттеу техникалық университеті, Алматы, Қазақстан, E-mail: gaukhar.ri@ gmail.com, https://orcid.org/0000-0002-8689-9293;

Пахомов Максим Александрович – физика-математика ғылымдарының докторы, профессор, бас ғылыми қызметкер, С.С. Кутателадзе атындағы Жылуфизика институты, Ресей ғылым академиясының Сібір бөлімшесі, Новосібір, Ресей; E-mail: pakhomov@ngs.ru, https://orcid.org/0000-0002-8127-3638.

Аннотация. Мақалада кенеттен кеңеюі бар құбырдағы тұтқыр-пластикалық сұйықтықтың изотермиялық емес турбуленттік ағыны қарастырылады. Тұтқырлық шегі бар тұтқыр-пластикалық сұйықтықтың реологиялық моделін сипаттау үшін эффективті молекулалық тұтқырлық әдісі қолданылады. Тұтқыр-пластикалық сұйықтықтың деформацияланбайтын аймағын түпкілікті есептеу үшін эффективті молекулалық тұтқырлық формуласы үшін Папанастасиудың регуляризация әдісі қолданылады.

Жылдамдық, температура және турбуленттіліктің кинетикалық энергиясының таралуын талдау үшін сандық модельдеу жүргізілді. Ньютондық және Ньютондық емес сұйықтықтардың ағын құрылымында айтарлықтай айырмашылықтар бар екені анықталды. Ньютондық сұйықтық жағдайында құбырдың кенеттен кеңею аймағынан кейін соңғы құйынды құрайтын теріс жылдамдықты рециркуляция аймағы байқалады. Алайда тұтқыр-пластикалық сұйықтықтарда ағымдық шектің әсерінен мұндай құйын құрылымы пайда болмайды, себебі ол екінші реттік ағынның түзілуін тежейді.

Сонымен қатар, құбырдың беті бойынша жылу алмасу сипаттамалары зерттелді.

Турбулентті Ньютондық және Ньютондық емес сұйықтықтар үшін құбырдың беті бойынша жылу ағынының таралуы сапалы түрде ұқсастық көрсетті. Зерттеу турбулентті жағдайда тұтқыр-пластикалық сұйықтықтардың күрделі әрекетін сипаттауға мүмкіндік береді және құбыр жүйелері, жылу алмастырғыштар мен энергия тасымалдау процестеріне байланысты инженерлік қолданбалар үшін пайдалы болуы мүмкін.

Түйін сөздер: изотермиялық емес турбулентті ағын, тұтқыр-пластикалық сұйықтық, аққыштық шегі, Рейнольдс бойынша орташаланған Навье-Стокс теңдеулері, кенеттен кеңею.

У.К. Жапбасбаев ¹, Г.И. Рамазанова *¹, М.А. Пахомов², 2025.

¹Университет Сатпаева, Алматы, Казахстан;

²Институт теплофизики имени С.С. Кутателадзе СО РАН, Новосибирск, Россия. E-mail: gaukhar.ri@gmail.com

ТУРБУЛЕНТНОЕ ТЕЧЕНИЕ ВЯЗКОПЛАСТИЧНОЙ ЖИДКОСТИ В ТРУБЕ С РЕЗКИМ РАСШИРЕНИЕМ

Жапбасбаев Узак Кайрбекович – доктор технических наук, профессор, научно-производственная лаборатория «Моделирование в энергетике», Казахский национальный исследовательский технический университет имени К.И. Сатпаева, Алматы, Казахстан, E-mail: uzak.zh@mail.ru, https:// orcid.org/0000-0001-5973-5149;

Рамазанова Гаухар Избасаровна – кандидат физико-математических наук, ведущий научный сотрудник, научно-производственная лаборатория «Моделирование в энергетике», Казахский национальный исследовательский технический университет имени К.И. Сатпаева, Алматы, Казахстан, E-mail: gaukhar.ri@gmail.com, https://orcid.org/0000-0002-8689-9293;

Пахомов Максим Александрович – доктор физико-математических наук, профессор, главный научный сотрудник, Институт теплофизики имени С.С. Кутателадзе, Сибирское отделение Российской академии наук, Новосибирск, Россия, E-mail: pakhomov@ngs.ru, https://orcid.org/0000-0002-8127-3638.

Аннотация. В статье рассматривается неизотермическое турбулентное течение вязкопластичной жидкости в трубе с резким расширением. Для представления реологической модели вязкопластичной жидкости с пределом текучести используется метод эффективной молекулярной вязкости. Для выполнения сквозного расчёта недеформируемой области вязкопластичной жидкости применяется метод регуляризации Папанастасиу в сочетании с формулой эффективной молекулярной вязкости.

Численные моделирования проведены для анализа распределений скорости, температуры и кинетической энергии турбулентности. Результаты показывают значительные различия в структуре течения ньютоновских и неньютоновских жидкостей. В случае ньютоновских жидкостей за участком резкого расширения трубы наблюдается зона рециркуляции с отрицательными скоростями, формирующая характерный концевой вихрь. Однако у вязкопластичных жидкостей такая вихревая структура отсутствует из-за влияния предела текучести, который подавляет формирование вторичного течения. Дополнительно исследованы характеристики теплообмена вдоль поверхности трубы. Установлено, что распределения теплового потока для турбулентных ньютоновских и неньютоновских жидкостей имеют качественные сходства, однако количественные различия обусловлены реологическими свойствами жидкости.

Исследование даёт представление о сложном поведении вязкопластичных жидкостей в турбулентных условиях и может быть полезным для инженерных приложений, связанных с трубопроводными системами, теплообменниками и процессами транспортировки энергии.

Ключевые слова: неизотермическое турбулентное течение, вязкопластичная жидкость, предел текучести, уравнения Навье-Стокса, осреднённые по Рейнольдсу, резкое расширение.

Introduction

The turbulent flow of non-Newtonian fluids in pipes or planar channels, accompanied by flow separation followed by reattachment, is one of the most common cases of shear flow. The study of such separated flows is of interest both from a fundamental perspective, as it provides new insights into the turbulent structure of flows, and from a practical standpoint, particularly in applications involving the flow around sharp-edged bodies. These flows are among the most important and complex cases of wall-bounded shear flows, characterized by elevated levels of turbulence.

In the flow separation region, significant changes in velocity, pressure, and heat transfer fields are observed, along with an intensification of turbulent wall-boundary transport processes (see monographs (Chang, 1970; Alemasov, et al., 1990; Terekhov, et al., 2021) and review papers (Eaton, et al., 1981; Simpson, 1989; Polyakov, et al., 1996; Ota, 2000; Chen, et al., 2018)). Sudden flow expansion is widely used to enhance transport processes in Newtonian flows and is encountered in many technical devices, such as when connecting pipes of different diameters. Understanding the characteristics of flow and heat transfer under such conditions is crucial from both fundamental and practical perspectives.

It should be noted that despite decades of intensive research and the involvement of numerous scientific groups, a comprehensive theory of momentum and heat transfer for turbulent flows of Newtonian fluids has yet to be developed.

To date, studies on the turbulent flow and heat transfer of viscoplastic fluids in a pipe following a sudden expansion have not been well-documented in the available literature.

The aim of this work is the numerical study of flow structure and heat transfer in a turbulent flow of an incompressible non-Newtonian fluid in a pipe with sudden expansion.

Materials and Methods Mathematical model

Rheology of a viscoplastic fluid

According to the rheology of viscoplastic fluids, the effective molecular viscosity

can be expressed as follows (Schwedoff, 1981; Bingham, 1922; Wilkinson, 1960; Pakhomov, et al., 2023):

$$\mu_{eff} = \begin{cases} \mu_p + \tau_0 |\dot{\gamma}|^{-1}, \text{ if } |\tau| > \tau_0 \\ \infty, \quad \text{if } |\tau| \le \tau_0 \end{cases}, \tag{1}$$

here τ_0 represents the yield stress and μ_p denotes the plastic viscosity. The other expressions in formula (1) are provided in (Pakhomov, et al., 2023).

However, because of mathematical complexities, expression (1) cannot be utilized without regularization. For this purpose, the formula presented in (Papanastasiou, 1987) is employed. In this case, the effective molecular viscosity has a limitation as the shear rate tends to zero $|\dot{\gamma}| \rightarrow 0$:

$$\mu_{eff} = \mu_p + \tau_0 \frac{[1 - exp(-10^3 |\dot{\gamma}|)]}{|\dot{\gamma}|}$$
(2)

The effect of carrier fluid temperature has a strong effect on rheological properties (Zhapbasbayev, et al., 2021; Pakhomov, et al., 2024) is taken into account by dependence of plastic viscosity $\mu_P(T)$, yield stress $\tau_0(T)$, and Bingham numbers on Bm = $\tau_0 R / (\mu_P U_{m1})$ fluid temperature (waxy crude oil) (Pakhomov, et al., 2023; Pakhomov, et al., 2024) (see Table 1). These dependencies rely on the experimental data (Pakhomov, et al., 2024).

	• •	•	-	-
t, °C	Т, К	$ au_0$, Pa	μ_p , Pa·s	Bm
0	273	589.6	0.36	822.32
10	283	2.03	0.06	17.01
20	293	7.01E-03	0.01	0.35
25	298	4.12E-04	0.004	0.05
30	303	2.42E-05	0.002	0.007

Table 1 - Values of yield shear stress, plastic viscosity and Bingham numbers vs fluid temperature of NNF

Governing equations

The equation system for the turbulent non-isothermal flow of viscoplastic NNF fluid is written in (Pakhomov, et al., 2023; Pakhomov, et al., 2024):

$$\nabla \cdot U = 0 \tag{3}$$

$$\nabla \cdot (\rho UU) = -\nabla P + \nabla \cdot (2\mu_{eff}S) + \nabla \cdot (-\rho \langle u/u/\rangle) + \nabla \cdot \langle 2\mu_{eff}'S/\rangle$$
(4)

$$\nabla \cdot \left(\rho C_p T U\right) = \nabla \cdot \left(\lambda \nabla T\right) + \nabla \cdot \left(-\rho C_p \left(u' t'\right)\right) + \tau: S$$
⁽⁵⁾

The turbulent Reynolds stress $-\rho \langle u'u' \rangle$ are modeled using $k-\tilde{\varepsilon}$ turbulence isotropic model and RSM approach. Turbulent heat flux $\rho C_p \langle u't' \rangle$ is given in (Pakhomov, et al., 2023). The expression $\nabla \cdot \left(2\mu_{eff}^{\prime}S^{\prime}\right)$ in equation (4) is found

according to representation of (Pakhomov, et al., 2023; Pakhomov, et al., 2024). The term τ :S considers the dissipation of kinetic energy and has the form as in (Pakhomov, et al., 2023). Formula for the averaged shear rate can be written as (Gavrilov, et al., 2016):

$$\langle \dot{\gamma} \rangle^2 = 2 \langle S_{ij} \rangle \langle S_{ij} \rangle + (\rho \varepsilon) / \langle \mu \rangle$$
, where $\langle \mu \rangle = \frac{\tau_0}{\langle \dot{\gamma} \rangle} + k_v \langle \dot{\gamma} \rangle^{n-1}$.

The elliptical relaxation Reynolds stress model (Fadai-Ghotbi, et al., 2008) partially considers anisotropy of complicated turbulent flows and is computationally more complicated than the isotropic two-equation $k-\varepsilon$ turbulence model:

$$\nabla \cdot \left(\rho U \langle u'u' \rangle\right) = \rho \left(P_{ij} + \phi - \varepsilon\right) + \nabla \cdot \left[\rho \frac{C_{\mu} T_T}{\sigma_k} \langle u'u' \rangle \nabla \left(\langle u'u' \rangle\right)\right]$$
$$\nabla \cdot \left(\rho U\varepsilon\right) = \frac{1}{T_t} \left(C_{\varepsilon 1} P_2 - C_{\varepsilon 2}\varepsilon\right) + \nabla \cdot \left[\rho \frac{C_{\mu} T_T}{\sigma_{\varepsilon}} \langle u^- u^- \rangle \nabla \varepsilon\right] +$$
$$+ \nabla \cdot \left(\mu \nabla \varepsilon\right) + C_{\varepsilon 3} \frac{\mu k}{\varepsilon} \langle u'u' \rangle \cdot \nabla^2 U \cdot \nabla^2 U$$
$$\chi - L_T^2 \nabla^2 \chi = 1/(\varepsilon T_T).$$

Here, P_{ij} is the intensity of the energy transfer from the average velocity to the pulsating one, TT is the turbulent time macroscale; φ is the redistribution term, ε is the dissipation rate. The constants and functions of (6) for Newtonian turbulent fluid are taken from (Fadai-Ghotbi, et al., 2008). The RSM models do not consider the effect of non-Newtonian fluid on fluid turbulence. The same assumption was used in our previous papers (Pakhomov, et al., 2023; Pakhomov, et al., 2024).

Boundary conditions

The flow schematic is shown in Fig. 1a. The boundary conditions on the wall surface $(r = R_2)$, pipe axis (r = 0), in the inlet section (x = 0), and at the outlet edge (x = L) are stated in the paper Waxy crude oil in the inlet cross-section is considered as a NF, then the behavior of a non-Newtonian SB fluid with yield stress appears.

On the inner surface wall $(r = R_2)$:

$$U = V = \langle u'u' \rangle = 0; \ T = T_w = const; \ \varepsilon = 2\nu \frac{k}{y^2}; \ \chi = 0$$
(7)

On the pipe axis (r = 0):

$$\frac{\partial U}{\partial r} = V = \frac{\partial T}{\partial r} = \frac{\partial \langle u/u/\rangle}{\partial r} = \frac{\partial \varepsilon}{\partial r} = \frac{\partial \chi}{\partial r} = 0$$
(8)

Constant values of variables are set at the pipe inlet, and soft boundary conditions are set at the outlet.

Numerical realization

All numerical predictions are performed using "in-house" code (Pakhomov, et al., 2023; Pakhomov, et al., 2024a; Pakhomov, et al., 2024b). The set of Eqs. (1–5) with boundary conditions (7–9) is solved numerically using the finite control volume method, QUICK, and SIMPLEC algorithms. The simulations use a non-uniform mesh (in axial and radial directions) with refinement close to the pipe wall and in the entrance zone (see Fig. 1b). The numerical realization is described in detail in (Pakhomov, et al., 2023; Pakhomov, et al., 2024a; Pakhomov, et al., 2024b). The grid convergence test for the local Nusselt numbers Nu = $-(\partial T/\partial y)_W H/(T_W - T_m)$ along the streamwise coordinate is performed on the grids: 250×100 ("coarse"), 500×150 ("basic") and 750×250 ("fine") (see Fig. 2), where y = R - r is a distance normal to a wall, *H* is step height, and T_m is a mean-mass fluid temperature. The difference between "basic" and "fine" grids is very small (up to 0.1%) and the "basic" grid is used in authors' simulations.



Figure 1. Schematic view of the flow behind pipe with sudden expansion (a) and the computational grid (not in the scale) (b). Arrow is a turbulent flow of a waxy crude oil.



Figure 2. Grid independence test for $T_W = 273$ K. "Fine" grid has 750×250 control volumes (CVs), "basic" has grid 500×150 CVs and "coarse" grid has 250×100 CVs.

Validation and verification for the Newtonian turbulent fluid in a pipe with sudden expansion

For validation and verification, a comparison was conducted with experimental data (Baughn, et al., 1984) on heat transfer in the turbulent flow of a Newtonian fluid (air) downstream of a sudden pipe expansion (see Fig. 3). The first two cross-sections are located within the recirculation zone, the third approximately corresponds to the reattachment point of the flow, and the fourth is situated in the relaxation zone downstream of the reattachment (see Fig. 3a).

In the first cross-section, an increase in the thermal mixing layer is observed behind the sudden pipe expansion. Intense turbulent mixing in the separation zone results in the majority of the temperature difference between the wall and the axis being concentrated in a thin near-wall layer at $r/R \ge 0.95$. Thus, mixing processes in this near-wall layer play a dominant role in the heat transfer between the pipe wall and the turbulent fluid flow.



Figure 3. Radial temperature profiles along the pipe length (a) and effect of the Reynolds numbers on heat transfer enhancement ratio Nu/Nu_{fd} in the pipe sudden expansion (b). Points are measurements of Baughn et al., 1984 at $T_w = \text{const}$; solid lines are authors' computations. Re₂ = $U_{m2}2R_2/v = 1.73 \times 10^4$.

Figure 3b presents the distributions of local heat transfer downstream of the sudden pipe expansion along the longitudinal coordinate. Here, Nu_{fd} represents the Nusselt number for a fully developed flow in a pipe without sudden expansion. It can be seen that as the Reynolds number (flow velocity) increases, the intensity of heat transfer significantly rises, which is expected.

Notably, the location of the maximum heat transfer approximately coincides with the reattachment point for Newtonian fluids. This finding is consistent with both the experimental measurements (Baughn, et al., 1984) and our calculations. Overall, the analysis of the data presented in Fig. 3 demonstrates good agreement between the measurements (Fadai-Ghotbi, et al., 2008) and the results of our calculations.

Results and Discussion

Numerical results for the non-Newtonian turbulent flow behind pipe sudden expansion and discussion

Anon-isothermal viscoplastic non-Newtonian fluid (waxy crude oil) flows along a pipe with sudden expansion. Pipe I.D. Diameter before sudden expansion is $D_1 = 2R_1 = 0.2$ m, pipe diameter behind the sudden expansion is $D_2 = 2R_2 = 0.3$ m, step height is H = 0.05 m, $H/(2R_1) = 0.25$, expansion ratio $ER = (R_2/R_1)2 = 2.25$. Pipe length is L = 20 m (x/D = 100). The temperature profile is uniform at the pipe inlet. Mean axial velocity and mean temperature at the inlet $U_{m1} = 0.25$ m/s, $T_1 =$ 303 K respectively. The wall temperature is uniform along the pipe length after sudden expansion and it varies $T_w = const = 273 - 293$ K. Reynolds number based on pipe diameter $Re = U_{m1}2R_1/v_{w1} = (0.7-3)\times10^4$, Reynolds number based on step height $Re_H = U_{m1}H/v_{w1} = (1.7-7.5)\times10^3$. The Prandl number of the Newtonian fluid is $Pr = \mu_{w1}C_{P1}/\lambda_{w1} = 42$. The Kolmogorov geometric scale η_K and time scale τ_K were determined using the following formulas of (Baughn, et al., 1984):

$$\eta_K = 2R_1 R e_{c1}^{-3/4}, \ \tau_K = \eta_K^2 / \nu,$$

where $Re_{c1} = 2R_1 < u'_{c1} > \nu$ is the Reynolds number, and $< u'_{c1} >$ represents the root-mean-square velocity fluctuations of the gas at the pipe axis before the separation section of the flow.

For the conditions of this study, $\eta_K = 0.002$ m and $\tau_K = 0.82$ s (at $Re = 10^4$).

All predictions are carried out in the region of hydrodynamic and thermal stabilization in a steady-state fluid flow in a pipe with sudden expansion. Waxy crude oil in the inlet cross-section is considered as a Newtonian turbulent fluid. Then, the process of heat transfer through a cold pipe wall starts with fluid movement through a pipe. A fluid temperature decreases by heat transfer with cold surrounding soil through a pipe wall. This leads to a sharp increase in viscosity and the appearance of yield shear stress τ_0 (Zhapbasbayev, et al., 2021; Pakhomov, et al., 2024).

Local flow structure and turbulent characteristics

Figure 4 shows the streamlines for Newtonian (a) and non-Newtonian SB (b) fluids downstream of a sudden expansion in a pipe. After the separation section, the streamlines undergo significant changes compared to the flow in the pipe prior to the sudden expansion. Due to flow separation, a recirculating flow zone is formed, and for the Newtonian fluid, a small end vortex is observed immediately downstream of the step. This is consistent with the conclusions for separated flows of Newtonian fluids (Chang, 1970; Alemasov, et al., 1990; Terekhov, et al., 2021). The flow attachment point is located at for the flow and for the non-Newtonian fluid.



Figure. 4. Streamlines of Newtonian $(T_1 = T_w = 303 \text{ K})$ (a) and non-Newtonian SB (b) $(T_1 = 303 \text{ K}, T_w = 273 \text{ K})$ fluids behind pipe sudden expansion.

The center of the main recirculating eddy is located around x/H = 5 and y/H = 0.5. The small corner eddy takes place around x/H = 1, and the mean flow velocity in this area is very small. The lengths of recirculation zones are determined from the zero value of mean axial flow velocity (U = 0) for the NF and NNF. The direction of rotation in this vortex coincides with the direction of the main flow. As the Newtonian flow cools, the non-Newtonian properties of the fluid begin to manifest (a significant increase in plastic viscosity μ_p and yield stress τ_0), and the flow takes on the characteristics of a turbulent viscoplastic Schwedoff-Bingham fluid. Flow attachment occurs at =6.2. Thus, it can be said that the length of the flow separation region is significantly reduced (by approximately 40%). It is noteworthy that the end vortex region disappears for the non-Newtonian fluids in the absence of heat exchange (Pereira, et al., 2000); Pereira, et al., 2002). It should be noted that qualitatively, the flow of non-Newtonian Schwedoff-Bingham fluid after the sudden expansion of the pipe is similar to that of Newtonian fluid.

Figures 5 show the profiles of the axially averaged velocity for Newtonian (bold lines) and non-Newtonian Schwedoff-Bingham (dashed curves) fluids downstream of the sudden expansion in the pipe. The first two cross-sections are located in the flow separation region for both fluids. The x/H = 15 cross-section is in the recirculation region (for the Newtonian fluid) and in the flow attachment region (for the non-Newtonian fluid). The fourth cross-section is located in the flow attachment zone for the Newtonian fluid. The x/H = 15 cross-section corresponds to the flow relaxation zone after the flow attachment point for both fluids.

It should be noted that downstream from the flow separation cross-section, a sharp change in the flow structure is observed. For the velocity profiles of the fluid (see Fig. 5a), a region of negative velocities appears, corresponding to the flow recirculation zone. After the flow attachment point, the flow begins to recover, and dynamic and thermal boundary layers develop. The flow starts to exhibit the characteristics of hydrodynamically stabilized flow in a circular pipe. Complete hydrodynamic stabilization of the Newtonian turbulent flow downstream of the sudden expansion in the pipe occurs at distances x/H>40 (Terekhov et al., 2021). For the non-Newtonian

viscoplastic turbulent fluid flow after the sudden expansion, the presence of a flow separation region is also observed. The intensity of such a flow is lower (approximately by 25%) compared to the corresponding Newtonian flow. The flow velocity in the core of the flow for the SB fluid slightly exceeds the corresponding value for the Newtonian turbulent flow. In the immediate vicinity of the wall, at r/R>0.9, the flow nearly stagnates due to yield stresses and plastic viscosity.



energy k (b).

In Figure 5b, the distributions of kinetic energy of turbulence (KET) across the radius of the pipe downstream of its sudden expansion are shown. Turbulence was determined using the Reynolds stress transport model (Fadai-Ghotbi, et al., 2008), and for axisymmetric NF and NNF, it was calculated using the relation: $2k = \langle u'^2 \rangle + \langle v'^2 \rangle + \langle w'^2 \rangle \approx \langle u'^2 \rangle + 2 \langle v'^2 \rangle$. The maximum value of the KET for both types of fluids studied in the work is observed in the shear mixing layer. As the flow progresses downstream, the magnitude of the turbulence energy maximum decreases and shifts toward the pipe wall. The profile of the averaged longitudinal velocity component for both Newtonian and non-Newtonian fluids becomes more gradual. The turbulence level in the recirculation zone for the SB fluid is noticeably lower than for the Newtonian flow due to the manifestation of the non-Newtonian properties of waxy crude oil as it cools (approximately up to 30%). In the immediate vicinity of the wall, at r/R > 0.9, where the fluid nearly stagnates (see Fig. 5a), the KET level k approaches zero.

Profiles of the averaged effective dynamic viscosity $\mu_{eff} = \mu_T + \mu + \mu_P$ at a few stations behind the sudden pipe expansion for various wall temperatures are presented in Fig. 6, where μ is the molecular (laminar) viscosity.



Figure 6. Radial dimensionless profiles of averaged effective dynamic viscosity μ_{eff} Re = 10⁴, Re_H = 2600, Pr = 42, Bm = 0.007.

With this form of writing the expression, it is easy to analyze the influence of non-Newtonian properties of the turbulent fluid on viscosity. It can be seen that the greatest manifestation of the viscoplastic behavior of turbulent fluid is revealed at $T_w = 273$ K. The flow shows the properties of a Newtonian fluid and the value of apparent viscosity $\mu_{eff} / (\mu_T + \mu) \rightarrow 1$ at $T_w = 303$ K. The main zone of manifestation of non-Newtonian behavior of turbulent fluid is limited to the recirculating region at r/R > 2. As we showed earlier (Zhapbasbayev, et al., 2021; Pakhomov, et al., 2023) for a turbulent flow of waxy crude oil in a pipe without sudden expansion, the properties of SB fluid appear at $T_w \le$ 293 K. Qualitatively similar behavior of turbulent non-isothermal fluid is obtained for the flow in a pipe with sudden expansion.

Conclusion

The transition of a Newtonian turbulent fluid into a viscoplastic non-Newtonian Schewedoff-Bingham fluid in a pipe with a sudden expansion is numerically studied. The kinetic energy of turbulence of a fluid flow is predicted using the elliptic relaxation Reynolds stress model.

For the velocity profiles of the fluid (see Fig. 5a), a region of negative velocities corresponding to the flow recirculation zone is observed. For the turbulent flow of non-Newtonian viscoplastic fluid after the sudden expansion, the presence of a flow separation region is also identified.

For the Schwedoff-Bingham viscoplastic fluid, it is characteristic that there is no local minimum in heat transfer in the angular part of the step. The turbulence level in the flow recirculation zone for the SB fluid is significantly lower than for the Newtonian flow, which is explained by the manifestation of non-Newtonian properties of waxy crude oil as it cools (approximately up to 30%). Near the wall, at r/R>0.9, where the fluid nearly stagnates, the turbulence level tends to zero.

Литература

Chang P. (1970) Flow Separation Control. Pergamon, Oxford, U.K. (in Eng.)

Алемасов В.Е., Глебов Г.А., Козлов А.П. (1990) Термоанемометрические методы исследования отрывных течений. Казань: Казанский филиал АН СССР, 178 с. (in Russ.)

Terekhov V.I., Bogatko T.V., Dyachenko A.Yu., Smulsky Ya I., Yarygina, N.I. (2021) Heat Transfer in Subsonic Separated Flows, Springer, Cham. https://doi.org/10.1007/978-3-030-94557-2 (in Eng.)

Eaton J.K., Johnston J.P. (1981). A review of research in subsonic turbulent flow reattachment. AIAA J. — 19, — 1093–1100. https://doi.org/10.2514/3.60048 (in Eng.)

Simpson R.L. (1989). Separation from two-dimensional sharp-edged bluff bodies and reattachment. Ann. Review Fluid Mech. -21, -220-233. (in Eng.)

Поляков, А.Ф., Комаров, П.Л. (1996) Исследование характеристик турбулентности и теплообмена за обратным уступом в щелевом канале. Препр. РАН. Ин-т высоких температур; № 2-396. (in Russ.)

Ota T. (2000) A survey of heat transfer in separated and reattached flows. Appl. Mech. Rev. — 53, — 219-235. https://doi.org/10.1115/1.3097351 (in Eng.)

Chen L., Asai K., Nonomura T., Xi G.N., Liu T.S. (2018) A review of backward-facing step (BFS) flow mechanisms, heat transfer and control. Thermal Sci. Eng. Progr. — 6, — 194–216. https://doi.org/10.1016/j. tsep.2018.04.004 (in Eng.)

Schwedoff F.N. (1900) La rigidité des fluides, Rapports du Congrès International de Physique. — 1, — 478. (in French)

Bingham E.C. (1922) Fluidity and Plasticity, McGraw-Hill, New York. (in Eng.)

Wilkinson W.L. (1960) Non-Newtonian fluids. Fluid Mechanics, Mixing and Heat Transfer, Pergamon Press, London. (in Eng.)

Pakhomov M.A., Zhapbasbayev U.K., Bossinov D.Zh. (2023) Numerical simulation of the transition of a Newtonian to a viscoplastic state in a turbulent flow. Journal of King Saud University – Science, — 35(2), — 102522. https://doi.org/10.1016/j.heliyon.2024.e24062 (in Eng.)

Papanastasiou T.C. (1987) Flows of materials with yield. Journal of Rheology, — 31(5), — 385–404. https://doi.org/10.1122/1.549926 (in Eng.)

Zhapbasbayev U.K., Ramazanova G.I., Bossinov D.Zh., Kenzhaliyev B.K. (2021) Flow and heat exchange calculation of waxy oil in the industrial pipeline. Case Studies of Thermal Engineering, — 26, — 101007. https://doi.org/10.1016/j.csite.2021.101007 (in Eng.)

Pakhomov M.A., Zhapbasbayev U.K. (2024a) Comparative predictions of turbulent non-isothermal flow of a viscoplastic fluid with yield stress. Heliyon, — 10, — e24062. https://doi.org/10.1016/j. heliyon.2024.e24062 (in Eng.)

Gavrilov A.A., Rudyak V.Y. (2016) Reynolds-averaged modeling of turbulent flows of power-law fluids. J. Non-Newton. Fluid Mech. — 227, — 45–55. https://doi.org/10.1016/j.jnnfm.2015.11.006 (in Eng.)

Fadai-Ghotbi A., Manceau R., Boree J. (2008) Revisiting URANS computations of the backward-facing step flow using second moment closures. Influence of the numerics. Flow, Turbulence and Combust. - 81(3), - 395–410. https://doi.org/10.1007/s10494-008-9140-8 (in Eng.)

Pakhomov M.A., Zhapbasbayev U.K. (2024b) RANS predictions of turbulent non-isothermal viscoplastic fluid in pipe with sudden expansion. J. Non-Newton. Fluid Mech. — 334, — 105329. https:// doi.org/10.1016/j.jnnfm.2024.105329 (in Eng.)

Baughn J.W., Hoffman M.A., Takahasi R.K., Launder B.E. (1984) Local heat transfer downstream of an abrupt expansion in a circular channel with constant wall heat flux. ASME J. Heat Transfer. — 106, — 789–796. https://doi.org/10.1115/1.3246753 (in Eng.)

Pereira A.S., Pinho F.T. (2000) Turbulent characteristics of shear-thinning fluids in recirculating flows. Exp. Fluids. — 28, — 266–278. https://doi.org/10.1007/s003480050387 (in Eng.)

Pereira, A.S., Pinho, F.T. (2002) The effect of the expansion ratio on a turbulent non-Newtonian recirculating flow. Exp. Fluids. — 32, — 458–471. http://dx.doi.org/10.1007/s00348-001-0386-3 (in Eng.)

References

Chang P. (1970) Flow Separation Control. Pergamon, Oxford, U.K. (in Eng.)

Alemasov V.E., Glebov G.A., Kozlov A.P. (1990) Termoanemometricheskie metody issledovaniya

otryvnykh techeniy [Thermoanemometric Techniques for Studying Separation Flows]. Kazan: Kazan Branch of the Russian Academy of Sciences, 178 p. (in Russ.)

Terekhov V.I., Bogatko T.V., Dyachenko A.Yu., Smulsky Ya I., Yarygina N.I. (2021) Heat Transfer in Subsonic Separated Flows, Springer, Cham. https://doi.org/10.1007/978-3-030-94557-2 (in Eng.)

Eaton J.K., Johnston J.P. (1981) A review of research in subsonic turbulent flow reattachment. AIAA J. — 19, — 1093–1100. https://doi.org/10.2514/3.60048 (in Eng.)

Simpson, R.L. (1989). Separation from two-dimensional sharp-edged bluff bodies and reattachment. Ann. Review Fluid Mech. -21, -220-233. (in Eng.)

Polyakov A.F., Komarov P.L. (1996) Issledovanie kharakteristik turbulentnosti i teploobmena za obratnym ustupom v shchelevom kanale [Study of the characteristics of turbulence and heat transfer behind a reverse step in a slot channel]. Preprint Joint Institute of High temperature RAS. — 2-396, — 70 p. (in Russ.).

Ota T. (2000) A survey of heat transfer in separated and reattached flows. Appl. Mech. Rev. — 53, — 219-235. https://doi.org/10.1115/1.3097351 (in Eng.)

Chen L., Asai K., Nonomura T., Xi G.N., Liu T.S. (2018) A review of backward-facing step (BFS) flow mechanisms, heat transfer and control. Thermal Sci. Eng. Progr. — 6, — 194–216. https://doi.org/10.1016/j. tsep.2018.04.004 (in Eng.)

Schwedoff F.N. (1900) La rigidité des fluides, Rapports du Congrès International de Physique. -1, -478. (in French)

Bingham E.C. (1922) Fluidity and Plasticity, McGraw-Hill, New York. (in Eng.)

Wilkinson W.L. (1960) Non-Newtonian fluids. Fluid Mechanics, Mixing and Heat Transfer, Pergamon Press, London. (in Eng.)

Pakhomov M.A., Zhapbasbayev U.K., Bossinov D.Zh. (2023) Numerical simulation of the transition of a Newtonian to a viscoplastic state in a turbulent flow. Journal of King Saud University – Science, — 35(2), — 102522. https://doi.org/10.1016/j.heliyon.2024.e24062 (in Eng.)

Papanastasiou T.C. (1987) Flows of materials with yield. Journal of Rheology, — 31(5), — 385–404. https://doi.org/10.1122/1.549926 (in Eng.)

Zhapbasbayev U.K., Ramazanova G.I., Bossinov D.Zh., Kenzhaliyev B.K. (2021) Flow and heat exchange calculation of waxy oil in the industrial pipeline. Case Studies of Thermal Engineering, — 26, — 101007. https://doi.org/10.1016/j.csite.2021.101007 (in Eng.)

Pakhomov M.A., Zhapbasbayev U.K. (2024a) Comparative predictions of turbulent non-isothermal flow of a viscoplastic fluid with yield stress. Heliyon, — 10, — e24062. https://doi.org/10.1016/j. heliyon.2024.e24062 (in Eng.)

Gavrilov A.A., Rudyak V.Y. (2016) Reynolds-averaged modeling of turbulent flows of power-law fluids. J. Non-Newton. Fluid Mech. — 227, — 45–55. https://doi.org/10.1016/j.jnnfm.2015.11.006 (in Eng.)

Fadai-Ghotbi A., Manceau R., Boree J. (2008) Revisiting URANS computations of the backward-facing step flow using second moment closures. Influence of the numerics. Flow, Turbulence and Combust. - 81(3), - 395–410. https://doi.org/10.1007/s10494-008-9140-8 (in Eng.)

Pakhomov M.A., Zhapbasbayev U.K. (2024b) RANS predictions of turbulent non-isothermal viscoplastic fluid in pipe with sudden expansion. J. Non-Newton. Fluid Mech. — 334, — 105329. https:// doi.org/10.1016/j.jnnfm.2024.105329 (in Eng.)

Baughn J.W., Hoffman M.A., Takahasi R.K., Launder B.E. (1984) Local heat transfer downstream of an abrupt expansion in a circular channel with constant wall heat flux. ASME J. Heat Transfer. — 106, — 789–796. https://doi.org/10.1115/1.3246753 (in Eng.)

Pereira A.S., Pinho F.T. (2000) Turbulent characteristics of shear-thinning fluids in recirculating flows. Exp. Fluids. — 28, — 266–278. https://doi.org/10.1007/s003480050387 (in Eng.)

Pereira, A.S., Pinho, F.T. (2002) The effect of the expansion ratio on a turbulent non-Newtonian recirculating flow. Exp. Fluids. — 32, — 458–471. http://dx.doi.org/10.1007/s00348-001-0386-3 (in Eng.)

CONTENTS

PHYSICS

B.Zh. Abdikarimov, A.Zh. Seitmuratov, B.K. Kaliev, A.G. Ganiulla, T.M. Karabala
VISCOSITY PROPERTIES OF THE ISOBUTYRIC ACID-WATER SOLUTION
NEAR THE CRITICAL SEPARATION TEMPERATURE
D.T. Agishev, S.A. Khokhlov, A.T. Agishev, N.L. Vaidman, A.T. Agishev
THE STUDY OF RADIATIVE AND CONVECTIVE TRANSPORT IN CLOSE
BINARY SYSTEMS WITH LOW ACCRETION RATES
T.M. Aldabergenova, M.F. Vereshchak, A.S. Dikov, S.B. Kislitsin
FINE STRUCTURE OF COATING BASED ON HIGH ENTROPY ALLOY
NITRIDES (ALTIZRYNB)N, DETERMINED BY THE CAMS METHOD
ON IMPLANTED IRON-57 CORES
E. Bondar, A. Shongalova, A. Fedosimova, S. Ibraimova, A. Kemelbekova
ENHANCING HYDRONIUM ION MOBILITY IN GRAPHENE OXIDE-BASED
PROTON EXCHANGE MEMBRANES
N.N. Zhanturina, G.K. Beketova, Z.K. Aimaganbetova, K.B. Bizhanova
MODERN PEROVSKITE SOLAR CELLS: INNOVATIONS IN MATERIALS
AND TECHNOLOGIES FOR ENHANCED EFFICIENCY
U.K. Zhapbasbayev, G.I. Ramazanova, M.A. Pakhomov
TURBULENT FLOW OF VISCOPLASTIC FLUID IN A PIPE WITH SUDDEN
EXPANSION
D.M. Zazulin, S.E. Kemelzhanova, N.A. Beissen, A.Sh. Tursumbekov,
M.O. Alimkulova
GEOMETROTHERMODYNAMICS OF A HOLOGRAPHIC SYSTEM
WITH ZERO SOUND
Y. Myrzakulov, A. Altaibayeva, A. Bulanbayeva
PHASE TRANSITIONS AND THERMODYNAMIC BEHAVIOR OF AdS BLACK
HOLES COUPLED WITH NONLINEAR ELECTRODYNAMICS
Sh.A. Myrzakulova, A.A. Zhadyranova
INVESTIGATION OF F(G) GRAVITY USING NOETHER SYMMETRY101

D.A. Tolekov, D.M. Zharylgapova, A.M. Mukhambetzhan, A.A. Almagambetova,
ELECTRON HOLE TRAPPING CENTERS IN LILTRA VIOLET IRRADIATED
LI2SO4-Mn CRYSTALS 115
S.U. Sharipov, I.F. Spivak-Lavrov
ELECTROSTATIC CHARACTERISTICS OF THE EDGE FIELD BETWEEN
THE DEFLECTOR PLATES AND THE GROUNDED SCREEN125
L.I. Shestakova, A.V. Serebryanskiy, Spassyuk Ruslan, Ch.T. Omarov
SEARCH FOR COMETARY-METEORITIC DUST IN THE INNER REGION OF
THE SOLAR SYSTEM: THERMAL EMISSION IN THE DUST CORONA
CHEMISTRY
R.S. Abzhalov, Sh.T. Koshkarbayeva, A.K. Dikanbayeva, M.S. Satayev,
B.S. SETIKDAYEVA
STUDY OF THE OBTAINING OF SILVER NANOPARTICLES ON THE
POLYMER SURFACE USING PHOTOCHEMICAL ACTIVATION
K.T. Arynov, A.P. Auyeshov, Ch.Z. Yeskibayeva, A.K. Dikanbayeva,
A.M. Ibrayeva
X-RAY PHASE AND THERMOANALYTICAL STUDY OF NEMALITE FROM
THE ZHITIKARINSKOE DEPOSIT (KAZAKHSTAN)160
G.Zh. Baisalova, A.S. Zhumadil, B.B. Torsykbaeva, D.T. Sadyrbekov,
K.T. Umerdzhanova
CHEMICAL COMPOSITION OF FRUITS OF ELEAAGNUS
ANGUSTIFOLIA173
NN Zhanikulov DK Zhurgarayoya C Mukhtarhanova
INVESTIGATION OF THE SUITABILITY OF HEAD LEACHING WASTE FROM
THE PROCESSING OF GOLD REARING ORE AS A RAW MATERIAL
EOD DODTI AND CEMENT 124
TOK FORTLAND CEMENT
A.A. Zheldybaeva, A.CH. Katashova, K.A. Iskakov, D.E. Nurmukhanbetova,
A. Azamatkyzy
NATURAL CRITERIA OF VEGETABLE JUICES AND THEIR QUALITY
DETERMINATION196
A.B. Issayeva, A.A. Sharipova, M.O. Issakhov, G.A. Kadyrbekova
ROLE OF MICROENCAPSULATED HUMIC ACID BASED ON BIOPOLYMERS
IN PLANT GROWTH STIMULATION

A.T. Massenova*, A.S. Zhumakanova, I.I. Torlopov, K.S. Rakhmetova, A.Z. Abilmagzhanov 2025
HIERARCHICAL ZEOLITES BASED ON SYNTHETIC ZEOLITES ZSM-5 HV
AND BEA FOR ALKYLATION OF AROMATIC HYDROCARBONS
A.K. Nurlybekova, A.A. Minkayeva, E. Shybyrai, H.A. Aisa, J. Jenis
GC-MS STUDY OF ORGANIC AND MINERAL COMPONENTS IN ARTEMISIA
SPECIES FROM KAZAKHSTAN
T.S. Khosnutdinova, A.O. Sapieva, N.G. Gemedzhieva, Zh.Zh. Karzhaubekova,
N.A. Sultanova
DEVELOPMENT OF A BIOLOGICALLY ACTIVE COMPLEX FROM THE
ROOTS OF FERULA FOETIDA (BUNGE) REGEL EXHIBITING
ANTIOXIDANT ACTIVITY

МАЗМҰНЫ

ФИЗИКА

Б.Ж. Әбдікәрімов, А.Ж. Сейтмұратов, Б.К. Калиев, Ә.Ғ. Ғаниұлла,
Т.М. Қарабала
СЫНДЫҚ ТЕМПЕРАТУРА МАҢЫНДАҒЫ ИЗОМАИ ҚЫШҚЫЛЫ – СУ
ЕРІТІНДІСІНІҢ ТҰТҚЫРЛЫҚ ҚАСИЕТТЕРІ5
Д.Т. Агишев, С.А. Хохлов, А.Т. Агишев, Н.Л. Вайдман, А.Т. Агишев
АККРЕЦИЯ ҚАРҚЫНЫ ТӨМЕН ТЫҒЫЗ ҚОС ЖҮЙЕЛЕРДЕГІ
РАДИАЦИЯЛЫҚ ЖӘНЕ КОНВЕКТИВТІ ТАСЫМАЛДАУДЫ ЗЕРТТЕУ17
Т.М. Алдабергенова, М.Ф. Верещак, А.С. Диков, С.Б. Кислицин
ИМПЛАНТАЦИЯЛАНҒАН ТЕМІР-57 ЯДРОЛАРЫНДА КИМС ӘДІСІМЕН
АНЫҚТАЛҒАН ЖОҒАРЫ ЭНТРОПИЯЛЫҚ ҚОРЫТПА НИТРИДТЕРІ
(ALTIZRYNB) N НЕГІЗІНДЕГІ ЖҰҚА ЖАБЫН ҚҰРЫЛЫМЫ29
Е. Бондарь, А. Шонғалова, А. Федосимова, С. Ибраимова, А. Кемелбекова
ГРАФЕН ОКСИДІ НЕГІЗІНДЕГІ ПРОТОН АЛМАСУ МЕМБРАНАЛАРЫНДА
ГИДРОНИЙ ИОНДАРЫНЫҢ ҚОЗҒАЛҒЫШТЫҒЫН АРТТЫРУ
Н.Н. Жантурина, Г.К. Бекетова, З.К. Аймаганбетова, К.Б. Бижанова,
Л.У. Таймуратова
ҚАЗІРГІ ЗАМАНҒЫ ПЕРОВСКИТТІ КҮН БАТАРЕЯЛАРЫ: ТИІМДІЛІКТІ
АРТТЫРУҒА АРНАЛҒАН МАТЕРИАЛДАР МЕН ТЕХНОЛОГИЯЛАРДАҒЫ
ИННОВАЦИЯЛАР
Ұ.Қ. Жапбасбаев, Г.І. Рамазанова, М.Ф. Пахомов
КЕНЕТТЕН КЕҢЕЮІ БАР ҚҰБЫРДАҒЫ ТҰТҚЫР-ПЛАСТИКАЛЫҚ
СҰЙЫҚТЫҚТЫҢ ТУРБУЛЕНТТІК АҒЫНЫ64
Д.М. Зазулин, С.Е. Кемелжанова, Н.Ә. Бейсен, А.Ш. Турсумбеков,
М.О. Алимкулова
НӨЛДІК ДЫБЫСЫ БАР ГОЛОГРАФИЯЛЫҚ ЖҮЙЕНІҢ
ГЕОМЕТРОТЕРМОДИНАМИКАСЫ
Е.М. Мырзакулов, А.Б. Алтайбаева, А.С. Бұланбаева
СЫЗЫҚТЫ ЕМЕС ЭЛЕКТРОДИНАМИКАМЕН БАЙЛАНЫСҚАН AdS ҚАРА
ҚҰРДЫМДАРДЫҢ ФАЗАЛЫҚ АУЫСУЛАРЫ МЕН ТЕРМОДИНАМИКАЛЫҚ
СИПАТТАМАЛАРЫ

Ш.А. Мырзакулова, А.А. Жадыранова
НЕТЕР СИММЕТРИЯСЫН ҚОЛДАНА ОТЫРЫП, F(G) ГРАВИТАЦИЯСЫН
3EPTTEY
Л.А. Төлеков, Л.М. Жарылғапова, А.М. Мухамбетжанова,
А.А. Алмағамбетова, Ұ.Ә. Әбітаева
УЛЬТРА-КҮЛГІНМЕН СӘУЛЕЛЕНГЕН Ц. SOMn-легі ЭЛЕКТРОНЛЫ-
КЕМТІКТІ КАРМАУ ОРТАЛЫКТАРЫ
С.У. Шарипов, И.Ф. Спивак-Лавров
ДЕФЛЕКТОРЛЫҚ ПЛАСТИНАЛАР МЕН ЖЕРГЕ ТҰЙЫҚТАЛҒАН ЭКРАН
АРАСЫНДАҒЫ ШЕТТІК ӨРІСТІҢ ЭЛЕКТРОСТАТИКАЛЫҚ
СИПАТТАМАЛАРЫ125
Л.И. Шестакова, А.В. Серебрянский, Р.Р. Спасюк, Ч.Т. Омаров
КҮН ЖҮИЕСІНІҢ ІШКІ АИМАҒЫНДАҒЫ КОМЕТАЛЫҚ-МЕТЕОРЛЫҚ
ШАҢДЫ ІЗДЕУ: ШАҢДЫ КОРОНАДАҒЫ ЖЫЛУ ЭМИССИЯСЫ138
химия
Р.С. Абжалов, Ш.Т. Кошкарбаева, А.К. Диканбаева, М.С. Сатаев,
Б.С. Серикбаева
ФОТОХИМИЯЛЫҚ АКТИВТЕНДІРУ АРҚЫЛЫ ПОЛИМЕР БЕТІНЕН
КҮМІС НАНОБӨЛШЕКТЕРДІ АЛУДЫ ЗЕРТТЕУ147
L'Anvien A Avenuer II Foundance A Tumoutages A Hérages
м. Арынов, А. Аусшов, Ч. Ескиоаева, А. диканоаева, А. пораева WITIVADA VEHADULIULIU HEMA ПИТУУДАМПАС УДИЗАТИП АСТЕСТИ
MITIGARA REPORTEDING TEMAJITI χ FRAMARC APPISOTULI-ACDECTIC DEUTEEUOAA2A ILLIV WALE TEDMOALA IIATAVA ILLIV 2EDTTEV 160
геппенофазалық жөне тегмоаналитикалық зегттеу100
Г.Ж. Байсалова, Ә.С. Жұмаділ, Б.Б. Торсыкбаева, Д.Т. Садырбеков,
К.Т. Умерджанова
ELAEAGNUS ANGUSTIFOLIA ЖЕМІСТЕРІНІҢ ХИМИЯЛЫҚ
КОМПОНЕНТТЕРІ
Н Н. Жаничилов, П.К. Живсаваева, Г. Миктаруанара, А.С. Байдан
п.п. маникулов, д.к. мургарасва, г. мұхтарханова, А.С. даилен, А.К. Сридорский
Α.Κ. Свидерский ΠΩΦΤΠΛΗΠΙΕΜΕΥΤ Λ ΠΥ VIIIΙΗ Λ ΠΤΕΙΗ ΓΕΥΙΗ ΔΗΠΕΥΠΕΗ Λ ΠΕΙΗΓΛΗ
ТОГ ГЛАНДЦЕМЕНТ АЛУ ТШПТАЛТЫН КЕНПТОНДЕ УДЕН АЛЫШ АН УЙНИП ШАЙМАЛАУ КАЛЛЫКТАРЛЫ ШИКТЭАТ РЕТІНЛЕ
\mathcal{W} арамлынын зерттеу 194 шикизки гетинде 194
А.А. Жельдыбаева, А.Ч. Каташева, К.А. Искаков, Д.Е. Нурмуханбетова,
А. Азаматқызы
КӨКӨНІС ШЫРЫНДАРЫНЫҢ ТАБИҒИ КРИТЕРИЙЛЕРІ МЕН САПАСЫН
АНЫҚТАУ

А.Б. Исаева, А.А. Шарипова, М.О. Исахов, Г.А. Кадирбекова
БИОПОЛИМЕРЛЕРГЕ НЕГІЗДЕЛГЕН МИКРОКАПСУЛДАНҒАН
ГУМИН ҚЫШҚЫЛЫНЫҢ ӨСІМДІКТЕРДІҢ ӨСУІН ЫНТАЛАНДЫРУДАҒЫ
РӨЛІ
А.Т. Масенова, А.С. Жумақанова, И.И. Торлопов, К.С. Рахметова,
А.З. Абильмагжанов
АРОМАТТЫ КӨМІРСУТЕКТЕРДІ АЛКИЛДЕУГЕ АРНАЛҒАН ZSM-5, НҮ
ЖӘНЕ ВЕА СИНТЕТИКАЛЫҚ ЦЕОЛИТТЕРІНЕ НЕГІЗДЕЛГЕН
ИЕРАРХИЯЛЫҚ ЦЕОЛИТТЕР
А.К. Нурлыбекова, А.А. Минкаева, Е. Шыбырай, Х.А. Айса, Ж. Жеңіс
ҚАЗАҚСТАНДАҒЫ ARTEMISIA ТҮРЛЕРІНІҢ ОРГАНИКАЛЫҚ ЖӘНЕ
МИНЕРАЛДЫ ҚҰРАМЫН ГХ-МС АРҚЫЛЫ ЗЕРТТЕУ
Т.С. Хоснутдинова, А.О. Сәпиева, Н.Г. Гемеджиева, Ж.Ж. Қаржаубекова,
Н.А. Сұлтанова
FERULA FOETIDA (BUNGE) REGEL ТАМЫРЫНАН АНТИОКСИДАНТТЫҚ
БЕЛСЕНДІЛІГІ БАР БИОЛОГИЯЛЫҚ БЕЛСЕНДІ КЕШЕНДІ АЛУ252

СОДЕРЖАНИЕ

ФИЗИКА

ΨΠΣΗΙΚΑ	
Б.Ж. Абдикаримов, А.Ж. Сейтмуратов, Б.К. Калиев, А.Г. Ганиулла,	
Т.М. Карабала	
СВОЙСТВА ВЯЗКОСТИ РАСТВОРА ИЗОМАСЛЯНАЯ КИСЛОТА –	
ВОДА ВБЛИЗИ КРИТИЧЕСКОЙ ТЕМПЕРАТУРЫ РАССЛОЕНИЯ	5
Л.Т. Агишев, С.А. Хохлов, А.Т. Агишев, Н.Л. Вайлман, А.Т. Агишев	
ИССЛЕЛОВАНИЕ РАЛИАЦИОННОГО И КОНВЕКТИВНОГО ПЕРЕНОСА В	3
ТЕСНЫХ ДВОЙНЫХ СИСТЕМАХ С МАЛЫМ ТЕМПОМ АККРЕЦИИ	
ВЕЩЕСТВА	.17
Т.М. Алдабергенова, М.Ф. Верещак, А.С. Диков, С.Б. Кислицин	
ТОНКАЯ СТРУКТУРА ПОКРЫТИЯ НА ОСНОВЕ НИТРИДОВ	
ВЫСОКОЭНТРОПИЙНОГО СПЛАВА (ALTIZRYNb)N, ОПРЕДЕЛЕННАЯ	
КЭМС МЕТОДОМ НА ЯДРАХ ИМПЛАНТИРОВАННОГО ЖЕЛЕЗА-57	.29
Е. Бондарь, А. Шонгалова, А. Федосимова, С. Ибраимова, А. Кемелбекова	
ПОВЫШЕНИЕ ПОДВИЖНОСТИ ИОНОВ ГИДРОНИЯ В	
ПРОТОНООБМЕННЫХ МЕМБРАНАХ НА ОСНОВЕ ОКСИДА ГРАФЕНА	.39
Н.Н. Жантурина, Г.К. Бекетова, З.К. Аймаганбетова, К.Б. Бижанова,	
Л.У. Таймуратова	
СОВРЕМЕННЫЕ ПЕРОВСКИТНЫЕ СОЛНЕЧНЫЕ ЭЛЕМЕНТЫ:	
ИННОВАЦИИ В МАТЕРИАЛАХ И ТЕХНОЛОГИЯХ ДЛЯ ПОВЫШЕНИЯ	
ЭФФЕКТИВНОСТИ	.50
У.К. Жапбасбаев, Г.И. Рамазанова, М.А. Пахомов	
ТУРБУЛЕНТНОЕ ТЕЧЕНИЕ ВЯЗКОПЛАСТИЧНОЙ ЖИДКОСТИ В	
ТРУБЕ С РЕЗКИМ РАСШИРЕНИЕМ	.64
Д.М. Зазулин, С.Е. Кемелжанова, Н.А. Бейсен, А.Ш. Турсумбеков,	
М.О. Алимкулова	
ГЕОМЕТРОТЕРМОДИНАМИКА ГОЛОГРАФИЧЕСКОЙ	
СИСТЕМЫ С НУЛЕВЫМ ЗВУКОМ	.78
Е.М. Мырзакулов, А.Б. Алтайбаева, А.С. Буланбаева	
ФАЗОВЫЕ ПЕРЕХОДЫ И ТЕРМОДИНАМИЧЕСКОЕ ПОВЕДЕНИЕ AdS	

ЧЕРНЫХ ДЫР СВЯЗАННЫХ С НЕЛИНЕЙНОЙ ЭЛЕКТРОДИНАМИКОЙ....89

Ш.А. Мырзакулова, А.А. Жадыранова ИССЛЕДОВАНИЕ F(G) ГРАВИТАЦИИ С ПРИМЕНЕНИЕМ СИММЕТРИИ НЁТЕР
Д.А. Толеков, Д.М. Жарылгапова, А.М. Мухамбетжанова,
А.А. Алмагамбетова, У.А. Абитаева
ЭЛЕКТРОННО-ДЫРОЧНЫЕ ЦЕНТРЫ ЗАХВАТА В ОБЛУЧЕННОМ
УЛЬТРА-ФИОЛЕТОМ-КРИСТАЛАХ Li ₂ SO ₄ -Mn115
С.У. Шарипов, И.Ф. Спивак-Лавров
ЭЛЕКТРОСТАТИЧЕСКИЕ ХАРАКТЕРИСТИКИ КРАЕВОГО ПОЛЯ МЕЖДУ
ДЕФЛЕКТОРНЫМИ ПЛАСТИНАМИ И ЗАЗЕМЛЕННЫМ ЭКРАНОМ125
Л.И. Шестакова, А.В. Серебрянский, Р.Р. Спасюк, Ч.Т. Омаров
ПОИСК ПЫЛИ КОМЕТНО-МЕТЕОРНОГО ПРОИСХОЖДЕНИЯ ВО
ВНУТРЕННЕЙ ОБЛАСТИ СОЛНЕЧНОЙ СИСТЕМЫ: ТЕПЛОВАЯ
ЭМИССИЯ В ПЫЛЕВОИ КОРОНЕ
ХИМИЯ
Р.С. Абжалов, Ш.Т. Кошкарбаева, А.К. Диканбаева, М.С. Сатаев,
Б.С. Серикбаева
ИССЛЕДОВАНИЕ ПОЛУЧЕНИЯ НАНОЧАСТИЦ СЕРЕБРА НА
ПОВЕРХНОСТИ ПОЛИМЕРА С ПОМОЩЬЮ ФОТОХИМИЧЕСКОИ
К.Т. Арынов, А.П. Ауешов, Ч.З. Ескибаева, А.К. Диканбаева, А.М. Ибраева
РЕНТГЕНОФАЗОВОЕ И ТЕРМОАНАЛИТИЧЕСКОЕ ИССЛЕДОВАНИЕ
НЕМАЛИТА ЖИТИКАРИНСКОГО МЕСТОРОЖДЕНИЯ
(KA3AXCTAH)
Г.Ж. Байсалова, А.С.Жумадил, Б.Б. Торсыкбаева, Д.Т. Садырбеков,
К.Т. Умерджанова
ХИМИЧЕСКИИ СОСТАВ ПЛОДОВ ELAEAGNUS ANGUSTIFOLIA1/3
Н.Н. Жаникулов, Д.К. Жургараева, Г. Мухтарханова, А.С. Байлен, А.К. Сридерский
ИССЛЕЛОВАНИЕ ПРИГОЛНОСТИ ОТХОЛОВ КУЧНОГО
ВЫЩЕЛАЧИВАНИЯ ПРИ ПЕРЕРАБОТКЕ ЗОЛОТОСОЛЕРЖАШИХ РУЛ В
КАЧЕСТВЕ СЫРЬЯ ДЛЯ ПОЛУЧЕНИЯ ПОРТЛАНДЦЕМЕНТА

А.А. Жельдыбаева, А.Ч. Каташева, К.А. Искаков, Д.Е. Нурмуханбетова,
А. Азаматкызы
ОПРЕДЕЛЕНИЕ ЕСТЕСТВЕННЫХ КРИТЕРИЕВ И КАЧЕСТВА
ОВОЩНЫХ СОКОВ
А.Б. Исаева, А.А. Шарипова, М.О. Исахов, Г.А. Кадирбекова
РОЛЬ МИКРОКАПСУЛИРОВАННОЙ ГУМИНОВОЙ КИСЛОТЫ НА ОСНОВЕ
БИОПОЛИМЕРОВ В СТИМУЛЯЦИИ РОСТА РАСТЕНИЙ
А.Т. Масенова, А.С. Жумаканова, И.И. Торлопов, К.С. Рахметова,
А.З. Абильмагжанов
ИЕРАРХИЧЕСКИЕ ЦЕОЛИТЫ НА ОСНОВЕ СИНТЕТИЧЕСКИХ ЦЕОЛИТОВ
ZSM-5, НҮ И ВЕА ДЛЯ АЛКИЛИРОВАНИЯ АРОМАТИЧЕСКИХ
УГЛЕВОДОРОДОВ
А.К. Нурлыбекова, А.А. Минкаева, Е. Шыбырай, Х.А. Айса, Ж. Женис
ИССЛЕДОВАНИЕ ОРГАНИЧЕСКИХ И МИНЕРАЛЬНЫХ КОМПОНЕНТОВ
ВИДОВ ARTEMISIA ИЗ КАЗАХСТАНА МЕТОДОМ ГХ-МС
Т.С. Хоснутдинова, А.О. Сапиева, Н.Г. Гемеджиева, Ж.Ж. Каржаубекова,
Н.А. Султанова
ПОЛУЧЕНИЕ БИОЛОГИЧЕСКИ АКТИВНОГО КОМПЛЕКСА ИЗ КОРНЕЙ
FERULA FOETIDA (BUNGE) REGEL, ОБЛАДАЮЩЕГО
АНТИОКСИДАНТНОЙ АКТИВНОСТЬЮ

Publication Ethics and Publication Malpractice in the journals of the National Academy of Sciences of the Republic of Kazakhstan

For information on Ethics in publishing and Ethical guidelines for journal publication see http:// www.elsevier.com/publishingethics and http://www.elsevier.com/journal-authors/ethics.

Submission of an article to the National Academy of Sciences of the Republic of Kazakhstan implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see http://www.elsevier. com/postingpolicy), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. In particular, translations into English of papers already published in another language are not accepted.

No other forms of scientific misconduct are allowed, such as plagiarism, falsification, fraudulent data, incorrect interpretation of other works, incorrect citations, etc. The National Academy of Sciences of the Republic of Kazakhstan follows the Code of Conduct of the Committee on Publication Ethics (COPE), and follows the COPE Flowcharts for Resolving Cases of Suspected Misconduct (http:// publicationethics.org/files/u2/New_Code.pdf). To verify originality, your article may be checked by the originality detection service Cross Check http://www.elsevier.com/editors/plagdetect.

The authors are obliged to participate in peer review process and be ready to provide corrections, clarifications, retractions and apologies when needed. All authors of a paper should have significantly contributed to the research.

The reviewers should provide objective judgments and should point out relevant published works which are not yet cited. Reviewed articles should be treated confidentially. The reviewers will be chosen in such a way that there is no conflict of interests with respect to the research, the authors and/ or the research funders.

The editors have complete responsibility and authority to reject or accept a paper, and they will onh accept a paper when reasonably certain. They will preserve anonymity of reviewers and promote publication of corrections, clarifications, retractions and apologies when needed. The acceptance of a paper automatically implies the copyright transfer to the National Academy of sciences of the Republic of Kazakhstan.

The Editorial Board of the National Academy of sciences of the Republic of Kazakhstan will monitor and safeguard publishing ethics.

Правила оформления статьи для публикации в журнале смотреть на сайте: www:nauka-nanrk.kz ISSN 2518-1483 (Online), ISSN 2224-5227 (Print) http://reports-science.kz/index.php/en/archive

Директор отдела издания научных журналов НАН РК А. Ботанқызы Редакторы: Д.С. Аленов, Ж.Ш. Әден Верстка на компьютере Г.Д. Жадырановой

> Подписано в печать 31.03.2025. Формат 60х88¹/₈. 18,0 п.л. Заказ 1.

РОО «Национальная академия наук РК» 050010, Алматы, ул. Шевченко, 28, т. 272-13-19