ISSN 2518-170X (Online)
ISSN 2224-5278 (Print)

«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ
АКАДЕМИЯСЫ» РҚБ

«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ
«ХАЛЫҚ» ЖҚ

# ХАБАРЛАРЫ

# ИЗВЕСТИЯ

РОО «НАЦИОНАЛЬНОЙ
АКАДЕМИИ НАУК РЕСПУБЛИКИ
КАЗАХСТАН»
ЧФ «Халық»

# NEWS

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF
KAZAKHSTAN
«Halyk» Private Foundation

## SERIES
## OF GEOLOGY AND TECHNICAL SCIENCES

## 5 (467)

**SEPTEMBER – OCTOBER 2024**

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

Clarivate
Analytics

*NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.*

*Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.*

*НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.*

**Бас редактор**

**ЖҰРЫНОВ Мұрат Жұрынұлы**, химия ғылымдарының докторы, профессор, ҚР ҰҒА академигі, «Қазақстан Республикасы Ұлттық ғылым академиясы» РҚБ-нің президенті, АҚ «Д.В. Сокольский атындағы отын, катализ және электрохимия институтының» бас директоры (Алматы, Қазақстан) **Н = 4**

**Ғылыми хатшы**

**АБСАДЫКОВ Бахыт Нарикбайұлы,** техника ғылымдарының докторы, профессор, ҚР ҰҒА жауапты хатшысы, А.Б. Бектұров атындағы химия ғылымдары институты (Алматы, Қазақстан) **Н=5**

**Редакциялық алқа:**

**ӘБСАМЕТОВ Мәліс Құдысұлы** (бас редактордың орынбасары), геология-минералогия ғылымдарының докторы, профессор, ҚР ҰҒА академигі, «У.М. Ахмедсафина атындағы гидрогеология және геоэкология институтының» директоры (Алматы, Қазақстан) **Н = 2**

**ЖОЛТАЕВ Герой Жолтайұлы** (бас редактордың орынбасары), геология-минералогия ғылымдарының докторы, профессор, Қ.И. Сатпаев тындағы геология ғылымдары институтының директоры (Алматы, Қазақстан) **Н=2**

**СНОУ Дэниел**, Ph.D, қауымдастырылған профессор, Небраска университетінің Су ғылымдары зертханасының директоры (Небраска штаты, АҚШ) **Н = 32**

**ЗЕЛЬТМАН Реймар**, Ph.D, табиғи тарих мұражайының Жер туралы ғылымдар бөлімінде петрология және пайдалы қазбалар кен орындары саласындағы зерттеулердің жетекшісі (Лондон, Англия) **Н = 37**

**ПАНФИЛОВ Михаил Борисович,** техника ғылымдарының докторы, Нанси университетінің профессоры (Нанси, Франция) **Н=15**

**ШЕН Пин,** Ph.D, Қытай геологиялық қоғамының тау геологиясы комитеті директорының орынбасары, Американдық экономикалық геологтар қауымдастығының мүшесі (Пекин, Қытай) **Н = 25**

**ФИШЕР Аксель,** Ph.D, Дрезден техникалық университетінің қауымдастырылған профессоры (Дрезден, Берлин) **Н = 6**

**КОНТОРОВИЧ Алексей Эмильевич,** геология-минералогия ғылымдарының докторы, профессор, РҒА академигі, А.А. Трофимука атындағы мұнай-газ геологиясы және геофизика институты (Новосибирск, Ресей) **Н = 19**

**АГАБЕКОВ Владимир Енокович,** химия ғылымдарының докторы, Беларусь ҰҒА академигі, Жаңа материалдар химиясы институтының құрметті директоры (Минск, Беларусь) **Н = 13**

**КАТАЛИН Стефан,** Ph.D, Дрезден техникалық университетінің қауымдастырылған профессоры (Дрезден, Берлин) **Н = 20**

**СЕЙТМҰРАТОВА Элеонора Юсуповна,** геология-минералогия ғылымдарының докторы, профессор, ҚР ҰҒА корреспондент-мүшесі, Қ.И. Сатпаев атындағы Геология ғылымдары институты зертханасының меңгерушісі (Алматы, Қазақстан) **Н=11**

**САҒЫНТАЕВ Жанай,** Ph.D, қауымдастырылған профессор, Назарбаев университеті (Нұр-Сұлтан, Қазақстан) **Н = 11**

**ФРАТТИНИ Паоло**, Ph.D, Бикокк Милан университеті қауымдастырылған профессоры (Милан, Италия) **Н = 28**

---

**«ҚР ҰҒА» РҚБ Хабарлары. Геология және техникалық ғылымдар сериясы».**
**ISSN 2518-170X (Online),**
**ISSN 2224-5278 (Print)**
Меншіктеуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).
Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 29.07.2020 ж. берілген **№ KZ39VPY00025420** мерзімдік басылым тіркеуіне қойылу туралы куәлік.
Тақырыптық бағыты: *геология, мұнай және газды өңдеудің химиялық технологиялары, мұнай химиясы, металдарды алу және олардың қосындыларының технологиясы.*
Мерзімділігі: жылына 6 рет.
Тиражы: 300 дана.
Редакцияның мекен-жайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., тел.: 272-13-19
http://www.geolog-technical.kz/index.php/en/

© «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ, 2024

**Главный редактор**

**ЖУРИНОВ Мурат Журинович,** доктор химических наук, профессор, академик НАН РК, президент РОО «Национальной академии наук Республики Казахстан», генеральный директор АО «Институт топлива, катализа и электрохимии им. Д.В. Сокольского» (Алматы, Казахстан) **Н = 4**

**Ученный секретарь**

**АБСАДЫКОВ Бахыт Нарикбаевич,** доктор технических наук, профессор, ответственный секретарь НАН РК, Институт химических наук им. А.Б. Бектурова (Алматы, Казахстан) **Н = 5**

**Редакционная коллегия:**

**АБСАМЕТОВ Малис Кудысович,** (заместитель главного редактора), доктор геологоминералогических наук, профессор, академик НАН РК, директор Института гидрогеологии и геоэкологии им. У.М. Ахмедсафина (Алматы, Казахстан) **Н = 2**

**ЖОЛТАЕВ Герой Жолтаевич,** (заместитель главного редактора), доктор геологоминералогических наук, профессор, директор Института геологических наук им. К.И. Сатпаева (Алматы, Казахстан) **Н=2**

**СНОУ Дэниел**, Ph.D, ассоциированный профессор, директор Лаборатории водных наук университета Небраски (штат Небраска, США) **Н = 32**

**ЗЕЛЬТМАН Реймар,** Ph.D, руководитель исследований в области петрологии и месторождений полезных ископаемых в Отделе наук о Земле Музея естественной истории (Лондон, Англия) **Н = 37**

**ПАНФИЛОВ Михаил Борисович,** доктор технических наук, профессор Университета Нанси (Нанси, Франция) **Н=15**

**ШЕН Пин,** Ph.D, заместитель директора Комитета по горной геологии Китайского геологического общества, член Американской ассоциации экономических геологов (Пекин, Китай) **Н = 25**

**ФИШЕР Аксель,** ассоциированный профессор, Ph.D, технический университет Дрезден (Дрезден, Берлин) **Н = 6**

**КОНТОРОВИЧ Алексей Эмильевич,** доктор геолого-минералогических наук, профессор, академик РАН, Институт нефтегазовой геологии и геофизики им. А.А. Трофимука СО РАН (Новосибирск, Россия) **Н = 19**

**АГАБЕКОВ Владимир Енокович,** доктор химических наук, академик НАН Беларуси, почетный директор Института химии новых материалов (Минск, Беларусь) **Н = 13**

**КАТАЛИН Стефан,** Ph.D, ассоциированный профессор, Технический университет (Дрезден, Берлин) **Н = 20**

**СЕЙТМУРАТОВА Элеонора Юсуповна**, доктор геолого-минералогических наук, профессор, член-корреспондент НАН РК, заведующая лаборатории Института геологических наук им. К.И. Сатпаева (Алматы, Казахстан) **Н=11**

**САГИНТАЕВ Жанай,** Ph.D, ассоциированный профессор, Назарбаев университет (Нурсултан, Казахстан) **Н = 11**

**ФРАТТИНИ Паоло,** Ph.D, ассоциированный профессор, Миланский университет Бикокк (Милан, Италия) **Н = 28**

---

**«Известия РОО «НАН РК». Серия геологии и технических наук».**
**ISSN 2518-170X (Online),**
**ISSN 2224-5278 (Print)**

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

Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан **№ KZ39VPY00025420,** выданное 29.07.2020 г.

Тематическая направленность: *геология, химические технологии переработки нефти и газа, нефтехимия, технологии извлечения металлов и их соеденений.*

Периодичность: 6 раз в год.

Тираж: 300 экземпляров.

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, оф. 219, тел.: 272-13-19

http://www.geolog-technical.kz/index.php/en/

© РОО «Национальная академия наук Республики Казахстан», 2024

**Editorial chief**

**ZHURINOV Murat Zhurinovich,** doctor of chemistry, professor, academician of NAS RK, president of the National Academy of Sciences of the Republic of Kazakhstan, general director of JSC "Institute of fuel, catalysis and electrochemistry named after D.V. Sokolsky» (Almaty, Kazakhstan) **H = 4**

**Scientific secretary**

**ABSADYKOV Bakhyt Narikbaevich**, doctor of technical sciences, professor, executive secretary of NAS RK, Bekturov Institute of chemical sciences (Almaty, Kazakhstan) **H = 5**

**Editorial board:**

**ABSAMETOV Malis Kudysovich,** (deputy editor-in-chief), doctor of geological and mineralogical sciences, professor, academician of NAS RK, director of the Akhmedsafin Institute of hydrogeology and hydrophysics (Almaty, Kazakhstan) **H=2**

**ZHOLTAEV Geroy Zholtaevich,** (deputy editor-in-chief), doctor of geological and mineralogical sciences, professor, director of the institute of geological sciences named after K.I. Satpayev (Almaty, Kazakhstan) **H=2**

**SNOW Daniel,** Ph.D, associate professor, director of the labotatory of water sciences, Nebraska University (Nebraska, USA) **H = 32**

**ZELTMAN Reymar,** Ph.D, head of research department in petrology and mineral deposits in the Earth sciences section of the museum of natural history (London, England) **H = 37**

**PANFILOV Mikhail Borisovich,** doctor of technical sciences, professor at the Nancy University (Nancy, France) **H=15**

**SHEN Ping,** Ph.D, deputy director of the Committee for Mining geology of the China geological Society, Fellow of the American association of economic geologists (Beijing, China) **H = 25**

**FISCHER Axel,** Ph.D, associate professor, Dresden University of technology (Dresden, Germany) **H = 6**

**KONTOROVICH Aleksey Emilievich,** doctor of geological and mineralogical sciences, professor, academician of RAS, Trofimuk Institute of petroleum geology and geophysics SB RAS (Novosibirsk, Russia) **H = 19**

**AGABEKOV Vladimir Enokovich,** doctor of chemistry, academician of NAS of Belarus, honorary director of the Institute of chemistry of new materials (Minsk, Belarus) **H = 13**

**KATALIN Stephan,** Ph.D, associate professor, Technical university (Dresden, Berlin) **H = 20**

**SEITMURATOVA Eleonora Yusupovna,** doctor of geological and mineralogical sciences, professor, corresponding member of NAS RK, head of the laboratory of the Institute of geological sciences named after K.I. Satpayev (Almaty, Kazakhstan) **H=11**

**SAGINTAYEV Zhanay,** Ph.D, associate professor, Nazarbayev University (Nursultan, Kazakhstan) **H=11**

**FRATTINI Paolo,** Ph.D, associate professor, university of Milano-Bicocca (Milan, Italy) **H = 28**

---

**News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.**
**ISSN 2518-170X (Online),**
**ISSN 2224-5278 (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. KZ39VPY00025420,** issued 29.07.2020.
Thematic scope: *geology, chemical technologies for oil and gas processing, petrochemistry, technologies for extracting metals and their connections.*
Periodicity: 6 times a year.
Circulation: 300 copies.
Editorial address: 28, Shevchenko str., of. 219, Almaty, 050010, tel. 272-13-19
http://www.geolog-technical.kz/index.php/en/

© National Academy of Sciences of the Republic of Kazakhstan, 2024

NEWS of the National Academy of Sciences of the Republic of Kazakhstan
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224–5278
Volume 5. Number 467 (2024), 47–62
https://doi.org/10.32014/2024.2518-170X.444

UDC 621.01

**D. Karaivanov[1], M.F. Kerimzhanova[2], M.E. Isametova[2], N.S. Seiitkazy[2*], G. Turymbetova[3], 2024.**
[1]University of Chemical Technology and Metallurgy, Sofia, Bulgaria;
[2] K. Satpayev Kazakh National Research Technical University,
Almaty, Kazakhstan;
[3] M. Auezov South Kazakhstan University, Shymkent, Kazakhstan.
E-mail: seytkazy.nurgul@mail.ru

# INVESTIGATION OF KINEMATICS AND POWER OF COMPOSITE PLANETARY GEARS FOR WIND TURBINES

**Karaivanov D. –** Doctor of Engineering, University of Chemical Technology and Metallurgy, Sofia, Bulgaria, E-mail: dipekabg@yahoo.com, https://orcid.org/0000-0002-1709-677X;
**Kerimzhanova M.F. –** Candidate of Technical Sciences, Professor, Department of Mechanical Engineering, Kazakh National Research Technical University named after K. I.Satpayev, Almaty, Kazakhstan, E-mail: m.kerimzhanova@satbayev.university, https://orcid.org/0000-0002-9475-8239;
**Isametova M.E.** – Candidate of Technical Sciences, Associate Professor, Department of Mechanical Engineering, Kazakh National Research Technical University named after K. I.Satpayev, Almaty, Kazakhstan, E-mail m.issametova@satbaeyv.university, https://orcid.org/0000-0003-4630-271X;
**Seiitkazy N.S.** – Master's degree, Doctoral student of the Department of Mechanical Engineering, Kazakh National Research Technical University named after K. I. Satpayev, Almaty, Kazakhstan, E-mail: seytkazy.nurgul@mail.ru, https://orcid.org/0000-0002-7255-5692;
**Turymbetova G.D. –** doctor PhD, Associate Professor of the Department of "Energetics and renewable energy systems", M.Auezov South Kazakhstan State University, Shymkent, Kazakhstan, E-mail: gulzuhra62@mail.ru , https://orcid.org/0000-0002-9201-6127.

**Abstract.** The article presents a method of complex kinematic analysis of a mechanical wind turbine system. Input data, such as the speed of rotation of the input shaft of the gearbox, for the multi-criteria analysis of the planetary multiplier of the wind turbine were obtained from the results of computer simulation of the air flow. The fundamentals of the torque method were used to study planetary compound gears (PCG), called a multiplier. The variants of kinematic schemes of composite planetary transmission are analyzed in order to determine the most optimal distribution of the energy flow. The torque method allows not only kinematic analysis (determining the ratio of speeds), but also power analysis (determining the direction and magnitude of internal power flows), as well as determining efficiency. Relatively simple formulas for calculating the ratio of speeds and efficiency made it possible to carry out multi-purpose optimization of the parameters of the considered

PCG. As a result of the analysis, the most optimal scheme of a composite planetary gearbox was determined, taking into account the kinematics of the airflow on the wind turbine wheel.

**Key words:** Wind energy system, multiplier, torque method, kinematic analysis, computer modeling.

**Д. Караиванов[1], М.Ф.Керимжанова[2], М.Е. Исаметова[2], Н.С. Сейітқазы[2*], Г. Турумбетова[3] , 2024.**
[1] Химиялық технология және металлургия университеті, София, Болгария,
[2] Қ.И.Сәтбаев атындағы Қазақ ұлттық техникалық зерттеу университеті, Алматы, Қазақстан;
[3] М. Әуезов атындағы Оңтүстік Қазақстан университеті, Шымкент, Қазақстан.
E-mail: seytkazy.nurgul@mail.ru

# ЖЕЛ ТУРБИНАЛАРЫ ҮШІН КОМПОЗИЦИЯЛЫҚ ПЛАНЕТАРЛЫҚ БЕРІЛІС БӘСЕҢДЕТКІШІНІҢ КИНЕМАТИКАСЫ МЕН ҚУАТЫН ЗЕРТТЕУ

**Караиванов Д. –** техника ғылымдарының докторы, Химиялық технология және металлургия университеті, София, Болгария,
E-mail: dipekabg@yahoo.com, https://orcid.org/0000-0002-1709-677X;
**Керимжанова М.Ф.** – т.ғ.к., Қ.И.Сәтбаев атындағы Қазақ ұлттық техникалық зерттеу университеті, Машина жасау кафедрасының доценті, Алматы, Қазақстан, E-mail: m.kerimzhanova@satbayev.university, https://orcid.org/0000-0002-9475-8239;
**Исаметова М.Е.** – т.ғ.к., Қ.И.Сәтбаев атындағы Қазақ ұлттық техникалық зерттеу университеті, Машина жасау кафедрасының доценті, Алматы, Қазақстан, E-mail: m.issametova@satbaeyv.university, https://orcid.org/0000-0003-4630-271X;
**Сейітқазы Н.С.** – магистр, Қ.И.Сәтбаев атындағы Қазақ ұлттық техникалық зерттеу университеті, Машина жасау кафедрасының докторанты, Алматы, Қазақстан, E-mail: seytkazy.nurgul@mail.ru, https://orcid.org/0000-0002-7255-5692;
**Турымбетова Г.Д. –** Ph.D, М.Әуезов атындағы Оңтүстік Қазақстан университеті, «Энергетика және дәстүрлі емес энергетикалық жүйелер» кафедрасының доценті,, Шымкент, Қазақстан, E-mail: gulzuhra62@mail.ru , https://orcid.org/0000-0002-9201-6127.

**Аннотация.** Мақалада ЖЭО механикалық жүйесін кешенді кинематикалық талдау әдістемесі келтірілген. ЖЭО планетарлық мультипликаторын көп критериалды талдау үшін редуктордың кіріс білігінің айналу жылдамдығы сияқты кірістер, ауа ағынын компьютерлік модельдеу нәтижелері бойынша алынды. Мультипликатор деп аталатын планетарлық құрама берілістерді (РТБ) зерттеу үшін момент әдісінің негіздері қолданылды. Энергия ағынының оңтайлы таралуын анықтау үшін күрделі планеталық берілістің кинематикалық схемаларының нұсқалары талданды. Момент әдісі кинематикалық талдауды (жылдамдық қатынасын анықтау) ғана емес, сонымен қатар қуатты талдауды (ішкі қуат ағындарының бағыты мен шамасын анықтау), тиімділікті анықтауға мүмкіндік береді. Жылдамдық пен тиімділіктің арақатынасын есептеудің салыстырмалы түрде қарапайым формулалары қарастырылып отырған РТБ параметрлерін көп мақсатты оңтайландыруға мүмкіндік берді. Талдау нәтижесінде ЖЭО жел дөңгелегіндегі ауа ағынының кинематикасын ескере отырып, күрделі планетарлық редуктордың ең оңтайлы схемасы анықталды.

**Түйін сөздер:** Жел қондырғысы, мультипликатор, момент әдісі, кинематикалық талдау, компьютерлік модельдеу.

**Д. Караиванов[1], М.Ф. Керимжанова[2], М.Е. Исаметова[2],**
**Н.С. Сейітқазы[2*], Г. Турумбетова[3], 2024.**
[1] Университет химической технологии и металлургии, София, Болгария;
[2] Казахский Национальный Исследовательский Технический Университет
им. К.И. Сатпаева, Алматы, Казахстан;
[3]Университет Ауэзова, Шымкент, Казахстан.
E-mail: seytkazy.nurgul@mail.ru

# ИССЛЕДОВАНИЕ КИНЕМАТИКИ И МОЩНОСТИ КОМПОЗИТНЫХ ПЛАНЕТАРНЫХ РЕДУКТОРОВ ДЛЯ ВЕТРОГЕНЕРАТОРОВ

**Караиванов Д. –** доктор технических наук, Университет химической технологии и металлургии, София, Болгария, E-mail: dipekabg@yahoo.com, https://orcid.org/0000-0002-1709-677X;
**Керимжанова М.Ф.** – кандидат технических наук, доцент кафедры машиностроения, Казахский Национальный Исследовательский Технический Университет им. К. Сатпаева, E-mail: m.kerimzhanova@satbayev.university, https://orcid.org/0000-0002-9475-8239
**Исаметова М.Е.** – кандидат технических наук, доцент кафедры машиностроения, Казахский Национальный Исследовательский Технический Университет им. К. Сатпаева, Алматы, Казахстан, E-mail m.issametova@satbaeyv.university, https://orcid.org/0000-0003-4630-271X ;
**Сейітқазы Н.С.** – магистр, докторант кафедры машиностроения, Казахский Национальный Исследовательский Технический Университет им. К. Сатпаева, Алматы, Казахстан, E-mail: seytkazy.nurgul@mail.ru, https://orcid.org/0000-0002-7255-5692;
**Турымбетова Г.Д. –** PhD, доцент кафедры «Энергетика и нетрадиционные энергетические системы», Южно-Казахстанский университет им. М.Ауэзова, Шымкент, Казахстан, E-mail: gulzuhra62@mail.ru , https://orcid.org/0000-0002-9201-6127.

**Аннотация.** В статье представлена методика комплексного кинематического анализа механической системы ВЭУ. Входные данные, такие как скорость вращения входного вала редуктора, для многокритериального анализа планетарного мультипликатора ВЭУ были получены по результатам компьютерного моделирования воздушного потока. Для исследования планетарных составных зубчатых передач (ПЗП), называемыми мультипликатором, использовались основы метода крутящего момента. Проанализированы варианты кинематических схем составной планетарной передачи, с целью определения наиболее оптимального распределения потока энергии. Метод крутящего момента позволяет проводить не только кинематический анализ (определение соотношения скоростей), но и анализ мощности (определение направления и величины внутренних потоков мощности), а также определение КПД. Относительно простые формулы для расчета соотношения скоростей и КПД позволили провести многоцелевую оптимизацию параметров рассматриваемого ПЗП. В результате анализа были определены наиболее оптимальная схема составного планетарного редуктора, с учетом кинематики воздушного потока на ветроколесе ВЭУ.

**Ключевые слова:** ветроэнергетичская установка, мультипликатор, метод крутящего момента, кинематический анализ, компьютерное моделирование.

## Introduction

The expediency of the study of wind turbines kinematics today is due to the increased interest of society in environmental problems and the desire to make the transition to environmentally friendly and resource-saving energy (the so-called "green" economic transition). Thus, the green approach in power engineering is associated, in particular, with the transition to alternative energy sources, including energy of moving media (Dosaev, 2021). In this regard, there is a large layer of mechanics problems dealing with the description of the motion of bodies and energy transfer. Partially, methods of computer modeling of kinematics of fluid and gas dynamics and solid bodies successfully cope with such problems (Arnaudov, et al., 2005). With their help, rather accurate both qualitative and quantitative results are obtained. However, despite the current level of development of computer technology and computing power, it is not possible to simulate the entire range of possible scenarios of behavior of complex objects in the flow of the medium within a reasonable time. The solution of problems of combined systems that transfer the potential of wind energy and its conversion is nowadays as relevant as possible for the design of energy-efficient wind turbines.

When designing wind energy systems (WES) in regions with low wind speeds, precise solutions are required to increase the rotation speed of the generator shaft. When using a multiplier, several revolutions of the generator shaft are required for one revolution of the turbine wheel. If the multiplier's design is multi-stage, the gear ratio can be increased by orders of magnitude. On the other hand, it is necessary to consider that a multi-stage multiplier can have multiple structural schemes, which allows both achieving high rotation speed and reducing efficiency and power at the generator shaft. Achieving high speed in this case implies a loss of force necessary to initiate rotor rotation, overcome the inertia of the stiff shaft, and overcome magnet sticking. It is not advisable to use multipliers with high gear ratios and an increased number of stages for wind turbines, as the performance of the complex suffers from power loss. Therefore, a properly conducted multi-criteria kinematic analysis of the WES system from the turbine wheel to the generator shaft is an important task (Giger, et al., 2011).

The study of the kinematic characteristics of the mechanical system of the wind turbine was devoted to the authors' works (Arnaudov, et al., 2019). The authors refined the enhancement of wind turbine efficiency through the reduction of planetary gearbox wheel vibrations by altering the phase relationships of dynamic forces induced by tooth meshing. In the investigated planetary gearbox design, through appropriate selection of tooth numbers in the second stage, the theoretical limit of vibration reduction at the tooth meshing frequency exhibits an effect of 20–40 dB. In (Mihailidis, et al., 2010) the modeling of a two-stage PGT using a linkage graph is presented. A generalized kinematic and dynamic model of the two-stage PGT is created. The result serves as an indication that the model can not only predict the natural frequencies and displacement stroke shape, but also the generalized deformation stroke shapes can be simultaneously expressed. Authors (Arnaudov et al., 2019) have devoted a large amount of work to the problem of equalizing the load distribution for all powertrains. Researcher (Karaivanov, 2000) notes that increasing the accuracy of PGT manufacturing is limited by increasing costs; therefore, one of the ways to improve the compound PGT is the appropriate choice of the structural scheme and its parameters. the torque method was proposed for the study of compound PGTs (Arnaudov, et al., 2017), which allows not only kinematic analysis, but also the determination of the magnitude of torques on all its shafts (elements), the determination of the direction of power flows and the presence of power division or power circulation; as well as the simplicity of the torque method for the study of complex multi-carrier PGTs (Arnaudov et al., 2005) and for the creation of calculation algorithms for optimization (Karaivanov, et al., 2022).

Regardless of the arrangement, PGTs in wind turbines operate as multipliers. In the vast majority of cases, PGTs (with one external gear, one internal gear and a single rim planet - Fig. 1a) are used. Mainly as a stage of multi-carrier compound PGTs (Giger, 2007). As wind turbine power increases, the importance of gear quality also increases. Despite attempts to utilize new schemes (Giger, et al., 2021), three-carrier PGTs remain the most suitable for wind turbines.

The purpose of this paper is to present a methodology for a comprehensive kinematic and power (efficiency) analysis of three-carrier PGTs for a wind turbine using computer simulation of airflow kinematics and torque method.

## 1 Object of research

The object of research is a designed wind turbine with horizontal axis for power supply of machine workshop. Consumed power of the workshop 50 kW, wind speed 20 m/s

The kinematic scheme of the wind turbine is shown in figure 1

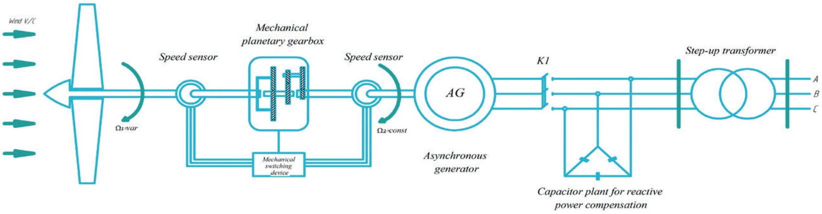


Fig 1. Kinematic diagram of wind turbine with horizontal axis, planetary gearbox

According to the selected scheme, the planetary gearbox has three stages, each stage contains three planets. In the wind turbine system, the MPR increases the angular velocity (speed) and revolutions of the generator of the wind turbine. In addition, the MPR, based on the principle of automatic gearboxes in automobiles, is simultaneously used to stabilize the output shaft speed by changing the speed ratio.

## 2 Methodology

### 2.1 Computer modeling of flow kinematics in a wind wheel

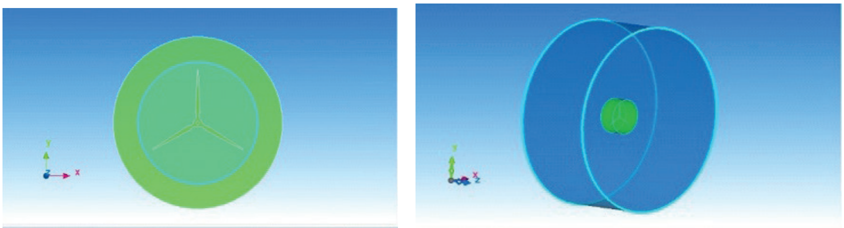
The modeling was performed using the state-of-the-art top-level CAD software Cradle CFD. The program allows to obtain detailed pictures of the kinematics of the air flow around the working surface.

In the Cradle CFD program we investigate the operation of the rotor of the wind turbine and the calculation of the streamline and the main aerodynamic forces and moments that arise on the industrial wind turbine when blowing it with wind flow.

The first step is to import the geometric model from the CAD system. It is possible to calculate both the model as a whole and a separate part of it.

The problem of stationary flow of uniform wind flow around a rotating rotor in the presence of a stationary domain was taken. This problem was taken as the main calculation scheme. The computational domain was built from 2 domains as cylinders: the outer cylinder r = 6 m and L = 100 m, and was described as a stationary translational motion of the medium, the cylindrical working area - domain, includes blades of the wind turbine, radius of 10 m and the length of 2.5 m (Isametova, 2021).

Mesh generation was carried out in semi-automatic mode in CFX-Mesh grid generator. The mesh was generated by three-dimensional hybrid tetrahedral elements with prismatic layers in the regions of the boundary layer on solid surfaces. Figures 2,3 show the steps of model building.



A) б)

Fig 2. Computer model of wind wheel a) Calculation domain b) Rotating domain

Mesh generation was carried out in semi-automatic mode in the CFX-Mesh grid generator. The mesh was generated by three-dimensional hybrid tetrahedral elements with prismatic layers in the boundary layer regions on solid surfaces. Figure 3 shows the generated cone-volume mesh of the wind wheel

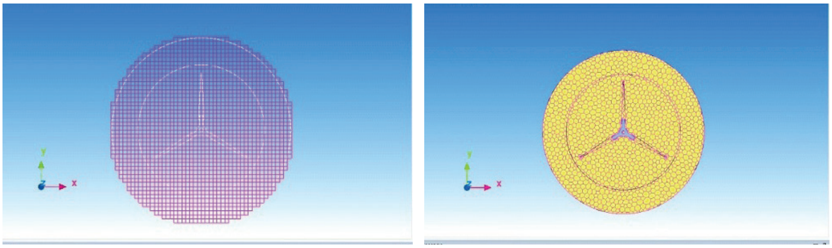


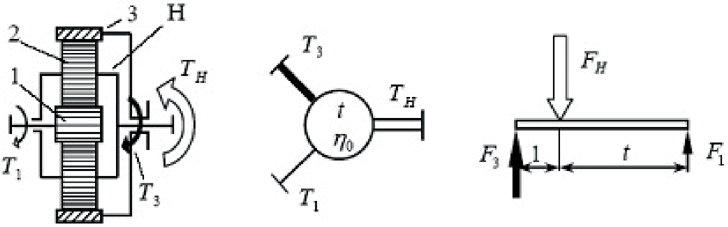
Fig 3. Fragment of triangular mesh on the surface of the nacelle and blades

Design meshes with 500 thousand, 600 thousand and 1 million cells were constructed. Analysis of the integral values obtained from the numerical results for meshes with different densities showed that the results differ by no more than 1% when the number of cells exceeds 700 thousand. This result indicates the mesh independence. Further numerical study was carried out for meshes having ≈ 700 thousand cells. The value of the variable y+, which characterizes the densification of the mesh near the walls, was in the range of $20 < y+ < 60$ units, (Isaeva et al., 2016).

### 2.2 Torque method

As is mentioned above, created by Arnaudov for two-carrier PGTs investigation (Karaivanov, 2000), based on a lever analogy torque method (Arnaudov et al., 2017) is very appropriate for complex multi-carrier PGTs analysis (Arnaudov et al., 2005) and optimization (Karaivanov et al., 2022). The essence of this method is as follows:

Every simple PGT (including $\overline{AI}$-PGT from Fig. 1a) has three external shafts (in Fig. 4a – shaft of sun gear 1, ring gear 3, and carrier H) which torques are in constant ratio in dependance on the ratio of teeth number of central gears ($z_3/z_1$). This ratio is the same as a ratio of a lever forces (Fig. 1c). Two of torques are unidirectional ($T_1$ and $T_3$) and the third is in opposite direction ($T_H$) and equal to the sum of both unidirectional ones. This is a reason to call them summation torque ($T_H \equiv T_\Sigma$) and another torques – difference torques, smaller difference torque $T_1 \equiv T_{Dmin}$ and bigger difference torque $T_3 \equiv T_{Dmax}$. The ratio $t = T_{Dmax}/T_{Dmin}$ is so called *torque ratio* of the PGT (Arnaudov et al., 2017). For $\overline{AI}$-PGT in Fig. 4 this ratio is shown. For investigation of complex multi-carrier PGTs depicting of a simple PGT with the symbol of Wolf-Arnaudov is very conveniently. A PGT is presented as circle with three external shafts (Wolf, 1958) depicted with different lines according to the values of their torques – the sun gear shaft (with the smallest torque) with a thin line, the ring gear shaft with a thick line, and the carrier shaft (with the biggest torque) with double line (Fig.4b) (Arnaudov et al., 2005).



Precondition: $\eta_0 = \eta_{13(H)} \approx \eta_{31(H)} = 1$

$$t = \frac{T_3}{T_1} = \frac{F_3}{F_1} > +1$$

Torques:

$T_1 < T_3 < |T_H|$

$T_1 : T_3 : T_H = +1 : +t : -(1+t)$

$\sum T_i = T_1 + T_3 + T_H = 0$

Forces:

$F_1 < F_3 < |F_H|$

$F_1 : F_3 : F_H = +1 : +t : -(1+t)$

$\sum F_i = F_1 + F_3 + F_H = 0$

Fig. 4. Simple $\overline{\mathrm{AI}}$-PGT with its external torques (a), symbol of Wolf-Arnaudov (b) and a lever analogy (c).
1 – sun gear, 2 – planets, 3 – ring gear, H – carrier.

Because its three shafts a simple PGT has six modes of work with F = 1 degree of freedom – three as a reducer and three as a multiplier. In all this cases its speed ratio is considered by *basic speed ratio* $i_0$ (in work with fixed carrier).

The basic speed ratio of $\overline{\mathrm{AI}}$-PGT is

$$i_0 = -\frac{T_3}{T_1} = -t = -\frac{z_3}{z_1}. \tag{1}$$

For other working modes with F = 1 degree of freedom the speed ratio can be determined as follows [5]:

$$i_{AB} = \frac{\omega_A}{\omega_B} = -\frac{T_B}{T_A}, \tag{2}$$

where $\omega_A$ and $T_A$ are the angular velocity and the torque on the input shaft and $\omega_B$ and $T_B$ – on the output shaft.

## 3 Result

### 3.1 Simulation results of flow kinematics in the wind wheel

Figures 5,6 show a series of diagrams of the results of computer calculations that reveal the main patterns of wind turbine streamline and point characteristic features of the flow.

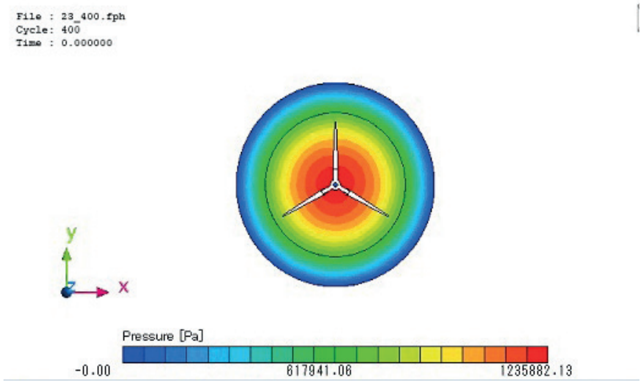


Fig 5. Air pressure

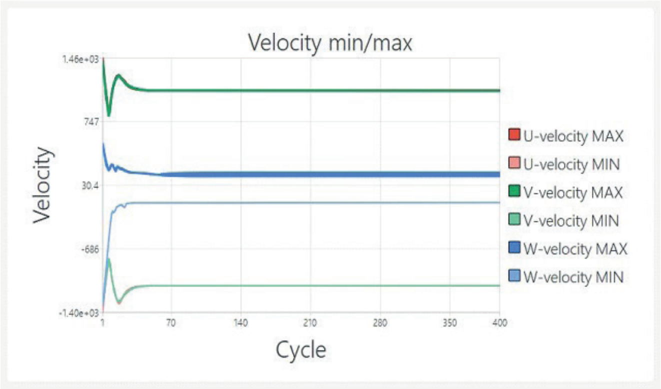


Fig 6. Wind speed components

The diagrams of the results indicate that the value of the flow velocity take maximum values of 146 m/s, which indicates a high productivity of the wind wheel of the designed wind turbine.

### 3.2 Three-carrier PGT for wind turbine

The simple $\overline{AI}$-PGT has maximal speed ratio in work with fixed ring gear $i_{1H(3)} = i_0 + 1$. The speed ratio of $\overline{AI}$ with three planets (the most common case because good load sharing between planets) is maximum 13 and to obtain a bigger speed ratio to use a compound PGT is needed. With connecting of a few simple PGD a compound (multi-carrier) PGT obtains (two-, three-, four-carrier, etc.). The two-carrier PGTs cover the biggest part of needed speed ratios in industrial machinery (Karaivanov, 2000). In the cases of classic wind turbine whit high-speed generator, practically, a three-carrier PGT is enough (Giger, 2011).

In this paper a tested in practice three-carrier PGT is investigated (Arnaudov et al., 2019) (Fig. 7). Four coupled shafts between planetary stages exist – two external (input shaft between the carrier of the first stage HI and the ring gear of the second stage 6, and fixed shaft between the carrier of the second stage HII and the ring gear of the third stage 9) and two internal (between the ring gear of the first stage 3 and the sun gear of the second stage 4, and between the sun gear of the first stage 1 and the carrier of the third stage HIII). The only single external shaft (of the sun gear of the third stage 7) is the output shaft of the train.

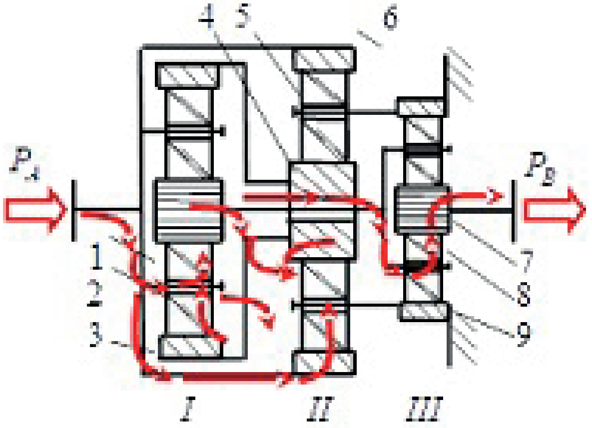


Fig 7. Three-carrier planetary multiplier for wind turbine [9].

In Fig. 8 the structural scheme of PGT in question depicted by Wolf-Arnaudov's symbol is shown – more clary, simpler, and easy-understandable way for visualization.

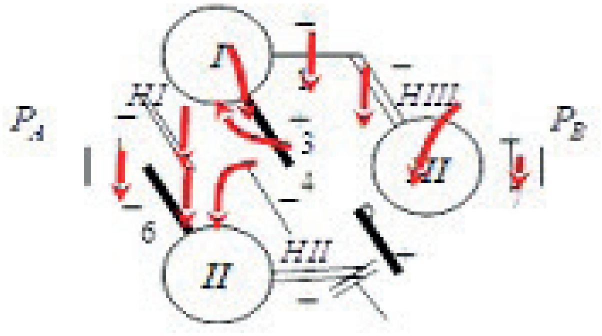


Fig 8. Structural scheme of PGT from fig. 2 through the Wolf-Arnaudov's symbol depicted.

In both figures by red arrows internal power flows are presented. In a closed loop between the first and the second stage the power division (not circulation) exist. This is determined by method of signs (the torques directions) (Arnaudov et al., 2005). The direction of the torque on a sun gear considered positive. In Fig. 8 this is the torque on the sun gear 1. After this, considering that the directions of toques on sun gear and ring gear is the same but the direction of the carrier torque is opposite, as well as that the torques on both ends of a coupled shaft are in opposite direction, step by step, the signs (torque directions) of all the shafts are determined. If the torques on the component shafts of the compound shaft are unidirectional – power division exists. In Fig. 3 this are shafts HI and 6 coupled in the input shaft.

**3.3 Kinematic analysis**

For purpose of kinematic analysis ideal torques on all the shafts are calculated. In Fig. 9 this calculation begins from the sun gear of third stage 7 (this is the output torque) accepting its value as $T_A = +1$. Others torques in this simple PGT depend on its torque ratio $t_{III}$ (see Fig. 1). With numbers in circles the sequence of ideal torques determination is shown.

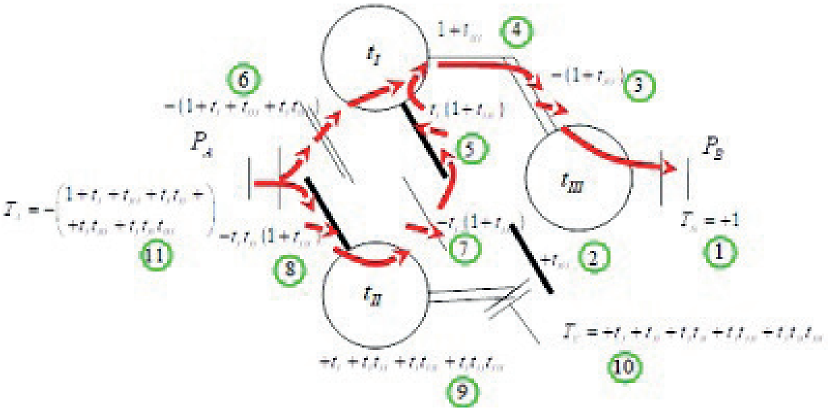


Fig 9. Ideal torques determination considering torque ratios ($t_I$, $t_{II}$, and $t_{III}$) of the component PGTs.

Determination of ideal torques on the shafts of PGT in Fig. 4 shous values of torques on three external shafts:

On the input shaft:

$$T_A = -\left(1 + t_I + t_{III} + t_I t_{II} + t_I t_{III} + t_I t_{II} t_{III}\right) \tag{3}$$

On the output shaft:

$$T_B = +1; \tag{4}$$

On the fixed shaft:

$$T_C = +t_I + t_{III} + t_I t_{II} + t_I t_{III} + t_I t_{II} t_{III}. \tag{5}$$

By the ideal external torques equilibrium the calculations correctness may be checked:

$$\sum T_i = T_A + T_B + T_C = 0 \tag{6}$$

By formula (2) the speed ratio of the PGT can be determine as follows:

$$i_k = -\frac{T_B}{T_A} = -- \tag{7}$$

This formula is very proper for determination of a plurality of combinations of $t_I$, $t_{II}$, and $t_{III}$ in which a desirable speed ratio $i_k$ is possible to obtain. By varying these parameters ($t_I$, $t_{II}$, and $t_{III}$) from 2 to 12, for example (Karaivanov et al., 2022). For every one of these values a relative overall dimension can be obtained too (Karaivanov, 2000). For purpose of optimization analysis, a software for overall dimension (reference diameter of pitch circle of the ring gear) under ISO 6336 load capacity calculations is developed for two-carrier PGTs (Troha, 2011). Its developing for three-carrier PGTs is in process.

All the above allows to determine values of $t_I$, $t_{II}$, and $t_{III}$ in which the PGT with desirable speed ratio $i_k$ and minimal overall dimensions can be obtained.

### 3.4 Power analysis

Direction of internal power flows depends on direction of torques on the shafts which are coupled in compound shafts of the PGT (Arnaudov et al., 2019). In the PGT in question in the closed loop between the first and the second stage there is a division of power because the direction (mathematical signs) of the torques on carrier HI (of the first stage) and ring gear 6 (of the second stage) are the same (unidirectional) (Fig. 3).

Real torques on all shafts in compound PGT may be determined in the same sequence as ideal ones (Fig. 4). Their values depend on basic efficiencies $\eta_{0I}$, $\eta_{0II}$, and $\eta_{0III}$ as well as on direction of relative (rolling) powers $P_{rel\,I}$, $P_{rel\,II}$, and $P_{rel\,III}$ of the stages (component PGTs).

Basic efficiency is the train efficiency in work with fixed carrier (as pseudo-planetary gear train). It depends on losses during relative movement of PGT elements with respect to the carrier (Arnaudov et al., 2019).

In a simple PGT relative (rolling) power has only two possible directions – from the sun gear to the ring gear or vice versa. In both cases if the real torque on the input shaft (of relative power) $T'_{inp}$ is known the real torque on the output shaft $T'_{outp}$ is equal to ideal output torque decreased by losses

$$T'_{outp} = \eta_0 \cdot T_{outp} \tag{8}$$

If the output (of relative power) torque $T'_{outp}$ is known the real input torque $T'_{inp}$ is equal to ideal input toque increased by losses

$$T'_{inp} = \frac{1}{\eta_0} T_{inp} \tag{9}$$

Considering dependances (8) and (9), in Fig. 5 real torques in PGT in question are determined. By doted arrows directions of relative (rolling) power in stages (simple PGTs) are shown. Relative (rolling) power directions in the second and the third stages are obviously from the ring gear to the sun gear because they both work with F = 1 degree of freedom and the sun gears are output shafts. The first stage works with F = 2 degree of freedom as a summing differential (see internal power flows directions in Fig. 10). As the sun gear is an output shaft – the relative (rolling) power direction is from ring gear to the sun gear too.

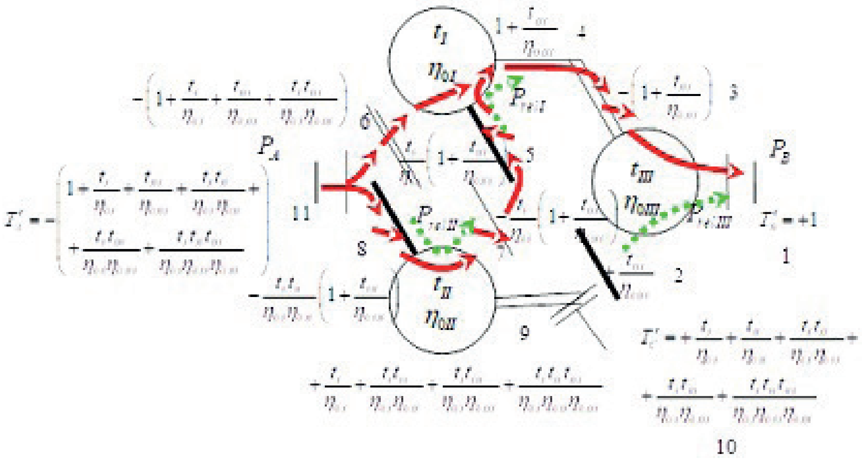


Fig 10. Real torques determination considering torque ratios ($t_I$, $t_{II}$, and $t_{III}$), basic efficiencies ($\eta_{0I}$, $\eta_{0II}$, and $\eta_{0III}$), and relative (rolling) power directions in component PGTs.

By the real external torques equilibrium the calculations correctness may be checked too – see formula (6).

### 3.5 Efficiency determination

The torque method allows efficiency $\eta$ determination by real external torques ($T'_A$ - an input torque and $T'_B$ - an output torque, determined considering the losses) (Arnaudov et al., 2005) through *torque transformation* $i_T$

$$i_T=\frac{T'_B}{T'_A}, \tag{10}$$

as follows:

$$\eta=-\frac{i_T}{i_k}=-\frac{\dfrac{T'_B}{T'_A}}{-\dfrac{T_B}{T_A}}. \tag{11}$$

Taking into account that

$$T_B = T'_B = +1 \tag{12}$$

the efficiency may be determined as follows:

$$\eta = \frac{T_A}{T'_A} = \frac{1 + t_I + t_{III} + t_I t_{II} + t_I t_{III} + t_I t_{II} t_{III}}{1 + \dfrac{t_I}{\eta_{0I}} + \dfrac{t_{III}}{\eta_{0III}} + \dfrac{t_I t_{II}}{\eta_{0I}\eta_{0II}} + \dfrac{t_I t_{III}}{\eta_{0I}\eta_{0III}} + \dfrac{t_I t_{II} t_{III}}{\eta_{0I}\eta_{0II}\eta_{0III}}}\,. \tag{13}$$

Preciseness of this calculation depends on preciseness of basic efficiencies $\eta_{0I}$, $\eta_{0II}$, and $\eta_{0III}$ determination, i.e., losses in the component PGTs determination. Different ways for simple or more precisely determination of losses in a simple PGT exist. For simple, preliminary calculation to choose $\eta_{0I} = \eta_{0II} = \eta_{0III} = 0,97$ may be enough (Karaivanov, 2000). In multi-stage PGTs consideration of speed of sun gears of stages is advisable (Karaivanov, 2005). Influence of torque ratio no the mesh losses considering (Tkachenko, 2003) is the optimal way to obtain good results without unnecessary complication. If it is necessary, more precisely methodologies for losses calculations may be used (Arnaudov et al., 2019).

Formula (13) is very proper for determination the efficiency for the plurality of combinations of $t_I$, $t_{II}$, and $t_{III}$ in which a desirable speed ratio $i_k$ is possible to obtain (see paragraph 4). This allows to search the combination with higher efficiency.

Using the input data from CFD modeling, it is the angular velocity (speed) of the wind wheel and the input shaft of the planetary gearbox, the kinematic and power parameters of the designed wind turbine were calculated using the above analytical algorithms (Arnaudov's Torque Method).

## 4. Conclusions

1. A comprehensive kinematic model of a planetary gearbox has been developed, enabling the investigation of design parameters such as torque, power, and efficiency.

2. The combination of analytical methods and finite element analysis (FEA) allows for precise evaluations of kinematic parameters with low time investment, achieved through modeling the kinematics process flow, providing input data for analytical optimization calculations of the most advantageous wind turbine planetary gearbox (WT-PGT) configurations.

3. The torque method facilitates easy and visual determination of speed ratios and efficiencies in complex three-support PGTs. Calculations demonstrate a straightforward approach to determining the directions of internal power flows.

4. Formulas derived using the torque method for speed ratios and efficiencies of the considered PGT are highly suitable for its multi-objective optimization, aiming to obtain more suitable values of torque coefficient components (α, β, and γ) for compound simple PGTs.

**References**

Arnaudow, K., Karaivanov, D. Systematik, Eigenschaften und Möglichkeiten von zusammengesetzten Mehrsteg-Planetengetrieben. // Antriebstechnik (2005) 5, S. 58 – 65.

Arnaudov, K., D. Karaivanov. Higher compound planetary gear trains. VDI-Berichte 1904-1, 2005, pp. 327-344. ISSN 0083-5560.

Arnaudov, K., D. Karaivanov. The complex compound multi-carrier planetary gear trains – a simple study. VDI–Berichte 2108-2, 2010, pp. 673-684. ISSN 0083-5560.

Arnaudov, K., Karaivanov, D. Torque method for analysis of compound planetary gear trains. Beau Bassin [Mauritius]: LAP Lambert Academic Publishing, 2017, 92 p., ISBN 978-620-2-01693-3.

Arnaudov K. and D. Karaivanov. Planetary gear trains. Boca Raton [NJ, USA]: CRC Press, 2019, 358 p. ISBN 978-1-138-31158-5.

Bezrukikh P. P. Wind Energy. Fictions and facts. Answers to 100 questions. M. Institute for Sustainable Development, 2014. P. 74.

Dosaev M., Ishkhanyan M., Klimina L., Masterova A., Selyutskiy Yu. A Wheeled Vehicle Driven by a Savonius-Magnus Wind Turbine // ROMANSY 23 - Robot Design, Dynamics and Control. ROMANSY 2020. CISM International Centre for Mechanical Sciences (Courses and Lectures) (Proceedings of the International Conference ROMANSY 2020). Springer. Cham. 2021. volume 601. p. 380-386

V. Miltenovic, M. Velimirovic, M. Banic. Increase of energy efficency of windturbines by application of CVT. International Conference on Gears. Technicaluniversity of Munich. VDI-Berichte 2108.2. Garching. Germany. 2-4.10.2010. P. 1095 – 1106).

GIGER, U. Neuer Ansatz für sehr große Windkraftgetriebe. Wind Kraft Journal. 2007, Nr. 5, S. 2-4.

GIGER, U. and K. ARNAUDOV. Redesign of a gearbox for 5MW wind turbines. Proceedings of the ASME International Design Engineering Technical Conferences & Computers and Information in Engineering Conference IDETC/CIE 2011 August 28-31, 2011, Washington, DC [USA], DETC2011-47492.

GIGER, U. and K. ARNAUDOV. New drive train design for ultra large 15 MW wind turbines. VDI-Berichte 2199-1, 2013, pp. 101-112. ISSN 0083-5560.

Giger, U., Kleinhansl, S., Schulte, H. Design study of multi-rotor and multi-generator wind turbine with lattice tower—A, Mechatronic Approach. Appl. Sci. 2021, 11, 11043.

Harry, A. *Project X-Gear*. Eurotrans, 6 June 2008, Brussels.

Ivanov K.S., Knol O.A., Shingissov B.T. Mechanical Adaptive Drive of Wind Turbine Generator. Proceedings of International Conference on Innovative Technologies. IN-TECH 2013. World Association of Innovative Technologies. Budapest. Hungary. 2013. PP 245-248.

Isaeva I Vitaly Povetkin, Madina Isametova, Manshuk Kerimzhanova, Amina Bukayeva, Zaure Ibragimova, Assessment of dynamic parameters of heavy-duty gears JVE INTERNATIONAL LTD. VIBROENGINEERING PROCEDIA. DEC 2016, VOL. 10. ISSN 2345-0533

Isametova M., Abilezova G., Dishovsky N., Velev P. Development And Verification Of Mechanical Characteristics Of A Composite Material Made Of A Thermoplastic Matrix And Short Glass Fibers Eastern-European Journal of Enterprise Technologies № 5(12-113), 2021, pp. 30–38

Karaivanov, D. *Theoretical and experimental studies of influence of the structure of coupled two-carrier planetary gear trains on its basic parameters*. Dissertation. Sofia: University of Chemical Technology and Metallurgy, 2000. (in Bulgarian)

Karaivanov, D. Structural analysis of the coupled planetary gears with considering the efficiency of the coupling gears. Proceedings of the 2th Int. Conf. on Manufacturing Engineering (ICMEN), Kallithea of Chalkidiki, Greece, October 5 – 7, 2005, pp. 381-387. ISBN 960-243-615-8.

Karaivanov, D. Structural analysis of coupled multi-carrier planetary gear trains – from lever analogy to multi-objective optimization. Proceedings of the 3rd Int. Conf. on Manufacturing Engineering (ICMEN), 1 – 3 October 2008, Chalkidiki, Greece, pp. 579-588.

Karaivanov, D., S. Troha. Optimal selection of the structural scheme of compound two-carrier planetary gear trains and their parameters, pp. 339-403 in: Radzevich, S.P., (Editor), Recent Advances in Gearing: Scientific Theory and Applications, Springer, 1st ed., 2022 edition (June 25, 2021), 569 pages. ISBN-10: 3030646378, ISBN-13: 978-3030646370. https://www.springer.com/gp/book/9783030646370

Kudryavtsev, V. *Planetary gear trains*. Moscow, Leningrad: Mashinostroenie, 1966. (in Russian)

Kurth, F. Efficiency determination and synthesis of complex-compound planetary gear transmissions. Dissertation. Munich: Technical University, 2012.

Leistner, F., G. Lörsch, O. Wilhelm. Umlaufrädergetriebe. 3. Auflage. Berlin: VEB Verlag Technik, 1987.

Looman, J. Zahnradgetriebe – Grundlagen, Konstruktion, Anwendung in Fahrzeugen. 3. Auflage, Berlin: Springer-Verlag, 1996.

Mihailidis, A. and C. Pupaza. Simulation Driven Design of Internal Gears. Multicriteria optimization of internal gears. VDI-Berichte, Nr. 2108, 2010, pp. 725-740.

Müller, H.W. *Epicyclic drive trains*. Detroit: Wayne State University Press, 1982. ISBN 0-8143-1663-8.

Pedrero, J. I., M. Pleguezuelos, M. Muños. Simplified calculation method for the efficiency of involute spur gears. Proceedings of the ASME Int. Power Transmissions and Gearing Conf. (PTG), San Diego [USA], 30 Aug. – 2 Sep., 2009. ISBN (CD-ROM) 978-0-7918-3856-3.

Pleguezuelos, M., J.I. Pedrero, M.B. Sanches. Analytical model of the efficiency of spur gears: Study of the influence of the design parameters. Proceedings of the ASME International Design Engineering Technical Conferences & Computers and Information in Engineering Conference IDETC/CIE 2011 August 28-31, 2011, Washington, DC [USA], DETC2011-47662.

Radzevich, S. An improved load-equalizing means for a multi-flow gear train. Gearsolutions, Dec. 2015, www.gearsolution.com

Serowy, S. Andrei, C.; Barenhorst, F.; Schelenz, R.; Jacobs, G.; Appunn, R.; Hameyer, K.; "6 MW Wind Turbine with Multiple High-speed Generators", CWD 2015, Aachen, Germany, 3 March 2015-4 March 2015, Conference Proceedings.

Stefanović-Marinović, J., S. Troha, and M. Milovančević. An application of multicriteria optimization to the two-carrier two-speed planetary gear trains. Facta Universitatis, Series: Mechanical Engineering. 2017, 15 (1), pp. 85-95. ISSN 0354-2025 (Print) , ISSN 2335-0164 (Online).

Stefanović-Marinović, J., S. Troha, B. Anđelković, and M. Milovančević. Efficiency of planetary gear trains as criterion for optimal solution selection. Machine Design. 2018, 3, pp. 95-98. ISSN 1821-1259.

Tkachenko, V. *Planetary mechanisms*. Kharkiv: Kharkiv Aviation Institute Publ., 2003. (in Russian)

Troha, S. Analysis of a planetary change gear train's variants. Dissertation: Engineering Faculty, University of Rijeka [Croatia], 2011. (in Croatian)

Wolf, A. *Die Grundgesetze der Umlaufgetriebe*. Braunschweig: Friedr. Vieweg und Sohn, 1958.

## CONTENT

**A.O.Baisalova, A.V. Dolgopolova, R. Seltmann, E.E. Akbarov, M.A. Mashrapova**
ROGRAPHIC AND MINERALOGICAL FEATURES OF THE KARAGAILY-AKTAS RARE METAL DEPOSIT (SOUTH KAZAKHSTAN REGION)....6

**V.V. Gerasidi, R.G. Dubrovin, O.I. Kukartseva, I.A. Panfilov, V.V. Tynchenko**
ANALYSIS OF TECHNICAL OPERATION OF CATERPILLAR ENGINEERING CORPORATION ENGINES IN INDUSTRY....23

**K. Yelemessov, D. Baskanbayeva , L. Sabirova**
OPTIMIZATION OF TECHNICAL MEANS AND TECHNOLOGICAL PROCESSES OF GAS COMPRESSION FOR THE MINING INDUSTRY OF THE REPUBLIC OF KAZAKHSTAN....36

**D. Karaivanov, M.F. Kerimzhanova, M.E. Isametova, N.S. Seiitkazy, G. Turymbetova**
INVESTIGATION OF KINEMATICS AND POWER OF COMPOSITE PLANETARY GEARS FOR WIND TURBINES....47

**A.Zh. Kassenov, A.Zh. Taskarina, K.K. Abishev, A.D. Suleimenov, D.D. Alipbayev**
COMBINED TOOL FOR CUTTING INTERNAL THREADS OF TUBING....63

**Z.A. Kutpanova, D.O. Kozhakhmetova, G. Baiseitov, A.Dolya, G.A. Uskenbayeva**
ROUTE CONTROL AND COLLISION AVOIDANCE FOR MULTIPLE UAVS IN A SMART CITY CONTEXT USING GEOGRAPHIC INFORMATION SYSTEM....71

**I.Yu. Matasova, Yu.S. Kuznetsova, T.A. Panfilova, V.S. Tynchenko, S.V. Tynchenko.**
FEATURES OF THE BEHAVIOR OF ROCKS IN THE UNDERGROUND FIELD DEVELOPMENT....94

**M. Nurpeisova, B. Mingzhasarov, K. Temirkhanov, Y. Kakimzhanov, Zh. Nukarbekova**
GEODETIC MONITORING OF DEFORMATION PROCESSES AT KAPCHAGAY HYDROPOWER PLANT....107

**L. Nurshakhanova, S. Zakenov, A. Zakenova**
TECHNOLOGIES OF WATER-GAS IMPACT ON THE RESERVOIR USING SIMULTANEOUSLY PRODUCED PETROLEUM GAS................................118

**T.K. Salikhov, A.I. Abekeshev, G.O. Abisheva, Zh.B. Issayeva, . M.B. Khussainov**
STUDY OF THE ECOSYSTEM AND UNIQUE NATURAL OBJECTS OF THE CHINGIRLAU DISTRICT OF THE WEST KAZAKHSTAN REGION USING GIS TECHNOLOGIES...........................................................................128

**V.V. Sirota, S.V. Zaitsev, M.V. Limarenko, D.S. Prokhorenkov, A.S. Churikov**
THERMOMECHANICAL PROCESSING OF MINERAL RAW MATERIALS TO PRODUCE $La_{1-x}Sr_xMn_zO_3$ POWDER WITH PEROVSKITE STRUCTURE.........................................................................................155

**A.V. Taranov, A.D. Mekhtiyev, F.N. Bulatbayev, Y.G. Neshina, V.S. Balandin**
PNEUMATIC LOAD HOISTS FOR MINERAL TRANSPORTATION FROM MINES...............................................................................167

**Y.A. Tynchenko, B.V. Malozyomov, V.V. Kukartsev, M.A. Modina, G.L. Kozenkova**
APPLYING ELEMENTS OF A TOTAL EQUIPMENT CARE STRATEGY TO ANALYZE THE OPERATION OF MINING MACHINERY............................178

**O.G. Khayitov, J.B. Toshov, K.T. Sherov, B.N. Absadykov, M.R. Sikhimbayev**
OIL AND GAS POSSIBILITY OF THE CENTRAL GRABEN OF THE BUKHARA-KHIVA PALEORIFTS AND ITS PERSPECTIVES......................191

**Z.I. Chernenko, M.A.Mizernaya, I. E. Mataibayeva, N.A. Zimanovskaya**
GOLD ORE DEPOSITS ASSOCIATED WITH CARBONATE FORMATIONS (EAST KAZAKHSTAN)........................................................................201

## 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 described work 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 Cross Check originality detection service 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 only 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 сайтах:
**www:nauka-nanrk.kz**
**http://www.geolog-technical.kz/index.php/en/**
**ISSN 2518-170X (Online),**
**ISSN 2224-5278 (Print)**

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

Подписано в печать 15.10.2024.
Формат 70x90$^1/_{16}$. Бумага офсетная. Печать – ризограф.
18,0 п.л. Тираж 300. Заказ 5.

---

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