

**VERTIKAL O'QLI SHAMOL TURBINALARINI MATEMATIK MODELLASHTIRISH****Sadullayev N.N., Muzaffarov F.F.***Buxoro muhandislik –texnologiya instituti, Buxoro, O'zbekiston*

Annotatsiya: Ushbu maqolada O'zbekiston Respublikasida elektr energiya ehtiyojining oshishi va bu ehtiyojni qoplaydigan shamol energetik qurilmalar hamda ularning samaradorligiga ta'sir etuvchi ba'zi bir parametrlar haqida so'z boradi. Bundan tashqari turbina parraklarini tayyorlashda ishlatiladigan NACA 4412 aerodinamik sirti va taklif etilayotgan aerodinamik sirt tahlil qilingan. Vertikal o'qli shamol energetik qurilmalarining samaradorligiga ta'sir ko'rsatuvchi parametrlar o'rganilgan. Tadqiq qilinayotgan qurilmaning matematik modeli taklif etilgan.

Kalit so'zlar: shamol tezligi, aerodinamik sirt, oqim, vertikal o'qli shamol turbinasi, shamol turbinasi parragi, aerodinamika, optimal, ta'sir etuvchi kuchlar.

МАТЕМАТИЧЕСКОЕ МОДЕЛИРОВАНИЕ ВЕРТИКАЛЬНЫХ ВЕТРО УСТАНОВОК**Садуллаев Н.Н., Музаффаров Ф.Ф.***Бухарский инженерно-технологический институт, Бухара, Узбекистан*

Аннотация: В данной статье излагается рост потребности в электроэнергии в Республике Узбекистан и ветроэнергетических устройствах, покрывающих эту потребность, а также о некоторых параметрах, влияющих на их эффективность. Кроме того, были проанализирована аэродинамическая поверхность NACA 4412, используемая при изготовлении лопаток турбины, и предлагаемая аэродинамическая поверхность. Исследованы параметры, влияющие на эффективность ветроэнергетических установок с вертикальной осью. Предложена математическая модель исследуемого устройства.

Ключевые слова: скорость ветра, аэродинамическая поверхность, поток, вертикальный ветродвигатель, лопасть ветродвигателя, аэродинамика, оптимум, действующие силы.

MATHEMATICAL MODELING OF VERTICAL AXIS WIND TURBINES**Sadullaev N.N., Muzaffarov F.F.***Bukhara Engineering and Technology Institute, Bukhara, Uzbekistan*

Abstract: This article talks about the increase in the need for electricity in the Republic of Uzbekistan and the wind energy devices that cover this need, as well as some parameters that affect their efficiency. In addition, the NACA 4412 aerodynamic surface used in the manufacture of turbine blades and the proposed aerodynamic surface were analyzed. The parameters affecting the efficiency of vertical axis wind energy devices are studied. A mathematical model of the device under study is proposed.

Keywords: wind speed, aerodynamic surface, flow, vertical axis wind turbine, wind turbine blade, aerodynamics, optimum, acting forces.

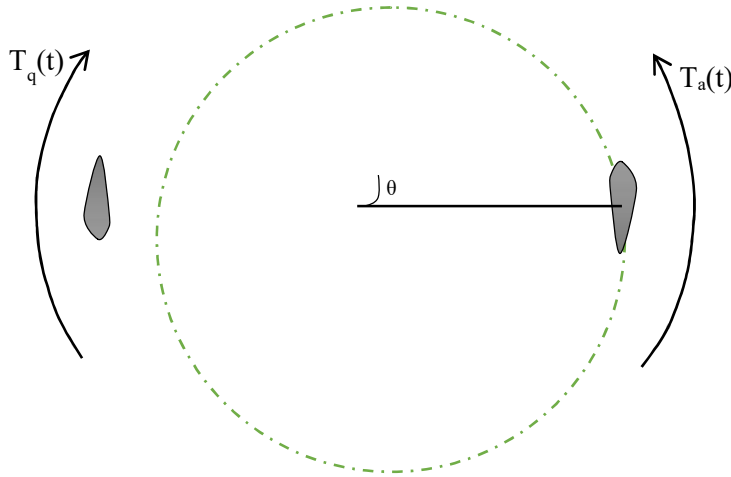
Hududda shamol yo'nalishining tez-tez o'zgarishi, iste'molchilarning cho'l hududlarida joylashganligi sababli (yozda haroratning +60°C, qishda -20°C bo'lishi) turbina parraklari shaklining o'zgarishi, bu hududlarda changlanganlik miqdorining (normal 0,05 mg/m³) me'yoridan ko'pligi tufayli podshipnik qismlardagi mexanik isroflarning oshishi natijasida bunday iste'molchilarni ShEQ orqali ta'minlashda muammolar kelib chiqmoqda. Bunday muammolar





standart ShEQ larni samarali qo'llash imkoniyatini bermaydi. Bundan tashqari kichik tezlikli shamol oqimlarida turbinalarning qo'zg'ala olmaslik holatlari kuzatilmoqda. Shuning uchun turbinalarning vaznini yengillashtirish dolzarb masala hisoblanadi. Bu omillar tufayli kichik quvvatli ShEQlarni joriy etishni yetarli deb bo'lmaydi. Shu sababli iqlimiy sharoitlarga moslashtirilgan texnik parametrlari yaxshilangan vertikal o'qli shamol turbinalarni tadqiq etish va yaratish dolzarb ahamiyat kasb etmoqda.

Shamol turbinalarini aylanishiga majburlovchi momentlar quyidagi 1-rasmda o'z aksini topgan.



1-rasm. Turbina qismining yuqoridan (frontal) ko'rinishi.

$$T_a(t) - T_q(t) = J\theta(t) \quad (1)$$

$T_a(t)$ - aerodinamik harakatlantiruvchi kuch funksiyasi, $T_q(t)$ - qarshilik qiluvchi kuch funksiyasi, J -turbining umumiy inersiya momenti, θ -turbina parraging burchagi.

Yuqoridagi (1) ifodada keltirilgan tenglikning natijasi katta bo'lishi kerak. Buning uchun aylantiruvchi moment $T_a(t)$ o'zining eng katta qiymatiga, $T_q(t)$ esa o'zining eng kichik qiymatiga erishishi kerak. Bu holatda inersiya momenti o'zining maksimumiga erishadi, natijada turbina proporsional miqdorda kinetik energiya sig'imiga ega bo'ladi. Turbinaga ta'sir qiluvchi kuch va momentlarni quvvatdan boshlab tahlil qiladigan bo'lsak u quyidagicha bo'ladi.

Turbina kechadigan mexanik va fizik jarayonlarni biz bevosita analitik tahlil qilish orqali baholashimiz mumkin. Bizga ma'lumki shamol energetik qurilmasining quvvati quyidagicha: [1, 2]

$$P = \frac{1}{2} \cdot \rho \cdot A \cdot V^3 \cdot C_p \quad (2)$$

Bunda: Shamol turbini tomonidan beriladigan mexanik quvvat (3) tenglik orqali aniqlanadi [2].

$$P = \omega \cdot T \quad (3)$$

Lekin (2) tenglikda keltirilgan quvvat Betz koeffitsiyentiga nisbatan hisoblaniladi. Betzga ko'ra bu koeffitsiyent $C_p \leq \frac{16}{27}$ tenglikni qanoatlantirishi shart. Betz nazariyasi gorizontaal o'qli shamol turbini misolida ishlab chiqilgan, [3,4] ga ko'ra bu koeffitsiyentni vertikal o'qli shamol turbini uchun tadbiq etish hisoblashlarni aniqlikdan uzoqlashtirishi mumkin. Vertikal o'qli turbinalarning juda ko'p turi mavjud, shu sababli bunday turbinalardagi bu koeffitsiyentni tajriba natijalari asosida aniqlash maqsadga muvofiq.[5] Bundan tashqari shamol energetik qurilmasining umumiy quvvatiga turbining foydali ish koeffitsiyenti η ham ta'sir ko'rsatadi.

$$P = \frac{1}{2} \cdot \rho \cdot A \cdot V^3 \cdot C_p \cdot \eta \quad (4)$$

(2) va (4) tengliklarda keltirilgan A turbinaning yuzasi bo'lib u (5) ifoda orqali hisoblaniladi [6,7].

$$A = 2 \cdot R \cdot h \quad (5)$$

Shamol turbinasining ildamlik koeffitsiyenti λ , quvvat koeffitsienti C_p bilan chambarchas bog'liq. (5) tenglamada ko'rsatilganidek, ildamlik koeffitsiyenti parrak chekka nuqtasi tezligining shamol tezligiga nisbati bilan aniqlanadi [8].

$$\lambda = \frac{\omega \cdot R}{V_{sh}} \quad (6)$$

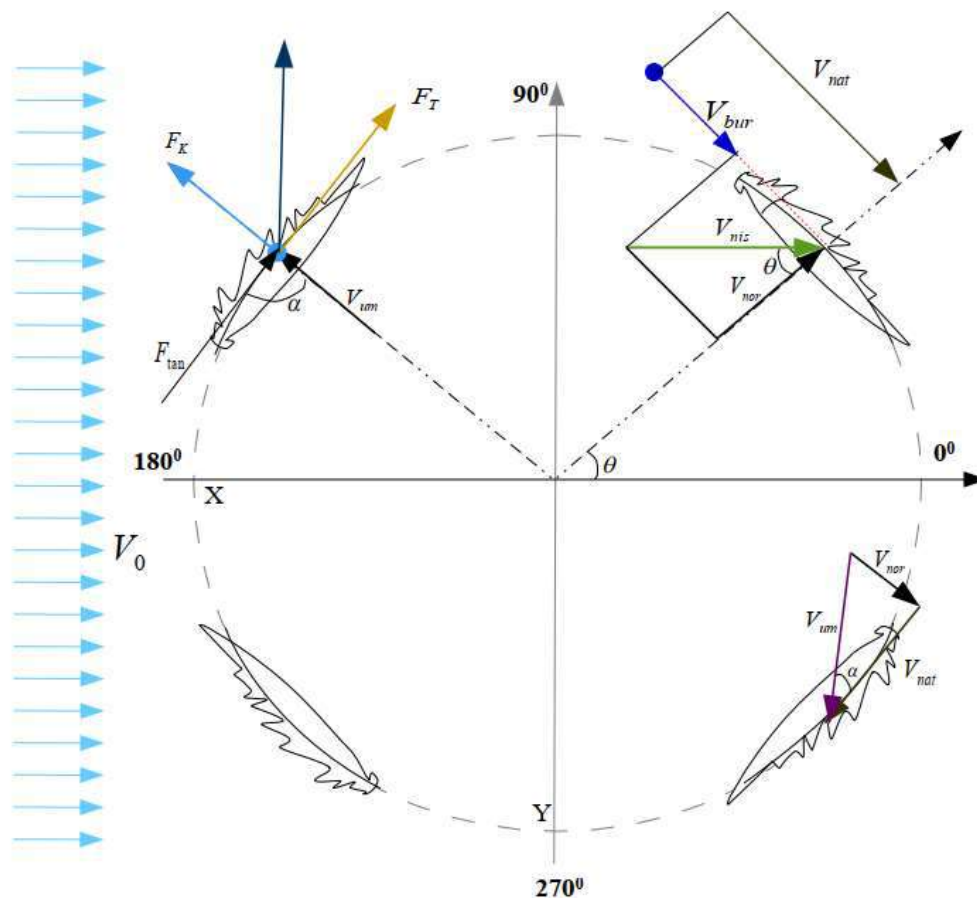
Shamol turbinasi parragining harakatlanish sohasi turbinaning balandligi (h) va radiusi (R) bilan xarakterlanadi. turbina radiusi qanchalik uzun bo'lsa, hosil bo'lgan moment shunchalik yuqori bo'ladi, lekin turbina radiusi uzun bo'lganda, strukturaning barqarorligi past bo'ladi. Turbina balandligi (h) ning qiymati radius (R) ga nisbatan uzun bo'lsa, hosil bo'lgan moment past bo'ladi bu esa turbinaning aylanishlar sonini oshirishni talab qiladi. Tomonlar nisbati (aspect ratio) quyidagicha:

$$AR = \frac{h}{2 \cdot R}; \Rightarrow h = 2 \cdot AR \cdot R \quad (7)$$

Qattqlik (σ) shamol turbinalarining ishlashiga ta'sir ko'rsatuvchi muhim kattalik. Qattqlik turbina parraklarining umumiy sohasining ($N \cdot c$) shamol turbinasi aylana uzunligiga nisbati bilan aniqlanadi [9, 10].

$$\sigma = \frac{N \cdot c}{2 \cdot \pi \cdot R} \quad (8)$$

Quyidagi rasmda turbina parragiga ta'sir qiluvchi kuchlar va tezlik vektorlarini tahlil qilamiz hamda tenglamalarini ko'rib chiqamiz.



2-rasm. Shamol turbinasi parragiga ta'sir qiluvchi parametrlarning vektor kattaliklarda ko'rinishi.



Bunda V_0 -shamolning turbinagacha; V_{bur} -burchakli; V_{nis} -nisbiy; V_{um} -umumiy; V_{nor} -normal; V_{nat} -natijaviy tezliklar, F_K -ko'taruvchi, F_T -tortuvchi kuchlar.

Burchakli tezlik quyidagicha aniqlanadi:

$$V_{bur} = \omega \cdot R = \frac{2\pi \cdot n \cdot R}{60} = \frac{\pi \cdot n \cdot R}{30} \quad (9)$$

Bunda n -turbinaning aylanish tezligi, [ayl/min]

Natijaviy tezlik esa:

$$V_{nat} = V_{bur} + V_{nis} \cdot \sin \theta = \omega \cdot R + V_{nis} \cdot \cos \theta = \lambda \cdot V_{nis} + V_{nis} \cdot \cos \theta = V_{nis} (\lambda + \cos \theta) \quad (10)$$

Tadqiqot ishlarida keltirilishicha nisbiy tezlikning miqdori [84] $V_{nis} = (V_0 + V_2) / 2$ ga teng.

Bunda V_2 -turbinadan (o'tgan) keyingi shamol tezligi.

Turbina parragiga ta'sir qiluvchi normal tezlik (11) tenglikda keltirilgan.

$$V_{nor} = V_{nis} \cdot \sin \theta \quad (11)$$

Shamol turbinasiga ta'sir etuvchi umumiy tezlik quyidagicha:

$$V_{um} = \sqrt{V_{nor}^2 + V_{nat}^2} = \sqrt{(V_{nis} \cdot \sin \theta)^2 + (V_{nis} (\lambda + \cos \theta))^2} = V_{nis} \sqrt{1 + 2 \cdot \lambda \cdot \cos \theta + \lambda^2} \quad (12)$$

Shamolning kelish burchagi α esa (13) ifoda bilan aniqlaniladi: [5, 11, 12]

$$\alpha = \tan^{-1} \left(\frac{V_{nor}}{V_{nat}} \right) = \tan^{-1} \left(\frac{V_{nis} \cdot \sin \theta}{V_{nis} (\lambda + \cos \theta)} \right) = \tan^{-1} \left(\frac{\sin \theta}{\lambda + \cos \theta} \right) \quad (13)$$

Turbinaning mexanik quvvatini hisoblashda tangensial kuch koeffitsiyenti C_{tan} va normal koeffitsiyent C_n larni bilish talab etiladi, ularni aniqlash uchun esa C_K , C_T kabi koeffitsiyentlar kerak bo'ladi. Bu koeffitsiyentlar NACA aerodinamik sirtlarning maxsus dasturlari orqali aniqlaniladi. Masalan NACA 4412 aerodinamik sirti uchun $\alpha = 3^\circ$ da C_K , C_T ning qiymatlari mos ravishda 0.5279, 0.04426 ga teng, odatda C_K , C_T koeffitsiyentlar o'rtacha 3° ga nisbatan beriladi. Tangensial va normal koeffitsiyentlarni quyidagicha hisoblaymiz:

$$C_{tan} = C_K \cdot \sin \alpha - C_T \cdot \cos \alpha \quad (14)$$

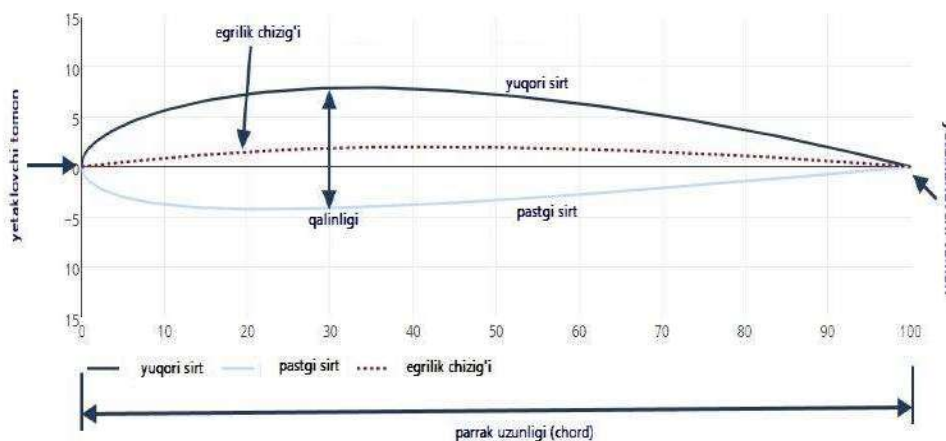
$$C_n = C_K \cdot \sin \alpha + C_T \cdot \cos \alpha \quad (15)$$

Tangensial kuch F_{tan} va normal kuch F_n ni quyidagicha ifoda orqali hisoblaniladi:

$$F_{tan} = \frac{1}{2} \cdot C_{tan} \cdot \rho \cdot S_{par} \cdot V_{um}^2 \quad (16)$$

$$F_n = \frac{1}{2} \cdot C_n \cdot \rho \cdot S_{par} \cdot V_{um}^2 \quad (7)$$

Bunda S_{par} -parrakning shamol bilan ta'sirlashuvchi yuqori sirtining yuzasi, (3-rasm), tadqiqot ishlarida bu miqdor taxminan $S_{par} = c \cdot h$ ga teng deb keltirilgan, bunda c -parrak uzunligi, lekin $c \cdot h$ -shamol bilan ta'sirlashuvchi real yuzaga teng emas, shamol bilan ta'sirlashuvchi haqiqiy yuzani topishimiz uchun yuqori sirt egriligi uzunligini parrak balandligiga ko'paytirish kerak bo'ladi: ya'ni $S_{par} = c^1 \cdot h$, bunda c^1 -yuqori sirt yoyining uzunligi, h -parrak uzunligi. S_{par} -miqdorining katta bo'lishi (16) ifodaga muvofiq F_{tan} kuching katta bo'lishiga olib keladi. Tangensial kuchni oshirish turbina momenti miqdorini oshishiga sabab bo'ladi, shuning uchun turbina parraklarining shamol bilan ta'sirlashuvchi yuzasini oshirish samara beradi.



3-rasm.NACA 4412 aerodinamik sirtining qismlari.



4-rasm.NACA 4412 aerodinamik sirtining egriliklar bilan to'ldirilgan yuzasi.

4-rasmdagi parrakning yuqori sirti standartdagi NACA 4412 aerodinamik sirtga nisbatan kattaroq, bu shaklning yuzasi shamol oqimiga samarali ishlovchi maxsus egriliklar bilan to'ldirilgan. Bu egriliklar birinchidan yuzaning oshishiga, ikkinchidan oqim ilashuvining yaxshilanishiga olib keladi.

Yuqoridagi tahlillarni davom ettirgan holda o'rtacha tangensial kuchning qiymati F_{tan} ga va turbina parragining burilish burchagi θ ning qiymatiga quyidagicha bog'liq [13]:

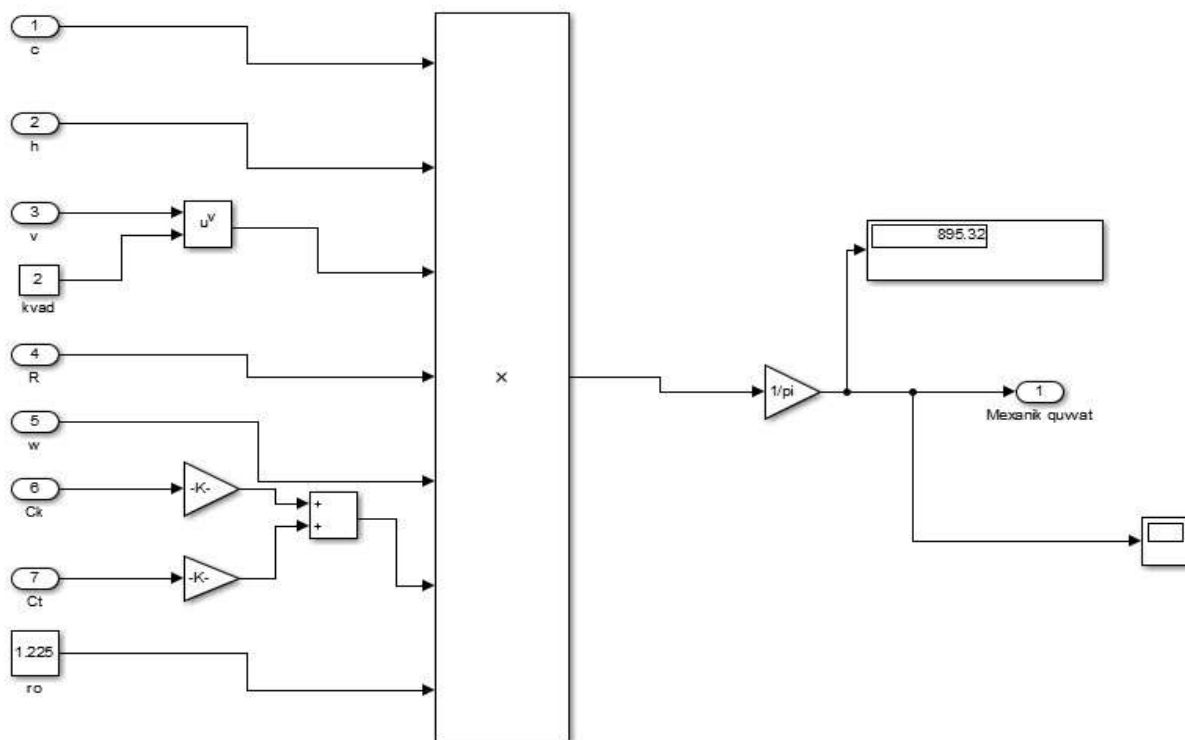
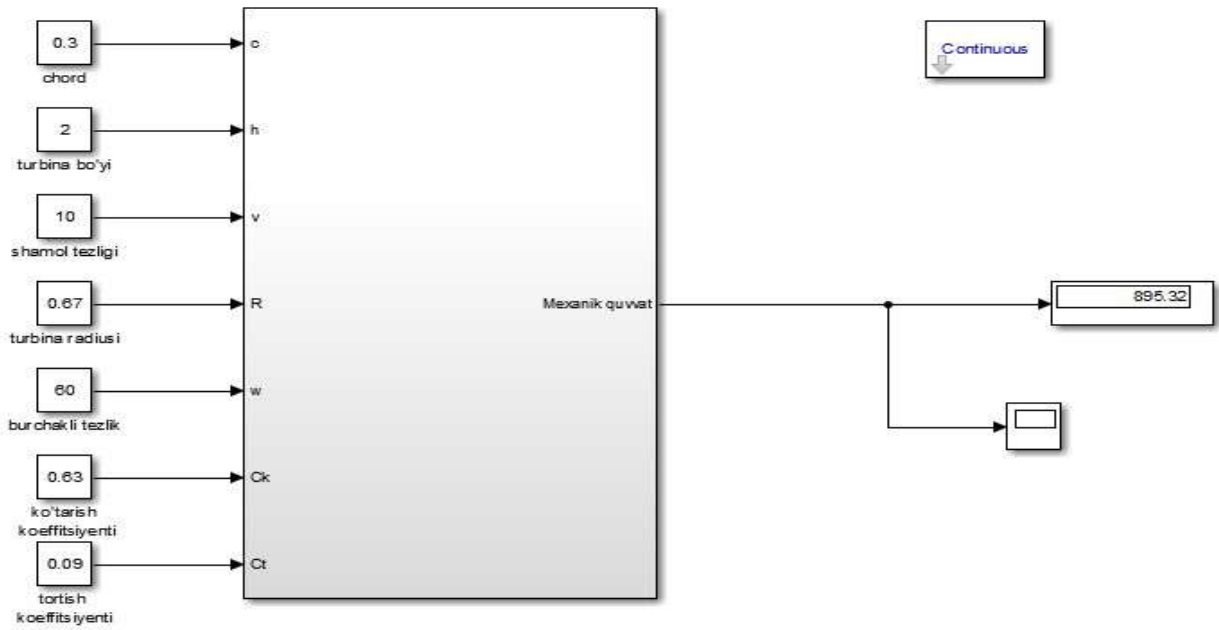
$$F_{ta.o'r} = \frac{1}{2 \cdot \pi} \int_0^{2\pi} F_{tan}(\theta) d\theta \quad (18)$$

(18) ifodani yoyish orqali biz umumlashtirilgan quyidagi tenglikka ega bo'lamiz

$$T = n \cdot F_{ta.o'r} \cdot R = \frac{4 \cdot \rho \cdot c^1 \cdot h \cdot V_{um}^2 \cdot R}{4 \cdot \pi} \cdot (0,63662 \cdot C_K + 6,12087 \cdot C_T) \quad (19)$$

Bu yerda c^1 -maxsus egriliklar bilan to'ldirilgan NACA 4412 aerodinamik sirtining tashqi sirti. c^1 -ning qiymati to'g'ri burchakka to'ldirish orqali aniqlaniladi. Hisoblashlarga ko'ra NACA 4412 aerodinamik sirtning tashqi sirti uzunligi 0,1 m bo'lsa, taklif etilayotgan sirtning uzunligi 0,109 m ga teng bo'ladi.

Olingan ifodalarni umumlashtirib Matlab dasturiga kiritish orqali quyidagi model ko'rinishini olamiz.

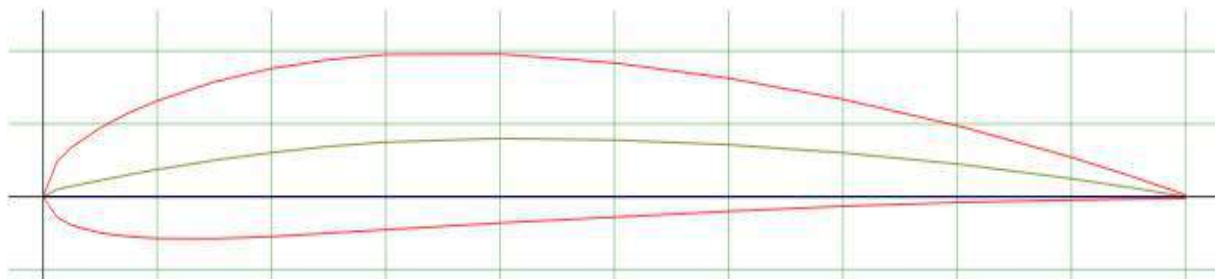


5-rasm. Matlab amaliy paketida qurilgan shamol energetik qurilmasi modeli.

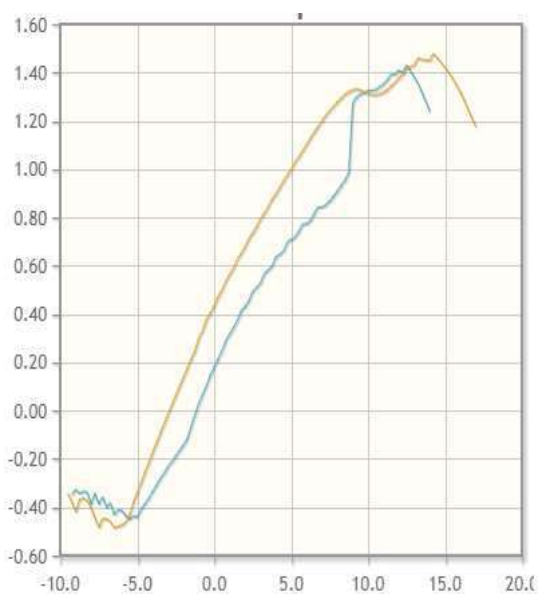
Matlab dasturida quvvatni hisoblashdagi miqdorlar sifatida turbinaning haqiqiy o'lchamlari kiritilgan, masalan $c = 30 \text{ sm}$, $h = 2 \text{ m}$, $R = 0,7 \text{ m}$ kabi miqdorlar uchun hisoblanilgan.

Yuqorida keltirilgan ifodalarda ma'lum bir holatlarda ya'ni shamolning kelish burchagi α ga bog'liq. Bunda (14 va 15) ifodalarda keltirilgan C_K va C_T ko'tarish va tortish koeffitsiyentlari α ga muvofiq o'zgaradi. Bu koeffitsiyentlarni NACA4412 aerodinamik sirt uchun Xfoil va Ansys dasturlari yordamida aniqlash mumkin. Qolaversa Airfoils tools bazasi orqali shamolning kelish

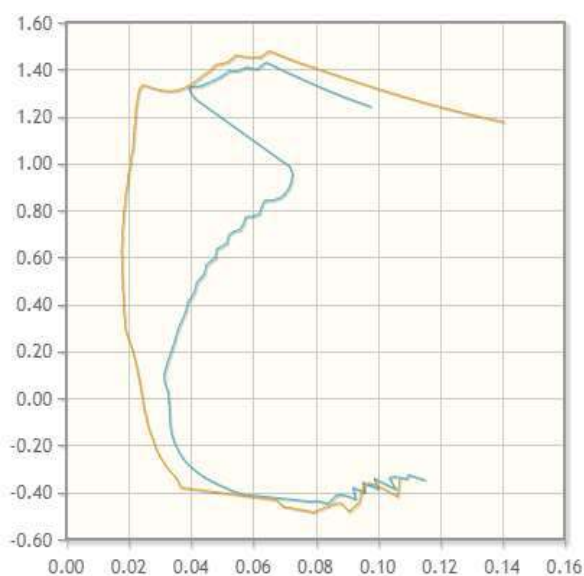
burchagi α , moment koeffitsiyenti C_m va C_K, C_T ning qiymatlarini orasidagi grafik bog'liqliklarni olishimiz mumkin. Bu grafiklar yordamida shamol oqimining turli kelish burchaklari uchun C_m va C_K, C_T larning koeffitsiyentini aniqlaymiz va bu grafiklardan Reynolds soni miqdori C_K ga to'g'ri, C_T ga esa teskari proporsional ekanligi haqida xulosa chiqaramiz.



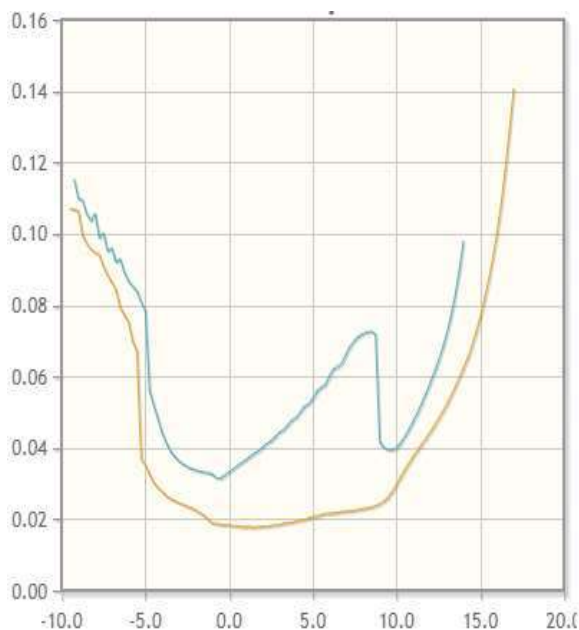
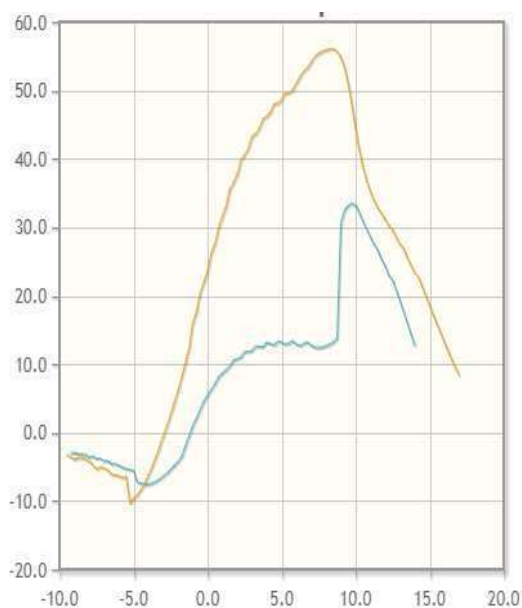
6-rasm. NACA4412 aerodinamik sirtining umumiy ko'rinishi.



7 a-rasm. C_K va α orasidagi bog'liqlik.



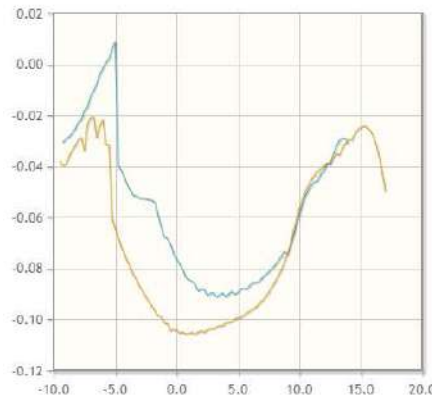
7 b-rasm. C_K va C_T orasidagi bog'liqlik.





7 c-rasm. C_K / C_T va α orasidagi bog'liqlik.

7 d-rasm. C_T va α orasidagi bog'liqlik.



7 e-rasm. C_m va α orasidagi bog'liqlik.

7 rasmga fikrlaridagi ko'k rangli xarakteristika Reynolds soni $R_e = 0,5 \cdot 10^6$, sariq rangli xarakteristika esa $R_e = 10^6$ ga teng qiymatlar uchun olingan. Bu grafiklarning shakli noodatiy ekanligining sababi parrak harakatlanishi jarayonida o'zining stereonometrik pozitsiyasini doimiy o'zgartiradi, unga ta'sir qiluvchi oqim burchagi uzluksiz o'zgaradi, natijada ko'tarish va tortish koeffitsiyentlarining qiymatlari keskin o'zgaradi, shuning uchun xarakteristikalar yuqoridagi kabi ko'rinishga keladi [14]. Agar e'tibor berib qaralsa NACA 4412 uchun $R_e = 0,5 \cdot 10^6$ va $R_e = 10^6$ larga bog'liq bo'lgan xarakteristikalarni nisbatan bir-biriga parallel deyish mumkin. 7 a,b,c rasmlardan Reynolds sonining ko'tarish koeffitsiyentiga to'g'ri, d,e rasmlardan esa tortish va moment koeffitsiyentlariga teskari proporsional ekanligi ayon bo'ladi.

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**ENERGIYA TEJAMKOR TEXNOLOGIYALAR VA QURILMALAR//
ЭНЕРГОСБЕРЕГАЮЩИЕ ТЕХНОЛОГИИ И УСТАНОВКИ// ENERGY
SAVING TECHNOLOGIES AND INSTALLATIONS**

**ВЛИЯНИЕ СПЕКТРОВ НИЗКОЭНЕРГЕТИЧЕСКОГО СВЕТОВОГО ИЗЛУЧЕНИЯ
НА РОСТ ДЕРЕВЬЕВ ЛИМОНОВ**

Ботиров Б.М.¹, Дыскин В.Г.², Шогучкаров С.К.¹, Курбанов Ю.М.¹

¹Ташкентский государственный технический университет
Узбекистан, 100095, Ташкент, ул. Университетская, 2
тел.: +99(871) 246-03-04; e-mail:bbozorbek@bk.ru

²Институт Материаловедения АН РУз, ул. Чингиза Айтматова -2б,
Ташкент, 100080, Узбекистан

Аннотация: В работе кратко проанализированы методы, стимулирующие развитие культурных растений в закрытом грунте, а также изучен спектр низкоэнергетического светового излучения, который участвует в регуляции морфогенеза растений. Изучено влияние различных областей спектра (желтого, оранжевого, зеленого, синего, красного, естественного света) на рост молодых саженцев лимона в возрасте 1 года. Эксперименты проводились в течение 47 дней в домашних условиях. Результаты показывают, что для сеянцев лимона, освещенных желтым и красным спектром света, рост примерно на 22,2% выше по сравнению с контрольным образцом. В дальнейшем в качестве источника энергии в теплице планируется использовать автономную фотоэлектрическую установку специально для станции «Лимонное дерево», предусмотрено использование светодиодных ламп с разным спектром.

Ключевые слова: Спектр, солнечная радиация, морфометрические показатели, стимуляция лимонов, фотосинтез, длина волны, интенсивность.

**INFLUENCE OF LOW ENERGY LIGHT SPECTRA ON THE GROWTH OF
LEMON TREES**

Botirov B.M.¹, Diskin V.G.², Shoguchkarov S.K.¹, Kurbanov Y.M.¹

¹Tashkent State Technical University, 100095, Tashkent, Uzbekistan

²Institute of Materials Science of the Academy of Sciences of the Republic of Uzbekistan,
Tashkent, Uzbekistan

Abstract: The paper briefly analyzes the methods that stimulate the development of cultivated plants in the closed ground, and also studied the spectrum of low-energy light radiation, which is involved in the regulation of plant morphogenesis. Has been studied the influence of various spectral regions (yellow, orange, green, blue, red, natural light) on the growth of young lemon seedlings aged 1 year. The experiments were carried out for 47 days at home. The results show that for lemon seedlings illuminated by the yellow and red light spectrum, the growth is ~22.2% higher compared to the control sample. In the future, as an energy source in the greenhouse, it was planned to use an autonomous photovoltaic installation specifically for the lemon tree station, the use of LED lamps with a different spectrum is provided.

Keywords: Spectrum, solar radiation, morphometric indicators, stimulation of lemons, photosynthesis, wavelength, intensity.