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Tashkent state transport university

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Improving the cold-start process in fourth-generation gas-cylinder vehicles operating on compressed natural gas fuel

A. Azimov[1] [a]
[1]Tashkent state transport university, Tashkent, Uzbekistan

Abstract: This article investigates the reduction of hazardous exhaust pollution and rational energy conservation in vehicle transportation, both essential for protecting urban ecosystems from environmental deterioration. Fourth-generation gas-cylinder equipment equipped with a universal fuel supply system, installed on gas-cylinder vehicles, was selected as the object of the study. The article analyzes the process of switching the engine from gasoline fuel to compressed natural gas fuel during a cold start, and substantiates the adjustment of the temperature threshold governing this transition — recommended by manufacturers to be in the range of 30–40°C — to a level of 25°C, adapted to the climatic conditions of the Republic of Uzbekistan. Based on the operational tests and experiments carried out, empirical formulas for determining gasoline fuel consumption during the engine's cold start were developed, along with a mathematical model describing the "gasoline-gas" and "gas-gasoline" control modes as a function of crankshaft rotation frequency and coolant temperature. The results of the study contribute to improving the energy efficiency and ensuring the environmental safety of gas-cylinder vehicle engines during the cold start process.

Keywords: gas-cylinder vehicle, gas-cylinder equipment, compressed natural gas, "gasoline-gas" control, engine cold start, crankshaft rotation frequency, coolant temperature, energy efficiency, environmental safety, mathematical model

Siqilgan tabiiy gaz yonilg'isida ishlovchi IV-avlod gaz ballonli avtomobillarda sovuq ishga tushirish jarayonini takomillashtirish

Azimov A.[1] [a]
[1]Toshkent davlat transport universiteti, Toshkent, O‘zbekiston

Annotatsiya: Maqolada markazlashgan shaharlar ekotizimiga salbiy ta’sir ko‘rsatuvchi asosiy omillardan biri bo‘lgan avtomobil transporti ekspluatatsiyasi jarayonida atmosferaga chiqariladigan zararli chiqindi gazlar miqdorini kamaytirish va energiya resurslaridan oqilona foydalanish masalalari ko‘rib chiqilgan. Tadqiqot ob’yekti sifatida universal yonilg‘i ta’minot tizimiga ega IV-avlod gaz ballon uskunalari bilan jihozlangan gaz ballonli avtomobillar tanlangan. Maqolada dvigatelning sovuq holatda ishga tushirilishidan benzin yonilg‘isidan siqilgan tabiiy gaz yonilg‘isiga o‘tish jarayoni tahlil qilingan hamda ushbu o‘tishni belgilovchi harorat ko‘rsatkichi ishlab chiqaruvchilar tomonidan tavsiya etilgan 30–40°C oralig‘idan O‘zbekiston Respublikasi iqlim sharoitlariga moslashtirilib 25°C darajasiga o‘tkazilgani asoslangan. O‘tkazilgan ekspluatatsiya sinovlari va eksperimentlar asosida dvigatelning sovuq ishga tushirilishi davomidagi benzin yonilg‘isi sarfini aniqlovchi empirik formulalar hamda tirsakli val aylanishlar chastotasi va dvigatel haroratiga bog‘liq holda “benzindan gazga” va “gazdan benzinga” boshqaruv rejimlarini tavsiflovchi matematik model ishlab chiqilgan. Tadqiqot natijalari gaz ballonli avtomobil dvigatellarining sovuq ishga tushirish jarayonidagi energiya samaradorligini oshirish va ekologik xavfsizligini ta’minlashga xizmat qiladi.

Kalit so‘zlar: gaz ballonli avtomobil, gaz ballon uskunasi, siqilgan tabiiy gaz, “benzindan gazga” boshqaruvi, dvigatelning sovuq ishga tushirilishi, tirsakli val aylanishlar chastotasi, dvigatel harorati, energiya samaradorligi, ekologik xavfsizlik, matematik model

1. Kirish

Dunyo bo’yicha antropogen omillar natijasida ekologik vaziyatning yomonlashuvi va iqlim o’zgarishlari natijasida yuzaga kelayotgan ulkan tabiiy ofatlar kun sayin ortib bormoqda. Markazlashgan shaharlar ekotizimining buzilishi xususan, havo sifatining yomonlashuvi, issiqxona effekti, PM zarrachalarining yuqori darajasi ijtimoiy muhit uchun jiddiy xavflardan hisoblanadi. Ushbu muammolarning bartaraf etishning asosiy yechimi, ularni keltirib chiqaruvchi

[a] https://orcid.org/0000-0002-8385-804X

manbalarni tadqiq etish va ularning muqobil turlarini yaratish hamda joriy etishdir. Shahar ekotizimiga salbiy ta'sir etuvchi asosiy manbalardan biri avtomobil transporti hisoblanadi. Avtomobillashtirish darajasining yil sayin ortib borishi nafaqat ekspluatatsiya jarayonidagi zararli gazlar miqdorini oshiradi balki energiya resurslariga bo'lgan talabning ham oshib borishiga olib keladi.

Markazlashgan shaharlar ekotizimini barqaror saqlash hamda energiya resurslaridan oqilona foydalanishda barcha energiya iste'molchilari uchun energiya tejamkor texnologiyalar va muqobil energiya manbalaridan foydalanish yuqoridagi muammolarni bartaraf etishda samarali yechimlardan hisoblanadi. Xususan, avtomobil transporti ekspluatatsiyasida an'anaviy yonilg'ilariga muqobil bo'lgan yonilg'ilardan foydalanish va energiya tejamkorligi yuqori bo'lgan texnologiyalarni yaratish rag'batlantirilmoqda. Avtomobillar uchun mavjud neft yonilg'ilariga muqobil sifatida siqilgan va suyultirilgan tabiiy gaz yonilg'isidan foydalanish keng ommalashib bormoqda.

Benzin yoki dizel dvigatellarini siqilgan tabiiy gaz (STG) yonilg'isi uchun qayta jihozlashda, avtomobil maxsus gaz ballon uskunalari (GBU) bilan qayta jihozlanadi va ularni umumiy nom bilan gaz ballonli avtomobillar (GBA) deb nomlaymiz. Benzinli dvigatelarga GBU o'rnatilishi, dvigatel maksimal quvvatini biroz pasaytiradi, lekin shu bilan birga, chiqindi gazlarning toksikligini va shovqin darajasini sezilarli darajada yo'qotib, yonilg'i va moylash materiallari narxini sezilarli darajada kamaytiradi.

Avtomobillar ekspluatatsiyasida gaz yonilg'ilaridan foydalanish iqtisodiy jihatdan istiqbolli bo'lishi bilan birga, gaz ballonli avtomobillarning yuqori yonilg'i samaradorligini va ekologik xavfsizligini ta'minlashi gaz yonilg'isidan foydalanish ko'lamini yanada oshirmoqda.

Gaz ballonli avtomobillar dvigatellarining STG yonilg'isini ishlatish usuliga ko'ra [1,2], ikki yonig'ida ishlovchi ya'ni siqilgan tabiiy gazda ishlovchi, aralash (kombinatsiyalashgan) va faqat gazda ishlovchi turlarga bo'linadi. Ular ichida birinchi guruh gaz ballonli avtomobillar, umumiy avtomobil parkining asosiy qismini tashkil etadi va asosan yengil avtomobillarda o'rnatiladi.

Gaz ballon uskunalarining yillar davomida takomillashib borishi va yonilg'i tejamkor texnologiyalarga asoslangan elektron dasturiy ta'minotlar asosida ishlab chiqarilishi, avtomobillar ekspluatatsiyasi samaradorligini oshirishda yanada keng imkoniyatlarni taqdim etdi. Ushbu o'zgarishlarning bosqichma-bosqich amalga oshirilishi natijasida, turli avlod gaz ballon uskunalarini guruhlanishiga olib keldi.

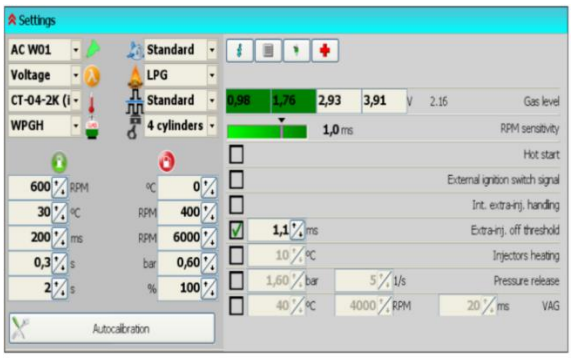
Adabiyotlar tahlili

Bugungi kunda gaz ballonli avtomobillarda mavjud gaz ballon uskunalari oltita avlodga bo'linadi. Shulardan to'rtta avlod gaz ballon uskunalari STGda ishlovchi universal yonilg'i ta'minlash tizimli gaz ballonli avtomobillarda keng miqyosda qo'llaniladi. Uchinchi va to'rtinchi avlod gaz ballon uskunalari avtomobillarga o'rnatilish salmog'i bo'yicha yuqori hisoblanadi. Aynan uchunchi va to'rtinchi avlod gaz ballon uskunalari avtomobil dvigateli dastlab benzinda ishga tushirilib so'ng gaz yonilg'isiga o'tadi. III-avlod gaz ballon uskunalari benzindan gazga rejimining o'zgarishi tirsakli val aylanishlar chastotasiga bog'liqdir ya'ni benzinda ishga tushirilgan dvigatel, tirsakli valning belgilangan ko'rsatgichida gaz yonilg'isiga o'tadi. IV-avlod GBU ega avtomobillarida ham dvigatel dastlab benzinda ishga tushadi va ma'lum vaqt davomida belgilangan haroratgacha (ekspluatatsiyadagi asosiy gaz ballonli avtomobillar dasturiy sozlamalarida 30°C dan 40°Cgacha) qizdirilgandan so'ng gazga o'tadi [3,9]. Tadqiq etilayotgan siqilgan tabiiy gazda ishlovchi IV-avlod GBUning asosiy modellarida (STAG, Digitronic, Tomasetto, Landi Renzo va boshqa) dvigatelning sovuq ishga tushirilib benzindan gazga o'tishidagi ("benzindan gazga" boshqaruvi) bazaviy sozlamalarda tavsiya etilgan harorat 30°C qilib belgilangan. Benzindan gazga o'tish vaqt davomiyligi tashqi muhit haroratiga bog'liq holda o'zgaradi ya'ni harorat pasayishi bilan gaz ballonli avtomobillar benzindan gazga o'tish vaqti oshib boradi.

Dvigatel benzindan gazga o'tish jarayoni quyidagi hollardan bo'lmaydi [3, 4]:

- dvigatel yuklanishi belgilangan kalibrlash chegarasidan tirsakli valning aylanishlar chastotasi (TVACh) oshgan bo'lsa;
- dvigatel harorati me'yor chegaradan quyi bo'lsa;
- injektorlardagi gaz harorati past bo'lsa;
- taqsimlash valining holat datchigi ishlamayotgan bo'lsa;
- elektr jihozlarida kuchlanish miqdori 24 V dan yuqori bo'lsa;
- dvigatel ish holati elektr jihozlaridagi kuchlanish miqdori 8 V dan past bo'lsa.

GBUga ega dvigatellarning benzindan gazga o'tish parametrlaridagi harorati (gaz reduktori harorati), GBU ishlab chiqaruvchi kompaniyalar (Stag, Landi Renzo, Tomasetto va boshq.) tomonidan barcha mavsumlar uchun o'rtacha harorat 30° va 40°C norma belgilangan [5] (1-rasm). Bu haroratni O'zbekiston Respublikasi iqlim sharoitida 25°C ga tushirilgan (2-rasm), ushbu haroratda gazga o'tish dvigatel detallari va GBUning ish ko'rsatgichlariga hech qanday salbiy ta'siri mavjud emas. Bu dvigatel va GBUning STGda normal ishlash harorati, tashqi muhit harorati 10°C dan yuqori bo'lganda [6], shuningdek, dvigatelni STGda ishga tushirish imkoniyati tashqi muhit harorati -5°C [7,6] ekanligi bilan asoslanadi. Shuningdek benzindan gazga o'tishdagi dvigatel harorati 25°C etib belgilanishi, ko'plab yengil avtomobillarda o'tkazilgan eksperimentlar natijasida asoslanadi. Eksperimentlar dvigatel ishga tushirilib benzindan gazga o'tishdagi dvigatel harorati 25°C dan quyi ko'rsatgichlarda, dvigatel barqarorligining buzilishi, tebranish kuchayishi va dvigatelning o'chishi bilan tugadi.



1-rasm. GBUni diagnostika dasturidagi "benzindan gazga" boshqaruvining zavod tomonidan tavsiya etilgan universal rostlash tartibi [8]

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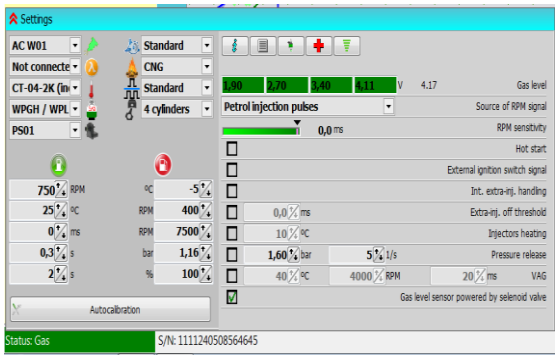
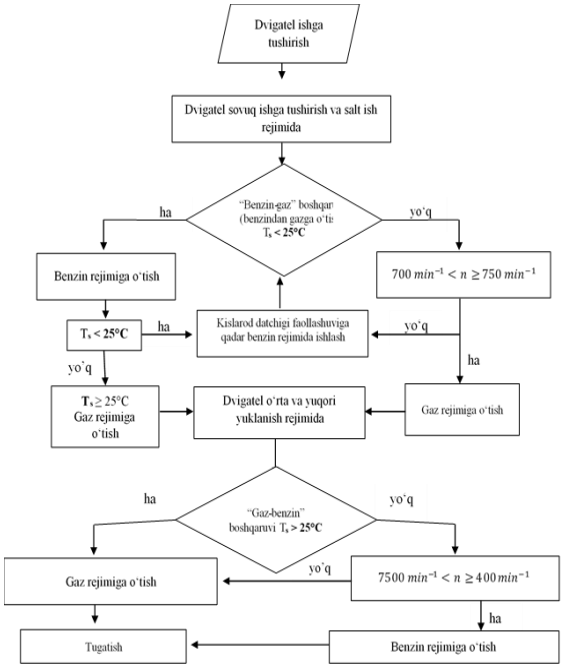


2-rasm. GBUni diagnostika dasturidagi "benzindan gazga" boshqaruvini past (< 25°C) va yuqori (≥ 25°C) haroratli ekspluatatsiya sharoitiga ko'ra rostlash tartibi

2. Tadqiqot metodologiyasi

Dvigatelning benzindan gazga o'tish algoritmining optimallashtirilishi, uning gazga o'tish jarayonini tezlashtiradi va benzinda ishlash vaqtining qisqarishiga, yonilg'i xarajatlarining tejalishiga hamda atmosferaga chiqariladigan ZChG miqdorini kamayishiga olib keladi. Tashqi muhit harorati 25°C gacha bo'lgan holatlarda dvigatelning ishga tushirilib benzindan gazga o'tish jarayoni dvigatel haroratiga binoan amalga oshsa, 30°C yuqori haroratli sharoitlarda tirsakli val aylanish chastotasi asosida amalga oshadi (3-rasm).



3-rasm. GBAning sovuq ishga tushirishda benzindan gazga - gazdan benzinga o'tish algoritm blok sxemasi

Siqilgan tabiiy gazda ishlovchi IV-avlod gaz ballonli yengil avtomobil dvigatellarining benzinda ishga tushirilib STGga o'tish parametrlarini ratsional o'zgartirish orqali GBAning ekspluatatsion ko'rsatgichlarini oshirishning matematik modelini yaratishda ekspluatatsiya sharoitini hisobga olish eng muhim shartlardan hisoblanadi.

GBAning ishga tushirishda benzindan gazga o'tish shartlarini tashqi muhit harorati (IYoD sovitish suyuqligi harorati), IYoD TVACh va gaz ballon idishini gaz bilan to'ldirish holatlariga qarab IYoDni sovuq ishga tushirish jarayonini 3 xil ekspluatatsiya sharoiti bo'yicha quyidagicha matematik modellashtirishimiz mumkin [3,9]:

a. T_s<10°C da

- har qanday holatda dvigatel benzinda ishga tushiriladi.

b. 10°C ≤ T_s <25°C

- Gaz ballon idishini gaz to'ldirishdan oldin:

Dvigatel benzinda ishga tushiriladi.

Sovuq ishga tushirish fazasi tugagach, dvigatel harorati T_s≥25°C bo'lganda yoki tirsakli val aylanishlar chastotasi 750 min^{-1} ga etganda gaz rejimiga o'tadi.

- Gaz ballon idishini gaz bilan to'ldirishdan keyin:

Benzinda ishga tushiriladi.

λ-zond faollashganidan so'ng, dvigatel harorati T_s≥25°C bo'lganda gaz rejimiga o'tadi.

c. T_s ≥25°C

- Gaz ballon idishini gaz bilan to'ldirishdan oldin:

- Benzinda ishga tushiriladi, dvigatel ishdan chiqib ketgandan keyin 30 sekundgacha benzin rejimida qoladi;
- Agar tirsakli val aylanishi 750 min^{-1} dan oshsa, gaz rejimiga o'tadi.

– Gaz ballon idishini gaz bilan to'ldirishdan keyin:

- Benzinda ishga tushiriladi;
- Tirsakli val aylanishi 750 min^{-1} dan oshganda gaz rejimiga o'tadi.

Avtomobillar ekspluatatsiyasida dvigatelning asosiy sifat ko'rsatkichlardan biri yonilg'i sarfi yoki uning tejamkorligi hisoblanadi. Dvigatel ish ko'rsatgichlarini aniqlashda maxsus stend bilan belgilangan ish rejimlarida (Ni;pi;n=const), sinash vaqtidagi ma'lum quvvat uchun sarflangan yonilg'i miqdorlari o'lchanadi. O'lchash natijalari har soatda kg hisobida sarflangan yonilg'i miqdori quyidagicha aniqlanadi [3]:

$$G_{yo} = \frac{\Delta g}{\tau} \cdot 3{,}6\ kg/soat, \qquad (1)$$

bu yerda Δg – o'lchangan yonilg'i miqdori, g; τ – yonilg'ining sarf vaqti, s.

IV-avlod GBAning sovuq ishga tushirishda benzindan avtomatik gazga o'tish algoritmiga ko'ra, dvigatelning sovuq ishga tushirilishidan gaz yonilg'isiga o'tishi davomidagi benzin sarfi sovitish suyuqligi haroratiga T_s bog'liq hisoblanadi. Ya'ni T_s miqdori 25°C dan past bo'lganda dvigatel benzin sarflaydi va T_s miqdori 25°C da avtomatik gaz yonilg'isi sarfi boshlanadi. Ushbu shartlarni (1) formulaga bog'laydigan bo'lsak, τ -ning qiymati T_s <25°C bo'lganda benzin sarflanish vaqti τ_{benzin} qabul qilinib, T_s ≥25°C bo'lganda benzindan gaz yonilg'isiga o'tishini bildiradi, biz ushbu shartlarni matematik formula sifatida quyidagicha ifodalaymiz:

1. τ-ni harorat T_s ga bog'liq holda quyidagicha aniqlaymiz:

$$\tau = \begin{cases} \tau_{benzin}, & agar\ T_s < 25°C \\ \tau_{gaz}, & agar\ T_s \geq 25°C. \end{cases} \qquad (2)$$

2. τ-ni TVACh ga bog'liq holda quyidagicha aniqlaymiz:

$$\tau = \begin{cases} \tau_{benzin}, agar\ 7500\ min^{-1} < n < 400\ min^{-1} \\ \tau_{gaz}, \ agar\ 700\ min^{-1} < n \leq 750\ min^{-1} \end{cases} \qquad (3)$$

- Indikator funksiya (I) yordamida benzin uchun τ -ning qiymatini quyidagicha ifodalaymiz:

$$\tau = \tau_{benzin} \cdot I \qquad (4)$$

bu yerda:

$$I = \begin{cases} 1, & agar \quad T_s < 25℃ \\ 1, agar\ 7500\ min^{-1} < n < 400\ min^{-1} \end{cases} \quad (5)$$

Yuqoridagilardan kelib chiqib, (1) formulaga benzin yonilg‘i sarflanish vaqtiga (τ), GBAning “benzindan gazga” boshqaruvi asosida yaratilgan indikator funksiya (I)ni bog‘laymiz va sovuq ishga tushirish davomidagi salt ish rejimi uchun benzin yonilg‘i sarfini quyidagi empirik formula orqali aniqlaymiz:

$$G_b = \frac{\Delta g}{\tau_{benzin}{}_I} \cdot 3{,}6, \qquad kg/soat \quad (6)$$

IV-avlod GBU ega siqilgan tabiiy gazda ishlovchi avtomobil dvigatellarini ratsional rostlangan “benzindan gazga”/“gazdan benzinga” boshqaruvini funksional ko‘rinishdagi matematik modeli asosida dvigatelni sovuq ishga tushirishdagi benzin sarfi quyidagi ifoda orqali aniqlanadi:

$$G_{yo(b,g)} = \begin{cases} \frac{\Delta g}{\tau_{benzin}{}_I} \cdot 3{,}6\ agar\ T_s<25℃,\ 7500\ min^{-1} < n < 400\ min^{-1} \\ \frac{\Delta g}{\tau_{gaz}} \cdot 3{,}6\ agar\ T_s\geq 25℃, 700\ min^{-1} < n \leq 750\ min^{-1} \end{cases} \quad (7)$$

3. Natijalar va muhokamalar

Siqilgan tabiiy gazda ishlovchi IV-avlod GBU bilan jihozlangan gaz ballonli yengil avtomobil dvigatellarining sovuq ishga tushirish jarayonidagi energiya samaradorligini oshirish va ekologik xavfsizligini yaxshilash bo‘yicha amalga oshiriladigan benzindan gazga boshqaruv sozlamalarini ratsional rostlash tamoyillariga asoslangan GBA ekspluatatsion ko‘rsatkichlarini oshirish konsepsiyasining qo’llanilishi GBA ekspluatatsion ish sanarasini oshirishda eng muhim ishlardan hisoblanadi.

Siqilgan tabiiy gazda ishlovchi IV-avlod bilan jihozlangan GBA ihlashida yonilg‘ining benzindan gazga yoki aksi o‘tishida dvigatel barqarorlikni saqlashi, tebranish, shovqin chiqarmasligi umuman olganda turg‘un holatda ishonchli o‘t olishi lozim, bu benzindan gazga o’tish sozlamalariga bog‘liqdir. Ushbu sozlamalarning gaz yonilg’isida ratsional ishlash harorati, tashqi muhit haroratidan 10°C yuqori bo‘lganda, dvigatelni gazda ishga tushirish imkoniyati esa tashqi muhit harorati -5°C yuqori haroratlarda oson amalga oshadi. Past haroratli sharoitlarda benzindan gazga o‘tish dvigatelning noturg‘un ishlashiga, o’t olmasligi o‘tkazilgan ekspluatatsiya sinovlarida aniqlandi.

4. Xulosa

Xulosa qilib aytganda, siqilgan tabiiy gazda ishlovchi IV-avlod GBU bilan jihozlangan gaz ballonli yengil avtomobil dvigatellarining sovuq ishga tushirish jarayonida “benzindan gazga” va “gazdan benzinga” o’tkazuvchi elektron boshqaruv sozlamalarini ratsional rostlash tamoyillariga asoslangan holda, GBA ish ko‘rsatkichlarini oshirish imkoniyati aniqlandi. Ekspluatatsiya sinov natijalariga ko’ra GBUning STGda normal ishlash harorati tashqi muhit harorati (10°C) dan yuqori bo‘lganda, dvigatelni STGda tezda ishga tushirish harorati -5°C dan yuqori bo‘lganda oson amalga oshadi. Past haroratli tabiiy iqlim sharoitlarida benzindan gazga o‘tish jarayoni dvigatel ishini noturg‘un holatga kelishi va uning to‘xtab qolishiga olib kelishini ko‘rsatdi.

GBA ekspluatatsiyasida GBUning bazaviy sozlamalarda ko’rsatilgan harorat Respublikamiz tabiiy iqlim sharoiti bo‘yicha 25°C ga rostlanishi sovuq ishga tushirish vaqtini qisqarishiga olib keladi.

Siqilgan tabiiy gazda ishlovchi IV-avlod GBA benzindan gazga o’tish algoritmi takomillashtirilib shu asosida GBA dvigatellarining sovuq ishga tushirish jarayonidagi energiya samaradorligini oshirish va ekologik xavfsizligini ta’minlash bo‘yicha “benzindan gazga” yoki “gazdan benzinga” boshqaruvining ratsional rostlanishi ularning ekologik vca iqtisodiy samaradorligini oshirish imkoniyatini taqdim etadi.

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Mualliflar to‘g‘risida ma’lumot/ Information about the authors

Azimov Akmal / Akmal Azimov — Toshkent davlat transport universiteti, “Transport energetik qurilmalari” kafedrasi dotsent v.b.
E-mail: akmaldotsent@gmail.com
Tel.:+ 998995536014

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