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RESEARCH, INNOVATION, RESULTS

TOSHKENT DAVLAT TRANSPORT UNIVERSITETI
Tashkent state transport university

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# Digitalization method for calculating vehicle exhaust emissions

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Abstract: Exhaust gases emitted by vehicles have a significant negative impact on environmental sustainability and the environment, accounting for a significant share of the total emissions. Therefore, large-scale research and practical measures are being carried out around the world to reduce the negative effects of these emissions and effectively manage them. Along with the gradual tightening of the EURO environmental requirements developed and implemented by the United Nations, test methods used to determine exhaust emissions are constantly being improved, and the technical level of testing equipment is aimed at ensuring high accuracy, speed and reliability. In particular, taking into account the above environmental requirements in the production of cars, the environmental safety of the design is assessed using modern test methods based on international standards, such as dynamometers, PEMS (Portable Emission Measurement System), WLTP (Worldwide Harmonized Light-Duty Vehicles Test Procedure) and RDE (Real Driving Emissions). However, the process of measuring the composition of exhaust gases of operating vehicles is labor-intensive, time-consuming and expensive, which makes it difficult to carry out emission measurements on a large number of vehicles. The development of a digital method for monitoring exhaust gases using data from the electronic control unit (ECU) of operating vehicles is currently relevant. This article proposes a method for determining the amount of CO2 in exhaust gases per unit of mileage by digitalizing the vehicle ECU data.

Keywords: exhaust gases, gasoline engine, EBD, digitization, OBD-II, monitoring

# Avtomobil chiqindi gazlar hisobini raqamlashtirish uslubi

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Annotatsiya: Transport vositalaridan ajralib chiqadigan zararli gazlar ekologik barqarorlikka hamda atrof-muhit holatiga sezilarli darajada salbiy ta’sir ko‘rsatib, umumiy emissiya manbalari tarkibida yuqori ulushni tashkil etadi. Shu bois, jahon miqyosida ushbu chiqindilarning salbiy oqibatlarini kamaytirish va ularni samarali boshqarish bo‘yicha keng qamrovli ilmiy-tadqiqot ishlari hamda amaliy choralar olib borilmoqda. Birlashgan Millatlar Tashkiloti tomonidan ishlab chiqilgan va joriy etilgan EURO ekologik talablari bosqichma-bosqich kuchaytirilishi bilan bir qatorda, chiqindi gazlarni aniqlash bo‘yicha qo‘llaniladigan sinov metodologiyalari ham izchil takomillashib, sinov jihozlarining texnologik darajasi yuqori aniqlik, tezkorlik va ishonchlilikni ta’minlashga yo‘naltirilmoqda. Xususan, avtomobillarni ishlab chiqarish jarayonida yuqorida qayd etilgan ekologik talablarni inobatga olgan holda, konstruksiyaning ekologik xavfsizligi shassi dinamometrlari, PEMS (Portable Emission Measurement System), WLTP (Worldwide Harmonized Light-Duty Vehicles Test Procedure) va RDE (Real Driving Emissions) kabi xalqaro standartlarga asoslangan ilg‘or sinov uslublari orqali baholanadi. Lekin foydalanishdagi transport vositalarining chiqindi gazlari tarkibini o‘lchash jarayoni katta ishchi kuchi, ko‘p vaqt talab qiladi hamda xizmat narxi yuqoriligi ko‘p sonli avtomobillarda emissiya o‘lchovlarini o‘tkazishda murakkab bo‘lib qolmoqda. Foydalanishdagi avtomobillarning elektron boshqaruv bloki (EBB) ma’lumotlaridan foydalanib chiqindi gazlarni monitoring qilishning raqamlashtirilgan uslubini ishlab chiqish bugungi kunda dolzarb hisoblanadi. Ushbu maqolada avtomobilning EBB malumotlarini raqamlashtirish orqali chiqindi gazlar tarkibidagi CO2 yo‘l birligiga to‘g‘ri keluvchi miqdorini aniqlash uslubi taklif qilingan.

Kalit so‘zlar: chiqindi gazlar, benzinli dvigatel, EBB, raqamlashtirish, OBD-II, monitoring

## 1. Kirish

O‘zbekiston Avtotransport vositalari sonining ortib borishi ekologiya va atrof-muhitga ta’sir darajasining sezilarli darajada oshishiga sabab bo‘lmoqda [1]. Ushbu jarayonni boshqarish maqsadida jahon miqyosida avtomobillardan ajralib chiqadigan zararli gazlarni kamaytirishga qaratilgan qat’iy ekologik talablar, normativ hujjatlar hamda ilg‘or sinov va baholash uslublari joriy etilmoqda [2]. Jumladan WLTP - laboratoriya sharoitida avtomobilni real haydash sharoitlariga yaqinlashtirilgan sikllarda sinovdan o‘tkazishni ta’minlaydigan metodologiya

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bo‘lib, RDE esa transport vositalarining haqiqiy yo‘llarda chiqindi gazlarini PEMS (Portable Emission Measurement System) qurilmalari yordamida bevosita o‘lchash imkonini beradi [3,4]. Mazkur yondashuvlarning afzalligi shundaki, chiqindi gazlar real haydash sharoitida baholanadi, laboratoriya natijalari bilan yo‘l sharoitidagi tafovutlar bartaraf etiladi hamda ishlab chiqaruvchilarning ekologik mas’uliyati kuchayadi. Shu bilan birga, bu sinovlarning ayrim kamchiliklari ham mavjud bo‘lib, ular yuqori xarajat talab etishi, ko‘p vaqt olishi va natijalarni qayta ishlab chiqish jarayonining murakkabligi bilan tavsiflanadi. WLTP va RDE sinov metodologiyalari Euro 6 ekologik talablari bilan uzviy bog‘liq bo‘lib, ushbu standartlarda belgilangan NOx, CO, HC va PM bo‘yicha qat’iy me’yoriy ko‘rsatkichlarga muvofiqlikni real sharoitlarda ham nazorat qilish imkonini beradi[5,6,7]. Natijada, Euro 6 standartlarining amaliy samaradorligi oshib, avtomobil transporti chiqindilarini kamaytirish bo‘yicha xalqaro ekologik siyosat yanada mustahkamlanadi.

Zamonaviy avtomobilsozlikda ekologik talablarni bajarish va zararli chiqindilarni kamaytirish maqsadida bir qator ilg‘or texnologiyalar keng qo‘llanilmoqda. Masalan, turbocharging (turbokompressor) texnologiyasi dvigatel quvvati va momentini oshirish, yonilg‘i sarfini kamaytirish hamda $CO_2$ emissiyasini pasaytirishda muhim rol o‘ynab, kichik hajmli dvigatellarda yuqori samaradorlik (“downsizing”)ni ta’minlaydi [8]. Biroq, ushbu tizimning murakkab tuzilishi va yuqori ishlab chiqarish xarajatlari, turbolag hodisasi hamda texnik xizmat ko‘rsatishda qo‘shimcha ehtiyotkorlik zarurati uning asosiy kamchiliklari hisoblanadi. Shuningdek, Gasoline Direct Injection (GDI) - yoqilg‘ini bevosita purkash texnologiyasi yoqilg‘i-havo aralashmasining aniq nazoratini ta’minlab, dvigatel samaradorligini oshiradi, yonilg‘i sarfini kamaytiradi va $CO_2$ chiqindilarini pasaytiradi. Shu bilan birga, yuqori bosimli tizimning murakkabligi va qimmatligi, NOx emissiyasining ortishi hamda karbonat qoldiqlari hosil bo‘lishi ushbu texnologiyaning salbiy jihatlaridan hisoblanadi [9]. Bundan tashqari, start-stop tizimlari ham keng tatbiq etilib, transport vositalari svetofor yoki tirbandliklarda to‘xtaganda dvigatelni avtomatik ravishda o‘chirib-yoqib turishi orqali yonilg‘i tejamkorligini ta’minlaydi hamda $CO_2$ va CO chiqindilarini kamaytiradi [10].

Shu bilan birga, starter va akkumulyatorning tez eskirishi, sovuq iqlim sharoitida samaradorlikning pasayishi va qisqa masofali harakatlarda amaliy foydaning cheklanishi uning kamchiliklarini tashkil etadi. Uch komponentil katalitik neytrallash texnologiyasi (3-way catalyst) CO, HC va NOx komponentlarini bir vaqtning o‘zida neytrallash imkoniyatiga ega bo‘lib, Euro 6 kabi qat’iy ekologik me’yorlarni bajarishda asosiy vositalardan biri hisoblanadi [11]. Biroq, platina, palladiy va rodiy kabi qimmatbaho metallardan foydalanish zarurati, yuqori harorat sharoitida samarali ishlashi (cold start davrida samaradorlikning pastligi) hamda vaqt o‘tishi bilan samaradorlikning pasayishi uning muhim cheklovlari sifatida qayd etiladi. Yuqorida qayd etilgan texnologik yutuqlar va ekologik me’yoriy talablarning inobotga olgan holda ekspluatatsiyadagi avtomobillardan chiqayotgan chiqindi gazlarni monitoring qilish jarayonlarini raqamlashtirilgan usullarini ishlab chiqish, dolzarb yo‘nalishlaridan biri hisoblanadi. Mazkur yondashuv nafaqat real vaqt rejimida emissiya jarayonlarini kuzatish imkonini yaratadi, balki yig‘ilgan ma’lumotlarni tahlil qilish, ekologik xavf darajasini baholash hamda transport vositalarining xalqaro standartlarga muvofiqligini ta’minlashda muhim ahamiyat kasb etadi. Shu sababli, raqamlashtirilgan monitoring tizimlarini joriy etish avtomobilsozlik sanoati va ekologik nazorat amaliyotining integratsiyalashgan rivojlanishini ta’minlovchi muhim ilmiy-texnik vazifadir.

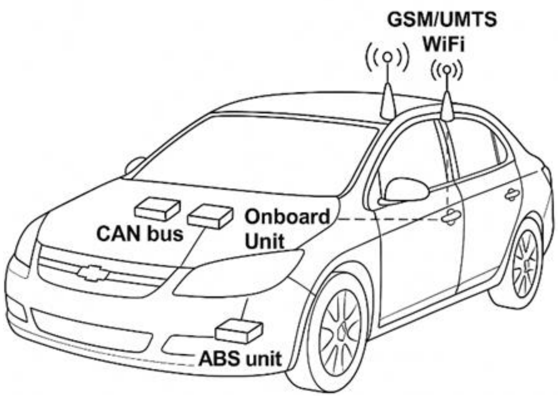
Chiqindi gazlarni xisob uslublari xamda sinov uslublari bilan aniqlash 1936 yildan boshlanib kelgan. Mualliflar B. A. D'Alleva and W. G. Lovell ning maqolasida karbonat angidrid, uglerod oksidi, vodorod, metan va kislorod uchun to‘liq chiqindi gaz tahlillari turli xil ish sharoitlari va turli xil havo o‘lchash moslamalari bo‘lgan uchta dvigatel uchun havo-yonilg‘i nisbatlarini bevosita o‘lchangan[14].

Yevropa mamlakatlari bu soxada ko‘plab ilmiy tadqiqotlar bilan shug‘ullanib kelishmoqda. Jumladan Justin D.K. Bishop va boshqalar tomonidan avtomobilning xarakat siklidagi yonilg‘i sarfi va undagi chiqindi gazlarning vaqt birligida miqdorlari xaqida ish olib borgan [15]. Marcin Noga tomonidan turbinali besh zarbli dvigatel uchun chiqindi gazni tozalash tizimini ishlab chiqish bo‘yicha tadqiqotlar natijalari keltirilgan. Besh zarbli dvigatelning xarakterli xususiyati umumiy samaradorlikni oshirish uchun qo‘shimcha kengaytirish jarayonidan foydalanish hisoblanadi. Katalitik konvertor uchun qiyinchilik shundaki, u past chiqindi gaz haroratiga ega. [16]

Hata Hiroo va boshqalar. Ular ushbu tadqiqotida turli xil to‘xtash vaqtlaridan keyin ishlaydigan benzinli dvigatellarning chiqindi gazlari shassi dinamometri yordamida o‘lchashdi. Uch tomonlama katalitik konvertorni qayta ishlashdan keyingi quvvati vaqtga bog‘liq energiya tejash tenglamasi bilan birlashtirilgan katalizatordagi kimyoviy reaksiyalarni kimyoviy kinetik modellashtirish orqali baholashdi [17].

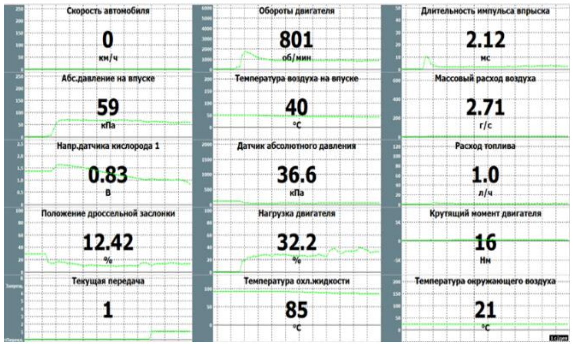
## 2. Tadqiqot metodologiyasi

NEDC va WLTC sikllarini o‘z ichiga olgan an’anaviy transport vositalarini sinovdan o‘tkazish usullari haqiqiy haydash sharoitlarini to‘liq aks ettira olmaydi, chunki haydovchining haydash uslubi yoqilg‘i sarfi va chiqindilariga sezilarli darajada ta’sir qiladi. Haqiqiy ish sharoitida transport vositasining atrof-muhitga ta’sirini va atrof-muhitga ta'sirini aniqlash murakkab ilmiy va texnik vazifadir. Shuning uchun, haqiqiy ish sharoitida transport vositasining atrof-muhitga ta’sirini aniqlash uchun bort elektron boshqaruv tizimiga ulangan turli sensorlardan olingan ma’lumotlar asosida haqiqiy haydash jarayonlari qayd etildi va tahlil qilindi.




**1-rasm. Bortdagi o'lchov tizimlari**

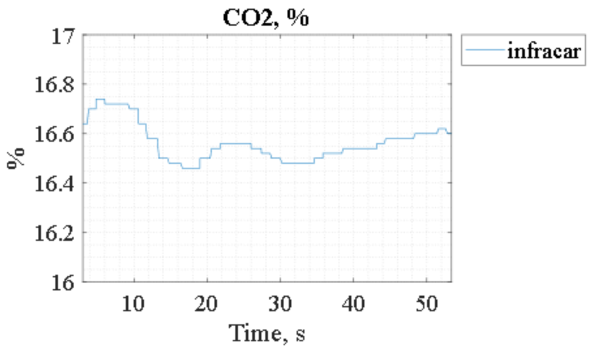
OBD-II interfeysi orqali yig‘ilgan parametrlar transport vositasining ishlash rejimlari va chiqindi gazlar shakllanishi bilan bevosita bog‘liq bo‘lgan bir qator muhim ko‘rsatkichlarni o‘z ichiga oladi. Bular jumlasiga avtomobil tezligi, havo-yoqilg‘i aralashmasining stexiometrik nisbatini belgilovchi ko‘rsatkichlar, kiruvchi havoning massaviy oqim tezligi, dvigatelning aylanish chastotasi (rpm), dvigatel yuklamasi, gaz pedali holati, lambda sensorining chiqish kuchlanishi, yonilg‘i injektorining ochiqlik vaqti hamda kiruvchi havoning harorati kiradi 1-rasm. Mazkur parametrlarning tizimli monitoringi va ularning o‘zaro bog‘liqligini tahlil qilish dvigatel ish jarayonining ekologik samaradorligini baholash va chiqindi gazlarni raqamli usulda aniqlash uchun muhim ilmiy asos yaratadi. Eksperimental tadqiqotlarni o‘tkazish jarayonida sinov obyekti sifatida Chevrolet Cobalt rusumli avtomobil tanlab olindi. Mazkur avtomobilning tanlanishiga bir necha omillar sabab bo‘ldi, jumladan, uning 1,5 litr hajmdagi benzinli dvigateli mintaqada keng tarqalgan va amaliyotda faol ekspluatatsiya qilinadigan transport vositalariga xos texnik ko‘rsatkichlarga ega ekanligi, shuningdek, mahalliy sharoitlarda qo‘llanilayotgan ekologik talablar va xalqaro standartlarga mos keluvchi sinov natijalarini olish imkoniyatini berishi. Bundan tashqari, Chevrolet Cobalt avtomobilining OBD-II tizimi orqali zarur diagnostik parametrlarni ishonchli qayd etish imkoniyati mavjudligi ham ushbu modelni tanlashda muhim mezon bo‘lib xizmat qildi. Chiqindi gazlar tarkibini aniqlashda Infrakar gazanalizatoridan foydalanildi. Gazanalizator statsionar ish rejimida ishlashini inobotga olgan holda sinovlar har xil o‘zgarmas tezliklarda o'tkazildi.



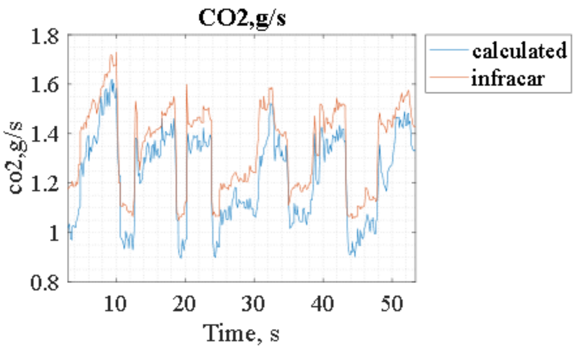
**2-rasm. Avtomobil OBD II parametrlarini to‘plash uchun dasturiy interfeys**

## 3. Tahlil va natijalar

Avtomobil chiqindi gazlarida $CO_2$ konsentratsiyasini aniqlash jarayonida dastlab eksperimental sinovlar o‘tkazilib, INFRACAR gazanalizatori yordamida real vaqt rejimida turli o‘zgarmas tezlik rejimlarida $CO_2$ ning hajmiy ulushi qayd etildi (2-rasm). Keyingi bosqichda olingan eksperimental ma’lumotlar matematik tahlil asosida qayta ishlanib, $CO_2$ emissiyasining vaqt birligiga to‘g‘ri keluvchimassaviy miqdori aniqlandi. Shu bilan birga, OBD-II interfeysi orqali olingan parametrlar asosida $CO_2$ miqdori hisoblandi va natijalar eksperimental sinov ko‘rsatkichlari bilan taqqoslandi. Solishtiruv natijalari shuni ko‘rsatdiki, hisoblangan qiymatlar va gazanalizator yordamida qayd etilgan ma’lumotlar o‘rtasidagi farq 3–4 % dan oshmadi (3-rasm), bu esa ishlab chiqilgan hisoblash metodikasining yuqori aniqligi va amaliy qo‘llash uchun yetarlicha ishonchliligini tasdiqlaydi.




**3 – rasm. Gaz analizatori natijalari**




**4 – rasm. Hisob va sinov natijalari**

## 4. Xulosa

O‘tkazilgan eksperimental sinovlar va matematik tahlillar shuni ko‘rsatdiki, avtomobil chiqindi gazlaridagi $CO_2$ konsentratsiyasini aniqlashda laboratoriya sharoitida INFRACAR gazanalizatori yordamida olingan natijalar bilan OBD-II parametrlari asosida hisoblash uslubi orasida farq 3–4 % dan oshmaganligi kuzatildi. Ushbu ko‘rsatkich ishlab chiqilgan hisoblash metodikasining yuqori aniqlikka ega ekanligini va uni amaliyotga qo‘llash imkoniyatlarini tasdiqlaydi. Bunda raqamlashtirilgan yondashuv sinov o‘lchovlariga nisbatan tezkorlik, qulaylik va iqtisodiy samaradorlik kabi ustunliklarga ega bo‘lib, transport vositalarining ekspluatatsiya jarayonida ekologik monitoring samaradorligini oshirish uchun keng imkoniyat yaratadi. Shu bilan birga, natijalar hisoblash algoritmlarini yanada takomillashtirish, hamda turli haydash sharoitlari va dvigatel yuklama rejimlarida qo‘shimcha sinovlar o‘tkazish zarurligini ko‘rsatadi.

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