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Restoration of the thermophysical properties of antifreezes via a regeneration method based on regression analysis

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Abstract: This paper presents an assessment of the efficiency of coolant regeneration based on the analysis of their thermophysical properties. Experimental studies were carried out on three antifreeze samples: fresh, used, and regenerated. Based on the obtained temperature data, heating and cooling curves were constructed, and a comparative analysis of heat capacity and heat transfer time was performed. Regression modeling methods were applied for quantitative evaluation, allowing the derivation of approximating relationships between temperature and time. The results show that the regenerated antifreeze exhibits temperature characteristics that are nearly comparable to those of the fresh sample, while the used antifreeze demonstrates degraded heat transfer performance. The obtained findings confirm the effectiveness of the proposed regeneration method and the feasibility of restoring the operational properties of cooling liquids.

Keywords: antifreeze, regeneration, coolants, thermophysical properties, heat capacity, heat transfer, regression modeling, temperature behavior, ethylene glycol

Regressiya tahliliga asoslangan regeneratsiya usuli yordamida antifrizlarning issiqlik-fizik xususiyatlarini tiklash

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Annotatsiya: Mazkur ishda sovituvchi suyuqliklarning issiqlik-fizik xususiyatlarini tahlil qilish asosida ularni regeneratsiya qilish samaradorligi baholangan. Tadqiqot doirasida uch xil antifriz namunasi — yangi, ishlatilgan va regeneratsiya qilingan namunalar ustida eksperimental izlanishlar olib borildi. Olingan harorat ma'lumotlari asosida qizish va sovish egri chiziqi qurildi hamda issiqlik sig'imi va issiqlik uzatish vaqti bo'yicha taqqoslama tahlil amalga oshirildi. Miqdoriy baholash uchun regressiya modellashtirish usullaridan foydalanilib, haroratning vaqtga bog'liqligini ifodalovchi approksimatsion tenglamalar olindi. Natijalar shuni ko'rsatdiki, regeneratsiya qilingan antifriz o'zining harorat xususiyatlari bo'yicha deyarli yangi namunadan kam emas, ishlatilgan antifriz esa issiqlik uzatish ko'rsatkichlarining yomonlashgani bilan tavsiflanadi. Olingan natijalar taklif etilgan regeneratsiya usulining samaradorligini hamda sovituvchi suyuqliklarning ekspluatatsion xususiyatlarini tiklash imkoniyatini tasdiqlaydi.

Kalit so'zlar: antifriz, regeneratsiya, sovituvchi suyuqliklar, issiqlik-fizik xususiyatlar, issiqlik sig'imi, issiqlik uzatish, regressiya tahlili, harorat xususiyatlari, etilenglikol

1. Kirish


Avtomobil transporti jadal rivojlanib borayotgan sharoitda ichki yonuv dvigatellarining sovitish tizimlarining ishonchli ishlashini ta'minlash alohida ahamiyat kasb etadi. Ushbu tizimlarning samaradorligi ko'p jihatdan qo'llaniladigan sovituvchi suyuqliklar, xususan antifrizlar sifatiga bog'liq bo'lib, ular nafaqat issiqlikni chiqarib yuborish, balki tizim elementlarini korroziya va cho'kmalardan himoya qilish vazifasini ham bajaradi [1, 2].

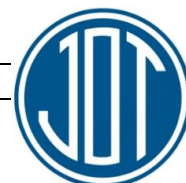
Ekspluatatsiya jarayonida antifrizlar yuqori haroratlar, oksidlanish jarayonlari va turli ifloslanishlar ta'sirida bo'lib, bu ularning fizik-kimyoviy hamda issiqlik-fizik xususiyatlarining yomonlashishiga olib keladi. Avvalo, bu issiqlik sig'imining kamayishi va issiqlik uzatish

barqarorligining buzilishida namoyon bo'ladi, natijada dvigatelning qizib ketish xavfi ortadi va uning xizmat muddati qisqaradi [3]. Shu sababli, faqatgina ishlatilgan sovituvchi suyuqliklarni almashirishga asoslangan an'anaviy yondashuv har doim ham iqtisodiy va ekologik jihatdan maqsadga muvofiq emas.

Mazkur muammoning dolzarbligi yana shundan iboratki, etilenglikol asosidagi antifrizlar zaharli moddalarga kiradi va ularni noto'g'ri utilitatsiya qilish atrof-muhit, jumladan tuproq va suv resurslarining ifloslanishiga olib keladi [4]. Hozirgi vaqtda ishlatilgan suyuqliklarning ekspluatatsion xususiyatlarini tiklash va ularni qayta foydalanishga yo'naltirilgan resurs tejovchi texnologiyalarni ishlab chiqishga katta e'tibor qaratilmoqda [5].

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Mavjud tadqiqotlar tahlili shuni ko'rsatadiki, antifrizlarni tozalash va regeneratsiya qilishga bag'ishlangan ayrim ishlar mavjud bo'lishiga qaramay, ularning issiqlik-fizik xususiyatlarini tiklash hamda bunday jarayonlarning samaradorligini miqdoriy baholash masalalari yetarlicha o'rganilmagan. Xususan, qizish va sovish jarayonlarida harorat o'zgarishlarining dinamikasini tahlil qilishda matematik usullardan foydalanish qo'shimcha asoslashni talab etadi [6,7].

Shu munosabat bilan, mazkur ishning maqsadi antifrizlarni regeneratsiya qilish samaradorligini ularning harorat xususiyatlarini tahlil qilish asosida, regressiya modellashtirish usullaridan foydalangan holda baholashdan iborat. Bunda ishlatilgan, regeneratsiya qilingan va yangi antifriz namunalarning issiqlik-fizik xulq-atvori o'zaro taqqoslab o'rganiladi.

2. Tadqiqot metodologiyasi

Oldingi tadqiqotlarda uch turdagi antifriz — yangi, ishlatilgan va regeneratsiya qilingan namunalarning issiqlik-fizik xususiyatlari o'rganilgan [10]. Eksperimental natijalar jadval ko'rinishida taqdim etilib, har bir namuna uchun qizish va sovish jarayonlarining harorat egri chiziqlari qurilgan. Ushbu ma'lumotlar asosida issiqlik uzatish vaqti hisoblab chiqilgan va issiqlik sig'imi bo'yicha taqqoslama tahlil o'tkazilgan. Aniqlanishicha, issiqlik sig'imi yuqori bo'lgan suyuqliklarda qizish jarayoni uzoqroq davom etadi va sovish sekinroq kechadi.

1-jadval

Antifrizlarning qizish haroratlari (tuzatilgan variant)

№	Tajriba vaqti	Ishlatilgan antifriz, °C	Regeneratsiya qilingan antifriz, °C	Yangi zavod antifrizi, °C
1	00:00:00	31.0	31.0	30.1
2	00:03:45	40.6	40.7	44.8
3	00:07:30	57.5	57.2	60.4
4	00:11:15	71.8	70.6	73.5
5	00:15:00	83.5	81.9	83.2
6	00:18:45	92.0	88.4	88.6
7	00:22:30	99.7	92.8	94.6
8	00:26:15	101.7	97.0	99.4
9	00:30:00	99.8	98.7	98.2
10	00:33:45	96.3	94.9	92.5

11	00:37:30	92.4	88.9	87.8
12	00:41:15	87.8	85.3	83.1
13	00:45:00	84.4	80.3	77.7
14	00:48:45	81.1	75.0	74.5
15	00:52:30	77.5	71.9	70.4
16	00:56:15	74.3	68.6	66.4
17	01:00:00	71.6	65.4	64.1
18	01:03:45	69.4	62.3	62.2
19	01:07:30	66.8	60.0	59.1
20	01:11:15	64.5	57.7	57.9
21	01:15:00	62.4	55.9	55.8
22	01:18:45	60.7	54.5	54.0
23	01:22:30	58.8	52.5	52.5
24	01:26:15	57.2	51.2	50.8
25	01:30:00	55.7	49.4	49.1
26	01:33:45	54.2	48.2	47.8
27	01:37:30	52.4	47.1	46.9
28	01:41:15	51.3	46.1	45.7
29	01:45:00	49.8	45.0	44.5
30	01:48:45	49.1	43.9	43.9
31	01:54:50	47.4	42.6	42.5

2-jadval

Tadqiq etilgan sovutuvchi suyuqliklarning o'rtacha harorat qiymatlarini taqqoslama tahlili

Taqqoslanayotgan suyuqliklar	Harorat farqi, °C	Og'ish, %	Izoh
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Ishlatilgan va regeneratsiya qilingan	+4,61	+7,08	Ishlatilgan antifriz ko'proq qiziydi
Ishlatilgan va yangi	+4,45	+6,83	Ishlatilgan antifrizning issiqlik uzatish qobiliyati past
Regeneratsiya qilingan va yangi	-0,15	-0,23	Deyarli mos keladi

Jadvaldan ko'rinadiki, regeneratsiya qilingan va yangi antifrizlarning o'rtacha haroratlari o'rtasidagi farq 0,3 % dan kam bo'lib, bu sovituvchi suyuqlikning issiqlik-fizik xususiyatlari regeneratsiyadan so'ng tiklanganligini ko'rsatadi. Shu bilan birga, ishlatilgan antifriz yuqoriroq ishchi haroratlar bilan tavsiflanadi, bu esa ifloslanishi va qo'shimchalarning degradatsiyasi natijasida uning issiqlikni olib chiqish qobiliyati yomonlashganini bildiradi.

Olingan eksperimental ma'lumotlar asosida tadqiq etilgan antifrizlarning termodinamik xususiyatlari matematik tahlil qilindi. Ma'lumotlarga ishlov berishda regressiya modellashtirish usullaridan foydalanilib, har bir namuna uchun haroratning qizish va sovish vaqtiga bog'liqligini ifodalovchi approksimatsion tenglamalar olindi. Hisoblashlar Microsoft Excel 2021 va OriginPro 2023 dasturiy paketlari yordamida amalga oshirildi. Ushbu bog'liqliklar asosida harorat o'zgarishlarining dinamikasini ifodalovchi grafik modellar qurildi. Mazkur grafiklar jarayonni nafaqat vizual ko'rsatish, balki ishlatilgan, regeneratsiya qilingan va yangi antifrizlar o'rtasidagi farqlarni miqdoriy baholash imkonini beradi.

Approksimatsiya funksiyasi sifatida uchinchi tartibli polinomial regressiya tanlandi, chunki aynan shu model eksperimental va hisobiy ma'lumotlar o'rtasida eng yaxshi moslikni ta'minladi. Olingan bog'liqliklar asosida harorat o'zgarishining dinamikasini ifodalovchi grafik modellar (3-rasm) qurildi. Ushbu grafiklar jarayonni vizual ifodalash bilan birga, ishlatilgan, regeneratsiya qilingan va yangi antifrizlar o'rtasidagi farqlarni miqdoriy jihatdan baholash imkonini beradi.

Olingan modellar quyidagi ifoda bilan tavsiflanadi:

$$T(\tau) = a_0 + a_1\tau + a_2\tau^2 + a_3\tau^3$$

bu yerda: $T(\tau)$ – suyuqlik harorati, °C;

τ – qizish/sovish vaqti, s;

a – har bir namuna uchun aniqlangan regressiya koeffitsiyentlari.

Regressiya tenglamasi koeffitsiyentlari quyidagi o'lchov birliklariga ega:

a_0 – harorat, °C;

a_1 – °C/c;

a_2 – °C/c²;

a_3 – °C/c³.

Harorat T (°C) ning vaqt τ (sekund) ga bog'liqligi uchun quyidagi tenglamalar olindi:

1 — Ishlatilgan antifriz:

$$T(\tau) = 36.95 + 0.0624\tau - 2.03 \cdot 10^{-5}\tau^2 + 1.70 \cdot 10^{-9}\tau^3,$$

$R^2 = 0.895$

Determinatsiya koeffitsiyenti: $R^2 = 0.895$

2 - Regeneratsiya qilingan antifriz:

$$T(\tau) = 37.12 + 0.0599\tau - 2.02 \cdot 10^{-5}\tau^2 + 1.72 \cdot 10^{-9}\tau^3, R^2 = 0.90$$

2

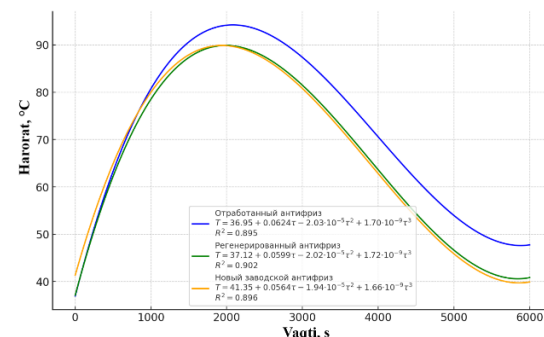
Determinatsiya koeffitsiyenti: $R^2 = 0.902$

3 - Yangi zavod antifrizi:

$$T(\tau) = 41.35 + 0.0564\tau - 1.94 \cdot 10^{-5}\tau^2 + 1.66 \cdot 10^{-9}\tau^3, R^2 = 0.89$$

6

Determinatsiya koeffitsiyenti: $R^2 = 0.896$



1-rasm. Tadqiq etilgan antifrizlarning harorat xususiyatlari bo'yicha regressiya modellari

O'tkazilgan matematik tahlil natijalari shuni ko'rsatdiki, tadqiq etilgan barcha namunalar — ishlatilgan, regeneratsiya qilingan va yangi antifrizlar — uchinchi tartibli polinomial modellar yordamida yetarli darajada aniq tavsiflanadi. Bunda determinatsiya koeffitsiyentlari 0,895 dan 0,902 gacha bo'lgan oraliqda joylashgan bo'lib, bu tanlangan approksimatsiya usulining yuqori ishonchligini tasdiqlaydi.

3. Xulosa

Olingan harorat egri chiziqlarini taqqoslash shuni ko'rsatdiki, ishlatilgan antifriz sovish jarayonida yanada kuchliroq nolinearlik bilan tavsiflanadi. Bunday xulq-atvor uning issiqlik sig'imining kamayganligini va natijada issiqlikni samarali olib chiqish qobiliyati yomonlashganligini ko'rsatadi.

Shu bilan birga, regeneratsiya qilingan antifrizning harorat o'zgarishlari deyarli yangi antifriz ko'rsatkichlariga mos keladi. Egri chiziq shakli, shuningdek qizish va sovish tezliklari o'rtasidagi farqlar juda kichik bo'lib, hisoblangan koeffitsiyentlar ham o'zaro yaqin qiymatlarga ega.

Olingan natijalar qo'llanilgan regeneratsiya usulining yuqori samaradorligini ko'rsatadi hamda sovituvchi suyuqliklarning issiqlik-fizik xususiyatlarini yangi antifriz darajasiga yaqin holda tiklash imkonini tasdiqlaydi.

Foydalangan adabiyotlar / References

[1] Кузнецов В.В., Иванов А.С. Исследование эксплуатационных свойств охлаждающих жидкостей // Химия и технология топлив и масел. – 2015. – №4. – С. 32–36.

[2] Петров Д.А., Смирнов И.В. Влияние качества охлаждающих жидкостей на тепловой режим двигателей внутреннего сгорания // Вестник машиностроения. – 2018. – №7. – С. 45–49.

[3] Сидоров А.П., Климов Н.Н. Анализ теплофизических свойств антифризов в процессе



эксплуатации // Известия вузов. Машиностроение. – 2019. – №10. – С. 58–63.

[4] Морозов С.В., Ефимов П.А. Экологические аспекты утилизации и регенерации охлаждающих жидкостей // Транспорт на альтернативном топливе. – 2020. – №2. – С. 25–30.

[5] Фёдоров В.И., Николаев Д.С. Влияние отходов этиленгликоля на окружающую среду и методы их переработки // Экология и промышленность России. – 2017. – №6. – С. 40–44.

[6] Алексеев Р.В., Громов К.Н. Применение методов математического моделирования при анализе теплообмена жидкостей // Современные наукоемкие технологии. – 2021. – №9. – С. 112–117.

[7] ГОСТ 28084-89. Жидкости охлаждающие низкотемпературные. Технические условия.

[8] Nakimov, R., & Ayrapetov, D. (2024). Regeneration of spent low-freezing liquids. AIP Conference Proceedings, 3045, 030064. <https://doi.org/10.1063/5.0197857>

[9] Айрапетов Д.А., Хакимов Р.М., Алимухамедов Ш.П. Усовершенствованный метод очистки и повторного использования отработанных охлаждающих жидкостей // Universum: технические науки : электрон. научн. журн. 2025. 9(138).

[10] Айрапетов Д.А., Хакимов Р.М. Экспериментальная оценка теплофизических свойств

антифризов на основе температурных зависимостей // Development of science Ilmiy jurnal 2026/4 VOLUME 6 369- 377 (ISSN 3030 -3907) <https://www.devos.uz/article.php?id=4741>.

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