Method of cleaning from the carbon deposits of the surfaces of the elements of internal-combustion engines without their unbuttoning

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Abstract. A review of existing technologies for cleaning carbon deposits from machine parts and mechanisms working in contact with hydrocarbon substances (fuel, lubricant, heating agency) at a wall temperature of 120 ° C to 350 ° C shows the diversity of such deposits in chemical composition and physical properties. Carbon deposits are divided into easily removable and difficult to remove deposits. Soot (black smoke) belongs to easily removed carbon deposits; varnish and coke are difficult to remove deposits. Soot is a product of incomplete combustion of fuel and includes carbon, light hydrocarbons (up to 30% by weight) and in small quantities various compounds, including carcinogenic. Lake and resinous deposits are carbon deposits that form as a thin layer, firmly held on the surfaces of the channels. Lake is a product of liquid-phase oxidation and consists of 20 ... 40% of carbon molecules and 60 ... 70% of hydrogen molecules. Coke (or coke deposits) are black solid carbonaceous substances consisting mainly of a mixture of carbon molecules and high-molecular-weight hydrocarbons (80%) and hydrogen molecules (20%). The most common methods of cleaning machine parts from various kinds of pollution and sediments are physical, chemical and chemical-thermal methods. Experimental work has been performed to evaluate the effectiveness of these methods. The experiments were carried out on an open loop installation with a flow reactor. Replaceable stainless steel and high-temperature alloy tubes were used as a reactor. The regime parameters during the experiment were maintained unchanged, and the temperature state of the reactor was monitored at specified intervals.

Keywords: Internal combustion engine, machine parts, carbon deposits, solvent - emulsifying agents, multicomponent synthetic detergents.

Introduction

Replaceable tubes made of 12X18H10T stainless steel and XH60BT heat-resistant alloy were used as a reactor. The regime parameters during the experiment were maintained unchanged, and the temperature state of the reactor was monitored at specified intervals. After testing, the tubes were cut into 20 pieces of 50 mm each [1].

Elemental and group chemical composition of carbonaceous deposits was determined by microelement analysis, selective dissolution, IR spectroscopy and ozonolysis, as well as by thin-layer chromatography [17].
Determination of the elemental composition of carbon deposits was carried out by means of thermal decomposition, oxidation to carbon dioxide (CO2) and water (H2O), followed by absorption of CO2 and H2O in the absorption apparatus, using a microelement analysis unit. The formed amount of carbon dioxide and water was determined by the difference in the mass of the respective absorbers before and after the burning of the sediments [3]. Based on the data obtained: the elemental composition of carbonaceous deposits was determined by the amount of carbon dioxide and water formed.

Group chemical composition of carbon deposits was determined by successive extraction with n-heptane, with a mixture of ethanol and benzene (ratio 1:3) and pyrite. The choice of these solvents is based on the fact that they are respectively eluted resinous compounds (oil, neutral resin and hydroxy acid), asphaltrotule connections and pirobox [2]. The selected sediment fractions were analyzed by IR spectroscopy, thin-layer chromatography and low-temperature ozone.

The following solvent mixtures were used as the mobile phase: hexane - benzene (1:1 ratio), methanol - water - acetone (2:1:1 ratio). The manifestation of the plates was carried out with iodine vapor and an aqueous solution of potassium permanganate.

Removal of carbonaceous deposits by synthetic detergents and solvent-emulsifying agents was carried out by the method of immersion [16].

As synthetic detergents were used multicomponent compositions of the two options shown in the Table 1.

Table 1. The compositions of multicomponent synthetic detergents

| Composition number | Component Name       | Content by weight [%] |
|--------------------|----------------------|-----------------------|
| Composition 1      | Calcined soda        | 50                    |
|                    | Triopolyphosphate natrium | 30                  |
|                    | Sodium Metasilicate  | 16,5                  |
|                    | Synthanol DS-10      | 3,5                   |
|                    | Calcined soda        | 50                    |
| Composition 2      | Triopolyphosphate natrium | 30                  |
|                    | Sodium methyl silicate | 10                 |
|                    | Synthanol DT-7       | 8                     |
|                    | Alkyl sulfate        | 2                     |

The following multicomponent compositions given in the table 2 were used as solvent-emulsifying agents.

The choice of the compositions of synthetic detergents and solvent-emulsifying agents is due to the fact that they currently have the most effective cleansing properties [1].

Cleaning mode using synthetic detergents: concentration 30 ... 80 g/l, temperature 70 ... 85 oC, duration 30 ... 60 min.

Cleaning mode using solvent-emulsifying agents: concentration 40 ... 80 g/l, temperature 20 ... 50 oC, duration 30 ... 60 min.

Table 2. Compositions of multicomponent solvent-emulsifying agents

| Composition number | Component name         | Content by weight [%] |
|--------------------|------------------------|-----------------------|
| Composition 1      | Diesel fuel            | 48                    |
|                    | White ethanol          | 35                    |
|                    | OP-4                   | 10                    |
|                    | OP-1                   | 1                     |
|                    | Sulphonate paste       | 0,15                  |
|                    | Water                  | 1,85                  |
The removal of carbon deposits by burning was carried out at a temperature of 800 ... 950 °C, for 20 ... 40 minutes.

Analysis of carbon deposits by the methods of selective dissolution of IR spectroscopy, liquid and thin-layer chromatography showed that their group chemical composition is strongly dependent on the surface temperature [4,5]. The obtained data on the chemical composition of sediments depending on the wall temperature are shown in the Table 3.

When cleaning the elements of the diesel engine from carbon deposits formed at different temperatures, by synthetic detergents and solvent-emulsifying agents (table 4) it was found that the degree of purification from carbon deposits using solvent-emulsifying agents about 2...3 times more compared to synthetic detergents.

| Sediment components (%) weights | The temperature of deposits formation, [°C] |
|--------------------------------|------------------------------------------|
|                                | 300           | 400           | 500           | 600           |
| Resinous substances            | 90...98       | 80...90       | 55...70       | 20...30       |
| Asphaltene-resinous substances | 1,5...5       | 3...6         | 15...35       | 30...40       |
| Carbene and Carboid Substances | 0,1...0,7     | 0,2...0,8     | 2...10        | 20...40       |

This degree of purification is not sufficient for practical purposes, especially for parts operating in the field of high temperatures of sediment formation [18].

| Temperature of formation of carbon deposits, °C | Degree of purification [%] |
|-----------------------------------------------|-----------------------------|
|                                               | Synthetic detergents | Solvent-emulsifying agents |
| 300                                           | 25...45                 | 60...70                    |
| 400                                           | 20...30                 | 40...50                    |
| 500                                           | 15...20                 | 30...40                    |
| 600                                           | 10...15                 | 20...30                    |

The obtained results on cleaning of carbon deposits by synthetic detergents and solvent-emulsifying agents explain the fact that they allow to remove mainly resinous substances, however, they are ineffective in cleaning from asphaltene-resinous and carbon-like substances [6-8].

Removal of carbon deposits by burning is carried out at a high temperature (800.. .950 oC). At this temperature, there is a complete combustion of carbon deposits to form carbon dioxide and water. The duration of removal of deposits from the elements of the diesel engine takes about 60...90 min, depending on their number the level of removal is 90... 100%. It should be noted that the degree and duration of removal depends on the temperature of formation of carbon deposits [9-11].
temperature of sediment formation decreases, the degree of channel coking decreases and the duration of sediment removal decreases.

The main disadvantage of removing deposits by burning is the high energy intensity of the process and the possible deformation of the material of the engine elements due to high temperatures [12].

The essence of the method proposed by the authors is the following sequence of actions. Conversion of sediments, which are a mixture of high-molecular organic substances, into compounds with a lower molecular weight, which have increased solubility in solutions, by processing a special gas mixture containing ozone at a temperature of 80...130 °C for 0.1...0.5 hours.

After processing, the formed low-molecular products are removed, consistently washing with a mixture of solvents (at a temperature of 70...90 °C for 0.1...0.5 hours) and an aqueous solution of a mixture of detergents (at a temperature of 60...80 °C for 0.1...0.5 h.) followed by washing with hot water and drying with compressed air. The degree of removal reaches 100%.

Conclusion

The main technical and economic indicators of the new method include the following aspects: increase of overhaul life of engine parts; possibility of using standard equipment; universality (the ability to remove deposits in products of complex shape without disassembling and under operating conditions); low power consumption of the process; complete safety of cleaned parts; high environmental performance [13-15].

The novelty of the proposed method include: the special composition of the gas mixture; low cleaning mode settings; high efficiency and versatility; the possibility of developing new technologies for cleaning engine parts and other machines and mechanisms from pollution of various origins.

References

[1] Petrovski, S. V., Kozlovski, V. N., Petrovski, A. V., Skripnuk, D. F., Schepinin, V. E., & Telitsyna, E. (2018). Intelligent diagnostic complex of electromagnetic compatibility for automobile ignition systems. Paper presented at the 2017 6th International Conference on Reliability, Infocom Technologies and Optimization: Trends and Future Directions, ICRITO 2017, 2018-January, 282-288. doi:10.1109/ICRITO.2017.8342439

[2] Klochkov, Y., Gazizulina, A., Golovin, N., Glushkova, A., & Zh, S. (2018). Information model-based forecasting of technological process state. Paper presented at the 2017 International Conference on Infocom Technologies and Unmanned Systems: Trends and Future Directions, ICTUS 2017, 2018-January, 709-712. doi:10.1109/ICTUS.2017.8286099

[3] Indeitsev, D. A., Porubov, A. V., Skubov, D. Y., Lukin, A. V., Popov, I. A., & Vavilov, D. S. (2018). On the influence of the microstructure on the stress-strain state of material. Materials Physics and Mechanics, 35(1), 66-70. doi:10.18720/MPM.3512018_9

[4] Rudskoi, A. I., Bogatov, A. A., Nukhov, D. S., & Tolkushkin, A. O. (2018). On the development of the new technology of severe plastic deformation in metal forming. Materials Physics and Mechanics, 38(1), 76-81. doi:10.18720/MPM.3812018_11

[5] Patrikeev, A., Tarasov, A., Borovkov, A., Aleshin, M., & Klyavin, O. (2017). NVH analysis of offroad vehicle frame. evaluation of mutual influence of body-frame system components. Materials Physics and Mechanics, 34(1), 70-75. doi:10.18720/MPM.3412017_8

[6] Leoro, J., Krutitskiy, S., Tarasov, A., Borovkov, A., Aleshin, M., & Klyavin, O. (2017). Vehicle dynamics prediction module. Materials Physics and Mechanics, 34(1), 82-89. doi:10.18720/MPM.3412017_10

[7] Ziniakov, V. Y., Gorodetskiy, A. E., & Tarasova, I. L. (2016). Control of vitality and reliability analysis. Studies in Systems, Decision and Control, 49, 193-204 doi: 10.1007 / 978-3-319-27547-5_18

[8] Ziniakov, V. Y., Gorodetskiy, A. E., & Tarasova, I. L. (2016). System failure probability modeling. Studies in Systems, Decision and Control, 49, 205-215. doi: 10.1007 / 978-3-319-27547-5_19
[9] Demidov, R., Pechenkin, A. (2018) Vector representation of machine instructions for vulnerability assessment of digital infrastructure components. Proceedings - 2018 IEEE Industrial Cyber-Physical Systems, ICPS 2018, 935-940

[10] Evgrafov, A.N., Karazin, V.I., Khisamov, A.V. (2018) Research of high-level control system for centrifuge engine. International Review of Mechanical Engineering, 12(5), 400-404

[11] Khludova, M. (2017) Evaluation model for the stochastic flowshop cyclic scheduling problem. 2017 International Conference on Industrial Engineering, Applications and Manufacturing, ICIEAM 2017 – Proceedings, Article number 8076385. DOI: 10.1109/ICIEAM.2017.8076385

[12] Krasnova, N., Pavlov, V., Solovjev, K., Marzinovsky, I. (2018) Deconvolution algorithms for electron spectroscopy. Proceedings of the 2018 IEEE International Conference on Electrical Engineering and Photonics, EEExPolytech 2018, Article number 8564426, 126-130. DOI: 10.1109/EEExPolytech.2018.8564426

[13] Davydov, V.V., Dudkin, V.I., Karseev, A.Y., Vologdin, V.A. (2016) Special Features in Application of Nuclear Magnetic Spectroscopy to Study Flows of Liquid Media. Journal of Applied Spectroscopy, 82(6), 1013-1019. DOI: 10.1007/s10812-016-0220-6

[14] Mityakov, A., Mityakov, V., Sapozhnikov, S., Gusakov, A., Bashkatov, A., Seroshtanov, V., Zainullina, E., Babich, A. (2017) Hydrodynamics and heat transfer of yawed circular cylinder. International Journal of Heat and Mass Transfer, 115, 333-339. DOI: 10.1016/j.ijheatmasstransfer.2017.07.055

[15] Davydov, V.V., Myazin, N.S. (2017) Compact multifunction nuclear-magnetic spectrometer. Measurement Techniques, 60(2), 183-189. DOI: 10.1007/s11018-017-1171-x

[16] Denisov, V., Korotaev, V., Titov, A., Blokhina, A., & Kleshchenok, M. (2017). Overview of field gamma spectrometries based on si-photomultiplier. Paper presented at the Proceedings of SPIE - the International Society for Optical Engineering, 10231, Article number 1023121. doi:10.1117/12.2265837

[17] Kozlovsky, V., Klochkov, Y., Ostapenko, M., Ushanova, N., & Antipov, D. (2016). Conformity assessment of car quality databases exemplified on the case of the russian car manufacturer ‘auto VAZ’. Paper presented at the 2016 5th International Conference on Reliability, Infocom Technologies and Optimization, ICRITO 2016: Trends and Future Directions, 57-60. doi:10.1109/ICRITO.2016.7784925

[18] Korshunov, G.I., Polyakov, S.L., Shunmin, L. (2017) Assurance of reliability and safety in liquid hydrocarbons marine transportation and storing. IOP Conference Series: Earth and Environmental Science, 87(6), Article number 062009. DOI: 10.1088/1755-1315/87/6/062009