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QUALITY OF FUEL IN AUTOMOTIVE INDUSTRY

Bożena SZCZUCKA-LASOTA[1*], Tomasz WĘGRZYN[2*], Feng CHEN[3], Katarzyna TUROŃ[4], Łukasz WSZOŁEK[5], Jerzy KALWAS[6]

[1] Politechnika Śląska, bozena.szczucka-lasota@polsl.pl, ORCID: 0000-0003-3312-1864
[2] Politechnika Śląska; tomasz.wegrzyn@polsl.pl, ORCID: 0000-0003-2296-1032
[3] Sino-US Global Logistics Institute, Antai College of Economy & Management, Shanghai Jiao Tong University, Shanghai, China; fchen@sjtu.edu.cn, ORCID: 0000-0001-8656-7910
[4] Politechnika Śląska; katarzyna.turon@polsl.pl, ORCID: 0000-0001-6744-8887
[5] Energo-Transport Łukasz Wszołek, Mysłowice, Poland; lukasz.wszolek@diagno-test.pl, ORCID: 0000-0003-0010-120X
[6] VIGO Photonics, Ożarów Mazowiecki, Poland; kalwasjerzy@gmail.com, ORCID: 0000-0002-7375-8846
* Correspondence author

Purpose: The aim of the article is to determine the quality of aged fuels. It has been shown that laboratory tests of resins formed in fuels are insufficient to determine the quality of gasoline.
Design/methodology/approach: Morphological tests of deposits released in fuels during long-term storage were carried out. The research was qualitative in nature. Morphological tests of deposits released in fuels during long-term storage were carried out. The research was qualitative in nature. Samples of diesel oil, ON95 and ON98 gasoline were tested.
Findings: The novelty of the article is to show that fuels from one manufacturer and stored in the same tank, depending on the fraction, have different properties and significantly differ in quality. In the article different mechanisms of resin release in fuels and their impact on fuel quality were demonstrated.
Research limitations/implications: Glass containers were used in the tests, limiting chemical reactions between the tested fuel and the vessel material. On the other hand, aging processes in glass vessels occur slower than in steel tanks. Due to the roughness of the surface, deposits in glass vessels flow off the walls more easily than in steel and PET vessels.
Practical implications: It is suggested to thoroughly clean fuel tanks intended for transport or storage and to extend the quality testing of liquid fuels such as gasoline by institutions supervising the quality of fuels on the market.
Originality/value: It is to show that fuels from one manufacturer and stored in the same tank, depending on the fraction, have different properties and significantly differ in quality. The article is addressed to institutions dealing with fuel storage.

Keywords: automotive, fuel, quality of gas, quality of oil.

Category of the paper: Research paper.

1. Introduction

The impact of ageing processes of motor fuels on their functional properties is manifested, m.in, by structural changes occurring in fuels (Hirota, Kashima, 2020; Matijošius, Sokolovskij, 2009; He et al., 2021). As a result of chemical oxidation reactions, resin deposits and acids are formed in stored fuels (Vasileiadou, et al., 2021; Correia, et al., 2018; Debe, 2012; Blaabjerg, et al., 2006; Jiang et al., 2024). During the operation of vehicles, these compounds are a source of damage to fuel system components, such as corrosion of seals, blockage of fuel lines, etc. The quality of fuels is therefore extremely important for the functioning of vehicles. Chemical reactions occurring in long-term stored fuel, as well as the deposits formed, cause changes in the density of fuels, which in turn affects the amount of fuel injected into the engine compartment, and the amount of energy released in the combustion process in the piston. The heaviest sediments that are emitted in the fuel (from a collection of several dozen types of hydrocarbons of different molecular weights) combining into larger conglomerates can cause mechanical problems in the propulsion system. The release of dense and heavy fractions that significantly reduce the quality, including the functional properties of fuels, is extremely dangerous. Ageing processes occurring in fuels affect the loss of oxidative stability.

The aim of the article is to examine samples of long-term stored fuels and to determine the level of their quality and suitability for further exploitation in the transport industry.

2. Materials and investigation methods

In order to confirm the decrease in the level of functional properties of the tested fuels, qualitative tests of the structure of the emitted sediments were carried out for them. The fuels (oil and gas) were stored for a period of 4 years in glass vessels. Glass vessels were chosen due to the limitation of possible chemical reactions between the tested fuel and the material of the tank in which the material was stored. According to the literature, this is extremely important in the case of fuels containing biocomponents (Matijošius, Sokolovskij, 2009; He et al., 2021). It should also be noted that glass walls of vessels are less conducive to precipitation of sediments compared to the walls of steel tanks, used, m.in, in non-tank stations. The surface roughness of the materials that are in direct contact with the tested fuel and the tank material itself have an impact on the precipitation processes that take place. According to the literature, the use of polymer tanks of the PET type accelerates the processes of fuel degradation (Jeon, Park, Na, Kim, 2017; Stępień, 2015).

Studies of the structure of sediments emitted in fuels after long-term storage were carried out using an X-ray microscope. The aim of the research was to assess whether the samples of long-term stored fuel are subject to ageing processes manifested by the formation of deposits on the vessel walls. Observations were made at a magnification of 10 × (10-fold).

3. Results of investigation

Figure 1-3 shows the results of tests of the wall of a laboratory vessel on which sediments were separated when the diesel fuel sample was stored in a vertical position for a period of approx. 4 years. It should be noted that the glass walls of the vessels are less conducive to the precipitation of sediments compared to the walls of steel tanks, used, m.in, at non-tank stations, so it can be assumed that the results of the tests were obtained, indicating a better quality of fuels than it would be in non-laboratory conditions, carried out on a real facility. Figure 1 shows the results of the near-surface fraction, Figure 2 shows the results of the central fraction, and Figure 3 shows the results of the lowest fraction, near the bottom of the tank.

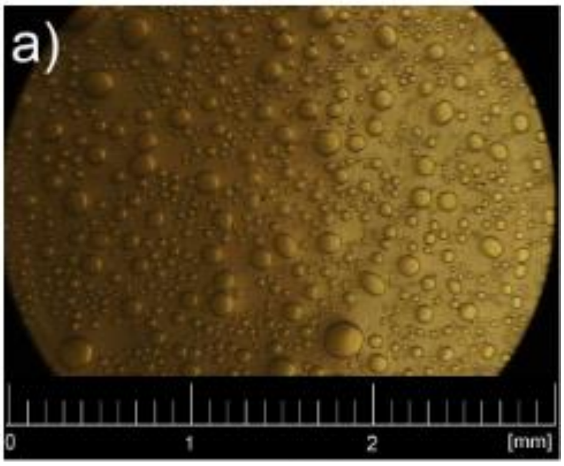


Figure 1. Sediments emitted on the walls of the vessel during long-term storage – in the near-surface fraction

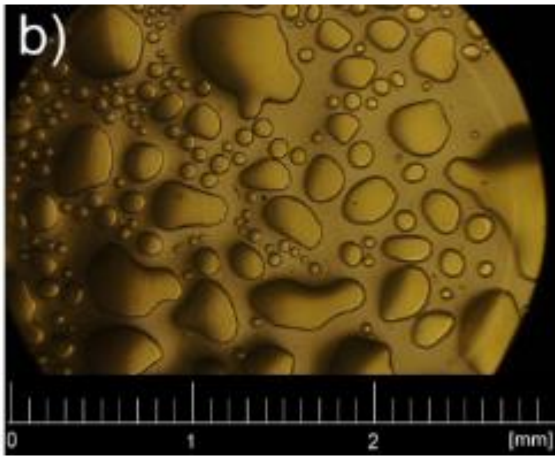
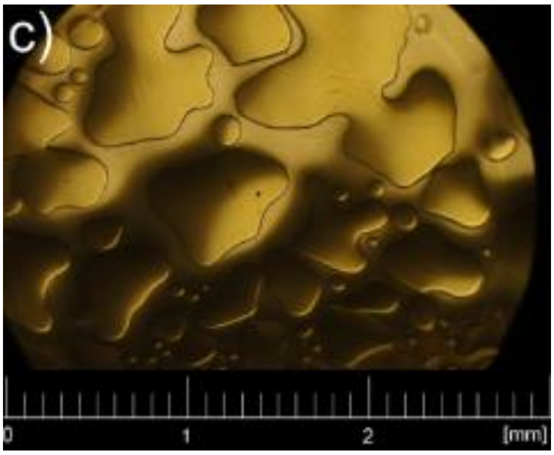


Figure 2. Sediments emitted on the vessel walls during long-term storage – sample taken from the center of the vessel.



A sample taken at the bottom of the tank.

Figure 3. Deposits emitted on the vessel walls during long-term storage.

Comparison of the results of the tests presented in Figure 1-3 allows to find significant differences in the morphological structure of the sediments emitted from different depths of the glass tank. The uppermost layer, located near the surface, is characterized by spherical sediments of the smallest diameter. Single precipitates have a diameter of up to about 0.3 mm. The results of the study, presented in Figure 2, indicate that the forming spherical sediments coagulate, forming clusters of larger sizes and irregular, sometimes elongated shapes. The largest changes were observed in sample 3, taken at the bottom of the vessel. The observed precipitates cover almost the entire surface of the laboratory slide. The observed precipitates are heavier fractions, formed as a result of coagulation of particles that merge together and are emitted during the aging process. The sediments that coagulate become heavier and sink to the bottom of the vessel, according to the action of gravitational forces. Hence the higher concentration of sediments observed in sample 3, in the form of larger, uneven droplets. The results of the study confirm the literature data and clearly indicate that in the case of long-term stored fuel, its physico-chemical properties undergo changes under the influence of ageing processes (Ukhanov et al., 2022; Sacha, 2020). The results of studies conducted in the world indicate that the observed changes are responsible for the decrease in oxidative stability of diesel oils (Silva, 2021).

Therefore, the operational properties of these fuels change adversely. Observation of heavy fractions of sediments (Fig. 3) correspond to very low quality fuels for applications in the automotive industry. In the conducted tests, it was unequivocally confirmed that in the analyzed liquid fuels, non-volatile compounds with a tendency to deposition – called resins – are emitted. The analysis of the results, combined with the literature data, allows us to conclude that the tested fuel is characterized by low quality, as it has lost its original physicochemical properties. The use of fuel of this quality level results in the formation of carbon deposits that reduce the performance of the engine and increases the emission of harmful substances into the atmosphere. Due to the fact that sediments are deposited on the walls of the vessels, it can be concluded that inaccurate cleaning of the tanks during the liquid change may be the cause of contamination of the next batch of fuel, reducing its functional properties. The conclusion is consistent with the literature data presented by numerous authors (Hirota, Kashima, 2020; Matijošius, Sokolovskij, 2009; He et al., 2021; Silva, 2021; Vasileiadou et al., 2021; Correia et al., 2018; Debe, 2012; Blaabjerg et al., 2006; Jiang et al., 2024; Jeon, Park, Na, Kim, 2017; Stępień, 2015; Ukhanov et al., 2022; Sacha, 2020). In addition, it should be noted that in the case of conventional testing of fuels with sampling only from the upper tank, it may not be sufficient to determine the quality of the stored fuel. Heavy fractions are deposited at the bottom of the tank, so the fuel taken from this area will have worse operating properties compared to the fuel taken only from the top layer (near-surface). Such an observation may explain why fuel from the same manufacturer distributed and delivered to other stations may have different oxidative properties if it were not mixed.

Similar observations were made for long-term storage of ON 95 and ON 98 gasoline. Also in this case, precipitates were observed on the walls of glass vessels in which the liquid was stored for a period of more than 4 years. The vessels were stored in an upright position and filled with gasoline up to 2/3 of their height.

Observations made with the use of an X-ray microscope showed that in the case of gasoline no changes in the form of precipitation of deposits inside the liquid were observed (Figures 4-5). The sediments shown in Figure 4-5 were observed on the walls of the vessel, only above the surface of the stored fuel.

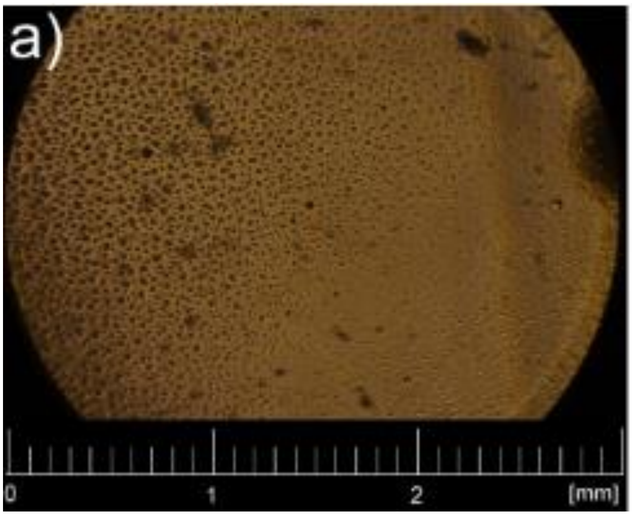


Figure 4. Sediment forming above the Pb98 fuel level.

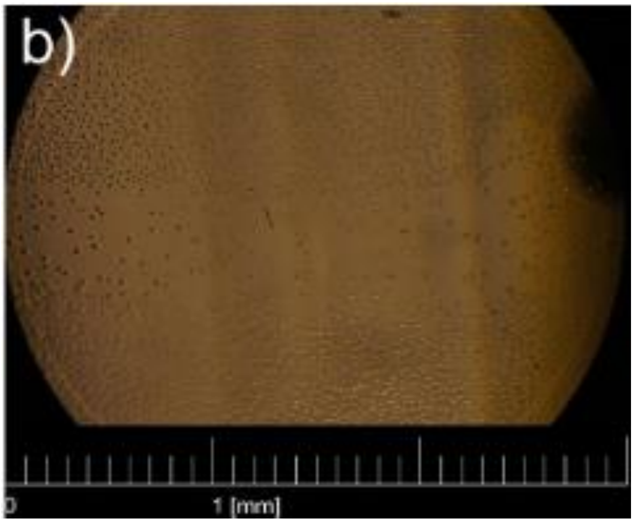


Figure 5. Sediment forming above the Pb95 fuel level.

The analysis of the obtained results allows us to see that the mechanism of deposit formation is therefore different for gasolines and diesel oils. A fuel sample enclosed in a glass vessel filled to approx. 2/3 of its volume with gasoline creates an atmosphere of thermodynamic equilibrium, in which the gasoline vapours mix with the air left in the vessel and carry away all the fractions contained in it. These vapours, as a result of oxidation with the air contained in the vessel, form resins that settle on the walls of the vessels, transforming into condensation centers for the next particles. Resins are released in the form of deposits above the surface of the liquid, while the same compounds in gasoline are dissolved. Due to this mechanism, no precipitation of deposits was observed on the vessel walls within the liquid or in the liquid itself. It can only be assumed that physico-chemical changes occurred in the liquid, related to the aging processes and the mechanism of dissolving deposits in gasoline. It is likely that these changes will be observed at a much later date, as gasoline consists of much lighter molecules than diesel fuels and this process takes much longer. The results of the research presented in the literature indicate, a.o. changes in the clarity of liquids.

The observed phenomenon of fuel ageing and sediment formation is confirmed by the number of fuel samples inspected by the Trade Inspectorate, which during the year detected almost 9% of diesel oil samples that did not meet the specified quality parameters among all tested oil samples and not a single sample that did not meet the resin content parameter in gasolines (UOKIK report, 2023). Since the UOKIK report provides only values that do not meet the standards, on the basis of the research carried out as part of this study, it can be concluded that ageing effects in gasolines also occur, but their intensity is so low that it does not yet exceed the standards in the analyzed time. It should also be considered whether laboratory tests specified in the standards are sufficient to determine the quality of liquid fuels.

4. Summary and conclusions

Chemical reactions occurring in long-term stored fuel are the cause of sediment accumulation, cause changes in the density of fuels and their operational properties. These changes adversely affect motor vehicles by causing mechanical problems in the drive system, premature wear of parts of the structure, as well as changes in the thermodynamics of fuel combustion and the amount of substances emitted unfavorable to the environment. The research carried out as part of the study indicates that fuel stored for a long time adversely changes its properties as a result of spontaneous aging processes. In addition, it has been shown that the same fuel, coming from one manufacturer and stored in one tank, can have different properties within the liquid, depending on whether it comes from the upper or lower fraction of the tank.

A detailed analysis of the study results highlights that:

1. The observed phenomena correspond to ageing changes occurring in fuels (both in the case of the analyzed gasolines and diesel oil) As a result of long-term storage, the functional properties of the fuels have been significantly reduced.
2. The tested fuel – diesel should be withdrawn from circulation due to its inadequate functional quality, resulting from progressive ageing processes, manifested by the formation of deposits. According to the literature, the identified deposits in fuels may be the cause of a decrease in the efficiency of vehicles powered by these fuels, result in the formation of carbon deposits that reduce engine performance and contribute to the increasing emission of harmful substances into the atmosphere.
3. Different fractions of fuel from the same tank may have different performance characteristics. In the case of diesel fuels, fractions taken from the bottom of the tank showed a significant progress in degradation processes compared to near-surface fractions. In the case of long-term storage of fuels, it is necessary to blend them and carry out qualitative tests before placing them on the market.
4. Taking samples of fuels for laboratory tests only from the near-surface fraction may result in an erroneous estimation of fuel quality. Fuel of inadequate quality may be approved for use.
5. When testing gasoline-type fuels, estimating the amount of deposits formed in the liquid is insufficient to determine the quality of the fuel and its service life. Deposits usually form above the surface of the liquid, and in the gasoline itself they are unobservable with the help of an X-ray microscope.
6. Comparing the test results for gasolines and oil, it can be stated that the amount of sediments precipitated in diesel fuels is many times higher than in gasolines.
7. The results of the study show that despite the fact that the mechanisms of deposit formation are different for gasolines and diesel oils, the results clearly indicate that the quality of liquid fuels results from the ageing processes taking place in them.

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