SELECTED PHYSICAL PROPERTIES OF SOME TRANSMISSION OILS

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Abstract
Selected properties of two types of transmission oils were analysed in this paper. First two samples were from manual and second two samples were from automatic transmission systems (new and used). For each sample were measured quantities as density on densimeter Mettler Toledo DM40 and dynamic viscosity on viscometer Brookfield DV2T. Measurements were performed twice at each temperature and arithmetic average was used for the dependencies. In both cases were in relations obtained decreasing characters with increment of temperature, for density was applied polynomial function of second degree and dynamic viscosity was modelled by exponential function. Used samples had higher densities and viscosities than new samples, which could be caused by oxidation and thermal degradation of oils. From results is clear that used oils had reached or overlapped the time for the oil change due to their longer performance.

Key words: *transmission oils, dynamic viscosity, density, temperature dependencies, comparison of new and used oil.*

INTRODUCTION

Manual and automatic transmission systems serve the essential function of transferring engine power to the wheels, but they operate quite differently. A manual transmission requires the driver to manually shift gears using a clutch pedal and gear stick, giving greater control over gear selection and often resulting in better fuel efficiency and simpler maintenance. In contrast, an automatic transmission shifts gears on its own using a torque converter and planetary gear set, which provides a smoother and more convenient driving experience, especially in stop-and-go traffic. While manuals are generally more durable and less costly to repair, automatics are more complex but easier to use, making them the preferred choice for most drivers today. Both systems have their pros and cons, with manual transmissions favoured for control and performance, and automatics valued for ease and comfort *(Skulić et el., 2022; Sethubalan et al., 2023, Wang et al., 2024)*.

Oils in transmission apparatuses play a crucial role in ensuring smooth and efficient operation. Their primary function is to lubricate internal components, reducing friction between gears and metal parts, which minimizes wear and extends the lifespan of the transmission system. Additionally, transmission oils act as a cooling medium, dissipating heat generated by friction and power transfer, thus preventing overheating and potential damage. In automatic transmissions, these oils also facilitate the transfer of power from the engine to the wheels, enhancing vehicle performance. Proper selection and maintenance of transmission oil are essential to avoid premature wear, costly repairs, and to maintain optimal transmission function throughout the vehicle's life *(Hildebrand et al., 2024a; Hildebrand et al., 2024b)*. Transmission oil helps manage high temperatures during operation primarily by dissipating the heat generated from friction and power transfer within the transmission system. As the transmission operates, components like gears and clutch discs produce significant heat, which the oil absorbs and carries away, preventing the system from overheating and suffering damage. Transmission oil circulates through coolers – often liquid-liquid heat exchangers or dedicated transmission oil coolers – that transfer this heat to the surrounding air or engine coolant, maintaining the oil within an optimal temperature range. By keeping the fluid temperature stable, the oil preserves its viscosity and lubricating properties, preventing breakdown, sludge formation, and excessive wear on transmission parts. Furthermore, synthetic transmission oils offer improved oxidation stability and can reduce operating temperatures by *(10 – 20)* °C compared to mineral oils, enhancing fluid life and transmission efficiency. Regular maintenance and using the correct type of transmission oil are essential to ensure effective heat management and prolong transmission lifespan *(Hildebrand et al., 2024a; Hildebrand et al., 2024b; Zhang et al., 2024)*.

Many authors including Wolak et al. *(2020)*, Kumbár & Votava *(2014)* stated that viscosity is a parameter that characterizes the flow resistance created by a fluid during movement. The viscosity of a liquid changes with temperature and it had decreasing character as the temperature increases. Authors also emphasized that viscosity is one of the most important properties of oils and it has a direct impact on the lubrication process *(Wolak et al., 2020)*. They also described the temperature dependence of dynamic viscosity by Vogel model, which has decreasing exponential shape *(Wolak et al., 2020)*. For same dependence authors Kumbár & Votava *(2014)* applied different model, but also with decreasing exponential character.

The viscosity of transmission oil can increase or decrease over time due to several factors related to usage and operating conditions. Reasons for increased viscosity include: adding a higher-viscosity oil to an existing lower-viscosity oil; oxidation and thermal degradation; water contamination; evaporation of lighter oil molecules. Reasons for decreased viscosity include: dilution by lower-viscosity fluids or contaminants; shear degradation of viscosity index improvers; excessive heat can break oil molecules into smaller fragments. Overall, viscosity changes are a key indicator of oil condition and can affect transmission performance, lubrication, and component wear. Proper oil selection, monitoring, and maintenance help manage viscosity stability during operation *(Liñeira del Río et al., 2025)*.

Properties of transmission oil were investigated by many authors. Degradation of transmission oil on the physical properties and tribological performance was investigated by Duran et al. *(2024)*. Authors compared dynamic viscosity of new and used oils after different operational time in form of graphical dependency of viscosity to the temperature *(Duran et al., 2024)*. For all samples they observed decreasing character of viscosity with the temperature. Duran et al. *(2024)* explained the lower viscosities of used samples by low thermal oxidation. Heat transfer between oil dip-lubricated gears and fluid was examined by Hildebrand et al. *(2024a)*. Authors mentioned that local interaction between gears and fluid strongly influences the gear heat transfer, as well as fluid flow properties *(Hildebrand et al., 2024a)*. Analysis of steady-state temperature field of planetary gears considering load distribution and mixed oil-air medium was performed by Zhang et al. *(2024)*. Authors compared more decreasing models for describing temperature dependence of oil viscosity in the temperature range *(30 – 100)* °C and used Walther formula for subsequent calculations *(Zhang et al., 2024)*. Liñeira del Río et al. *(2025)* had investigated tribological enhancement of low viscosity polyalphaolefin transmission oil using functionalized graphene additives. Authors had observed notable improvements in friction coefficient in comparison to the base oil *(Liñeira del Río et al, 2025)*. Abdulrahman *(2021)* had used response surface methodology at modelling and optimization of dynamic viscosity of copper nanoparticles dispersed in gear oil. Author had stated that dynamic viscosity of gear oil is affected mainly by temperature, nanofluid volume and shear rate. Author observed decreasing of dynamic viscosity in temperature range *(10 – 80)* °C *(Abdulrahman, 2021)*. Hildebrand et al. *(2024b)* had described the classification of numerical, experimental, and analytical approaches for gearbox oil flow and no-load gear power loss. Possibilities of waxy oil viscosity reduction were listed by Wang & Lu *(2025)*. Authors named for example addition of chemicals or external heating of the pipeline which could be sometimes ineffective, but very promising is electrical treatment *(Wang & Lu, 2025)*. They monitored the changes in the oil's viscosity under DC electrical fields till ± 3 kV·mm^{-1}, and observed significant viscosity reductions of up to 89 % *(Wang & Lu, 2025)*. Dependency of gearbox efficiency on changing viscosity of oil due to the variating temperature was examined by Sethubalan et al. *(2023)*. Experimental investigation into the influence of oil viscosity on gear churning losses in splash-lubricated transmission systems were performed by Shore et al. *(2023)*. Hawley et al. *(2010)* had performed modulations of both engine and transmission lubricating oils properties to achieve lower fuel consumption. Temperature dependencies of transmission oil dynamic viscosity and density were analysed by Wang et al. *(2023)*. In both cases authors obtained decreasing characters with temperature increase. Mlynarczak & Sikora *(2014)* had analysed the changes of oil viscosity during its operation in combustion engines. Authors observed the decrease of viscosity and stated some reasons for this behaviour *(Mlynarczak & Sikora, 2014)*. The impact of lubricant viscosity and materials on power losses and

efficiency of worm gearbox was examined by Skulić et al. *(2022)*. Armioni et al. *(2024)* had examined the impact of degradation on the viscosity of used engine oils, which plays a crucial role in engine lubrication and performance. Authors had focused on analysis of viscosity changes across various temperature ranges, and highlighted how contaminants, especially water and fuel, influence oil performance *(Armioni et al., 2024)*.
For these facts, the aim of this study is to investigate the effect of temperature and longer performance on selected properties of transmission oils.

MATERIALS AND METHODS

In our research we analysed new and used oils from manual and automatic transmission systems. In the first group were synthetic oil Castrol Syntrans B 75W *(Sample 1)*, which is devoted for manual transmission systems, and its used alternative *(Sample 2)* after 200 000 km. In case of automatic transmission system were measured synthetic oils FEBI DSG both in new *(Sample 3)* and used version *(Sample 4) (after 150 000 km)*.
For the dynamic viscosity measurement was used digital viscometer Brookfield DV2T and analysis was performed in the temperature range *(20 – 90)* °C. Density of oils was determined on the densimeter Mettler Toledo DM40 in temperature interval from 0 °C to 90 °C. Measurements were repeated twice and arithmetic average of each quantity was applied for temperature dependencies. In case of density was applied decreasing polynomial function of second degree

$$\rho = -A\left(\frac{t}{t_0}\right)^2 - B\left(\frac{t}{t_0}\right) + C \qquad (1)$$

where ρ is density *(kg·m⁻³)*, t is temperature *(°C)*, t_0 is 1 °C, A, B and C are coefficients of regression equation *(1)*, and are constants dependent on kind of material, and on ways of processing and performance. Dependence of viscosity was characterized by Arrhenius type equation

$$\eta = K\, e^{-L\left(\frac{t}{t_0}\right)} \qquad (2)$$

where η is dynamic viscosity *(Pa·s)*, t is temperature *(°C)*, t_0 is 1 °C, K and L, coefficients of regression equation *(2)*, are constants dependent on kind of material, and on ways of processing and performance.

RESULTS AND DISCUSSION

In the first part of results we compared the densities of all transmission oils. Temperature dependencies of density for all samples are shown in Fig. 1.

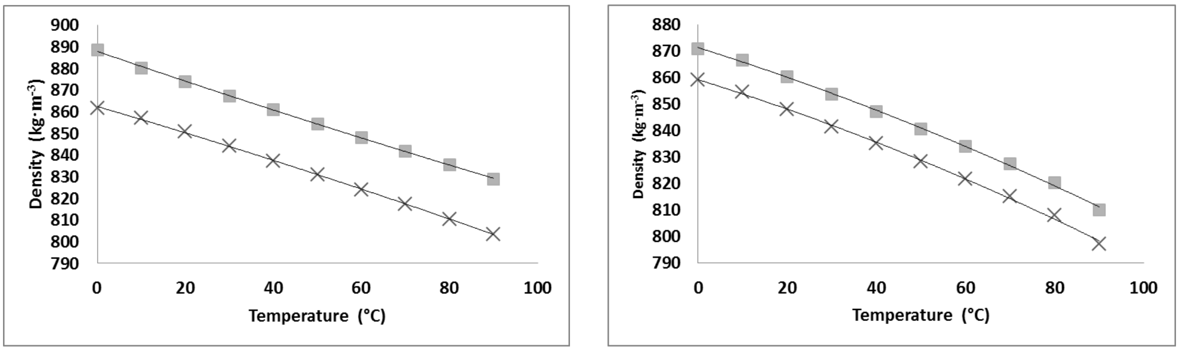

Fig. 1 Temperature dependencies of transmission oil density *(× – new oil; ■ – used oil)*
(Samples 1 and 2 on the left; Samples 3 and 4 on the right)

It is evident that for all transmission oils the density decreases with rising temperature. In all cases was applied decreasing polynomial function of second degree and all coefficients are summarized in Tab. 1. Similar tendencies in temperature dependencies of density were obtained by other authors *(Thomas et al., 2015; Wang et al., 2024)*. It can be also seen that both used oils had higher densities than the new ones, which could be caused by fact that these oils were used for a very long performance, reaching or overlapping the time for the oil change.

Tab. 1 Coefficients of regression equation *(1)* and coefficients of determination

Material	A kg·m^{-3}	B kg·m^{-3}	C kg·m^{-3}	R^2
Sample 1	0.0007	0.5945	862.43	0.9996
Sample 2	0.0005	0.6977	887.90	0.9996
Sample 3	0.0017	0.5219	859.24	0.9984
Sample 4	0.0015	0.5286	871.35	0.9987

Next analysed parameter was dynamic viscosity. On Fig. 2 are presented temperature dependencies of transmission oil dynamic viscosity.

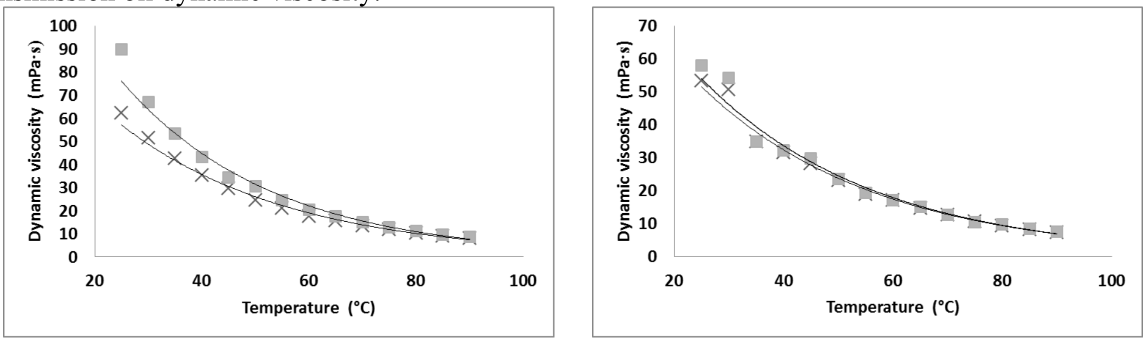

Fig. 2 Temperature dependencies of transmission oil dynamic viscosity *(× – new oil; ■ – used oil)* *(Samples 1 and 2 on the left; Samples 3 and 4 on the right)*

Decreasing character of dynamic viscosity with increment of temperature can be seen for all samples in Fig. 2. This finding is in accordance with Arrhenius equation *(Figura & Teixeira, 2007)* and also with other authors *(Kumbár & Votava, 2014; Wolak et al., 2020; Abdulrahman, 2021; Wang et al. 2023; Duran et al., 2024; Zhang et al., 2024)*. Coefficients of regression equation *(2)* and coefficients of determination are summarized in Tab. 2. Also in this case were viscosities of used oil higher than for the new ones, which could be caused by oxidation and thermal degradation, water contamination or evaporation of lighter oil molecules, which also indicates that the time for the oil change was reached or overlapped due to the longer performance.

Tab. 2 Coefficients of regression equation *(2)* and coefficients of determination

Material	K mPa·s	L	R^2
Sample 1	125.62	0.031	0.9932
Sample 2	184.33	0.035	0.9898
Sample 3	111.61	0.031	0.9927
Sample 4	118.67	0.031	0.9867

CONCLUSIONS

Oils in transmission apparatuses play a crucial role in ensuring smooth and efficient operation. Their primary function is to lubricate internal components, reducing friction between gears and metal parts, which minimizes wear and extends the lifespan of the transmission system. Additionally, transmission oils act as a cooling medium, dissipating heat generated by friction and power transfer, thus preventing overheating and potential damage. Selected physical properties of two types of transmission oils were measured and analysed in this paper. First two samples were from manual and second two samples were from automatic transmission systems *(in each case it was new and used sample)*. For each sample were investigated physical properties such as density and dynamic viscosity. The first parameter was measured on densimeter Mettler Toledo DM40 and dynamic viscosity on digital rotational viscometer Brookfield DV2T. All measurements were performed twice at each temperature and arithmetic average of each quantity was used for the temperature dependencies. In both cases were obtained decreasing relations with rising temperature, for density was applied polynomial function of second degree and dynamic viscosity was modelled by exponential function. Used samples had higher densities and viscosities than new samples, which could be caused by oxidation and thermal degradation of oils. From results is clear that used oils had reached or overlapped the time for the oil change due to their longer performance.

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