A laser-based, non-contact Brillouin light scattering (BLS) spectroscopy technique was used to study viscoelastic properties of binary hydrocarbon mixtures: crude oil - gasoline and crude oil - cyclohexane. The center frequency position of Brillouin spectral peaks ($\omega_B$) is a direct measure of longitudinal hypersonic sound velocity ($v_s$) or a longitudinal elastic property, while the linewidth of the peaks ($\Delta \omega_B$) is a signature of total (longitudinal) viscosity ($\eta_{\text{long}}$) of the studied fluids. Measured sound velocity was used to determine adiabatic compressibility. Measured longitudinal and shear viscosity values were used to find bulk viscosities of the mixtures. These parameters have been investigated in our BLS experiments as a function of the volume fraction of gasoline-to-oil and cyclohexane-to-oil. The mass densities ($\rho$), shear viscosities ($\eta_{\text{shear}}$), and refractive indices ($n$), of studied binary mixtures were independently measured over the entire composition range at room temperature and atmospheric pressure. Since bulk viscosity $\eta_{\text{bulk}}$ of Newtonian liquids ($\eta_{\text{bulk}}=\eta_{\text{long}}-4/3 \eta_{\text{shear}}$) can only be a positive value [1], we use this criterion to distinguish between Newtonian and non-Newtonian behavior of the studied binary liquids based on critical volume fraction concentration ($\phi, \%$) at which $\eta_{\text{shear}}$ changes its sign. We demonstrate that viscoelastic properties of the studied liquid mixtures strongly depend on $\phi$. Bulk viscosities of the “oil – cyclohexane” mixture become positive at higher $\phi$ values than that of the “oil – gasoline” mixture. Besides $\eta_{\text{shear}}$ of the former tend to be higher than that of the latter. This implies that cyclohexane has stronger non-Newtonian behavior than gasoline. Adiabatic compressibility values of the investigated liquid mixtures reach their maxima at about the same volume fractions at which their $\eta_{\text{bulk}}$ values change their sign, suggesting that viscous and elastic properties of these binary mixtures are correlated. Additionally, we found that excess adiabatic compressibility of the “crude oil – cyclohexane” mixture is less positive than that of “crude oil – gasoline” across all $\phi$ values due to smaller repulsive interaction between unlike species, i.e. more rigid local structure [2]. Thus, the presence of cyclohexane (compared to gasoline) in the crude oil, causes the binary mixture to be more non-Newtonian, more viscous (shear and bulk), as well as have a more rigid local structural arrangement.

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References:

[1] Landau & Lifshitz “Hydrodynamics”