ADVANCED IONIC-LIQUID-BASED HYDRAULIC FLUIDS: FROM MOLECULAR DESIGN TO SUSTAINABLE HIGH-PERFORMANCE SYSTEMS

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ABSTRACT

Hydraulic fluids are essential for power transmission, lubrication, cooling and corrosion protection in modern mechanical systems. Although petroleum-based hydraulic oils are still widely used, their flammability, limited thermal stability, environmental persistence and dependence on complex additive packages motivate the search for safer and more sustainable alternatives. Ionic liquids represent a promising class of next-generation functional fluids due to their negligible vapor pressure, high thermal stability, tunable structure and excellent lubrication potential.

This contribution discusses the role and perspectives of ionic liquids as advanced hydraulic fluids, with emphasis on the relationship between molecular structure, physicochemical properties and practical performance. Particular attention is given to ionic-liquid–water systems and protic ionic liquids that can be prepared by simple acid–base neutralization directly in aqueous media. Such formulations may combine the favorable heat-transfer properties of water with the lubricating, anti-wear and anticorrosive effects of ionic species.

The main advantages of ionic liquids include reduced volatility and flammability, improved lubricity, adjustable viscosity, low compressibility and potential formation of protective interfacial layers on metal surfaces. Selected formulations may also improve thermal management through higher heat capacity and thermal conductivity than conventional mineral oils. However, challenges related to production cost, viscosity optimization, biodegradability, toxicity and compatibility with seals and metals still limit their wider application.

Overall, ionic liquids should be considered not only as alternative solvents, but as programmable engineering fluids with significant potential for the development of safer, more efficient and more sustainable hydraulic systems.

Keywords: ionic liquids, hydraulic fluids, green solvents, tribology, sustainable engineering fluids.

Acknowledgements

The authors would like to acknowledge the contributions of the Ministry of Science, Technological Development and Innovation of the Republic of Serbia for grants No. 451-03-33/2026-03/ 200125 & 451-03-34/2026-03/ 200125.