FUNCTIONALIZED CARBON NANOMATERIALS AS COMPONENTS REFINING INDUSTRIAL LUBRICANTS

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The aim of this dissertation was to develop modified carbon nanotubes (CNTs) and graphene (nGr) capable of forming stable dispersions in hydrocarbon bases, such as mineral oils. The research included a literature review, experimental studies, and implementation activities.

In the literature section, available methods for functionalizing carbon nanomaterials and their impact on the tribological properties of oils were reviewed. Based on this, physicochemical modification pathways for CNTs and nGr were selected, focusing on functional groups such as alkyl, alkylaryl, and oligo-/polyester groups, which show potential for improving lubricating properties.

In the experimental part, selected nanomaterials and functionalizing agents were thoroughly characterized using FTIR, *cryo*-TEM, TGA, and Boehm titration. Optimal synthesis conditions were developed for various types of modifications, considering variables such as temperature, reaction time, and sonication parameters. Functionalization reactions were carried out by introducing functional groups both at defect sites and on the sidewalls of the nanomaterials. The resulting derivatives were evaluated for their ability to form stable dispersions in base oils SN-100, SN-150, and SN-650. Stability was assessed visually and using light scattering techniques (DLS, MLS, SLS). Based on these tests, derivatives with the best stability and lubricating properties were identified, particularly in SN-100 oil, which posed the greatest research challenge. Tribological tests were conducted on stable dispersions using a four-ball tester to determine welding load for 0.1% dispersions. Selected derivatives containing amine and amide bonds showed better lubricating performance than the base oil alone. Application tests were also performed using base grease provided by an industrial partner. Based on the results, mechanisms for improving lubrication through carbon nanomaterials were proposed, including rolling, nanoprotection layer formation, surface repair, and polishing. Ultimately, the best formulations were selected for further application testing with end users.

In the implementation section, market analysis revealed growing interest in modern additive technologies that could reduce the use of conventional components in lubricants. A patent review was conducted three times – April 2021, July 2022, and July 2025 – to assess the state of the art regarding carbon nanomaterials as functional additives in lubricants. New patent disclosures in this field were also monitored continuously.

Application evaluation included tribological testing of lubricants containing functionalized carbon nanomaterials. For plastic grease, key parameters such as welding load, oscillating friction coefficient (SRV), sliding friction coefficient (μ), and wear scar diameter were determined and compared with a commercial grease from the same product group.

For emulsifying oil and machining fluids, friction coefficients and wear indicators were measured under defined test conditions. Machining trials were conducted under simulated real-world conditions to assess anti-seizure and anti-wear properties. These included evaluating tool durability, surface roughness, and wear characteristics on the contact surface during longitudinal turning. To minimize the influence of material variability, tool wear measurements were alternated. The results confirmed the effectiveness of the developed formulations in improving the tribological and operational properties of machining fluids.