Abstract of the Thesis

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Discipline/Branch: Mechanical

Title of the Thesis: An Investigation of Turning Operation Characteristics Using Hybrid Nanofluid Minimum Quantity Lubrication (MQL)

Abstract

Turning is simple and one of the most used fundamental machining operations, where a single-point cutting tool is used for material removal from a rotating part in order to shape cylindrical surfaces, shoulders, and grooves. Nanofluid-assisted minimum quantity lubrication (MQL) offers a promising route towards cleaner and more resource-efficient machining in line with UN SDG 9, by reducing coolant consumption while maintaining or improving cutting performance.

This study investigates the turning behaviour of AISI 1040 medium-carbon steel under thirteen cooling cases/conditions, including dry cutting, conventional wet cooling with water and SAE-40 oil, MQL with base oil, MQL with Al_2O_3 and ZnO mono nanofluids, and MQL with Al_2O_3-ZnO hybrid nanofluids prepared in SAE-40 oil. In each case the CS: Cutting Speed ranges from 31.71-107.55 m/min, FR: feed rate from 0.11-0.25 mm/rev and the DC: depth of cut from 0.2-0.6 mm were adjusted to Box-Behnken Response Surface Methodology (RSM) design for each cooling condition in the total of 195 runs, after which CF: Cutting Force, CT: Cutting Temperature, and SR: Surface Roughness were measured. Separate regression models developed for all thirteen cases were statistically significant, with high coefficients of determination and reasonable residual diagnostics, as indicated by ANOVA. In all conditions, FR and DC were significant in influencing all three responses, and CS was significant, though to a lesser extent. Comparative analysis of nanofluid formulations shows that Al_2O_3 yields lower forces and better surface integrity, whereas ZnO provides greater temperature reduction; an intermediate nanoparticle concentration of 1 wt% offers the best overall balance.

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A desirability-based multi-response optimization (equal weighting, smaller-is-better) identifies MQL with 1 wt% Al_2O_3/ZnO (75/25, Case-H1) as the most suitable overall lubrication condition among the thirteen cases. It yields a global optimum at a CS of 107.55 m/min, a FR of 0.11 mm/rev, and a DC of 0.2 mm. Validation tests in this setting show prediction errors of only 8.23% (force), 6.83% (temperature), and 3.56% (roughness), and reductions of about 25.1%, 18.26%, and 16.33% in these responses, respectively, compared with dry cutting. In parallel, Artificial Neural Network modeling demonstrates that a feed-forward distributed time-delay network (N4P2T2) most accurately predicts the three responses across all cooling conditions, indicating that the combined RSM-desirability-ANN framework provides a robust, data-driven basis for designing sustainable, high-performance turning processes using hybrid nanofluid MQL.

This PhD Thesis will help in designing and implementing sustainable, high-performance turning processes for medium-carbon steels by identifying an optimal hybrid nanofluid-MQL strategy, quantifying its benefits over dry and wet cooling, and providing predictive ANN models to support selection of cutting parameters and cooling conditions in practice.

List of Publication(s):

1. A. H. Nalbandh, N. K. Chavda, and R. K. Bumataria, “Response Surface Methodology-based Modeling and Optimization of AISI 1040 Turning Using Al_2O_3 and ZnO Nanofluids Under Minimum Quantity Lubrication,” *Journal of Environmental Nanotechnology*, vol. 15(1), March, pp. 603–615, 2026 https://doi.org/10.13074/jent.2026.03.2612063 (Scopus)
2. A. H. Nalbandh, N. K. Chavda, and R. K. Bumataria, “Comparative Study of Mono and Hybrid Nanofluids in MQL Turning of AISI 1040 Steel Using Box–Behnken RSM Approach,” *International Journal of Technology & Emerging Research*, vol. 2(4), April, pp. 26–44, 2026 https://doi.org/10.64823/ijter.2604004 (Academia)
3. A. H. Nalbandh, N. K. Chavda, and R. K. Bumataria, “Current research aspects in minimum quantity lubrication for turning operations: Cutting fluid as mono and hybrid nanofluid,” *Sigma Journal of Engineering and Natural Science*, vol. 44(2), April, pp. 1344–1368, 2026 https://doi.org/10.14744/sigma.2026.2041 (ESCI, Scopus)
4. A. H. Nalbandh, N. K. Chavda, and R. K. Bumataria, “Performance Analysis of AISI 1040 Steel Turning Under Al_2O_3–ZnO Hybrid Nanofluid MQL Using Response Surface Methodology - A Step Towards Sustainable Machining,” *Journal of Materials and Engineering*, vol. 4(2), pp. 155–168, 2026 https://doi.org/10.61552/JME.2026.02.003 (DOAJ)

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