Masters Thesis Information Showcase

Fall Semester-2026
Year 2026

Department: Chemistry
Programme: Masters in Industrial Chemistry
Specialization: Industrial Chemistry

1	**Title of the Thesis** An Approach to Industrial Application of Recycled Carbon Black (rCB) to Tire Compounding – Finding Optimum Composition
2	**Abstract** (min 300 to 500 words) Tire manufacturing sector is highly affecting environmental concerns by consuming fossil based carbon blacks as well as the accumulation of end of life tires. Considering these issues, this study investigates the industrial suitability of replacing traditional fossil based furnace Carbon blacks (vCB, grade N339) with sustainable Recycled Carbon Black (rCB) derived from pyrolysis of end of life tires. Master compound (MT-260) with systematic substitution of rCB was executed across nine distinct formulations, ranging from virgin control to fully replaced modifications i.e. R000 to R080 corresponding to 0 to 80 phr rCB, using laboratory scale kneader, mill and curing press. The study initiated with the preliminary examination of rCB sourced from three different origins in which Pakistan origin rCB qualified for further studies due to its comparable BET Surface area, pour density and low fine percentage relative to commercial vCB benchmarks. Results from Moving Die Rheometer (MDR2000) and Mooney Viscosity (MV) reveal that process safety margin was extended by introducing rCB. Due to functional adsorption of primary sulfenamide accelerators onto residual carbonaceous char of rCB aggregates, Mooney scorch time (t'5) extended by 27% and Rheometer scorch safety margin (t's2) by 15%. However compound's Mooney viscosity observed at 125°C decreased up to 88% indicating considerable advantage of low energy consumption during further processing on mixing and extrusions. Macro-mechanical evaluation exposed a critical performance transition threshold at 40 phr, where degradation actively begun. The definitive optimum industrial composition of Variant R030 (30 phr rCB / 50 phr vCB) was identified by multi-criteria optimization index mapping. At this limit, the compound balances macro structural rigidity and resistance to surface indentation, retaining 83% of absolute Tensile strength (TS) , 91% of tear propagation resistance (TR) and 82% high strain modulus (M300) compared to the control variant R000. Beyond 40 phr, due to mechanical collapse triggered by severe starvation towards curatives and self-agglomeration of filler, causing a reduction of 57% high strain modulus and an unacceptable 247% spike in mass wear loss on tread observed through standard test on Gibitre drum abrasion tester. Unit economic modelling and lifecycle environmental forecasting confirm that raw material carbon filler cost can be reduced by 9.85% at the optimized R030 hybrid filler configuration, yielding savings of 10.02 PKR/Kg of finished compound, and that also alleviates the filler phase carbon foot print by 27.23%. On scaling of carbon black consumption of 6.0 metric tons per day over an operational cycle of 300 days, implementation of R030 formulation yields an annual cost reduction of 57.375 Million PKR, simultaneously preventing 2038.5 metric tons of CO2 emissions annually. This research demonstrates that a targeted 30 phr rCB integration offers an economically sound, industrially competitive and environmental sustainable solution to modern circular tire manufacturing workflows.

3	**Impact on Sustainability of Urban Regions or SDG-11 "Sustainable Cities and Communities** (min 500 words)

This research aligns with the following United Nations Sustainable Development Goals (SDGs):

SDG 9: Industry, Innovation, and Infrastructure
This research puts forward a fresh take on modern rubber compounding, offering a validated framework for swapping in more sustainable materials.

Optimized Hybrid Formulation: The study finds that a 30 phr blend of rCB (Variant R030) hits the optimized composition, keeping structural rigidity intact while still allowing the material to process well mechanically.
Enhanced Process Efficiency: This hybrid formulation also cuts down on compounding energy use, bringing viscosity at 125°C down to 88%, a meaningful gain for manufacturing efficiency.

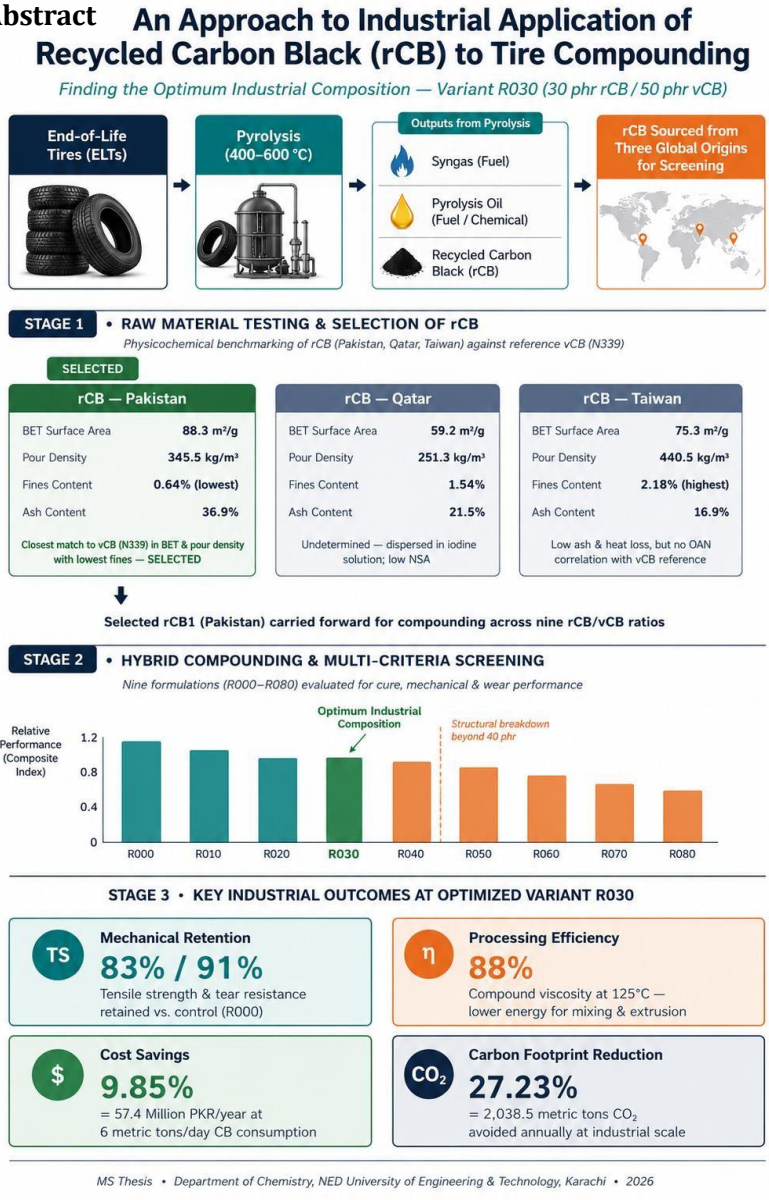
SDG 11: Sustainable Cities and Communities
By turning recycled tire material into something industry actually wants, this research gives a boost to municipal waste management and urban resilience alike.

Target 11.6 (Reduction of Urban Environmental Impact): Every year, urban transportation generates millions of tons of End-of-Life Tires. Left unmanaged, these pile up in municipal dumps, where they become fire hazards and breeding grounds for disease-carrying pests.
Landfill Diversion: Showing that rCB can replace vCB at up to 30 phr opens the door to diverting large volumes of rubber waste away from landfills and into productive industrial recycling loops instead.

SDG 12: Responsible Consumption and Production
The study also pushes forward the shift toward a circular economy, tackling the broader problem of non-biodegradable rubber waste head-on.

Waste Valuation: Rather than letting waste tires pile up or burning them off inefficiently, this approach uses pyrolyzed recover carbon black – a valuable material that industry can put straight back to use.
Resource Conservation: Swapping in a recycled filler for the primary industrial one cuts down on raw fossil resource extraction and reduces waste across the product's entire life cycle.

SDG 13: Climate Action
The measurable drop in life cycle greenhouse gas impact shows this work makes a real contribution to climate mitigation.

Carbon Footprint Reduction: Producing carbon black the traditional way i.e. through incomplete combustion of fossil fuel hydrocarbons, leaves behind a hefty carbon footprint. Switching to the optimized R030 rCB configuration cuts the filler phase's carbon footprint by 27.23%.
Quantifiable Industrial Impact: Scaled up to an industrial operation using 6 metric tons of carbon black a day, this switch prevents 2,038.5 metric tons of CO_2 emissions every year.

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6	**Graphical Abstract**