Developing Sustainable Chain Case Rubber Bush from Glove Trimmings and Rejected Gloves in Sri Lanka

H.P.G.P.A. Sewwandi
Department of Materials Technology
Rajarata University of Sri Lanka
Mihintale, Sri Lanka
pravini.sew@gmail.com

P.W.C.L.K. Polkotuwa
Department of Materials Technology
Rajarata University of Sri Lanka
Mihintale, Sri Lanka
chiranga02@gmail.com

R.A.I.U. Ramanayaka
Department of Materials Technology
Rajarata University of Sri Lanka
Mihintale, Sri Lanka
ent1819074@tec.rjt.ac.lk

T.G.K.C. Senarath
Department of Materials Technology
Rajarata University of Sri Lanka
Mihintale, Sri Lanka
ent1819085@tec.rjt.ac.lk

M.S. Sanjeewa
Department of Materials Technology
Rajarata University of Sri Lanka
Mihintale, Sri Lanka
ent1819082@tec.rjt.ac.lk

P.G.M.P.B. Pallegedara
Dipped Products PLC
(Hayleys Group)
Biyagama, Sri Lanka
mshan.bet@gmail.com

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I. INTRODUCTION

The global rubber industry is a critical backbone of modern manufacturing, providing indispensable materials for automotive components, industrial machinery, and personal protective equipment [1]. However, the sector faces significant environmental challenges due to the accumulation of rubber waste, particularly in developing nations such as Sri Lanka. A notable contributor to this issue is the disposal of nitrile glove trimmings and rejected gloves generated by the local rubber product manufacturing sector. Traditional disposal methods such as landfilling and incineration not only squander valuable resources but also contribute to long-term environmental degradation.

In line with sustainable development goals and the principles of a circular economy, there is growing interest in converting such waste into high-value products. One viable avenue is the fabrication of rubber bushes critical components in automotive and industrial systems that mitigate vibrations, reduce mechanical wear, and enhance durability. This research investigates the feasibility of developing a sustainable chain case rubber bush using mechanically recycled nitrile glove waste. The study employs a systematic methodology involving material collection, mechanical pulverization, advanced rubber compounding, and performance testing. Preliminary findings suggest that the recycled rubber composites demonstrate mechanical properties comparable to conventional products, indicating strong industrial applicability [2]. This innovation promotes eco-efficient manufacturing while addressing Sri Lanka's pressing rubber waste challenges [3].

II. LITERATURE REVIEW

Nitrile gloves, composed primarily of nitrile butadiene rubber (NBR), are widely employed in medical and industrial sectors owing to their exceptional chemical resistance, elasticity and barrier properties. These characteristics arise from the copolymerization of acrylonitrile and butadiene, where the acrylonitrile content governs oil resistance and flexibility. However, the extensive use of nitrile gloves has intensified environmental concerns due to their non-biodegradability and the ecological burden posed by conventional disposal methods such as landfilling and incineration. In response, recent studies have explored mechanical and chemical recycling techniques as sustainable alternatives. Mechanical pulverization and reprocessing of nitrile glove waste into rubber based composites have demonstrated promising results, offering material cost reductions without compromising functional performance. Applications such as rubber mats produced from compounded waste nitrile rubber affirm the material's mechanical viability in industrial settings. The formulation of high-performance rubber components, including seals and bushes, necessitates precise control of vulcanization parameters, filler dispersion, and crosslinking behavior. Research confirms that recycled NBR can be compatible with virgin rubbers, maintaining acceptable tensile, elongation and fatigue properties [4]. Furthermore, optimizing recycled particle size is critical, as smaller particles enhance cure kinetics but may adversely affect tensile strength due to interfacial incompatibility. Thermal recycling via pyrolysis further enables resource recovery while advancing circular economy objectives.

III. MATERIALS AND METHODS

Waste rubber gloves, including trimmings, rejected products, off-spec batches, and end-of-cycle leftovers, were collected from manufacturing processes. These non-biodegradable nitrile and latex materials were cleaned using a chlorine solution and dishwashing detergent to remove oils and processing residues, then rinsed and air-dried.

The cleaned gloves were pulverized using a two-roll mill to achieve uniform particle size and ensure effective dispersion in the rubber matrix [5]. Glove waste was incorporated as a partial replacement for virgin nitrile butadiene rubber (NBR), while all other compounding ingredients remained constant.

Ingredients such as ZnO, stearic acid, TMQ, carbon black, DOP, MBT, TMTD, and sulfur were accurately weighed

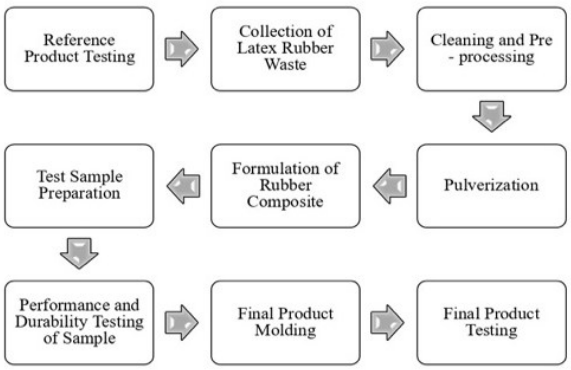

Fig. 1. Process Flow Diagram Illustrating the Stages of the Study

using an electronic scale, with formulation ratios doubled for batch processing. Mixing was conducted with a 0 mm roll gap to ensure uniform dispersion, while the final step was performed at a 2.5 mm gap to obtain the required thickness [6]. Curing was carried out at 150°C to achieve proper vulcanization and mechanical performance of the rubber composite.

IV. Results and Discussion

The mechanical evaluation of the developed rubber bush samples focused on tensile strength, hardness, and swelling behavior for automotive suitability. Tensile strength results (TABLE I) showed that recycled nitrile glove (rNBRg) particles affected elasticity and load-bearing performance. Smaller rNBRg particles increased hardness and crosslink density but slightly reduced tensile strength, while larger particles improved elongation at break, indicating better flexibility. This demonstrates the influence of particle size in balancing strength and elasticity in rubber composites.

TABLE I. TENSILE DATA FOR RNBRG RUBBER COMPOSITES

Compound	Results	
	Tensile strength (N/mm²)	Angle Tear (knm)
C0	16.7	50.03
C1	13.7	49.1
C2	15.5	52.4
C3	13.8	46.5
C4	15.4	42.7
C5	10.1	41.4

Hardness test data (TABLE II) confirmed a clear dependence on rNBRg content higher filler levels enhanced Shore A hardness, improving stiffness and wear resistance. However, excessive recycled content slightly reduced elasticity, indicating an optimum loading threshold beyond which flexibility diminishes. The optimized formulation achieved sufficient toughness and flexibility for effective vibration damping in automotive bush applications.

TABLE II. HARDNESS TEST RESULTS

COMPOUND	Hardness (IRHD)
C0	56.60
C1	58.69
C2	65.40
C3	66.80
C4	71.52
C5	74.86

The swelling index results demonstrated low fluid absorption, reflecting the composite's strong crosslinked network and resistance to oil and solvent ingress. Oil absorption data (TABLE III) further supported these findings, indicating minimal fluid uptake and good compatibility with automotive environments. These characteristics are essential for maintaining dimensional stability and mechanical integrity when exposed to lubricants and fuels.

TABLE III. OIL ABSORPTION DATA WITH SWELLING INDEX

Compound	Before	After	Swelling Index
C0	0.8394	0.8444	0.5956%
C1	0.7373	0.7439	0.8951%
C2	0.9267	0.9368	1.0898%
C3	0.7472	0.7577	1.4052%
C4	0.8014	0.8140	1.5722%
C5	0.8520	0.8676	1.8309%

V. Conclusion

This study demonstrates the promising potential of recycling nitrile glove waste into functional rubber composites for automotive and industrial applications. The findings confirm that recycled nitrile rubber can effectively enhance sustainability without significantly compromising mechanical performance. Particle size optimization is critical, as smaller particles increase hardness while larger ones improve flexibility and tensile strength. By achieving a balanced formulation, the developed rubber bushes exhibited durability, elasticity, and resistance to wear key properties for real world applications. Beyond technical benefits, the approach contributes to waste reduction, cost efficiency, and environmental preservation. Continued research should refine processing techniques, explore large-scale implementation, and expand the use of recycled rubber in diverse engineering components, supporting the transition toward a circular and sustainable rubber industry.

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