BRIEFING NOTE

June 2024

COMPATIBILIZATION OF POLYPROPYLENE - WASTE TYRE CRUMB RUBBER BLENDS FOR USABLE TPES

Lukanyo L. Bolo, Beryl Kamanga, Atupele Bunu, Ntombebhongo Ngxovu & Shanganyane P. Hlangothi
Nelson Mandela University, South Africa

KEY FINDINGS

This project sought to utilize waste plastics and end-of-life tyres to develop thermoplastic elastomers that can potentially be useful for various applications, with a special focus on the automotive components. Key findings include, (i) the source of these waste materials can influence the ultimate properties, where for instance flexural strength of rPP sourced from domestic and mixed crates outperformed the premium automotive based rPP; (ii) increasing content of tyre crumbs into rPP matrix has a negative influence on the flexural strength of TPEs irrespective of rubber type and loading; (iii) buffing dust obtained from the sidewall of truck tyres displayed better performance in terms of damping effect, making it ideal for low temperature applications; and (iv) of the seven investigated compatibilizers, maleic-anhydride modified EPR showed generally superior performance that is on-par with the benchmark formulation.

INTRODUCTION

The use of plastics covers a wide range of domestic and industrial applications; particularly thermoplastics such as polypropylene (PP) which is the most sought-after plastic due to its low cost, chemical resistance, ease of processing and durability. However, in dynamic applications, PP is typically modified using an elastomer such as ethylene propylene diene monomer (EPDM) to improve is dynamic performance to mimic the thermoplastic-elastomer (TPE) behaviour. TPEs generally consist of two phases, comprising of a solid-rigid phase such as PP, and a soft-mobile phase which would be provided by the elastomer such as EPDM. There is, however, paucity in the use of alternative TPE materials in the local polymer industries that can secondarily assist in alleviating the environmental problems associated with scrap materials such as plastics and end-of-life tyres. It has been postulated that such alternative TPEs can be obtained by blending recycled PP (rPP) with crumbed rubber (CR) obtained from waste tyres. The rPP is available from many sources, and its characteristics depend on factors such as primary application of the product (i.e. formulation composition) and its thermal history (during and post-processing). Tyres crumbs, on the other hand, generally contain carbon black which provide UV stability and reinforcement, plus a significant amount of the rubber component which is typically known for good rebound, tensional resistance, and elasticity, which makes it attractive as a potential replacement for virgin rubbers such as EPDM.

It has been hypothesized that the use of both rPP and CR would address two critical points relating to low-cost alternative materials and promotion of the circular economic activity. However, PP and tyre crumbs are well-known to be immiscible. There are, nonetheless, several commercially available compatibilizing agents that are compatible with both phases, and they differ in characteristics and purchase price. Therefore, achieving optimal performance at lower doses is critical to ensure cost-effectiveness.

METHODOLOGY

Taking advantage of the Eastern Cape’s automotive footprint, the study was guided by benchmarking against VW Polo door panel (Figure 1) and radiator grill. The materials of interest were blended in accordance with formulations obtained from the OEM components. This benchmarking against commercial products assisted in creating a Pass/Fail criterion for the developed alternative TPE blends. The blends were evaluated for mechanical performance through break strength, impact strength, and flexural strength. Additional evaluation was performed for radiator grill-based application where the TPE’s were tested for their Heat deflection under load.

Figure 1: VW Polo front door panel, obtained from Van Auto Parts.

The study first looked at the selectivity of rPP from various sources to potentially reduce the material cost. Currently, virgin PP (vPP) trades at about R28/kg, whereas the cost of rPPs varied depending on the source, with the automotive based rPP costing about R12/kg, while the price for domestic rPP is R8/kg and that of mixed crates is bout R6/kg. Figure 2 displays the potential cost reduction upon loading rPP to partially replace vPP.

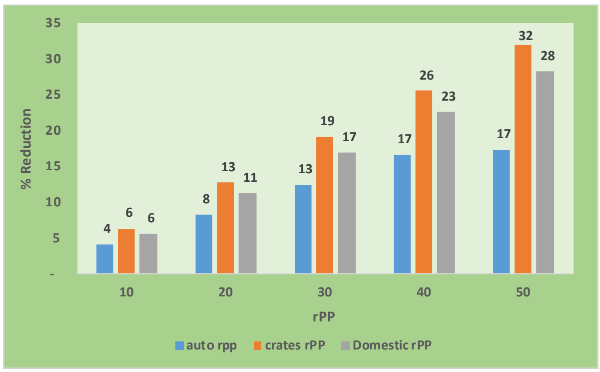

Figure 2: Potential Cost reduction by introduction of rPP

Secondly, the study focused on screening the optimal amount of crumb rubber to be added into the PP matrix, including various types of tyre crumbs. The third part of the investigation was to optimize the compatibilizer for optimal dynamic mechanical performance correlating to the ideal compatibilizer for PP-CR blends.

MAIN RESULTS

Results showed that higher loading of rPP result in a decline of product performance, particularly for rPP obtained from the automotive scrap. However, the opposite was observed in flexural strength where domestic and mixed crates sourced rPPs outperformed automotive scrap rPP (Figure 3). On the other hand, the introduction of tyre crumbs into PP matrix had a negative influence on the flexural strength of the TPE, irrespective of rubber type and loading. The impact strength gains were observed on selected crumbs at specific loadings. Moreso, the buffing dust crumb obtained from the sidewall of truck tyres displayed better damping effect, making it ideal for low temperature applications such as the automotive underbody cover. Amongst the seven investigated compatibilizers, only three showed positive performance. The ethylene-propylene rubbers (EPR) and ethylene-octene rubber were able to match the benchmark formulation, while EVAs and waxes critically failed by exhibiting poor impact resistance and tensile strengths. Amongst the EPRs, the maleic anhydride modified EPR showed superior performance, which is on par with the benchmark formulation.

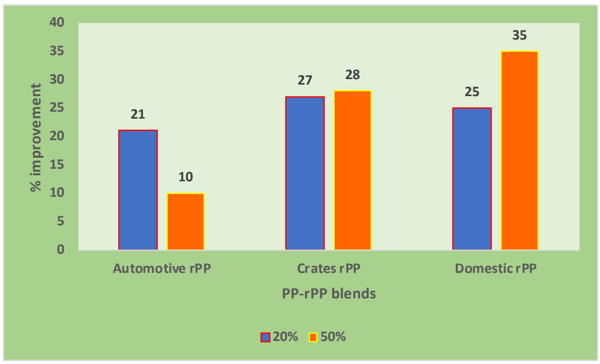

Figure 3: Effect of rPP on TPE flexural strength

Acknowledgements: The authors acknowledge the funding received from the Department of Science and Innovation under the Waste RDI Roadmap.

This Briefing Note is produced as part of the Waste RDI Roadmap Briefing Note Series,
an initiative of the Department of Science and Innovation managed by the CSIR.
The Note stems from the findings of a grant project funded under the Roadmap, entitled
"*Compatibilization of polypropylene - waste tyre crumb rubber blends for usable TPEs*".