FACULTY OF ENGINEERING AND NATURAL SCIENCES

Sustainable Engineering of Polyamide Compounds for Automotive Components

Maksim Berk Gökova[1], Mustafa Emin Eryılmaz[1], Esra Tuncer[1], Cem Çağlar Arı[1]
Alper Gül[2], Burcu Saner Okan[1 3]

[1] Sabancı University, Faculty of Engineering and Natural Sciences, Materials Science and Nanoengineering Sabancı University, Tuzla, 34956, İstanbul, Türkiye
[2] Kordsa Technical Textile A. S., Alikahya Fatih, Sanayi Cd. No:90, 41310 İzmit, Kocaeli, Türkiye[3] Kordsa Technical Textile A. S., Alikahya Fatih, Sanayi Cd. No:90, 41310 İzmit, Kocaeli, Türkiye
[3] Sabancı University Integrated Manufacturing Technologies Research and Application Center & Composite Technologies Center of Excellence, Teknopark, Pendik, 34906, Istanbul, Turkey

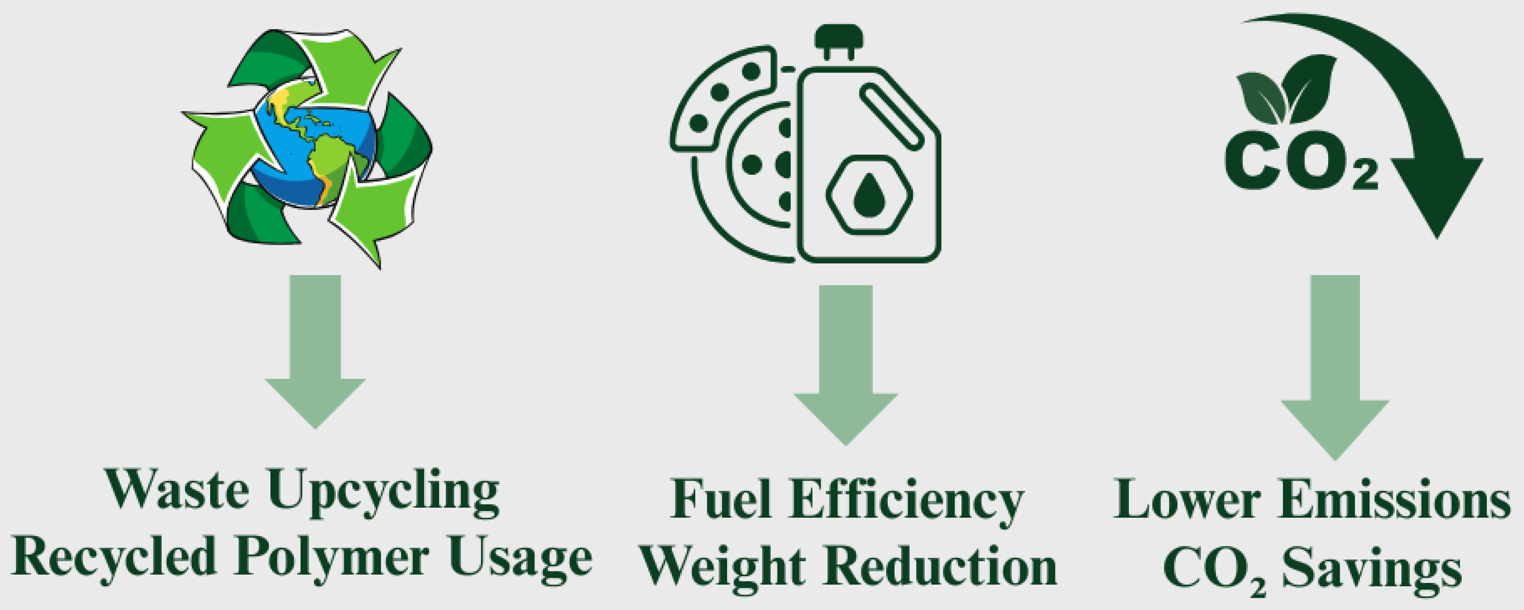
ABSTRACT

Demand for sustainable engineering materials is growing, making the development of environmentally friendly polyamide compounds increasingly crucial. This project focuses on formulating recyclable polyamide-66 (PA66) and Acrylonitrile Butadiene Styrene (ABS) blends enhanced with suitable compatibilizers to attain suitable blend formulation for wheel rim cover production by injection moulding and minimize the environmental impact of the automotive industry by lowering CO_2 emissions.

A comprehensive Life Cycle Assessment (LCA) was conducted to evaluate the environmental performance of different blend formulations. Key indicators such as Global Warming Potential (GWP) and carbon footprint were analyzed. The results show a measurable decrease in CO_2 equivalent emissions compared to conventional unalloyed and stainless steel alternatives. Additionally, the mechanical properties and processability of the material were evaluated to ensure its industrial applicability. The findings suggest that the proposed material supports lightweight design and contributes substantially to sustainable automotive manufacturing.

Current State and Demands in Automotive Industry

Motivation and Goals



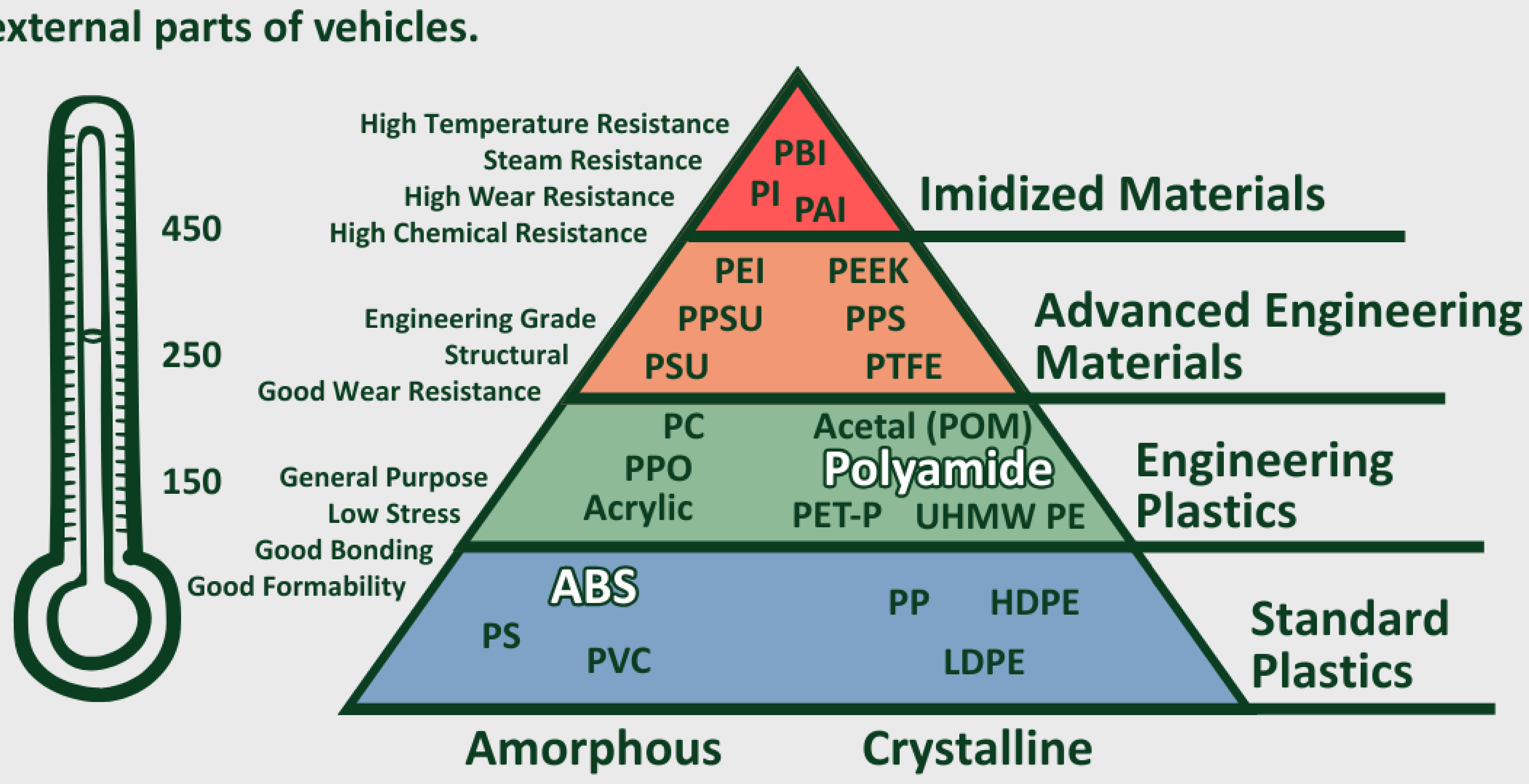
Promises of PA/ABS Blends in Automotive Industry

Replacing steel and aluminum components in vehicles with polymer blends allows a remarkable reduction in

- manufacturing costs,
- energy consumption,
- CO_2 emissions,
- weight,
- and total fuel and electric consumption.

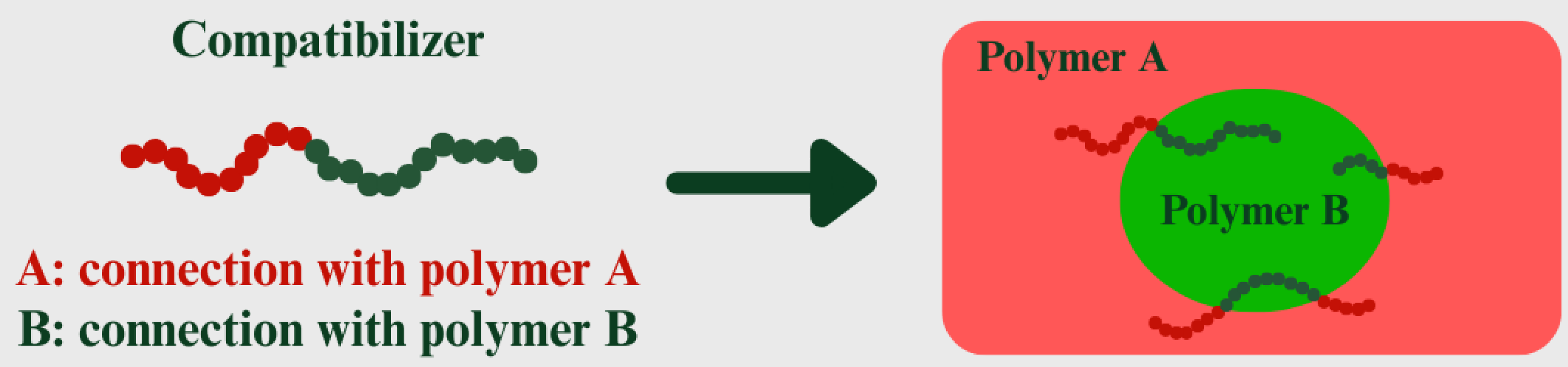
Why PA and why ABS?

Polyamides are one of the best performing polymers in mechanical domain. PA's high tensile strength and high fatigue resistance, when combined with high impact resistance of ABS, makes PA/ABS blends as one of the most promising replacement materials in automotive industry for both internal and external parts of vehicles.



Compatibilizers in Blends

While ABS/PA blends are a superior replacement in theory, the incompatibility of ABS with PA brings important challenges to the commercialization of a product. Compatibilizers enhance the compatibility between two or more immiscible polymers in a blend by reducing the interfacial tension between the phases, leading to an improvement in mechanical and physical properties. In this project, OLEBOND 7404, a maleic-anhydride grafted ABS compatibilizer were used in both 3 wt.% and 6 wt.% concentrations.



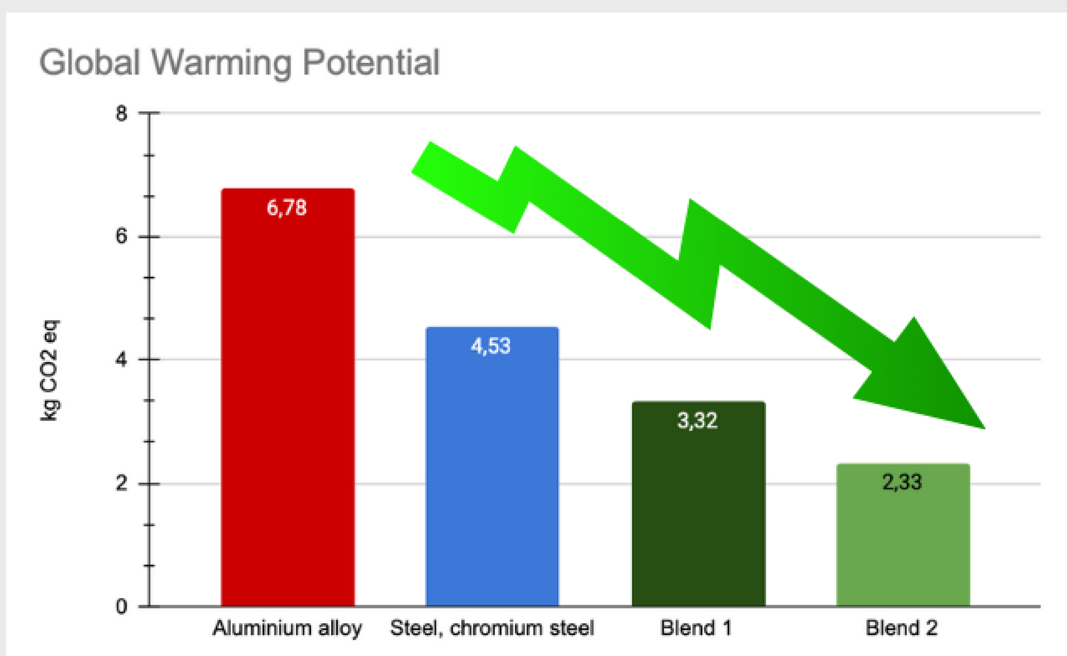
Mechanical Results of the Recycled PA/ABS Blends

	PA66 %100	PA66 %78,5 ABS %18,5 OLEBOND %3	PA66 %58,5 ABS %38,5 OLEBOND %3	PA66 %38,5 ABS %58,5 OLEBOND %3	PA66 %77 ABS %17 OLEBOND %6	PA66 %57 ABS %37 OLEBOND %6	PA66 %37 ABS %57 OLEBOND %6	ABS %100
Tensile Stress (MPa) ISO 527-2	80.92 ∓ 1.2	70.97 ∓ 0	63.72 ∓ 0	52.99 ∓ 0	69.15 ∓ 0	61.75 ∓ 0	52.75 ∓ 0	45.46 ∓ 0.37
Tensile Strength at Break (MPa) ISO 527-	70.95 ∓ 12.68	69.91 ∓ 0	59.9 ∓ 0	52.23 ∓ 0	68.41 ∓ 0	57.18 ∓ 0	51.36 ∓ 0	35.15 ∓ 0.71
Elongation at Break (%) ISO 527-2	17.37 ∓ 2.58	11.62 ∓ 0	18.02 ∓ 0	5.73 ∓ 0	13.33 ∓ 0	22.64 ∓ 0	7.88 ∓ 0	31.25 ∓ 3.58
Elastic Modulus (MPa) ISO 527-2	3,061.45 ∓ 137.57	3,004.31 ∓ 0	2,737.97 ∓ 0	2,657.84 ∓ 0	2,917.87 ∓ 0	2,764.16 ∓ 0	2,629.62 ∓ 0	2,258.27 ∓ 69.34
Maximum Force (MPa) ISO 527-2	3.35 ∓ 0.04	2.99 ∓ 0	2.68 ∓ 0	2.24 ∓ 0	2.86 ∓ 0	2.59 ∓ 0	2.22 ∓ 0	1.91 ∓ 0.03
Yield Stress (MPa) ISO 527-2	69.84 ∓ 1.25	57.76 ∓ 0	54.44 ∓ 0	49.23 ∓ 0	56.72 ∓ 0	53.32 ∓ 0	48.85 ∓ 0	43.82 ∓ 0.41
Elongation at Yield (%) ISO 527-2	2.60 ∓ 0.08	2.24 ∓ 0	2.25 ∓ 0	2.14 ∓ 0	2.25 ∓ 0	2.22 ∓ 0	2.14 ∓ 0	2.23 ∓ 0.05
Charpy Impact Strength (kJ/m²) (ISO 179)	2.43 ∓ 0.45	2.38 ∓ 0.19	2.58 ∓ 0.16	2.55 ∓ 0	2.61 ∓ 0.11	2.68 ∓ 0.18	1.93 ∓ 0.16	17.16 ∓ 0.9
Izod Impact Strength (kJ/m²) (ISO 180)	2.81 ∓ 0.22	2.78 ∓ 0.6	3.28 ∓ 0.55	0.11 ∓ 0	2.35 ∓ 0.12	3.61 ∓ 0.1	1.68 ∓ 0.06	15.42 ∓ 1.62
Melt Flow Rate (g/10 min) (MFR)	38.49 ∓ 0	22.46 ∓ 0	24.40 ∓ 0	22.08 ∓ 0	23.40 ∓ 0	23.23 ∓ 0	19.69 ∓ 0	21.72 ∓ 0
Density (g/cm³) (Archimedes Principle)	1.11 ∓ 0.002	1.10 ∓ 0.002	1.08 ∓ 0.001	1.06 ∓ 0.002	1.10 ∓ 0.002	1.08 ∓ 0.002	1.06 ∓ 0.001	1.01 ∓ 0.002

Blend 2 - Highest Mechanical Performance

Blend 1 - Highest Impact Strength

Life Cycle Assessment (LCA)



↓ ~66 % CO_2 in wheel rim production with Blend2

Blend 2 reduces CO_2 emissions by ~66% vs aluminium and ~49% vs stainless steel, offering a more sustainable option for wheel rim production.

Conclusions

- The incorporation of recycled PA66 and ABS, combined with OLEBOND as a compatibiliser, made it possible to develop sustainable, high-performance polymer blends for use in the automotive industry.
- A Life Cycle Assessment (LCA) confirmed the environmental advantages of optimized mix ratios, revealing that blend formulations produces fewer CO_2 equivalent emissions than other wheel rim materials.
- This study shows that reformulating polymer blends is an effective way to reduce the carbon footprint of automotive-grade thermoplastic compounds while maintaining or improving their mechanical properties.

Acknowledgement

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