Fabrication of Lightweight Aluminium Metal Matrix Composites and Validation in Green Vehicles

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The FLAMINGo project, funded under the Horizon 2020 program (LC-GV-06-2020 theme), represents a pioneering effort to enhance the development of high-performance aluminium composites specifically designed for automotive applications. The core objective of the project is to engineer reinforced aluminium metal matrix nanocomposites (Al-MMnCs) that surpass the strength and stiffness of conventional aluminium alloys. These advanced materials are crucial in the burgeoning battery electric vehicle (BEV) industry, where weight reduction is directly linked to improved energy efficiency and extended range.

1 Introduction

As electric vehicles (EVs) gain momentum, driven by both market demands and regulatory pressures aimed at reducing carbon emissions, automakers are seeking innovative lightweight materials to replace heavier components like steel. Aluminium has long been favoured for its impressive strength-to-weight ratio, and FLAMINGo aims to push these advantages further. By integrating nanotechnology into aluminium composites, the project aims to create materials that can outperform existing solutions, enabling the substitution of steel with lighter Al-MMnC parts. This innovation will help the automotive industry meet weight reduction targets and contribute to the production of greener, zero-emission vehicles.

2 Experimental procedure

One key application in development is the aluminium steering knuckle, which replaces steel (S355) components that typically require welding. By casting and optimizing the design of the aluminium part using topology optimization techniques, FLAMINGo is able to achieve the same mechanical performance as steel while significantly reducing weight. The project envisions producing right and left configurations for a full front suspension system, further contributing to vehicle weight reduction in BEVs.

The demand for composite materials in BEVs continues to rise as manufacturers strive to make vehicles lighter and more efficient. FLAMINGO's approach focuses on producing reinforced metal-matrix castings or extruded parts (Al-MMnCs) with superior properties in terms of weight, strength, and stiffness compared to the steel currently used in electric vehicles. These parts will be produced using advanced manufacturing techniques such as high-energy ball milling (HEBM) by MBN, ensuring improved mechanical properties while maintaining cost-efficiency.

Figure 1 highlights the differences in hardness between samples containing nanoparticles and those without. The results indicate that the hardness increase observed in the samples without nanoparticles can be attributed to the formation of thermally activated precipitations. These precipitates form under heat treatment and contribute to an increase in hardness.

Figures 1: Differences in hardness between samples containing nanoparticles and those without

On the other hand, the samples with nanoparticles exhibit a distinct behaviour. The increase in hardness in these samples is primarily due to the presence of non-thermally activated dispersoids, introduced by the nanoparticles. These nanoparticles are temperature-stable, meaning they do not undergo changes at elevated temperatures, and as a result, the hardness of the samples remains relatively constant across different temperature ranges.

This sustained hardness, irrespective of thermal influence, serves as indirect evidence of the existence and stability of nanoparticles within the casting. Their presence effectively reinforces the material and provides consistent mechanical properties, even under thermal conditions that would typically alter the hardness in nanoparticle-free samples.

3 Project Objectives

The overarching goal of the FLAMINGo project is to significantly reduce vehicle weight by improving the mechanical properties of aluminium alloys. By developing Al-MMnCs with enhanced strength and stiffness, the project enables manufacturers to use less material without sacrificing performance. This is expected to result in a 50%

reduction in weight for certain vehicle components, even those that have already undergone previous weight optimization (Fig 2.).

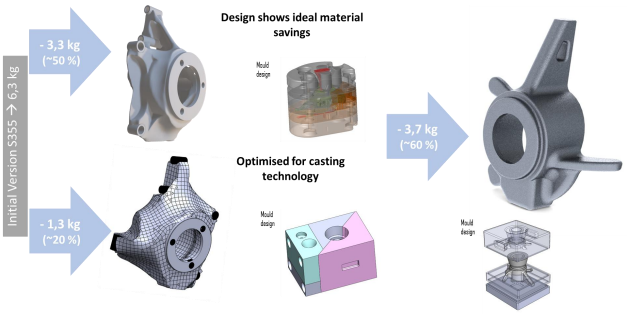

Figure 2: Weight was reduced by 58% from the initial geometry to a first topology-optimized casting.

In line with the growing trend toward lightweight materials in electric vehicles, FLAMINGo focuses on producing reinforced metal-matrix castings or extruded parts that outperform existing aluminium alloys. One of the key tasks is optimizing the casting and extrusion processes by adapting nanoparticle inclusions within the material matrix. Masterbatches, produced using HEBM, introduce nanoparticles into the molten metal, enhancing the material's properties. Rigorous testing and evaluation of these components will ensure they meet the stringent mechanical property requirements for use in electric vehicles.

4 Alignment with Market Trends

The electric vehicle market is experiencing rapid growth, driven by increasing environmental awareness and government initiatives promoting zero-emission technologies. The FLAMINGo project is strategically positioned within this market, responding to the need for lighter, more efficient materials in the automotive sector. Aluminium, a key material in this transformation, plays a vital role in reducing vehicle weight while maintaining high performance. Through its focus on advanced aluminium nanocomposites, FLAMINGo is well-aligned with market trends and is poised to make a significant impact on the development of next-generation vehicles.

5 Impact

Composite materials will be increasingly used in battery electric vehicles (BEV) to make them lighter. By replacing heavier steel parts with lightweight Al-MMCs, BEVs can achieve better energy efficiency, longer driving range, and improved performance. Additionally, the enhanced mechanical properties of these composites contribute to higher structural integrity, ensuring that the reduction in weight does not compromise vehicle safety or durability. This shift towards Al-MMCs in BEVs aligns with industry trends aimed at creating more sustainable, efficient, and high-performing electric vehicle.

The FLAMINGo project is expected to deliver significant benefits across several key areas of the automotive industries:

Vehicle Weight Reduction: The development of reinforced aluminium alloys enables a reduction in the weight of vehicle components, leading to better fuel efficiency and improved overall performance.

Optimized Manufacturing Processes and Lead Times: By integrating advanced material modelling techniques, FLAMINGo streamlines product development, reduces lead times, and simplifies the adoption of new materials by manufacturers.

Improved Structural Integrity and Safety: The project emphasizes stringent monitoring and control of the structural integrity of FLAMINGo components, ensuring they meet the safety standards required for automotive applications.

Compliance with Circular Economy and Zero-Emission Legislation: In line with EU goals for sustainability and circularity, FLAMINGo supports zero-emission technologies, helping the automotive industry meet environmental regulations.

6 Summary

The FLAMINGo project represents a transformative step forward in the development of lightweight materials for the automotive sectors. Through innovative metallurgical processes and a focus on high-performance aluminium nanocomposites, the project is well-positioned to support the global shift toward more efficient, sustainable transportation solutions.

References

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