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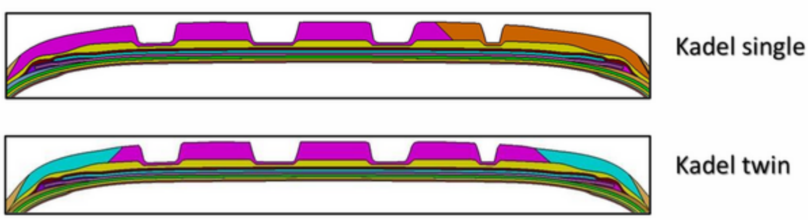
KADEL

Executive summary

The rise of high-performance electric SUVs creates new tyre challenges: higher torque, battery weight, and the need for durability, grip, efficiency, and sustainability. Michelin responded with Project KADEL, aiming to design tyres optimized for EVs without compromising safety.
Central to the project is the MX7 extruder, capable of combining seven rubber compounds in a single step. The study focused on improving efficiency, repeatability, and adaptability, with particular attention to the link between screw rotation speed, tread geometry, and product quality.
Innovation also included an automated vision system to verify colored lines on treads for traceability and compliance, replacing manual checks. Maintenance and cleaning processes were optimized through modular design, safer solvents, and reduced downtime.
Conducted over 18 months, the project combined training, experiments, and data-driven modeling to identify optimal operating parameters.
Expected results: improved manufacturing precision, real-time quality control, more sustainable operations, and tyres tailored for the demands of electric sport SUVs.

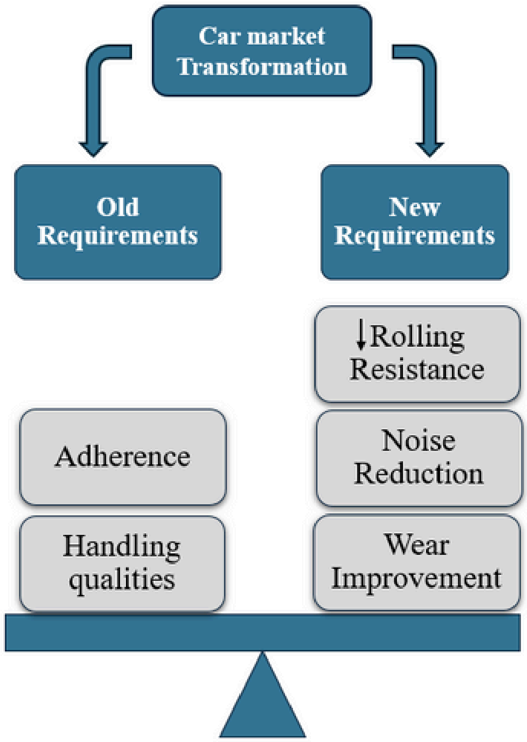
Key Words

Tyres, extrusion, MX7, correlation, optimization



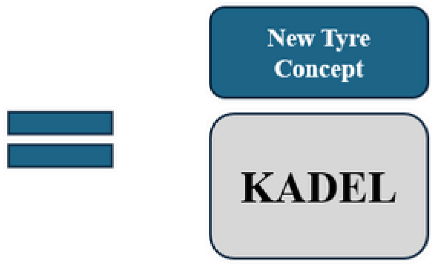
Layering scheme of the innovative tyre produced by Michelin

What is KADEL ?



The passenger car market is undergoing a profound transformation driven by the rise of electrification.

This has led to the emergence of new requirements that must be met while still maintaining existing ones.



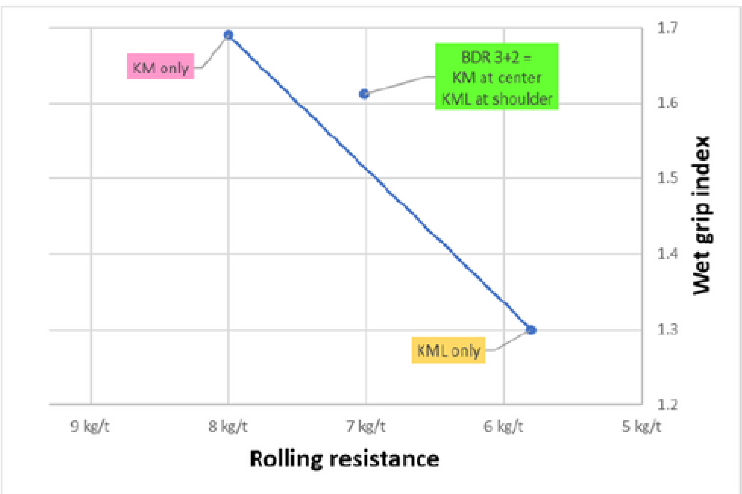
The innovation in the project

New product KADEL

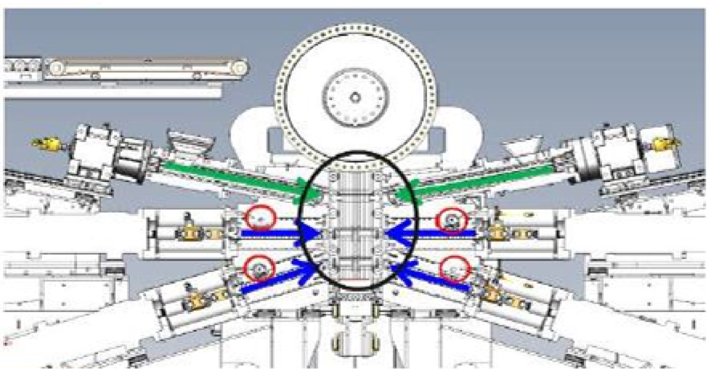
New process MX7

- Single extrusion
- Different types of rubber for more complex properties

- Volumetric control
- Multiple extrusion in a single thread
- Control on rubber distribution



Optimization of tyre properties obtained by KADEL



MX7 extruder head

Project description written by the Principal Academic Tutor

Complex Extrusion of Tire Thread – KADEL
Project Type: Industry & Innovation Oriented
Partner: Michelin – Cuneo Plant

Description
The KADEL project supports the ramp-up of the MX7, an innovative prototype machine capable of extruding seven different rubber compounds simultaneously. This technology enables the production of next-generation tires with highly complex tread and underlayer structures, designed to optimize grip, wear resistance, and rolling efficiency—key performance factors in the evolving electric vehicle market.

Objectives
Monitor and optimize the MX7 extrusion process.
Achieve precise geometrical characteristics of multi-compound tire components.
Ensure high productivity and process stability during industrial scale-up.

Expected Impact
The project contributes to the development of advanced tires tailored for electric vehicles, addressing emerging challenges in adherence, durability, and energy efficiency. It supports Michelin's innovation strategy by refining process parameters for complex multi-material extrusion.

Team description by skill

The project team adopted a dynamic and flexible working methodology, organizing members into sub-groups according to domain expertise to address the technical challenges of the MX7 capacity expansion.

- Mechanical and Materials Engineers – Focused on compound adhesion to cutting blades. Materials engineers analyzed viscosity, surface energy, and thermal behaviour of the compound, while mechanical engineers developed solutions such as blade geometry modifications, surface coatings, and mechanical cleaning systems to ensure continuous production efficiency.
- Aerospace Engineers – Responsible for developing the product–process correlation framework, a data-intensive and highly analytical task aimed at identifying key influencing factors and validating correlations experimentally.
- Mechatronics and Automation Engineers – Led the design of the visual recognition system for color line verification. Their expertise in control and vision systems was critical in adapting existing methods and building a robust, case-specific solution.

This skill-based division of tasks optimized the use of specialized knowledge while maintaining coherence at the system level. Regular interdisciplinary meetings ensured alignment, facilitated knowledge exchange, and enabled iterative refinement of solutions.

Goal

The KADEL project aims to enhance tyre performance by achieving the optimal balance between rolling resistance and adherence, improving both efficiency and safety. Within this broader framework, our team contributed with three specific goals:

- **Process–Product Correlation** – establishing links between process parameters, extrusion behaviour, and final tread performance. This work aimed to improve product consistency, limit scrap generation, and support scalability of the manufacturing process.

- **Extruder Head Cleaning** – developing more efficient and sustainable cleaning solutions to reduce downtime, defects, and maintenance costs, while also improving operator safety and environmental impact.

- **Line Detection System** – designing and testing an automated visual recognition tool for colored line verification on extruded treads, ensuring compliance with customer and industry standards while reducing reliance on manual inspections.

Through these three objectives, the team addressed key technical challenges and supported the industrial integration of KADEL technology.

Image of the head cleaning problem after a production cycle

Understanding the problem

The KADEL project operates in the highly complex domain of tyre manufacturing, where the preparation and extrusion of multi-material rubber compounds present significant technical challenges. Achieving consistent product quality requires precise control over processing parameters, careful management of equipment performance, and reliable monitoring systems. Variations in material behaviour, accumulation of residues in the extrusion head, and limitations in current quality control practices can all lead to inefficiencies, defects, and increased waste. Understanding these intertwined issues was crucial for the team to define effective strategies, improve process reliability, and develop solutions that support industrial scalability, product consistency, and operational efficiency.

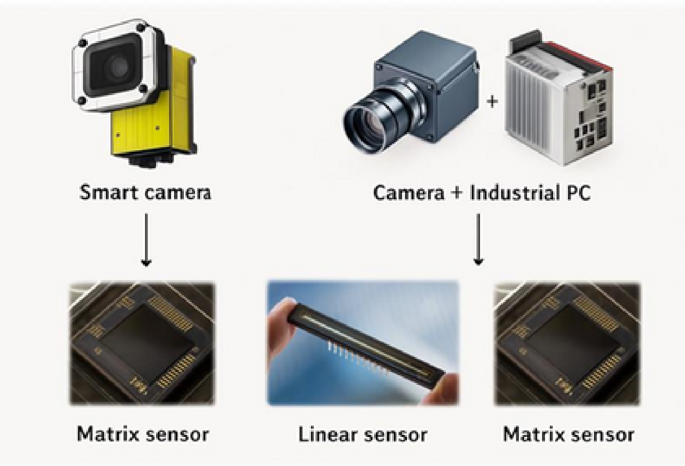
Exploring the opportunities

The challenges identified in the KADEL project also represent significant opportunities for innovation and improvement in tyre manufacturing processes. In multi-material extrusion, maintaining dimensional stability, product homogeneity, and repeatability is particularly complex, especially in the MX7 system, where seven independent inlets must be synchronized to extrude compounds with different rheological properties.

The precise control of screw speed, pressure, and temperature across multiple channels directly affects flow distribution, interface quality between rubber layers, and overall tread architecture. Even minor imbalances can generate asymmetries, increasing scrap rates and reducing consistency. This situation highlights the opportunity to adopt advanced predictive and real-time **parameter control strategies**, including inline monitoring and feedback loops, to optimize extrusion performance and support industrial scalability.

Similarly, the management of **extruder head cleaning** presents both operational and technological opportunities. Traditional manual cleaning and solvent-based approaches (i.e. with toluene[1]), while inexpensive, are time-consuming, operator-dependent, and potentially damaging to blade surfaces.
Mechanical sandblasting offers more thorough cleaning but requires careful control of abrasives and containment of dust[2], while laser cleaning provides a high-precision, contactless alternative with minimal consumables and lower environmental impact[3].
These options allow for process automation, reduced downtime, improved safety, and sustainable practices, representing a clear path to operational efficiency while preserving product quality.

Finally, the automation of **line detection** on extruded treads is a critical area for process innovation. Currently, manual inspections are labor-intensive, prone to human error, and limited in speed and repeatability. Exploring industrial camera solutions, whether smart cameras with integrated processing or a combination of standard industrial cameras with custom software on an Industrial PC, opens opportunities for real-time quality control, automated correction of machine parameters, and enhanced traceability.



The analyzed available options for line detection

The choice between linear and matrix sensors further allows the team to balance resolution, coverage, and analysis speed depending on the specific production requirements.

Taken together, these opportunities demonstrate how addressing the technical challenges of the MX7 extrusion process can lead to more efficient, reliable, and sustainable tyre manufacturing. By implementing advanced parameter control, effective cleaning, and intelligent vision systems, the team can not only mitigate existing issues but also enhance product quality, reduce waste, and support the broader objectives of the KADEL project, ultimately contributing to the industrial scalability and technological advancement of next-generation tyres.

Generating a solution

The solutions developed in this project aim to address the challenges identified in the MX7 extrusion process, focusing on process control, maintenance, and quality verification.

1. Process Control and Parameter Optimization

To understand how production parameters affect the final tread, the team studied the impact of the Kg coefficient, dual-screw synchronism, and compound ageing. By modifying the Kg coefficient and measuring pressures along active extruder lines, it was found that changes mainly provide corrective control without significantly affecting product quality. Synchronism adjustments of the dual screws enabled precise volumetric control, keeping exit pressures constant and ensuring small, localized product variations. Furthermore, tests on fresh and aged rubber compounds demonstrated that volumetric control maintains consistent product quality despite variations in raw material properties, confirmed through DAR profilometry and Mooney viscosity measurements.

Compound condition	Storage time	Mooney viscosity (ISO 289)	Observed processability
Fresh compound	< 5 days	Higher: 38.86	Standard, good flow
Aged compound	> 7 days	Lower: 38.01	Changed processability, stiffer behaviour

Comparison of Mooney viscosity and processability between fresh and aged compounds

2. **Extruder Head Cleaning**

Manual cleaning proved slow, operator-dependent, and inconsistent. Solvent immersion offered limited improvement but posed safety and environmental concerns. Automated methods—sandblasting and laser cleaning—were evaluated, considering effectiveness, cycle time, surface integrity, operator safety, environmental impact, and cost. Sandblasting was selected as the optimal solution, providing high cleanliness, repeatability, and safety while minimizing environmental impact and operating costs.

3. **Line Detection on Extruded Treads**
To ensure precise verification of colored lines on treads, an industrial camera system combined with custom software was chosen. The software adapts ADAS-inspired model-based image processing techniques, detecting lines based on color and geometry without black-box machine learning. Steps include Gaussian filtering, HSV color masking, contour detection, and linear fitting to identify edges, slopes, and colored regions. Feasibility tests confirmed that processing times are within production constraints, and a proposed laser stripe enhancement can improve groove and rib recognition for greater reliability.

By integrating these approaches, the project delivered solutions that are technically robust, industrially feasible, and repeatable, ensuring high-quality production, reduced downtime, and enhanced process safety.

Main bibliographic references

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[3] Laser ablation. https://en.wikipedia.org/wiki/Laser_ablation