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EXTERNAL INSTITUTIONS

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VISIOMAC

Executive summary

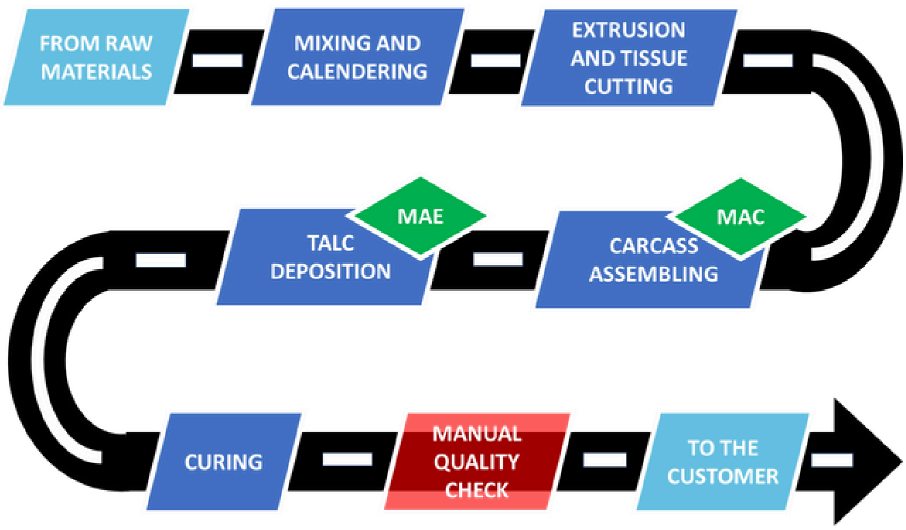
The VisioMAC initiative aims at introducing quality control along the production line of tires. The project was conducted in collaboration with the Michelin site of Cuneo, where we attended to the steps of tire production: mixing and calendering, extrusion and tissue cutting, carcass assembling, geen tire (unvulcanized tire) fabrication, curing, and final inspection.
The quality control systems check the two stages that are particularly prone to faults:

- the assembly of the carcass - Macchina Automatica di Confezione (MAC) subproject
- the talc deposition before the curing of the tires. - Machine Automatique d'Enduction (MAE) subproject

By enabling immediate recognition of faults, the project seeks to enhance productivity, reduce waste, and improve overall quality while respecting a cost budget that guarantees the feasibility of the solution.
The final result is two detecting systems based on computer vision and tailored to the manufacturing environment, able to adapt to different tire sizes and with an elaboration time that respects the cycle time of the line.

Keywords

Quality control, Computer Vision, Tire production, Waste reduction



Scheme of the production sequence

Project description written by the Principal Academic Tutor

This research project focuses on developing a system to ensure the correct positioning of welds in a manufacturing process while maintaining cycle times and sustainable costs. The project is divided into two parts: the first involves using a camera and laser system to detect weld placement accuracy on the machine axis. The software analyzes disruptions in the laser line near interfaces and determines if the weld is within acceptable tolerances. The system provides a binary "ok/nok" evaluation based on this analysis and measures the cycle time, which is well within acceptable limits for production. This cost-effective solution offers a significant reduction in expenses compared to the traditional system, using only one camera per machine location instead of two profilometers.

The second part of the project focuses on identifying defects in the talc application process during manufacturing. A Fluke infrared thermal camera, installed with the help of ASP researchers, detects areas where talc is missing before the vulcanization process. This enables early identification and potential correction of talc defects, such as missing, overlapping, or unevenly applied talc, thereby saving materials. The thermal camera effectively differentiates talc coverage based on temperature variations, and initial tests have shown promising results.

Overall, this dual-system approach leverages both optical and thermal technologies to improve quality control in manufacturing. The system offers significant cost savings and improved durability, with the potential to reduce material waste through early defect detection. Future efforts will focus on refining the software to make the talc detection process more efficient and user-friendly.

Team description by skill

The team comprises six engineers with different technical backgrounds: three automation and control engineers, two electronic engineers, and a chemical and materials engineer.
Our six-person group split into two subgroups with mixed skills. One group worked on the MAC problem, and the other on the MAE.
MAC subgroup members are Mattia Mattiauda, electronic engineer, Giuseppe Festa, and Elena Maria Pesci, both automation and control engineers.
MAE subgroup members are Ilaria Ferrari, electronic engineer, Ottavio Soldera, materials engineer, and Martina Giampaglia, automation and control engineer. Knowledge of the chemical field was necessary to treat the talc deposition.
Nevertheless, we cooperated many times: many brainstorming sessions helped us find original and new solutions. We didn't work all the time together mainly because of distance problems: some of us worked more on the prototype development because they had the hardware available, others were more focused on communicating the results, and others organized the work, managing all the deadlines and relationships inside the group.

Goal

The primary objective of the VisioMAC project is to develop two distinct quality control systems tailored to the specific challenges of the MAC and MAE production lines. The MAC system aims to ensure that sidewalls are correctly positioned on the carcass, the internal structure made of fabric and steel wires that give basic shape and strength to the tire, by analyzing real-time images captured by overhead cameras. The system must adhere to stringent constraints, including the width of the sidewalls, their distance apart, and symmetry. Conversely, the MAE line system focuses on detecting various faults during the talc deposition process, a critical stage of manufacturing with a non-negligible fail rate. This includes identifying issues such as inhomogeneous application, incomplete coverage or dripping of a talc-based solution. The system employs a nozzle that sprays while performing a 360-degree rotation inside the so-called green tire, a piece made of uncured polymer. This time, the optic is a thermal sensor that discriminates the presence of the talc thanks to the temperature gradient of the cold liquid on the warmer rubber. The conceptual design phase of both projects also had to consider the harsh and dusty environment of the production lines, ensuring that the hardware components are robust enough to withstand these conditions and maintain optimal performance. Additionally, the algorithms developed must prioritize speed to avoid falling behind the stringent production lines' deadlines, while maintaining top detection accuracy.

Understanding the problem

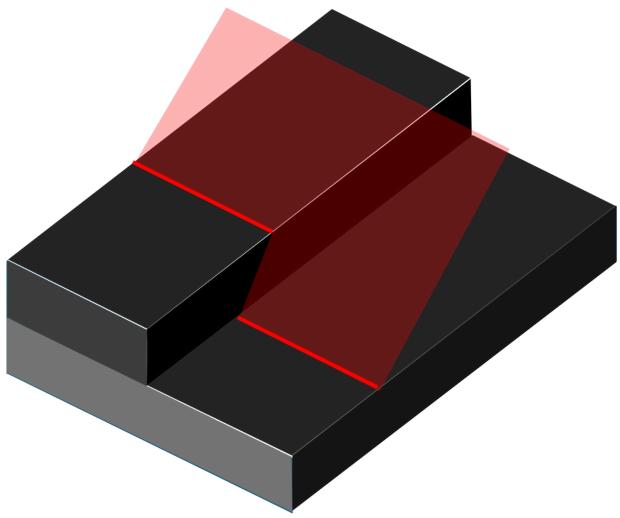
The leader company of the tire manufacturing Michelin entrusted our group with the task of designing and implementing two advanced quality control systems. Note that all the manufacturing machines and productive lines active inside the Michelin sites worldwide are designed internally. This characteristic requires the formulation of application-specific solutions, such as the one we developed. The devices are located at two of the most error-prone stages of operation, the rubber layer deposition onto the carcass and the talc layer application before curing. The primary goal is the immediate recognition of the occurrence of a fault, which allows the rectification of the process. In the current situation, the defect goes unnoticed and is committed on a sequence of pieces, which are further worked until one of them reaches the quality control at the end of the production. The delay of recognition causes a waste of energy and materials on faulty work-in-progress (WIP). Moreover, rectifying a faulty finished product is significantly more challenging and, in some cases, impossible when compared to a semi-finished one. The recycling of scrap tires can be performed in various ways, e.g. waste-to-energy allows the recovery of thermal energy. Nonetheless, the reduction of waste and scrap tires has to be recognized as a priority to lower the emissions related to the sector. Early fault detection entails not only quantitative but also qualitative advantages for the company, in fact, the reliability of the brand can be compromised by a faulty finished product sold on the market. Additionally, the materials and energy saved by the detection of defects along the production line constitute an important asset in terms of production costs and pollution. The requirements set by quality control and environmental preservation are met, while the line doesn't stop and the productivity is not only preserved but enhanced by eliminating non-value-added activities. The concurrent satisfaction of the needs of the quality and productivity departments is a strong added value. Often, the two points of view are conflicting in the automotive industry, leading to worse performances in both fields.

Exploring the opportunities

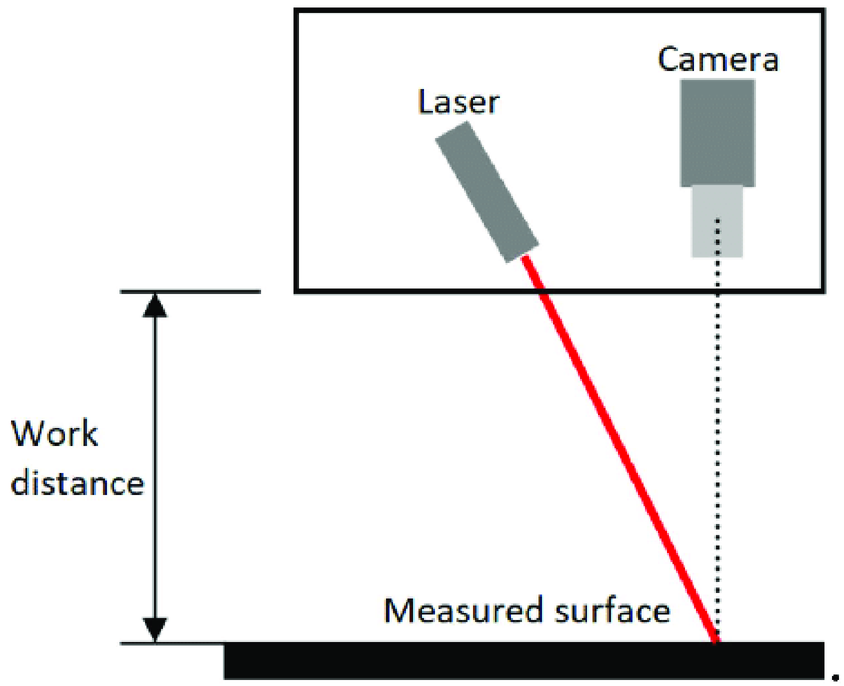
The automotive industry represents one of the most significant driving sectors of the economy due to its multiplier effect on upstream companies and the employment it generates. The subsector of tire production retains the defining characteristics that make it an integral part of the automotive landscape. The manufacturing of tires comprehends a series of steps, it begins with the selection of raw materials and ends with final product control. Furthermore, as the automotive industry undergoes a notable shift towards electric vehicles, there is a growing demand for specially designed tires. This shift is expected to drive innovation and further evolution within the tire manufacturing sector. The tire manufacturing market is expected to maintain its leading role in the future. The research in manufacturing is driven by the desire to improve quality control and increase productivity. These two aspects seem to collide when pursued individually, but the setting of cohesive goals is possible and necessary. In this complex scene in the last decade also, a new factor has earned a place: the undeniable necessity to lower environmental pollution. The opportunity exploited by the VisioMAC project lies in the interconnection of these needs, making our work a step in the path of a more responsible, sustainable, and efficient tire production.

Generating a solution

In the MAC line, the interface between the two layers is thin and the black colour of the rubber makes it hard to identify it consistently. The solution found consists of a laser light, whose beam is shaped as a thin line. The projection of the rays on the carcass enhances the contrast between the different rubber bands. The algorithm is then responsible for insulating the bright line and detecting where it is not continuous. Those breaking points are where the interface between two different layers lies. Thanks to this newly added element, a sub-millimetre accuracy has been reached, along with a fast 2 seconds execution time, without the need for any specialised hardware. Upon request, a custom user interface has been developed to allow ease of access to the software for the workers, to select the proper configuration for different models of tire and to feature flawless synchronization with the industrial computer driving the line. A further study was conducted on the illumination intensity to find a compromise between visibility and reflections and avoid image degradation.

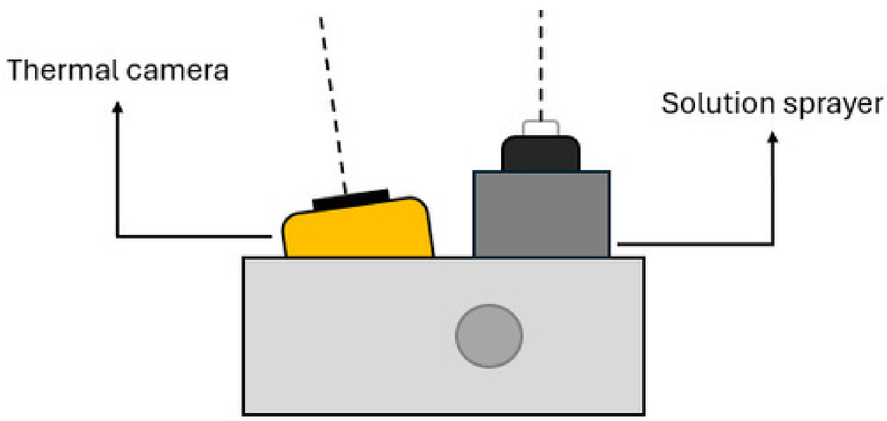


Laser projected on overlayed layers

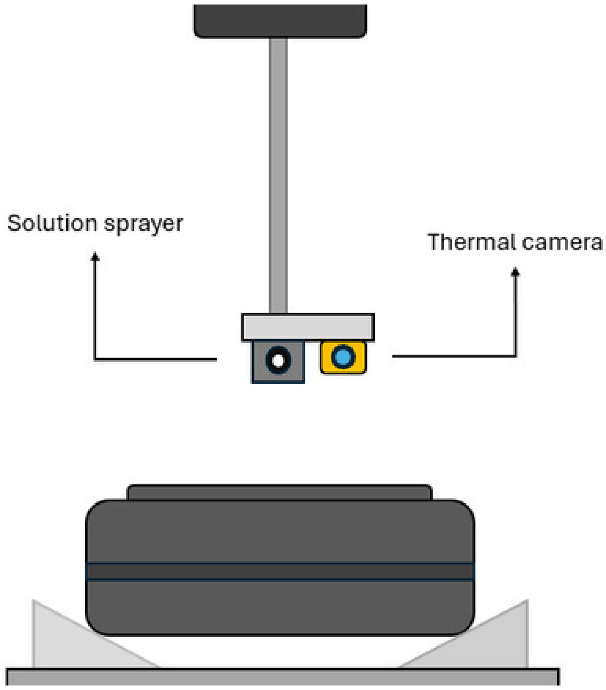


Set-up of MAC quality control system

The decision to utilize thermography for detecting improper talc distribution on tires in the MAE lines resulted from an iterative process involving both initial intuitions and practical field tests. Various methods were considered, including the use of chemical tracers, video cameras and spectrometers, before arriving at the most viable solution: the thermal camera. The talc solution, a waterbased liquid, has to be sprayed on the internals of the tire to hinder the sulfur diffusion with the membrane of the vulcanization mould. The deposition quality is critical for correct curing but no other methods have been reliable enough to make the check, because of the occluded workspace and the low contrast between the solution and the internal surface of the tire. Instead, by focusing on the temperature gradient between the warm tire and the cold liquid, a crisp map of the talc deposition can be obtained. Another driver for this solution was the speed at which talc presence could be revealed on the surface of the rubber, largely fitting the cycle time of the production line.



MAE: thermal camera position



Set-up MAE quality control system

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