Opening photo: **Mapsa, a part of the Corporación Mondragón, the eighth Spanish business group, provides all major OEMs w its alloy wheels: PSA Group, Opel, Seat, Volkswagen-Audi Group, Kia, and Ford.**

How to Coat 700 Alloy Wheels per Hour with One Plant: Mapsa's Solution

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With a speed of 7.99 m/min., it is among the fastest coating lines in use in the alloy wheel industry and one of the largest in the world in terms of productivity. It was designed with an Industry 4.0-oriented approach for full traceability of wheels, each of which is matched with its actual process parameters. It is also equipped with innovative solutions to solve the typical and unique problems of wheel coating processes, now intensified by the industry's strict specifications, such as wheel shape, paint thicknesses, presence of surface areas not to be coated, oven temperature control profiles, temperature at the exit from coolers, and soft wheel grip during transfer among synchronised circuits.

These are just some of the features of the turnkey plant designed and built by Olpidürr (Milan, Italy), the world competence centre for alloy wheels of the German group Dürr, and installed by the Spanish cooperative Mapsa (Pamplona, Spain) in 2018. With a productivity of almost 700 alloy wheels per hour – 685, to be precise – this is an imposing plant, built

in the framework of the expansion of the already existing paintshop. "Conceiving an optimal layout with the space and material flow constraints imposed by Mapsa was the first challenge faced already in the offer phase," says Flavio Bodini, the Sales Manager for the wheel sector at Olpidürr. The line is arranged on three levels, with five synchronised conveyors; a robotised loading station and a continuous flow unloading station sending the parts to the inspection and final check lines; two identical powder primer application booths; two booths applying liquid base coats and clear coats and overlooking an air-conditioned clean room; ovens and coolers for each process phase; a Dürr Ecopure TAR recovery afterburner with a capacity of 25,000 Nm³/h, i.e. the largest in Dürr's range, to purify the air exiting the liquid coating booths, the flash-off units, and the cross-linking oven; auxiliary systems and devices including chemical-physical water treatment, demineralised water production, and coating sludge separation units.
This line was designed in compliance with the principles of Industry 4.0, i.e. with a supervision system that, in addition to managing and controlling all machines, allows full traceability of each wheel, which is identified by a Datamatrix code reader during loading so as to uniquely match it with its process parameters when passing through the individual sections of the system.
Currently, the plant is in the ramp up phase, ready to handle the increasing production volumes of Mapsa, one of the leading companies in the European automotive sector.

"With a speed of 7.99 m/min., it is among the fastest coating lines in use in the alloy wheel industry and one of the largest in the world in terms of productivity. It was designed with an Industry 4.0-oriented approach for full traceability of wheels and equipped with innovative solutions to solve the typical and unique problems of wheel coating processes."

Mapsa: corporate leadership for customer satisfaction and safety

Wheels guarantee a vehicle's safety: they ensure stability, road holding, and braking effectiveness. At the same time, they are also an important aesthetic element, able to define and enhance the design of a car. Established in Orkoien, a town on the outskirts of the famous Pamplona, in the Spanish region of Navarre, in 1957, in 1991 Mapsa turned into a cooperative and became part of the Corporación Mondragón, the eighth Spanish business group, thus becoming one of the main industrial cooperatives of Navarre. Its strong custome orientation and focus on the research and development of new design and finishing solutions for alloy wheels have made Mapsa an important supplier for all major OEMs: P Group, Opel, Seat, Volkswagen-Audi Group, and Ford (**ref. Opening photo**).
"Mapsa manufactures alloy wheels for some of the leading OEMs" says Investments & Engineering Manager Jesús Rodríguez Buen "Our fully integrated cycle starts with meltin low pressure moulding, and fully automatec X-ray control and ends with machining, ther treatments, and coating. Design, quality, and flexibility are the characteristics that set us apart from our competitors. We work in clos collaboration with our customers also to develop suitable finishing solutions. We sup our wheels in 25 European countries, as we India, United States, Russia, and South Africa We only produce OEM rims between 15 and inches. We have two coating lines in additio to the new Olpidürr one: one applies acrylic products and also treats diamond wheels and the other performs conventional coatin operations. We decided to install a third coa line, particularly such a large line, because w wanted to increase the productivity and pair capacity of this factory, Mapsa's only one."

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Figure 1: **The robotic loading station.**

Line features

"The whole line is automated. The loadi station is equipped w a robot that picks up the wheels from a rol conveyor and arrange them, three at a time on the load bars of the one-rail overhead conveyor (**Fig. 1**) goin through the whole pre-treatment sectio – the only overhead conveyor out of the five linked to this line, explains Mapsa Proje Manager Oleksandr Kudinov.

Figure 2: **The spray pre-treatment tunnel.**

"The new plant's load bars have been designed to avoid balance differences between full and empty bars; they are suitable for wheels with significant differences in diameter and height and to prevent any contact with the exposed areas of the wheels."
Pre-treatment occurs through a Chemetall 12-stage process that includes a surface conversion step with the well-known SAM product, specifically developed for the alloy wheel industry by Chemetall itself (**Fig. 2**).
The cycle is composed as follows: three degreasing stages, two rinses with mains water, a deoxidation stage, a rinse with demineralised water, a conversion stage with the SAM polymer to increase the corrosion resistance of parts, and two rinses with recirculated demineralised water first and then with fresh demineralised water. Specific analysis tools continuously monitor the active baths, so that the control system automatically doses the various chemical products. Conductivity is measured at the exit of this line section, since it is an indicator of the final cleanliness degree of wheels.

"If required by customer specifications, we can increase the parts' corrosion resistance by activating a stage with zirconium salts," adds Mapsa Coating Director Raul Velasco. "We guarantee a minimum corrosion resistance value of 1,000 hours in the salt spray test and 240 hours in the CASS Test. We have an internal laboratory that performs any quality test required by the alloy wheel industry: cyclic corrosion tests, solvent, acid, and gravel resistance tests, coating adhesion tests, water immersion tests (one of the most important ones to check the quality of finishes), and acetone immersion tests (to verify the proper polymerisation of coatings)."
At the end of the pre-treatment circuit, which also includes a drying and degassing oven and a forced cooling tunnel, another 6-axis robot with a gripper grasping the wheels by their rims picks up three parts at a time from the load bars and deposits them on a stabilised inverted one-rail conveyor. T is equipped with piece-holders, or spindles, with a contact area with the wheels' bearing surfaces and centring cones and a retractab mask in a polymeric material, which avoids indentations in the coupling areas inside th hub and prevents paint adhesion. The floor conveyor is linked to the powder coating station, where the primer is applied in four different colours: white, black, dark grey, and light grey (**Fig. 3**). At the entrance of each powder booth, the operators cover the whe areas that must not be painted with suitable masks in an air-conditioned room.
In order to ensure maximum quality, after being transferred to the first floor conveyor the wheels always move within closed and ventilated areas with filtered and condition air. "We installed two identical GEMA booths for applying the powder primer (**Fig. 4**)," say Kudinov. "This unusual choice for the sector of alloy wheels has enabled us to significant increase our productivity by taking advanta of the quick colour change system.

Figure 3: **The robotic transfer from the overhead conveyor of the pre-treatment circuit to the floor conveyor of the powder applicatio circuit.**

The booths are multicolor, that means that each booth can apply any colour. The booths work in parallel: while one is applying a colour on the wheels, the other one is changing the colour whitout the need to stop the production. This also improves flexibility."
"The powder coatings are applied with a feeding technology using dense phase pumps AP01.1 and a last generation Opticenter powder management unit with separate management modules for each gun (**Fig. 5**)," states Esteban Reboiras, Managing Director at System Pulver, the sole distributor of GEMA in Spain. "Moreover, thanks to the excellent collaboration we started with Dürr, our booth air purification system also treats the air from the machines removing powder residues from the spindles, the conveyor, and all wheel areas on which no deposits are allowed.
This has enabled Mapsa to avoid installing any additional filtration systems."

After the powder application station, the wheels are deposited on the metal spindles (with a simplified centring device) of the stabilised inverted one-rail conveyor linked to the curing oven and cooler circuit, through another automatic transfer by a 6-axis robot with a grip that picks up three rims at a time. "Among the many technical challenges of this project, one in particular required the attention of Olpidürr's engineers: the wheels' transfer from the powder booth conveyor to the curing oven and cooler one. Indeed, the involved robot also has to perform an intermediate stop-over in the hub and bearing surface cleaning station. Moreover, the two conveyors with a speed of 8 m/min. and a cycle time of 15 s must be synchronised while moving a mass (grip and wheels) of almost 200 kg with a 2 m footprint inside a robotised cell with a necessarily limited size. Finally, all this must be made while avoiding the obstacles in the area consisting of the devices that must necessarily be installed near the robot's work area," explains Flavio Bodini from Olpidürr. "In these case, it was essential to perform simulations during planning, thus defining the best layout and moving obstacles so that the fastest axes can always be used and critical points are avoided in the pre-set trajectories."
"As for the powder curing oven, Mapsa's specifications were also extremely challenging in terms of temperature consistency and maximum temperature allowed. Therefore, the oven features separate and independent temperature rise and maintenance areas, in order to minimise any differences in the temperature profiles of the various wheel surfaces with extremely different

thicknesses and, at the same time, ensure compliance with the dwell time required by paint suppliers. Thanks to the conveyor routing, however, the footprint remains extremely compact," explains Olpidürr Project Manager Alessandra Sapla.
After the forced cooling station, another robot automatically transfers the wheels on the spindles of the stabilised inverted conveyor of the liquid coating application and drying circuit. The first section of this circuit consists of a quality inspection booth and an oven with IR lamps to heat the wheels' mounting faces before the application of the liquid base coat and clear coat, as requested by paint suppliers to achieve better finishing quality. "Always coating at the same temperature and preventing sudden changes is very important for quality purposes," states Sapla. "Therefore, even though the system is fully air-conditioned and consequently the booths operate with constant temperature and humidity (differentiated between winter and summer to reduce energy consumption), we chose to include a chamber equipped with fast medium wave IR lamps featuring a power regulation system and mounted on specific frames. This also ensures that the wheels constantly reach the optimal temperature for paint distension (**Fig. 6**)." In order to save energy, if conditions permit, it is possible to set the cooling section so as to turn off the IR station and send th wheels to the liquid coating station at the required constant temperature.
The area including the liquid base coat + clea coat system applicatio station and the cross- linking oven is crossed by the fifth and last floor one-rail conveyo equipped with alumin spindles (**Fig. 7**). The two spray booths for and CC are configured integrating EcoBell + EcoGun technology complete with an automatic servo axis system. "Mapsa tries to apply its base coats and clear coats main employing the electrostatic bells (**Fig. 8**), wh using the guns only for the touch-up operat needed to reach an adequate coverage degree," says Alessandra Sapla. "This minim the use of paint, thanks to the high transfer efficiency of the bells that reduces overspra and production costs."

Figure 4: **Powder primer application.**

Figure 5: **Gema's Opticenter powder management unit.**

"Mapsa installed two identical GEMA booths for applying the powder primer: an unusual choice for the sector of alloy wheels which has enabled the company to significantly increase our productivity by taking advantage of the quick colour change system."

Figure 6: **A sample check of the wheel temperature after passing into the IR pre-heating chamber.**

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Figure 7: **The robotic transfer from the powder application circuit to the liquid application one.**

Advanced solutions for the application of liquid base coats and clear coats

The application of liquid coatings (one-component solvent-based products) occurs in two opposite booths, separated by an air-conditioned clean room that allows observing the painting process and adjusting the different parameters as needed with total process control ergonomics. "From this clean room, it is possible to fully monitor both the application process and the state of the adjacent coating management unit without the need for the operator to physically move," explains Alessandra Sapla from Olpidürr. "The operations to be performed in the paint management unit are limited to loading and cleaning: this increases operator safety by exposing them as little as possible to an environment with the presence of solvents, although adequately ventilated."

The solution adopted for the liquid application booths is the Dürr Vertijet side water-veil technology including a wet abatement unit and a Venturi scrubber, which minimises overspray with an exclusively fluid dynamic process and with no need for abatement nozzles or filters in the extraction tower, while maintaining a very limited footprint.

The aeraulic system includes recirculation units in order to guarantee consistent thermo-hygrometric conditions in the booths and reduce the airflow to be sent to the afterburner for the abatement of VOCs, while increasing their concentration to reduce this machine's consumption. The system includes a downstream heat recovery unit to produce hot water for heating the pre-treatment baths and for air conditioning (**Fig. 9**). Each booth is equipped with an air conditioning unit featuring heating and cooling batteries, droplet separator, and preliminary filtra and finishing stages. A CO_2 flame detect and extinguishing system protects the booths, the recirculation pipes, and the treatment recirculation units.

Verind (Milan, Italy), belonging to the international group Dürr as its world competence centre for application technologies in the wheel sector, integra the coating booths with automatic equipment and eco-technologies specif developed for high-end wheel coating processes by combining advanced solut used in the automotive industry and adapted to the high line speed of the M plant. The project was developed with flexibility and modularity criteria, installi the innovative Dürr EcoBell2 electrostat technology for the application of liquid coat and achieving a very high automation degre in compliance with the Industry 4.0 principle The Dürr EcoBell2 electrostatic technology titanium bells guarantees as follows:

- high surface finishing performance for the application of base coats and clear coats;
- high transfer efficiency and high reliability;
- extensive control of the spray cone thanks the separate adjustment of the two flows;
- closed-loop control of turbine rotations ar high voltage control.

Figure 8: **The base coat and clear coat are applied with EcoBell2 Dürr electrostatic technology.**

"The coating process of aluminium wheels is very complex due to the 3D shape of these products. That is why we integrated automatic colour change systems, the servo axis technology for the EcoBell2 bells, and Dürr automatic guns conveniently arranged and activated with an automatic cycle (**Fig. 10**)," says Alessandro Soba, Sales Manager at Verind. "An electronic supervision system including PLCs and PCs with a graphic interface for line operators enables to monitor and record all application process phases and their related data. The base coat and clear coat paint mix room unit is equipped with Dürr pumps with a continuous paint recirculation system; each pumping group has a paint level and pressure control (**Fig. 11**).
Variable speed agitators have been installed, driven by electric motors for energy saving and efficiency reasons."
"The automatic system developed by Verind to recover the products generated by colour change cycles, which are collected in a tank placed in the coating management unit through specific fluid circuits, is a true innovation for Mapsa. This reduces contamination of the water veils in the booths and therefore both the use of waste water purification products and overspray," adds Verind Commissioning Engineer Ivan De Angelis. Verind also designed and supplied the booths' waste water treatment and demineralised water production system.
Demineralisation occur with an ion exchange resin system (**Fig. 12**) allowing removing all salts dissolved in water It is fed with recirculate water from the cleanin processes.
The plant consists of an activated carbon column for the elimination of organic matte and a duplex system (i.e. while the first unit is operating the second remains in stand-by mode) to handle a 24/7 production flow. The plant operation and the resin regeneration process are managed automatically through a control panel and by appropriately sized valves in acid-proof material.


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Figure 9: **One of the technical levels of Mapsa's painting installation.**

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Figure 10: Automatic control panel of paint application parameters of EcoBell and EcoGun.

Figure 11: Paint mix room box with paint pumping unit for BC and complete with Dürr pumps and controls.

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Figure 12: **Duplex automatic demineralization system.**

Regeneration water (acid and alkaline eluates), together with process water, is then treated in a chemical-physical plant for the abatement of metals (aluminium), fluorides, COD, and other salts. The chemical-physical plant is composed of an acidification station dosing an acid ar a metal salt, a neutralisation station dosing lime milk, and a flocculatio station dosing polyelectrolyte. This mixture is then separated in the subsequent lamellar decanter. Such separation leads to the formatior of two flows: water, free of any dissolved substances, and sludge, collecting all the removed impurities. After filtration with sand and coa water can be discharged; the sludge collected from the bottom of the decanter is sent to a thickening and dehydration section with a plate filter press.

Accessory systems

Mapsa's line also includes an innovative cleaning system for the wheel hub interiors and bearing surfaces after the powder primer applicatio "Developed by Olpidürr and currently patent-pending, this machine is set according to the coating program matched with each wheel, which includes specific cleaning requirements for its hub and mounting face, depending on the car manufacturer's specifications," explains Alessandra Sapla. The patent-pending cleaning system for the powder conveyor's spindles is also extremely high performing, as it was design to completely solve the cleaning issues of powder application circuits' spindles and conveyors.

Attention to maintenance

The line must produce quality wheels (**Fig. 13**): that is why the machines must be able to be inspected and both the replacement of consumables and wear parts and the scheduled maintenance operations in general must be carried out easily and safely. This line has been designed keeping these needs in mind. For instance, all air conditioning machines and the oven heating and forced cooler ventilation units are installed on a platform with easy-access spaces and paths for machinery maintenance.

Figure 13: **A finished wheel.**

Attention to safety

The plant was designed and built while constantly checking compliance with safety regulations and criteria. For example, the whole route along which the load bars can be carrying wheels is protected with wire nets and all access doors to robotised plant sections are equipped with electric locks. It if is necessary to see a station in function, as in the case of the pre-treatment tunnel, operating procedures have been defined to allow observation only to specialised personnel. Another example is the liquid coating application station: due to the presence of solvents, concentration detection tools have been installed in suitable positions to guarantee the intervention of the supervision system in any situation of potential danger.

"Mapsa's line includes an innovative cleaning system developed by Olpidürr for the wheels' hub interiors and bearing surfaces after the powder primer application and a vibrator supplied by Rösler to clean the Teflon masking caps used on wheels."

The supervision system

The supervision system is based on Siemens 1500 Series PLCs and the Wonderware System Platform software package. In addition to all the alarm, displaying, and process parameter and machinery status setting functions, the supervision system includes a wheel tracking software system that enables each wheel in the plant to be identifiable on the control PC workstations' screens and the operator panels equipped with this feature.

All wheel types, together with their geometrical characteristics and matching cycles, are stored in the supervision system and they can be retrieved and matched with the batches to be produced during the day through a panel in the loading area. In this way, the supervision system communicates the required process parameters to the line machines, the pick up and deposit coordinates to the robots, and the information needed to implement the program corresponding to the wheel's type and cycle to the PLCs. If a Datamatrix code is present on the wheel, the process and coating data are also matched with the individual wheel and transferred to Mapsa's mass memory units.

Figure 14: **From left to right: Raul Velasco from Mapsa, Esteban Reboiras from System Pulver, Juan Mari Ormart from Mapsa, Alessandra Sapla from Olpidürr, Oleksandr Kudinov and Jesús Rodríguez Bueno from Mapsa, Ivan De Angelis from Verind, and Alessia Venturi from ipcm.**

Conclusions

"The line's commissioning ended about a month ago," says Jesús Rodríguez Bueno (**Fig. 14**).

"We are now implementing the ramp up phase, and especially optimising the coating thicknesses. It is early to disseminate any savings and efficiency data, but one look is enough to perceive that Olpidürr has designed a solid, advanced, and well-conceived line. Above all, this plant gives us an impressive productivity level and it will be able to meet our needs for many years to come."