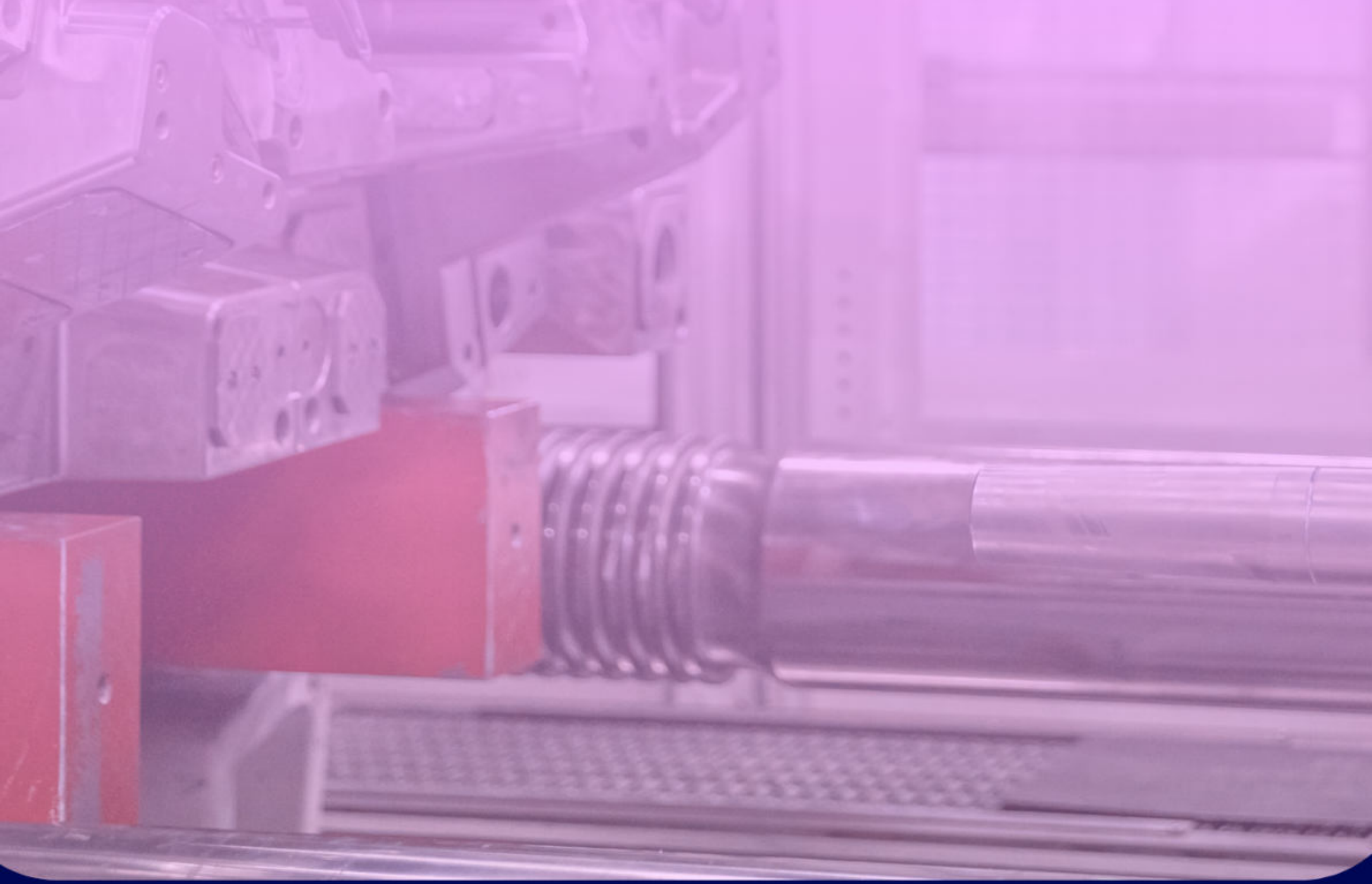
Industry Trends and Challenges

Investigating Automotive Plastics Manufacturing

Including a case study on **ZF Friedrichshafen AG** and how they developed a new efficient process.



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Introducing Automotive Plastics Manufacturing

Ever since its boom in the early 1900s, automotive manufacturing has continued to prosper into the twenty-first century. Cars, vans, public transport, and heavy goods vehicles are becoming ever more accessible, with commercially ready models and their production processes showing profound growth alongside the emergence of Industry 4.0.

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Moreover, plastics components play a significant role in the automotive industry. The use of plastics in automotive part production drives innovation and redefines vehicle designs, efficiency, and functionality. However, the COVID-19 pandemic brought with it numerous challenges for plastics production in the automotive industry.

This white paper will guide you through the recent trends of the automotive industry, outline a few historical insights, discuss the advantages of plastics use in automotive manufacturing, list a few commonly used manufacturing processes within the industry, and navigate the various production-specific and industry wide challenges faced by automotive plastics manufacturers.

Additionally, a success story about how a global automotive supplier developed a new efficient production process through their collaboration with sensXPERT and integration of the sensXPERT Digital Mold solution will be presented.

21st Century Automotive Industry Trends

Every year, the number of vehicles that populate our roads has grown exponentially, with no sign of stopping. An estimated 1.5 billion vehicles are in use around the world, a statistic backed up by the increasing growth of automotive manufacturing. In 2022, The European Automobile Manufacturers' Association reported a 5.7% increase in vehicle production to the previous year, totaling 85.4 million new vehicles produced around the world.

With this annual increase, it is no surprise that automotive manufacturing has come under fire in recent years for its contribution to global warming and the fossil fuels crisis, as well as straining a supply chain dependent on critical materials. Passenger vehicles can contain up to 50 different types of critical materials, of which elements such as cobalt (used in electric automotive batteries) make up a majority of conflict demands from untenable mining processes. Along with commonly sought materials such as rubber, plastic, aluminum, and steel, automotive manufacture is reliant on a number of material factors that begs the question: Is its future unsustainable?

For the past decade, automotive manufacturing trends have been looking to tackle this question with the emergence of Industry 4.0, and the economic benefits of electric vehicles (EV), shared and autonomous mobility, as well as a renewed focus on materials that can contribute to a circular economy. By 2025, plastics and composite materials are expected to make up 8% of a production vehicle's total share of material, with the majority parts continuing to be produced from steel and aluminum. Additionally, forecasts for 2030 show an uptick in electric and hybrid vehicle technology, as well as an increased interest in shared mobility. Managed fleets of shared vehicles look to reduce the cost of mobility and will impact key markets such as China and Europe by up to 50%, accounting for 1 out of 10 vehicles sold.

Autonomous mobility continues to fuel interest in the market for shared vehicles, and subsequently, fit-for-purpose mobility solutions such as e-hailing services. North America and Germany have seen over 30% annual growths in car-sharing members in the space of five years, showcasing an opportunity for materials such as composites and plastics to accommodate for tailored vehicle designs: driving unique properties like robustness, lightweight, and passenger comfort.

Automotive Plastics Manufacturing Throughout History

If posed the question, “what are cars made of?”, few people would jump at the thought of plastics. Aside from salient materials like steel and aluminum, plastics have existed prominently within automotive manufacturing ever since the car entered serial production.

Coincidentally, the invention of artificial plastic and the birth of the automobile occurred around the same time period. In 1909, the world's first synthetic plastic, coined Bakelite, was created by Leo Baekeland. Just one year prior, The Ford Motor Company produced its first Ford Model T, regarded by contemporary culture as the world's first mass-affordable, consumer vehicle. Although the Model T Ford wouldn't gain global attraction until its serial production kicked off in the first quarter of the century, its manufacture coinciding with breakthroughs in polymerization would eventually lead to a unique partnership for plastics and automobiles.

23 years after Bakelite, fiber reinforced plastics were invented from a mixture of glass fibers and polymer resin. This new composite material quickly gained attraction from the automotive industry, spawning a range of fiber-reinforced plastics often utilizing thermoset polymers. Thermosetting plastics helped to produce strong and durable shaped components that were easier to mass produce over traditional methods of folding sheet metal. The first fiberglass car, the Stout Project Y, was a coupe built in 1946, eight years before fiberglass bodies would begin being mass produced for Chevrolet. The 1960s revolutionized the field of polymer research with the adoption of polypropylene. Thanks to its light weight and mechanical properties, polypropylene continues to be used in automotive manufacture to this day.

Plastic eventually found its purpose in major vehicle components and body parts. In the 1970s, the revolutionary plastic bumper spawned a whole generation of aesthetic, lightweight vehicles that demonstrated the rigid and durable capabilities of the material, able to absorb four to five times more energy than alternative bumpers. Nowadays plastic parts are ubiquitous with lightweighting innovation on the very latest automotive models.

Plastic parts make up 8% of today's passenger vehicle material. These plastic and composite parts are specially designed to withstand rigorous weather and operating conditions, including extreme temperatures, dynamic loading, and electrical currents, as well as humidity and corrosion. Below is a list of the most commonly produced plastic parts in the automotive manufacturing industry.

Examples of Plastic Automive Parts

Vehicle bumpers and exterior components

- Engine covers
- Cable insulation
- Seats
- Interior panels
- Dashboards, knobs, and switches
- Wheel covers
- Fuel caps
- Headlamp/taillight lenses

Automotive Plastics Manufacturing Trends: 2023 and Onwards

With the increasing demand for next-generation automotive manufacturing solutions, coupled with challenges to sustainable practices regarding the climate crisis, the plastics industry is set to grow alongside the automotive industry for the foreseeable future.

The global market size of automotive plastic parts was valued at 35 billion USD in 2019, with a forecast rise of up to 83 billion USD by 2027 based on a CAGR of 11.1%. These statistics align with the current automotive plastics market size, calculated to be worth 70 billion USD as of 2023, with an expected ten-year growth that will see the market almost double; forecasted market size for 2033 sits at 136 billion USD.

The key 2023 automotive industry trends fueling market growth in plastics manufacturing primarily involve increasing energy efficiency for petrol and electric vehicles by reducing weight and opting for more sustainable solutions down the automotive supply chain.

By 2025, automakers are aiming to phase-out petrol and diesel internal combustion engines, with VW looking to fill this gap with 70 new EV vehicle models by 2028. The biggest challenge facing EV manufacture is production expense and concerns for thermal runaway. EV lithium-ion batteries require extensive research into their potential for thermal generation. Consequently, R&D into fire retardant options for battery housings and components had led to an increased interest in the benefits of advanced plastics and composites. These materials diminish propagation of flames with effective fire retardant or heat transfer resistant properties. The research continues to aid in EV weight reduction, with materials such as carbon fiber reinforced plastic being tested for lightweight structural batteries, lowering EV mass to battery capacity.

More investments are being made into research and development for plastics manufacturing, including Internet of Things to connect operations to a central network, and the adoption of A.I. and machine learning to monitor and report on part conditions in-mold.

Advantages of Plastics in Automotive Manufacturing

There are many advantages to using plastic in automotive manufacturing over alternate materials like metal. Not only are metals heavier, but they surprisingly offer little impact resistance and tensile strength. Over time, metal begins to rust if not treated with protective coatings—coincidentally, these coatings are also made from specialized polymers.

Plastics components are widely manufactured for automotive applications on account of the materials' versatility and functionality. Plastics are dynamic in their ability to fulfill multiple roles, and they resolve a number of strength and durability issues, while showcasing aesthetic versatility for more components. Here are some key reasons for plastics being used in automotive manufacturing.

Lightweighting

Lightweight plastics and composite parts contribute to fuel efficiency and reduced emissions, thus aligning with the industry's sustainable goals. Being lightweight also benefits electric vehicles, in which every kilogram saved contributes to an extended battery life.

Additionally, plastic and composite parts are much lighter than heavy metal molded parts. This is particularly significant for heavy body panels and underskirts as the effect on the vehicles end-use can show a dramatic increase in energy efficiency. 100kg of plastic can replace up to 300kg of traditional materials and has shown to reduce a car's fuel consumption by 750 liters.

Energy Efficiency

The aforementioned benefit of lightweighting a vehicle has been proven to improve fuel efficiency, extending the distance vehicles can travel while reducing their CO2 output. Countries around the world have continued to challenge this rate of reduction with fuel economy targets; Japan recently noted a 96% improvement in fuel efficiency for passenger vehicles over the last two decades. As well as energy reduction in end-use applications, further reductions can be seen in plastics manufacturing, with many more opportunities for recycling material using clean energy. This also eliminates a large demand for new parts, as the automotive industry works to embrace a circular economy. However, the challenges to plastics recycling remain prevalent.

Design Flexibility

The malleability of many plastics allows for ease in producing parts with intricate designs, features, and diverse geometries. Not only does this enhance aesthetics, but it also improves functionality.

Safety and Durability

Contrary to belief, plastic parts can easily outlast strong metals with the correct production processes and post treatment. Many plastics materials have properties that enhance safety measures in manufactured vehicles. Impact resistance and thermal stability are two highly important properties that can be found in plastics components. For example, fiber-reinforced polymer crumple zones – areas that are designed to absorb impact during a crash or collision – absorb four times the impact that steel would absorb.

Additionally, thermoset plastics are most commonly utilized in the automotive industry for manufacturing large, solid parts. The plastic showcases impressive strength after curing, unable to be re-shaped, though beneficial for its dielectric properties, corrosive resistance, and low-tooling production costs. In summary, thermosets offer high-performance in conjunction with advantageous mechanical properties, at a lower production cost.

Cost-Effectiveness

Using plastics in automotive manufacturing offers a cost-effective alternative to traditional materials such as aluminum and steel, without compromising quality. With increased sustainability operations throughout the plastics industry, the cost of manufacturing plastic automotive parts has been heavily reduced, thanks to advanced technological production insights from Industry 4.0 and Internet of Things, along with the amount of recycled material continuously increasing. Assembly costs and tooling are also dramatically reduced with plastic molding. The process offers a continuous source of reliable, serial manufacturing, with the ability to reduce lead times by combining multiple parts into a single mold and allowing for complex shapes.

Collectively, these attributes position plastics as a cornerstone in automotive innovation. They empower manufacturers to produce vehicles that are efficient, technologically advanced, and safe. Before detailing the challenges manufacturers face in automotive part production, it is worth noting the four most common processes used to manufacture these advantageous plastic parts.

Advantages of Plastics in Automotive Manufacturing

- Lightweighting
- Energy Efficiency
- Design Flexibility
- Safety and Durability
- Cost-Effectiveness

Processes in Automotive Plastics Manufacturing

While many production processes apply to plastics manufacturing, automotive parts required for their high impact and safety features are routinely manufactured in mass using different methods of molding. These processes allow for consistent, reliable serial production that is fast and cost-effective. As is detailed below, each process bears its own advantages and is suitable for the production of specific automotive components.

Injection Molding

Injection molding is the process of injecting molten plastic into a hydraulic press mold. Plastic pellets are melted down and injected through a screw into the chamber, wherein the material's molecular structure is altered by extreme temperature. This strengthens the newly formed plastic part as it cures and solidifies. The hardened part is then removed from the mold mechanically or by air compression.

In the case of automotive parts, thermosets are favored for their increased strength and corrosion resistance. Thermoset plastic parts require a similar process coined Reaction Injection Molding (RIM), whereby two liquid components are used in the molding process and injected at low pressure. On contact, they perform a chemical reaction that increases temperature and pressure inside the mold, eventually producing a thermoset part. This process can be greatly adapted to apply a range of formulations and pre-mixed material, altering thermoset properties for different physical performance requirements.

Being one of the most common and efficient plastic production processes, injection molding has a high output rate, making it a cost-effective process. This process is incredibly well-suited for medium to high-volume production and offers high precision. In comparison to other processes, injection molding also produces less waste. In the automotive industry, injection molding can be used for the production of interior trims, bumpers, and dashboards.

Blow molding

Blow molding is best suited for the high-volume production of hollow plastic parts. The process involves shaping molten plastic into a hollow form by blowing air into a mold cavity.
This process is cost-effective, allows for the manufacturing of a wide variety of products, has high reproducibility, among other advantages. For automotive applications, blow molding can be used to produce components like air ducts, armrests, and fuel tanks.

Thermoforming

In comparison to other processes, thermoforming has relatively low tooling costs and can produce incredibly large and complex parts. This process works by shaping flat plastic sheets into three-dimensional objects. Thermoforming is used to process automotive components such as door panels, engine covers, trim pieces, and more.

Compression molding

Compression molding is a popular process with plastic and advanced composites. This process is also simpler than other molding or plastics manufacturing processes. It involves preheated polymer placed inside an open, heated mold cavity. A cover, or plug, is then pressed against the plastic, filling the space inside the mold. Compression molding is a process that is better suited for small production runs and beneficial for parts requiring even thickness, parts of varying sizes, and parts which may be too complex for injection molding.

Parts suited to compression molding are often pre-formed to help improve the overall performance of the compression process. Its advantage to automotive plastic manufacturing lies with its potential to create parts with intricate geometries, offering molded composite parts with longer fibers. Automotive applications of parts produced using compression molding include hoods, fenders, roof panels, brake pedals, and more.

While each process has its own advantages and unique applications, manufacturers select the processes that best align with their specific needs for various automotive components.

Automotive Plastics Manufacturing Processes

- Injection Molding
- Blow Molding
- Thermoforming
- Compression Molding

Production Challenges in the Automotive Industry

Albeit having efficient and effective processes and materials in place, the automotive industry has faced several disruptions that have tested its resilience and adaptability. With the COVID-19 pandemic, fluctuations in consumer demand, and the advent of Industry 4.0, automotive manufacturing finds itself confronted by a number of challenges.

COVID-19 impacted all facets of society, and the automotive industry was no exception. Factory shutdowns, supply chain interruptions, and a sharp decline in consumer demand were a few ramifications of the pandemic on the automotive industry. The ebbing of the pandemic led to a phase of production recovery, during which production lines resumed operations and consumer demand slowly began to rebound.

Consumer Demand Fluctuations

Depending on the region, economic conditions, and vehicle types, consumer demand fluctuated in the post-pandemic phase. Manufacturers faced the challenge of predicting demand patterns and striking the right balance to avoid either overproducing or underproducing. At the same time, adaptation and innovation were key to responding to the evolving and recovering economic landscape.

Supply Chain Disruptions

Vulnerabilities in global supply chains were amplified by the pandemic, leading to disruptions in part availability. With the production ramp-up, maintaining a steady supply of essential materials and parts became paramount for automotive manufacturers. Disruptions in supply chains also triggered increased costs with manufacturers resorting to alternative material sources and transportation methods. Furthermore, disruptions at one point in the supply chain can cascade through the entire web of suppliers, manufacturers, and service providers in the automotive industry. Therefore, ensuring a robust set-up of processes is paramount to deal with supply chain difficulties.

Lacking a Skilled Workforce

One of the more pressing challenges faced by the automotive manufacturing industry is the scarcity of a skilled workforce. During the pandemic, the industry was hit by workforce reductions and altered economic priorities. As the industry strives to rebound from the disruptive impact of the pandemic, automotive manufacturers have been grappling with developing and retaining skilled talent. The automotive industry's post-pandemic production recovery has added pressure on manufacturers to optimize their processes. One way of doing so is to embrace technologies that help propel recovery and align with the advent of Industry 4.0.

The Paradigm Shift of Industry 4.0

Characterized by digitization, connectivity, and automation, Industry 4.0 heralded transformative opportunities for the automotive industry. However, the integration of advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), and robotics poses both challenges and opportunities. On the one hand, manufacturers require a skilled workforce to understand, integrate, and operate these new technologies. On the other hand, the implementation of advanced technologies can increase production efficiency and data-driven decision-making.

How Automation Improves Production Efficiency

While the automotive plastics industry is expected to grow exponentially in the next ten years, the path towards achieving automotive energy efficiency begins with plastics production and its necessary processes.

A current solution that is already changing the way plastics manufacturing operates for the automotive industry is through process optimization for industry 4.0. The plastics industry has already begun to integrate cutting-edge IoT automation into its production processes. Advanced sensors play a crucial role in detecting early faults, providing detailed data that was once hard to obtain. Coupled with sophisticated software solutions, this technology streamlines the entire manufacturing operation. The implementation of artificial intelligence can further ensure the highest quality control, with cloud software allowing data monitoring to take place remotely. This ultimately saves both time and money for automotive plastics manufacturers.

One specific solution that can help eliminate several challenges brought on by post-pandemic production ramp-ups, fluctuations in consumer demand, disruptions in global supply chains, and the integration of advanced technologies in manufacturing processes is sensXPERT Digital Mold. This process control solution combines over 50 years of material science expertise and predictive machine learning algorithms. Digital Mold enables manufacturers to optimize their processes in real-time with the technology's ability to characterize materials during processing and forecast their qualitative outcomes.

sensXPERT's solution is paving the way for industry 4.0 in automotive plastics manufacturing. It seamlessly integrates with molding solutions, accommodating both plastics and composite materials.

The Equipment-as-a-Service solution provides real-time process control by comprehending internal and external mold conditions. Material characterization sensors within manufacturing molds measure material behavior in real time, while the edge device gathers this data and presents it through a user-friendly edge device interface. It allows automotive plastics manufacturers to monitor, adjust, and predict optimal molding conditions. The sensXPERT digital Cloud service is a further visual aid to historical process data from multiple machines, regardless of location, ensuring transparency and compliance with regulations while supporting smart financial decisions.

sensXPERT's quality assurance testing can be conducted during molding, swiftly identifying errors and minimizing waste. It promotes sustainable practices by reducing production costs, shortening cycle times, lowering energy consumption, and eliminating unnecessary scrap.

Overall, sensXPERT Digital Mold provides manufacturers with dynamic process adaptation, which has proven to achieve a decrease of up to 50% in existing scrap, an increase of up to 23% in energy savings, and up to 30% cycle time reduction. In essence, sensXPERT is a comprehensive solution driving efficiency, sustainability, and regulatory adherence across the automotive plastics manufacturing sector.

Therefore, by integrating advanced technology - such as sensXPERT Digital Mold - in production processes, automotive manufacturers can maintain consistent output to meet supply chain and consumer demands, boost their production efficiency, ease the need for a skilled workforce, and reduce both waste and costs.

How Global Automotive Supplier ZF Friedrichshafen AG Developed a New Efficient Process

In 2020, sensXPERT began a collaboration with automotive supplier ZF Friedrichshafen AG. In its Synergy Group Electronics division, the company produces critical, high-power electronic components used in electric drive (powertrain) systems for eMobility.

The process in question involved overmolding high-value electric components with reactive thermoset resins to encapsulate and seal the devices against dust, moisture, chemicals, fluctuating temperatures and humidity, as well as mechanical shocks in an end-use environment. With greater electrical integrity, products such as electric vehicles become more reliable by extending service life and reducing maintenance costs.

sensXPERT's technology was evaluated on its performance to help reduce cycle time and material waste, lower energy usage, and enrich the automotive supplier's sustainable practices (therefore complying with E.U. taxonomy reporting).

Before the collaboration, ZF's Electronics Systems business unit was setting up many new processing lines to encapsulate circuit boards for a new program with a major European automaker. The latest equipment and processing lines were to accommodate a new grade of reactive epoxy, chosen for its low viscosity during encapsulation and improved mold filling.

The sensXPERT process monitoring system presented a unique opportunity to try new approaches in refining processes and reducing investment costs. The system was installed on one of the encapsulation molds to increase understanding of the impact of parameters inside and outside the mold on material behavior. This enabled the ZF team to examine material behavior consistency and monitor the reliable quality of encapsulated electronic components being produced on the new production line.

Another strategy was to further understand the material behavior and its relationship to changes in the processing environment, both inside and outside the mold. Rather than controlling the process, a molder would set out to control material behavior by selecting a critical property that explained material behavior and indicated the quality of parts produced.

The joint ZF/sensXPERT team ran a series of encapsulation studies with the new resin shot into an instrumented mold mounted in a new transfer press. The mold was instrumented with sensXPERT integrated dielectric sensors and temperature and pressure sensors. Classical process-control guidelines were used to examine the effect of DoC on the encapsulated parts.

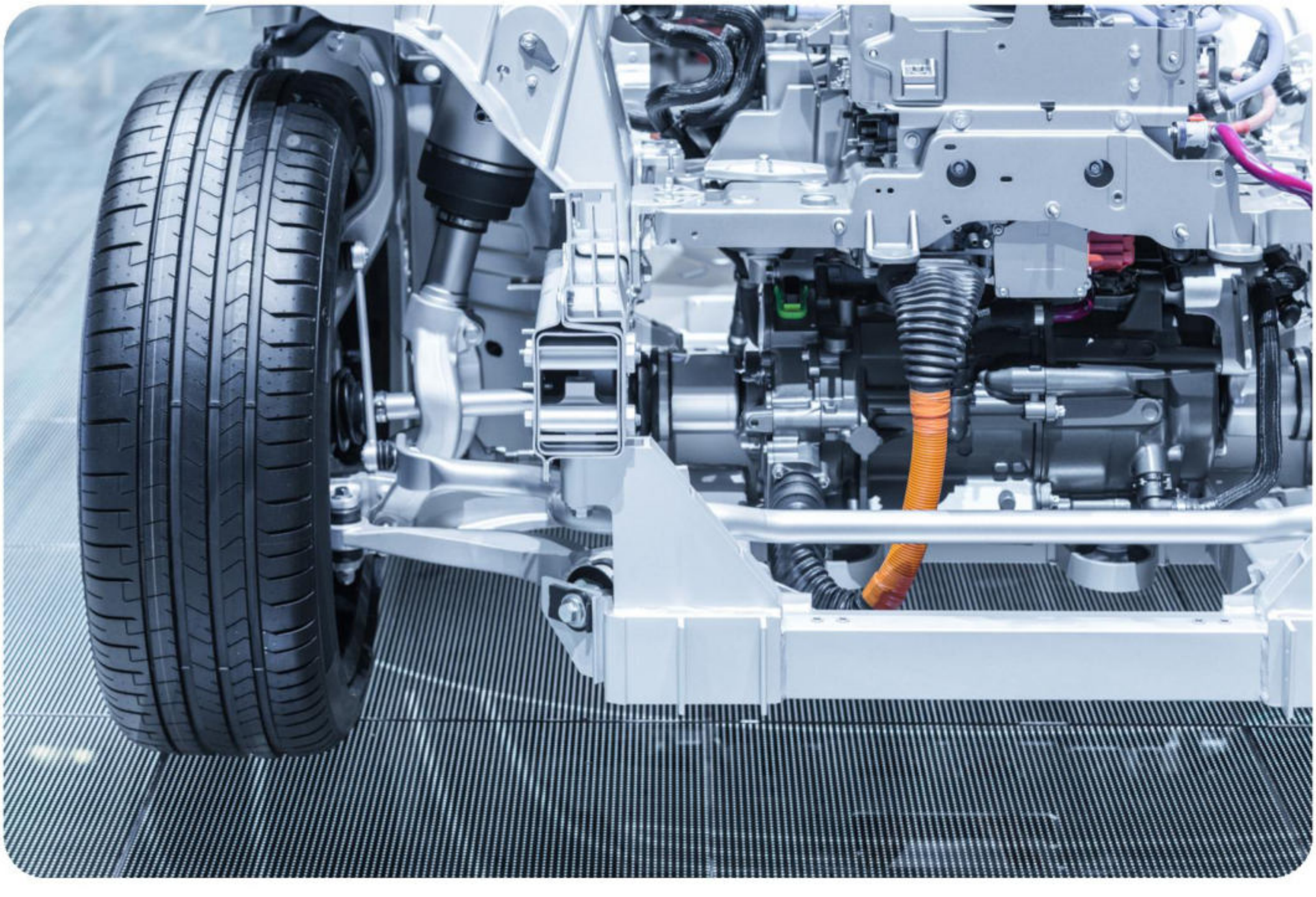
Collaboration Outcomes

After sensXPERT application specialists reviewed the preliminary process data and observed the DoC measurements from the dielectric sensors, they noticed several things. At a target DoC of 90%, all parts cured in less than a few minutes. Yet, comparing the curing times, some parts took significantly less time to achieve the target DoC than others. This potential for time-saving is lost if a fixed curing time with a safety margin for varying material batches and process drift is applied. With sensXPERT dielectric sensor data and predictions from the machine learning models, cycle times were pushed to the limit, as the sensors alerted when the target DoC had been reached.

In line with these observations, the curing time could be reduced by an average of 4%. A fully dynamic adaptation of the curing time bears the potential for saving up to 9% in cycles that exhibit the fastest cure.

Rico Zeiler, Specialist in Process Engineering at ZF, said the sensXPERT technology allowed more insight into material behavior throughout the molding process. Ultimately, in collaboration with sensXPERT, ZF reinforced sustainability and efficiency in their molding process. sensXPERT has demonstrated the potential for reduced cycle time, lowered energy usage, and decreased cost of goods sold in part production.

Based on the results of the sensXPERT technology, the ZF Synergy Group Electronics' operations unit has decided to outfit all molds in all presses on its new production line with sensXPERT's process monitoring systems.



Learn more at www.sensxpert.com or contact the team at www.sensxpert.com/contact

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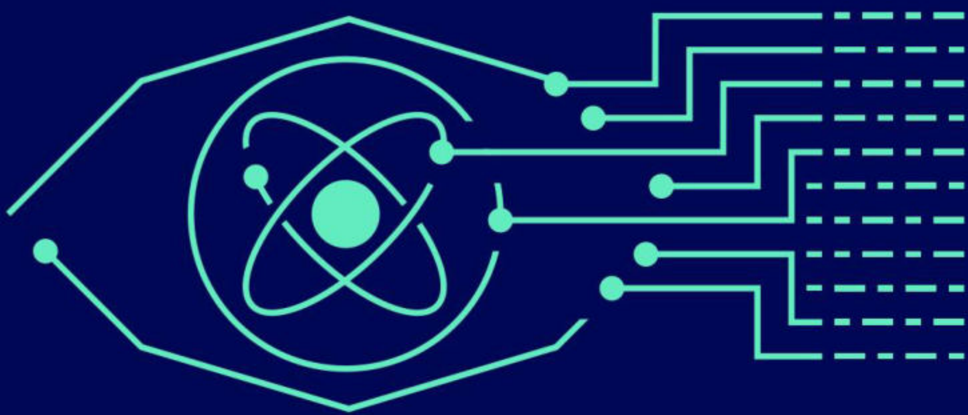

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