

The Engineer's Guide to CMM Technologies

Exploring CMM technologies for
quality assurance of sheet metal parts.



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Introduction

The need for precision

Humanity's quest for precision has a long history. Researchers trace the origins of the French measurement unit 'pied du roi' (the king's foot) back to 1789¹. By 1795, the French introduced the metric system, which remains in use today. Moving beyond rudimentary scales and micrometers, the world's first Coordinate Measuring Machine (CMM) was unveiled by the Ferranti Company in Scotland during the 1950s, followed by a three-axis prototype from the Italian company DEA in the 1960s. Since then, CMMs have evolved significantly and become an indispensable part of modern manufacturing.

These developments reflect our ongoing drive for accuracy and efficiency in industrial processes. Today, precision in manufacturing is crucial because it directly impacts the performance and reliability of the parts. Even a slight deviation in dimensions can lead to issues such as misalignment or malfunction, which can significantly affect how well the final product works.

Consistency across production batches is another critical aspect influenced by precision. Consistent part dimensions ensure that each batch of components performs identically, which is vital for maintaining quality standards in mass production. This is crucial for industries where a single mistake can lead to serious consequences, such as the aerospace and automotive sectors.

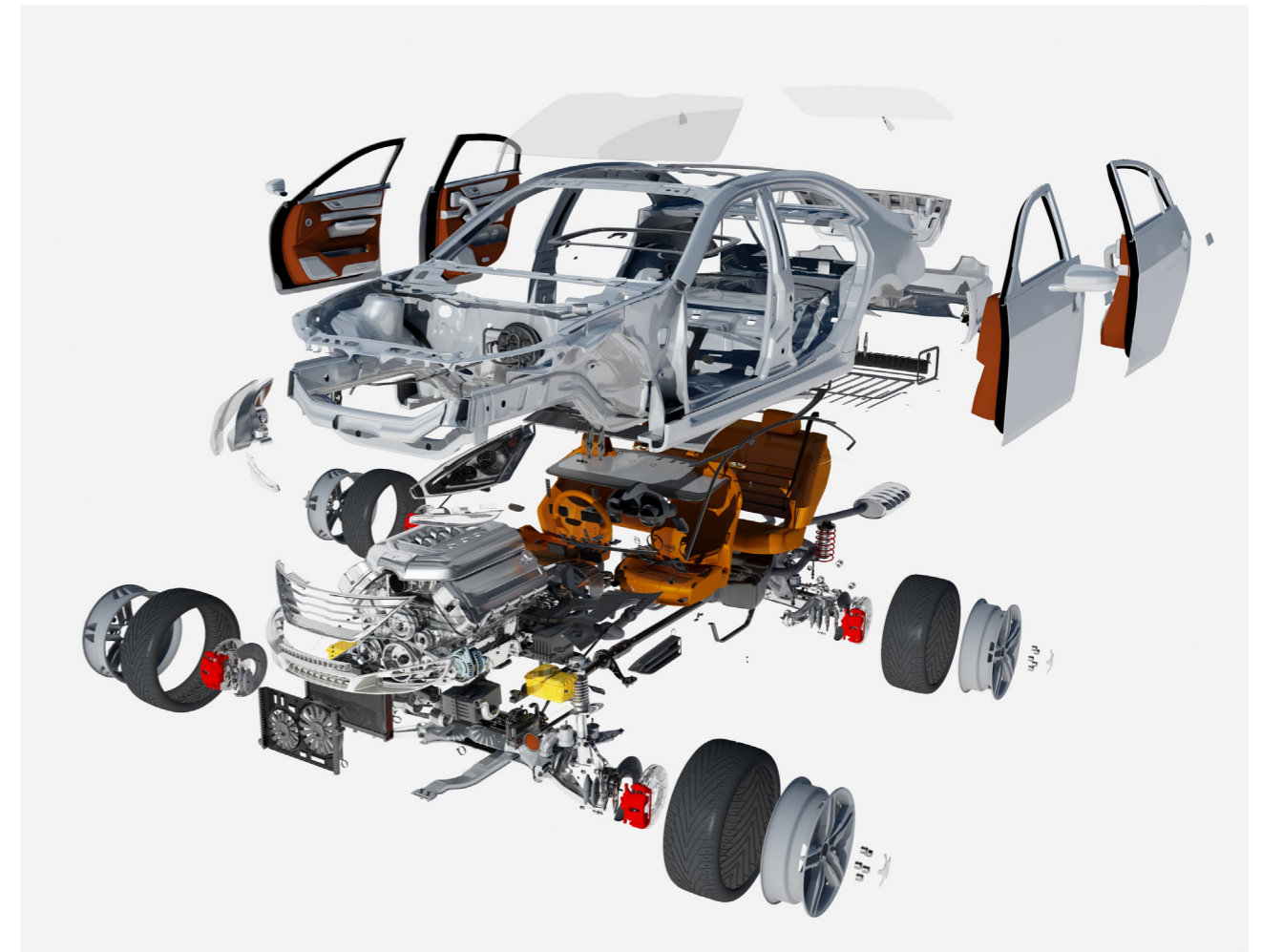
Regulatory compliance is a significant factor in sheet metal part manufacturing. Many industries are subject to strict regulations that mandate specific tolerances and quality standards. Precision in manufacturing helps ensure that products meet these regulatory requirements. For instance, the International Organization for Standardization (ISO) provides guidelines on tolerances and quality control that manufacturers must adhere to².

Inaccurate parts often lead to increased scrap rates and the need for corrective actions, which add to the overall cost. That's why even though achieving high precision may require expensive and advanced tools, they ultimately end up reducing costs by minimizing waste and rework.

Challenges with modern designs

Modern products often incorporate intricate shapes and detailed geometries. These geometries may include complex curves, irregular surfaces, and fine features that are tough to measure accurately with traditional tools. For instance, aerospace components, such as turbine blades, structural parts, and high-precision automotive parts, require measurements that traditional gauges and callipers are not designed to handle effectively. Traditional tools, while useful for straightforward measurements, often fall short when it comes to capturing the detailed and precise specifications required in modern manufacturing.

Precision in this context refers to achieving accuracy up to 1000 times smaller than a millimeter. Traditional measurement instruments typically cannot provide such a level of detail. For example, a standard calliper might provide measurements with an accuracy of 0.1 mm, whereas components in high-tech industries may require accuracy within a few micrometers or less. Additionally,



The complex nature of design in today's automobiles.

operating these tools often involves manual measurement processes, which can introduce human error. This is particularly problematic for intricate sheet metal parts and complex assemblies, where even minor deviations from design specifications can lead to significant issues.

This is where CMMs come into the picture. These specialized tools are designed to address stringent requirements by providing the required accuracy and precision. For instance, optical CMM laser scanners capture

detailed surface profiles without making contact and allow for rapid measurement of intricate shapes.

Furthermore, the ability of CMMs to automate measurement processes minimizes human error and increases repeatability³. Automated CMMs can perform high-speed measurements with minimal operator intervention, ensuring consistent results across multiple parts and production batches. This automation also enhances efficiency, as CMMs can handle complex measurement tasks that

would be time-consuming and prone to error with manual tools.

Overall, CMMs offer a robust solution by providing the necessary accuracy, resolution, and automation capabilities to meet the challenges posed by intricate geometries. Their advanced capabilities ensure that modern products are manufactured to exact specifications, ultimately contributing to improved performance and reliability in their respective applications.

Evaluating the precision and performance of various coordinate measuring machines

Coordinate measuring machines (CMMs) come in various forms, each employing distinct methodologies to achieve their measurements. These machines are critical tools in ensuring the accuracy and quality of manufactured parts. Among these, tactile and optical CMMs are particularly popular in industrial applications due to their unique measurement techniques and capabilities. Each method offers advantages while facing specific limitations.

Getting a good grasp of these technologies and what they each bring to the table is key for making smart choices in manufacturing. Knowing the ins and outs of each type helps engineers and quality control experts pick the best CMM for their specific needs, making sure they get the most accurate and efficient results in their production processes.

Traditional CMMs

Traditional CMMs rely on a probe that makes physical contact with the part being measured. Most traditional CMMs feature probes made of materials such as ruby or carbide. During the measurement process, the probe's

stylus makes physical contact with the part's surface⁴. As the probe touches the surface, it records the exact coordinates of the touchpoint. Each contact point's coordinates are recorded in the CMM's data acquisition system. The machine's software processes these coordinates to create a digital representation of the part's surface. Once the touchpoints are collected, the CMM software compares the measured coordinates to the part's design specifications. It is used to determine whether the part meets the required tolerances.

There are four categories that traditional CMMs fall under, each based on their configuration:

1. Bridge CMMs

The term "bridge" in Bridge Coordinate Measuring Machines (CMMs) refers to the machine's distinctive design. The bridge-like structure supports the measurement probe. This probe, or touch-trigger, moves along the X, Y, and Z axes with high precision, enabling the machine to capture detailed measurements of manufactured parts. The accuracy of bridge CMMs makes them ideal for applications requiring meticulous dimensional analysis and quality control. However, their design comes with some trade-offs: they are

typically large and stationary, requiring substantial floor space, and they lack portability. These factors can limit their use in environments where space is constrained or mobility is essential.

2. Cantilever CMMs

A cantilever-type CMM is characterized by its measuring head being mounted on one end of a cantilever arm, which extends outwards to access the part being measured. This design provides improved accessibility for smaller parts and components. It allows metrologists to reach intricate areas more easily than with a bridge CMM. The cantilever setup allows for flexibility in positioning, making it ideal for tasks requiring close inspection and detailed measurements. However, cantilever CMMs are generally not portable. Additionally, they are sensitive to vibrations and environmental disturbances. A stable and controlled environment is crucial for maintaining precision with cantilever CMMs.

3. Gantry CMMs

Gantry CMMs feature a design where the measuring head moves along a bridge supported by two vertical columns. This setup is particularly suited for measuring large parts with high precision, as it allows for a significant measuring range and stability. The gantry design provides ample clearance for oversized components, making it ideal for industries such as aerospace and automotive, where large and complex parts need to be inspected. However, gantry CMMs require substantial floor space due to their size and the need for a robust setup to ensure stability and accuracy. The large footprint and the need for a stable environment can be a limitation. Despite these challenges, their ability to handle

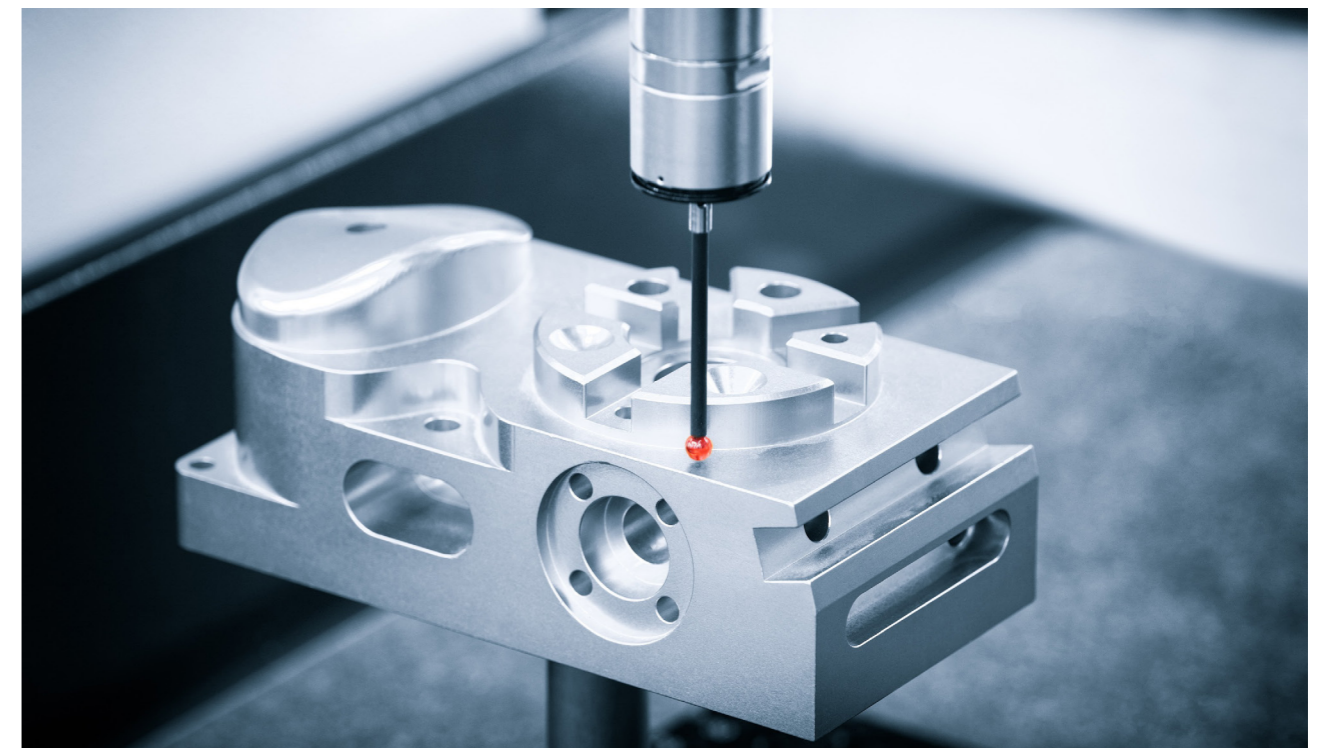
large-scale measurements with high precision makes them a valuable tool in precision manufacturing.

4. Horizontal arm CMMs

Horizontal arm CMMs feature horizontally mounted probes. This configuration allows for easy access to measure long and slender items. Horizontal arm CMMs are relatively straightforward to install and cost-effective compared to other types of CMMs. However, they are not ideal for parts requiring tight tolerances, as the horizontal arm design may not provide the same level of accuracy as more advanced CMM types. This limitation can impact their effectiveness in applications where stringent dimensional control is crucial. While horizontal arm CMMs are well-suited

at measuring elongated components, their design limits their ability to measure wide parts. This often requires adjusting or disassembling components to accommodate the part's dimensions. Definitely, not ideal on a factory floor where each second counts.

Overall, traditional CMMs offer high accuracy and reliability, making them well-suited for detailed inspections. However, the process can be relatively slow, as the probe must touch multiple points to gather data⁵. Additionally, there is a risk of the probe scratching or damaging the delicate parts or those with a sensitive surface finish. Because of these limitations, traditional CMMs are not ideal for inspecting every single item in a production run. Instead, they are better suited for sample inspection.



Traditional CMM machine equipped with a touch-trigger probe. Image credit: Crearform.

Optical CMMs

Optical CMMs utilize advanced light-based technologies to measure the dimensions and geometries of parts with high precision. Unlike traditional CMMs, which rely on physical contact with the part to gather data, optical CMMs use optical methods to assess parts. This non-contact approach is ideal in scenarios where physical probes could interfere with the part's integrity. Optical CMMs can capture a large amount of data quickly, often in a matter of seconds. The swift process makes these CMMs a great option for manufacturers to keep up with fast-paced production environments. In addition to their speed and non-contact nature, optical CMMs are well-suited for a broad range of materials.

In the context of sheet metal manufacturing, optical CMMs are usually categorized into two main types: laser scanners and photogrammetry systems. Both types have their own set of advantages and should be selected based on the specific measurement needs and production criteria.

1. Laser scanners

The principle behind laser scanners involves projecting a laser beam onto the sheet metal surface. As the laser beam reflects back to the scanner, it records the time it takes for the reflection to return. This data is used to calculate the precise distance between the scanner and the part, creating a dense cloud of data points. These points are then processed to form a detailed 3D map of the part's geometry. This makes it ideal for

inspecting complex geometries and intricate shapes⁶.

Depending on the model, laser scanners feature blue or red lasers, each offering unique benefits and constraints.

Blue Lasers

Blue lasers, thanks to their shorter wavelengths, provide impressive precision and fine detail. Because of this reason, they are perfect for industrial applications where accuracy is crucial. Blue lasers are especially popular in fields such as aerospace, automotive, and high-tech manufacturing, where getting exact measurements is key.

However, blue laser CMMs come with a higher price tag compared to other systems. Despite the relatively higher cost, this investment is often worth it for industries that can't afford to compromise on precision. Its benefits, such as better quality control and fewer errors, make the higher price a reasonable tradeoff in the long run.

Red Lasers

Red lasers provide a more budget-friendly alternative to blue lasers, making them a popular choice when cost is a key consideration. Their longer wavelengths, however, result in slightly lower accuracy compared to the finer resolution of blue lasers. This tradeoff means that red laser scanners are often used in applications where precision is not as critical and cost savings are essential.

These scanners work well for tasks that don't demand top-tier accuracy, like general inspections or less detailed

measurements. Their lower price allows businesses to invest in multiple units or use the savings elsewhere, making them a practical choice for cost-conscious operations⁷.

Laser CMMs are further divided into fixed and portable laser systems.

Fixed laser CMM

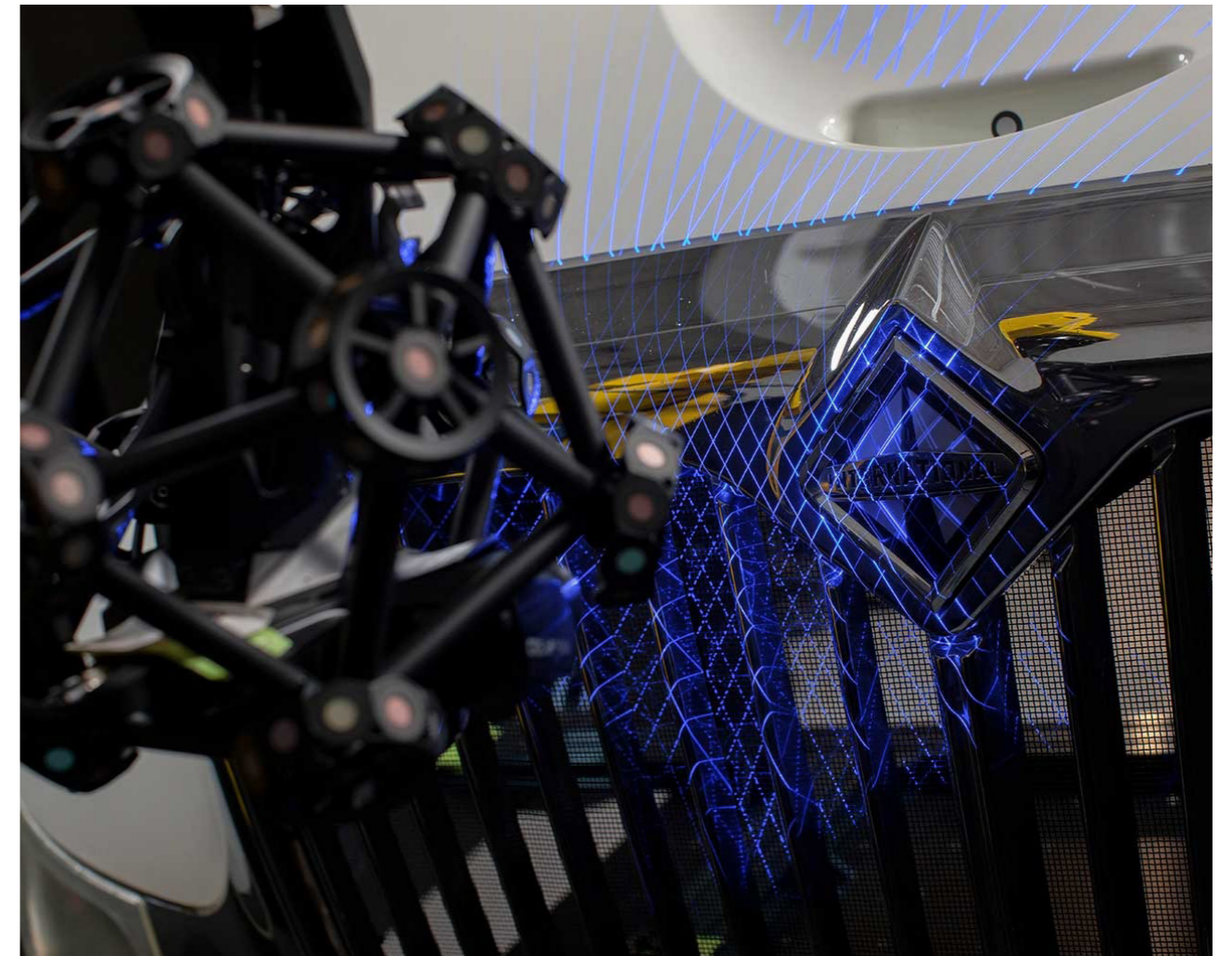
In a fixed laser CMM setup, the laser scanner stays in one place while the part is moved into position for measurements. This stationary design enhances stability, leading to accurate and consistent measurements. Fixed laser CMMs are also relatively easy to integrate into automation systems, reducing the need for manual handling.

However, the fixed nature of these systems does come with some drawbacks. For starters, they require a considerable amount of floor space to accommodate both the scanner and the parts being measured. Additionally, since the scanner doesn't move, the inspection area is limited to a specific zone. This can be a challenge in facilities with limited space.

Portable laser CMM

Portable laser CMMs offer flexibility and convenience that fixed systems lack. These devices can be easily moved around the part, allowing for measurements anywhere on the factory floor. In short, you don't need to bring the product to the scanner.

This capability is particularly useful for complex or large components that might be difficult to move. While portable systems are generally accurate, factors such as the operator's



A laser scanner recording 3D data of a specific part. Image credit: Creaform.

movement and alignment issues can introduce slight measurement errors.

2. Photogrammetry

Generally used in creating maps and architecture, photogrammetry is also quite useful in the industrial sector⁸. In a typical photogrammetry setup, the process begins with capturing a series of high-resolution photographs of the metal part from various angles⁹.

Specialized software then analyzes these images to generate a detailed 3D model of the object. This 3D model allows for precise measurements of various attributes, such as distances, angles, and surface profiles.

Much like laser scanners, photogrammetry is a non-contact method. This technique can handle large parts and assemblies, making it an ideal choice for industries such as aviation, shipbuilding, and energy.

Thanks to advancements in camera technology and image processing algorithms, modern photogrammetry systems can achieve exceptional precision.

However, the accuracy of measurements can be influenced by the surface characteristics of the object. Highly reflective surfaces may present challenges for image capture and feature detection, potentially necessitating special coatings or

treatments to ensure precise results. Environmental conditions are also crucial; consistent and controlled lighting is essential to prevent discrepancies in the images.

Multisensor CMMs

Multisensor CMM systems integrate various measurement technologies within one machine. These systems combine tactile probes, laser scanners, and sometimes cameras to offer a broad range of measurement capabilities¹⁰. This multi-technology approach allows for dimensional checks, surface profile analysis, and geometric inspections all from a single platform.

At the heart of a multisensor CMM is its ability to incorporate different sensors on a common base. For instance, a tactile probe is used for precise measurements by touching specific points on a part, which is ideal for checking dimensions and tolerances with high accuracy. On the other hand, a laser scanner provides detailed 3D surface mapping.

These machines come with sophisticated software capable of integrating data from different sensors in a unified system. Plus, you get the freedom to choose the right tool for your requirements on the fly. For example, you can choose the tactile probe for intricate features and switch to the laser scanner for larger parts.

However, multisensor CMMs are not without their share of downsides. The integration of multiple measurement technologies means higher upfront costs compared to single-sensor systems. Additionally, managing the various sensors requires sophisticated software, which can make the system more complex to operate.



3D laser scanners with integrated photogrammetry are well suited for large parts and assemblies typically used in the heavy industry, aviation and shipbuilding.

Inspection software and processing algorithms

The new cutting-edge measuring tools aren't just about the hardware. Software plays a key role in the functioning of these CMM systems. More recently, advanced algorithms have been contributing heavily to improve accuracy, efficiency, and overall quality control.

Improving accuracy

Processing algorithms and machine learning in CMM inspection software significantly boosts accuracy by addressing systematic errors caused by factors such as mechanical wear, temperature fluctuations, and calibration drift¹¹. Once raw data is collected, these algorithms apply

correction factors to refine the measurements, ensuring precise results.

Data analysis

Algorithms are essential for extracting and analyzing geometric features from measurement data. They calculate dimensions, angles, and surface profiles, then compare these with design specifications to ensure critical parameters are accurate.

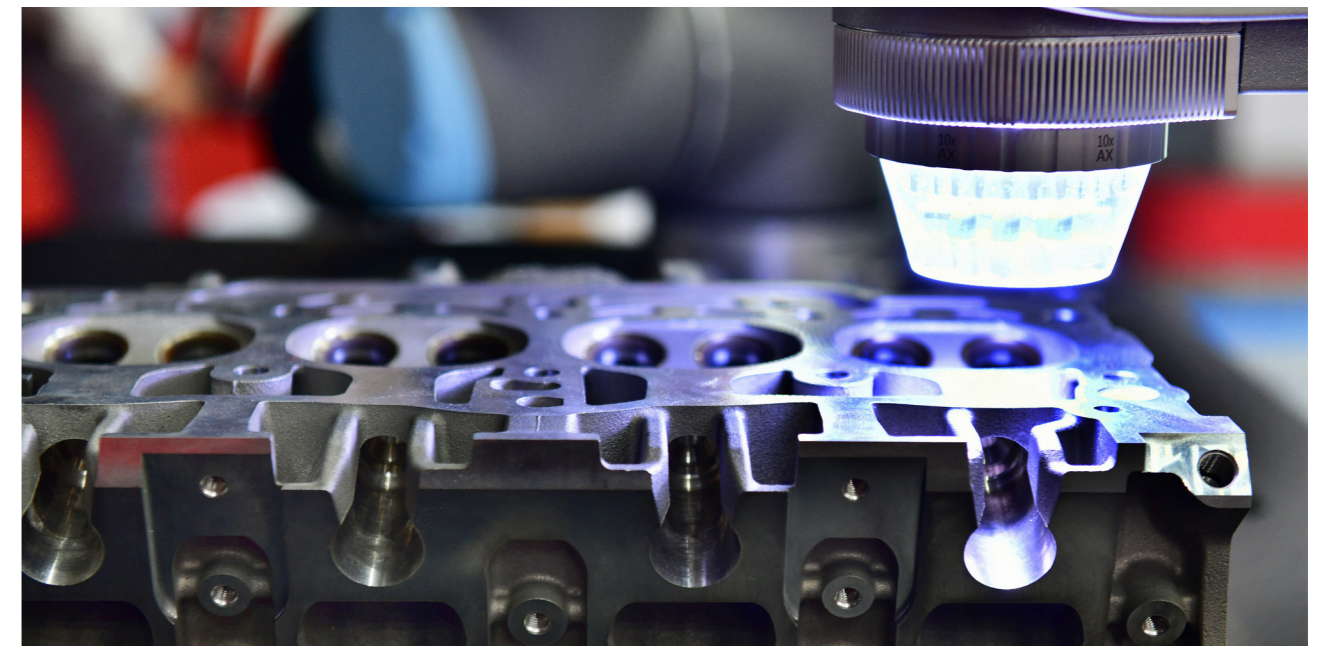
GD&T compliance

Processing algorithms enhance compliance with Geometric Dimensioning and Tolerancing

(GD&T) standards by automating the evaluation process. They compare measured data with GD&T specifications to ensure parts meet all required tolerances and geometric constraints. This reduces the manual effort required for GD&T analysis and improves consistency in evaluations.

Boosting automation

Algorithms significantly improve automation for repetitive measurement tasks, such as scanning and probing. This reduces the need for manual intervention, increasing both efficiency and consistency across inspections.



A multisensor CMM combines several measurement technologies to capture comprehensive data from a single setup. Image credit: Stock image from Alamy.

Key considerations for choosing quality control solutions

Industry requirements

In industrial sheet metal manufacturing, producing high-quality parts is crucial for maintaining safety and functionality. The components must not only meet stringent safety standards but also adhere to precise aesthetic requirements¹². For example, in the aerospace industry, components such as aircraft fuselage panels and wing sections must be manufactured to exact specifications. Any alteration, no matter how minor, can impact the aerodynamic properties and structural integrity of the aircraft.

In addition to ensuring that parts meet safety and aesthetic requirements,

quality assurance processes play a vital role in identifying potential issues early in the manufacturing process. By detecting defects early, manufacturers can address them promptly, preventing costly rework and production delays. Therefore, it is essential to adhere to industry-specific requirements when selecting a quality control solution.

Technological needs

Modern manufacturing environments require technologies that deliver both high accuracy and rapid measurement capabilities. Traditional methods often struggle to keep up with the pace of high-volume

production lines, especially in sheet metal manufacturing. In this context, it's crucial that the equipment can measure complex geometries and detailed features both quickly and accurately.

Additionally, the technology used must be adaptable to measure parts of varying sizes, materials, and complexities. Sheet metal components can differ significantly in dimensions, shapes, and material properties. Therefore, the measurement solutions need to be versatile and robust, capable of handling a wide range of parts without sacrificing accuracy.

Portability and adaptability

In large-scale manufacturing facilities or field environments, the ability to perform on-site measurements can prove advantageous. Portable measurement equipment enables swift inspections directly at the production site, eliminating the need to transport parts to a central location¹³. This approach not only saves time but also minimizes the risk of damaging the sheet metal parts during transport.

Manufacturing settings are dynamic, with fluctuating ambient light, various material reflectivity, and other environmental factors impacting measurement accuracy. Therefore, inspection equipment must be able to accommodate these changing conditions to ensure consistent performance. Portable laser 3D scanners excel in this regard, as they can adjust to different lighting conditions and material surfaces, providing reliable results in diverse environments.

Compatibility with automation

For manufacturers running high-volume automated production lines, seamless integration of measurement technology with existing systems is essential. The technology must not only automate the measurement process but also interface effectively with other automated equipment to ensure production efficiency and consistency.

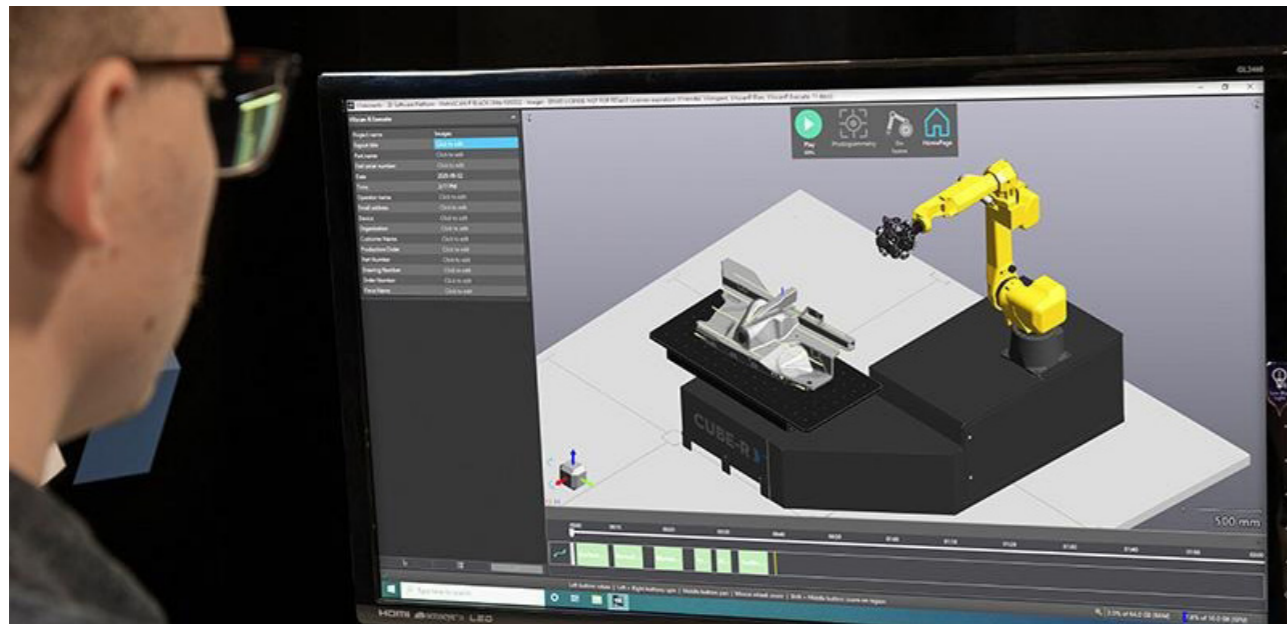
When measurement technology integrates with automation systems, it makes quality control a lot easier¹⁴. Automated systems can offer real-time feedback, so you can quickly tweak the production process and catch issues before they turn into defects. This kind of integration helps keep everything running efficiently and ensures you maintain high-quality standards.

Recommended solution

Portable laser 3D scanners have become a game-changer for quality assurance in industrial sheet metal manufacturing, offering both precision and flexibility. These advanced tools deliver highly accurate, rapid, and reliable measurements, making them ideal for various applications and settings.

These scanners are easy to move around, whether within a manufacturing facility or between different sites. This makes it simple to take measurements and assess quality on the spot, so you don't have to move or disassemble parts just for inspection.

Overall, portable laser 3D scanners are a fantastic addition to quality assurance efforts in sheet metal manufacturing. Their accuracy, speed, and versatility make them perfect for today's demanding manufacturing environments.



A robust software is essential for overseeing dimensional quality control. Image credit: Creaform.



With a portable 3D scanner, parts can be measured right on the production floor. Image credit: Creaform.

Case study

How a European Car Manufacturer Enhanced Production Efficiency with Creafom Laser 3D Scanning Tools

Introduction

The company is a prominent automobile manufacturer known for producing cars that adhere to the highest standards of quality and safety. Over the past decades, the company has established a reputation for its focus on innovation and efficiency within the automotive industry. It strives not only to enhance its production processes but also to work towards sustainability.

Recognizing the need for continuous improvement, this manufacturer actively seeks ways to optimize their manufacturing processes. In addition to its focus on increasing production efficiency, they place significant emphasis on minimizing its environmental footprint whenever possible.

The challenge

The company previously depended on traditional methods for inspecting vehicle components such as body panels and chassis components. This conventional approach, while reliable, was notably time-consuming and frequently resulted in delays.

Moreover, one of the significant limitations of these traditional inspection techniques was the inability to conduct inspections at various stages of the manufacturing process. As a result, any issues or defects were often identified later in the assembly line. This often led to extensive rework or corrections, further delaying overall production efficiency.

Considering that bottlenecks on the factory floor contribute directly to increased operational costs, the need for an efficient measurement process became evident. The challenge for the manufacturer was to find a solution that could not only accelerate the inspection process but also provide the flexibility required to adapt to various measurement needs.

To overcome these challenges, they needed a solution that could enhance both the speed and flexibility of the inspection process without compromising accuracy and reliability.

The solution

After extensive research, the company chose Creafom's 3D scanning solutions. This decision was strongly influenced by Creafom's reputation for delivering reliable and high-performance measurement tools. The manufacturer's choice was driven by the need for a solution that could meet their high standards for accuracy and efficiency while integrating smoothly into their existing production workflow.

They specifically selected two of Creafom's advanced systems: the [MetraSCAN 3D](#) scanner and the HandyPROBE portable CMM. The MetraSCAN 3D is known for its precise 3D models of complex geometries. The HandyPROBE, on the other hand, allows for precise tactile inspections in various production settings.

One of the significant advantages of these Creafom systems is their seamless integration into production environments.

Furthermore, Creafom's commitment to robust maintenance and customer support played a key role in the company's decision. Creafom's support infrastructure helps to minimize downtime and maintain the accuracy and reliability of the measurement systems, contributing to the long-term benefits of the manufacturer's quality control processes.

Result

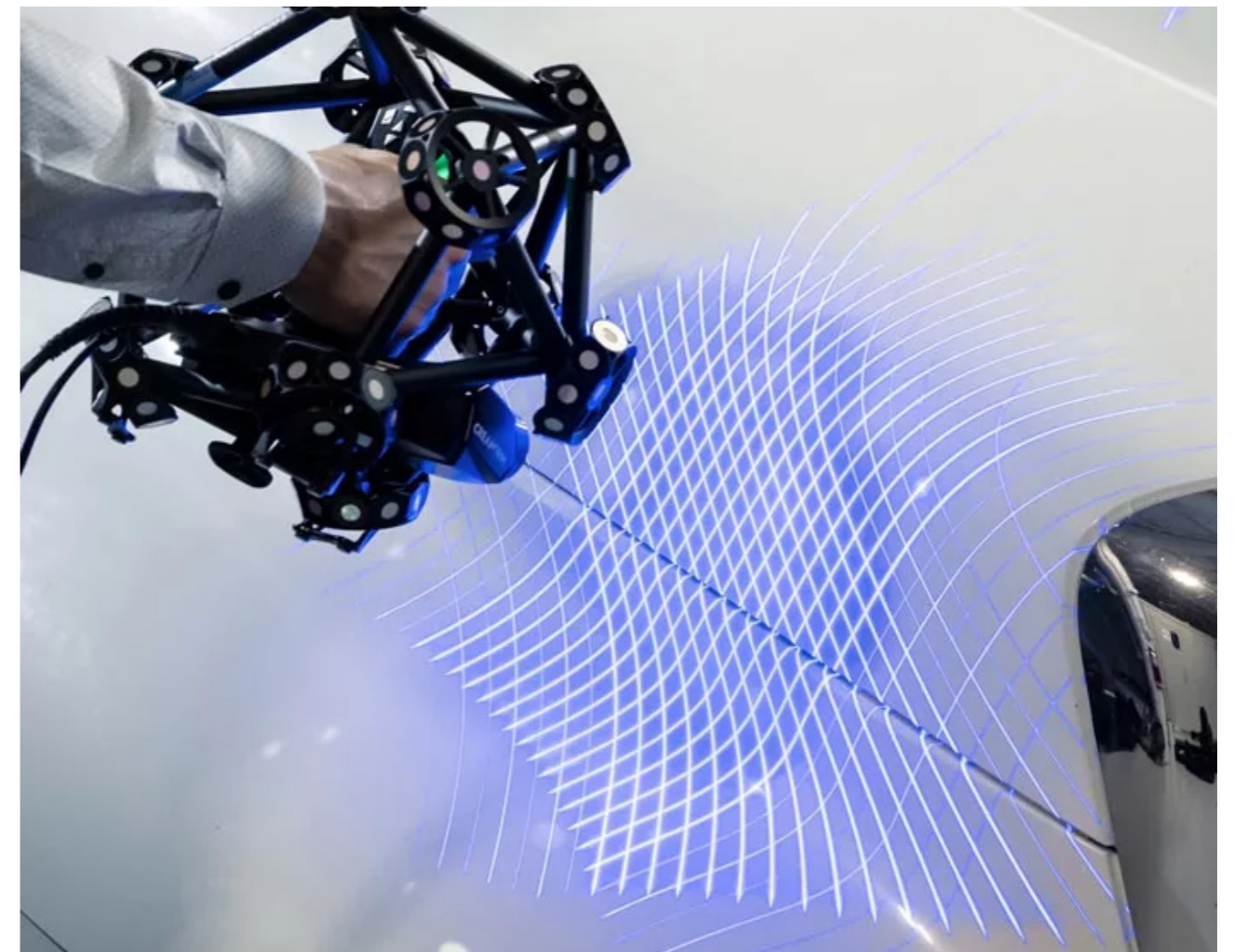
With the implementation of the new 3D scanning technology, the company significantly streamlined its production processes and recorded a marked increase in throughput. The advanced 3D scanning systems, including the MetraSCAN 3D and HandyPROBE, brought several key improvements to the table.

Designed to operate with minimal setup time, these tools do not require additional fixtures for many of their measurement tasks. The ability to

perform on-site inspections with these scanners allowed quality control to be integrated seamlessly into the production line. This efficiency not only accelerated the identification of potential issues but also enabled immediate corrective actions. As a result, production bottlenecks were reduced, and issues that might have previously caused significant delays were resolved more promptly.

The enhanced accuracy provided by the 3D scanners ensured that parts met design specifications more reliably. This level of precision was crucial for maintaining high-quality standards, particularly in complex assemblies where precise alignment and dimensional correctness are critical. For example, in automotive manufacturing, achieving high tolerances in components such as body panels and chassis elements directly impacts vehicle safety and performance.

As a result, the company saw a notable increase in the number of vehicles produced within the same production cycle. The new technology also led to a reduced need for rework and adjustments, further enhancing overall efficiency. The company's success highlights that investing in cutting-edge measurement technology pays off well in the long run.



The MetraSCAN 3D is renowned for its ability to accurately produce 3D models of complex geometries. Image credit: Creafom.

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About Creaform

Creaform is a pioneering company in 3D measurement technologies renowned for its commitment to innovation, precision, and customer-centric solutions. Established in 2002, Creaform has consistently pushed the boundaries of what is possible in portable 3D measurement, offering solutions that empower industries to enhance quality, efficiency, and product development.

At the heart of Creaform's success is its unwavering dedication to innovation. The company is driven by a passion for developing cutting-edge technologies that solve complex challenges across a variety of industries, including aerospace, automotive, manufacturing, and healthcare. This innovation is not just about creating new products; it's about rethinking the way industries approach measurement and inspection processes, making them more efficient, accurate, and accessible.

Creaform's technological advancements are characterized by

their portability, precision, and ease of use. These features are integral to the company's mission of providing tools that can be utilized in even the most challenging environments. Whether on the factory floor, in the field, or a laboratory, Creaform's technologies are designed to deliver accurate results quickly and reliably, helping companies maintain the highest standards of quality control and product development.

Creaform's technology is designed to address the growing need for precise and efficient 3D measurement solutions in an increasingly complex industrial landscape. The company's products enable industries to improve their processes, reduce waste, and accelerate time-to-market for new products. By leveraging the latest advancements in 3D scanning, reverse engineering, and quality inspection, Creaform is helping to shape the future of manufacturing and product development.

Moreover, Creaform's commitment to continuous improvement and R&D ensures that it remains at the cutting edge of the industry. The company is constantly exploring new ways to enhance its technologies, driven by the belief that innovation is essential for progress.

In conclusion, Creaform is more than just a technology provider; it is a partner in innovation. Through its dedication to excellence, integrity, and customer satisfaction, Creaform is helping industries around the world achieve greater precision, efficiency, and success in their operations. As the company continues to evolve, it remains steadfast in its mission to provide the most advanced and reliable 3D measurement solutions on the market, setting new standards for the future.

Learn more at creaform3d.com



About Wevolver

Wevolver is a global platform and community that provides engineers with the knowledge and connections to develop better technology.

We bring a professional audience of engineers informative and inspiring content, such as articles, videos, podcasts, and reports, about state-of-the-art technologies.

The knowledge on Wevolver is published by various sources: universities, tech companies, and individual community members. Next to that, we manage a network of over 50 technical writers who create content for our customers and publish that on Wevolver.com

Millions of engineers leverage Wevolver to stay up to date, find knowledge when they are developing products, and leverage the platform to make meaningful connections.

Wevolver has won the SXSW Innovation Award, the Accenture Innovation Award, and the Top Most Innovative Web Platforms by Fast Company. Wevolver is how today's engineers stay cutting edge.

This report was written by Chandrakant Isi. Chandrakant is a content marketing specialist by profession and a 3D-printing enthusiast by choice, constantly shuffling between Word files and filaments.

