Introduction

The automotive industry, like many other manufacturing segments, faces constant pressure to simultaneously reduce costs and maximize throughput while ensuring higher standards of quality. Over the last decade, extensive use of digital technology in both design and production has yielded enormous cost and quality benefits. However, the ability to leverage digital technology for inspection and quality control without incurring expensive time penalties has not kept pace with the ability to produce complex, close tolerance parts.

To be practical for broad Automotive Industry applications, a digital inspection technique must embody a number of simultaneous characteristics:

- High speed
- High accuracy
- A large measurement volume
- Ability to measure features on both simple and complex parts
- Ability to measure parts with complex surface finishes ranging from freshly machined to dark paint
- Operation in normal lighting conditions
- Real time data analysis
- Simple to operate

Touch probe (CMM) technology has been the mainstay in providing high quality 3D surface geometry data from complex parts. Unfortunately, CMM systems generate measurement data very slowly and require extensive operator training to both setup and run the equipment. The introduction of optical scanning hardware has enabled fast characterization of surface geometry in many niche applications. However, the hardware has generally suffered from difficulties in measuring complex parts or surface finishes as well as trade-offs between small field of view and high accuracy.

The effect of these and other technology limitations is that digital inspection is primarily utilized for characterizing large, loose tolerance structures such as frames and panels, or is used for infrequent measurement tasks such as reverse engineering, first article inspection and infrequent statistical sampling. The ultimate goal of using non-contact 3D optical inspection techniques to accomplish automatic in-line inspection of complex parts and assemblies has not yet been realized.

Metron Systems Inc. has developed a new optical scanning technology to meet highly demanding 3D scanning application in the aerospace industry. The commercial form of this scanner, the Metron MSG2, possesses all of the characteristics required by the automotive industry listed above. As such, it is uniquely positioned to bring digital inspection to a wide variety of applications to which there have been no cost effective Inspection and QA solutions. Further, this scanning technology provides an ideal hardware platform for developing automatic in-line inspection applications for complex parts and assemblies.
Abilities of the Metron Scanner

Metron Laser Scanner System

The Metron System is optimized to maximize the measurement volume that can be measured with one sweep of the mirror while maintaining the high accuracy and extremely fast measurement rates required by in-line inspection applications. One advantage of the unique optical configuration is that manipulating independent configuration parameters can optimize many of the scanner performance characteristics:

- The width of the FOV is controlled by the amount of mirror rotation allowed.
- The depth of the FOV is controlled by the magnification in the optical system.
- The resolution of the scan is controlled primarily by the pixel count of the linear array camera.
- The number of measured points per second is controlled primarily by the pixel rate of camera.
- The scan point density is controlled by a combination of the camera exposure rate and the sweep rate of the mirror.

The scan head is engineered so that its performance will support the needs of a complete integrated scanning system. To support the “Point of Scan Intelligence”, a significant amount of processing power is hosted internally in each scanner. This allows all the image processing shown in Error! Reference source not found. to be conducted in real time inside each Scan head. Since each measured point is the result of a unique laser position and camera exposure, the Scan head adjusts the laser intensity to optimize each exposure and thus reduce the noise in the scan. Further, the real time signal processing allows the Scan head to identify and reject bad data points without requiring any part specific knowledge, producing almost error free data sets.

The architecture allows all data from a scanner as well as all commands and status information to be exchanged with a remote host over a single Ethernet connection. Further, the scan head’s are spatially aware, allowing the host motion controller to inform a scan head of its real time positional attitude in a global coordinate frame. This feature enables a scan head to report Cartesian surface geometry of a part that is accurately registered into the coordinate frame of the part instead of local coordinate frame of the scanner. Together, these “Point of Scan Intelligence” features make it possible to seamlessly integrate single or multiple Scan head’s together with a complex motion system to scan different aspects of a part, collect all data in real-time in a single coordinate frame with a single host, all without the need for any patch processing.

The Metron scan head measures a 2 dimensional “slice” of a part’s surface geometry. A fundamental attribute of the scan head is that it is easily integrated with motion platforms to provide the third dimension of measurement and satisfy a broad range of customer requirements. This means that the scan head can be configured into systems as simple as a single scanner and linear stage to complex systems involving multiple scanners and precision motion carriages. Other options such as attachment to a robot arm or integration onto a large CMM also avail themselves based upon the scan head’s ease of integration.

Metron has integrated the scan head onto a modular motion system, resulting in the Metron Measurement System. This system provides customers with a robust scanning station that represents a tightly integrated inspection solution. The system can provide customers with
immediate benefit without disrupting their current operations. The system also provides the opportunity for customers to become quickly familiar with the system’s capabilities and evaluate opportunities for integrated solutions tailored to their specific manufacturing challenges while minimizing risk.

An example of the utility of the Metron System is shown in Figure 1. This complex aluminum part would require many hours of setup and several more hours to measure using traditional single point touch probes. Typical optical scanners would require operator intervention to acquire scan data from several different viewpoints and then to align or “knit” the individual scans together. The Metron System generated this 450,000-point data set from six separate views in five minutes, automatically.

Figure 1. This complex cast aluminum part cannot be effectively inspected with single point methods but can be quickly characterized using Metron’s 3D Scanner.

Applications of the Metron Scanning System

Reverse Engineering

Reverse Engineering (RE) is the art of taking 3D surface data from a component and creating a CAD model that can be used in the digital design process or, in some cases, utilized directly for creating CNC tool paths. This process requires comprehensive, high density, high accuracy data. The more comprehensive and accurate the scan data is, the less manipulation that is required by the operator to reproduce the surface geometry. The Metron Scanner System is well suited for use in RE because it quickly produces dense, accurate data that can be directly utilized by all major RE software packages. Further, since the Metron System can be configured to automatically knit together multiple views taken from different view angles, it is simple for the operator to gather the comprehensive 3D part scan data without complicated and time consuming setup. Figure 2 shows a complex, highly reflective machined aerospace part that has been scanned and converted to a surface file in a remarkably short time.
Data Mining

Data Mining differs from RE in that, instead of producing a surfaced CAD model, the goal is to understand and characterize features of a component by directly manipulating and interrogating the scan data. Data Mining is usually a manual operation that is often aimed at discovering non-compliance with individual components or sources of interferences in assemblies. A related example of this type of discovery is shown in Figure 3 where the wear pattern on an EDM electrode is quantified to understand the defects in the resulting injection mold. Discoveries from Data Mining are often used to improve the manufacturing process and update the digital models. A common example is when successful second ops on cast metal parts are quantified and used to provide specifications for future part modifications. Data Mining requires accurate, comprehensive scans of complex parts. The Metron System is excellent at quickly providing this data to the operator without long setup and cycle times.

First Article Inspection

First Article Inspection is a critical link in any manufacturing process. It is the step where the design and manufactured part meet for the first time, allowing verification of the design and validation of the manufacturing process. Figure 4 shows a first article inspection performed an actual component from the Metron System. The entire measure, compare and report process that would have taken 3 or more hours using conventional inspection techniques was completed in less than 30 minutes using the Metron System. The fast, accurate 3D scans were able to detect
several flaws in this part, yet required NO special set up and only a simple, generic clamping fixture. The comprehensive nature of the scans means that the entire part was inspected, reducing the chances that additional errors, which weren’t part of the inspection protocol, will show up later during the assembly process.

![Image of anodized component and CAD file comparison]

Figure 4. First Article Inspection was performed on this anodized component that is actually in use in the Metron scan head (a). The part was scanned and compared to the CAD file (b) showing out-of-spec flatness errors (the yellow regions) and a feature misplaced by 0.035” (the orange region). The red close up patches show the 3D scan points from the actual part do not line up with the geometry of the CAD model. This comprehensive analysis took less than 30 minutes.

The Metron System is an optical inspection tool that does not require non value-added steps such as painting or powder coating. It enables the elimination of bottlenecks and can drastically reduce cycle times. It also provides a simple way to generate the data required to complete digital assembly of parts based on First Article Inspection, even when the part are not located in the same geographic vicinity.

**Offline 3D Inspection and Statistical Process Control**

The First Article Inspection example in Figure 4 also fits under the larger category of Offline Inspection. Offline Inspection describes the situation where the part is removed from the production line and inspected for Geometric Compliance and other QA factors. This information provides the backbone for Statistical Process Control. The faster the inspection can be accomplished and the less value-add steps required to gather the data, tighter the control of the process and less non value add cost incurred. Figure 5 shows an example of an engine component that has a critical volume geometry that fundamentally affects its performance. The Metron System allowed the surface geometry of the part to be quickly and accurately characterized without extensive setup and fixturing. Although most offline inspection tasks require aligning and comparing the data with the CAD model, this analysis utilized tools from RE to quickly determine the volume.
Online 3D Inspection and Quality Control

One implication of moving offline 3D inspection as close to the production line as possible is that the ultimate inspection application is to accomplish the inspection on the production line. This would allow real time feed back into the process as well as 100% QA inspection. There are many challenges still to be solved before online 3D inspection is commonplace in manufacturing of complex, high tolerance parts. The 3D scanning hardware must be fast and provide highly accurate and clean data. The analysis software must be fast and allow a high degree of automation and customization. The manufacturing organization must have evolved a stable and robust procedure for utilizing the information.

Metron Systems has developed a hardware 3D scanning technology that can meet the requirements of online 3D inspection. We currently offer a robust scanning system that can be used as both an offline inspection tool and a proof of principle for migration to online inspection. Metron has worked closely with vendors of many analytical software packages to gain the expertise provide tightly integrated turnkey inspection systems.

Conclusion

Metron’s 3D laser scanner is an enabling technology, which allows manufacturers to take advantage of the digital technology they have already invested in. This leverage has allowed manufacturer’s to produce parts and assemblies at a speed, precision and cost which is unprecedented. However, the abilities of measurement systems are critical to the QA and process controls for these advanced systems haven’t kept pace. Metron System provides the combination of speed, accuracy, flexibility and ability to scan reflective surfaces that is required to meet the unfilled needs for a broad range of digital inspection applications.