Technology White Paper

Reverse Engineering with 3D Measurement

What is reverse engineering?

Reverse engineering is the process of duplicating an existing product without the aid of drawings, documentation, or computer models.

In ordinary engineering, the product designer creates a drawing showing how an object is to be built, and then the object is manufactured by following the design drawing.

In reverse engineering, the steps are inverted. First, engineers identify the system components and their interrelationships. The object is taken apart to discover its structure, function, and operation. Duplication of the part is enabled by capturing physical dimensions, features, and material properties.

Next, a CAD drawing or other representation of the system is created. Then a reproduction of the original system is accurately created based on that drawing.

Why reverse engineering is needed

A common scenario in which reverse engineering is needed is as follows: a company has a machine. A part fails and a replacement part is needed. But the manufacturer has discontinued the machine and no longer makes parts for it. The machine owner can reverse engineer a replacement part from the failed part, preventing the machine from going out of service.

Reverse engineering can shortcut product development time. It quickly captures a product in 3D digital form and exports the data for rapid prototyping, tooling, or manufacturing.

There are many other situations in which reverse engineering can be used:

- Substituting an original part design that has inadequate or no documentation available.
- Redesigning a part to eliminate a bad feature or to reinforce good features.
- Analyzing competitor products.
- Supporting new modifications where original CAD models cannot.
- Updating obsolete products with current technology.
- Updating or creating as-built documentation.
- Supplying a part with little downtime that is mission-critical to a system, reproduced in large quantities, or reflects a big investment.
- Performing fine element analysis or computational fluid dynamics on parts for which no design information is available.

How objects are measured for reverse engineering

To reverse engineer an object, you need to know its physical dimensions. Unless the dimensions are extremely precise, the reverse engineered product will not be an accurate reproduction of the original and may not function.

Parts may be measured carefully by hand using calipers, micrometers, and other similar tools. In modern reverse engineering, a coordinate measuring machine (CMM) can measure the geometry of an object faster and more accurately than these traditional hand tools.

A typical CMM measures three orthogonal axes, X, Y, and Z, operating in a 3D coordinate system. Each axis has a scale that indicates the position of a point on that axis.

CMMs use touch probes to record points as the probe contacts the surface of the part being measured. Points are measured one at a time until the CMM collects enough data for the software to determine lengths, diameters, angles, and other geometric elements. The machine reads input from the touch probe as directed by the operator or software. Then the XYZ coordinates of each point are used to determine size and position.

A CMM can measure dimensions either through contact with the object or with a laser scanner. The point cloud collected is converted into surfaces. This measurement data is then exported to a CAD package for refinement, analysis, and generation of cut tool paths for CAM.

Portable CMMs

3D measurement arms are portable CMMs that operate much in same manner as traditional CMMs in that they determine and record the location of a probe in 3D space and report the results through software. One of the main benefits of a portable CMM over a traditional, or fixed, CMM is portability. Portable CMMs are considerably smaller and lighter and can therefore be taken to the part needing inspection. This removes the need to take the part to the CMM and minimizes machine downtime and quality bottlenecks. Furthermore, portable CMMs do not require the controlled temperature conditions that traditional CMMs demand. Portable CMMs are also easier to use and substantially less expensive than traditional CMMs.

A laser line scanner can be attached to a measurement arm to allow for non-contact measurement. A laser scanner can quickly capture data to create a point cloud of millions of points of data that can be used to create a CAD file. The benefits of adding a laser scanning probe to a measurement arm include not only the speed in collecting large amounts of data, but also the ease-of-use and lower risk of impacting a part during measurement.

The FARO ScanArm

The FARO ScanArm is a portable CMM ideally suited for reverse engineering applications. Non-contact measurement is usually a faster way to inspect and measure parts, and industry as a whole is moving away from hard probing toward laser scanning. One key advantage of laser scanning is that soft, deformable, and complex shapes can be easily inspected without coming into contact with the part.

The core of the system is the FaroArm, an articulating measurement arm that captures dimensional data by hard probing the surface being measured. With contact measurement repeatability up to .024mm and accuracy up to ±.034mm, the FaroArm weighs 11.3kg or less.

A FARO Laser Line Probe (LLP) can be combined with the FaroArm to add laser scanning capability to the ScanArm. The advantage of the LLP is that the laser probe is small enough to remain attached to the ScanArm so the system can operate as a contact (hard probing) or non-contact (scanning) device without any alterations to the machine itself.

The FARO LLP is the smallest and lightest laser probe on the market today, weighing less than half a pound. Measurements are accurate up to 35µm (+0.0014 inch). That accuracy, combined with light weight, means the user can perform reverse engineering functions without fatigue.

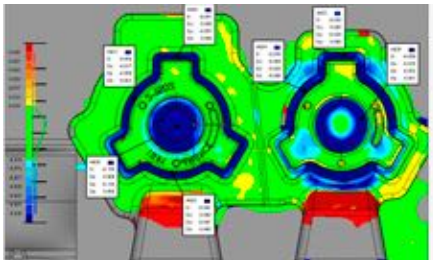
A triangulation process is used to find the position of objects in 3D space. A laser stripe emitted by a diode is projected onto the surface being measured. A camera looks at the laser stripe from a known angle and determines the location for each point on the line. High frame rates and high resolution image sensors improve scanning speed and produce high-density point clouds capable of detecting finer details.

A major advantage of the FARO ScanArm is that it is a portable solution. They system can easily be carried to the part or machine to be measured. Operating temperature range is 50 to 140° F. Fixed CMMs, by comparison, are large machines that require their own specialized air conditioned rooms to strictly control temperature and conditions. Because the fixed CMM is immobile, objects to be measured must be transported to and from the inspection area, which can present a challenge depending on weight and size.

Reverse engineering success stories

The Andretti Autosport team has the most wins of any Indy car team. To make sure each race car leaves the shop with the same design set-up specifications, the Andretti team reverse engineers sanctioned parts and carbon fiber components for their cars. They use the FARO ScanArm to scan incoming parts and the entire race car assembly for proper set-up.

Having FARO in-house enables Andretti technicians to measure and inspect parts, scan models, and verify set-ups. It also eliminates the time and expense of paying outside service providers to do their reverse engineering measurements.



Trinity Forge is a closed-die forging plant that specializes in complex shapes in a wide variety of sizes. To meet the stringent specifications of their customers, Trinity uses the FARO ScanArm daily to inspect dies when they come off the CNC machines, to track die wear, and to reverse engineer products that may not have prints or legacy data available. The speed at which they can now operate is a great value to the company.

Conclusion

Reverse engineering is an important discipline that can greatly extend the useful life of machines by allowing the machine owner to fabricate his or her own parts when the OEM has discontinued the product. Reverse engineering also enables parts to be updated with new technology or redesigned to add new features or even eliminate flaws.

The easiest, fastest, and most affordable way to measure parts and products for reverse engineering is with a lightweight portable CMM that offers both contact and non-contact measurement. The combination of these benefits – as manifested in the FARO ScanArm – provides a fast and efficient solution for today's competitive needs.