The twin screws are machined to precision clearances in relation to the compression housing. The counterrotating screws cause a low pressure area in the suction port. Air is drawn in and trapped by the rotating screws and transported to the discharge end. This does result in a high decibel range of 95 to 100, and maintenance of these units includes regular oil changes (for oil pumps) and expensive repairs on switches and shut down devices.

Displacement Pump

All the pumps mentioned have their place in the CNC market. The level of performance varies from one model to another and also from manufacturer to manufacturer. Regardless, maximum vacuum and efficiency is the goal. There are simple ways to increase efficient vacuum such as routing gasket around the perimeter of the vacuum table (if applicable), or seal the edges of the scavenger board. The yardstick for proper vacuum table hold-down is a system that performs at 11"Hg or higher (a specific scfm).

CNC Accessories

Since CNC Routers are used to increase production in so many different industries, most CNC Router suppliers have to offer a wide variety of CNC accessories. Products that must integrate seamlessly with the router's existing electronics, mechanics and software include: lasers, probes, rotary tables, dust collection systems and several different styles of coolant, just to name a few. The following four sections provide an overview to some of the most common CNC accessories.

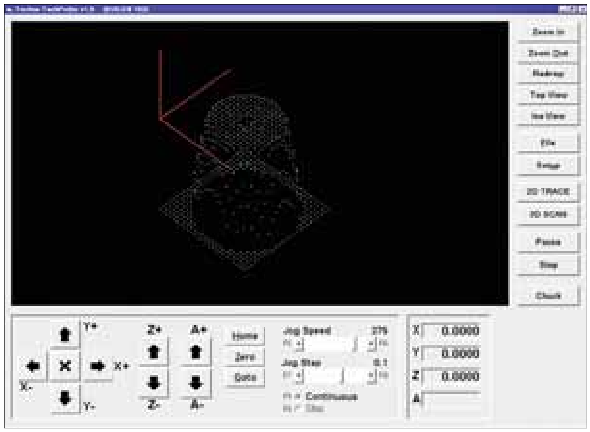
Reverse Engineering

Reverse Engineering is the process of recreating a model from an original. The term can be applied to software, electronics and, in our particular case, to mechanical modeling. There are a number of steps involved in the process, but the first is the generation of the coordinate data points that lie on the surface of the part. Several devices that can be used to generate these coordinates – laser scanner, structured light scanner, digitizing arms and touch probes, to mention just a few. Each system has its own set of advantages, but the end result for each is a point cloud of coordinates.

Whether you manually use a digitizing arm to touch-off these points, or attach a probe or laser scanner to a 3-axis CNC machine, each procedure finishes with a graphical file format to manipulate and/or export. The manner in which you collect, export and use the data may differ to a greater or lesser degree, but the shared result of each system is an organized series of standard geometric entities in space.

There are several geometric entities you may encounter. A laser scanner or digitizing probe can produce a point cloud representing the object's 3D space.

A point cloud or NURB is stored on your computer as an electronic file and then imported into standard industrial



CAD/CAM software packages where it can be manipulated to generate a G-Code toolpath.

Determining which digitizing system to purchase depends as much on your application as it does on how much you want to spend. If you intend to reverse-engineer 2D geometry only, then you can rule out the laser scanner in favor of a less expensive contact-type digitizer. If you need to perform 3D applications, then you have to weigh the type of scan (surface, material and size), accuracy requirements and time considerations in order to determine the best, cost-effective system for your shop.

Types of Scanners

There are basically two types of 3D scanners available, contact and noncontact. The first type of scanner includes items like touch probes as well as digitizing arms. These devices collect data by physically touching the surface of the object and collecting the relative position information of the touch point. The noncontact type of scanner is generally laser-type or in some cases even ultrasonic based scanners. These

scanners determine the relative distance from the scanner to the surface. This is usually the Z coordinate. The machine positioning the scanner usually supplies the travel to collect the X and Y coordinates. Another subcategory of noncontact type of scanner is structured light types. These scanners work with a specific varying intensity of light and multiple images of the object from known positions. A mathematical algorithm is then used to create a surface with the measured amount of reflectivity. This basically recreates the 3D visible surface of the object. The speed and accuracy of the scanner varies greatly depending on the model and drive system of the CNC machine. In addition, the scanners share the same attributes from one manufacturer to another.

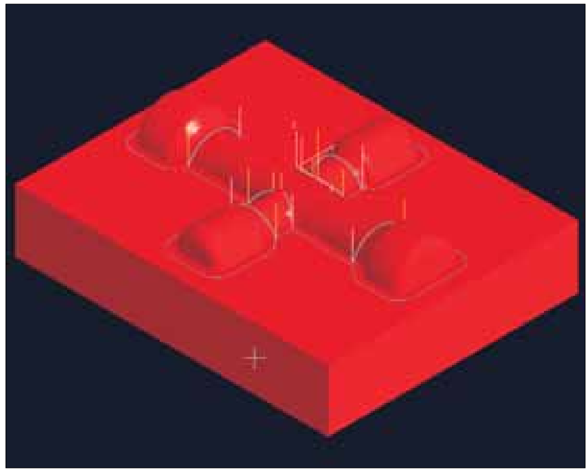
Types of Laser Scanners

There are a number of different types of laser displacement scanners, each offering advantages in certain applications.

> **Interferometry** is probably the most accurate but requires the greatest precision in the equipment and the surfaces to be measured.
>
> **Triangulation** looks at the angle of reflection off the target surface and is generally very inexpensive but is limited by the inclination angle of the surface to be measured. Steeper angles produce very erratic results.
>
> **Dynamic focusing** uses a system to adjust the focus of a camera to determine the distance. This method requires moving parts and is thus limited by its speed and cost of equipment.
>
> **The Conoscope method,** used by the Techno laser scanner, uses polarized light and holographic methods to determine the distance to the reflecting surface. Because only a single beam is used, the angle of the surface does not affect the results and even measurements in "deep holes" can be taken.

What to Scan and What to Scan with

The different types of scanners are typically suited for different types of applications. The contact process is usually more time consuming but can also be more efficient for smooth engineered types of surfaces such as the fender of a car. Because of the contact, specific points can be digitized to get the features of the surface, such as an edge or cusp or hole. This allows for the features to be quickly and



accurately recognized and digitized. Another advantage of contact scanner arms is that the surface generation is a more simple process. In most cases, the points being collected are directly used for creating splines or features in the software. There is generally little filtering that is required.

The noncontact types of scanners are usually faster at collecting large numbers of data points but they typically are designed to gather points over a grid surface with a specific spacing along the X and Y axes. This process collects what is called a "point cloud" with a greater number of XYZ coordinate pairs. This approach is better suited for collecting data off very detailed surfaces which might be found on hand-carved objects such as furniture or coins. The drawback to this approach is that the features such as the cusps, edges and sharp corners might not be captured completely in the grid being used to collect the data unless the grid is relatively fine and then a great number of points have to be collected. Collecting vast amounts of data often creates processing problems. Remember that the number of data points increases geometrically as the grid gets finer.

For example, over a 1”x1” grid:

Grid spacing in Inches	Number of Points Collected
.2	36
.1	121
.05	441
.025	1681

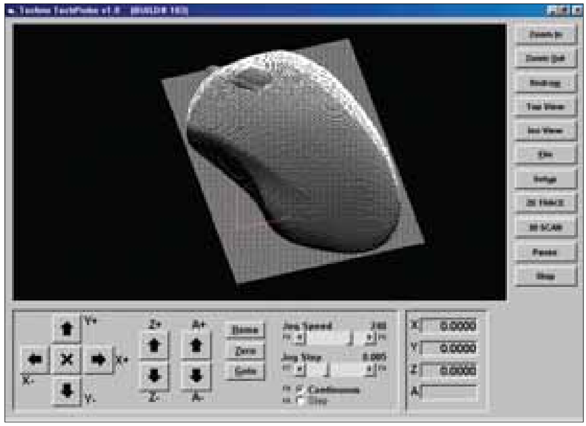
By cutting the grid spacing in half, you wind up collecting approximately 4 times as many points. As you can see, collecting data to reproduce fine detail can quickly involve scanning millions of data points. This produces a calculation burden on the computer as well as a processing problem to get all the required detail from the data. Dealing with this large quantity of data can become burdensome.

Cleaning Up the Act

Once the points are collected, the next stage is to generate the surface or the toolpath for the surface and this is where the software becomes critical. Think of the software as the word processor needed to edit the rough draft. Some software packages are available to reproduce the surface straight from the scanned data. Scanned surfaces can be projected onto existing surfaces or other G-Code programs with this software. The other approach is to create surfaces from the scanned data which will be integrated with other surfaces for an application or for reverse engineering. This approach is best done with a program like RHINO for the data collection and the surface manipulation. If the data collected is a point cloud, we would also recommend a program called COPIOUS. This is an add-on to RHINO and is specifically designed to convert a great number of data points into surfaces. It also performs critical tasks such as filtering and feature recognition, both of which are extremely important. When a sea of data points is collected with a 3D

scanner, it is very similar to a flat bed scanner scanning a sheet of paper in that both processes collect the data and under the best of circumstances; one should expect some noise in the data in both cases. This noise can come from a number of sources such as an imperfect surface, dirt on the surface and so on. Filtering and surface clean up is a crucial stage of reverse engineering and COPIOUS and RHINO are some of the best tools for accomplishing this.

There are major software packages devoted exclusively to recreating surfaces from point cloud data. Some examples of these software packages are Imageware, Rapidform and Geomagic. These packages are designed to filter the noise as well as recreate the features of the object from the point cloud, such as holes, cusps, edges and so on.



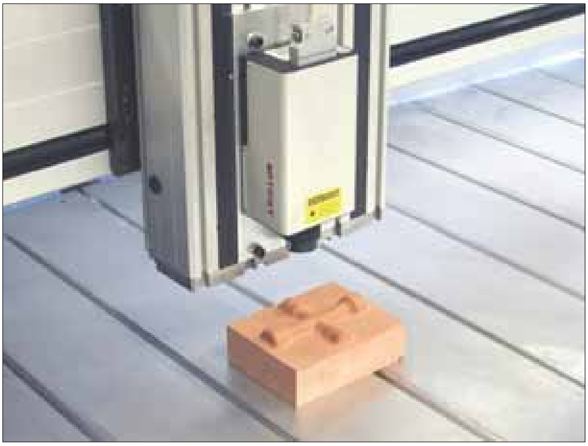
The Grand Finale

Once the surfaces have been created, edited and filtered they can be used for various applications. The results can be incorporated into other designs or transferred to a CAM program for machining or even projected onto existing parts as secondary machining on molds or models.

Matching a System to Your Application

Each of the three systems has its own advantages anddisadvantages in relation to an application. Although the laser scanner is the most expensive and is not typically used for 2D scanning, it also collects the most data in the most time-efficient manner. Laser scanning is an automated digitizer, which means you attach the laser module to the Z-axis of your CNC machine. X- and Y-axis data is collected via the CNC machine’s XY travel, while Z-axis data is collected by the laser. Through the software connected to the CNC machine’s controller, the laser creates a highly detailed point cloud from the XYZ data it collected. The point cloud, in turn, is saved to your computer hard drive in any number of standard formats.

Laser Scanning is the fastest system and generates the best results, but does have some limitations. First, you need a CNC machine to use it; the depth of scan is determined by the Z-axis height as well as the specific lens selected for a particular depth of field or readable area. Another limitation arises when objects to be scanned have contours under the top surface. In order to collect data on these contours during the initial scan, the end user needs a 4th axis to rotate the object so that it can be scanned from another angle.



A digitizing arm, on the other hand, through its manual operation, can collect points under the top surface of an object. The digitizing arms also have an impressive work range and are available in numerous work ranges of spherical radii. It works in tandem with a CAD program, giving the operator complete control of how points, lines and surfaces are reverse-engineered. The quality and accuracy of the final model depends on the skill of the operator, as does the time. However, the end result is a NURBS model, a mathematical representation of a 3D surface, that is much more flexible and smaller than a point cloud created by the other tools. That being said, they are also the most reasonably priced digitizing systems, versatile in that they perform 2D or 3D scans and do not require a CNC machine to operate.

If you do have a CNC machine and want a cost-effective digitizer, then you should look at a CNC digitizing probe. These probes share the same benefits of the laser scanners in that they are automated, and subsequently faster in collecting data than digitizing arms and are less prone to error. They are also a more economical option than the laser scanner. Although, what you save in money, you lose in the detail a laser provides.

Also, a digitizing probe shares some of the disadvantages of the laser scanner. Because you need a CNC machine to generate a point cloud, you lose whatever shop time you would otherwise use your machine for. A probe will not be able to collect points from sharp, deep cavities or grooves located underneath the object's top surface without rotating and rescanning, but it can quickly and easily do 2D scans.

Access to reverse engineering tools and the advantages they provide is abundant, but which system to choose greatly depends on the nature of your application. Do you require 2D or 3D capabilities? What is the shape and contour of the objects being scanned? Do you have or plan to get a CNC machine? What is your work load? How accurate does your scan have to be and what funds are available for this purchase?

Finding the right match between your application and a particular reverse engineering system is just the beginning. It helps to know how the system works in order to garner the best results. For instance, the noncontact digitizing CNC laser scanner collects data that is reflected back, off the scanned object. The laser shoots a stream of light toward the object; when the light reaches the object, it bounces back toward the scanner in waves (i.e., Diffraction Principle and Interference Patterns). Depending on the intensity and range of the waves, the laser's sensor interprets the depth of the object.

When the laser's sensor is able to clearly interpret the reflected light waves, the resulting point cloud is extremely detailed. It is possible, however, for some aspects of the object to give a misrepresented reading of the surface area being scanned. The cleanliness of the surface, for one, can contribute to an inaccurate point cloud. Again, the laser's scan is so detailed that even the smallest of debris can be recorded.

Other laser scanning aspects to consider include the texture and color of the surface to be scanned. As mentioned already, the surface area needs to be clean and free of debris; but clean should not be confused with glossy. Objects that have shiny or transparent surfaces do not scan well due to the nature of the scanner's reflected data collection. When the laser scans a glossy surface, the reflected light that bounces off and back to the sensor is too strong and thus, misrepresented. On the other end of the spectrum, if the surface is at all transparent or translucent, then a portion of the laser's light will be absorbed into the surface, resulting in too little information returning to the laser.

Color saturation also plays a significant role in the quality of a laser's scan. Darker colors tend to absorb the laser, while lighter colored surfaces reflect too much. There are controls to manipulate a scan's range of intensity. Tweaking these controls can compensate for the amount of