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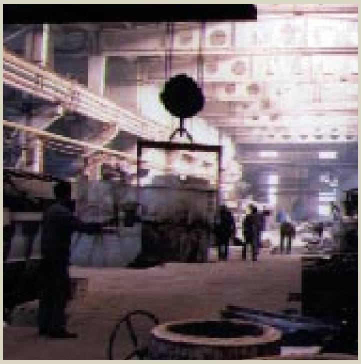
Gantry CMMs Fly High at ADI 4



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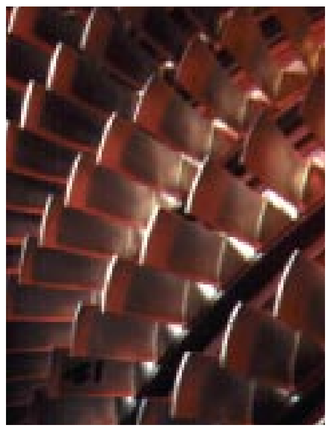
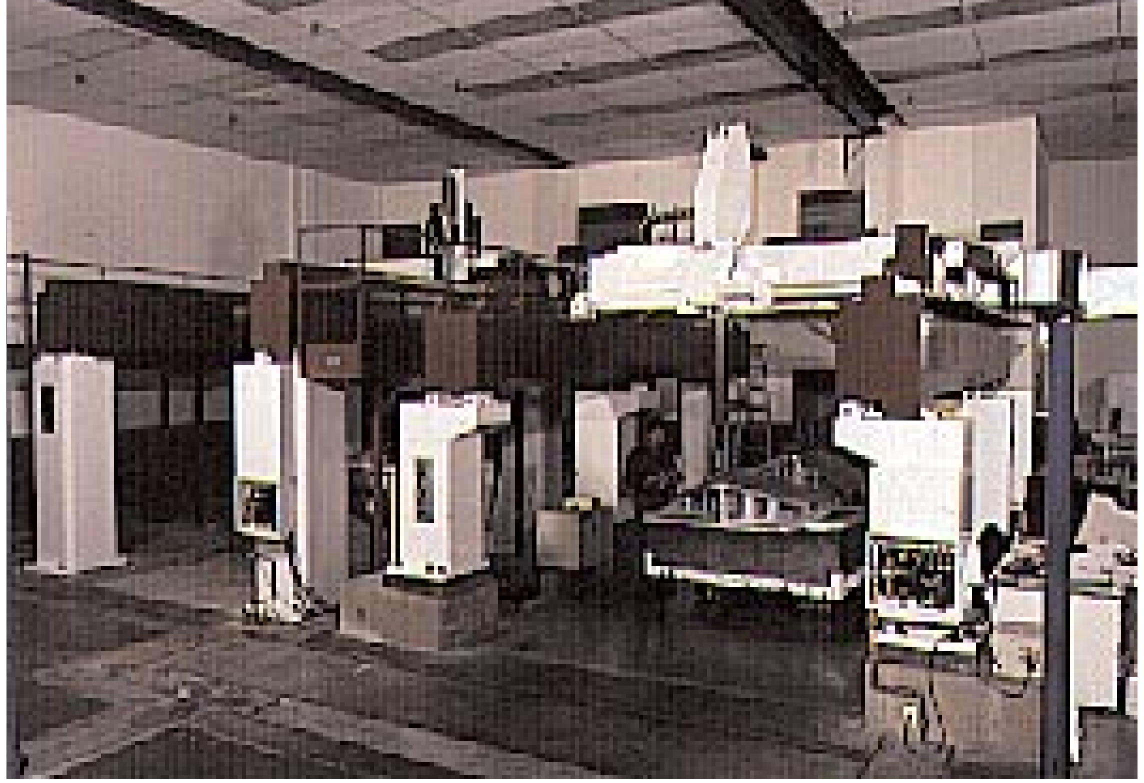


On the Cover
Accurate inspection of turbine engine components, like these titanium compressor section fan blades, is a critical step in the production of aircraft engines. Blades manufactured to close tolerances result in more efficient engine operation and longer service life.

Bigger Is Better:

Gantry CMMs Help Aerospace Suppliers 'Take Off' In A Highly Competitive Market



Gantry-type CMMs like this DEA DELTA SP at Aerospace Dynamics International provide accurate dimensional measurement of large aircraft structural components and tooling. This machine was modified, by extending the height of its columns, to accommodate workpieces up to 86" high.

Doing jobs faster and at less cost are the keys to success in any manufacturing operation, but in the aerospace industry, production efficiency takes on even greater importance. It means survival in a market that has suffered serious economic setbacks in the past decade.

For example, a California sub-contractor who has weathered the economic storms and cyclical nature of the aerospace business believes that investing in technology and expanding operations, rather than cutting them back, is the way to prosper in difficult times. At Aerospace Dynamics International (ADI) in Valencia, management's decision to invest in 5-axis CNC machine tools and gantry-type coordinate measuring machines has made the company a premier supplier to the aerospace market.

These machines offer the same benefits as their smaller counterparts—high speed, highly accurate measurement, and the ability to be integrated with CAD/CAM systems.

Boeing's new 777, the largest twin-engine commercial air transport ever built, is the first 100 percent "paperless" major transport design. Boeing used the Dassault/IBM CATIA 3D CAD system to design and develop the entire aircraft.

Gantry CMMs are essentially large vertical measuring machines that can accommodate workpieces the size of aerospace tooling. Gantries employ three components moving along mutually perpendicular guideways. The probe is attached to a probe quill that moves vertically, in the Z-axis direction, relative to a cross beam. The probe quill is mounted in a carriage that moves horizontally, in the Y-axis direction, along the cross beam. The cross beam is supported and moves along two elevated rails which are supported by columns attached to the floor. These machines offer the same benefits as their smaller counterparts—high speed, highly accurate measurement, and the ability to be integrated with CAD/CAM systems.

"The ability to hold close tolerances in manufacturing and guarantee them through accurate dimensional inspection will be the mark of the new generation sub-contractor."

Large Size Sells Jobs

At Aerospace Dynamics International, DEA DELTA SP gantry-type CMMs with TUTOR™ for WINDOWS™ measurement software are playing a critical role in manufacturing. The seven-year-old company is building a reputation as a major tool builder and manufacturer of large airframe structural components and subassemblies. The company specializes in building large composite-type advanced technology tooling, floor assembly jigs, mill fixtures, and superplastic forming dies. Large tools and parts measure up to 164" wide, 54" high, and 65' long.

"ADI's customers increasingly require a complete inspection of these large tools and parts by a large CMM gantry capable of volumetric measurements within

0.002" accuracy in a temperature controlled environment," said John Cave, ADI Chief Executive Officer. "In addition to our own tools, we inspect tools and hardware that are shipped in from other vendors who don't have the capability for inspecting large articles." ADI is one of the primary subcontractors for tool inspection in support of several programs for a major commercial aerospace manufacturer.

The expanded features of the DELTA gantry enhance ADI's opportunities to participate in programs that they perhaps otherwise would have missed. One of the DELTA gantries has been re-engineered by DEA to allow the inspection of tooling and parts as wide as 125" and as high as 86". The expansion of the machine's inspection envelope significantly increased ADI's capability for inspecting extremely large tools and assemblies without sacrificing accuracy. It has recently been certified to a volumetric accuracy of 0.002", the tightest tolerance of any machine its size on the West Coast.

The large size of the DEA DELTA gantry at ADI does not preclude accuracy. It has been certified to a volumetric accuracy of 0.002" to handle dimensional inspection of the most precisely built workpieces.

A DEA BETA SP gantry CMM in operation performing a dimensional measurement routine on a large airframe structural component. The BETA is a cost-effective medium-size gantry available in both manual and computer-controlled versions. Its structural design allows the operator to remain close to the part being inspected.

The market for aerospace components is entering a new era, one characterized by degrees of dimensional accuracy that were unheard of just a few years ago, according to Gary Card, Product Manager, Systems Group at Brown & Sharpe, the group responsible for marketing DEA gantry CMMs.

"The ability to hold close tolerances in manufacturing and guarantee them through accurate dimensional inspection will be the mark of the new generation subcontractor," Card said.

Uses of gantry CMMs in aerospace manufacturing are not limited to only dimensional measurement. In the case of manufacturing "skins" for aircraft exterior body sections, these large machines are used to trace a polyester film template of the skin, recording the dimensional information. Tooling paths can be created from that data.

"This approach is much faster and more accurate than using hand tools to measure these templates," Card said.

The ability of the CMM to be linked with CAD/CAM programs is also an important feature of these large machines. Often, gantry CMMs are used to compare actual measurements with data supplied by the customer in an IGES file. In some applications, such as those used in conjunction with the Boeing 777 and other commercial and military aircraft, dimensional data from electronic models of components produced using programs like Dassault/IBM CATIA design software are used to develop inspection programs.

"Indications that we are getting from the market is that as a subcontractor, if you don't have the high technology equipment in place, you may not get an order from a prime. The aerospace market is so competitive now that the primes don't have time to wait for a subcontractor to come up to speed technologically," Card said.❖

The view from a Boeing 777 cockpit. The 777 is one of the most advanced commercial aircraft in production. Cockpit ergometrics were fine tuned using the Dassault/IBM CATIA design software program to generate human models that repeatedly performed routine and emergency procedures. The CMM determines the fit and finish of virtually every component in the cockpit.

C.Q. Machining

Builds Its Reputation Making Tough Jobs Look Easy

C.Q. Machining, Inc., Phoenix, AZ, has found a niche for itself in the highly competitive world of aerospace and medical devices machining. Although it wasn't easy, founder Carroll Peterson made it look that way, particularly to his competitors.

Peterson opened for business in 1989, but not on a necessarily optimistic note. His opportunity came in the form of a technically demanding, low volume job for a major aerospace manufacturer that other shops in the area had turned down. With two used Bridgeport CNC milling machines, he completed the job on time, and at a profit.

Since then, C.Q. Machining has built a reputation for high-quality machining of medical implants and surgical tools, and components for communications satellites, even NASA's space station.

That may seem like a big jump in a short period of time, but for a man with 30+ years of hands-on machining and management experience, it was a matter of knowing how to stay a step ahead of customer requirements by investing in the right machine tools and support equipment.

"To succeed in these high technology markets takes a new approach to manufacturing…and advanced inspection capability that can keep pace with production."

"To succeed in these high technology markets takes a new approach to manufacturing," Peterson said. The materials are tough—titanium, cobalt, chrome, and stainless steel, and tolerances for many parts are 0.005 mm. "It requires not only advanced machining and finishing capability, but also advanced inspection capability that can keep pace with production."

In addition to conventional milling and turning equipment, the company has specialty jig grinding and boring equipment, surface and OD grinding capability, and eight CNC vertical machining centers. To complement that capability, the company has, over the past five years, added three Brown & Sharpe coordinate measuring machines. These CMMs have not only helped provide the company with a better and faster way to inspect parts than conventional measurement tools, they have also helped C.Q. Machining win contracts it might not otherwise have gotten.

The MicroVal at C.Q. Machining is a versatile manual CMM used primarily to inspect workpieces not having compound angles. It is one of three Brown & Sharpe CMMs at the shop.

A Multitude of Features

Peterson points to one job in particular that he couldn't have produced without a CMM. It is a 7075 aluminum disconnect plate that will be used to attach the Space Shuttle and the space station in orbit. It is about 27 inches in diameter and has approximately 2,800 features machined into it.

"We perform 100 percent inspection on everything we machine, so this piece presented a special challenge," Peterson said. "Checking this type of part using traditional surface plate tools would have taken us about two weeks."

To meet the inspection requirements for this part, the company installed a Brown & Sharpe MicroXcel® coordinate measuring machine. The MicroXcel is a mid-size CMM with a 830 mm x 942 mm x 576 mm work zone that accommodates virtually any component-sized part manufactured today, making it extremely flexible for the type of short run, highly detailed machining performed by C.Q.

Fast inspection was critical to maintain the company's profitability on the job. With its ZMouse® Z-axis mounted control, the MicroXcel reduces inspection and part programming time by more than half that of standard manual CMMs, while delivering volumetric accuracy of 0.010 mm with a repeatability of 0.004 mm.

"With the MicroXcel it takes us about two days to fully inspect this part. Without it we couldn't inspect it efficiently at all," Peterson said.

Medical Parts—A Cut Above the Rest

A major portion of C.Q. Machining's business is the manufacture of a wide range of medical devices including instruments such as broaches and reamers, used in surgical procedures, and surgical implants. Surgical implants being designed today have numerous compound angles to more realistically emulate their biological counterparts. These new implants present both a machining and inspection challenge.

In order to provide an inspection capability to match his CNC machine tool precision and throughput, Peterson installed a MicroVal® PFx® coordinate measuring machine. The MicroVal PFx is a high-performance measuring machine with an advanced disengagable drive that allows users to toggle between manual and direct computer control (DCC) operation.

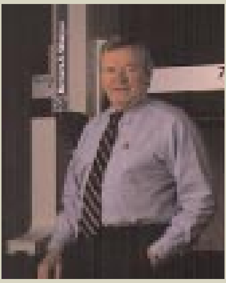
"Without the DCC capability, we couldn't be competitive on these newer implants," Peterson said. "The PFx gives us the capability to automate the inspection process in much the same way our machining is automated."

For the reamers and broaches and other surgical implements that don't have compound angles, C.Q. Machining uses a MicroVal® CMM. The MicroVal is a manual CMM that can be used on the shop floor for a variety of measurement tasks including first piece inspection, layout inspection, reverse engineering, and tool setup.

"There's a lot of talk about competitiveness today," Peterson said. "There's no mystery to success. You need skilled people plus quality equipment and the willingness to take some justifiable risks. Nothing is guaranteed in business, but that's the approach we've taken at C.Q. and it's working."❖

CIRCLE 404 ON THE READER SERVICE CARD

Partnering Assures Full Benefits Of Dimensional Measurement



by Frank T. Curtin
President and
Chief Executive Officer
Brown & Sharpe

The ability to accurately measure the dimensions of parts is the foundation not only of quality improvement, but of improved process control that reduces operating costs.

In this issue of *mfg.*, you'll read about companies that have integrated metrology into their production operations and you'll discover, as they did, the benefits of this integration.

Component parts fit together more precisely when information about their size can be used to control production to produce them to tighter tolerances. Controlled production results in less scrap and rework, meaning that precision parts can be manufactured at less cost. When dimensions are held to close tolerance, parts don't have to be sorted before assembly, further reducing manufacturing costs. Properly fitting parts last longer in service, reducing warranty costs.

We know that the benefits of dimensional inspection are magnified the closer the measurement operation is to the process that created the part. This proximity allows dimensional data to be quickly communicated to machine tools so that process aberrations can be eliminated before they result in nonconforming parts.

Right now, at Brown & Sharpe, we are working with companies throughout the world to put the power of metrology where it does the most good—on the factory floor. We're also working on the next generation of measuring systems. Systems that will provide even higher standards of accuracy and repeatability than we have today.

Our goal in developing these systems is to make them practical for the specific measurement and inspection requirements of our customers. In order for these systems to meet those requirements, we are asking our customers to work in partnership with us. The story in this issue describing the Leitz Cygnus X™ evaluation program at Caterpillar will give you a sense of how that partnership can work.

Together, we can ensure that the next generation of inspection systems further extends the potential of reduced operating costs through process control. ❖

CMMs Provide Fast, Flexible Inspection At Major Chinese Engine Plant

by
Jianzhong Xing
Engineer, Shanxi Diesel Engine Plant
and Technical Specialist,
DEA CMM Users' Association,
People's Republic of China

Shanxi Diesel Engine Plant's foundry produces aluminum alloys for use in manufacturing a variety of engine components.

The Shanxi Diesel Engine Plant in Datong, People's Republic of China, is a specialized engine production facility with the largest aluminum alloy foundry in China—and some of the most advanced manufacturing equipment and research instruments in the world.

To improve the speed and accuracy of inspecting complex workpieces…the company replaced surface plate tools with two DEA coordinate measuring machines.

Throughout its history, the company has developed a range of products that are sold not only in China, but throughout the world as well. These include the 150-Series diesel engines, GF-Series generators, the high-powered 396-Series diesel engines which were imported from MTU in Germany and are manufactured under license, and the 492QS "Jet-Flow" fuel-economizing gasoline engine.

In order to improve the speed and accuracy of inspecting complex workpieces such as engine blocks, cylinders, crankshafts, and fuel-injection pumps, the company replaced surface plate tools with two DEA-Brown & Sharpe coordinate measuring machines, an IOTA and an OMEGA.

The OMEGA is one of the largest CNC bridge-type coordinate measuring machines available with an X-axis stroke of 1,499 mm to 3,302 mm, Y-axis stroke of 1,499 mm, and Z-axis stroke of 1,016 mm to 1,346 mm. Its aluminum alloy bridge provides a high stiffness to weight ratio, and aluminum construction minimizes structural stress and deformation from temperature gradients. The result is a CMM that provides a volumetric accuracy of 0.013 mm with a resolution of 1 µm and repeatability of 2 µm, even in harsh shop environments.

The IOTA is an older design CMM that engineers at the plant upgraded, with the help of DEA applications engineers, by modifying its control system, adding gage attachments and the TUTOR™ for WINDOWS™ software system. Now both CMMs have the same functions and share TUTOR for WINDOWS measurement software.

A 150-Series diesel engine block undergoes dimensional inspection at the Shanxi Diesel Engine Plant. Use of coordinate metrology for both quality control and process control has helped the facility build its position as one of China's leading large-scale state enterprises.

TUTOR for WINDOWS includes multi-tasking capabilities, a standard operator interface, a high-speed point-to-point scanning function, and feature oriented measuring and programming along with a large library of fully integrated application programs and more than 100 canned cycles.

The open architecture of TUTOR for WINDOWS allows great flexibility in developing in-house programs for special measurement tasks. During the past dozen years, more than 200 gaging and utility programs have been written.

For example, the company developed a software program for the IOTA that puts a floating pen on the Z-axis for the production of precision drawings. Not long after the company began using the OMEGA, programmers developed an automatic coordinate-fixing and correction program in DEA/PPL for operating PH9/PH10 star contact probes in the TUTOR for WINDOWS environment.

This greatly facilitates coordinate-fixing and correction of the probe contact point. At the same time, this program makes use of graphic parameters for man-machine communication.

The Shanxi Diesel Engine Plant has inspected nearly 30,000 workpieces with the CMMs. Accurate gaging has provided a reliable basis for adjustment of machine tools and verification and revision of numerical-control programs.

As a result of 10 years of practical application, the coordinate measuring machines have become highly-effective precision testing instruments. Together with more traditional inspection tools such as out-of-roundness indicators, contour indicators, and laser interferometers, they have become an important part of production, scientific research, and technical progress at the Shanxi Diesel Engine Plant.

Everyone has come to know from personal experience the value of coordinate metrology. The CMMs are capable assistants for scientific and technological development.❖

GUI Simplifies Shop Floor Turbine Hub Inspection

Total quality requirements of modern turbine engine hub manufacturing require not only a quick and thorough final inspection of parts, but efficient setup and adjustment of the machine tools used to make these critical jet engine components. Historically, machine tool setup has been aided by dimensional data derived from evaluating a test piece against the nominal drawing using an optical comparator.

Leitz-Brown & Sharpe engineers have developed a new approach to shop floor inspection of the machined slots of turbine hubs that allows measurement of closer tolerances and larger workpieces than optical comparators and can also provide documentation, quantitative evaluations, statistical process control, and traceability. Using QUINDOS® measuring software on a Digital Equipment Corporation VAX 4000 and a SIRIO® Shop Floor Gaging Station, a special graphical user interface (GUI) has been developed for GE, Wilmington that allows the operator to interact with the SIRIO in a simple, straight-forward manner.

Just Point and Click

The GUI is designed around the concept of a system status window using color-coded icons to represent actions. A top row of icons represents the actions necessary to prepare the CMM for measurement. The right hand column holds icons depicting the status of various devices including the CMM, printer, plotter, and a text file library. Operators use the text file library to keep notes relevant to each part type and each machine tool. Along the bottom of the window, three buttons activate software program selections and editing.

Interaction with the icon menu is simple and fast. Action is initiated by clicking on the appropriate icon. For example, peripheral parameters are modified quickly and easily by selecting either "Printer" or "Plotter," and entering the required information in the window.

Part program selection is performed through the selection of the appropriate family, via pull-down menu, and use of an icon-based description of each program. When the program is started, each probe configuration necessary for the inspection is displayed on screen. These pictures contain information regarding the parts necessary to construct the probe, as well as the relative orientations and tool changer location. The operator is asked to confirm that all probes are available and correct. The software also performs a test to determine the time elapsed since the last calibration. If it is longer than the programmed value, the system indicates that probe recalibration is required.

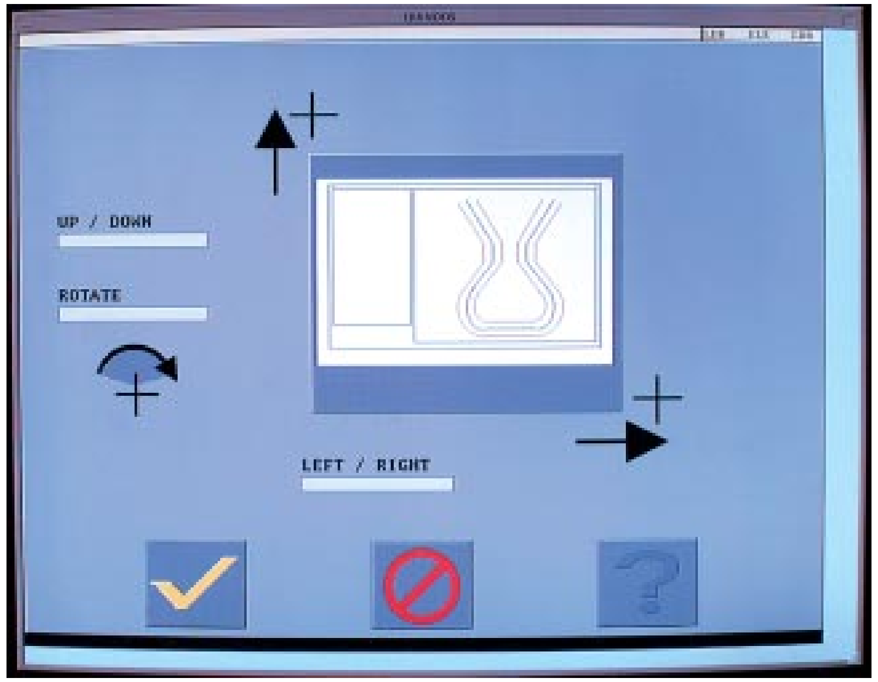
QUINDOS graphic user interface (GUI) leads the operator through powerful inspection routines. From this window, the operator can prepare the SIRIO Shop Floor Gaging Station for measurement operations.

Once these steps have been completed, the operator is returned to the status screen. With a program loaded, the screen depicts three additional actions available: "Single Slot/Coupon," "Four Symmetric Slots," or "100% Inspection." The operator may select one of these modes, or, if necessary, recalibrate probes, or reconfigure his peripherals.

With the selection made, the program continues and prompts the operator to locate the part on the SIRIO's table, and to locate the probe in either the reference timing hole, or the reference slot. Once the action is taken, and acknowledged, the program displays an estimated run time in the form of a large clock. This feature was designed to allow the operator to determine when it is necessary to be present at the CMM, and to determine the progress of the program at a glance.

One of the additional advantages of the CMM is the ability to examine areas of the curve in detail.

When the program is successfully completed, the operator is presented with a summary showing those slots with features out of tolerance, or the system creates the plot for the reference slot automatically at the zero level. The resulting plot provides information which is similar in format to that of a comparator. A nominal curve is shown surrounded by magnified tolerance bands (tolerance bands in red, nominal black), and the deviation of each measured value is shown with its color determined by its location in or out of the tolerance zone.



The operator has the choice of selecting "Best Fit Slot" in the program's Evaluation Mode. This provides the capability to perform best fits on slot data to help in determining correction values. These values are fed back to machine tools.

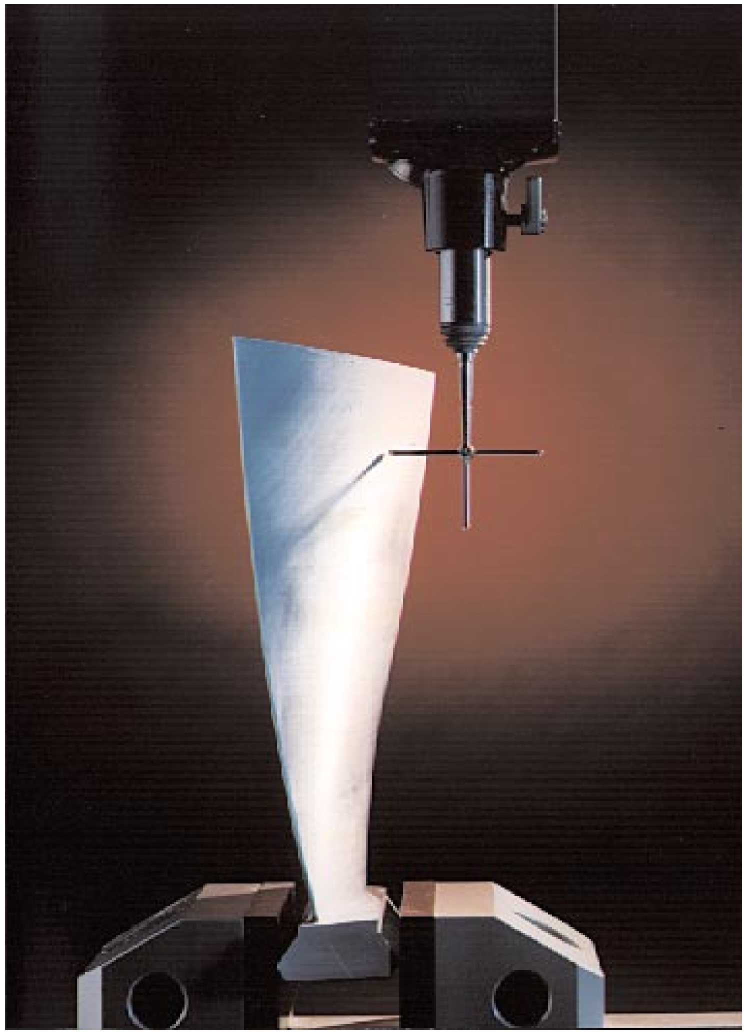
Once the picture is acknowledged by the operator, he is returned again to the status screen. This time the "Inspection Mode" icons are no longer visible, and in the bottom row are the "Evaluation" icons: "Select Slot & Level," "Best Fit Slot," and "Magnify Slot Section." By selecting "Best Fit Slot," the operator has the capability to perform various best fit routines on the slot data to determine correction values. The system keeps track of all fits performed, allowing the operator to fit cumulatively and delete any bad fit without having to start again. This also allows the operator to easily perform a "Custom Fit" or manual adjustment. After every fit, the plot is updated to show the new values for the fitted curve, as well as the total shift from actual.

One of the additional advantages of the CMM is the ability to examine areas of the curve in detail. On every plot there are small orange markers placed along the actual curve at intervals of 10 points. These are used to select curve sections to be magnified. The operator selects 'Magnify Section' and he is prompted to enter the point range he would like magnified. The result is a plot that has been scaled to maximize the selected region on the screen. The picture represents the actual curve section in relation to the nominal and tolerance curves.

To aid the programmer, a complete library of procedures was developed and integrated into the QUINDOS GUI. This makes all of the tools necessary to build additional programs running under the operator's GUI available to simplify the programming task.❖

CIRCLE 406 ON THE READER SERVICE CARD

Turbomeca Reduces Inspection Time For Critical Turbine Engine Parts With Fully Integrated Measurement Systems



Turbine blade undergoes dimensional inspection at Turbomeca. Using coordinate metrology for process control has helped the company manufacture components to tighter tolerances, improving the overall efficiency of their turbine engines.

The installation of two DEA-Brown & Sharpe MISTRAL coordinate measuring machines at the Turbomeca-Microturbo Division of the Labinal Group in France has helped increase inspection throughput and improve process control. The machines are installed in production plants located in Tarnos and Bidos in the Toulouse area.

Turbomeca manufactures turbine engines for helicopters, civil and military aircraft, power plants, supercharged compressors, and auxiliary power systems. In the company's extensive machining facility, cast or forged components are transformed into finished components that are assembled into a variety of engine models.

Prior to the installation of the CMMs, Turbomeca used traditional quality control techniques to inspect parts, particularly height gages and multi-gaging systems.

According to Mr. Lavignotte, Production Manager at the Bidos facility, Turbomeca management decided at the end of 1994 to organize production using flexible manufacturing cells equipped with Okuma and Warner lathes, as well as Landis grinding machines.

Process control is facilitated by MISTRAL dimensional inspection cells that provide real time feedback to the manufacturing cells for automatic tool offset control, and to R&D for verification of the product quality level.

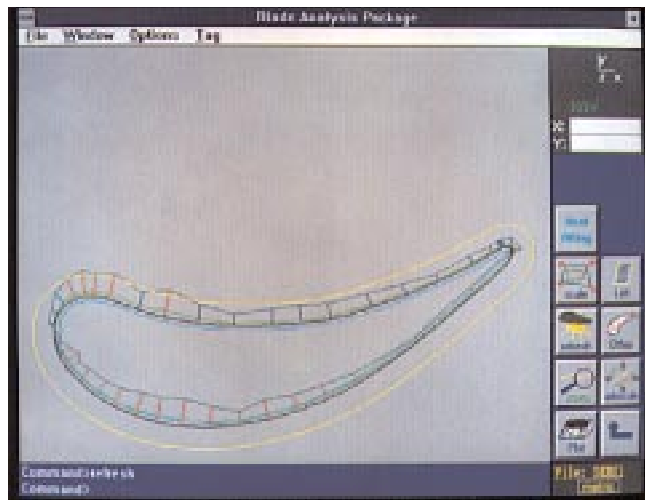
The MISTRALs are used to inspect both rough and finished parts. The cell installed at the Tarnos plant is dedicated to the measurement of air intake rotors and blades, while the cell at Bidos is used to inspect centrifugal compressor rotors. The workpieces are moved directly from the machine tools to the inspection area where they are mounted on an anchor plate and manually loaded on the MISTRAL.

The accuracy of the MISTRALs has helped Turbomeca produce tighter coupling tolerances between rotor and stator blades. This allows higher turbine efficiencies at all operating conditions.

The MISTRAL coordinate measuring machine features DEA's exclusive Slant Bridge Technology® that combines lightweight bridge construction for high-speed and rapid acceleration with optimum stiffness-to-mass ratio for dimensional stability. This design gives the machine a VDI measuring accuracy of 3+4 L/1000 and a resolution of 0.5 µm. The machine has a velocity of 26 m/min. with 3D acceleration of 1 m/sec^2. Continuous axes motion interpolation, called the "fly" feature, allows the MISTRAL to collect up to 45 data points per minute, significantly increasing inspection throughput when compared with traditional methods. A typical inspection routine at Turbomeca runs about five minutes.

The MISTRALs are equipped with TUTOR™ for WINDOWS™ measurement software. This advanced software program features multi-tasking capabilities to support multiple simultaneous applications, an easy-to-use standard operator interface with color graphics, icons, and pop-up windows, feature-oriented measuring and programming, and more than 100 canned cycles with a large library of integrated application programs.

"We've found the Profile inspection and Best Fit programs particularly helpful in solving our metrology problems," said Mr. Arretche, Production Manager at the Tarnos plant.❖



Advanced measurement software gives Turbomeca engineers detailed information about the shape of turbine blades. The data is used to fine-tune the manufacturing process.

Improving the Vibration Resistance of CMMs

by David R. Meredith, P. E.
Kinetics Noise Control, Inc.

Today's coordinate measuring machines are capable of extremely accurate measurements. Vibrations from machine tools, climate control systems, materials handling systems, and other external sources, however, can influence CMM accuracy and repeatability. Because of this, an accurate determination of the magnitude of external vibrations is an important part of the pre-installation site qualification for a coordinate measuring machine, whether it is being installed on the shop floor or in an environmentally-controlled inspection lab.

All CMM manufacturers quantify the maximum amount of vibration that their machines can withstand without affecting accuracy and repeatability. However, there are ways to increase the machine's resistance to vibration. Special vibration isolation systems can be used in conjunction with a CMM to reduce the effects of site vibration, allowing the machine to be placed in a high-vibration environment if necessary. Selecting the right vibration isolation system depends upon the specific engineering requirements of the application and vibration characteristics. Here are some guidelines.

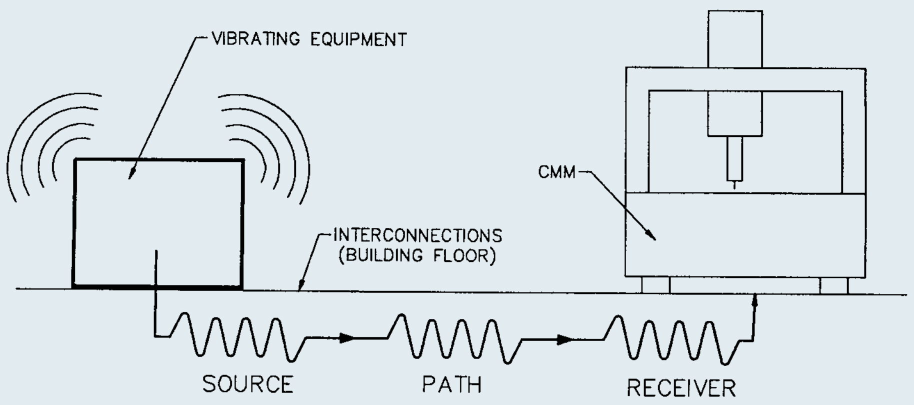


Figure 1
Source–Path–Receiver

Interactive and Passive Isolation

There are two general types of vibration isolation systems that are used with CMMs, interactive and passive. Interactive vibration control uses transducers to produce a vibratory force equal in frequency and amplitude to the vibration present at the installation site, but 180 degrees out of phase. In principle, this application of an equal but opposite vibratory force results in a net cancellation of the disturbing vibration. Interactive vibration control technology is still somewhat experimental and has an unproven field record.

Passive vibration isolators can be grouped into three broad categories: pads, springs, and air springs. They are comparatively easy to design, install, and troubleshoot, they have been proven in thousands of installations, and their initial cost is modest. For most installations, little or no maintenance is required.

Pads are typically manufactured from neoprene, fiberglass, felt, cork, or other similar compressive material. Their natural frequencies generally fall within a range of 5 Hz to 30 Hz, and they can be manufactured in a variety of sizes, thicknesses, and load carrying capacities. Pads are the least expensive type of isolation material, and they exhibit a high damping rate when excited at their natural frequency.

Stability over time is an important consideration with pads. Many types of pads will continue to creep and compress when statically loaded, resulting in continuous change in elevation for the isolated equipment. Some pad material, primarily neoprene, exhibits age stiffening so that the natural frequency of the pad increases over time. This can result in the isolation capabilities of the material becoming less effective as the CMM ages and begins to "loosen up."

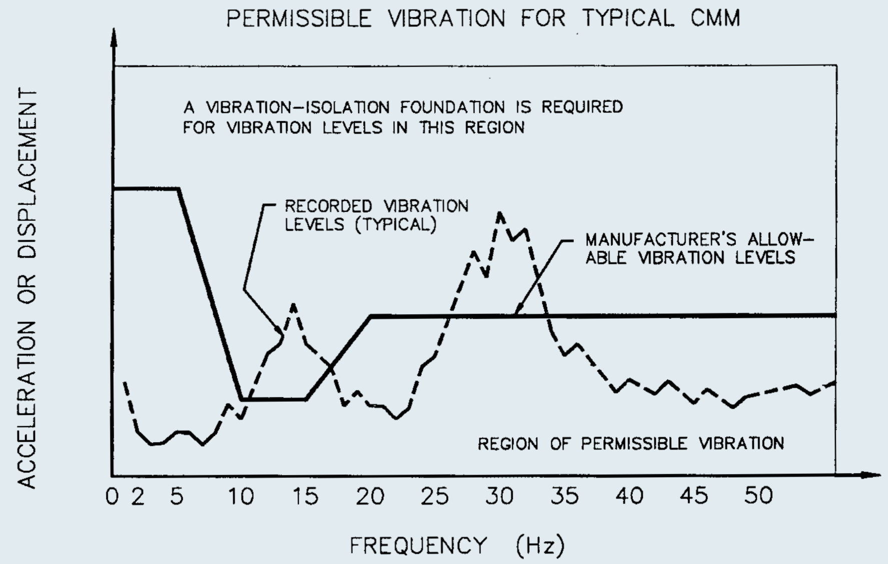


Figure 2
Measured Vibration Levels vs. Manufacturer's Criteria

The selection of the correct isolator for a particular application is best accomplished through the use of a site vibration analysis.

Helical coil springs are available in many different sizes and load carrying capacities. They are classified in terms of deflection under load. A 1" spring is a spring that compresses by 1" when supporting its rated load. The natural frequency range for coil springs is typically from 6 Hz to $1\frac{1}{2}$ Hz corresponding to deflections of $\frac{1}{4}$" to 4". Springs exhibit a fairly low damping rate, so amplification at resonance may become a concern. External snubbers can be readily added should this amplification occur. Properly manufactured coil springs do not suffer from creep or settling, and are generally manufactured within assemblies equipped with isolator adjustment bolts to facilitate equipment leveling. Coil springs are more costly than pads, but can still provide an economical solution to a vibration problem.

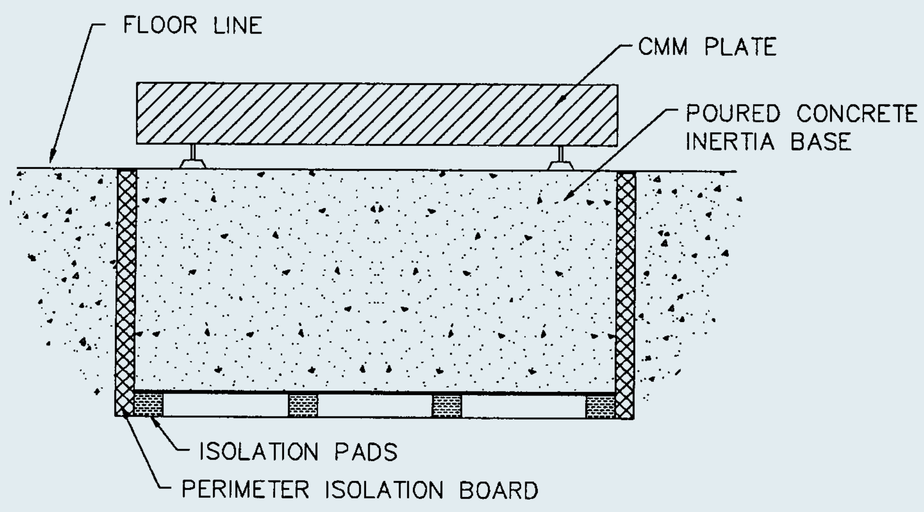


Figure 3
Inertia Base With Pad Isolators

Air springs, the most expensive type of passive isolators, offer a number of unique features. With natural frequencies falling in the $\frac{3}{4}$ Hz to 4 Hz range, they are the softest and most efficient isolators available. Since the air pressure within these springs is easily varied, users can quickly adjust the height, load carrying capacity, and stiffness to meet installation requirements. The air spring system can be equipped with automatic height sensing valves that adjust air pressure in the springs to compensate for load changes—CMM bridge travel for example—and to maintain a preset machine level. Air spring isolators can also be designed to provide an adjustable damping rate which permits a high degree of "fine-tuning" to match unique installation requirements.

Working From the Base

An important part of many isolation systems is a suitably designed inertia base. The inertia base is the platform, supported by vibration isolators, upon which the CMM sits. It is typically manufactured from concrete or heavy steel. The inertia base is designed to match the support requirements of the CMM, and is especially important for CMMs that rely on a rigid floor for alignment. Such machines can distort if an inertia base is not used.

Inertia bases lower the overall isolated center of gravity of a CMM which minimizes the tendency for the equipment to "rock" on the isolators. Isolator rocking modes are decoupled when the CMM/base vertical center of gravity coincides with the isolator centerline, resulting in an extremely stable installation. The heavier the inertia base, the less CMM motion for a given vibratory input. Bases should be designed with pockets to accept alternate isolator types in the event that the job site isolation requirements change.

The selection of the correct isolator for a particular application is best accomplished through the use of a site vibration analysis. A comparison of the site vibration levels with the CMM manufacturer's vibration criteria specifications will indicate the required isolation efficiency at those frequencies where the measured data exceeds the criteria. An isolator's efficiency curve can then be used to establish the natural frequency requirements for the application.❖

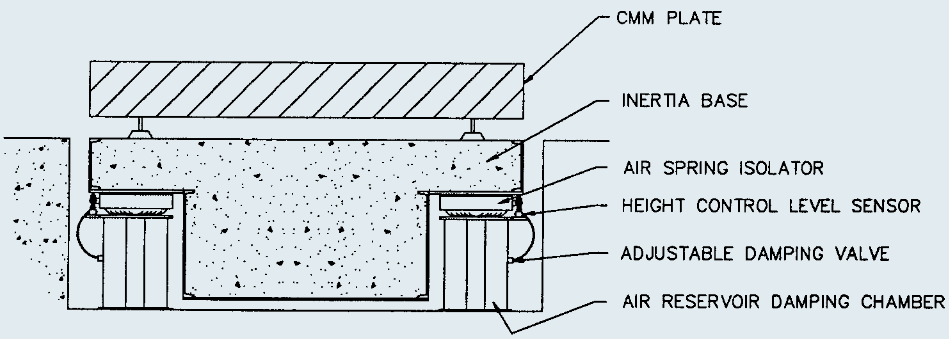


Figure 4
Inertia Base With Air Spring Isolators

HOW TO ACCURATELY DETERMINE SITE VIBRATION LEVELS

The most effective way of determining vibration levels at a proposed CMM site is to place a set of three-axis vibration transducers on the floor where the CMM will be installed. These transducers produce an electronic signal that is proportional to the vibrations at the site. This signal is recorded, analyzed by frequency, and compared with the manufacturer's vibration criteria specification. A review of the data can confirm site suitability and assist the vibration system designer in selecting the correct isolators for the application.

One difficulty often encountered is the use of an inappropriate vibration transducer, such as a conventional accelerometer. A better approach is the use of low frequency seismometers or geophones for monitoring low level ground vibrations. The primary frequency range of interest for vibration isolation is below 40 Hz, and it is in this range that seismometers are capable of providing optimum data.

A vibration site survey should be performed over a time span of at least 30 minutes. During this time, all relevant disturbing sources should be individually cycled to analyze the influence of each potential source. Longer tests tend to generate redundant data. The exception to this is the potential for short-term transient sources that cannot be scheduled, a freight train passing the site, for example. In this case, a long-duration test should be performed to ensure that all transient data are captured.

A vibration survey requires specialized equipment, and the knowledge of experienced isolation systems designers.

CMMs Replace Fixed Gages

SWIFT Makes Fast Work of Complex Inspection Routines

While speed is essential for efficient gaging procedure, it is also important that sustained repeatability remains a high priority, together with flexibility, particularly in high volume automotive component production.

Prior to re-evaluating their SPC operation, Britax Vega Ltd., a Droitwich, UK, manufacturer of front and rear automotive lamp clusters for major original equipment manufacturers, operated a large range of multi-probe fixtures, each dedicated to one product. This approach to inspection did not provide the flexibility required to allow measuring points to be changed, and suffered from reliability problems as well.

The installation of four DEA-Brown & Sharpe SWIFT coordinate measuring machines—one in the standards room and three located in dedicated production cells—provided the flexibility required for inspecting the wide variety of components at various stages of manufacture and assembly.

"Operating our own part programs enables us to have greater flexibility and higher accuracy to cope with the complex curves and surface geometry of the products, and, in providing real time statistics for process control, reduces waste," said Quality Engineer Nigel Chance.

"Using the SWIFT CMMs for critical inspection of 3D free-standing forms—many of which have remote datum points," said Tom Wilkins, Britax Vega's Quality Director, "has given us a flexible, reliable and cost effective means of assuring our product meets customer requirements."❖

The dimensions of a BMW 7 Series turn signal lens are checked on a DEA SWIFT coordinate measuring machine at Britax Vega Ltd. The move to CMMs has given the company the flexibility it needs to inspect a wide range of products.

CMMs Have a Pivotal Role In SEAT-Martorell's Total Quality Program

About 30 kilometers from Barcelona, Spain, is the 404,000-square-meter SEAT-Martorell industrial complex, opened officially in 1992. Each day, its 7,000 employees make 1,700 SEAT cars (Toledo, Cordoba, Ibiza and Inca) and VW (POLO Classic and KADDY) at the rate of about one car every 34 seconds.

Total quality is a corporate philosophy at SEAT-Martorell, the practical applications of which can be found throughout the entire production operation. In an interview with Juan Antonio Feixas, SEAT Production Quality Manager, Jordi Jordana, Regional Sales Manager of DEA-Brown & Sharpe SA in Barcelona, explores the functions of total quality management and the role of coordinate measuring machines in the system.

Jordana: What are the concepts on which the total quality philosophy is based and how are they applied in SEAT-Martorell?

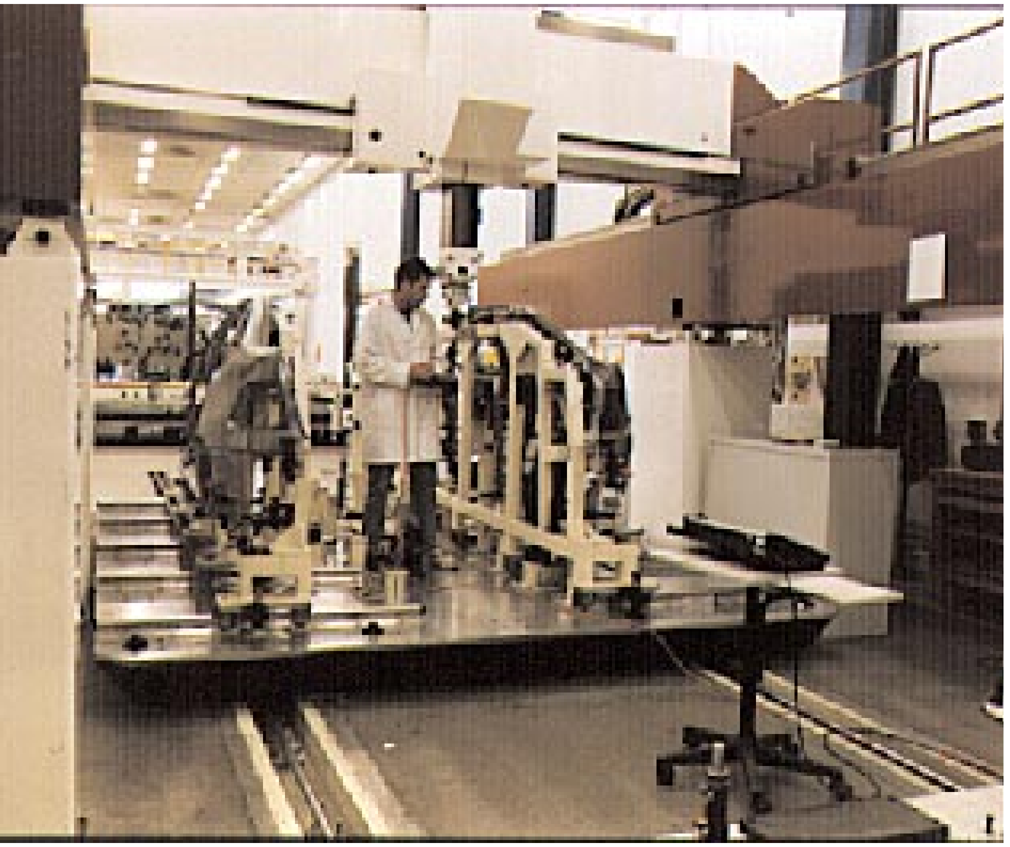
Feixas: Quality is supported within the production process on two pillars: safe processes controlled by the Production Organization itself, and a series of "gates" controlled by Quality Management. First, there is the self-check carried out by the worker and, second, there is the QRK or Quality Regulating Circle. This technique was implemented at Martorell in the early '90s and consists of placing a worker at the end of a team of about 25 people with a specific checklist that monitors the quality of the work done.

What is the QRK and what is its ultimate goal?

It is a specific organization within production operations whose function is to verify and generate feedback to the team on the work done. This feedback is very important for solving problems on-site. Furthermore, this information flow is processed statistically and enables us to improve our day-to-day operations.

Where are the DEA metrology machines installed at SEAT?

We have 2 BRAVO measuring robots and one DELTA gantry-type CMM in the sheet metal shop and we will soon have the first TYPHOON fully on-line. Also, with the planned production increase as a result of the addition of new models for VW, such as the POLO Classic and the KADDY, and the commencement of sheet metal subassembly manufacture–about 1,000 units per day for South Africa, China, Mexico, and Argentina–we will need new machines to cover our requirements for measuring capacity.



A DEA DELTA gantry-type CMM in SEAT-Martorell's quality lab is used to check the dimensions of a sheet metal sub-assembly destined for use in an auto body. The versatile DELTA has a work area large enough to accommodate a complete car body for dimensional inspection.

Where does SEAT-Martorell's production cycle start and how does quality control act in each of its phases?

It starts in the press area where the body work parts produced by SEAT are formed. Here, there are dimensional controls performed using specific gages for each part; surface controls performed in production; and audits performed by quality workers. For example, every four hours a different part is checked randomly. This audit is carried out using a method similar to that implemented in the VW Consortium, with a common checklist for all of the Consortium's centers. That way the SEAT audit is similar to and comparable with the AUDI audit in Ingoldstadt or the GOLF audit in Wolfsburg, thus ensuring a similar quality level for all of the Consortium's products.

After that, the parts go to the sheet metal shop?

Yes, the parts are sent to the sheet metal shop for welding and forming the body work. Here, the role played by the CMMs is decisive. The controls carried out are dimensional and use gages, CMMs, measuring robots, and even destructive tests where the body is destroyed to check that the welding is correct.

Another operation which is very important in the sheet metal shop is the measurement of the bodies or assemblies before forming the complete body. Two types of inspection are performed. One is on-line, involving measurement within the production flow, and the other involves measurement and inspection in the quality lab.

In the first of these procedures, we use DEA BRAVO measuring robots integrated in the production flow. The bodies are diverted to these machines, which automatically verify that output stays within certain tolerances using preset measurement programs. The BRAVOs not only measure bodies, but can also measure sub-assemblies such as frames or side panels.

> **"The DELTA is a very sophisticated and precise machine… storing and supplying important quantitative and qualitative information for improving production."**

What are the differences between the on-line measurement and that carried out in the quality lab?

In the first case, the CMM is integrated within a fully automated process which can be programmed in accordance with production requirements. The quality measurement lab, on the other hand, has another model, a high-precision DELTA gantry-type CMM which is not automated with respect to production, but does have an automatic measuring program.

The DELTA is attended by an operator who manually places the part to be measured underneath the machine. The most important function in the quality room is the analysis performed to check that production is held within certain tolerances. The DELTA is a very sophisticated and precise machine with a large capacity for storing and supplying important quantitative and qualitative information for improving production.

Where does the quality route in SEAT-Martorell continue from here?

After passing all the controls in the sheet metal shop, the body goes to the paint shop. There, specific controls are carried out on the paint work, verifying thickness, finish, gloss, adhesion, and anti-corrosion.

From then on, whether or not the body continues along the assembly line is the responsibility of the production quality area. If the painted body passes through this control gate, it continues to assembly.

How does quality control operate in the assembly shops?

At Martorell, there are four main assembly shops. In the first, the pre-assembly is carried out (wiring, doors, brake lines). In the next shop, the engines and the entire sub-chassis are assembled. Then, in the third shop, the assembly is completed and the upholstery and trim are added. In the fourth shop the car is mounted on a test bench which simulates a short drive. A second operation here consists of checking that each car meets the pollution levels required in the country, out of a total of 38 served by SEAT, it will be shipped to.

Have we reached the end of the quality control cycle?

No. There is a team that reports directly to SEAT's Quality Manager who performs a final audit on six cars of the 1,700 we manufacture each day. This final control checks 2,000 parameters. It is very important for us since it focuses on the perceived quality and defines how the car will be judged by the customer. Unlike the other audits, the results of this "customer audit" are analyzed by the Consortium's Management Committee. SEAT's President is answerable for the audit's findings. In short, the entire Quality Assurance System is a macro Quality Regulating Circle covering the entire company.❖

Integrated Design, Manufacturing, Inspection Make Long Island Machine Shop More Competitive In Aerospace Market

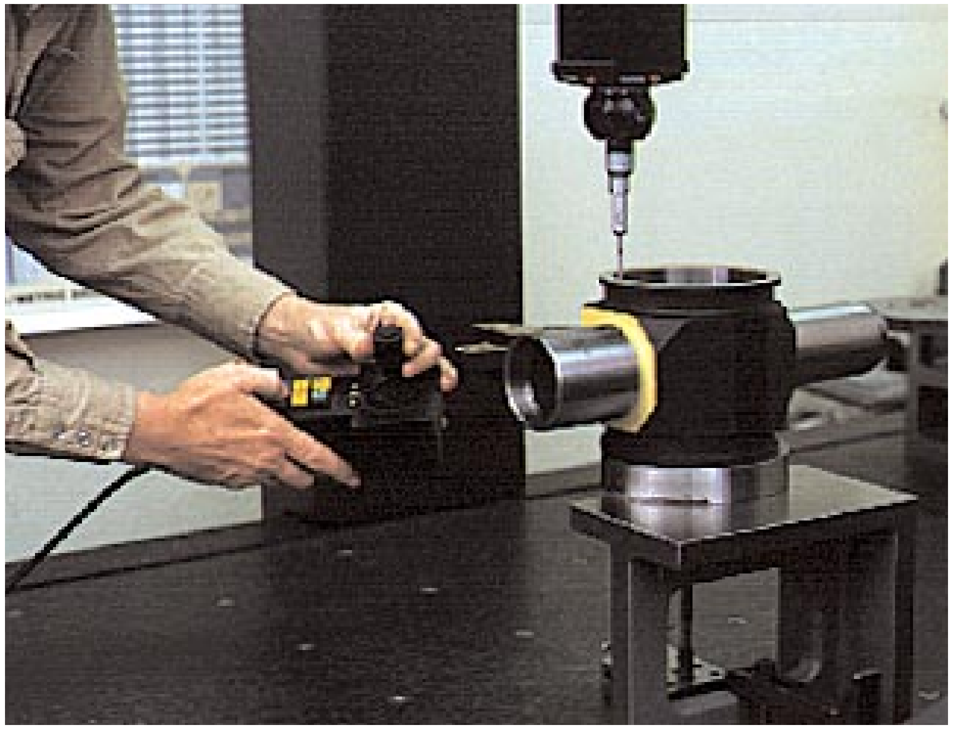
Linking the inspection process with design and manufacturing is a way to assure component conformance to blueprint specifications.

At B&R Machine and Tool Corp. in Westbury, Long Island, NY, it's a way to assure a successful future in very competitive market conditions. B&R Machine and Tool, celebrating its 35th anniversary this year, is a fully-equipped CNC machining facility that specializes in the production of close tolerance aerospace components ranging in size from bolts and bushings to airframe structurals and helicopter transmission parts in a range of materials that includes Inconel, titanium, and magnesium. The company has developed an expertise in flight critical parts including dynamic control components for helicopter rotor hubs.

About 2 1/2 years ago, B&R instituted a capital improvement program that included the addition of a number of CNC machines and a Brown & Sharpe Xcel® coordinate measuring machine.

"We saw prime aerospace contractors scale down, reducing the size of their supplier base," said B&R General Manager Michael Gross. "Our goal is to be in a position to provide high technology machining capability so that we'll be the vendor of choice."

That strategy has worked. The company is a supplier to Boeing for work on the 777 and V-22 programs, and to Sikorsky Aircraft for the S92 commercial helicopter, a version of the successful Blackhawk military helicopter. B&R has been named a supplier to Allied Signal Aerospace, Eatontown, NJ, and Ft. Lauderdale, FL, and has been nominated to become a member of that company's corporate commodities team.



Brown & Sharpe Xcel coordinate measuring machine at B&R Machine and Tool Corp. provides fast, accurate measurement of critical aerospace components. The Xcel's large measuring range can accommodate virtually all of the parts manufactured by B&R.

Fully Integrated Manufacturing and Inspection

One of the keys to B&R's success in the competitive world of aerospace machining is its fully-integrated CAD/CAM and inspection operation using the Dassault Systèmes/IBM CATIA computer-aided design system. CATIA's digital design capability combined with computer-controlled machining and inspection techniques significantly reduces scrap and rework. CATIA is used by Boeing, Sikorsky Aircraft, and other prime aerospace contractors for a variety of engineering requirements including three-dimensional preassembly checks to assure the precise fit of parts and early detection of design interference, cockpit ergonomics, interior layout, and the design of test equipment and tooling.

"We receive 3D CATIA models electronically from Boeing and then construct tool paths directly from the data model rather than from part drawings or prints," Gross said. Along with the 3D models, Boeing supplies an inspection program developed directly from the CATIA data. It arrives as a separate software program, called VALISYS, that works in concert with the Xcel's MicroMeasure® IV measurement software. Boeing's certification of the Brown & Sharpe, VALISYS, and CATIA integration at B&R was the first in the US.

The Xcel is a high throughput, high accuracy CMM that has a measurement throughput of up to 60 points per minute. With its Sharpe Control System, it has a maximum positioning velocity of 500 mm/sec. (1200"/min.) and a maximum acceleration of 1 m/sec.^{2} (40"/sec.^{2}). The large measuring range of the Xcel at B&R, 900 mm (35.4") x 1200 mm (47.2") x 850 mm (33.5") accommodates the largest parts produced by B&R including seat rails for the V-22 and rib sections for the 777 made on a new Kuraki KMV-130 Double Column Bridge Mill.

An IBM RS/6000 CAD workstation, which interfaces with the computer on the Xcel, automatically runs the inspection routine. Parts are inspected at the completion of the machining cycle, and the system generates a report that records each "hit" of the Xcel measuring machine.

This approach to the inspection process uses CATIA's database to the fullest extent. The same model that is used to create the tool paths is used to create the inspection program. "Boeing engineers can select the specific inspection points they're interested in and include the tolerances," Gross said. "There's no interpretation necessary between the CAD program and the inspection program. It virtually eliminates errors in inspection."

According to Gross, the integration of the Xcel with the CATIA-based CAD/CAM system at B&R has not only been a selling point in terms of vendor certification, it has helped improve the company's efficiency as well.

"Our vision has always been to reinvest in technology that helps us operate more efficiently, smarter, and faster," he said.❖

Circle 410 on the READER SERVICE CARD

An IBM RS/6000 CAD workstation provides the interface between the computer on the Xcel coordinate measuring machine and the inspection routine developed with the CATIA software. The routine runs automatically and generates a printed inspection report.

Dassault Systèmes, Brown & Sharpe To Develop On- And Off-Line Metrology Software

As part of Dassault Systèmes' groundbreaking CAA (CATIA Application Architecture) Partnership Products Program, Brown & Sharpe has become an Original Software Developer (OSD) and, as such, is working closely with Dassault Systèmes' software designers in a strategic development partnership to expand the use of Dassault's CATIA products in the field of dimensional metrology.

Brown & Sharpe will use the close relationship with Dassault Systèmes to develop its next generation of on-line CMM software products. Dassault Systèmes will work closely with Brown & Sharpe to take advantage of its metrology knowledge and strong global customer base in the development of its own off-line CMM software product. Once complete, both on- and off-line products will operate completely within the CATIA architecture.

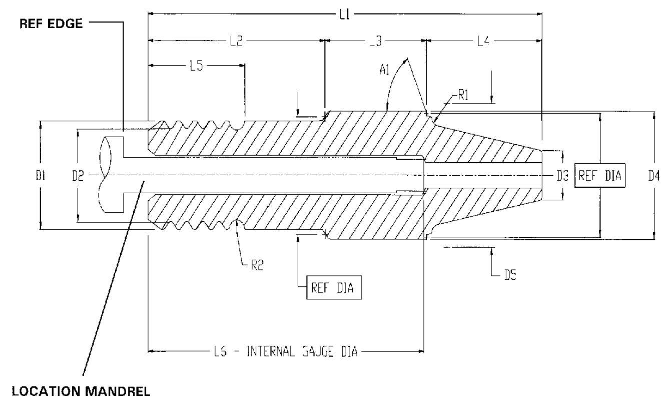
The benefits of this partnership, according to Brown & Sharpe President Frank Curtin, are "for both companies to strategically leverage their technologies together, providing their customers with a more complete set of tools to reduce the cost of their manufacturing while improving the quality of their products."

Dominique Florack, Vice President MCAD Division, said, "The aim of this partnership is to provide our customers with integrated and reliable tools to improve and streamline their control of the manufacturing process. CMM operators on the shop floor will be able to access concurrently both the manufactured part and the associated digital part, while sharing a common database and operator interface environment with the CATIA designers."

This partnership will also focus on the development of a common, open architecture, STEP CMM interface standard. This standard will guarantee seamless data transfer from initial prototyping through design, manufacturing, process control and final inspection.

Products from this partnership are presently under development, with the first expected on the market later this year.❖

PROFILE 30 Measures *'Untouchables'* at **Allied Signal Automotive**



A ceramic insulator and some of the dimensions that are measured by the PROFILE 30. Typical cycle time for 13 measurements is 37 seconds.

Brown & Sharpe's PROFILE 30 non-contact measuring system has replaced traditional contact measuring systems at Allied Signal Automotive plants in Fosteria, OH, and in South Wales, UK.

Due to the variety of components produced and their respective gaging criteria, Allied Signal Automotive realized the importance of replacing the existing traditional inspection methods with a flexible, shop floor alternative gaging system. A major consideration was the ability to measure the ceramic insulator which surrounds the core of the spark plug.

This was the most difficult task facing the quality control department, particularly since the insulator must be inspected after two different process stages. First, ceramic powder is molded into the form of an insulator. This is known as the green condition. At this stage the insulator is very soft and is untouchable by contact gaging systems. After the insulator is fired to harden it, the component must be remeasured. In this condition, the hardness of the insulator caused damage and wear on probe tips of existing dedicated contact fixtures.

Another concern was that not all required measurements could be made using dedicated fixtures. To measure small radii and angles, the company used an optical projector. This created an added expense and increased inspection time. The PROFILE 30 allowed quality control personnel to check all critical dimensions with a single piece of inspection equipment.

With the PROFILE 30, each insulator is held using a mandrel that locates on the internal diameter. This method of holding prevents the green insulator from being damaged during inspection. Loading and unloading is fast, and if necessary, the component position can be corrected for misalignment by the software.

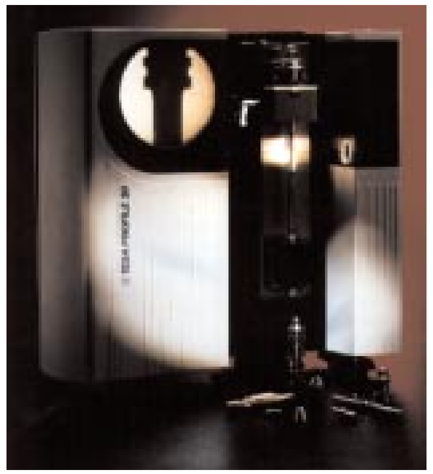
An important quality control requirement was to monitor insulator shrinkage. Shrinkage occurs between the green and fired conditions. When the PROFILE 30 measures the insulator in the green condition,

The PROFILE 30 allowed quality control personnel to check all critical dimensions with a single piece of equipment.

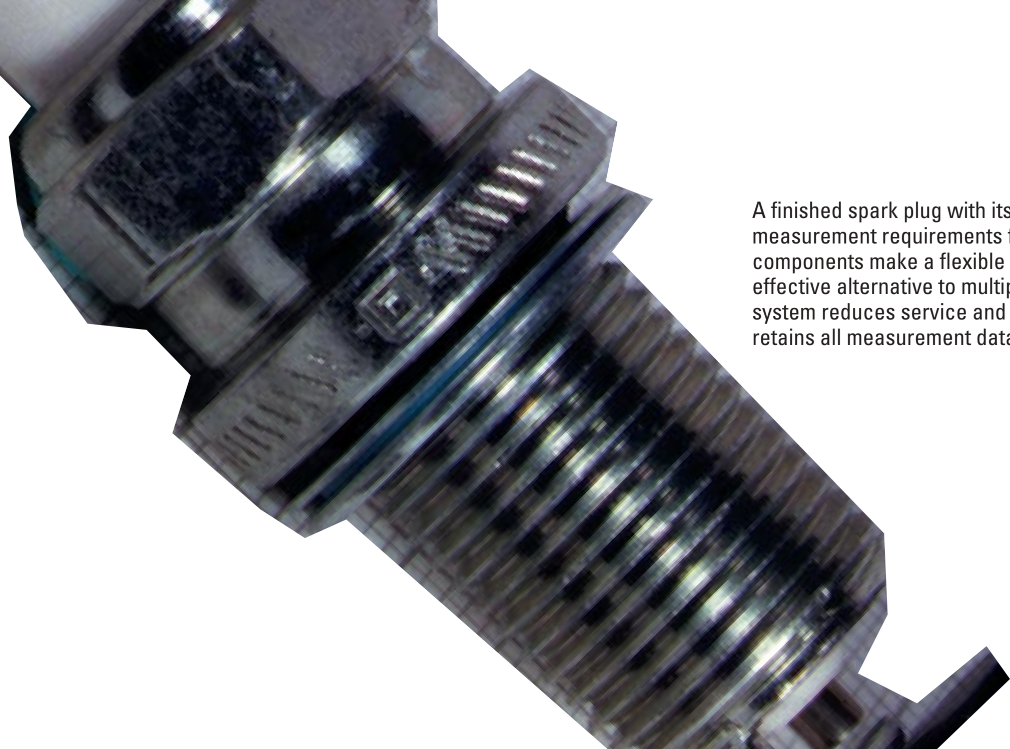
the information is stored in a file. When the insulator is remeasured after firing, the new dimensions are compared with the stored data. Actual shrinkage can be determined as a ratio or a percentage. Traditional methods of performing this measurement task were extremely time consuming.

The PROFILE 30 is flexible enough to inspect Allied Signal's complete range of spark plug components. If design changes are implemented or new components introduced, part programs can be developed or modified quickly and easily.❖

CIRCLE 411 ON THE READER SERVICE CARD



The PROFILE 30 provides Allied Signal an automated coordinate measuring machine to gage their complex cylindrical parts.

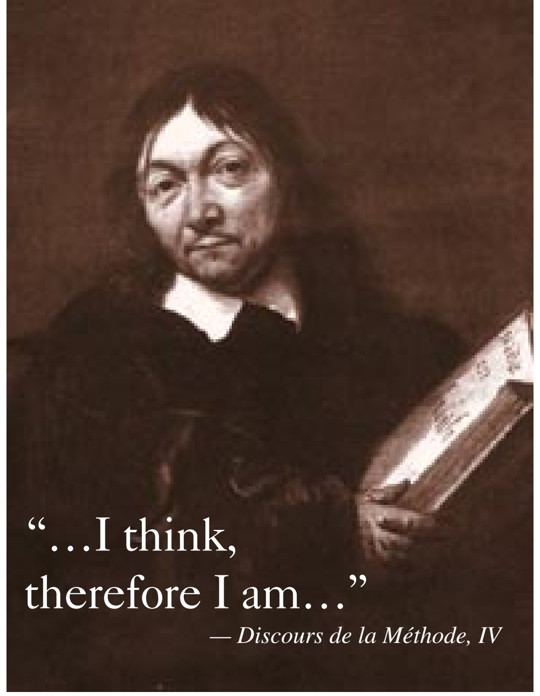


A finished spark plug with its component parts. Different measurement requirements for each of the four major components make a flexible inspection system a cost-effective alternative to multiple systems. Using one system reduces service and calibration costs and retains all measurement data in one location.

René Descartes
Quadricentennial

Uncertain times ensure deep doubts.
But some people transcend all that.

by *Alan Barta*
Corporate Communications
Brown & Sharpe



Europe, France in particular, was in chaos when René du Perron Descartes was born in La Haye, Touraine, 31 March, 1596, a time of strife between France's affluent one million Huguenots and the poor fifteen million Catholics. By the next year his mother had died. René's father was connected well enough to get him a solid education with the Jesuits at La Flèche and a Poitiers' law degree. By twenty he had mastered all that had ever been known in mathematics. He then signed on, ironically, as a Protestant mercenary, at the time a respectable position. In Bavaria, a soldier's "idleness and dissipation" led to his most important vision, to analyze nature through algebra. While the 30 Years War ravaged Europe, he roamed through Germany, Switzerland, Denmark, Poland and Italy (where he met his mentor and lifelong correspondent, Marin Mersenne), after which he returned to Paris to capture his insights. But Henry IV's assassination and the rise of Cardinal Richelieu had made the City of Light intolerant and dangerous.

In 1628 he settled in Holland, a safer and more liberal place of international commerce where he could explore any line of thinking. He experimented in natural phenomena with the zeal of Aristotle and read every new scientific paper. He wrote *Le Monde* and his famous *Discourse on Method* and three attendant works – *Optics*, *Meteorology*, *Geometry* – between '28 and '33, but didn't publish until '37. He was well aware (from Mersenne) that even less revolutionary ideas had resulted in Galileo's condemnation, not to mention Giordano Bruno's fate. Always, Descartes avoided politics and controversy; but central to his ideas was pagan, classical, DOUBT, forbidden by popes, kings and inquisitors alike yet crucial to any real advance in man's knowledge and his dominion over natural forces.

Meditations on the First Philosophy and *Principles of Philosophy* embellished his earlier work: the latter was most influential in the next century. *Les Passions de l'Ame* followed. By then Descartes was considered the foremost living philosopher.

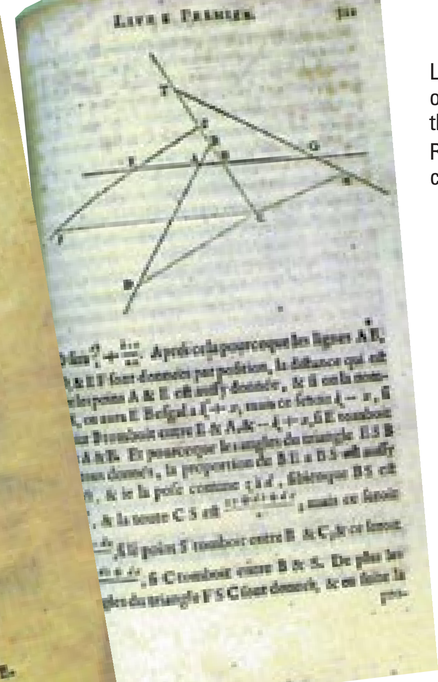
This fame compelled him to Queen Christina of Sweden; unhappily, the demands of her court and the harsh climate soon led to pneumonia and early death (at only 53 years) in the winter of 1650, though his impact had already been established. Restless as in life, his remains were disinterred several times before they were finally entombed with honor at St. Germain des Prés.

Vilified by Voltaire (habitual broiler of fellow Frenchmen), many of Descartes' contributions were attributed to the English. So often you hear the phrase, "stood on the shoulders of greats before him," that you look for a ground floor. Descartes was first to describe inertia, a big idea in Newton's masterwork, and prepared a basis for the calculus of Leibniz. His math and optics predated Newton's by half a century. Not to devalue the magnificent contributions of those before and after – Galileo's courage, Kepler's astronomy, Newton's synthesis or Fermet's *Isagoge* (some argue it put René on the path to solving Pappus' puzzle of 30 A.D. out of which came coordinate geometry) – generations have testified they were inspired by him. From this cosmopolitan amateur sprang the way physics describes relationships, the Enlightenment, the eclipse of scholastic thinking, materialism, the ascent of common man, perhaps even Satre's 20th century nihilism. Descartes has rightly been placed among the most important original thinkers of this millennia and is, undoubtedly, the cornerstone of our scientific age.

At Brown & Sharpe, premier manufacturer of coordinate measuring machines and microscopes, both direct consequences of his work, we are in his debt. On the occasion of his 400th birthday, we express our admiration, even though, in life, he sought no praise, asking only to address his "romance of nature" to minds "delivered from prejudice." Merci beaucoup, Monsieur Descartes.

"The brain may devise laws for the blood, but a hot temper leaps o'er a cold decree…I think the Frenchman became his surety…"
—Shakespeare, *The Merchant of Venice* (1596)❖


DISCOURS DE LA METHODE
Pour bien conduire sa raison, & chercher la verité dans les sciences.
PLUS
LA DIOPTRIQUE.
LES METEORES.
ET
LA GEOMETRIE.
Qui sont des essais de cete METHODE.
A LEYDE
De l'Imprimerie de IAN MAIRE.
CIↃ IↃ C XXXVII.
Auec Priuilege.



LEFT: *Discours plus*, scavenged from the politically dangerous *Le Monde*, brought Descartes immediate fame, even though, characteristically, his name doesn't appear.
RIGHT: *La Géométrie* unveiled an axial system of coordinates to solve a 1500 year old proposition.

Philosophy:

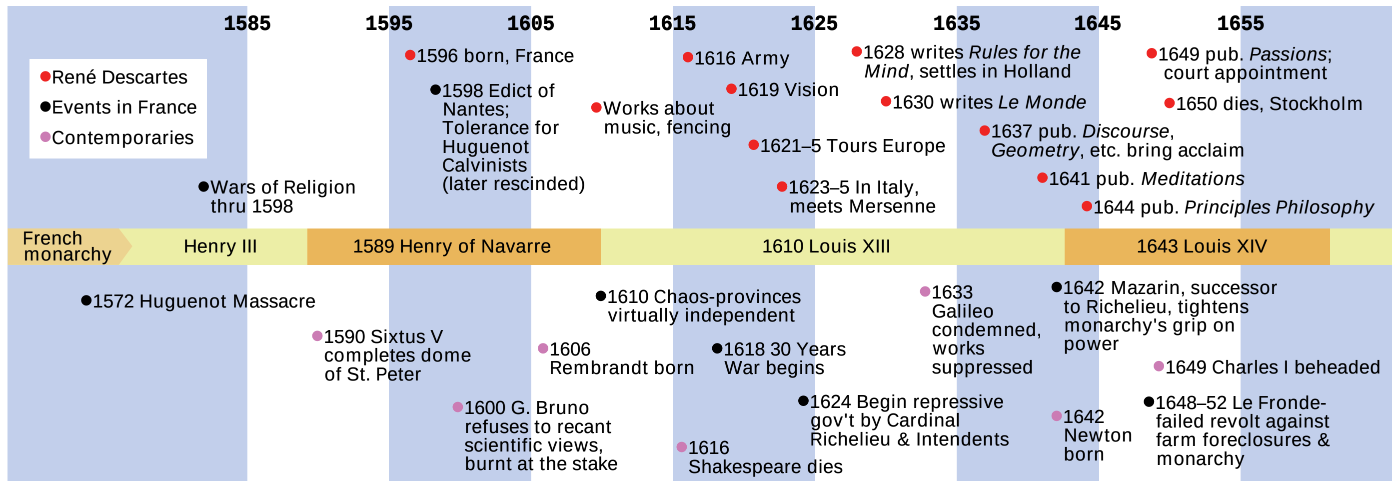
- Can I be Certain? From doubt comes certainty.
- "Cogito" is the pivotal statement in modern philosophy… importance of systematic doubt for everything until proven by mathematics
- Critical Investigation: divide problems into as many separate parts as possible
- Rational Method: sense, reason, intuition
- Dualism: mind and body are separate
- Essence, Extension, Motion: what makes a thing what it is… a body in motion
- Analysis/Synthesis: practical discovery vs. deduction from principles

Contributions:

- Invented System of Coordinate Geometry
- Invented Analytic Geometry
- Progenitor of Modern Scientific Method
- First to apply algebraic equations to natural phenomena; paved way for the calculus of Leibniz
- Theoretical Advances: acoustics, hydrostatics, mechanics, meteorology, molecular chemistry, physiology, psychology
- Practical Advances in Optics: first to describe surface refraction, wave theory of light, spherical aberration, substage for microscopes
- Wrote in native French, rather than Latin: the power of his work made it the language of European philosophers for centuries

Descartes (on right) at reasonable discourse amidst the shambles of Paris (circa 1627). Surrounded by uncertainty, he sought truth.

Life & Times:



Caterpillar Works With Leitz-Brown & Sharpe To Develop New Generation Shop Floor/Lab CMM

In modern metrology, it's important to know not only the true position of a workpiece feature, but also size, form, run out, flatness, and other dimensional form characteristics of the entire part that can indicate how well the part will perform as a component in a larger assembly, such as an engine or transmission. That concept is a philosophy that suggests a workpiece feature is not a separate entity, but is a set of relationships that together determine how closely a manufactured part reflects its blueprint dimensions and its intended functionality.

At Caterpillar's Technical Research Center located in Mossville, IL, near Peoria, there is a developmental program underway to study the practical applications of this philosophy by broadening the capabilities of traditional coordinate measuring machines. This world-recognized manufacturer of heavy-duty earth moving equipment is working with Leitz-Brown & Sharpe Meßtechnik GmbH to evaluate the performance of a new-generation CMM. This new machine combines the accuracy and repeatability of a laboratory grade precision measuring machine with high-speed data gathering capability and reduced environmental specifications.

"We see rapid scanning capability as the key to the future enhancement of coordinate measuring machines."

The Leitz Cygnus X combines rugged shop floor measuring speed with laboratory grade accuracy. Caterpillar's Technical Research Center is evaluating this new coordinate measuring machine in a variety of critical dimensional measurement and inspection applications.

For the past 18 months, engineers at the Technical Research Center have used a Leitz Cygnus X™ coordinate measuring machine in a variety of roles including gage calibration, prototype inspection, process control of engine and hydraulic system components, and as a tool for pure metrology research into the feasibility of high-speed scanning of forms and contours.

"We see rapid scanning capability as the key to the future enhancement of coordinate measuring machines. What we are looking for is a coordinate measuring machine that can provide the same quality of data as a precision measuring machine—in the neighborhood of U3 from 0.8 + L/300 (µm), but operate three times as fast and cost less than a laboratory machine," said Dean Beutel, Project Manager, Manufacturing Technology, who is heading up the Caterpillar program.

The Leitz Cygnus X being used in the program is a high-speed, high-precision industrial coordinate measuring machine that is a cross between a laboratory quality measuring system and a shop-hardened CMM.

Base, bridge, carriage, and Z-rail are constructed from specially engineered thermal materials to resist the effects of shop floor temperature differentials. The massive base is made from LeitzStone® to dampen vibration and to better isolate it from temperature gradients common in shop environments. LeitzStone has high thermal repeatability and is also non-hygroscopic, resisting moisture retention. The machine structure is surrounded by thermal shielding to insure a more predictable response to short-term thermal gradients.

The X and Y axes use precision, anti-backlash recirculating ballscrew drives like those used in machine tools. All drive structures are located on the machine's center of gravity to minimize their effect on geometric error, and are environmentally sealed for maintenance-free operation in harsh conditions.

Caterpillar is no stranger to the benefits of coordinate metrology when compared with other types of dimensional measurement. The company operates some 300 coordinate measuring machines throughout its worldwide manufacturing facilities, along with traditional surface plate tools and dedicated gages.

"A coordinate measuring machine represents a significant investment, and not everyone views it as a good investment, particularly if all you need to know is the location of a particular feature or features. To achieve the greatest return on the investment, we want to be sure that we take full advantage of all the CMM's features; that is to have a machine that can accommodate many types of workpieces, and that can provide critical information about form and function as well as feature location," Beutel said.

For example, the cylindricity of a bore in a hydraulic component has a direct relationship to the functionality, or the performance, of the part and to the performance of the entire subsystem it resides in. Cylindicity can be economically checked using a bore gage or other hand tool. A CMM has to be able to make this type of form measurement if it is to be cost effective, according to Beutel.

Most of the CMMs installed at Caterpillar are currently used in production operations, with the dimensional data acquired by the machines fed back in some manner to control the manufacturing process during setup and occasional audit functions. The CMMs used for process control have great potential to be more valuable than fixed gages in the future because not only can they accommodate a variety of different parts with a simple program change, they also provide more dimensional data than simply the location or size of a particular feature.

"The challenge is to gather even more data faster so that the manufacturing engineer has a clear picture of the actual geometry of the part and a better idea of how to change the process to eliminate errors. This provides a better handle on process control and a genuine continuous quality improvement capability," Beutel said. "Ultimately, this functional data must be fed back to the design engineer to facilitate the simultaneous engineering process and allow optimization of tolerancing and product performance."

The Cygnus X incorporates the new LeitzTRAX® All Terrain Probe system with three ultra-precise probe modes. The discrete, single point mode is the highest precision mode for simple geometric dimensions. The self-centering mode automatically determines the precise center and the high/low points of symmetrical features such as grooves, slots, and gears. In the MaxiScanning® mode, the probe can automatically scan unknown, convoluted surfaces at speeds of 25 mm/sec. Pre-defined surfaces can be scanned at speeds up to 150 mm/sec. with data acquisition rates of up to 1,000 points/sec.

The new-design electronic controller provides 0.3G acceleration and 400 mm/sec. velocity while maintaining extremely low VDI/U3 volumetric uncertainty. The LeitzSpeed® controller regulates volumetric and thermal error compensation, real time error recovery, service diagnostics, precision tracking, and high-speed data acquisition in the MaxiScanning mode.

The Cygnus X uses QUINDOS® Industrial Strength measurement software that features point-and-click feature-based measurement capability, intuitive program editing, and can be used effectively by operators of all skill levels.

In summary, Beutel said, "We've realized all of our aggressive technical targets for machine and probing performance. We are now ready to explore the limits of rapid scanning on parts of different material, with varying surface texture and random form error. This is truly the next frontier in coordinate metrology."❖

Software Retrofit Fills a Vacuum at Chess Plastics

Injection molded vacuum cleaner components undergo dimensional inspection at Chess Plastics Ltd. Brown & Sharpe metrology software has given the company a means of providing graphic SPC data to customers.

It's not a simple task finding software compatible with specific hardware that meets the demands of injection molding production, and at the same time can acquire dimensional information from CAD data or by reverse engineering processes.

However, custom injection molders Chess Plastics Ltd., Droitwich, UK solved these and other problems by adapting a PC-DMIS™ software package from Brown & Sharpe to upgrade their non-Brown & Sharpe coordinate measuring machine.

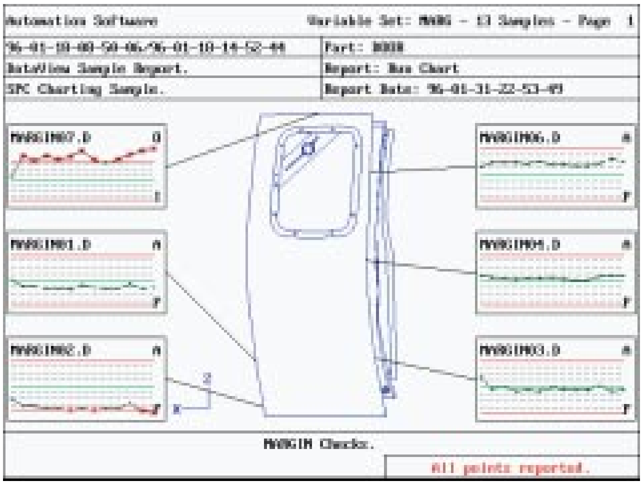
"We were looking for an easy-to-use program, totally flexible with good quality graphics, and capable of accepting CAD data, particularly from customers," said Chess Plastics General Manager Nigel Miller.

The DataPage™ routine SPC program, also from Brown & Sharpe, provides constant and fully traceable data that is available to Chess Plastics customers, such as Valeo in the automotive industry and both Hoover and Dyson in the electrical appliance markets.

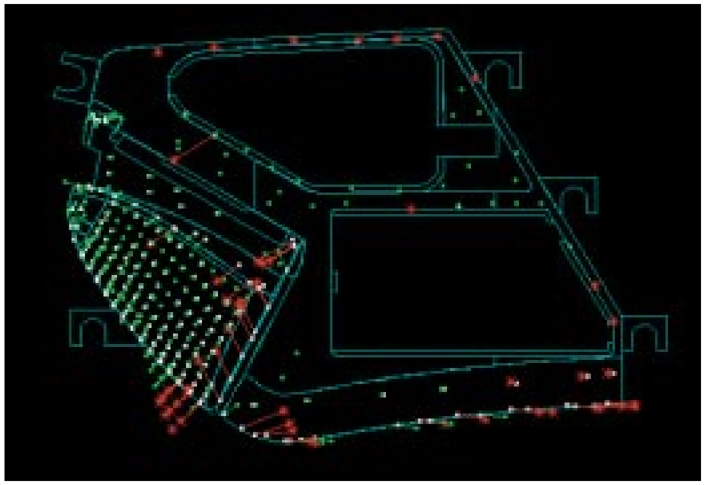
"The software we now operate", said Technical Sales Director Mick Riches, "affords us the opportunity to operate with total product management control, particularly with the CAD interface, and to offer our customers a tool design and development service with supporting ISO 9002 approvals, as well as Valeo 1000 for the motor industry."❖

Profile evaluation is just one of many new options available with the PC-DMIS software package.

A Visual Take On Manufacturing Data



Tell at a Glance: DataView appends critical dimensions or statistics to a drawing.



A Fast Fit: AutoFIT is the fastest way to determine how well complex parts fit the model.

For years, Automation Software's DataPage/RT™ SPC software has provided users with a fast and efficient way to sort through volumes of measurement data. DataPage/RT has a robust database capable of handling intensive data traffic generated by multiple CMMs and other automated measurement systems. This same database is the "engine" that supports Automation Software's Extended Analysis and Reporting tools.

The DataView™ graphic reporting tool links part data and statistics to an actual drawing, giving the user a fast visual take on what is happening to the part. Graphic reporting also provides a tool for communicating clearly and efficiently with other manufacturing teammates about what needs to be done to correct related process problems.

Capabilities of graphic reporting software include overlaying measurement and statistical information on a graphic part representation, viewing this information from different axes, generating graphic reports for a wide range of selectable part characteristics, and color coding out-of-tolerance conditions.

Does the Data Fit?

Some of the most frustrating measurement problems are complex parts that just barely fall out of tolerance. If these parts were realigned, twisted ever so slightly in two or three dimensions, there is a good chance that wayward features would fall in place without moving others out of their tolerance zone. However, doing the physical setup and measurement one more time could take hours, even days.

The AutoFIT™ best-fit analysis tool does this realignment operation in software in a matter of minutes.

AutoFIT automatically separates real errors in feature positions from relative errors between the feature pattern and the alignment datums. Then it makes a slight adjustment in part orientation to bring them into alignment. If the part is out of tolerance, AutoFIT can perform a statistical fitting operation to show which features are most responsible for making a pattern out of alignment. As a result, the fewest and most effective tooling adjustments can be made the first time, without throwing other features out of alignment.

No one-fit algorithm works best for all parts. So AutoFIT provides least squares, weighted least squares, min-max, and weighted min-max.

When To Jump In

DataView and AutoFIT can offer manufacturers true competitive advantages today. Most Brown & Sharpe users can take advantage of these capabilities at minimal additional cost because they already have core DataPage/RT software installed on their systems.❖

Custom Measuring System Assures Airbag Activation

Marley Automotive Ltd. of Maidstone, UK, a well-known manufacturer of automobile dashboard facias, asked Brown & Sharpe Ltd. to help them solve the difficult problem of 100 percent inspection of passenger-side facias used to house airbags.

The primary feature on the panel is the grooved "burst" line. In the activated condition, the inflating airbag relies on the line to fracture instantly. Safe operation requires the line to be no thicker than about 0.5 mm. To prevent untimely fractures, the thickness cannot be any less than 0.25 mm.

A high resolution, high data density custom gaging system designed by Brown & Sharpe Ltd. allows three line positions to be measured in a one-minute cycle. The gage includes two Brown & Sharpe "C-Point" lasers arranged to measure each side of the panel wall. The lasers scan across the line while low force clamps hold the panel in position. The system determines minimum material thickness and accepts or rejects the measured dimension.❖

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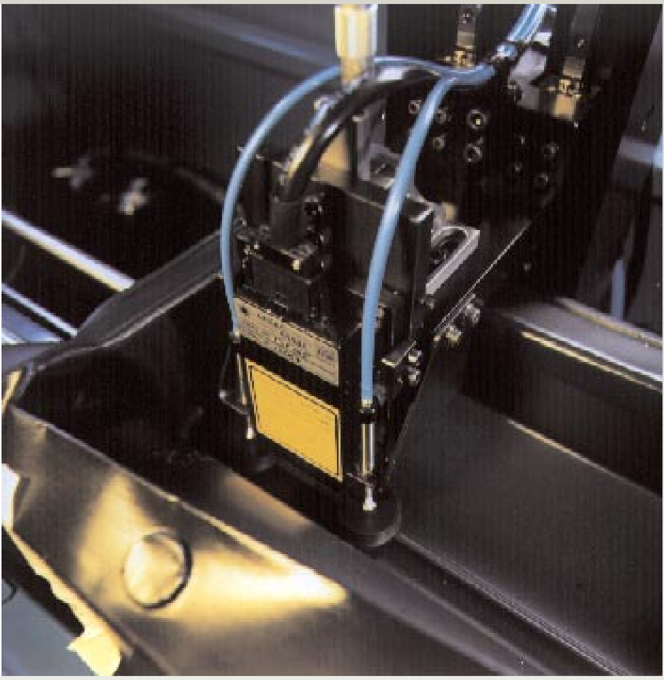
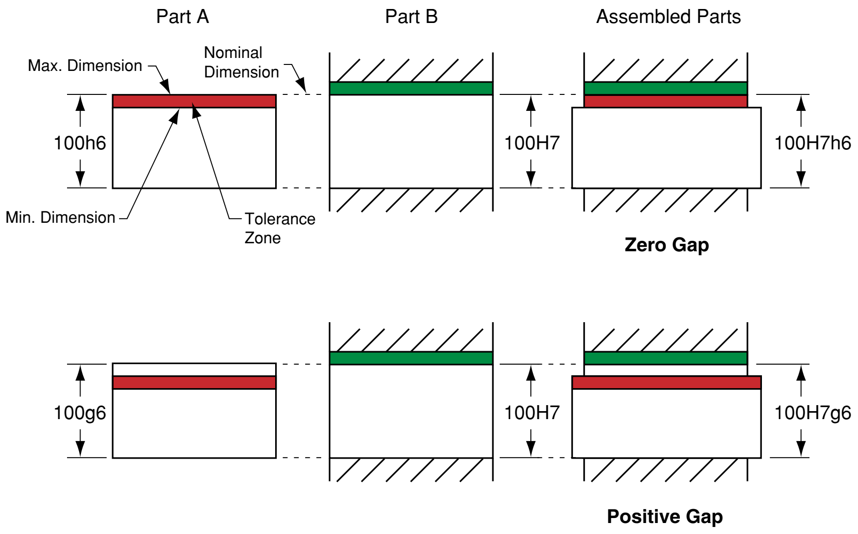


The upper of two C-point laser probes ready to measure the burst line groove of airbag containers at Marley Automotive.

Accommodating The '*Perfect*' World In The Design Of Component Parts

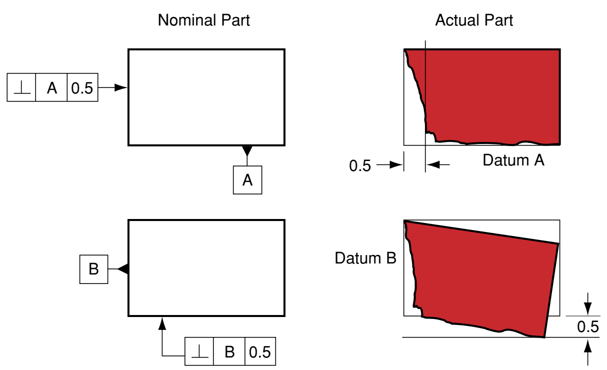
by Prof. André Clement
Dassault Systèmes



Zero gap and positive gap tolerancing schemes. The way in which a component part assembles is dictated by the choice of tolerancing scheme.

For a mechanical part to fulfill its role in an assembly, in spite of the uncertainties that influence its fabrication, engineers invented the concept of tolerancing. Tolerancing is the way engineers make the adjustment between the perfect physical world described by Euclidean mathematics, where form is perfect and the measurement of distance is symmetrical, and the realities of mass production. It defines the amount of variation allowed for different dimensions of a part.

With Dassault Systèmes next release of CATIA (Version 4, Release 1.6) engineers will have a powerful new tolerancing tool, TTRS (Technologically and Topographically Related Surfaces), to create a mathematically correct model, consistent with Euclid, and one that models the variations of the part. TTRS is a language that makes it possible to read tolerances in any international standard (ISO, ANSI, JIS, DIN) without manual translation or loss of semantics.



In Euclidian geometry, the measurement of distance is symmetrical. Since this is not true in reality, the concept of datum was invented to indicate the position from which measurements should be taken.

TTRS lets designers model a part with its tolerances, not simply as text on an engineering drawing, but as values integrated into the database and recognized by downstream applications such as machining and inspection. In the past, an experienced person would interpret an engineering drawing with tolerances to program a measuring machine. Now, the measuring machine will automatically extract the information from CATIA.

Assembly Modeling

In assembly modeling, the behavior of the assembly is affected by its component parts. Different functional requirements explain different assembly possibilities. The function of assembled parts dictates the type of tolerance needed. Nominal, or theoretical, dimensions are not enough to explain the behavior of the assembly. Two new concepts are needed: the tolerancing zone, and the position of the tolerancing zone.

Depending upon the function of the final part, engineers can choose from two tolerancing schemes, zero gap and positive gap. The one that is chosen dictates the way the parts will assemble.

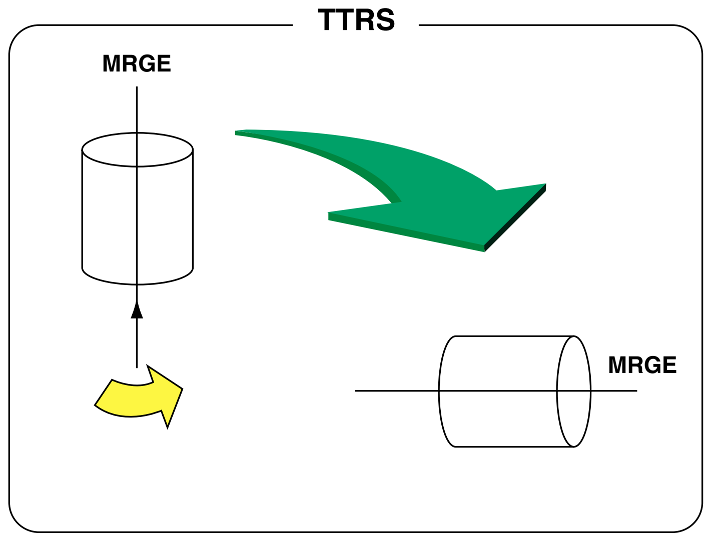
Modeling tolerances on a part requires positioning one surface with respect to another, since the positional error of a single surface cannot be defined. There must be at least two surfaces, each of which can be used as a datum for the other. TTRS considers these two surfaces as one feature; so, a TTRS is made up of a pair of surfaces, a pair of TTRSs, a surface and a TTRS that belong to the same solid, or any combination of these.

If we keep in mind that dimensioning is simply the positioning of a surface with respect to another, we can understand that to dimension a part we need to choose, on each surface, the elements that will serve as a reference. These are called Minimum Reference Geometrical Elements (MRGE). They can be the axis of a cylinder or the centerpoint of a sphere, but in every case, they are tangible elements that the user can choose to position his part relative to another. Multiple MRGEs are combined to become a TTRS.

We can illustrate this by trying to find the distance between two cylinders. These cylinders are defined by their respective mathematical equations. To find the distance between these two cylinders, an engineer will not use equations, however. He will choose the axis of each cylinder and dimension between the two. The axis becomes the minimum information needed to represent the cylinder for positioning purposes.

Using TTRS, dimensioning has another meaning: a dimension is the minimum significant displacement that will superimpose a MRGE of one surface on the MRGE of its related surface. Furthermore, we can define the distance not only between surfaces of the same class, but between surfaces of different classes.

What advantage does this bring to part design? Product design is being increasingly performed in parallel with other disciplines such as machining process development and determination of measurement and inspection procedures. Associativity becomes important; data from one discipline must relate to the others. To maximize productivity, associativity must be maximized. Now, since tolerances are integrated in the CATIA database, they can be fully used by downstream applications. The result is virtually error-free inspection at a throughput rate that can keep pace with CNC machining equipment.❖



A TTRS is the minimum significant displacement which will superimpose a MRGE of one surface on the MRGE of its related surface.

	MRGE
	One plane & One line on this plane & One point on this line
	The line of extrusion & A plane passing through this line
	Its own axis & One point on this axis
	Its own axis
	Its own axis
	Any plane parallel to P
	Center point of the sphere

The seven classes of surface elements with their Minimum Reference Geometrical Elements (MRGE) defined.

Quality Attitude Goes Beyond Quality Control

by Richard F. Paolino
Vice President & General Manager
Commercial Operations
Brown & Sharpe

Last December, inspectors audited the DEA-Brown & Sharpe Moncalieri facility in Italy to verify its continued compliance to ISO 9001 standards. They found that the facility was "fully compliant."

All of Brown & Sharpe's Measuring Systems facilities have been ISO certified. Recently, all of the North Kingstown, RI, operations of Precision Measuring Instruments have been ISO certified as well.

Becoming ISO certified is a difficult and time-consuming process. Because of the hard work associated with the certification process, there is the temptation to relax once the certification has been granted. The truth is that the real work begins after certification. It is the work of maintaining a high level of commitment to quality consciousness that not only determines whether an organization remains ISO certified, but whether it has what it takes to participate in the world market.

Quality goes beyond certification, although to be certified to ISO standards is indicative that the structure inside an organization exists to assure quality operations. Quality is an attitude, a distinctive cultural aspect of a business's corporate personality, that involves more than just doing a job right the first time. It means always looking for ways to do the job better.

The worldwide family of Brown & Sharpe companies is committed to maintaining a high quality consciousness by doing the job better. We do that by listening to what our customers tell us and developing measuring systems that meet their requirements—quality measuring systems that are not only flawlessly built, but also add quality to our customers' products. That's the way we believe success is measured today, and will be for the forseeable future.❖

Brown & Sharpe Named A Top Supplier In PACE Award Competition


Executive Declaration
On behalf of the citizens of Michigan, Governor John Engler hereby issues this Certificate of Commendation to
BROWN & SHARPE MANUFACTURING COMPANY NORTH KINGSTOWN, RHODE ISLAND

Brown & Sharpe has been named a finalist in competition for the prestigious PACE Award, presented annually by the Ernst & Young accounting firm and Automotive News magazine.

The PACE award, which acknowledges companies that have helped the automotive industry reduce costs through innovation, is presented in five categories: Small, Medium, and Large Com-panies, Service, and Capital Companies. Brown & Sharpe was a finalist in the Capital Companies category.

The company was acknowledged for the DEA-Brown & Sharpe FIVE Flexible Fixturing System. This fixturing system can be configured by computer to hold a infinite variety of thin-walled, contoured parts such as sheet metal body assemblies for dimensional inspection operations. These types of components are traditionally difficult to hold since the fixture itself, if not properly designed, can stress the workpiece, changing its shape so the accurate dimensional measurement is not possible. The solution has been to build expensive custom fixtures designed to hold a specific part.

The FIVE Flexible Fixturing System replaces expensive custom fixtures which can be rendered obsolete when part specifications change and often have to be rebuilt, retooled, or scrapped. With this fixturing system, a change in part specifications requires only that the computer controlling the system be reprogrammed to reflect the new part configuration.

"It is an honor to be a finalist in this program," said Frank T. Curtin, Brown & Sharpe President and Chief Executive Officer. "The company has been an active supplier to the automotive industry for decades, and we are pleased that our products are recognized as making a contribution to controlling manufacturing costs for our customers."❖

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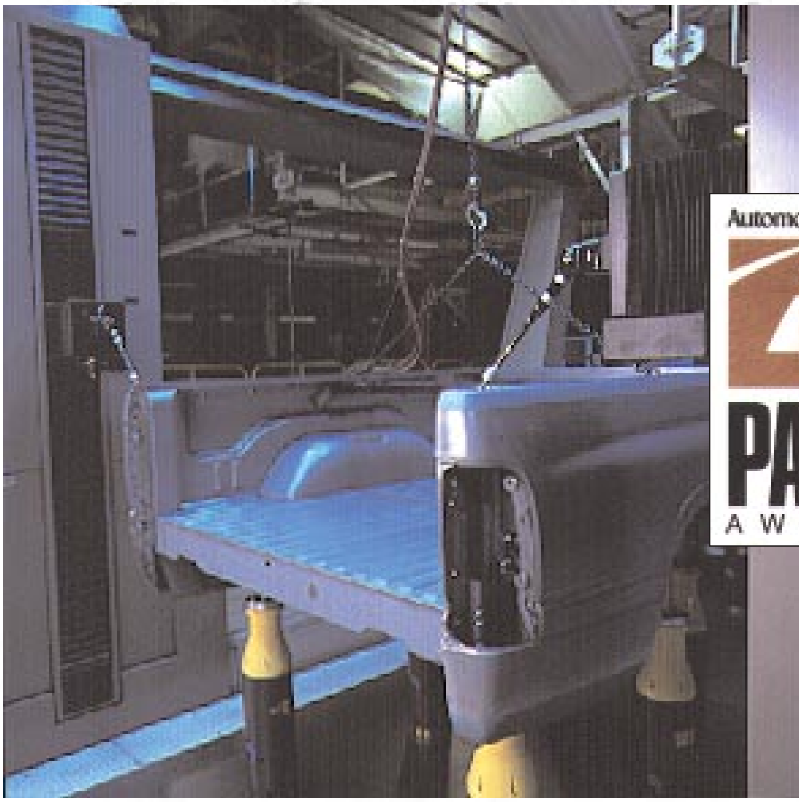


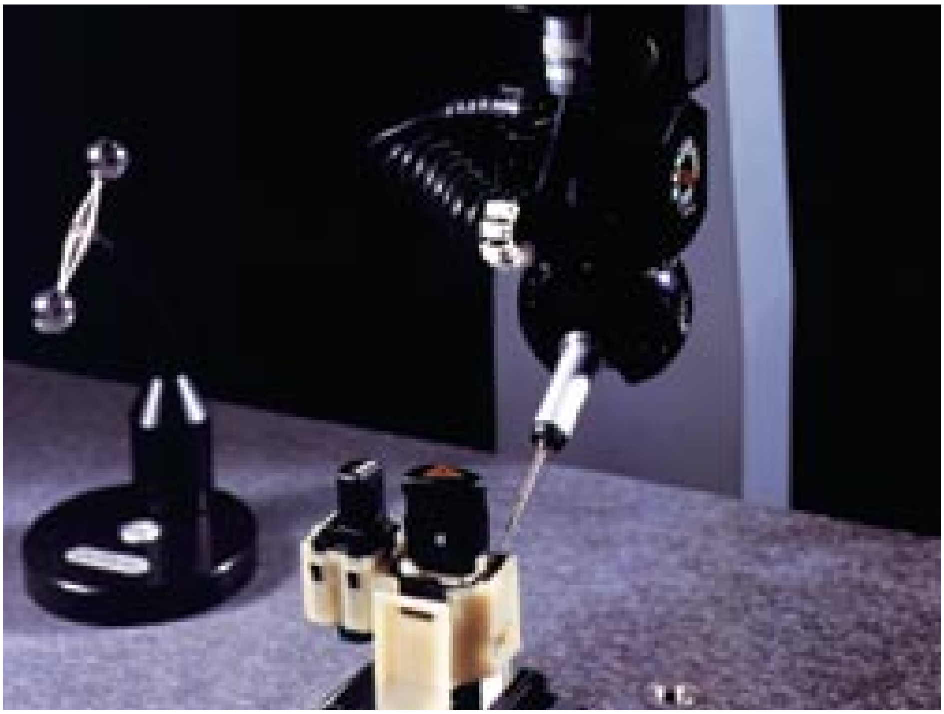
DEA FIVE Flexible Fixturing System can replace expensive custom gages used for inspecting sheet metal assemblies and entire vehicle bodies. The system can be quickly reconfigured by computer to accommodate a wide range of workpiece sizes and shapes.

CMM Review Sparks **Speed Up** of Ignition Component Inspection

Delta Schoeller, the Cheltenham, UK based electrical component manufacturer, recently reassessed the measuring capacity of its quality department as part of overall planning for future design and manufacturing demands of its complex units and assemblies for the automotive market. The company has been using a single Brown & Sharpe Validator® coordinate measuring machine.

Quality Manager Andy Williams and his team looked at a number of options from various CMM manufacturers, and selected a Brown & Sharpe MicroVal® PFx® fitted with a Renishaw PH9 motorized probe. At the same time, Delta Schoeller updated the software on the Validator to gain CNC/software capability and to provide a direct interface with its CAD department.

"…Brown & Sharpe could provide a more appropriate CMM…and cut the inspection times down from some three weeks to three hours."



Intricate prototype ignition components can be measured quickly and accurately with the MicroVal PFx.

"Cost efficiency evaluations indicated that for the price of a competitor's single machine installation, Brown & Sharpe could provide a more appropriate CMM, update existing programs and cut the inspection times down from some three weeks to three hours," said Williams.

"We required a sampling inspection program of around 100 parts and prototype gaging facilities to accommodate the various tool changes and modifications which occur in prototype manufacture and in some cases reverse engineering for intricate plastic moldings such as panel switches with involute surfaces and curves," he added.

Among the assemblies for major motor manufacturers such as GM, Toyota, and VW, prototype ignition units presented particular problems because of the smallness of some of the components coupled with their complicated shapes and the associated difficulties of specifically identifying culminating points and gaging patterns inside and outside the moldings.

"Using the PC-DMIS™ program with the MicroVal PFx has helped us isolate many difficulties and, by the use of our own part programs, establish automatic program selection and datum setting, and evaluation profiling," said Paul Farmer, Delta Schoeller Senior Quality Engineer.❖

CIRCLE 416 ON THE READER SERVICE CARD

Measuring Robots, Flexible Fixturing Keep Porsche In The Prestige Car Driver's Seat

Dual-arm DEA BRAVO measuring robot speeds body-in-white inspection at the Porsche Stuttgart plant. Dimensional data is used to control welding machines in the body assembly operation.

Keeping the Porsche name synonymous with quality and high performance is demanding for engineers, not only in design but in manufacturing as well. Sometimes it means adopting new approaches at the expense of traditional methodology.

After extensive research and investigation into alternative systems, Porsche Stuttgart management replaced fixed gages in its sheet metal inspection operation with two DEA-Brown & Sharpe BRAVO measuring robots. With the installation of these measuring systems, the company has not only been able to increase body panel and body-in-white inspection throughput, but has also developed a useful database for process control, and reduced gaging costs as well. Recently, the company purchased a DEA FIVE U-nique Flexible Fixturing System to extend the capability of the BRAVO in the subgroup parts inspection operation.

> **"…this fixturing system is extremely important in eliminating the high cost of fixed gages… and it can be used on other types of measuring machines, further extending its usefulness."**

At Porsche, pressed parts for car bodies are subcontracted and were formerly spot-checked when they arrived at the Stuttgart plant. Today, a BRAVO measuring robot inspects the quality of subgroup parts to assure their process capability. About 25 subgroups with an average of 30 points per part are measured in two shifts. Inspection cycle time per part is about 10 minutes.

The FIVE U-nique Flexible Fixturing System will be used in conjunction with the single-arm BRAVO measuring robot in the subgroup parts inspection operation. This modular workholding system can be easily configured and reconfigured to hold virtually any body panel shape, eliminating the need for costly dedicated fixtures.

"The configurable nature of this fixturing system is extremely important in eliminating the high cost of fixed gages for this operation, and it can be used on other types of measuring machines, further extending its usefulness," said Günter Hoffarth, Porsche Quality Assurance Manager for Body-in-White Production and Paint.

In the body assembly department, Porsche operates a flexible welding line that can produce car bodies in random sequence. A dual-arm BRAVO measuring robot is installed to handle the line. With the installation of the measuring robot, Porsche can check up to 15 percent of its bodies-in-white, using a main inspection program with 50 measuring points and about 130 dimensions.

"Because of the speed of this measuring operation, we can devote our time to more than 30 sub-programs that measure critical aperture areas like doors, hoods, and windshield openings," Hoffarth said.

In the past, using fixed gages, the company was only able to inspect one or two body-in-white assemblies per day.

"That didn't give us a statistical base to determine process trends," Hoffarth said. "We might have changed our production line after one, two, or three deviations and found that was not the right thing to do because these deviations did not represent an out-of-tolerance trend."

The results of the inspection routine are available in graphic form and related to Porsche's program for process capability analysis. By reviewing histograms after a defined number of bodies, manufacturing engineers can more realistically adjust welding machines on the production line. "We get better process control, and that's our goal," Hoffarth said.❖

CIRCLE 419 ON THE READER SERVICE CARD

DEA FIVE U-nique Flexible Fixturing System recently purchased by Porsche Stuttgart will eliminate the need for expensive custom workholding fixtures.

A Tale Of Two Tails

by Ed Morse and Herb Voelcker, Cornell University

As industry worldwide is pressed to meet higher and higher quality standards, the role of statistical manufacturing controls grows apace.

"What's the C_{pk} of this process?" is often the first question asked when things go wrong down the line. Unfortunately, questions like this can be dangerous if the assumptions built into popular indices, such as C_p and C_{pk}, are violated … and many operators and even some engineers don't understand the techniques well enough to know when they may be on dangerous ground.

This article focuses on the assumption of normal (gaussian) statistics used in almost all statistical tolerancing and SPC techniques. Normality is not a good assumption for some kinds of geometric tolerance data; it's dangerous because it can inflate yield predictions by orders of magnitude. Here's a simple example, based on data we have been collecting on the actual-value statistics of geometric tolerances.

Suppose that the following procedure is used to predict the failure rate for the position tolerance 'T' on the punched hole shown in Figure 1a.

- Measure the actual position values relative to true position (the distance *r* shown in Fig. 1b) on a sample run of parts, using a CMM and the ANSI Y14.5.1 definition of 'actual value'.
- Calculate the sample mean and sample variance of the measured values to provide parameters for ('fit') a normal distribution.
- Estimate the probability that *r* falls outside of the tolerance zone by integrating the normal distribution from T/2 to infinity.

A typical result of using the procedure: the predicted failure rate *under-estimates* the actual failure rate by at least a factor of ten.

To see why the procedure fails, we need a statistical model for position error. To keep things simple, suppose that the hole has no systematic error (i.e. the punching process is centered). We would expect a population of holes to be circularly scattered about the true position, as in Figure 2a, with independent, normally distributed dispersions having the same variance σ^2 in the x and y machine control directions. (If the process is decentered, we will see the same dispersion about an off-target point, as in Fig. 2b.)

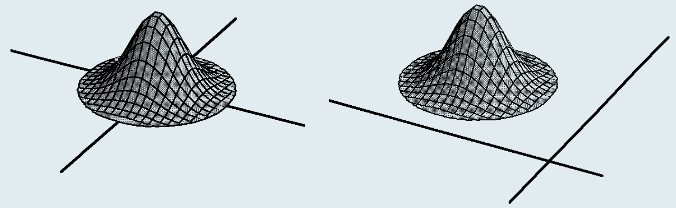


Figure 2: Centered and decentered statistical scatter.

Under these assumptions, it is easy to show that *r* will have the probability density function *p(r)* and the cumulative distribution function *P(r)* shown in Figure 3, when σ=1.

Unlike the standard normal density (the bell curve), the Rayleigh density *p(r)* is asymmetric and only defined for $r \geq 0$. Its mean value is $\mu_R = \sigma\sqrt{\pi/2}$; r-sample averages will converge to this value as the sample size grows. The Rayleigh variance is $\sigma_R^2 = \sigma^2(2-\pi/2)$ … again, the value to which r-sample variance estimates will converge as the sample size grows. Let's compare the failure probability P_R based on the probability PN based on a normal model that has the Rayleigh mean and variance values. Figure 4 shows how these failure rates vary with the tolerance-zone radius, T/2, for σ=1. Some specific values from these plots:

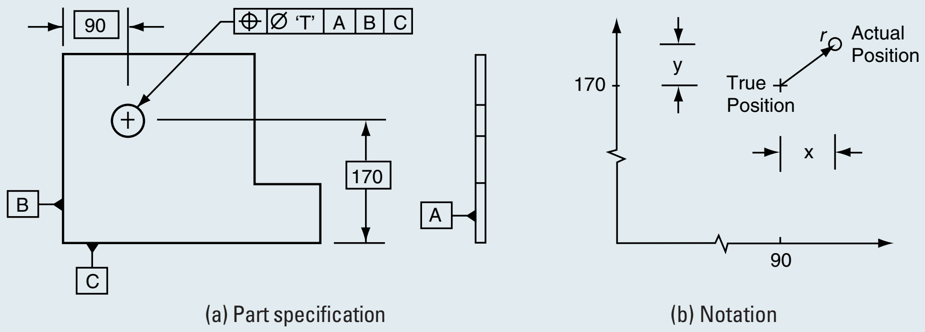


Figure 1: A position tolerance example

$$p(r) = \frac{re^{-r^2/2\sigma^2}}{\sigma^2}, \quad r \geq 0$$

$$P(r) = \int_{-\infty}^{r} p(x)dx$$

$$= 1 - e^{-r^2/2\sigma^2}$$

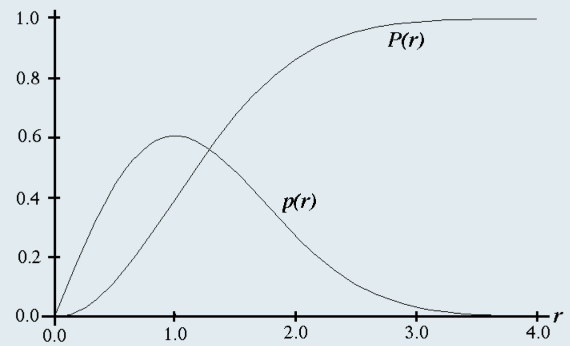


Figure 3: Rayleigh density (*p*) and cumulative distribution (*P*) functions.

T/2	Cpk	P_N Normal failure model	P_R Rayleigh failure model
3	0.89	3.8 per thousand	11.1 per thousand
4	1.40	14 per million	335 per million

Note that the failure rate predicted by the normal model underestimates the Rayleigh rate by at least a factor of twenty for failure rates in the one-per-million range. The divergence grows rapidly as the rates drop, because *the crucial tails of the two cumulative distributions converge at very different rates*. The numbers we report change modestly when more sophisticated normal-fitting procedures are used, but the asymptotic behavior is inescapable.

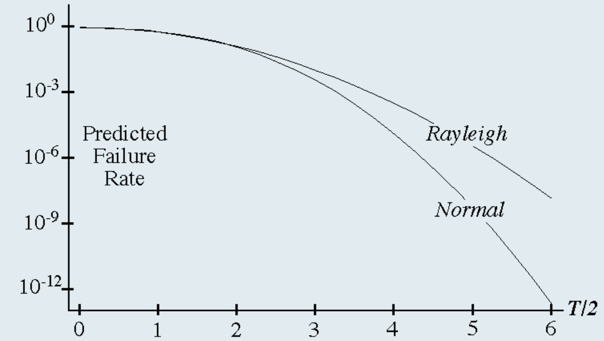


Figure 4: Failure probabilities for Rayleigh and normal models.

Just how valid is the Rayleigh model, and what happens if the hole-making process is decentered, as in Fig. 2b? Figure 5 shows how decentering affects the density *p(r)* when σ=1; broadly, *p(r)* changes from Rayleigh to asymptotically normal as decentering grows. The Rayeigh model is worst-case in terms of departure from normality, but it is also the state we generally seek (centered processes), because heavy decentering raises the failure rate dramatically.

$$p(r) = \frac{re^{-(r^2+A^2)/2\sigma^2}}{\sigma^2} I_0(rA/\sigma^2), \quad r \geq 0$$

where A is the offset of the process center, and I_0 is a modified Bessel function of the first kind, of order zero.

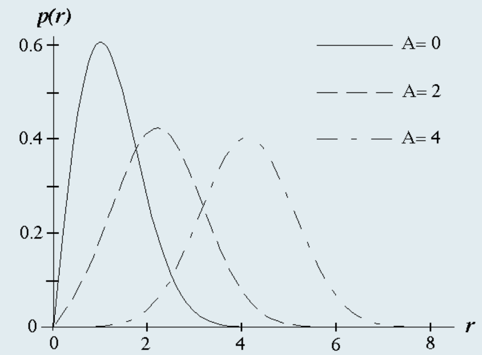


Figure 5: The effects of decentering on the position density *p(r)*.

In our experiments at Cornell, which are exploratory rather than comprehensive, we have seen the full progression shown in Fig. 5. We believe that the Rayleigh model is valid – or at least more accurate than a model based on normal statistics – for some classes of geometric tolerances. If true, this has ominous implications for QC and statistical tolerancing procedures that rely on blind use of techniques based on normal statistics. For example, if the Cpk index is used to qualify a process at a certain failure rate, we have shown that this index can be misleading, if not meaningless, as the process departs from normality.❖

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Ed Morse is a PhD candidate at Cornell. He is a former Brown & Sharpe employee.

Concurrent Engineering In Action
Getting Started On The Future

Much discussion over the past several years has focused on concurrent engineering, total quality, and other "cutting edge" systems and methods for enhancing and evolving collective and individual competitiveness. What do these terms mean, and how can we "do them" in any cohesive manner—particularly to "grow talent" for the future?

The Center for Quality, Measurement and Automation (CQMA) at Bowling Green State University has been developing and experimenting with these methods and systems over the past several years. The focus has not been on any one approach, but rather in trying to develop an integrated working model to study. This full sized, functional, "testbed" approach has resulted in several studies and projects which are beginning to provide various insights into necessary tools for the future.

by Prof. John W. Sinn
Executive Director
Center for Quality,
Measurement and Automation
Bowling Green State University

The model that CQMA continues to experiment with is shown in Figure 1. The approach combines common attributes of total quality and concurrent engineering focused toward change and improvement. A strong emphasis on data, documentation, and technical leadership is combined at the center since, it is being determined, they provide the necessary foundational infrastructure.

Applied technical research and a tool kit of knowledge are other key cornerstones and requirements in the model. The tool kit of knowledge requires all CAD-CAM acronyms commonly discussed, including design of experiments, finite element analysis, ongoing process control plans, the eight disciplines problem solving approach, quality function deployment, and statistical process control, among others. The point here is that organizations wishing to become involved in concurrent engineering should be mature and have a defined base of knowledge as reflected in the way they gather and document information.

The model provides a mechanism for doing all of the above because it recognizes that the root of addressing these issues is knowledge, collective and individual, inside and outside the organization. This accounts for virtually all communications, information, data, and documentation problems addressed, and hopefully solved.

Integrating Design and Manufacturing

Part of what CQMA has been pursuing is to define and explore concurrent engineering. S. Kalpakjian, writing about concurrent engineering in "Manufacturing Engineering and Technology," states that "it is a systematic approach that integrates the design and manufacture of products with the view of optimizing all aspects involved in the life cycle of the product, including costs, quality, scheduling and ultimate disposal of the product." Related to this, Ed Dean, in "Concurrent Engineering," provided further definition about concurrent engineering stating that "the most recent perception of concurrent engineering is that it includes concurrent design."

The view of concurrent engineering that is emerging in CQMA is that when designing the product itself, simultaneous functions similar to the following take place: prototyping, testing, after sales support, assembling, production, quality, launching, next model, disposal, and analysis.

When applied systematically in designing a product, the effect on new product introduction must be to reduce the time between the start of the design phase and the product launch, minimize engineering changes, and reduce the cost of production. The work of CQMA has also disclosed that the above can only occur in a broader culture of total quality.❖

For a copy of the paper on which this article is based:

CIRCLE 421 ON THE READER SERVICE CARD

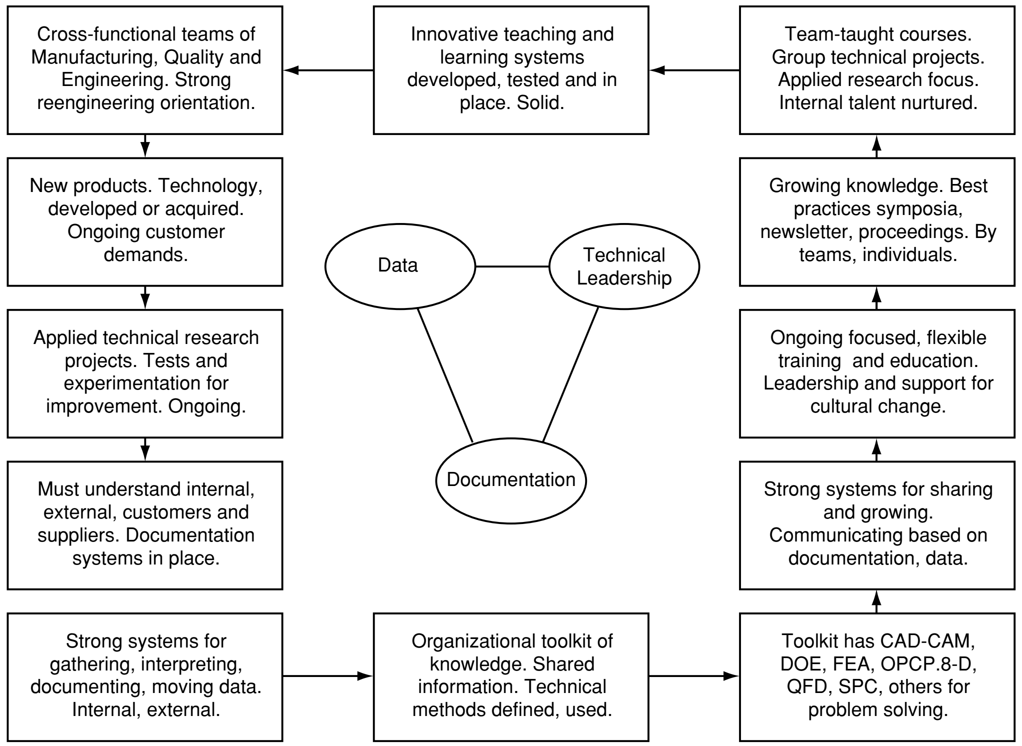


Figure 1.

Putting Concurrent Engineering To Work:
Using Rapid Prototyping To Increase Market Share

An example of the overall approach being experimented with in CQMA involves a project being conducted with a local manufacturer. The assignment was to redesign an existing metal storage container.

The customer wanted to keep the same details of shape and geometry currently being used with their highly successful container, but downsize and reengineer it to be more competitive in the marketplace.

Three key components were used in the fabrication of the new design: a Brown & Sharpe Xcel® coordinate measuring machine, MASTERCAM and ALGOR software, and a 600 series MAHO CNC 4.5 axis milling machine. The new container was created in four distinct phases. These phases consisted of data acquisition, design, testing, and machining.

Data Acquisition Using the CMM, profile scans of an existing container were taken and converted to ASCII code. The ASCII code was ported into MASTERCAM software. The code representing the overall profiles was scaled to become an acceptable smaller size. From the scaled profiles, or complex surfaces, a model could be graphically rendered to physically show final container appearance. The accurate complex surfaces also provided the foundation for further design work and CAM programming.

Design Design was actually an "edit" function performed in the design program within MASTERCAM. Beginning with the complex surfaces from the actual reverse engineered profiles, edits were performed to clean up the geometry and provide an acceptable 3-D wire frame model and actual prototype representations or renderings. In some cases it would be advisable to transfer the files into a CAD software such as CADKEY, but in this case the MASTERCAM software was more than adequate.

Testing The analysis of design was processed in ALGOR finite element analysis (FEA) software. In order to make this analysis possible, the initial reverse engineered profiles from the CMM were used to create surfaces which were appropriate for the FEA. The complex surfaces created in the CAD/CAM software were not appropriate for the ALGOR FEA software. After an appropriate model was obtained, linear stress and stain analysis was performed on the model. With the results obtained from the test, minor design modifications were made.

Machining To make machining of the model feasible, the design was sliced in three sections. Each section required individual programming and machining. The design was programmed in "TOOLMKR" and machined on the MAHO CNC 4.5 axis milling machine. This resulted in multiple prototypes which were actually provided to the customer for analysis, market feasibility, and other uses.

The entire rapid prototyping process is shown at left in Figure 2. At various phases along the way, 3-D models were configured and analyzed. As the final iterations of the process were being done, various prototypes were cut in Renwood modeling materials to show the customer, and for various other applications and analyses. Design of experiments (DOE) levels and factors are being pursued as possible additional tools to help assess the appropriateness of one design over another.

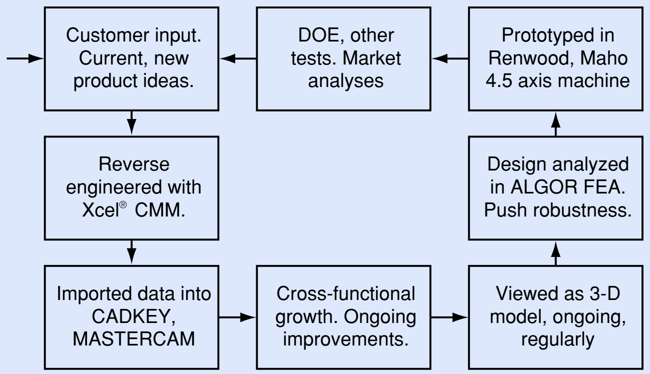
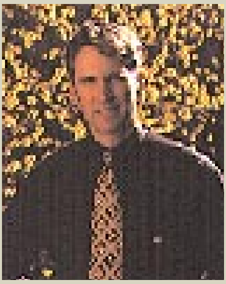


Figure 2.

The Art of Communication



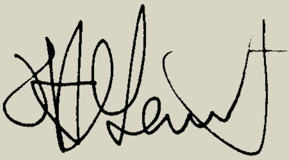
Communication began as art. Men and women scraping cave walls, creating images of their lives, fears and imagination. They invented words to describe the pictures, linked them into stories and songs and shared them with their neighbors, culturally enriching and challenging their communities.

Commerce, as art, got its start when decorative beads, coins and paper were used to buy our daily needs. With the exchange of money and a firm handshake, business was transacted and contracts formed.

Science, as well, began with art. As scientists struggled to explain nature, they turned to diagrams and formulas to prove their very existence.

The Internet now transports our "cave art" around the world instantly. The Web promises to eliminate time from our communications, further dissolving the distance between one human and another and creating one single world community.

We can't let technology, though, further obscure the handshake and the importance of the physical human relationship. It was, after all, the art of communication that started this whole journey, and art relies on the human touch.



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