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BY MICHAEL DEREN

Let's talk this over

When was the last time you discussed a project in a group setting that included someone from management and engineering, a shop floor supervisor and a machinist or operator? I'll bet it was some time ago, but such meetings should be held on a regular basis.

Why? Glad you asked.

Let's say you just finished a repeat job that you've run profitably several times. Is it possible that it could be done more profitably?

By having a "post mortem" on a project to dissect the project, perhaps you might find some unneeded costs. This is where a conscientious machinist or operator could help—not by working faster, but by working smarter.

Because a machinist understands the parts being produced, he might have a suggestion to change the sequence of operations, fixture, cutting tools or machining parameters. By having a roundtable of sorts, input from others might help produce a more profitable process.

Going one step further, why not have roundtable discussions before starting new or repeat projects? In some companies, this may seem like a unique or radical concept, but having a group evaluation of the process beforehand allows problem areas to be addressed.

Having roundtable discussions before starting new or repeat projects may seem like a unique or radical concept, but having a group evaluation of the process beforehand allows any problem areas to be addressed.

Leaving troubleshooting to one person limits possible solutions to those that one person can think of. By involving several people with different points of view, a process can and usually will be improved.

Basically, these preliminary discussions constitute a process review. When reviewing a new part or process, consider several things.

- **Review the purchase order.** Make sure there is a purchase order in-house. Many times I have seen shops start the work with only the promise of a purchase order to follow.
- **Determine the project's scope.** Make sure the shop is doing the work it's supposed to—no more, no less.
- **Allocate manpower.** Immediately after receiving the purchase order, determine the required manpower—shop personnel, engineering, programmers, QC and other personnel.
- **Review the drawing.** Make sure the shop is working to the correct drawing revision. Few problems are more disturbing than having a high-quality part machined to the wrong revision.
- **Determine inspection requirements.** Are there special inspection or gaging requirements? Are there tight tolerances that need to be inspected more frequently, or are tolerances too tight for your equipment capabilities? Can you meet the surface finish requirements? Let someone, such as a shop person, look at the drawing and that individual may see a problem or an opportunity for improvement.
- **Establish a customer promise date.** This is critical for customer satisfaction. Make sure everyone agrees with the delivery date. If delivering on time will be difficult, let the customer know immediately.
- **Allocate machines.** This goes hand-in-hand with the customer promise date and drawing review. When reviewing the drawing, determine the machine tools, workholding devices and other equipment needed for the project. If the job requires a heavily utilized piece of equipment, develop an alternate plan until that machine becomes available.
- **Determine tooling requirements.** Tooling needs should be covered during the drawing review. Is the required tooling in-house, or will it need to be ordered? Now is the time to act and order tooling.
- **Verify vendor requirements.** Can your shop do all the operations in-house, or do you need outside vendors? Again, determine this during the drawing review. If you do require outside vendors, get them involved as soon as possible.

These are just some highlights of the review process. Some shops may require more in-depth discussions, while others may require less. But one process review segment should be done by all shops—the post mortem. This is the actual vs. quoted process review.

The post mortem should be done as soon as possible after the project is completed, while everyone's memory is still fresh. Any elements that were difficult, costly or time consuming should be evaluated to develop possible solutions. Aspects that went well should also be reviewed.

About the Author

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Flat lapping basics

BY DR. LAROUX K. GILLESPIE

Lapping is a grinding process for polishing or accurately finishing a workpiece surface by abrasion using materials such as abrasive pastes or fine flourlike abrasive suspended in a liquid medium. For traditional flat lapping, slurry or paste compounds with loose abrasive are pressed or rolled into a flat metal or composite lapping disc. The individual abrasive grains protrude above the surface and perform the lapping. During processing, parts are continuously rotated and pushed down with a small weight over the lapping disc.

Lapping produces highly parallel and fine-finish components without introducing stresses and heat damage. This results in longer part surface life with improved sealing capability. Lapping effectiveness is a function of the lapping disc material, force between the part and lapping disc, abrasive material, abrasive size, cutting velocity and carrier fluid.

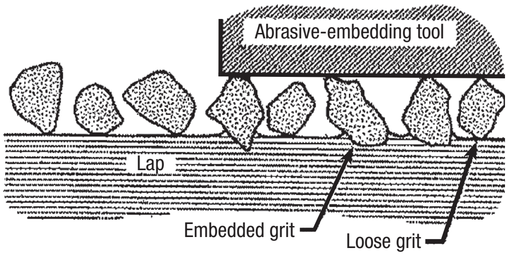
Flat lapping requires the workpiece to be rotated over the abrasive-laden master lap in ever changing patterns. This rotary motion with different paths provides uniform abrasion of the lap and workpiece and ensures part flatness. Lapping removes less than 0.0005" of stock to provide flatness to 0.000001", parallelism to 0.00001" and surface roughness values as fine as 0.6µin. R_a.

The disc material is softer than the workpiece so that the abrasive embeds in the disc and not the workpiece. Hard lapping discs cut slowly and impart dull finishes. If a cast iron lapping disc wears at 1 µm/min. for each $0.01mm^3$ removed from a part, cold-rolled steel discs will wear at 1.27 µm/min. and copper discs at 2.62 µm/min. While copper lapping discs wear faster, they also cut faster.

The carrier fluid serves to:

- Form a hydrodynamic film between the workpiece and lapping disc to avoid direct contact between the two solid surfaces.
- Pick up and transport abrasive grains to the active cutting area.
- Guarantee a homogeneous grain distribution.
- Cool and lubricate the disc and workpiece.

The carrier, or vehicle, fluids used include water-based gel, oil, water-



Metallographic Polishing by Mechanical Methods by Leonard E. Samuels

For traditional flat lapping, slurry or paste compounds with loose abrasive are pressed or rolled into a flat metal or composite lapping disc.

soluble oil, benzene and alcohol. Water-based gels are increasingly selected because of their cleaning ability and ease of waste removal. Additives are used in some solutions to reduce surface tension and to prevent packing of abrasive grains.

Fluid viscosity can be regulated with additives. Highly viscous fluids impart finer surface finishes, but they reduce metal-removal rates. Less viscous, or easier flowing, carriers are suited for high-speed applications. The lubricating function prevents scoring of the work and caking of the abrasive.

Silicon-carbide abrasive is used for lapping hardened materials, aluminum oxide for softer materials and diamond for precision work. (See the table on page 24.)

Abrasives with grains larger than 5µm are used for removing metal when lapping, while smaller sizes perform polishing. The variation in grain sizes affects the mrr and surface finish. The number of active grains increases with a decreasing standard deviation. Because more grains are cutting, the mrr is faster.

Abrasive is added in ratios of about 1:3 or 1:4 to the carrier liquid to make slurry. Diamond is applied in amounts of about 10 carats per liter for lapping glass and ceramic materials.

Path velocity—as opposed to machine spindle velocity—and the pressure between the part and lapping disc are the two primary variables once the lapping abrasive and carrier fluid are chosen. At path velocities above 150 m/min., aquaplaning occurs, which pulls the grains away from the workpiece. The mrr is directly proportional to path velocity and pressure as long as the pressure is below the workpiece material-dependent critical pressure.

About the Author

Dr. LaRoux K. Gillespie is a manufacturing engineer, writer and past quality-assurance manager with a 40-year history of precision part production and research. He is the author of 11 books on deburring and 200 technical reports and articles on precision machining. He can be e-mailed at laroux1@myvine.com.

Typical lapping combinations. (See article beginning on p. 22)

Abrasive	Carrier	Workpiece	Comments
180- to 800-grit silicon carbide	Oil or water-based gel	Hardened steel	For normal lapping
1,000-grit Al_2O_3	Oil or water-based gel	Steel	For high luster and cutting
1,200-grit Al_2O_3	Oil or water-based gel	Steel	For high luster and polishing
180- to 1,200-grit Al_2O_3	Oil or water-based gel	Nonferrous metals, soft steel and stainless steel	
700-grit Al_2O_3	Oil or water-based gel	Glass and ceramic	For cutting
900-grit Al_2O_3	Oil or water-based gel	Glass and ceramic	For finishing
Diamond	Oil	Steel	Precision lapping of all types of dies and molds and polishing of optical, ceramic and electronic components
Diamond	Water-soluble oil	Steel	Polishing of tools and dies prior to CVD or PVD nitride coating; there is no impregnation by the compound into the substrate prior to coating

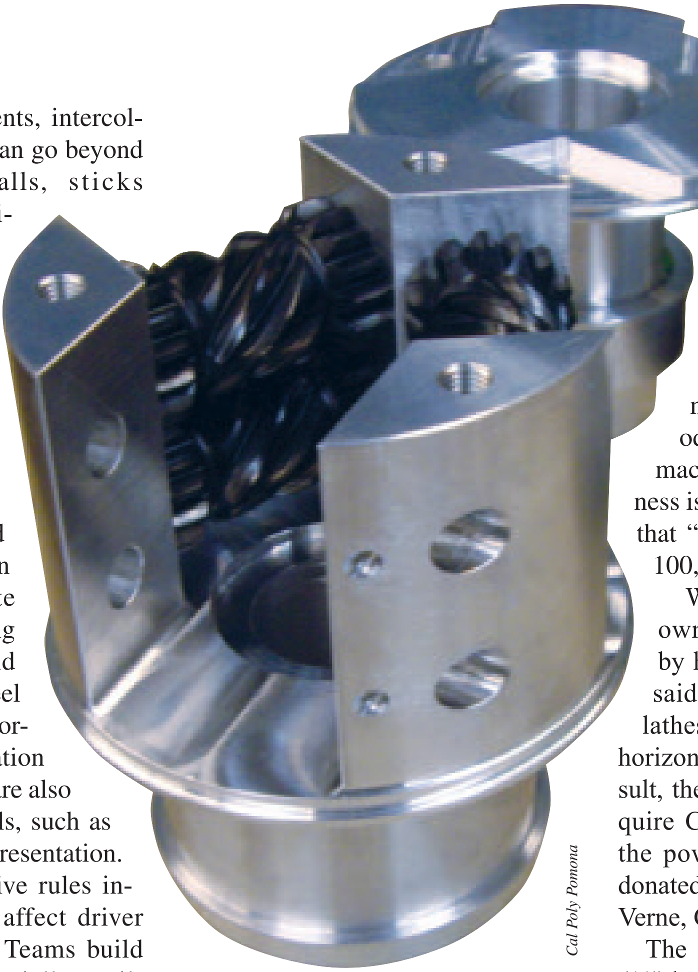
Learning fast

BY BILL KENNEDY, CONTRIBUTING EDITOR

For engineering students, intercollegiate competition can go beyond games played with balls, sticks and pucks. Future engineers, for example, use carbon fiber, aluminum, steel and computer chips to compete in the Society of Automotive Engineers' Formula SAE (FSAE) racing series. For nearly 30 years SAE has sponsored and regulated competitions between teams of undergraduate and graduate engineering students to design, build and race small open-wheel cars. The teams face performance tests for acceleration and endurance, but they are also scored on other key skills, such as cost control and design presentation.

FSAE's most restrictive rules involve components that affect driver safety, such as frames. Teams build their cars using commercially available parts, modified versions of existing components or unique parts that they make themselves. For example, the FSAE team from California State Polytechnic University (Cal Poly Pomona) machined its own housing for the gears that make up the car's Torsen (torque-sensing) slip-limiting differential. The differential proportions torque between driven wheels to manage traction and maximize available horsepower.

Torsen patent holder JTEKT Torsen North America Inc., Rochester, N.Y., produces—at a discount price for FSAE teams—a "university special" version of its differential, housed in a 1080 steel casting. However, Dustin Torkay, the Cal Poly Pomona team's design captain, said the team made its own housing from 7075 T6 aluminum to reduce weight. "A lot of this competition is about keeping the weight down," he said.



Cal Poly Pomona

This one-of-a-kind housing for the Torsen differential of the Cal Poly Pomona Formula SAE racer, shown before hard anodizing and with two of three gear sets in place, was machined from 7075 T6 aluminum.

JTEKT Torsen supplies a drawing with each differential, and Torkay used that as the basis for a SolidWorks CAD model of the new housing, incorporating specific changes for the racecar. "I translated them into CAD, tightened most of the tolerances and made a couple changes here and there," he said. For example, the original differential, based on an Audi unit, is driven by a spline shaft. The racecar features a chain drive via a sprocket, so the splines in the housing can be eliminated.

Torkay noted that 7075 T6 aluminum is stronger than cast 1080 steel, as measured in kips per square inch. "The yield strength of 7075 is about 75 ksi; for the 1080 steel it's about 60 ksi," he said. The aluminum, however, lacks the steel's surface hardness. The solution was hard anodizing the aluminum part after machining. Torkay said the hardness is still lower than steel but noted that "we are not driving the car for 100,000 miles."

When the team machines its own parts, "anything we can do by hand, we do in-house," Torkay said. The college's shop has two lathes, four vertical mills and one horizontal mill—all manual. As a result, the team outsources jobs that require CNC machining, and much of the powertrain machining time was donated by Z Manufacturing Inc., La Verne, Calif.

The shop programmed the roughly 4½"-long × 4"-dia. housing in Mastercam Version 9. The first set of operations took place on a Femco WNCL-35 CNC lathe. The 6"-dia. workpiece was rough and contour turned at 1,000 to 2,400 sfm, with feed rates of 0.01 ipr for roughing and 0.007 ipr for contouring. Holes measuring 1" in diameter were drilled at 1,000 rpm and a 0.012-ipr feed. The operations on the lathe took about 8 minutes.

"On the CNC lathe, they turned it to the appropriate size, and then put it on the mill and machined out the spaces for the gears," Torkay said. The differential consists of three separate gear sets spaced 120° apart in the housing. Z Manufacturing reproduced that spacing on an Akira-Seiki SV-1000 3-axis mill by machining flats in scrap areas on the sides of the housing at 120° intervals. Gripped in a vise, the flats enabled the shop to accurately index the housing between operations and generate the correct spacing.

Thirty-four operations took place on the mill, including milling, contouring, drilling, reaming and tapping. Endmill diameters ranged from ⅛" to 1", and the tools were run at 100 to 800 sfm and 15 to 50 ipm. Drills from 0.136" to 0.3906" in diameter generally ran at 3,000 rpm. The mill work took about 25 minutes.

When the part returned to the Cal Poly Pomona shop, "we measured everything out, made sure everything was in spec, and then sent it to get hard anodized on the wear surfaces," Torkay said.

Weighing only about 450 lbs., a four-cylinder Suzuki GSXR 600 motorcycle engine powers the car, putting about 85 hp to the rear wheels. The high power-to-weight ratio is "a lot of fun," Torkay said.

In addition to building cars with sparkling performance, the teams must also hone more prosaic skills. Cost control is what makes engineering a profession rather than simply an art. Expenditures are totaled using SAE-developed standardized lists of typical material, machining and other costs. At a theoretical production volume of 1,000 units, the cars must cost $25,000 or less. As the cost moves down from the limit, a team scores higher. "Usually, making a lot of your own parts decreases the costs," Torkay said. "For example, we made our own wheel shells, which took quite a bit off the cost of the car. We went from a $19,500 car last year to $13,800 this year."

The teams are also scored on formal design presentations made to a panel of industry professionals, including engineers from major automakers. "They know their stuff," Torkay said. "You can't trick them too much. Some of them are alumni, so they know how the cars are built."

An undergraduate majoring in mechanical engineering, Torkay said building the cars has given him excellent background in hands-on shop skills such as welding and machining. "Pretty much everything I know I learned here," he said. In addition, he said all the team members "really get a lot out of FSAE, everything from learning about people to going out and getting sponsorships. It's something I'll never forget."

For more information about Cal Poly Pomona's FSAE team, visit www.csupomona.edu/~fsae or call (805) 405-4678. For more information about Z Manufacturing Inc., visit www.zmanufacturinginc.com or call (800) 643-7265. For more about Formula SAE, visit students.sae.org/competitions/formulaseries.

'Paper CAD'

BY BILL FANE

Parts manufacturers now have a way to electronically view and mark CAD drawings without having to buy copies of expensive CAD software.

In the days before CAD, drafting was done on paper. Parts were designed and drawn, and then copies of the drawings were sent to the shop to have the parts made. Sometimes the shop marked the drawings to indicate errors or to suggest improvements, and the shop sent those versions back to the originator. The shop seldom did any drafting.

For the most part, that's still being done. The difference is the shop now receives CAD files via e-mail or from a file server. This is much faster and more efficient, but the process presents a problem. The shop may need to buy one or more copies of pricey CAD programs just to view, print and mark files.

In addition to its usual DWG format, AutoCAD from Autodesk Inc., San Rafael, Calif., is able to publish a drawing in a read-only format called DWF. Autodesk originally called DWF its Drawing Web Format, but now refers to it as Design Web Format. It is a simpler format that was originally intended to allow users to post drawings to Web pages.

DWF files download much faster when recipients access them for viewing and printing using a free viewer supplied with AutoCAD. It is also available at www.autodesk.com/dwfviewer, but don't download it yet! There is a better option.

Autodesk used to sell a program that included capabilities beyond the generic viewer. Recently, the company renamed that program Autodesk Design Review and is offering it free at www.autodesk.com/designreview. This is the one for general shop use.

Autodesk Design Review opens DWF files and allows users to zoom, pan, freeze and thaw layers, and print all or portions of the drawing, but it will not permit editing of the underlying drawing. This should make a shop's customers happy because they can send design information without exposing their design content.

Another big advantage to DWF files is that they are smaller than DWG files and, thus, easier to e-mail. How much smaller? Typical DWF files are about one-quarter the size of their parent DWG files.

Autodesk Design Review has added functionality compared to DWF Viewer or DWG TrueView, both of which are available for free downloading. The latter two enable viewing and printing of DWG and DWF files, but Autodesk

Design Review lets you add red marks to the DWF file.

Autodesk Design Review also lets you add lines, rectangles, ellipses, freehand scribbles, text and callout clouds and tags. You can measure approximate distances and areas, and add approximate dimensions. I say "approximate" because DWF files do not extend to as many decimal places as the 14 or so used by AutoCAD. In addition, DWF files use the units setting from the original drawing, so an actual dimension of 3.5021373973" might display as 3.5". The dimensions may not be exact, but they will match the values shown in the original drawing.

Autodesk Design Review includes several predefined rubber-stamp annotations, such as approved, rejected and preliminary, and allows users to create custom ones.

Having reviewed a drawing and marked it up, users can send it to the shop or back to the originator. The originator can open the original DWG file and import mark-ups from the DWF. If a user clicks on a mark-up in a list, then AutoCAD automatically zooms to the applicable location in the drawing.

A DWF file is effectively "electronic paper." You can view, review, mark, scribble on, make copies of and return it to its creator like a piece of paper without access to a copy of AutoCAD.

As indicated earlier, DWF files are virtual pieces of paper, so AutoCAD creates them through its plot command. The user selects the DWF6e Plot.pc3 plotter in AutoCAD, supplies a file name and out it comes.

A cunning bit is that a single DWF file is not limited to containing a single drawing. It can contain multiple sheets, from multiple drawing files. A DWF file can also contain files created by most standard Windows applications.

As a result, a single DWF file can contain AutoCAD drawings, Word documents and Excel spreadsheets—all the documentation necessary to produce something, including the drawings, the process specifications and the work orders.

No matter if you are at a small job shop or the toolroom of a large manufacturer, you can make good use of Autodesk Design Review. It is often said that "you get what you pay for," but in this case it is worth considerably more than its free price. △

About the Author

Bill Fane is a former product engineering manager, a current instructor of mechanical design at the British Columbia Institute of Technology and an active member of the Vancouver AutoCAD Users Society. He can be e-mailed at Bill_Fane@bcit.ca.