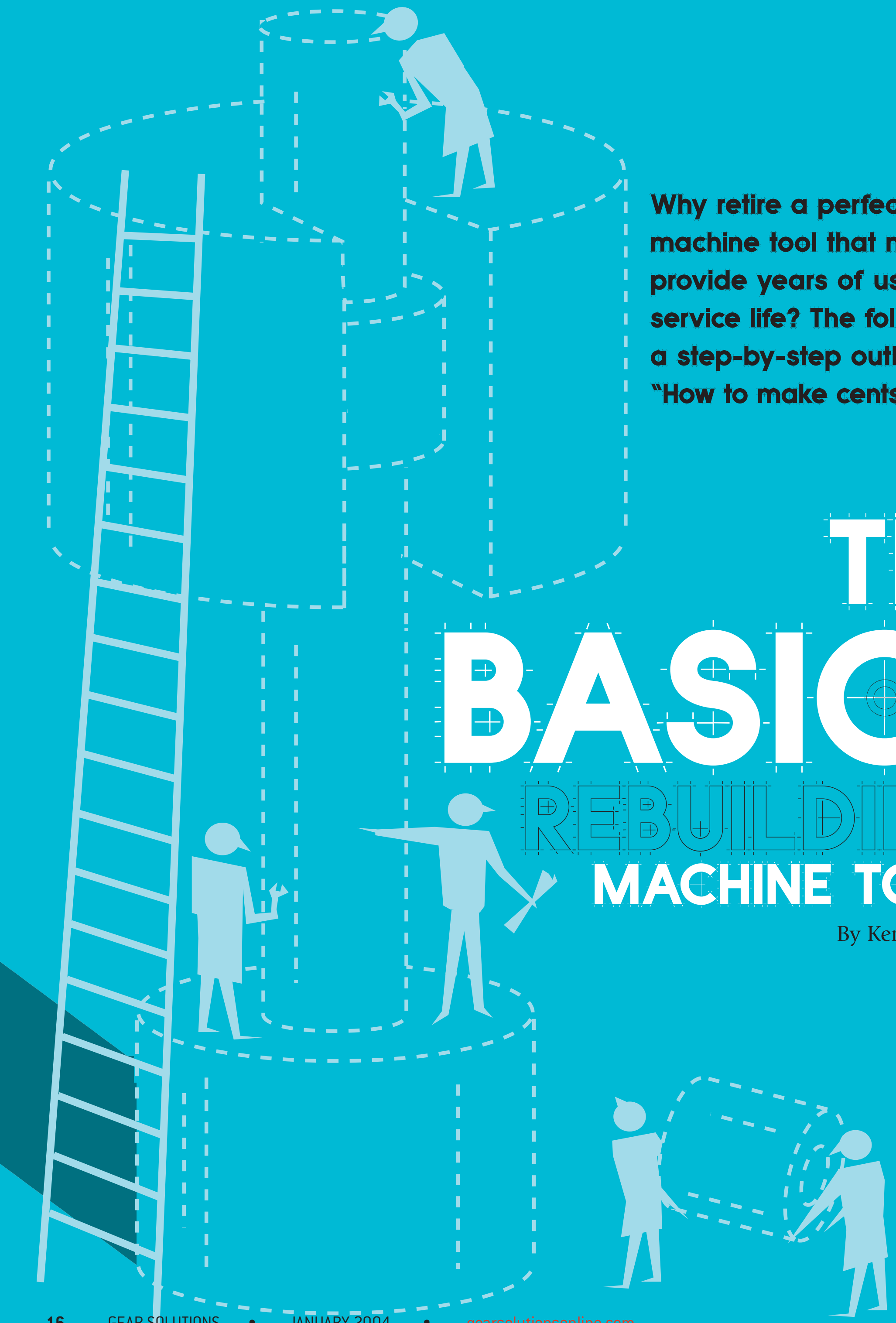


Why retire a perfectly good machine tool that may still provide years of useful service life? The following is a step-by-step outline of "How to make cents out of it."

THE BASICS OF REBUILDING MACHINE TOOLS

By Kenneth Flowers

Rebuilding a machine tool requires expertise in mechanical, hydraulic, lubrication, pneumatic, electrical, control, and coolant systems, as well as knowledge of the process the machine performs. The rebuilding process will require each of these systems to be disassembled, cleaned, inspected, and repaired or replaced as required. A complete rebuild process takes place in a series of steps, depending on the machine and its complexity. But, generally speaking, the process follows these basic steps.

1) Disassembly, cleaning, and inspection.
2) Engineering of software, electrical, mechanical, and fluid systems.
3) Ordering of the required parts.
4) Machine rebuilding.
   - Rescrape or regrind guideways, realignment verification of the slides.
   - Subassembly and electrical cabinet build.
   - Electrical and fluid system build and installation.
   - Painting of the machine, in


Subassembly, fully disassembled


Hand scraped surface

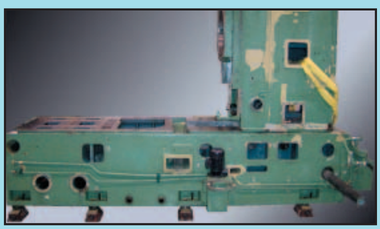
its disassembled state.
   - Reassembly of the machine.
5) Startup and debug.
6) Mechanical recertification.
7) Test cycling and initial test cutting.
8) Runoff and final testing.

Obviously, there is a significant number of details within each of the steps outlined above, and a small book could easily be devoted to the actual rebuilding process, but I will limit my discussion to a few key areas that I feel are among the most important in the rebuild process.

DISASSEMBLY

Any machine which is to be totally rebuilt should be completely disassembled into its individual parts. All the parts should be thoroughly cleaned and then inspected for wear, or other problems. No parts should be overlooked, or assumed to be okay and neglected. Thorough cleaning is required to insure that minute deficiencies are noticeable during the inspection, as well as to prepare the machine for the painting phase.

To speed reassembly, the parts should be categorized and photographed during the disassembly process. This simple step will save countless hours of questioning how something goes back together after it's been sitting on the parts shelf for two months. It also insures that your machine goes back together just as it came from the original manufacturer, not in some backward fashion, because the rebuilder did not know the proper reassembly order.


Fully disassembled bed

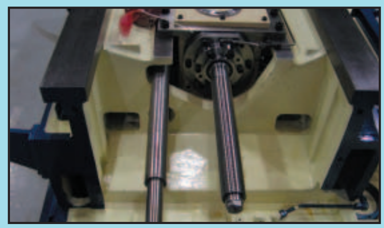
MECHANICAL

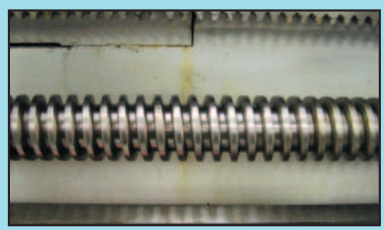
The mechanical portion of the rebuild encompasses not only mechanical but also hydraulic, lubrication, pneumatic, and coolant systems. Within each of these subcategories there are some key areas which should always be addressed in a good rebuild.

GUIDEWAYS

The machine guideways are one of the most important aspects of the rebuild. The process for refinishing the guideways differs, depending on the machine construction. On older machinery, many times you will have cast iron on cast iron construction. This type of design requires hand scraping to properly match the two mating surfaces for even contact, and to achieve parallelism and perpendicularity to the other ways. Hand scraping is a highly skilled trade that requires years of experience at which to become proficient. Two key indicators of a quality scraped surface are the proper bearing area and pattern, plus the final alignments that are achieved. A commonly used standard for the bearing area is 10 to 15 contact points in one square inch, and it is conceivable that you could achieve 40 or more points, by a series of repeated fine scrapings. But, regardless of the number of points, the total contact area should be roughly 50-60 percent.

On newer machine tools, you may find hardened and ground guideways that are not scraped. With this type of construction there will generally be a low friction coating like SKC3, Moglice,


Recirculating ball screw


Acme screw

or Turcite on one of the mating surfaces. This low friction compound sliding against the smooth ground way surface has a very low coefficient of friction. This is highly desirable, especially on servo-controlled axes, where stick slip can be a problem. The low friction coatings can be replaced if required, and the ways reground for finish and alignment.

The last type of guideway is a rolling or linear way that utilizes a rolling bearing pack running on a hardened and ground linear rail. These types of guideways are generally replaced completely, and are never repaired.

LEAD SCREWS

Equally important to the rebuild are the screws that move the machine slides. There are two basic types in use today: the acme screw and the ballscrew. All modern servo-controlled machines are equipped with preloaded, recirculating ballscrews. Older mechanical machines will probably be equipped with acme screws. During the course of the rebuild, the screws should be removed and inspected. Both types of screws can be repaired if the damage is not significant, otherwise the screw should be completely replaced. During the replacement process, new thrust bearings should be installed on the screws to insure that no axial lash is present in the drive mechanism. Some acme screws require adjustment of the nut lash after installation. Be sure the vendor does not overlook these critical areas during the rebuild process.

WEAR PARTS

During the course of the rebuild, items that are considered to be "wear parts" should be completely replaced. These include, but are not limited to, all bearings, bushings, seals, and wipers. With the machine fully disassembled, there is no excuse for not replacing these items. There are exceptions to the rule, of course. This includes items which seldom move during the routine machine operation and may not require replacement of the bearings and bushings because they were hardly used and are still in "like new" condition. However, any rubber or felt parts like seals, wipers, or packing materials should be replaced in case of dry rot, even though they are not visibly worn.

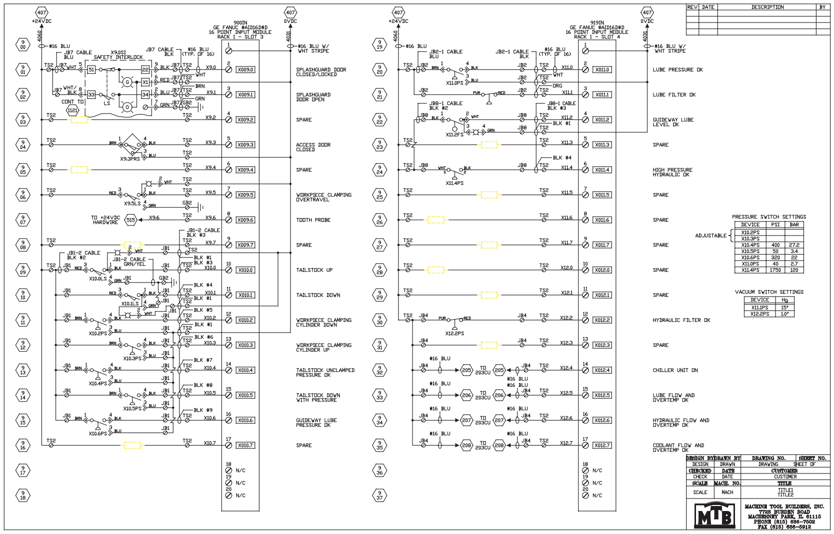
Parts such as clutches and brakes should be inspected closely, and probably replaced as a matter of caution. These types of parts are difficult to inspect because many of them are sealed units that cannot be opened or repaired. If in doubt, they should always be replaced.

GEARS

Machines that produce gears also require gears for their operation, and these gears must be inspected like any other wear item in the machine. Since gears do move constantly, the teeth, bores, and keyways can become worn. Some of the most critical gears within gear machinery are those that control the worktable rotation and the cutter rotation. Any errors in these gears will very likely show up as problems in the gears the machine produces. Inspection of the gear spacing and tolerances within the cutter spindle assembly and the worktable are crucial to the success of a rebuild. Adjustment of the lash for these gears during final assembly is equally important. An excessive amount of lash can manifest itself as spacing error on the gears produced by the machine.

ALIGNMENTS

Both during the rebuild and once it has been completed, alignment verification of the machine is critical. Check to verify that the parallelism and perpendicularity of the axes has been maintained, both as the ways are being refinished and after the machine is under power and capable of moving the slides via servo or mechanical control. There have been standards developed by the ISO and DIN organizations that define the allowable tolerances on these alignments. Most machine designs have an applicable standard that should be used to verify the alignments. For example, on gear hobbing machines, the standard is DIN ISO 6545 Acceptance Conditions for Gear Hobbing Machines—Testing of the Accuracy.



Detailed electrical drawing

ELECTRICAL

Design of the electrical system for the machine is a critical task, since it will control not only the operation of the equipment, but the safety of the operator and the machine itself. You should investigate the vendor to verify his ability to design a fully NFPA and OSHA compliant system. Proper control system architecture is required for the machine to function correctly and be safe to operate. The standards set down by OSHA and the National Fire Protection Agency—NFPA 70 National Electrical Code and NFPA 79 Electrical Standard for Industrial Machinery—are designed to supply the controls engineer with all the proper codes and regulations for a safe design. If your vendor does not use these standards, you should consider selecting another vendor.

Your electrical design should be done on a CAD system, rather than the old technique of hand drawing. It should be a thorough design, complete with identification numbers for devices, wire numbers, colors, sizes, and stock lists.

GENERAL CONTROLS

You have a choice in the selection of the general controls for your machinery. You can request the vendor to use Allen Bradley, Siemens, GE, or Square D equipment on your machine. Investigate the local sources you have for replacement parts and choose a manufacturer that has local stock. Bear in mind that a vendor may be able to offer you a much better price by selecting a certain manufacturer. This is more often the driving factor behind the vendor's choice of a particular manufacturer, instead of a technical reason.

CNC OR PLC CONTROLS

Generally speaking, the vendor will choose a PLC (Programmable Logic Controller) or CNC (Computer Numerical Control), based upon its capabilities. This is usually the case with gear machinery, because of the unique requirements these machines have. However, there is still some room for selecting a different manufacturer. There are just a few manufacturers of CNC controllers that are applicable to a fully servo-controlled gear machine to be found in this country. These include NUM, Siemens, GE Fanuc, BWO, and Allen Bradley. Of these five, Siemens and GE Fanuc are probably the best known. Although not as widely known, BWO (produced in Germany) and NUM CNCs (produced by Group Schneider, in France) are very powerful and economical systems that are easily applied on the simplest or most complex gear machinery. The presence of Allen Bradley CNCs on gear machines has dropped off significantly in recent years, and many new machine manufacturers or rebuilders do not commonly apply them.

Generally, the CNC manufacturer and model does not play a significant role in the final performance of the machine, unless a very specific feature like automatic stock division, synchronous tangential compensation, or custom interpolation is required. When these types of special features are required, some manufacturers have an edge over others, depending on the features needed. Your vendor should consider the requirements and choose the best control for the application.

SERVO SYSTEMS

An often-overlooked part of the control package is the servo system. The servos are the muscle behind the CNC's commands. I say "often overlooked" because so much emphasis

Typical conversational program screen

is usually placed on the CNC that the servos are something of an afterthought. There is at least one driving force behind this neglect: Most people assume that the CNC manufacturer will also be supplying the servo drives and motors. This is not always the case. When you are considering using NUM or Siemens, for example, you have the choice of using their servos or choosing servos from another manufacturer such as Indramat. However, if you are considering using a GE Fanuc system, you will discover that the GE Fanuc CNC must be coupled with GE Fanuc servos. Although there are exceptions, 90 percent of the time this is the case.

Not all servos are created equal. Performance, adjustability, and reliability are key factors in the selection of the servo system. The motors must have the proper torque and speed to move the axes at the required accelerations and speeds. The servo drives should have sufficient amperage for the motors and enough tuning parameters to correct for a variety of issues such as inertia mismatches, lash, and inherent response frequencies of the machine, plus full PID loop control. The motors and drives must also be highly reliable to insure they will survive the hottest summer days and will not succumb to the dirt, oil, and coolant contamination that is so common in many shops.

SOFTWARE

Software is probably the most underestimated aspect of an upgrade. Few people who consider performing upgrades stop to question how the PLC or CNC will be programmed. They simply assume the software will control the machine correctly. This is a sure recipe for disaster. Software architecture is a science, not a hobby. A sound software design can make a world of difference in the operation and safety of your machine. There are two types of software that are present in a machine, depending on the type of upgrade you are having performed.

PLC SOFTWARE

The PLC software is used to control the machine functions: things like actuators that go in and out, turning pumps on and off, monitoring fault and safety conditions, interlocking functions, mode selections, etc. It takes years of experience to refine the design methodologies required to produce a robust PLC program. You simply cannot produce a robust PLC program in a few days. When you couple the years of experience required with the fact that every manufacturer's PLC has a slightly different syntax, addressing scheme, and operational architecture, it becomes apparent that you need a highly skilled engineer to write the PLC program, and a database of well-written programs to use as templates.

One example of a robust PLC design is one that I call "event-driven fault and diagnostics." In this scheme the PLC logic is written to detect and catch every fault or warning. When a fault or warning occurs, the fault is used to display a message, and to stop the machine if required. Using this scheme, you can never have a fault that stops the machine without a message indicating why the machine has stopped. Another example of a good programming technique is called "operator prompting." If you have ever operated a machine and pressed a button, only to wonder why that button does not function, you know what I mean by operator prompting. Today's modern PLCs are so powerful that there is no reason why you cannot develop logic that informs the operator why he can or cannot press that button.

Development of these types of programming techniques requires a good deal of time. A vendor cannot afford to develop this type of program for every machine they upgrade, unless they routinely reuse code sections. Suppliers that are sole proprietorships, or that have few engineering talents, probably do not utilize these advanced techniques because of the time investment.

CNC SOFTWARE

This type of software can be further broken down into two main parts. The first part is how the operator enters the program data, and the second is the method used to turn the program data into the proper motions on the machine. Historically speaking, gear machinery software has been developed using what is called a "conversational" approach. In this type of design the operator enters the program data by answering a series of preprogrammed questions about his part, tool, and process. An intelligent macro program actually moves the axes in the proper sequence to machine the gear. This conversational technique is alive and well in today's modern gear machinery.

Consider for a moment the task of a rebuilder who is rebuilding a gear-shaping machine and will be applying a new CNC control as part of the process. To satisfy the demands of their customer, the rebuilder must supply a conversational program for this machine. The conversational software development time for such a machine can be measured in months, if not years. If the rebuilder doesn't already have software developed, they have a huge time and cost problem to overcome. Not to mention that you cannot develop such a program the first time and have it be fully tested and thorough enough to handle all the requirements on a particular machine. Developments of these types of conversational programs are evolutions, not revolutions. Be sure that any vendor you select is up to the task.

DOCUMENTATION

The final part of the rebuild process involves documentation. If you get a good rebuild done but end up with little or no supporting documentation, you will have future difficulties servicing the machine. At a minimum you should receive the following documentation.

- CNC and machine operation manual
- CNC programming manual
- OEM programming manual (conversational manual)
- Electrical schematics
- Mechanical drawings for assemblies and parts
- Lubrication drawings
- Hydraulic system drawings
- Coolant system drawings
- Software printouts of the PLC and CNC programs
- Parameter printouts
- CNC system option settings and firmware versions
- All the original machine mechanical drawings and parts books
- The CNC or PLC manuals
- The servo system manuals
- Complete software backup on CD-ROM or diskette
- All purchased component manuals and documentation

Although this article contains a variety of interesting topics on rebuilding a machine, there is simply not enough space to cover all the details that should go into a quality rebuild. Keep in mind when considering a rebuild that not all machinery rebuilders are created equal. Do not look solely at the price aspect of the rebuild, look very closely at the details, and ask a lot of questions. Hopefully the information contained here will be beneficial to you when investigating rebuilt machinery in the future.

For more information, visit the Machine Tool Builders Web site at [www.machinetoolbuilders.com].

About the author:

Kenneth Flowers is president of Machine Tool Builders: (815) 636-7502, or kflowers@machinetoolbuilders.com