Gear Software You Didn't Know About

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Designing and manufacturing gears requires the skills of a mathematician, the knowledge of an engineer and the experience of a precision machinist. For good measure, you might even include the art of a magician, because the formulas and calculations involved in gear manufacturing are so obscure and the processes so little known that only members of an elite cadre of professionals can perform them.

While it may seem like magic to the rest of us, no gear engineer can pull an involute out of his hat. The fact is that most of gear design and manufacturing is hard work, attention to detail and trial and error.

But wouldn't it be nice if someone invented a magic wand to take away some of the drudgery?

The computer revolution promised calculations at the touch of a button and design by menu. For many applications, that promise has been fulfilled. However, if you've ever gone shopping for gear software, you've probably found that there isn't much to choose from.

The gear market is so small that mainstream software developers have largely ignored it. But gear software is out there, if you know where to look. Most of it has been designed by gear shops, research institutions, independent consultants and universities for their own use. We suspect that many more shops have designed their own software but don't offer it for sale.

What we found comes in a variety of price ranges and performs a variety of functions. Some packages use text-only displays, while others have very detailed graphics and animation. We make no judgments about how useful any of this software is. We leave that to you.

For the Shop Floor

Sometimes the simplest programs can save time and make employees more productive. Calculating a gear's correct measurement over wires with a calculator and involute charts is a tedious project that no one enjoys.

Worrall Grinding Company, Anderson, CA, created a program called *WireSize (Version 1.0)* to make the calculation fast and simple.

"We wrote it out of necessity," says George Worrall, president. "It's really handy to use in the shop. If you do it on a calculator, it takes about an hour and a half. With this program, you could have the secretary do it."

WireSize uses the Zahorski long method to calculate wire sizes for spur or helical gears using information that can be taken directly from specifications on a drawing.

For example, after you enter the number of teeth, diametral pitch, pressure angle and amount of backlash, the program will give you values for involute check, pitch diameter and wire size, as well as theoretical measurement over wires and measurement over wires with backlash.
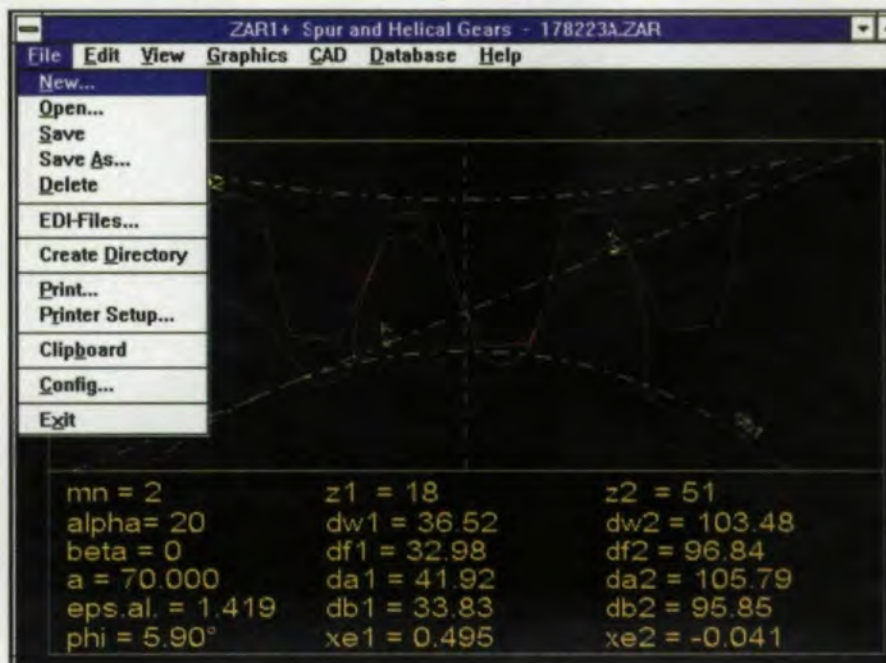
WireSize has limited error-detecting capabilities. For example, it will tell you if the calculated measurement over wires is larger than the outside diameter of the gear.

In addition, the program gives instructions to enable the person on the shop floor to make a second cut if the initial measurement over wires is bigger than the computed value. Simply enter the actual measured value, and the program will return the required depth of cut to achieve the correct measurement.

WireSize is a DOS-based program for IBM-compatible PCs, available on either 3.5" or 5.25" diskettes. It costs $25. According to the Worrall Grinding Co. Internet page, found at *http://www.snowcrest.net/wgc/software.htm*, the Windows version should be available around the time of this printing.

Gear Shareware

It seems everyone has a Web page these days. In fact, most of the software packages in this article were found by

The graphic display of *ZAR1* shows gear teeth in mesh.

GearCAD includes modules for cutter design and measurement over rollers.

doing research on the Internet. However, we were able to find only one piece of gear shareware.

GEARGEN, from ATS Software, Gouverneur, NY, was created as an aid for designing and manufacturing electrodes to cut the molds for die-cast gears. It has developed into software that can be useful in designing the gears as well.

The user can enter the number of teeth, diametral pitch and pressure angle to specify the gear he or she wants. Pressing the "Generate Gear" button causes the program to mathematically hob the gear form using the values entered. The program will return values based on ANSI B6.1-1968 and other standards for pitch diameter, outside diameter, root diameter, fillet radius and normal circular tooth thickness.

After the gear form is generated, the user can plot it on a printer or view it on screen to see the effects of changing the root radius, pressure angle or addendum. In addition, the form can be saved to disk in XY format or DXF format, which can be read by most CAD programs. Also available is a G-Code format, which can be used as toolpath instructions for a machine tool.

GEARGEN can also calculate the measurement over wires and wire sizes to be used for a given gear.

After calculating a gear form, the user can generate a second form, which corresponds to a mold cavity to be used to create the gear. This step includes an option that allows the user to compensate for shrinkage. From the mold cavity, you can generate a "cut plot," which can be used to create the EDM electrodes that will cut the cavity of the mold.

GEARGEN assumes a working knowledge of gear forms and machining operations. In many cases, the user is required to perform calculations and enter appropriate values. For example, the program offers pressure angles of 14.5, 20 and 25 degrees from the menu. While you can enter other values for the pressure angle, you have to calculate the responses yourself. However, from there, you can still have the program calculate wire sizes and mold and electrode forms.

GEARGEN is shareware, which means you can download the program in its entirety from the Internet. We found it at *http://www.shareware.com*. If you try the program and like it, a licensed version is available from ATS Software for $79.

Engineering Aids

While software can certainly help gear manufacturers by performing routine calculations on the shop floor, it can also save time and improve accuracy by helping the gear engineer perform some of the more complex calculations involved in design.

The Engineering Toolbox, from UNIK Associates, Brookfield, WI, is an electronic library of 101 programs for engineers.

The gear-related calculation modules included in the package are for helical, bevel and worm gear forces, involute spur gears, gear outside diameter, three-gear drives and worm lead.

For the helical gear force program, the user enters the input torque, pitch radius, helix angle and pressure angle. The program gives tangential force, radial force and force parallel to the axis. The results can be printed.

In addition users can view help screens that show the formulas used as well as sample input and output.

Also in the package are many generic engineering modules, including frustrum of a cone, fluid pressure on a piston, torsional stress on a shaft and Ohm's Law.

Engineering Toolbox costs $295. You can download a free demonstration version at *http://www.unik.com/unikeng.html*.

Beyond Calculation

At some point, a gear engineer needs more than a program that plugs values into formulas and spits out results. He or she needs something that will help design stronger, quieter or longer lasting gears.

One source of such gear design software is ESDU International plc in London. The company's "Data Items" are comprehensive handbooks on a variety of engineering disciplines, which are compiled from the latest standards and field data. Most of the data items are presented as printed handbooks, but many are supplemented by computer programs. The data items are available on an annual subscription basis.

Part of the company's sub-series on tribology, "Dimensions, Deflections and Stresses for Hertzian Contacts under Combined Normal and Tangential Loading" is the title of one computerized Data Item that would be of interest to gear engineers. The program locates critical stress points on rolling bearings, cams and gears for failure prediction.

The cost of the data item is $875 per volume per year, with a minimum order of $2625, which is the equivalent of three volumes for one year or one volume for three years.

ESDU also offers third-party software for the design of spur and helical gears according to AGMA, ISO/DIN or British standards. These programs are sold outright for £950 each.

Mechanical & Structural Design & Software has about a dozen gear and spline design programs that will provide complete manufacturing and inspection data, stress analysis and life ratings.

The company started writing gear software about 25 years ago, says Laszlo Keves, director of engineering. Originally programmed in FORTRAN, all programs are now written in BASIC and can be run on IBM-compatible computers.

Gear-related programs include packages for spur, helical, straight bevel, spiral bevel and hypoid gears. In addition, MSDS offers programs for simple epicyclic spur and helical gear trains, involute splines, roller bearings, threaded fasteners and helical compression springs.

The programs have very limited graphics capabilities, but the company plans to put more graphics into its software, Keves says.

MSDS software costs between $500 and $1000 per module, depending on the exact modules the customer requires.

Space Age Gears

For almost 30 years, the U.S. government has released computer software to the public through COSMIC, NASA's Software Technology Trans-fer Center located at the University of Georgia.

Software developed for use in the space program and software written at the NASA-run armed forces research centers around the country have been released over the years. In the past five years or so, some gear-related software has become available.

TLIFE — Spur, Helical and Spiral Bevel Transmission Life and Reliability Model estimates life, dynamic capacity and reliability of aircraft transmissions,

Screens from *GearCAD* (above and below, left) show gear geometry elements in different colors. *ZAR1+* comes with a materials database (below, right).

enabling optimization of transmissions during the design stage.

The analysis provided by the program is based on the two-parameter Weibull distribution lives of the component gears and bearings. Input and results can be formatted in either metric or English measurement units.

You can analyze spur, helical and spiral bevel reductions, as well as combinations of these reductions. Basic spur and helical reductions included in the program are single mesh, compound mesh and planetary gear trains. A variety of reduction types is also available for spiral bevel gear sets.

TLIFE was just released for public purchase in 1996. It is available for a variety of platforms and systems. It has been successfully implemented on IBM-compatible PCs and UNIX workstations. Cost is $500.00. Documentation, including user instructions and method of solution, can be purchased separately for $40 for evaluation purposes.

DANST (Dynamic Analysis of Spur Gear Transmissions), another NASA release, was developed in 1993. It can be used for parametric studies to predict the effect on dynamic load and tooth bending stress for spur gears due to operating speed, torque, stiffness, damping, inertia and tooth profile.

DANST calculates the properties of system components and substitutes them into the governing equations to solve for dynamic tooth loads and tooth bending stresses. The model includes driving and driven gears, connecting shafts, motor and load. The equations of motion were derived from basic gear geometry and elementary vibration principles. The dynamic solution is found by integrating the equations of motion.

DANST allows users to choose from a variety of gear materials, basic gear geometries and operating conditions. Users can also choose from a number of combinations of tooth profile variations and user-digitized profile modifications.

Three standard forms of tip relief are included among the tooth profile options.

The program is available from COSMIC for $500. It is provided in source code format so you can make changes. It runs on workstation-level computers. You may purchase the program documentation separately for $18. This will give you user instructions and an overview of the method of solution, as well as sample input and output.

Information about the NASA programs is available on the Internet at the COSMIC web site, *http://www.cosmic.uga.edu*.

Gear Design Systems

If you're looking for a complete gear design package, it might pay to extend your search outside the United States. We turned to Australia and Germany for two fairly comprehensive gear design packages.

GearCAD, by GearSoft Design, Lane Cove, NSW, Australia, is a complete gear design system written for IBM-compatible PCs. It includes calculations associated with the geometry of involute gears for the design of spur and helical gearsets. Some of the advanced features of the program include adjustable addendum, nonstandard center distance, selectable backlash, tooth sizing and load checking.

When designing spur gears, *GearCAD* allows the user to choose module, Fellows stub tooth or diametral pitch formats in external, internal or planetary configurations. The gears are graphically displayed on screen, and changing one or more basic parameters will cause the gear to be redrawn instantly.

Users can also use the zoom command to check for interference. Pressing a key will cause the gears to rotate in mesh. The display identifies each of the following by a different color: pinion, gear, pitch circle, outside/inside diameter circles, root circle, base circle, trochoidal fillet, line of action, start of involute profile circle, undercut circle, start of active profile and maximum allowable outside diameter.

"Our goal in developing GearCAD was to adopt the visual design concept," says Stan Koci, manager of GearSoft Design. "We wanted an easy-to-use program, simple enough for the occasional gear designer, but with the power for the very experienced designer."

Sub-windows include cutter selection, preliminary estimation of tooth size, center distance & gear ratio approximation, permissible load approximation, measuring roller calculation and AGMA geometry factors J and I.

The visual design concept makes the program an ideal teaching aid, says Koci. For example, if the user changes from a hob cutter to a 15-tooth pinion-type cutter, the designer can visually examine the effects on the SIP, root diameter, fillet radius and interference.

GearCAD includes many warning messages in case certain geometry parameters go outside permissible ranges. For example, if interference exists between the tips of the pinion teeth and the internal gear teeth as the teeth go out of mesh, the program will bring up a warning message that tip interference is present. Likewise, *GearCAD* will let you know if the operating pressure angle or the backlash is too large or too small.

Designs created can be printed or saved to disk in DXF or XY file format for use in CAD/CAM programs. The software comes with a detailed manual, including gear terminology, formulas used for calculations and examples of specific design problems and how they are solved with the software.

GearCAD Release 2.8 sells for approximately $1100. It is written for DOS but can be run under Windows 3.1, Windows 95 or Windows NT. A module for spiral gears is not yet completed.

Another comprehensive gear design package, *ZAR1 Gearing Calculation Software*, comes from Hexagon Mechanical Engineering Software in Germany. The program calculates geometry and strength of external and internal spur and helical gears with involute teeth in conformance with DIN 3960, 3961, 3967 and 3990.

Once the user has entered the pressure angle, helix angle, normal module, number of teeth, face width, addendum modification and center distance, *ZAR1* calculates complete gear geometry, tool dimensions and contact ratio factors.

After the basic gear design has been calculated, the user can enter a gear quality level and tolerance zone to determine the final gear data, tooth thickness, back-lash and measurements over balls or pins. In addition, *ZAR1* will calculate the load-bearing capacity with respect to tooth root fatigue, fracture and pitting.

ZAR1 comes with special windows for designing planetary gear trains and special profiles. It comes with a database interface that allows the user to select materials used for making the gears. The extended version, *ZAR1+*, comes with a materials database built in. Otherwise, users can develop their own dBase-style database of materials.

The graphic display of *ZAR1* draws the gear form on screen. Users can see the tooth form as generated by a simulation of the cutting tool action. In addition, the gears in mesh can be shown in animation.

ZAR1 can be integrated with most CAD/CAM programs through its DXF and IGES interfaces. The program generates drawings of the front and side elevations of the gears calculated, as well as tables containing the gear data and dimensions.

ZAR1 runs on IBM-compatible PCs using MS-DOS 3.1 or higher. The price is $1306 for *ZAR1 or* $1450 for *ZAR1+* with the materials database included. A demo version can be downloaded on the Internet at *http://www.hexagon.de/zar1_e.htm*. There you can also find information about distributors of the software and additional programs available, including *ZAR2*, a similar program for bevel gears that sells for $1033. ✪