# Gear Teeth With Byte

*Your guide to software for gear design, manufacturing and inspection.*

**William R. Stott**

Computers are everywhere. It's *gotten so* that it's hard to find an employee who isn't using one in the course of his or her day—whether he be CEO or salesman, engineer or machinist. Everywhere you look, you find the familiar neutral-colored boxes and bright glowing screens. And despite the gear industry's traditional reluctance to embrace new technology, more and more of what you find on those screens are gears.

Most of you are probably aware of a few software programs out there which are designed for gears. Some of you may even have them. But the rest of you have probably scrambled and struggled and scratched out your own code to create routines that would enable you to perform the calculations required to design, manufacture and inspect gears.

You may be surprised to realize that there's a lot more gear-specific software out there than you knew about. It ranges in quality and ease of use, and it ranges in price. We've included as much information as possible in this article without making judgments about which is better. If any of you are interested, we hope you'll take the time to contact the companies directly and find out more about their products.

## Who is Included?

The companies mentioned in this article all currently sell their software to the general public. A number of consultants, universities and others have gear design, analysis and manufacturing software which is available only to clients, customers or through other means.

For example, the Gear Dynamics and Gear Noise Research Laboratory at Ohio State University has developed a *Load Distribution Program* and a variety of other computer programs. *LDP* computes the load distribution, root stresses and transmission error for helical and spur gears. However, the Ohio State software is available only to the companies that sponsor the gear lab.

Complete contact information for each company mentioned in this article is available in the 1998 Gear Industry Software Buyers Guide, which you can find on pgs. 26–31. In addition, this article can be found on *The Gear Industry Home Page™* at www.geartechnology.com. The online version will include hyperlinks to the Web sites of companies who have them.

Unless otherwise noted, all software mentioned in this article runs on DOS-based PC computers.

## Manufacturing Software

Software for gear manufacturing falls into two very
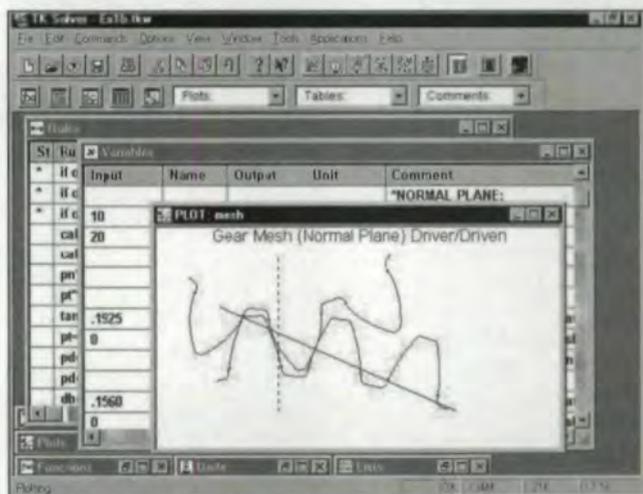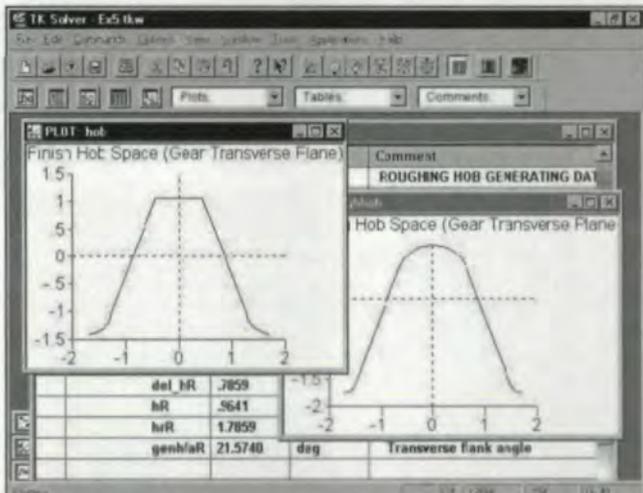


Universal Technical Systems now offers its programs for the Windows environment. Above: *Program 60-411, Hob Cutting Pattern for External Involute Gear* (top) and *Program 60-400, External Gear Line of Action Tooth Plot* (bottom).

broad categories: general shop management and gear-specific production and inspection software.

General shop management software includes very comprehensive factory floor software that would be useful in any medium- to high-volume manufacturing environment. These systems can tie together the usually separate functions of accounting, administration, engineering and production. Some will hook right up to your machine tools or tie in to a jobbing bar code system so that the salesman or manager in the corner office knows exactly where a particular part is in the production cycle.

This type of software allows management to keep track of people, machines and materials to shorten production times, reduce inventory and cut costs. Some packages are geared toward statistical process control and
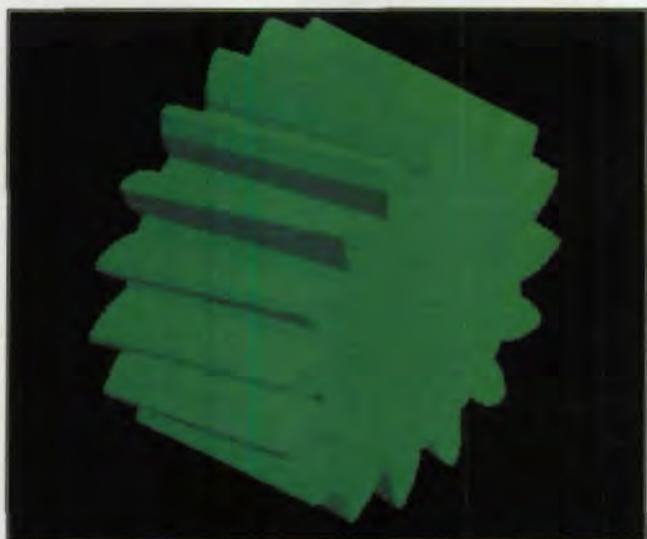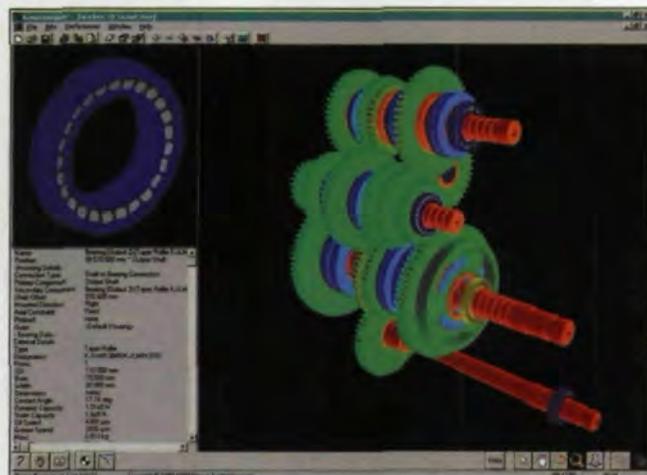
| Name: | Output Pinion [Di ▲ |
|---|---|
| Position: | @ 219.500 mm ˆ |
| Name of gear: | Output Pinion |
| | |
| **GEAR GEOMETRY** | |
| Number of teeth: | 16 |
| Gear type: | external, helical |
| Normal module: | 2.45 mm |
| Normal pressure angle: | 20.00 deg |
| Helix angle: | 20.00 deg left |
| Addendum mod. coeff: | 2.5128e-1 |
| Generating addendum mod. coeff: | 2.5128e-1 |
| Diameter for tooth thickness measurement: | 41.716 mm |
| Nominal normal tooth thickness: | 4.297 mm |
| Nominal transverse tooth thickness: | 4.572 mm |
| Tooth thinning factor: | 0.0 |
| Actual normal tooth thickness: | 4.297 mm |
| Actual transverse tooth thickness: | 4.572 mm ▼ |
| Measurement over/between balls: | 49.994 mm |

Romax Technologies offers its *RomaxDesigner* software for solid modelling of power transmission systems. Separate windows for the model and the design data allow the user to see instantly the changes made. *Romax-Designer* includes modules for bearings, gears, power takeoffs, belt & chain drives and differentials.

will provide all the documentation required for compliance with ISO 9000 or other standards. Others are geared toward cost estimation and production cycle times. Some will combine these functions with billing, shipping, purchasing and other functions to provide a "man-

ufacturing central," from which the entire operation can be run.

Examples of this type of software come from Alliance Manufacturing Software, BizSoft Corp., DataNet Quality Systems, Job-Boss Software, Micro Esti-mating Systems and many other manufacturers. Prices range from around $5,000 to $25,000 or more, depending on the complexity of the system and the number of connections or users.

There is also a great variety of shop floor software available that is tailored more specifically for the gear manufacturer. Most packages are available through machine tool suppliers, or they have been written by people at individual gear shops to calculate machine setups, figure out the correct measurement over pins or wires for a particular gear or to determine the appropriate hob or shaper cutter to use to cut a gear.

**American Pfauter, L.P.** offers its *Hobtime*® software for estimating hobbing cycle times based on material, hardness, hob and machine type. The user can enter specifications on the gear he wants to cut, and the program will suggest the best hob from his inventory or recommend suitable hobs available from Pfauter-Maag Cutting Tools, L.P. In addition, the program will recommend appropriate speeds and feeds for the parts in question. The "Gear Assistant" function will translate tolerance values and/or class levels among AGMA, DIN and ISO standards. Cost: $249.95.

**Ash Gear & Supply** is the exclusive distributor of *CPC-HOB*, a program for

determining hobbing machine setup for spur and helical gears on differential and nondifferential hobbing machines. The program keeps information on all of your hobs. The user enters gear specs to determine appropriate change gears and other setup information. Useful for determining setup when cutting unusual gear angles or when you don't have the change gears called for by your usual setup. Cost: $600.00.

**Bourn & Koch Machine Tool Co.** offers its *Gear Manufacturing Program*, which calculates index and feed gears for spur and helical gears using nondifferential hobbing machines. It also estimates production cutting times and provides measurement over pins. Cost: $495.00 for each index constant and feed constant.

Bourn & Koch's *Four Gear Ratio Program* determines specific four gear ratios using change gears from 20 to 100 teeth. The program will calculate the gear ratios with allowable programmed error, and it will produce a hard copy. Cost: $100.00.

Bourn & Koch's *Gear Size Measurement Program* is used to obtain the span measurement for specific tooth thickness tolerances of spur and helical gears and splines. The user can also enter the span measurement to obtain the tooth thickness, which can then be used to determine the measurement over pins. Cost: $495.00.

Finally, Bourn & Koch's *Production Estimating Program* estimates the production cycles for hobbing spur, helical and worm gears or for shaping spur and helical gears. Cost: $200.00.

**GB Gear Shop Tools** sells a suite of programs designed for use on the shop floor. *BOOK* is a computerized collection of basic gear manufacturing information and formulas. The program will determine recommended backlash by pitch, amount of oversize allowance for pre-shaving and index gears for some of the popular index constants. Cost $40.00.

*HOBCYCLE*, also from GB Gear Shop Tools, calculates the hobbing cycle and length of cut for approach, rough and finish operations. It can also be used to determine gear grinding cycles. Cost: $35.00.

*HS-CALC* will determine complete manufacturing data for a gear set operating on a non-standard center distance. Cost: $40.00.

One of GB's most popular programs is *DIFFERS*, according to owner Eugene Beson. This program calculates the required ratios to hob helical gears on nondifferential machines. Cost: $45.00.

**R.H. Software** sells a program called *Gear Professor*, which is used to calculate index gears and feed rates for nondifferential hobbing machines and change gears for differential hobbing machines. The *Gear Professor* also calculates internal and external measurements over pins. Cost: $95.00.

R.H. Software also makes custom accounting packages for gear manufacturers. Designed to run on workstation-level systems (but currently being reformatted for the Windows 95 platform), this software tracks shop time for billing and places parts in inventory for future use. Parts can be looked up by customer or by gear specs. Cost: Varies.

**Software Engineering Service** provides software that focuses on gear tool geometry, gear manufacturing and gear inspection. *HOBIT* software calculates change gear setups for hobbing machines or thread mills. It will find optimum helical setups for machines with or without differentials, and it comes with a library of popular machines. Cost: $250.00

**Worrall Grinding Company**'s *WireSize version 1.2* calculates the size of wires for measurement of helical and spur gears with odd or even numbers of teeth. It uses the Zahorski long method so there is no need for tables, and it automatically calculates for backlash. Cost: $25.00.

## Gear Geometry Software

Software for calculating gear geometry can be useful on many fronts. On the shop floor, it can provide important measurement data, such as the appropriate measurement over wires or pins. For the tool designer or engineer, the geometry can help determine the appropriate cutting tool for a particular part. Of course, the geometry of the gear is of obvious importance to the gear designer. Because many of the calculations are automated, this type of program saves time for any gear professional.

**Ash Gear & Supply Co.**, a distributor of cutting tools, created the *GCP2 Gear Calculation Program* for its primary customer base of gear job shops. "If someone gives them a mystery gear, they can take some measurements and figure out all the specifications to make a new
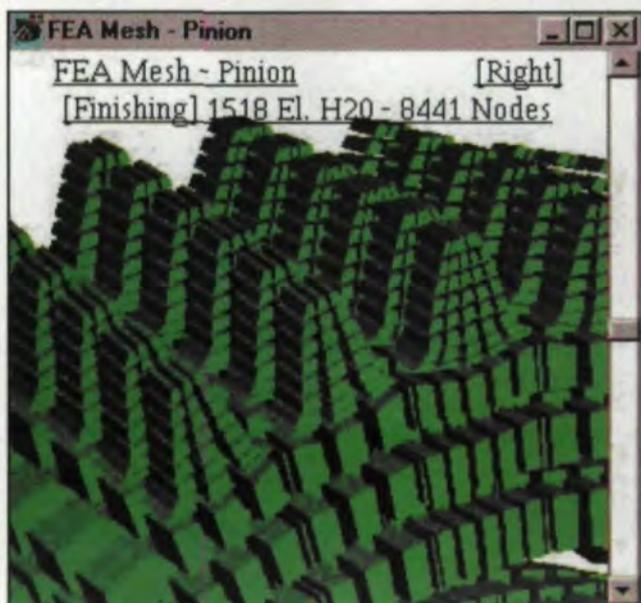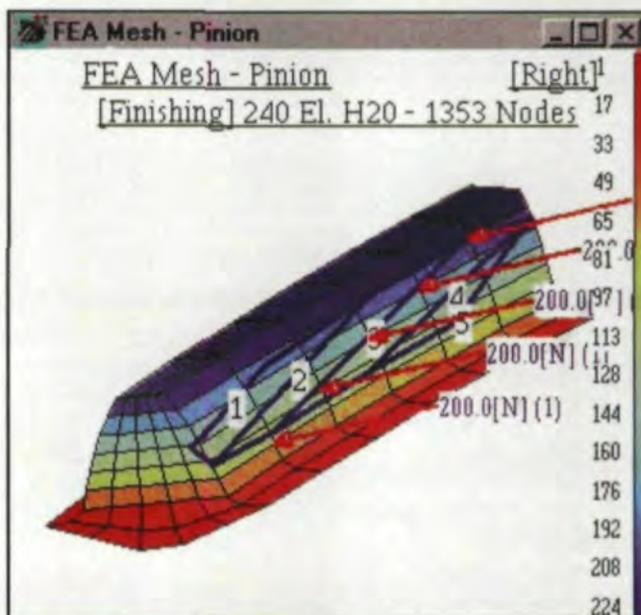


HyGEARS software from Involute Simulation Softwares includes modules for the finite element analysis of gears.

## GEAR SOFTWARE

one," says engineer Scott Atkinson.

*GCP2* handles the geometry of external and internal spur and helical gears, worm gears, racks and straight-sided splines. It allows you to choose from six AGMA standard depth systems. Some of the calculations included are land at major diameter, base tooth thickness, apex of gear, operating pitch and pressure angles, long and short addendums and helix angle at any diameter.

*GCP2* also has limited graphics capabilities. The user can press a key to view the space between two teeth to check for interference.

**CIMLOGIC** specializes in creating applications to be used within the popular AutoCAD system. *Power Transmission* streamlines the design and selection of cams, sprockets and gears within the AutoCAD environment. The user can specify gear requirements, including design diameter, surface speed, rpm, number of teeth and ratio, and the program will select and draw the gear based on AGMA standards.

*Power Transmission* can be used as a stand-alone or integrated with CIMLOGIC's *Toolbox* or *Toolbox Professional*, which are 2D and 3D geometry enhancement packages for AutoCAD. Cost: $495.00 for stand-alone; $1070 with *Toolbox*; $1340 with *Toolbox Professional*.

**PC Enterprises** offers its *GearShop for Windows* software, which will "design anything with an involute flank," says president Peter Conley. The program is a graphical gear design tool that animates gears in mesh to show whether there will be interference, backlash or undercut in the mesh.

*GearShop for Windows* will not calculate stresses or load factors for the gears, but it provides a complete geometry check of the gear train and creates DXF files for export to a CAD system.

The program is useful for fitting a gearbox in a particular space where shaft length and center distance are known, says Conley.

**Software Engineering Service** has two programs that calculate gear geometry. *GEARPACK* converts gear print information into manufacturing and inspection information—either for single gears or gear pairs. The program will calculate tooth thickness, over pins measurement, span measurement, general involute geometry, backlash, hob approach and overtravel. You can use this software to find the specs for replacement gears in old, worn or damaged machines when only the gear center distance and number of teeth are known. Cost: $265.00.

*CONFORMS* can be used to design your own hob or shaper cutter to generate any form, including spur, helical, worm, noninvolute forms, splines and ratchets. With *CONFORMS*, you can play back a generated form to get a direct comparison between the input form that you want and the generated form. You can also find potential interferences between mating gear teeth by comparing the theoretical form with the form actually generated. Cost: $500 for basic setup; $850 for a package that includes graphics, CAD transfer and other add-on modules.

**Analysis Software**

Several software providers have packages that are useful for determining the best gear for a given application. These packages analyze load distribution, bending strength, pitting resistance, thermal capacity, tribology or other factors affecting the potential life of individual gears or gear sets. Often, they are very specific and limited in scope.

**COSMIC**, the software technology transfer center for NASA, has been releasing computer software to the public for nearly 30 years. Hundreds of software packages developed and written at the NASA research centers around the country have been released over the years.

Most of the NASA software comes in source code format and is intended for a very specific purpose. "Much of it is research-oriented and often takes a large commitment in time on the part of the designer in order to be able to use it," says John J. Coy, chief of the mechanical components branch of the NASA Lewis Research Center. The Lewis Research Center is continually developing new codes for gear design and often uses industry experts for beta testing and development of the codes. Currently, the center is working on a helical gear dynamic analysis program, says Coy.

*GRA—Geared Rotor Analyzer* is designed to solve for the steady-state dynamic responses of multi-geared rotor systems. The algorithm includes an accurate gear-mesh model for spur and helical gears, a massless elastic shaft model and a linearly coupled fluid film bearing model. *GRA* is written in FORTRAN 77 to be machine independent, but has only been implemented on workstation or mainframe level machines. Cost: $500 within the U.S.; $1,000 outside the U.S.

*DANST—Dynamic Analysis of Spur Gear Transmissions* 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. *DANST* allows users to choose from a variety of gear materials, basic gear geometries and operating conditions. Users can also choose from combinations of tooth profile variations and user-digitized profile modifications. It has been used only on workstation-level machines and requires additional commercially available graphics libraries. Cost: $500 within the U.S.; $1,000 outside the U.S. A PC version has been submitted to COSMIC and is currently undergoing testing and evaluation.

*TLIFE—Spur, Helical and Spiral Bevel Transmission Life and Reliability Model* estimates life, dynamic capacity and reliability of aircraft transmissions, enabling the optimization of transmissions during the design stage.

## GEAR SOFTWARE

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 units. *TLIFE* has been successfully implemented on IBM-compatible PCs and UNIX workstations. Cost: $500 within the U.S.; $1,000 outside the U.S.

*SBGTAPER—Tooth Contact Analysis of Face-Milled, Tapered Tooth Spiral Bevel Gears With Improved Geometry* provides a new method for design and generation of spiral bevel gears of tapered teeth with localized bearing contact and low level of transmission errors. The program is an approach to detection and avoidance of vibration caused by misalignment and edge contact created by interference.

*SBGTAPER* is written for IBM PC-compatible computers and was released to COSMIC in 1997. Cost: $150 within the U.S. only.

Other NASA software related to gears, bearings and transmissions is available through COSMIC, and new titles will be released on an ongoing basis.

**ESDU International** produces "Data Items," which are comprehensive handbooks on a variety of engineering disciplines, compiled from the latest standards and field data. Most are presented as handbooks, but many are supplemented by computer programs. Data items are available on an annual subscription basis.

*Dimensions, Deflections and Stresses for Hertzian Contacts under Combined Normal and Tangential Loading* locates critical stress points on rolling bearings, cams and gears for failure prediction. Cost: $875 per volume per year, with a minimum order of $2675.

**Solid Dynamics** offers a software package for design, analysis, optimization and simulation of the motions and forces of 3D multibody mechanical systems. The *SDS/Gears* module analyzes spur and helical gears, pinions, racks and straight bevel gears.

The user can very quickly model normal backlash and positive or negative tooth shift. The program will calculate local shift on the tooth, specific sliding and relative sliding. Contact forces are calculated according to the Hertz theory. Cost: Contact Solid Dynamics.

**Specialists**

Much gear software has been written by experts in certain areas of gear design and manufacturing. Many of these experts have available software to perform very specialized tasks. While this software might not be useful to the average engineer who is creating traditional hobbed spur or helical gears, they can be of significant use to the right person.

**ABA-PGT** specializes in the manufacture of plastic injection molded gears. Their *Plastics Gearing* program enables the gear engineer to design spur or helical gears from any plastics material or any combination of plastics and metals. The software incorporates the "PGT" tooth form, which was developed specifically by ABA-PGT for plastic gears. Cost: $149.50 without manual; $179.50 with manual.

**C-Dot Engineering** is a consulting firm owned by Charles Dieterle, a former General Motors employee and spline design and manufacturing expert. Dieterle writes custom programs for splines and gears that determine design and durability based on the ANSI B92 spline standard. Cost: varies depending on customization.

**Euro-Tech Corp.** is the North American distributor of spline calculation software from Frenco. The Frenco software enables calculations of different parameters of spur & helical splines, including tooth thickness, space width, profile shift, dimension over pins, and radii at major and minor diameters. The software will calculate spline data according to ANSI 92.1 - 1970, DIN 5480 or ISO 4156. Demo versions are available at *www.frenco.de*.

**Roberts Engineering & Design** has software that has been in use since 1960. The software was originally developed to aid in the design and manufacturing of gear tools. The software will calculate all the geometry parameters for internal and external spur gears.

Roberts Engineering also specializes in software for designing, optimizing and manufacturing gear rotors. The software will generate DXF files for CAD systems or CNC output that can be used for wire EDM or CNC milling machines.

**Trogetec Inc.** specializes in trochoidal gear technologies. The Trogetec software emphasizes a quasi-cycloidal tooth form that allows highly precise positional accuracies for applications such as

micro gearboxes or instrument gearing. Cost: Custom combinations quoted on request.

Trogetec also has some more traditional gear design and development packages. *INVOGEAR* includes 8 subprograms on involute gear design, specification and inspection. Cost: $195.00.

*EZgearplot* includes 5 subprograms on standard and special involute gears, noninvolute gears, circles and polygons. Cost: $195.00.

**Comprehensive Systems**

Comprehensive gear design systems combine the functions of creating gear geometry with some or all of the analysis functions that help to optimize individual gears and gear sets. These systems create not only standard AGMA, DIN or ISO gears but also allow customization of tooth forms and provide the means to calculate load, life and wear characteristics based on materials, bending stress, contact stress, lubrication and more. These systems help not only design the gear, but design the best gear for the application.

**CIATEQ, A.C.** produces the *diseng* gear design software as a tool for optimizing a gear or gearset for a particular application. Each gear parameter can be entered as a single explicit value or as a range of values, giving the user flexibility in defining a design problem. Along the way, the program offers extensive help for determining input values. For example, a subroutine assists the user in the initial sizing of the gears based on factors such as power, torque and speed.

Calculations are based on AGMA 2001-B88 and sup-
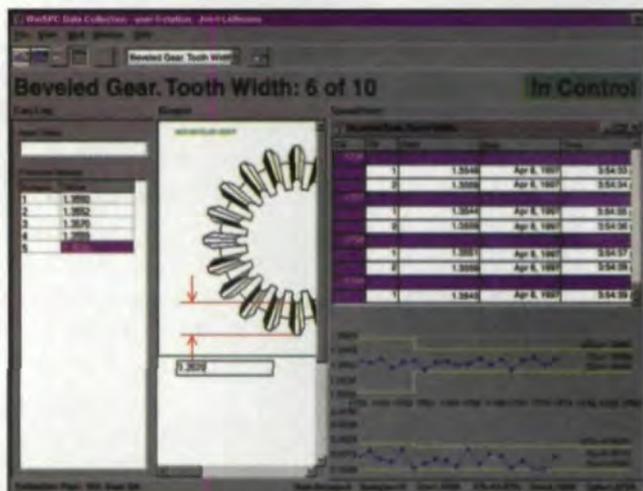


**WinSPC** from DataNet Quality Systems allows tracking of parts for statistical process control.



**HyGEARS** analyzes bearing pattern and tooth contact for spiral bevel and hypoid gear teeth.



**ZAR3 Software for Worm Gear Calculation** calculates geometry and strength factors for worm gears.

porting standards. The program automatically saves intermediate results so the user can compare between iterations made during the optimization process.

The data output by *diseng* gear design software includes all of the dimensional specifics for manufacture, along with a summary of loads, stresses, rated bending and surface fatigue lives and many other values.

The program runs under DOS, but an upgrade to Windows is in the works. A free demo demo disk is available, and a shareware version should be available soon via CIATEQ's Web site at *www.ciateq.mx*. Cost: $2,500 for commercial users; $1,500 for school and research users. Also, a fully-enabled demo is available for $500. This version stops working after five runs.

## AGMA TO RELEASE ISO 6336 SOFTWARE

After years of work, the AGMA Computer Programming Committee is nearly ready to release a program for calculating gear ratings according to the recently approved ISO 6336 standard.

*ISO 6336-Calculation of Load Capacity of Spur and Helical Gears* was approved in 1996. The standard offers five methods, labeled A through E, for calculating the rating of a gear. The A method, based on actual measurements of the part, is the most reliable. The B method is based on theoretical values and the application of formulas to determine results (along with some measurement for certain factors). C, D and E are less exact methods for determining capacity.

Because of the large number of inputs and formulas and because of the choices in methodology, the new standard is definitely not for the beginning engineer, says AGMA's computer programming committee chairman Michael Antosiewicz of the Falk Corporation. In fact, without a computer to automate the calculation process, the standard is unwieldly for even the most experienced gear engineers, Antosiewicz says.

The computer programming committee created a program, which will operate in DOS or Windows environments, to allow the user to input data and perform the calculations required by ISO 6336.

For most of the gear ratings, the software will compute according to the B method of ISO 6336, which is the highest level of accuracy that can be computerized. Only the calculation of the load distribution factor uses the C method.

With the gear industry heading more and more toward global standards, the development of this computer program becomes extremely significant. The amount of time the program will save engineers is "exponential," says Antosiewicz. Manual calculation would probably cost more in engineers' time and effort than the program will cost itself, Antosiewicz says.

AGMA hopes to be able to distribute the program at prices that are readily affordable. Look for the ISO 6336 software to be released by early 1998.

**Fairfield Manufacturing Company**'s *Gear Design Software* has been developed over the past 30 years from simple calculations designed to run on a mainframe system to the current version, which runs on a DOS-based PC.

Fairfield's *Gear Design Software* performs data, rating, stress and life calculations for spur, helical, bevel, planetary and spiral bevel gears. Calculations are based on AGMA 2001-B88 and publications of the Gleason Works. Other features include a quick pin-size routine and a two-bearing shaft routine to estimate bearing life.

While it may seem odd that a company manufacturing gears would sell one of its best design tools to its competitors, Fairfield has done so for some time.

"Back when we first offered this, gear engineering was still somewhat of a black art. Dudley and the others who were writing about gear design weren't giving anybody an easy way to perform all of these complex calculations," says Jim Dammon, VP of engineering. "So in the beginning, we kind of kept the software to ourselves."

But in the 1970s, the industry saw big companies laying off experienced workers, says Dammon. Many of these individuals started their own consulting firms and other sources of software became available. "Then it became to our advantage to go ahead and release it so that everybody could be speaking the same language," says Dammon. Cost: $850.

**Gearsoft Design**'s Gear-CAD software is a graphical gear design tool for the development of spur and helical gears and gear sets, including options for adjustable addendum, nonstandard center distance, selectable backlash, tooth sizing and load checking.

The graphic display allows the user to zoom in to check for interference, and changing any of the gear parameters will cause the part to be redrawn instantly. Pressing a key will cause the gears to rotate in mesh. The display identifies pinion, gear, pitch circle, outside and inside diameters, root circle, base circle, trochoidal fillet, line of action and other parameters by different colors on the screen.

*GearCAD* comes with sub-windows for cutter selection; preliminary estimation of tooth size, center distance and gear ratio; permissible load approximation; measuring roller calculation; and AGMA geometry factors J and I.

*GearCAD* also includes warning messages and help screens in case certain geometry parameters go outside permissible ranges. For example, interference between the tips of the pinion teeth and the internal gear teeth as the teeth go out of mesh, will bring up a warning message that tip interference is present.

Designs can be created and printed or saved to DXF or XY file format to export to CAD/CAM programs. The program comes with a detailed manual, including gear terminology, formulas used for calculation and examples of specific design problems and how they are solved using the software. Cost: $1130.

**Geartech Software** sells a trio of programs for designing and analyzing

gears. *GearCalc* designs spur and helical gears for optimum surface durability and bending strength. *AGMA-218* calculates power ratings and tooth pitting and bending fatigue life ratings for gears. Although the program uses AGMA standard 218.01, which has been superseded by AGMA 2001-B88, developers say that the calculations are still acceptable for all gears except those made of Grade 3 carburized material. Finally, *Scoring+* analyzes the scoring and wear probabilities of a gear set.

Geartech's programs work closely in conjunction with one another. A single keystroke will take you from one to the next. For example, you could design a gear set with *GearCalc*, check to see that it will perform as required with *AGMA218*, and determine if there are likely to be any lubrication, scoring or wear problems with *Scoring+*. Cost: $2,490 for all three programs.

**Hexagon Mechanical Engineering Software** has developed several programs for designing and analyzing spur, helical, spiral bevel and worm gears. *ZAR1 Gearing Calculation Soft-ware* 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 pressure angle, helix angle, normal module and other gear parameters, *ZAR1* calculates the 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, backlash and measurements over balls or pins. In addition, *ZAR1* will calculate the load-bearing capacity with respect to tooth root fatigue, fracture and pitting. The *ZAR1+* option includes a database of materials. Otherwise, users can build their own database.

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. Cost: $1,060 per user without materials database; $1,180 with materials database.

*ZAR2 Software for Spiral Bevel Gear Calculation* uses the Klingelnberg method to calculates the dimensions of bevel gears with cyclopalloid teeth in accordance with The program incorporates safety margins against root fatigue fracture, pitting and corrosion in accordance with DIN 3991.

*ZAR2* will calculate axial and radial forces during push/pull operations. These values can also be transferred to Hexagon's shaft calculation program *WL1*. Cost: $840 per user.

*ZAR3 Software for Worm Gear Calculation* calculates all the geometry and strength factors for worm gears. The strength calculation computes the fatigue fracture and pitting resistance along with tooth forces on the worm and worm gear. In addition, *ZAR3* calculates the efficiency of the gear set and provides recommended values and help graphics for deter-



*GearCAD* gear design software allows for output of gear designs in DXF or XY file formats.

mination of the tooth friction value. Cost: $430 per user.

Hexagon Software has other engineering modules available. Package pricing and discounts for multiple users are available.

**Involute Simulation Softwares** produces the *HyGEARS* advanced gear modelling software for spiral bevel and hypoid gears, which has been used for two years in the Japanese and Korean automobile industry. Version 2.0, soon to be released, will also include support for spur and helical gears and planetary gear trains.

*HyGEARS* supports Fixed Setting, Spread Blade, Formate and Helixform spiral bevel and hypoid gear manufacturing processes. Modified Roll and Duplex Helical processes are under development for inclusion in the software. Spur and helical gear cutting processes include rack and pinion cutters.

In addition to the standard gear calculations for geometry and manufacturing, *HyGEARS* includes some advanced modelling and analysis functions. Tooth contact analysis and loaded tooth contact analysis can be calculated, and motion error curves and bearing patterns are used to evaluate the behavior of the gear set under no load or under a given load.

One of the more important applications of the *HyGEARS* software is the calculation of corrective machine settings to bring the machined tooth surface as close as possible to the designed tooth surface. The software will accept data from a coordinate measuring machine and display errors between theoretical and measured surfaces.

Another advanced feature of *HyGEARS* is finite element analysis for tooth and web/hub meshing, concentrated point loads, distributed constant loads and distributed linearly varying loads. The FEA model is based on the actual tooth definition from the inputted machine settings, and it can contain up to 3,000 elements and 15,000 nodes. Finite strip analysis is available for calculation of the bending deformation and stresses.

Involute Simulation Softwares will customize the program to match your existing equipment. Cost: $50,000 for a lifetime license.

**Mechanical & Structural Design & Software** produces a series of comput-

er programs for gears and splines that will produce complete manufacturing and inspection data, stress analysis and life ratings.

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 capabilites. Cost: between $500 and $1000 per module.

**Romax Technologies** is a consulting firm in the field of mechanical power transmissions. Their *RomaxDesigner* software is made for transmission concept, design and analysis, and it includes a 3D solid modeller for gears and bearings.

*RomaxDesigner* allows simple design of multiple-pocket bearings; gears and

bearings mounted on support shafts; split powers and power take-offs; CVTs, belts and chains; and planetary gears as differentials or range changers.

The software calculates load, life and speed ratings, offers dynamic simulation of gear shift behavior and includes a feature for calculation and design of gear cutting tools and calculation of cutter paths.

The 3D modeller allows the user to interactively rotate the transmission model in real time to view the design. The design data appears in a separate window on the same screen so that the user can make changes and see the results instantly. Cost: $41,950 for the *RomaxDesigner* Core Modeller; $51,950 includes a Gear Optimization Module.

**Universal Technical Systems** offers one of the most complete gear design software selections available. They have recently released their programs in Windows format. UTS has both stand-alone programs, such as their *Program #500* for external involute gear analysis, and various programs for gear calculation and design to be used with their *TK Solver* program for numerical problem-solving.

*Program #500* is the main software available through UTS for external spur and helical gear design. The program, based on AGMA 908-B89, analyzes spur or helical gear sets to be sure that each gear will be compatible with its mate. *Program #500* will verify that your tools will be able to produce the gears. Also, the program computes the AGMA strength factor, J, and the AGMA durability

factor, I. The basic program for hobbed gears costs $1,950. Other options include the basic program for shaper cut gears and options for the use of shaving cutters, calculation of specific sliding ratio, use of tip relief, topping or semi-topping hobs, J-factor balancing, fillet grinding, output to CAD/CAM, and an integrated tooling database. Cost for additional options ranges from $500 to $1,700 per option.

*TK Solver* allows the solving of complex formulas and problems on a PC. The display combines plots, formulas and text with charts, graphs and drawings, and the program allows you to output reports based on the results. *TK Solver* is fully customizable, and it can be set up to solve many gear design and manufacturing problems. Cost: $349.00.

Universal Technical Systems has more than 75 preprogrammed models to accompany *TK Solver*. *First Gear* is a model for determining preliminary design calculations for external spur and helical gears. *First Gear* will calculate dozens of design parameters for gear geometry, provide K and unit load factors, produce a plot of the teeth in mesh, and determine measurement over pins for the gear. Cost: $599.

Other *TK Solver* models include load stress & life analyses based on AGMA standards, spline geometry and machining, internal gear and shaper cutter design, and many other options. Cost: ranges from $50 to $1,200 per module.

UTS also offers bundles for certain types of gear manufacturing. Prices range

from $3,000 to $25,000 per seat. For example, a complete plastic gear design and manufacturing bundle is available for $7,379.

**Van Gerpen-Reece Engineering** also has several software modules available for gear design and manufacturing. All together, the modules create a package that takes the gear from design through manufacturing and inspection.

The basic *Gear Design Program* calculates tooth beam strength factors, surface durability factors and all the dimensions required to manufacture the gears. The designer can create nonstandard gears with either standard or nonstandard tooling.

Additional modules available from Van Gerpen-Reece include cutting tool search programs that enable the user to locate the shaper cutters, shaver cutters and hobs that will generate the geometry of a gear designed with the *Gear Design Program*. A master gear module allows the user to determine a master gear that will satisfactorily mesh with and check a particular gear. Cost: Varies depending on the exact modules required. ✿

**Tell Us What You Think . . .** If you found this article of interest and/or useful, please circle **208**.