BETTER BEVEL GEARING

By Dr. Hermann J. Stadtfeld

Industry leader Gleason increases productivity in manufacturing straight bevel gears with a powerful suite of tools, techniques, and specialized equipment.

Above a ratio of 2.5 it is common gear design practice to convert a gearset from two generated members into a generated pinion and a non-generated gear. The name of those gearsets is FORMATE™. The idea to create this process came from the phenomenon that the generating roll to form the gear member takes an increasingly longer time the larger the ratio between pinion and gear is. However, the actual profile-forming action becomes lesser for ring gears of larger ratios. The FORMATE design takes advantage of this in forming a tooth profile that is straight, and therefore requires no time-consuming generating roll. The pinion in turn is generated with extra profile curvature (without a significant cutting time increase) such that it perfectly rolls with the non-generated gear. The results are good performing gearsets and greatly reduced manufacturing time. The surface is a combination of one member with generating feed marks and a second member with no texture other than a surface roughness caused by the finish of the cutting edges or the structure of the grinding wheel. Figure 1 shows a FORMATE straight bevel gear set. The ring gear was cut in 3.2 minutes and the pinion in 2.4 minutes, which is a third of the cutting time required in the traditional CONIFLEX® process.

CONVERSION SUMMARIES

CONIFLEX summaries that have been calculated for the Gleason machine numbers 2A, 102, 104, and 114 can be converted to general basic settings in order to perform CONIFLEX cutting on Phoenix II free form machines. The new Gleason CONIFLEX software allows the traditional settings to be entered and converts them into basic settings in order to duplicate the pinion and gear produced on a mechanical machine into the motions of a freeform machine, which will produce the identical part, compared to the traditional mechanical machine.

A new feature of the CONIFLEX Phoenix® program (*see last section of this article*) is the conversion of every suitable job into FORMATE. A switch in the input screen can be set to “FORMATE” in order to establish the non-generated version of this job. This means the pinion is generated with additional profile curvature, using the ring gear as the generating gear. The gear in turn is simply plunge cut, which reduces the cutting time greatly.

Figure 2 shows a graphic (next page, at left) of the typical basic setting of the pinion which mates with a generated gear member. The generating gear is a flat disc which rotates around the Y4,5-axis in a plane, perpendicular to the paper, containing the Z4,5-axis. The FORMATE conversion rotates the pinion together with the cutter head and the connection of the cutter head to the cradle around an axis, perpendicular to the presentation plane (X4-axis) until the angle between the pinion axis Z1,2,3 and the cradle axis Y4,5 is equal to the shaft angle between pinion and gear. In fig. 2 the Z1,2,3-axis matches the direction of the

Fig. 1: CONIFLEX FORMATE bevel gear set.

Z4-axis, which delivers an inclination of 90° to the cradle axis Y4,5. In this case the shaft angle between pinion and gear is also 90°. The generating gear is now the mating ring gear itself, which rotates around the cradle axis Y4,5 in order to generate the pinion flank surfaces.

The right configuration in fig. 2 allows for the calculation of all required basic settings such as cutter tilt and swivel angle, radial distance, and sliding base position. The ratio of roll is calculated from the number of teeth of the mating gear divided by the number of pinion teeth. If the ratio of roll was manipulated in the original generated summary in order to achieve the correct pressure angles, then an additional factor has to be considered to achieve the correct new pinion ratio of roll. In order to achieve the correct pressure angles in a case of non-matching blade and pressure angles in the non-generated ring gear, an incremental cutter tilt is applied.

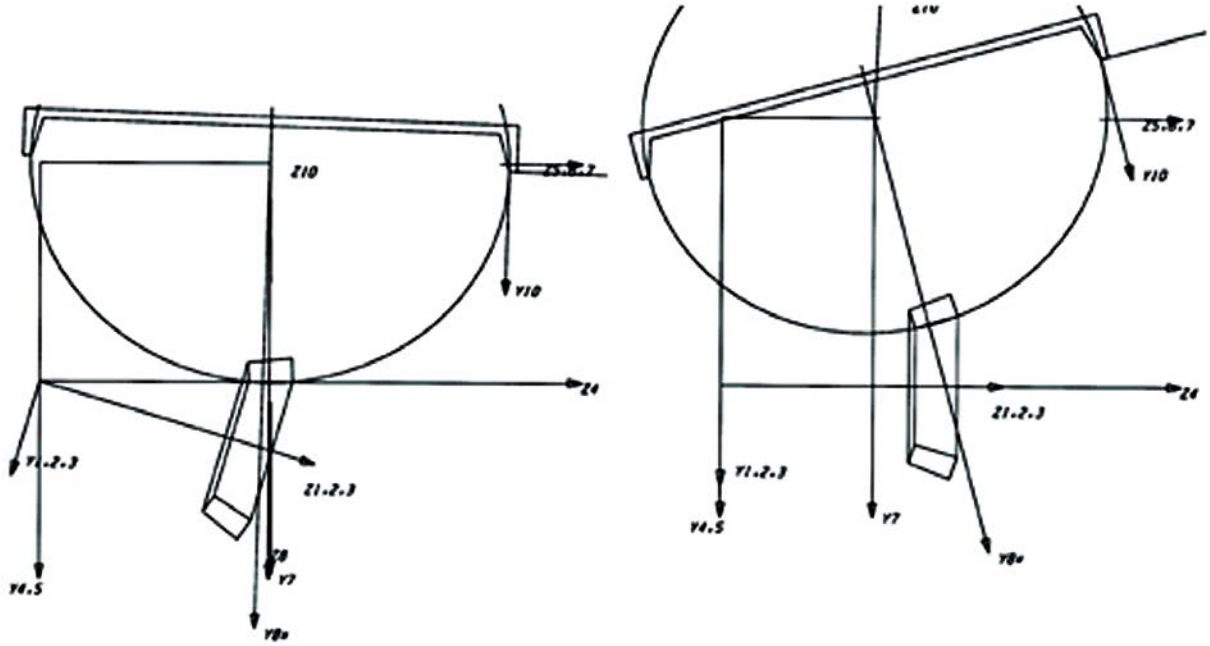

Fig. 2: Basic machine setup, left generated, right FORMATE.

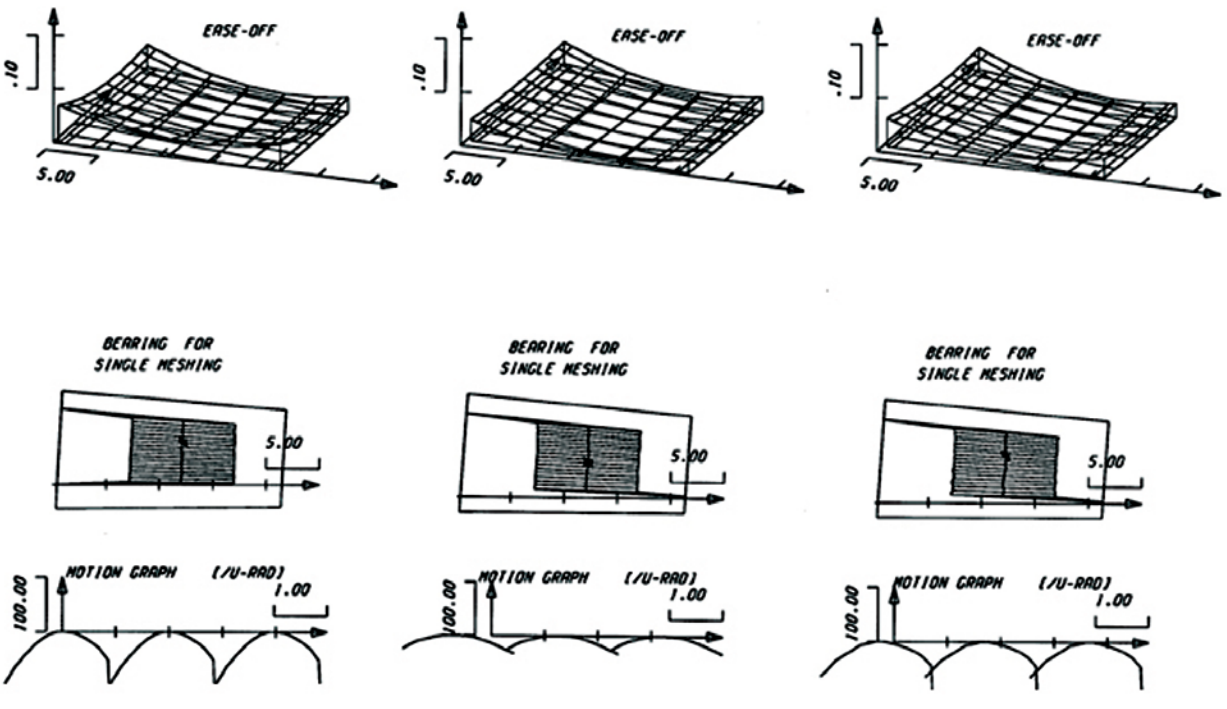

Fig. 3: TCA's, left generated, middle FORMATE, right FORMATE optimized.

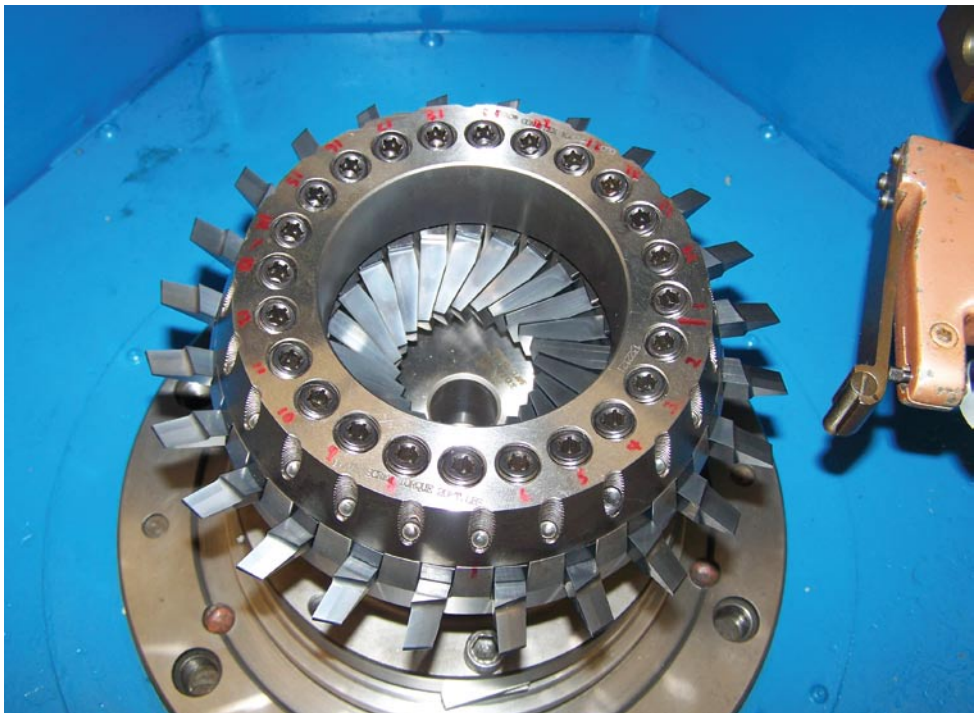

Fig. 4: Peripheral CONIFLEX carbide stick blade cutter head.

Figure 3 shows in the first vertical sequence a tooth contact analysis (TCA) for a generated CONIFLEX set. The TCA after the conversion into FORMATE (the second sequence in fig. 3) shows more potential profile contact and lesser profile crowning. The third sequence in fig. 3 represents the TCA result of a profile crowning optimization, using modified roll second order.

All investigations with the new CONIFLEX FORMATE process showed that the rolling characteristics improve versus the generated version and the transverse contact ratio even improves.

PLUNGE CYCLE/CYCLE TIMES

In the FORMATE ring gear cutting process, the upper position plunging is conducted first while the tool is following a predetermined vector feed with a single ramp plunging feed rate (end chip). Figure 4 shows the Pentac® carbide stick blade cutter, which is exclusively used for this high speed dry cutting process.

The upper plunge position 3 already forms flank 1 and the corresponding root fillet area. It also removed enough material from the slot in order to justify finishing parameters in the lower position cutting. After reaching the full depth position, the tool is withdrawn along a slightly modified plunge vector in order to eliminate flank contact to the indexing position. The sequence repeats for all slots before the tool moves in the lower cutting position. The material removal, left of the lower plunging is shown in fig. 5, which also shows a diagram with the double ramp plunging feed rate (end chip). The alternative is a single ramp with a 50 percent increased start feed rate as shown in the lower portion of fig. 5.

The diagram in fig. 6 shows a comparison of the CONIFLEX cutting times for different processes and tools. If the latest CONIFLEX Pentac cutters with coated carbide blades are used (see fig. 4), it is possible to achieve cutting times of down to 33 percent of the cutting times of mechanical cutting machines with interlocking cutters (comparison of red line to green line at “carbide formate cutting”).

PHOENIX RISING

An additional benefit to bevel gear manufacturers is the new Phoenix 280C bevel gear cutting machine (fig. 7), allowing users to reduce cycle times by as much as 35 percent on the production of bevel gears and pinions up to 280 mm in diameter.

Among the 280C’s many new standard features is a high-speed automatic loader that cuts workpiece changeover to just five seconds for gears and seven seconds for pinions. It’s an ideal solution for both automotive manufacturers seeking reduced workpiece costs on the highest vol-

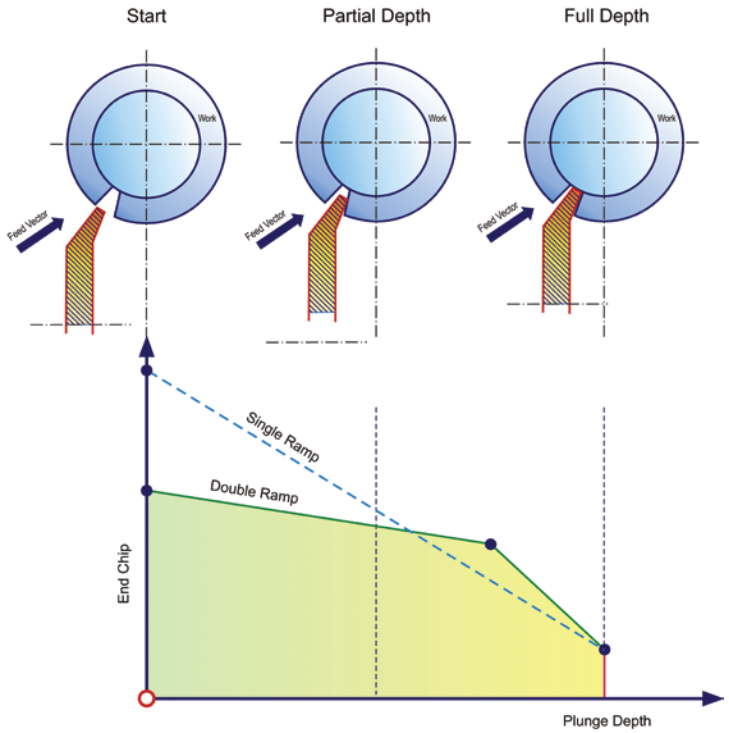

Fig. 5: FORMATE finish cutting of the lower position flank.

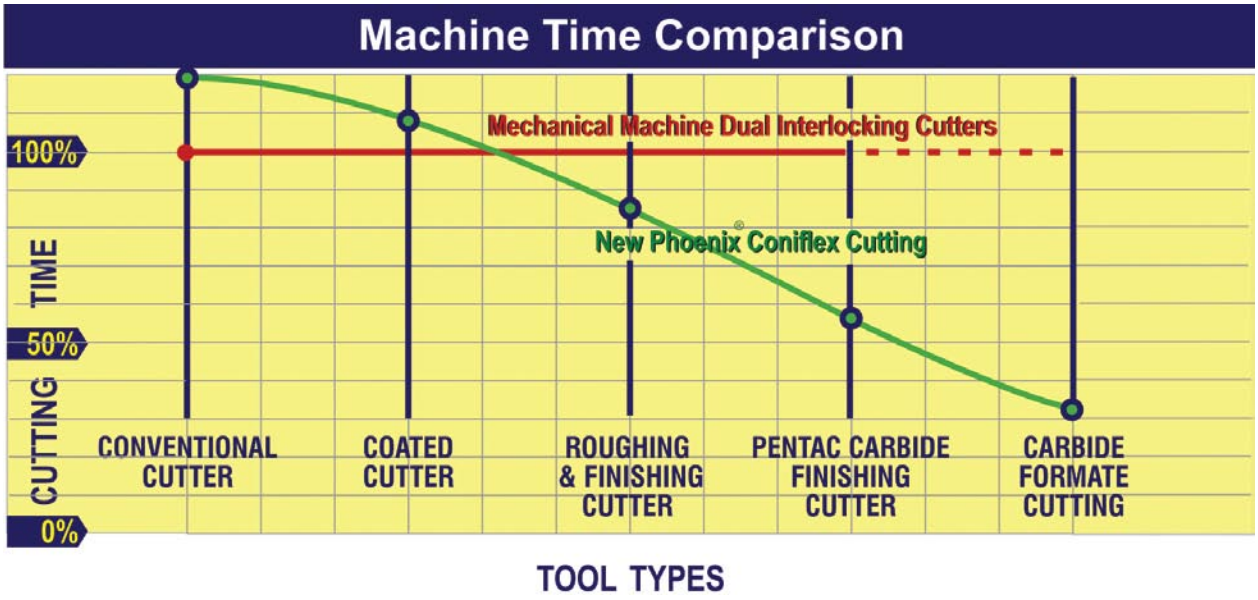

Fig. 6: Cutting time comparison.

umes and jobbers requiring greater flexibility to change rapidly from one part type to another. Nonproductive cycle times are further reduced through the use of an on-machine inspection device, which eliminates much of the time required to remove and inspect parts in a quality lab after a cutter change or when preparing to produce a completely new part or family of parts. The time required to chamfer/deburr gears has been greatly reduced, too, with an auxiliary chamfering spindle that chamfer/deburrs a gear in parallel to the one being cut, rather than as an operation typically performed in sequence after cutting.

The 280C is also designed to operate with greater reliability in production environments where dry machining is required. Its machine column is cast from an advanced polymer composite material delivering very high thermal stability and damping, making it ideal for high volume dry cutting conditions. Chip containment is excellent, ensuring that hot dry chips collect more efficiently away from the cutting zone. Overall the 280C is easier to service and maintain, with simplified guarding to improve access to service areas, and new features like a servo door system with robust rails to provide improved reliability as compared to conventional pneumatic door systems.

Fig. 7: The new Phoenix 280C bevel gear cutting machine.

A host of additional features make the 280C particularly easy for operators to perform more efficiently and productively. A new tool-less hydraulic cutter spindle clamping design eliminates much of the time and effort generally required for the operator to change a bevel gear cutter system. Arbor changeover is faster and easier for the operator, with a new quick-change workholding that is removed from the front of the machine rather than from the back, and with no special tools or fasteners.

Advanced software, used in conjunction with either Fanuc 30i or Siemens 840D CNC, also empowers even less experienced operators with all of the information they need to optimize the setup, programming, and operation of the 280C. Diagnostics screens also help operators "debug" problems when they occur, and the machine is also network ready for remote maintenance assistance.

ABOUT THE AUTHOR:

Dr. Hermann J. Stadtfeld is vice president of bevel gear technology at The Gleason Works. To learn more go to [www.gleason.com].