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CBN Gear Grinding — A Way to Higher Load Capacity?

Wilfried König, Fraunhofer Institute of Production Technology, Aachen, Germany
Georg Mauer, Mauer Metallurgic Process Engineering Ltd., Viersen, Germany
Gerhard Röber, GEDIA Company, Attendorn, Germany

Abstract

Because of the better thermal conductivity of CBN abrasives compared to that of conventional aluminum oxide wheels, CBN grinding technology promises a "cooler" grinding process, which induces residual compressive stresses into the component, and possibly improves the subsequent stress behavior. This thesis is the subject of much discussion. In particular, recent Japanese publications claim great advantages for the process with regard to an increased component load capacity, but do not provide further details regarding the technology, test procedures or components investigated. This situation needs clarification, and for the this reason the effect of the CBN grinding material on the wear behavior and tooth face load capacity of continuously generated ground gears was further investigated.

Introduction

The further development of the technology for gear grinding is aimed at both increasing productivity and efficiency and achieving product optimization. CBN grinding technology, i.e., grinding with abrasives of cubic boron nitride, promises to meet both requirements. CBN allows one to increase the cutting speed and, at the same time, increases the tool life. Because of the high thermal conductivity of the abrasive, CBN offers greater safety against thermal damage to the tooth flanks (Ref. 1).

As already established by G. A. Johnson (Ref. 2), CBN wheels grind "cooler" than conventional aluminum oxide wheels, because of the better thermal conductivity of the CBN abrasive, which improves the subsequent stress behavior of the components.

Japanese publications (Ref. 3) assert that the use of the CBN grinding technology for finishing gears increases the strength properties by about 30%. This would make it possible to reduce the size of gears by approximately 30% while maintaining the same load capacity of the gear elements. There is, however, no exact technical data or information on the conditions under which the investigations were performed, so that it is not possible to compare or assess the results.

On the other hand, American publications (Refs. 4 & 5) conclude that the CBN grinding technology for gear finishing does not improve the load capacity, but is preferred to conventional aluminum oxide grinding because of its improved process safety.

This contradictory information was the reason for investigating the influence of CBN abrasives on the face load capacity of continuously generated ground gears.

Test Program and Grinding Parameters

Spur gears manufactured using the continuous generating grinding method (Ref. 6) were used for the tests. To cover the subject "surface load capacity of gears" as comprehensively as possible, the surface zone was investigated for the progress of wear by measuring residual stress and profile deviations. The following grinding materials were used for finishing the gears:

Table I — Test Program and Grinding Parameters									
		Aluminum Oxide Multi-Pass Grinding	Aluminum Oxide Shift Grinding		Galvanically Plated CBN Multi-Pass Grinding, Roughing	Galvanically Plated CBN Multi-Pass Grinding, Finishing	Vitrified Bond CBN Multi-Pass Grinding Used Grinding Wheel	Vitrified Bond CBN Multi-Pass Grinding Newly Dressed Grinding Wheel	
		Variant 11	Variant 12	111	Variant 21	Variant 21	Variant 31	Variant 41	46
Residual Stress	σ_E	X	X	—	—	X	X	X	—
Load Capacity	σ_H	—	—	X	—	—	—	—	X
Total Infeed Amount	mm	0.60	0.60		0.42	0.18	0.60	0.60	
Roughing Infeed Per Pass	mm	0.02	0.24		0.42	0.02	0.3/0.1/0.1	0.02	
Finishing Infeed Per Pass	mm	0.02	0.04		—	0.02	0.1	0.02	
Roughing Feed Rate	mm/rev	1.60	1.00		0.75	1.40	1.0/1.6/1.6	1.40	
Finishing Feed Rate	mm/rev	0.80	0.85		—	0.70	0.50	0.60	
Grinding Wheel Speed	RPM	1,900	1,900		1,900	1,900	1,900	1,500	

Utilized Grinding Wheels: Aluminum Oxide: 64 A 80/100 F8V
Galvanically Plated CBN: B91
Vitrified Bond CBN: B64...126/V100...150

1. Conventional aluminum oxide grinding medium (64 A 80/100 F 8 V);

2. Galvanically plated CBN (grit size B91 in accordance with FEPA); and

3. Vitrified bond CBN (grit size B64–B126, concentration V100–V150, per FEPA).

The aluminum oxide shift grinding variant (Table I) was used as a reference for the test results from the galvanically plated CBN and vitrified bond CBN variants. Unlike the case of multi-pass grinding, during shift grinding the work piece is offset with respect to the grinding wheel by using the shift axis, so that the grinding wheel is always grinding with a freshly dressed section. This makes the process significantly more efficient and far safer.

The test gears were case-hardened spur gears made of 16 MnCr5E material.

The gears for the aluminum oxide shift grinding variant were finished as reference items using the given grinding data (Variant 12). According to the grinding machine manufacturer (Ref. 6) these parameters are applicable for finishing under production conditions. The multi-pass grinding variant (Variant 11), for which the rough and finish grinding infeed amounts are small, was designed to demonstrate the extent to which the aluminum oxide grinding medium influences the conditions of the material with the small amount of heat introduced.

All the CBN ground gears were produced using the multi-pass grinding method. For galvanically and vitrified bond CBN grain, the finish grinding infeed amounts selected were also very small, as they were with the aluminum oxide, in order to obtain a direct comparison of the grinding medium with regard to the effect on the surface zone. To minimize the introduction of heat, the rotational speed of the grinding wheel was reduced for the vitrified bond CBN grinding wheel (Variant 41).

The technological parameters selected for grinding with the CBN grinding wheel enabled an optimum working result to be achieved and, therefore, fully exploited the advantage of the CBN grinding medium. Compared to this, the settings chosen for the aluminum oxide variants were those typically used in production, but not the ones which produce the optimum results, particularly with regard to the roughness of the tooth faces.

The following is a summary of the most important results of the investigation.

High Residual Compressive Stresses on the Surface Using CBN

Knowledge of the residual stress is particularly important for gears because the component stress results from superimposing load and residual stress. The presented measured results were obtained by radiography

Prof. Dr.-Ing. Dr. h.c. Wilfried König
is Director of the Fraunhofer Institute for Production Technology, Aachen, Germany.

Dr.-Ing. Georg Mauer
is Managing Director of Mauer Metallurgic Processing Ltd., Vierson, Germany.

Dr.-Ing. Gerhard Röber
is Plant Manager at GEDIA Company, Attendorn, Germany.

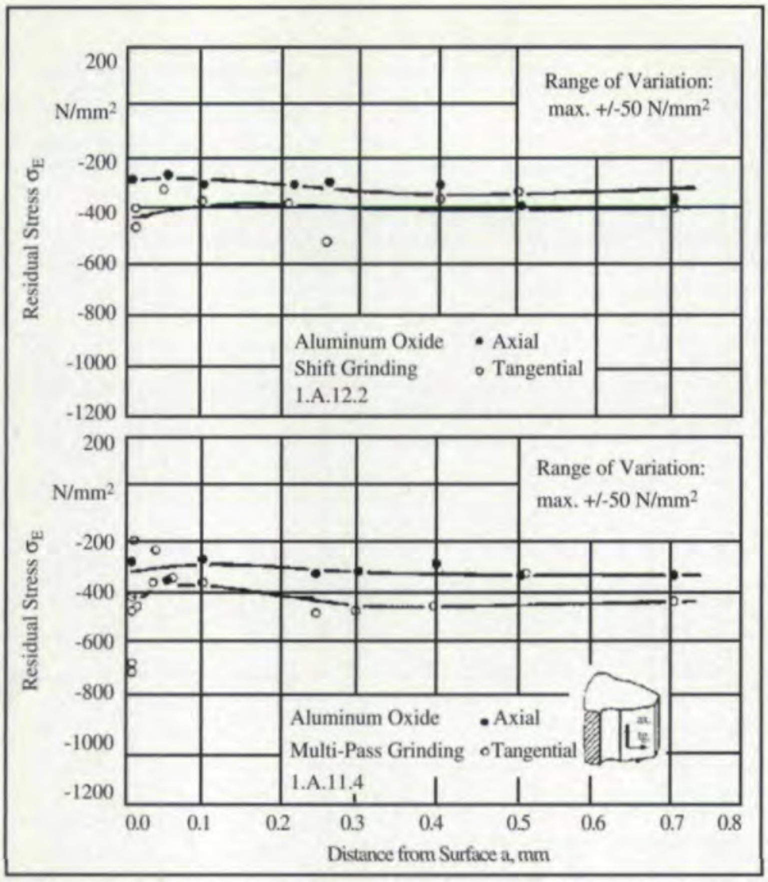

Fig. 1 — Residual stress pattern in the surface zone of the variants shift grinding aluminum oxide (Variant 12) and multi-pass grinding aluminum oxide (Variant 11).

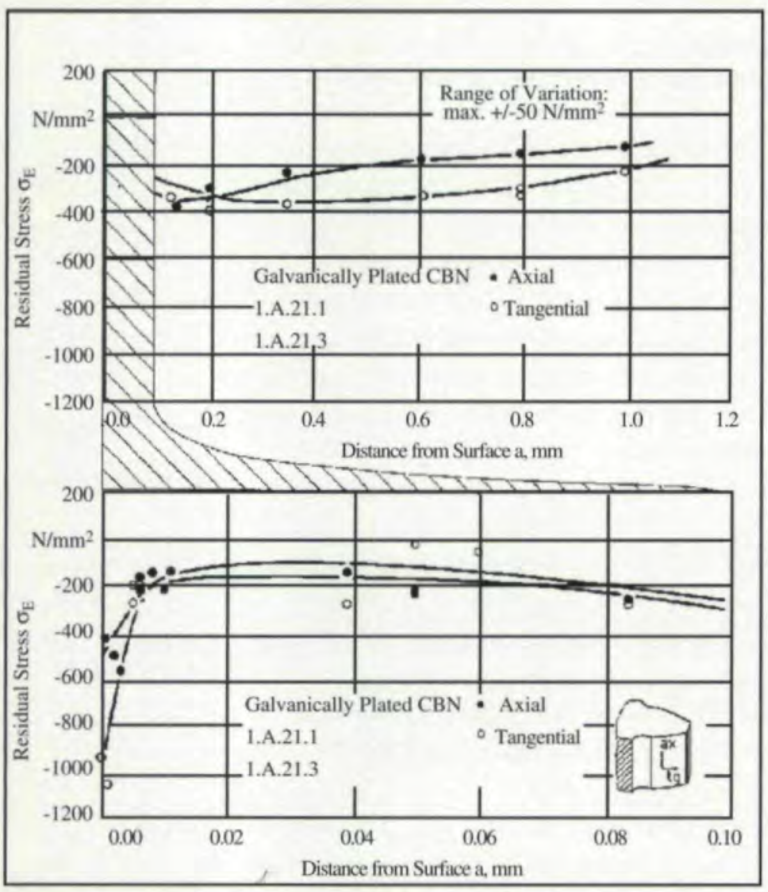

Fig. 2 — High residual compression stresses in the surface zone of gears ground with galvanically plated CBN wheels.

using the $\sin^2\psi$ method (Ref. 7) (211 level, Cr-$K\alpha$ radiation, 35 kV/35 mA, $2\ \theta = 156°$). The residual stress patterns in the surface zone of the aluminum oxide ground reference variant are shown in Fig. 1. For gears of Variant 11 (aluminum oxide multi-pass grinding) and Variant 12 (aluminum oxide shift grinding), the tangential residual compressive stresses on the surface were approximately -400 N/mm². The axial residual compressive stresses were somewhat lower, approximately -260 N/mm² on the surface.

The axial and tangential residual compressive stresses are almost the same on the surface for both variants. Overall, the residual stress pattern of both variants showed no significant influence by temperature in the surface zone because of the grinding process. Normally, if too much heat were introduced, residual tensile stresses on the surface would result. This confirms that in this case no deterioration of the surface zone influence occurred, even under normal production grinding conditions (shift grinding, Variant 12) using the conventional aluminum oxide.

For the gears of Variant 21 (galvanically plated CBN, multi-pass grinding), as shown in Fig. 2 the tangential residual compressive stresses on the surface were approximately -950 N/mm². The axial residual compressive stresses were somewhat lower, approximately -500 N/mm² on the surface. These values dropped very quickly to approximately -200 N/mm² at depths greater than 0.01 mm. Overall, the residual stress pattern revealed no temperature influence in the surface zone because of the grinding process. The high residual compressive stresses resulted from plastic deformation during the contact between the grinding wheel and the tooth face. The lower diagram in Fig. 2 shows clearly that the effect did not penetrate any further than 10 µm.

Two vitrified bond CBN variants were used: vitrified bond CBN with a newly dressed grinding wheel (Variant 41); and vitrified bond CBN with a used grinding wheel (Variant 31). The used grinding wheel with the vitrified bond CBN had already been used once before this grinding process and was not dressed for this particular application. A large infeed amount was chosen for finishing.

Fig. 3 shows the residual stress patterns in the surface zone for both variants. For the vitrified bond CBN variant with a used grinding wheel, the tangential residual compressive stresses on the surface were approximately -1000 N/mm^2. The axial residual compressive stresses were approximately -500 N/mm^2. In this case again there was a rapid drop of the stress values with increased depth to about -300 N/mm^2.

The residual stress pattern of the CBN variant with the used grinding wheel was somewhat different from the vitrified bond CBN variant with the newly dressed grinding wheel. In this case the tangential residual compressive stresses on the surface were only about -400 N/mm^2 and the axial compressive stresses were approximately -300 N/mm^2. These somewhat lower residual compressive stresses were possibly the result of the influence of the re-hardened zones which have a negative influence on the measured results.

Overall, high compressive stresses were found after CBN grinding even with high infeed amounts. The affected depth was very small (about 10 µm), and the stresses did not penetrate as deep as those resulting from sliding and rolling on the tooth faces.

Surface Roughness Measurements

The recordings of the roughness measurements in Fig. 4 show that the variants, aluminum oxide with multi-pass grinding or aluminum oxide with shift grinding, produced a higher roughness than the vitrified bond and galvanic plated CBN variants. It should be pointed out, however, that the roughness depth on the CBN ground gears at discrete points (for example, in the range of the 1 mm measuring length for galvanically plated CBN) deviated greatly from the average roughness R_z. This deviation also resulted in a substantially higher value for the maximum roughness R_t. It may have been caused by a protruding CBN grit. Indications of this were the ridges which appeared on the right and left and which were very similar to the plastic deformation caused by contact with the grit.

Under EHD conditions (complete separation of the metal surfaces through the elasto-hydrodynamic pressure build-up in the lubricant film) these ridges cause metallic micro-contacts of both tooth flanks which result in high micro-Hertzian stresses and

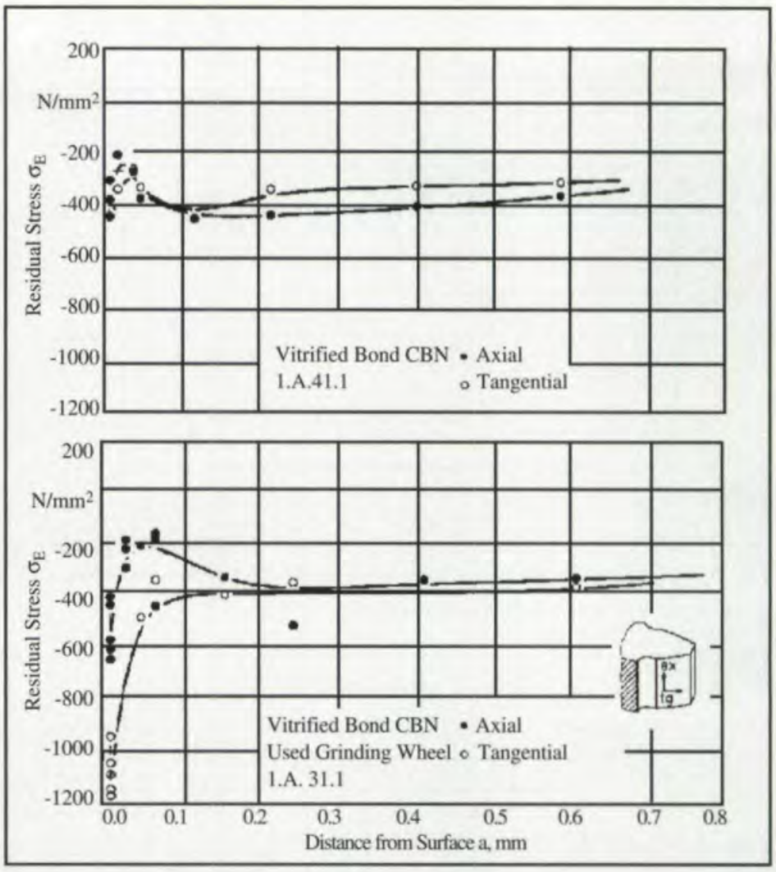

Fig. 3 — Residual stress pattern in the surface zone of gears ground with vitrified bond CBN wheels; used grinding wheel (Variant 31), newly dressed grinding wheel (Variant 41).

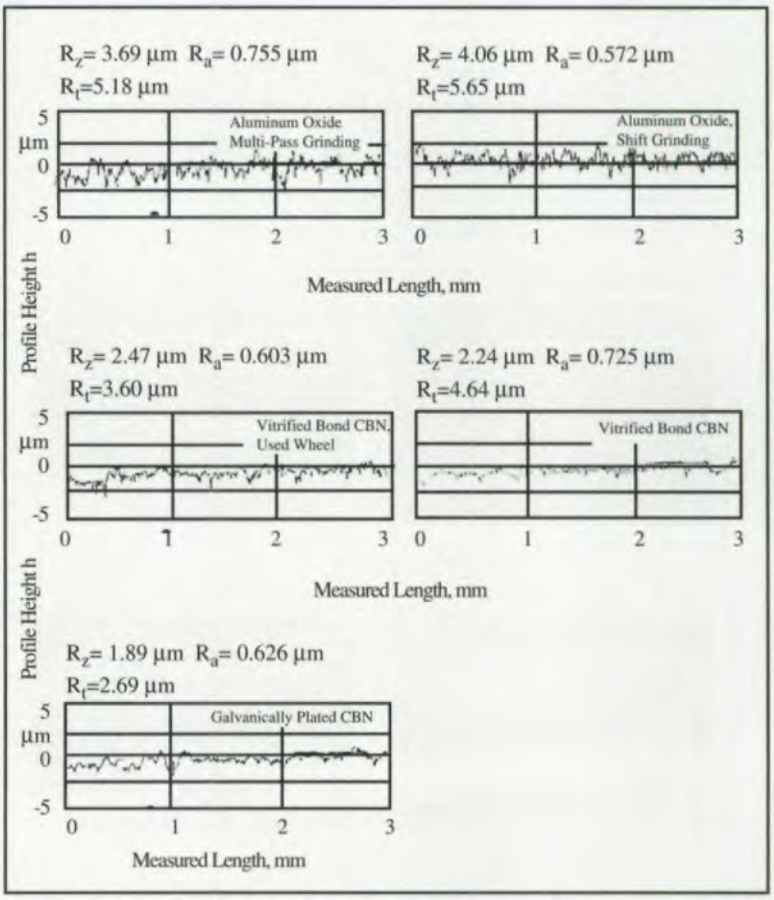

Fig. 4 — Recordings of roughness measurement of the ground surface of the tested gear variants in the initial state.

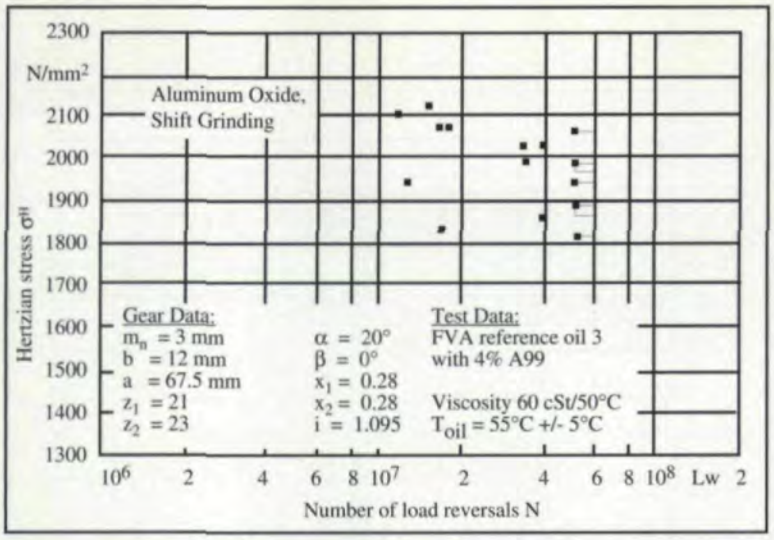

Fig. 5 — Endurable Hertzian face stress σ_H of case hardened gears (shift grinding aluminum oxide, Variant 111).

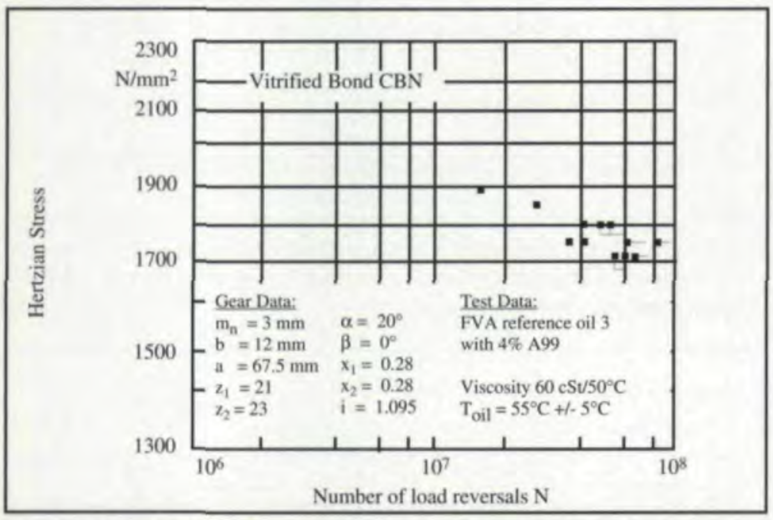

Fig. 6 — Endurable Hertzian face stress σ_H of case hardened gears (newly dressed vitrified bond CBN wheel, Variant 46).

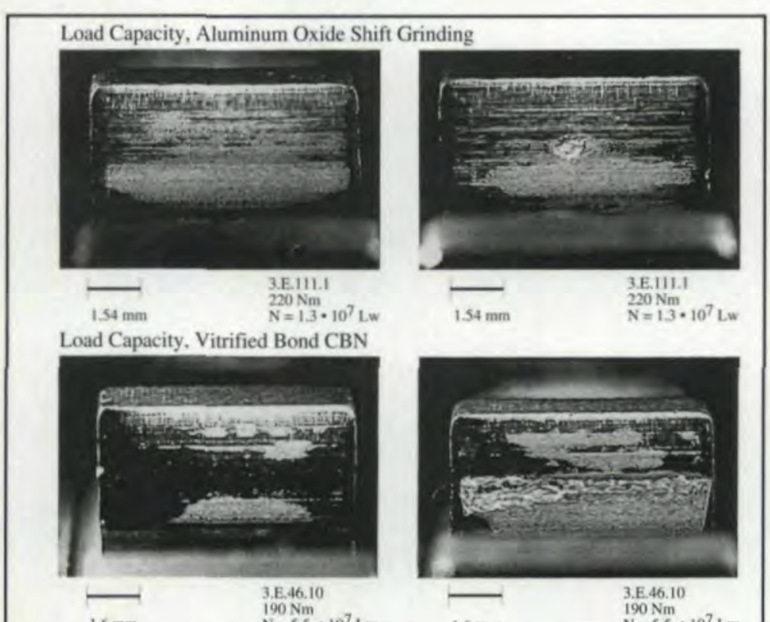

Fig. 7 — Wear and pitting on aluminum oxide and CBN ground gears (Variants 111, 46).

tangential stresses. These, in turn, can lead to damage to the material sub-surface zones. These processes could favor pitting.

No Increase in Tooth Face Load Capacity

Wöhler graphs were determined on a 3-shaft bracing test rig to analyze the face load capacity. On this test fixture a test pinion was meshed with two gears. The center distance was a = 67.5 mm. The maximum torque was 270 Nm. The amount of the load was varied by using the stair-step method (Ref. 8).

These limits were used as the basis for the wear criterion for pitting, depending on how the wear developed: failure of the gear at an individual tooth wear of 4% of the active tooth face, or failure of the gear at a total face wear of 1% of the entire active tooth face (Ref. 8).

The gears were continuously monitored while running, and the beginning and progress of the pitting was recorded. The results are presented in the form of a Wöhler diagram.

Fig. 5 shows the endurable Hertzian face stress σ_H during the running test (shift grinding with aluminum oxide, Variant 111). The torque of the gears was between *190* Nm (σ_H = 1712 N/mm^2) and a maximum of 267 Nm (σ_H = 2030 N/mm^2). Pitting occurred on the pinion and gear during the running.

After evaluation using the aforementioned criteria, a continuously endurable Hertzian face stress σ_H = 1750 N/mm^2 was established. At higher torques test gears could be found which did not reach the failure criteria after achieving the endurance strength limit of 5 x 10^7 load reversals, but there is insufficient empirically verified data available to allow one to specify higher continuously endurable Hertzian face stress with sufficient safety. Because of the considerable variation of the measured values, it is not possible to draw a suitable Wöhler line on the diagram.

Fig. 6 shows the endurable Hertzian face stress for the vitrified bond CBN variant with a newly dressed grinding wheel (Variant 46). In this case the torque of the gears was between 190 Nm (σ_H = 1712 N/mm^2) and a maximum of 230 Nm (σ_H = 1884 N/mm^2). Because the measured values show a considerable variation for this variant, no Wöhler line is drawn on the diagram. In this case a continuously endurable Hertzian face stress of approximately 1750 N/mm^2 was determined. Unlike the case of the aluminum oxide variant, fewer gears were found that passed the test without reaching the failure criteria at higher torque.

Pitting frequently occurred as mini-pitting in the form of striations in the range of gray discoloration which appeared as spots all over the entire face of the tooth (Fig. 7). With aluminum oxide ground gears, on the other hand, the gray spots appeared mainly in the negative slip area below the pitch circle. The results of the tests show no improvement in tooth face load capacity of the CBN ground gears compared with the aluminum oxide ground variants.

The main reason is to be found in the shallow depth that is influenced by the residual compressive stresses, which cannot affect the specific stress on the tooth faces in the lower material depths.

Review of Results

The results of the tests are summarized in Table II. High residual compressive stresses were found in the surface zone for CBN ground gears during measurement of the residual stress. These values were, however, found only on the surface or to a depth of approximately 10 µm. The deviations in the profile form, which were regarded as an indication of wear relative to the running time, were highest for the aluminum oxide ground variants, with a depth of 20 µm.

The aluminum oxide and CBN variants showed a different pattern with regard to the occurrence of gray discoloration. With the aluminum oxide ground gears a band of gray discoloration always occurred below the pitch circle. With the galvanically plated CBN variant, on the other hand, the gray discoloration was unevenly distributed (in spots) over the surface of the tooth face, because the surface structure was also not uniform and was interrupted by striations. The vitrified bond CBN variant showed a frequent occurrence of mini-pitting in the form of striations in the area of the gray discoloration.

With the exception of the aluminum oxide variant using shift grinding, the photographs of the structure for all other variants showed individual areas of rehardening to a maximum depth of about 2 µm (galvanically plated CBN, vitrified bond CBN, used wheels/newly dressed wheels) and approximately 8 µm for aluminum oxide multi-pass grinding. No adverse effects on the face load capacity could be found during the test because of the isolated occurrences on the face.

The average roughness depth R_z for the aluminum oxide variant was almost the same — approximately 3.86 µm (aluminum oxide multi-pass grinding) and 3.96 µm (aluminum oxide shift grinding). The values for the CBN ground variant were R_z = 2.17 µm (galvanically plated CBN), R_z = 2.39 µm (vitrified bond CBN, used wheel) and R_z = 2.28 µm (vitrified bond CBN, newly dressed wheel). These values are distinctly lower because of the surface topography of the CBN wheel and the favorable grinding parameters.

Table II — Summary of Results Showing Residual Stress Profile, Wear Pattern and Load Capacity of the Gear Variants.

Grinding Method	Residual Stresses (N/mm^2)	Affected Depth (µm)	Profile Deviation (Wear) µm	Gray Discoloration	Surface Zone (Re-Hardened Zones)	Average Roughness Depth R_Z	Face Load Capacity (n/mm^2)
Aluminum Oxide (Multi-Pass Grinding)	-260 (ax.) -400 (tg.)	Surface (residual stresses increase to about -300 N/mm^2 at depths > 0.01mm)	—	—	Isolated re-hardened zones, maximum depth approx. 8µm	Appx. 3.86 µm	—
Aluminum Oxide (Shift Grinding)	-260 (ax.) -400 (tg.)	Surface (residual stresses increase to about -300 N/mm^2 at depths > 0.01 mm)	Final state approximately 20 µm maximum	Gray discoloration occurring in band below pitch circle	Martensitic surface structure without influence from grinding process	Apprx. 3.96 µm	σ_H = 1,750
Galvanically Plated CBN	-500 (ax.) -950 (tg.)	In the surface zone down to 10 µm (values drop to about -200 N/mm^2 at depths > 0.01 mm)	Final state approximately 7 µm maximum	Irregular occurrence of gray discoloration	Isolated re-hardened zones, maximum depth approx. 2 µm	Apprx. 2.17 µm	—
Vitrified Bond CBN (Used Wheel)	-500 (ax.) -1,000 (tg.)	Surface (values drop to about -300 N/mm^2 at depths > 0.01 mm)	—	—	Isolated re-hardened zones, maximum depth approx. 2 µm	Apprx. 2.34 µm	—
Vitrified Bond CBN	-300 (ax.) -400 (tg.)	Surface (values drop to about -300 N/mm^2 at depths > 0.01 mm)	Final state approximately 14 µm maximum	Mini-pitting	Isolated re-hardened zones, maximum depth approx. 2 µm	Apprx. 2.28 µm	σ_H = 1,750

The investigations of the face load capacity showed that gears ground with vitrified bond CBN wheels reached the stress level of gears ground with aluminum oxide wheels, but by no means exceeded them. The favorable residual compressive stresses and improved roughness did not affect the permanent load capacity of the gears, because the depth to which the residual compressive stresses penetrate was not sufficient to reach the maximum stresses due to the Hertzian stress.

Summary

These investigations examined the influence of the grinding material (aluminum oxide, CBN) on the residual stress and face load capacity of case-hardened spur gears after continuous generating grinding. The CBN grinding technique promises a favorable surface zone influence in the form of high residual compressive stresses because of the better thermal conductivity of the CBN abrasive. Such residual compressive stresses can, in principle, improve the wear characteristics of the tooth face surface.

The test showed that the surface zone is not negatively influenced by the particular grinding method or grinding abrasive for any of the variants ground. The measurements of the residual stress for the CBN variants showed high residual compressive stresses in the zone close to the surface. These values were, however, only present in an extremely small band from the surface (approximately 10 µm for the galvanically plated CBN variant). The residual compressive stresses on the surface in the case of the aluminum oxide variants was approximately -260 N/mm^2 (axial) and -400 N/mm^2 (tangential). For the CBN variants it was approximately -500 N/mm^2 (axial) and -1000 N/mm^2 (tangential). At depths exceeding 0.01 mm these values dropped rapidly to about -300 N/mm^2.

The wear test of the aluminum oxide variants showed an increasing loss of material, depending upon the running time, below the pitch circle in the negative slip area. In contrast to this, the CBN variants showed an irregular gray discoloration over the complete tooth face. This can be explained by the different initial conditions of the surface structure. The average roughness depth R_Z is smaller (2.0 to 2.3 µm) on all CBN variants than on the aluminum oxide ground gears (3.9 to 4.0 µm). The reason for this may be the different grinding parameters and the surface topography of the CBN grinding wheel.

The aluminum oxide ground reference variant was produced under commercial production conditions, while the CBN variant ground for the tooth face load capacity tests used smaller infeed amounts and lower grinding wheel speeds with the best process selected for with regard to the minimum surface zone influence.

The continuously endurable tooth contact stress for both the aluminum oxide (shift grinding) variant and the vitrified bond CBN variant is at maximum 1750 N/mm^2.

No improvement in the tooth face load capacity could be found for the CBN ground gears even under the most favorable technological conditions. CBN grinding under commercial production conditions, therefore, does not point toward any significant improvement in the load capacity as described in Ref. 3. ■

References:

1. Sulzer, G. "Gehärtete Zahnflanken mit CBN wälzschleifen." (Hardened Gear Teeth With CBN Continuous Generating Grinding.) *Industrie-Anzeiger* 110, No. 89 (1988), pp. 21-23.

2. Johnson, G. A. "Günstige Druckrestspannung durch Schleifen mit CBN." (Satisfactory Residual Compressive Stress by Grinding With CBN.) Presentation, SME, Second International Grinding Conference, Philadelphia, PA.

3. Yokogawa, M. and Yokogawa, K. "Oberflächengüte und Dauerfestigkeit durch CBN Schleifscheiben verbessern." (Improvement of Surface Quality and Fatigue Stress by Grinding With CBN Grinding Wheels.) *Werkstatt und Betrieb* 124, No. 3 (1991), pp. 187-190.

4. Drago, R. J. "Comparative Load Capacity Evaluation of CBN-Finished Gears." *Gear Technology*, Vol. 7, No. 3 (May-June 1990), pp. 8-16.

5. Townsend, D. P. "Surface Fatigue Life of CBN and Vitreous Ground Carburized and Hardened AISA 9310 Spur Gears." *Gear Technology* 7, No. 1 (Jan.-Feb. 1990), pp. 10-17.

6. Cadisch, J. "Endbearbeitungsverfahen für Aussenstirnverzahnungen." (Finishing Methods For External Gears.) Company publication, Reishauer AG, Wallisellen, Switzerland.

7. Hauk, V.; Macherauch, E. *Eigenspannungen und Lastspannungen. Moderne Ermittlung — Ergebnisse — Bewertung.* (Residual Stresses and Load Stresses. Modern Investigations — Results — Assessments.) HTM-Beiheft, 1982.

8. FVA-Merkblatt No. 0/5. "Empfehlung zur Vereinheitlichung von Flankentragfähigkeitsverhalten an vergüteten und gehärteten Zylinderrädern." (Recommendation For Uniformity of Face Load Behavior of Heat Treated and Hardened Parallel Axis Gears.) *Forshcungsvereiningung Antriebstechnik e.V.*, 1979.

Hob Basics Part II

Keith Liston
Pfauter-Maag Cutting Tools, L.P.
Loves Park, IL

This is Part II of a two-part series on the basics of gear hobbing. Part I discussed selection of the correct type of hobbing operation, the design features of hobs and hob accuracy. This part will cover sharpening errors and finish hob design considerations.

Sharpening Errors

The hob errors which contribute to the profile error on a gear are the hob profile error and the hob lead error. A perfectly accurate hob with a proper setup, on an accurate machine with good tooling can cut a bad gear if the hob is improperly sharpened. Sharpening errors can contribute to both profile and lead errors since the hob profile is actually shifted from its true position by exposing the cutting edge in a different plane. The sharpening errors which affect the hob accuracy are as follows:

1. Rake angle error
2. Index error
3. Flute lead error

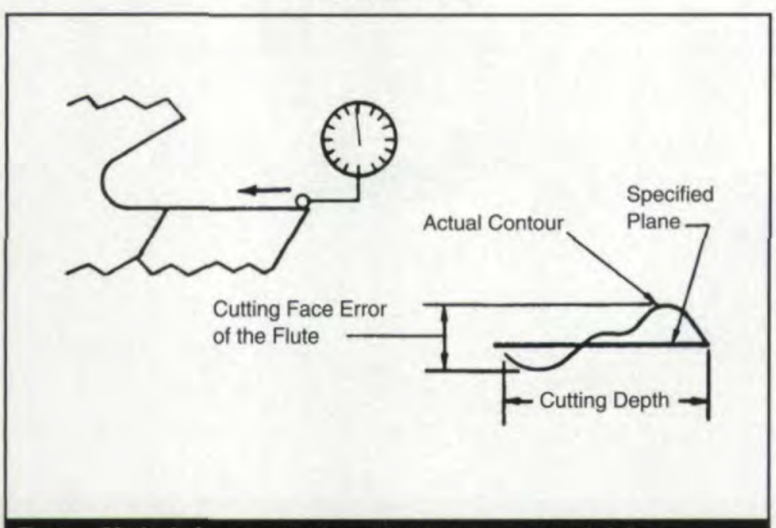

Fig. 1 — Method of measuring the cutting face error of the hob flute.

Rake angle error. The hob cutting face is designed to lie in a specified plane, and any variations of the actual hob flute cutting face from that plane are considered flute cutting face error. This error is measured from the outside diameter to the cutting depth. (See Fig. 1).

Negative rake error describes the condition when too much stock is removed from the upper portion of the tooth face. Negative rake decreases the depth and increases the pressure angle on the hob tooth. The result is cutting drag and a gear tooth that is thin at the top and thick at the bottom. The effect of negative rake is an involute chart that leans in the positive direction (Fig. 2).

Positive rake error describes the condition when too much stock is removed from the lower portion of the tooth face. Positive rake increases the depth and decreases the pressure angle on the hob tooth. The result is a gear tooth that is thick at the top and thin at the bottom. The effect of positive rake is an involute chart that leans in the negative direction (Fig. 3).

A belly or convex curve is produced at the tooth face when a straight line dresser is used to sharpen a helical fluted hob. This belly causes the hob tooth to be thin at the top and bottom. The resulting gear tooth will be thick at both the top and bottom. This will cause a bowed curve on the involute chart (Fig. 4).

Index Error. Hob flute indexing error is the deviations of the actual radial positions of the hob flutes from the theoretical positions (See Fig. 5). Index error occurs when stock is sharpened off the hob flutes unequally.

Hobs sharpened with unequally spaced

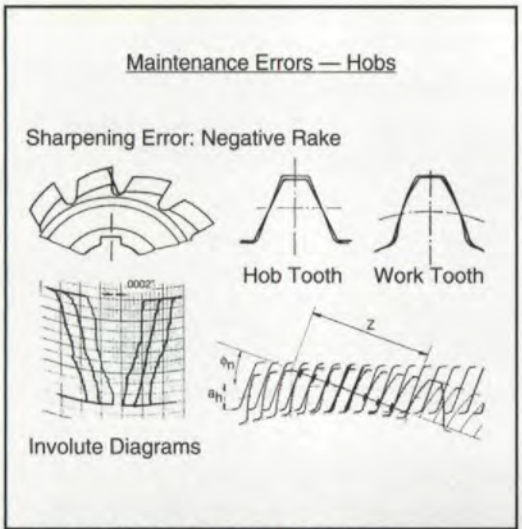

Fig. 2 — Effects of negative rake error.

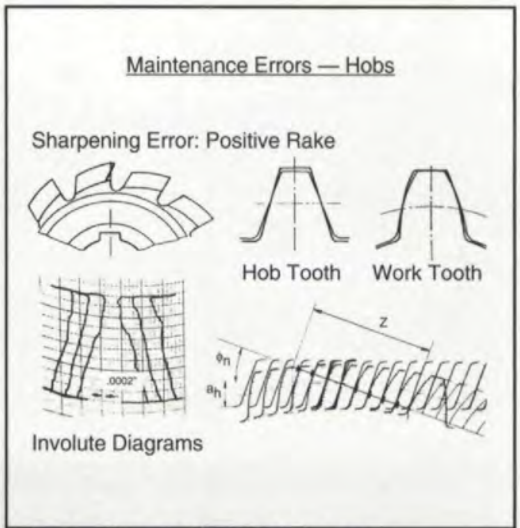

Fig. 3 — Effects of positive rake error.

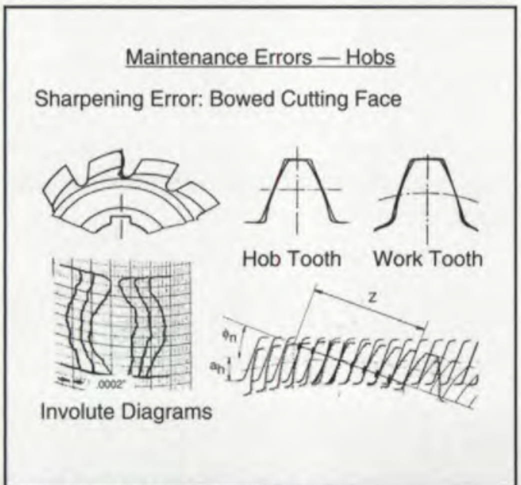

Fig. 4 — Effects of convex curve.

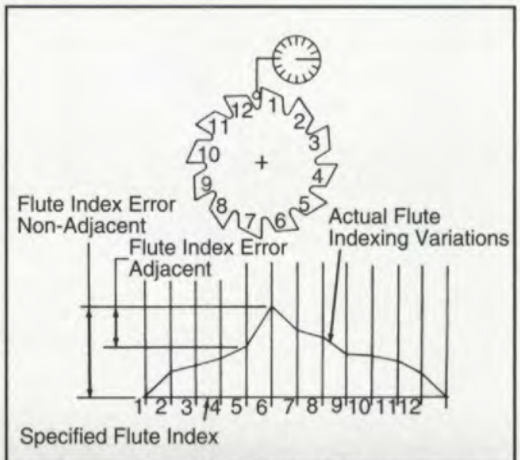

Fig. 5 — Method of measuring hob flute errors by use of an index mechanism.

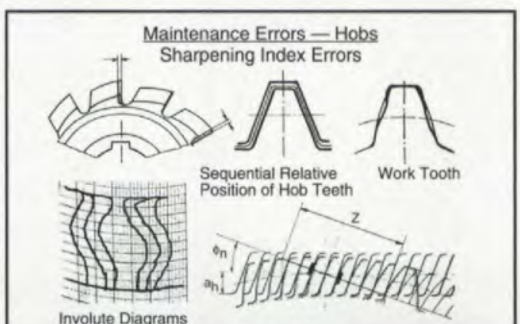

Fig. 6 — Effects of hob index error.

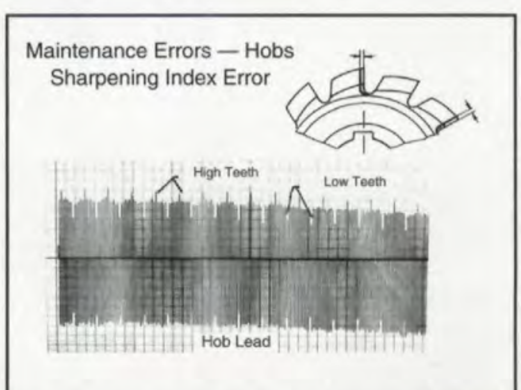

Fig. 7 — Lead chart of hob with index error.

flutes will not produce the correct involute form. The hob will have high and low teeth which will produce unequal generating flats on the gear teeth. High hob teeth will produce low flats or hollows on the gear profile. The resulting involute diagram will be wavy due to the high and low spots on the profile.

Hob runout during sharpening is a source for index error. It will result in unequal amounts of stock being ground from the face of the hob teeth (Figs. 6-7).

Flute lead error. Flute lead tolerance is the total allowable indicator variation when traversing the total face width of the hob in any one row of teeth following the specified lead of the flute. Hobs sharpened with flute lead errors have teeth which do not have the correct profile, and the profile differs on each side of the teeth. Due to the cam relief profile, the teeth on the end of the hob which has the most amount of stock removed will be at a smaller diameter than the teeth at the other end, making the hob

Keith Liston

is an Engineering Manager with Pfauter-Maag Cutting Tools, L. P. He holds a B.S. in Industrial Engineering from the University of Wisconsin — Platteville and an MBA from the University of Wisconsin — Whitewater.

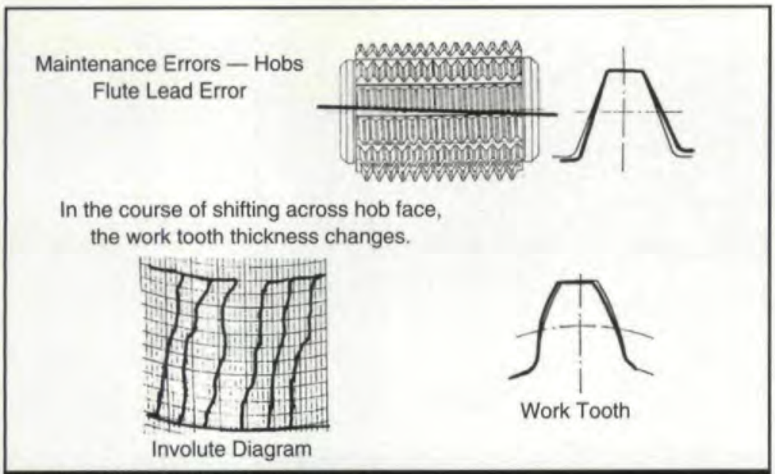

Fig. 8 — Effects of flute lead error.

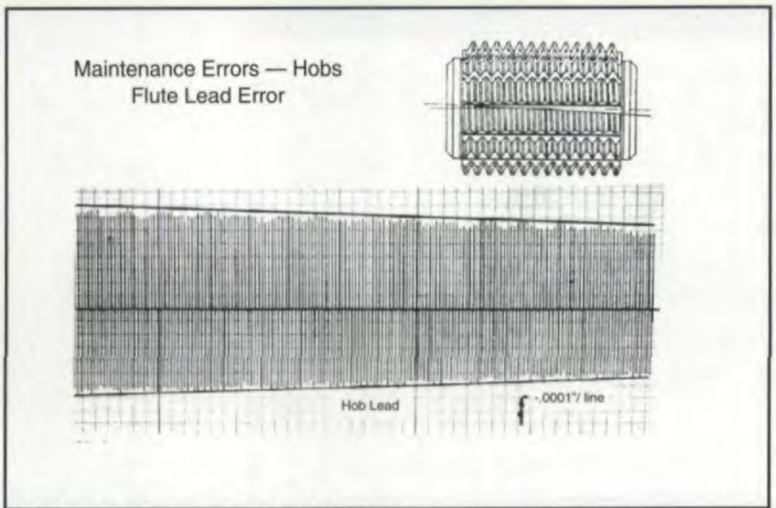

Fig. 9 — Lead chart of hob with lead error.

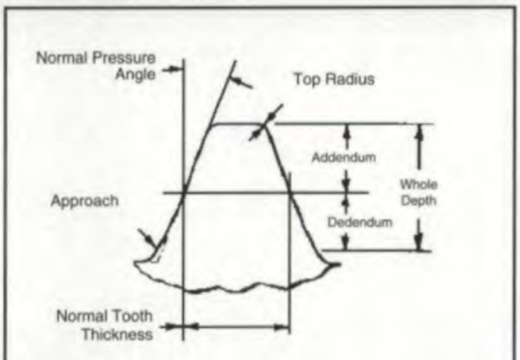

Fig. 10 — Hob nomenclature.

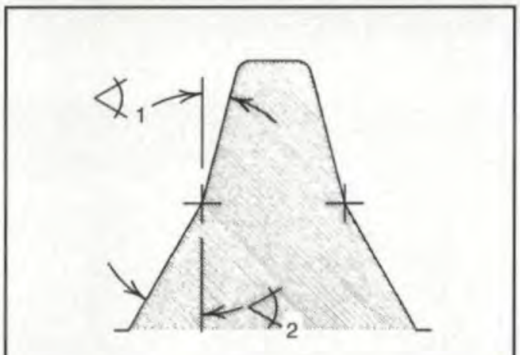

Fig. 11 — Dual pressure angle.

tapered. Gears cut by a hob with flute lead error will not have the correct involute form. The teeth are unsymmetrical, each side of the teeth having a different pressure angle. The teeth are said to be "leaning" or have cross bearing. The leaning of the teeth can be seen in the involute diagram (Figs. 8-9).

Mounting Errors. A hob which is mounted incorrectly can exhibit a condition known as runout. Traditional runout is in phase, while an out-of-phase condition is known as a wobble. A hob mounted with runout can destroy the accuracy of the hob. Hub runout causes errors in the part tooth form since the hob teeth are not in the proper position relative to the generating pitch line. In order to eliminate runout, hobs are designed with hubs which provide a qualifying surface. The hubs are used to true up the hob on the arbor. Since the hubs are held in relation to the form on the hob teeth, trueing the hubs makes the hob rotate about the proper axis.

Finish Hob Design Considerations

Depth System. The standard full depth system for 1-19.9 NDP is 2.25/DP with a gear addendum of 1.0/DP. The standard full depth system for 20 NDP and finer is 2.2/DP + .002, with a gear addendum of 1.0/DP.

The ASA stub-tooth depth system for 1-19.9 is 1.8/DP, with a gear addendum of .8/DP.

Modifications. Standard gear hobs with a full depth system have a standard modified tooth form. This consists of a corner radius, as mentioned previously, and an approach near the bottom of the hob tooth profile (See Fig. 10). The approach modifies the involute to prevent tip interference with the mating gear.

Hobs are sometimes ordered with special profile modifications. An example of a special double-angle profile can be seen in Fig. 11. The purpose of a double-angle profile is to provide tip relief much in the same manner as a standard approach. The double angle can also be used to provide relief in the root area.

Semi-Finish Hob Design Considerations

Depth System. The standard depth system for a pre-grind or pre-shave hob is 2.35/DP, with a gear addendum of 1.0/DP. This extra depth allows clearance in the root of the gear for the finishing tool. The depth also helps to maintain stock at the T.I.F. diameter which might otherwise be eliminated by undercut.

Protuberance. Protuberance is a modification of the hob tooth form at the top corner to produce undercut on the gear teeth (See Fig. 12). This undercut provides clearance for the shaving cutter or grinding wheel, and also prevents the formation of an abrupt change in profile with its resulting stress concentration. With small numbers of teeth, the tooth form cut with a hob without protuberance is often undercut enough, but a protuberance is required for larger numbers of teeth to eliminate contact between the tip of the shaving cutter or grinding wheel and the fillet of the gear tooth.

Undercut vs. the T.I.F. Diameter. Undercut is a condition in generated gear teeth when any part of the fillet curve lies inside of a line drawn tangent to the true involute form at its lowest point (Fig. 13).

Undercut occurs naturally and increases as the number of teeth cut decreases. It may also be deliberately introduced with the use of protuberance as discussed above.

Undercut, unless it is introduced to facilitate the finishing operations, may be a detriment to a gear designer. Undercut not only reduces the strength of the gear teeth, but may also reduce the contact ratio. A gear designer has two methods available for reducing undercut. These methods can be used separately or in combination with one another.

The first method is to increase the pressure angle. An increase in the pressure angle of the gear will allow a decrease in the number of teeth without undercutting the tooth profile. See Fig. 14 for the relationship between the number of teeth which can be hobbed without undercut for the 2.157/DP and 2.350/DP systems.

The second gear design method is the use of long-short addendum design. This method is accomplished by increasing the addendum of the pinion and decreasing the addendum of the gear by an equal amount. Although the outside diameter of the pinion increases and the diameter of the mating gear decreases, the pitch and base circles remain the same. Thus they run together on the same center distance and have the same ratio as standard gears. See Fig. 15 for comparison of tooth forms using the long addendum approach.

Hob designs which produce excessive undercut conditions violating the T.I.F. diameter occur most frequently in semi-finishing

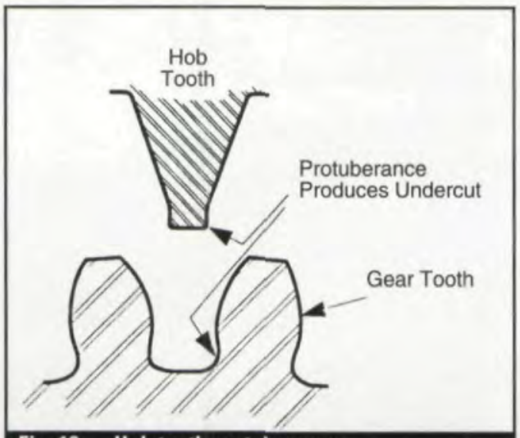

Fig. 12 — Hob tooth protuberance.

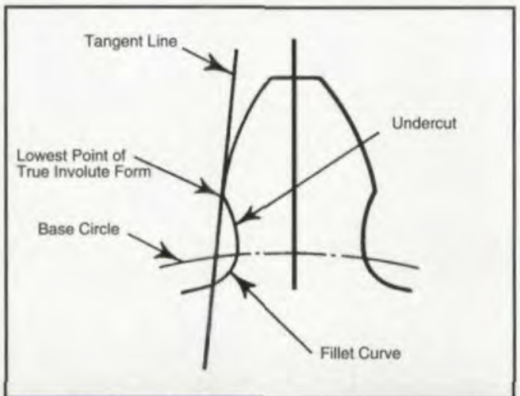

Fig. 13 — Gear tooth undercut.

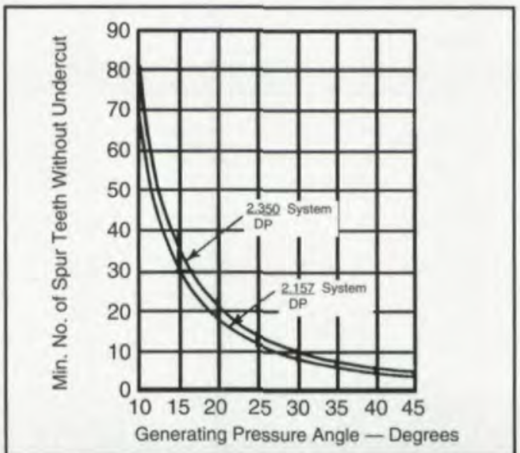

Fig. 14 — Hobbing without undercut.

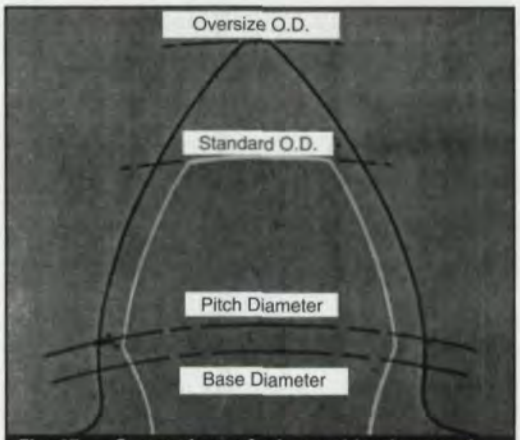

Fig. 15 — Comparison of a long addendum tooth with an undercut tooth.

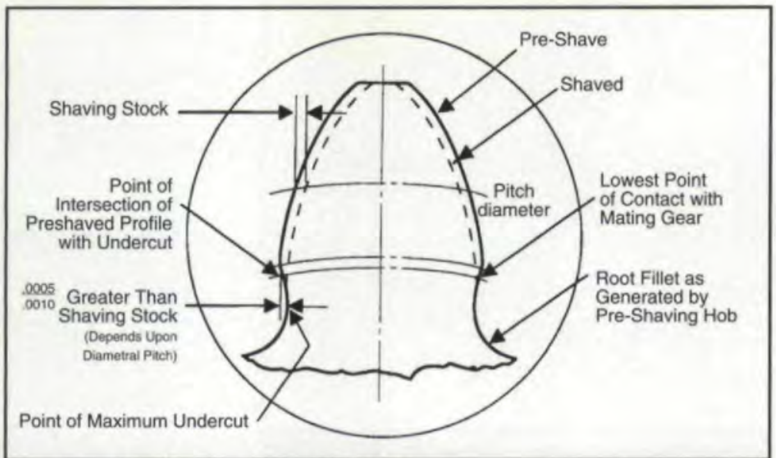

Fig. 16 — Standard pre-shave tooth form.

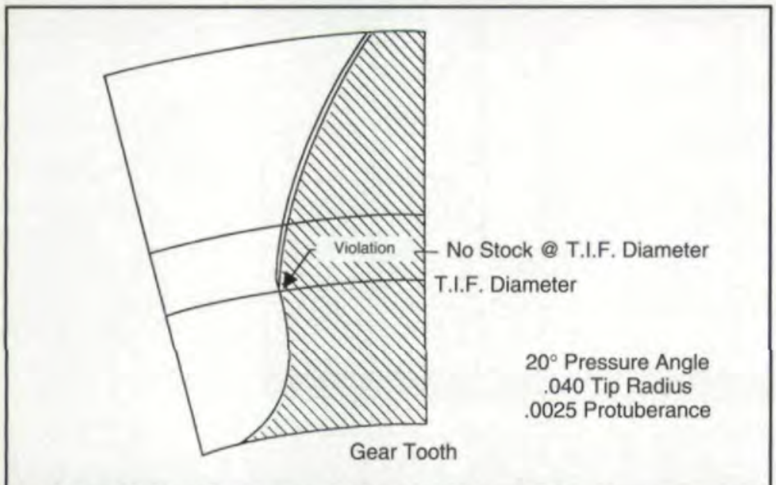

Fig. 17 — Gear tooth undercut which violates the T.I.F. diameter.

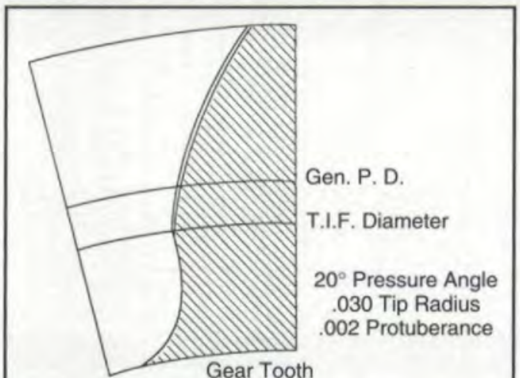

Fig. 18 — Acceptable gear tooth form.

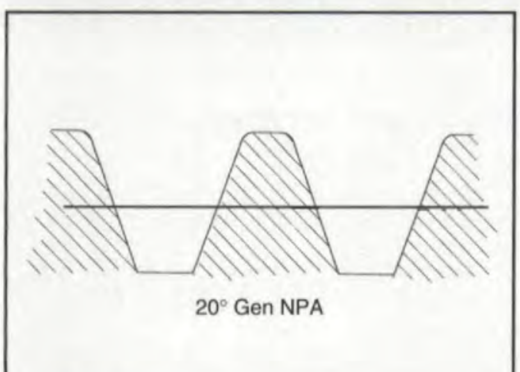

Fig. 19 — Hob rack form.

designs. When this condition is prevalent there are four options a designer has for eliminating the situation.

The first thing he can do is to get approval from the customer to reduce the root diameter of the gear. As the root diameter is reduced, the undercut is moved lower on the tooth.

T.I.F. violations sometimes occur when trying to cut too large of a radius on the hob. The second method is used in this situation. This method consists of simply reducing the size of the radius.

The third method is to get customer approval to reduce the undercut in relation to the finishing stock. For example, our standard practice is to specify undercut to be .00005 to .001 more than the amount of shave or grind stock (See Fig. 16).

Gear designers will sometimes specify undercut in excess of this standard. When excessive undercut exists it may be possible to reduce the amount. Reduction of the hob tooth radius and/or the hob protuberance will reduce the undercut.

Fig. 17 shows a gear tooth generated by a 20° normal pressure angle pre-shave hob with a .040 tip radius and .0025 protuberance. This hob design is unacceptable since it produces a condition where there is no stock at the T.I.F. diameter. By reducing the radius to .030 and reducing the protuberance to .002, an acceptable gear tooth can be generated (See Fig. 18). This design leaves a full amount of shave stock at the T.I.F. while still allowing ample undercut. Fig. 19 shows the final hob tooth configuration in this case.

The last method for improving a condition where the T.I.F. diameter is violated is to short-pitch the hob design. When a hob is short-pitched, the pressure angle of the hob is reduced. This allows the hob to generate at a lower pitch diameter which reduces the sweep-out diameter of the generated undercut.

Fig. 20 shows the results from a short-pitched hob design. The hob was short-pitched to 14.5° normal pressure angle with a .0026 protuberance and a full .071 top radius. As a result stock is still left at the T.I.F. diameter and a much larger fillet trochoid form is generated. Fig. 21 shows the final short-pitched hob tooth form.

Fig. 22 shows a comparison of the two dif-

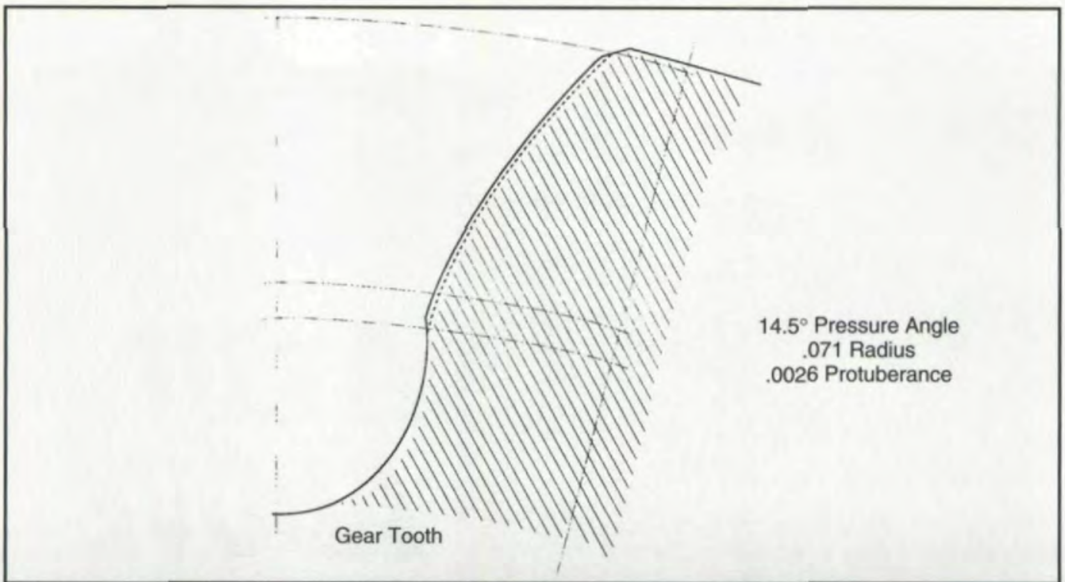

Fig. 20 — Gear tooth produced by short pitch hob.

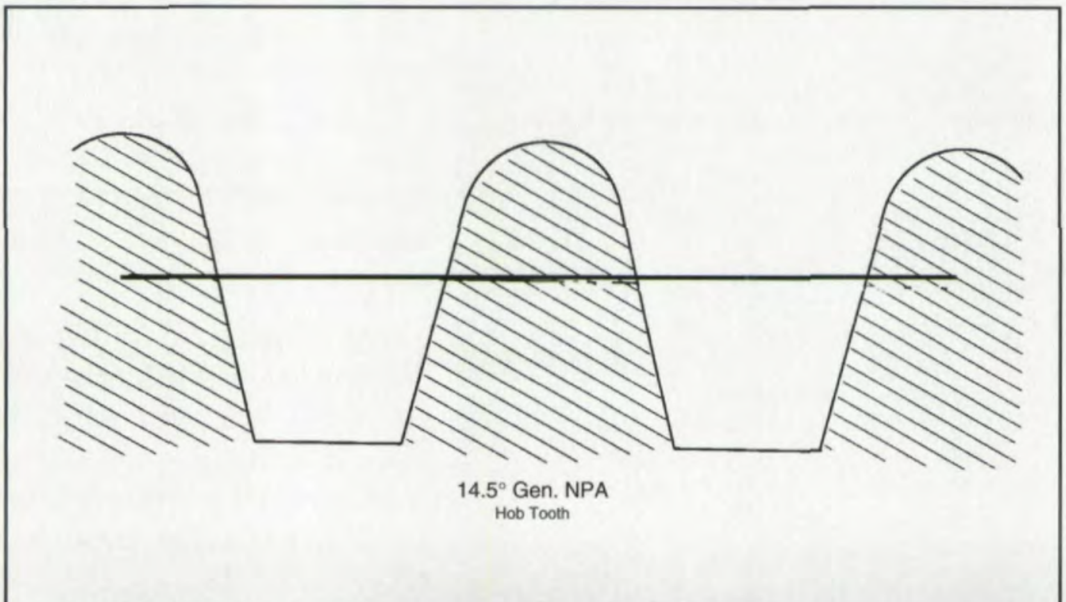

Fig. 21 — Short pitched hob tooth form.

ferent hob designs which both produced an acceptable gear tooth design. ■

References:

1. American Pfauter, L. P. *Gear Process Dynamics*, Malloy Lithography, Inc., 1985.
2. Barber Colman Company. *Hob Handbook*, Rockford, IL, 1954.

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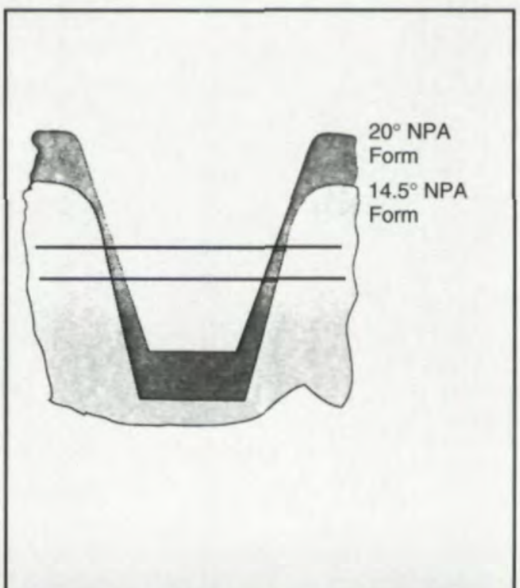
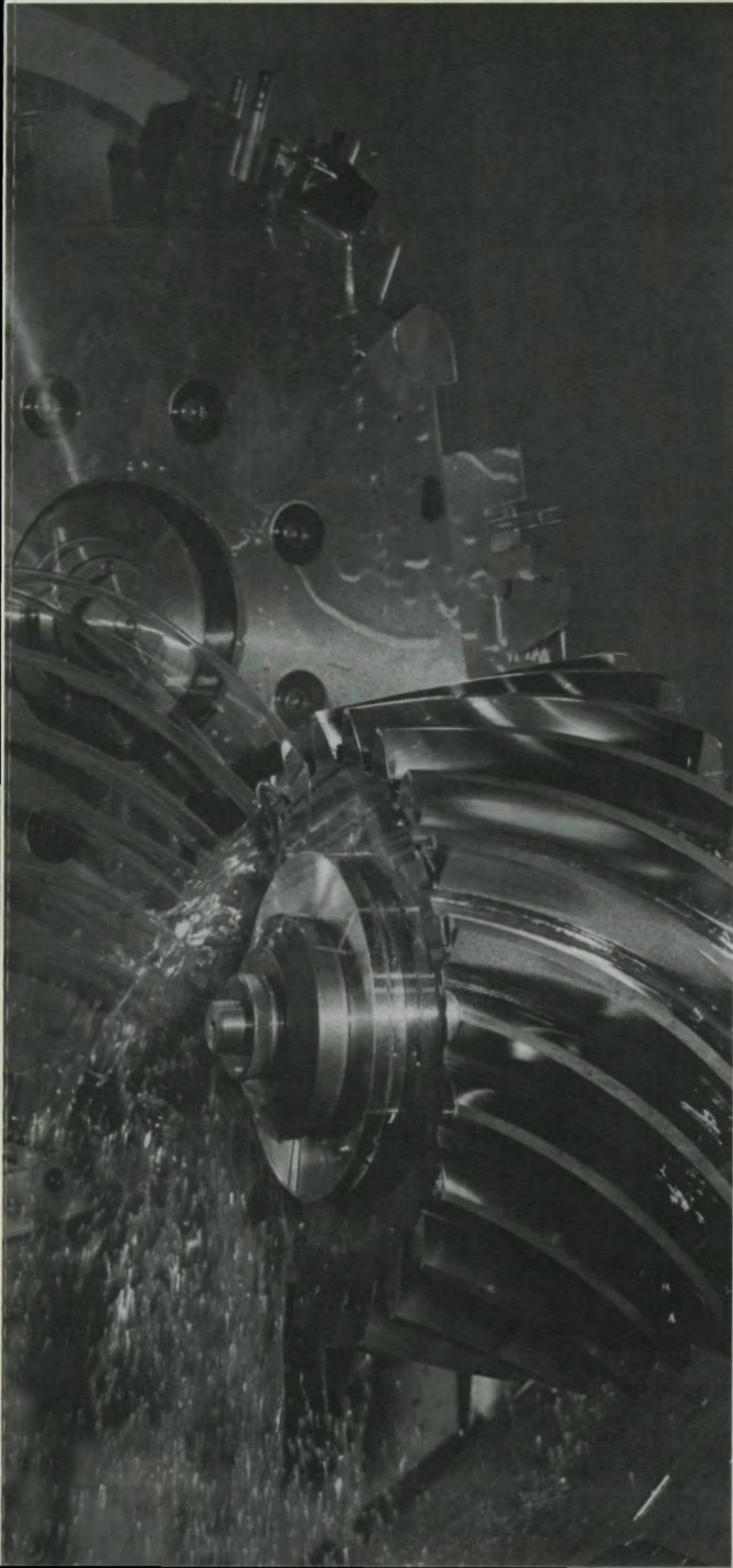


Fig. 22 — Comparison of hob tooth forms.



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Gear Technology

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PUBLISHER'S PAGE

This issue of *Gear Technology* marks another milestone in the life of our magazine. After publishing 51 issues — nearly 200 articles containing close to 2,500 pages — we're ready to try something new.

This issue contains our first-ever Buyer's Guide. This advertising directory, arranged by company name and by product/service categories, is another move on our part to provide you, our readers, with important information about the gear and gear products industries.

With that goal in mind, we have included in the guide not only information about our advertisers — some of the biggest names in gear machines and tooling, as well as other firms providing services to the industry — but also a list of gear schools and other informational and educational opportunities. We have also printed, at the request of many of our loyal readers, a complete index of articles which have appeared in *Gear Technology* arranged by subject, providing a comprehensive index of some of the most important gear research of the last decade. All this extra information was provided in the hope that The Buyer's Guide will be an important reference you will use again and again.

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"Analyzing Gear Tooth as a Function of Tooth Contact Pattern Shape and Position." Wilcox, Jan./Feb. 1985.

"Application Analysis." Bradley & McVittie, Jan./Feb. 1993.

"Approximating an Involute Tooth Profile." Billhardt, Sept./Oct. 1990.

"Basic Gear Generation — Designing the Teeth." Moderow, Sept./Oct. 1991.

"Basic Spur Gear Design." Janninck, Nov./Dec. 1988.

"Bevel Gear Development and Testing Procedure." Gleason Works, July/Aug. 1986.

"Calculation of Optimum Tooth Flank Corrections for Helical Gears." Weck & Mauer, Sept./Oct. 1988.

"Calculation of Spur Gear Tooth Flexibility by the Complex Potential Method." Cardou & Tordion, Sept./Oct. 1985.

"Classification of Types of Gear Tooth Wear — Part I." Faure, Nov./Dec. 1992.

"Classification of Types of Gear Tooth Wear — Part II." Faure, Jan./Feb. 1993.

"Computer-Aided Design of the Stress Analysis of an Internal Spur Gear." Hwang & Guenther, May/June 1988.

"Computer-Aided Spur Gear Tooth Design: An Application Driven Approach." Zarefar & Lawley, Nov./Dec. 1989.

"Cone Drive Double Enveloping Worm Gearing Design and Manufacturing." Loveless, Oct./Nov. 1984.

"Contact Analysis of Gears Using a Combined Finite Element and Surface Integral Method." Vijayakar & Houser, July/Aug. 1993.

"Contact Surface Topology of Worm Gear Teeth." Janninck, Mar./Apr. 1988.

"Crowned Spur Gears: Optimal Geometry & Generation." Litvin, Zhang, Chaing, Coy & Handschuh, Sept./Oct. 1988.

"Curvilinear Cylindrical Gears." Shue-Tseng, May/June 1988.

"Describing Non-Standard Gears — An Alternative to the Rack Shift Coefficient." McVittie, Jan./Feb. 1988.

"Design and Manufacture of Machined Plastic Gears — Part I." Chen & Juarbe, May/June 1985.

"Design and Manufacture of Machined Plastic Gears — Part II." Chen & Juarbe, July/Aug. 1985.

"Design of Internal Helical Gears." Buckingham & Buckingham, Mar./Apr. 1989.

"Design Guidelines for High-Capacity Bevel Gear Systems." Drago, Jan./Feb. 1992.

"Design of Involute Gear Teeth." Fellows Corp., Oct./Nov. 1984.

"Determination of Gear Ratios." Orthwein, Aug./Sept. 1984.

"Doing It Right and Faster . . . Computer Technology in Gear Design." Gitchel, May/June 1992.

"Dynamic Loads in Parallel Shaft Transmissions — Part I." Lin, Huston & Coy, Mar./Apr. 1990.

"Dynamic Loads in Parallel Shaft Transmissions — Part II." Lin, Huston & Coy, May/June 1990.

"Dynamic Analysis of Straight and Involute Tooth Forms." Lin, Huston & Coy, July/Aug. 1985.

"Elementary Theory for the Synthesis of Constant Direction Pointing Chariots (or Rotation Neutralizers)."

Bagci, Nov./Dec. 1988.

"Endurance Limit for Contact Stress in Gears." Mudd & France, Oct./Nov. 1984.

"Fillet Geometry of Ground Gear Teeth." Castellani, & Zanotti, Jan./Feb. 1989.

"Finding Gear Teeth Ratios." Orthwein, Nov./Dec. 1985.

"Form Diameter of Gears." Van Gerpen & Reece, May/June 1989.

"Functions of Gearing and Applications of the Involute to Gear Teeth." Fellows Corp. Aug./Sept. 1984.

"Gear Tooth Profile Determination from Arbitrary Rack Geometry." Vijayakar, Sarkar & Houser, Nov./Dec. 1988.

"Gear Tooth Scoring Design Considerations for Spur and Helical Gearing." Lynwander, May/June 1985.

"Gear Design." National Broach, May/June 1984.

"Gear Design Options." Janninck, May/June 1987.

"Gear Noise and Making Silent Gears." Liu, Wu, Qian & Chen, Mar./Apr. 1990.

"Gears for Non-Parallel Shafts." Hindhede, Sept./Oct. 1986.

"Geometric Design of Internal Gear Pairs." Colbourne, May/June 1990.

"Helical Gears with Circular Arc Teeth: Simulation of Conditions of Meshing and Bearing Contact." Litvin & Tsay, July/Aug. 1987.

"High Power Transmission with Case-hardened Gears and Internal Power Branching." Thiessen, Jan./Feb. 1985.

"Influence of Geometrical Parameters on the Gear Scuffing Criterion — Part I." Polder, Mar./Apr. 1987.

"Influence of Geometrical Parameters on the Gear Scuffing Criterion — Part II." Polder, May/June 1987.

"Influence of Relative Displacements between Pinion and Gear on Tooth Root Stresses of Spiral Bevel Gears." Winter & Paul, July/Aug. 1985.

"Internal Helical Gear Design." Fellows Corp., Mar./Apr. 1988.

"Involutometry." Van Gerpen & Reece, Sept./Oct. 1988.

"KHV Planetary Gearing — Part I." Yu, Nov./Dec. 1987.

"KHV Planetary Gearing — Part II." Yu, Jan./Feb. 1988.

"Line of Action: Concepts & Calculations." Tua & McElroy, Jan./Feb. 1993.

"Mechanical Efficiency of Differential Gearing." Yu & Beachley, July/Aug. 1986.

"Non-Involute Hobbed Forms." Ware, Nov./Dec. 1992.

"On the Interference of Internal Gearing." Yu, July/Aug. 1989.

"Practical Analysis of Highly-Loaded Gears by Using the Modified-Scoring Index Calculation Method." Hirt, Weiss & Stockmaier, Sept./Oct. 1986.

"Practical Optimization of Helical Gears Using Computer Software." Sansalvador & Jauregui C., May/June 1993.

"Pressure Angle Changes in the Transverse Plane for Circular Cut Spiral Bevel Gears." Huston & Coy, Sept./Oct. 1986.

"Synthesis of Compound Planetary Gear Trains." Bagci, July/Aug. 1990.

"Synthesis of Spiral Bevel Gears." Litvin, Mar./Apr. 1991.

"Systematic Approach to Designing Plastic Spur and Helical Gears." Paquet, Nov./Dec. 1989.

"The Uses and Limitations of Transmission Error." Smith, July/Aug. 1988.

"The European Rack Shift Coefficient "X" for Americans." McVittie, July/Aug. 1993.

"Use of Boundary Elements for Determination of the Geometry Factor." Vijayakar & Houser, Jan./Feb. 1988.

Failure & Wear (See also Troubleshooting)

"Comparing Surface Failure Modes in Bearings & Gears." Moyer, July/Aug. 1992.

"Predicted Effect of Dynamic Load on Pitting Fatigue Life for Low-Contact-Ratio Spur Gears." Lewicki, Mar./Apr. 1989.

Finishing

"Appreciable Increases in Surface Durability of Gear Pairs with a Mirror-Like Finish." Tanaka, Ishibashi & Ezoe, Mar./Apr. 1987.

"Deburring and Finishing Gears with Power Brushes." Pishek, Mar./Apr. 1989.

"Finishing Gears by Ausforming." Amateau & Cellitti, Nov./Dec. 1987.

"Gear Finishing by Shaving, Rolling & Honing — Part 1." Dugas, Mar./Apr. 1992.

"Gear Finishing by Shaving, Rolling & Honing — Part 2." Dugas, May/June 1992.

"Gear Roll-Finishing." Dugas, May/June 1987.

"Hard Finishing & Fine Finishing — Part 1." Schriefer, Sept./Oct. 1989.

"Hard Finishing & Fine Finishing — Part 2." Schriefer, Nov./Dec. 1989.

"Hard Gear Finishing." Moncrieff & Grutza, Mar./Apr. 1988.

"Hard Finishing by Conventional Generating and Form Grinding." Newman, Mar./Apr. 1991.

"Mirror Finishing of Tooth Surfaces Using a Trial Gear Grinder with a Cubic-Boron-Nitride Wheel." Ishibashi, Ezoe & Tanaka, Nov./Dec. 1986.

Forging

"Computer-Aided Design (CAD) of Forging and Extrusion Dies for the Production of Gears by Forming." Kuhlman, Horvat & Ostberg, Jan./Feb. 1985.

"Manufacturing Forged and Extruded Gears." Kuhlman & Raghupathi, July/Aug. 1990.

"Precision Forged Spiral Bevel Gears." Badawy, Raghupathi, Horvat & Ostberg, Aug./Sept. 1984.

Gear Drives

"Application of Miner's Rule to Industrial Gear Drives." McVittie & Errichello, Jan./Feb. 1990.

Grinding

"CBN Grinding in Drive Train Components." Kumar & Ratterman, Jan./Feb. 1991.

"CNC Bevel Gear Generators and Flared Cup Gear Grinding." Krenzer, July/Aug. 1993.

"Enhanced Product Performance through CBN Grinding." Johnson & Ratterman, Sept./Oct. 1988.

"Fillet Geometry of Ground Gear Teeth." Castellani, & Zanotti, Jan./Feb. 1989.

"Gear Grinding." Sharma, Sept./Oct. 1989.

"Gear Grinding Techniques — Parallel Axes Gears." Lange, Mar./Apr. 1985.

"Grinding of Spur and Helical Gears." Rao, July/Aug. 1992.

"Hard Finishing by Conventional Generating and Form Grinding." Newman, Mar./Apr. 1991.

"Lower Grinding Costs and Better Workpiece Quality by High Performance Grinding with CBN Wheels." Koening, Yegenoglu & Stuckenholz, Jan./Feb. 1986.

"Technological Fundamentals of CBN Bevel Gear Finish Grinding." Dodd & Kumar, Nov./Dec. 1985.

"Wheel Selection Technique for Form Gear Grinding." Schwartz & Rao, May/June 1986.

Heat Treating

"Achievable Carburizing Specifications." Kern, Jan./Feb. 1990.

"Controlling the Carburizing Process for Top Quality Gears." Kern, Mar./Apr. 1993.

"Dual Frequency Induction Gear Hardening." Storm & Chaplin, Mar./Apr. 1993.

"Frozen Gears." Paulin, Mar./Apr. 1993.

"Gear Hardness Technology." Broglie & Smith, Mar./Apr. 1992.

"Material Selection and Heat Treatment — Part I: Mechanical Properties." National Broach & Machine, July/Aug. 1985.

"Material Selection and Heat Treatment — Part II: Metallurgical Characteristics." National Broach & Machine, Sept./Oct. 1985.

"Selection of Material and Compatible Heat Treatments for Gearing." Jones, May/June 1986.

"White Etching Areas on Case-hardened Gears." Winter, Knauer & Gamel, Sept./Oct. 1989.

Helical Gears

"Calculation of Optimum Tooth Flank Corrections for Helical Gears." Weck & Mauer, Sept./Oct. 1988.

"Controlling Tooth Loads in Helical Gears." Buckingham, Mar./Apr. 1986.

"Design of Internal Helical Gears." Buckingham & Buckingham, Mar./Apr. 1989.

"Gear Tooth Scoring Design Considerations for Spur and Helical Gearing." Lynwander, May/June 1985.

"Grinding of Spur and Helical Gears." Rao, July/Aug. 1992.

"Helical Gears with Circular Arc Teeth: Simulation of Conditions of Meshing and Bearing Contact." Litvin & Tsay, July/Aug. 1987.

"Improvement in Load Capacity of Crossed Helical Gears." Shimokobe, Toyama & Qi-Jin, Jan./Feb. 1987.

"Internal Helical Gear Design." Fellows Corp., Mar./Apr. 1988.

"Longitudinal Load Distribution Factor of Helical Gears." Tobe & Inoue, July/Aug. 1985.

"Lubricant Jet Flow Phenomena in Spur and Helical Gears." Akin & Townsend, Jan./Feb. 1987.

"Practical Optimization of Helical Gears Using Computer Software." Sansalvador & Jauregui C., May/June 1993.

"Selection of a Proper Ball Size to Check an Involute Spur or Helical Gear Tooth." Reece & Van Gerpen, Sept./Oct. 1987.

"Systematic Approach to Designing Plastic Spur and Helical Gears." Paquet, Nov./Dec. 1989.

"The Involute Helicoid and the Universal Gear." Smith, Nov./Dec. 1990.

Hobbing

"Economics of CNC Gear Gashing vs. Large D. P. Hobbing." Coniglio, Aug./Sept. 1984.

"Economics of CNC Gear Hobbing." Sulzer, Mar./Apr. 1987.

"Effect of Reverse Hobbing At a High Speed." Ainoura & Nagano, Mar./Apr. 1987.

"Effects of Hob Quality & Resharpening Errors on Generating Accuracy." Cluff, Sept./Oct. 1987.

"Estimating Hobbing Times." Endoy, July/Aug. 1989.

"Gear Inspection; Hob Wear Questions." Janninck, Mar./Apr. 1991.

"Hard Cutting — A Competitive Process in High Quality Gear Production." Klein, May/June 1987.

"Hard Gear Processing with Skiving Hobs." Loy, Mar./Apr. 1985.

"High Speed Hobbing of Gears with Shifted Profiles." Nagano & Ainoura, July/Aug. 1988.

"Hob Length Effects." Kotlyar, Sept./Oct. 1985.

"Hobbing Ridges; Crooked Teeth; Crown Shaving." Janninck & McVittie, Mar./Apr. 1992.

"Non-Involute Hobbed Forms." Ware, Nov./Dec. 1992.

"Pineapples, Corncobs & Other Hobbing Matters." Janninck, July/Aug. 1991.

"SPC Acceptance of Gear Hobbing & Shaping Machines." Cluff, Sept./Oct. 1991.

"Tooth Forms for Hobs." Starcut Sales, Inc., Mar/Apr 1985.

"Using Hobs for Skiving." McElroy, May/June 1993.

Honing

"Gear Finishing by Shaving, Rolling & Honing — Part 1." Dugas, Mar./Apr. 1992.

"Gear Finishing by Shaving, Rolling & Honing — Part 2." Dugas, May/June 1992.

"Rotary Gear Honing." Dugas, May/June 1987.

Inspection & Measurement

"Automated Acoustic Intensity Measurements and the Effect of Gear Tooth Profile on Noise." Atherton, Pintz & Lewicki, Mar./Apr. 1988.

"Bevel Gear Development and Testing Procedure." Gleason Works, July/Aug. 1986.

"Checking Large Gears." Guenter, Mar./Apr. 1987.

"Contact Surface Topology of Worm Gear Teeth." Janninck, Mar./Apr. 1988.

"Effects of Temperature on Gage Repeatability & Reproducibility. Sagar, May/June 1992.

"Gear Inspection." Moderow, July/Aug. 1992.

"Gear Inspection and Chart Interpretation." Moderow, May/June 1985.

"Gear Inspection Chart Evaluation; Specifying Unusual Gear Sets." Smith & Janninck, Nov./Dec. 1991.

"Gear Inspection; Hob Wear Questions." Janninck, Mar./Apr. 1992.

"Gear Span Measurement — An Analytical Approach." Bass, May/June 1989.

"Gear Tip Chamfer and Gear Noise: Surface Measure of Spiral Bevel Gear Teeth." Janninck & Smith, July/Aug. 1993.

"Generating and Checking Involute Gear Teeth." Fellows Corp., May/June 1986.

"Identification of Gear Noise with Single Flank Composite Measurement." Smith, May/June 1986.

"Improving Gear Manufacturing Quality with Surface Measurement Technology." Moyer, Mar./Apr. 1993.

"Interrelationship of Tooth Thickness Measurements As Evaluated by Various Measuring Techniques." Dean, Sept./Oct. 1987.

"Involute Spline Size Inspection." Janninck & Nielsen, Mar./Apr. 1985.

"Optimum Number of Teeth for Span Measurement." Colbourne, Jan./Feb. 1986.

"Recent Developments in Gear Metrology." Sieker, Nov./Dec. 1991.

"Relationship of Measured Gear Noise to Measured Gear Transmission Errors." Smith, Jan./Feb. 1988.

"Selection of a Proper Ball Size to Check an Involute Spur or Helical Gear Tooth." Reece & Van Gerpen, Sept./Oct. 1987.

"SI Units — Measurements & Equivalencies." Jakuba, Sept./Oct. 1987.

"Single Flank Data Analysis and Interpretation." Smith, Sept./Oct. 1985.

"Single Flank Testing of Gears." Smith, May/June 1984.

"Transmission Errors & Bearing Contact of Gears." Litvin, Zhang, Lee & Handschuh, July/Aug. 1990.

Internal Gears

"Design of Internal Helical Gears." Buckingham & Buckingham, Mar./Apr. 1989.

"Geometric Design of Internal Gear Pairs." Colbourne, May/June 1990.

"High Power Transmission with Case-hardened Gears and Internal Power Branching." Thiessen, Jan./Feb. 1985.

"Internal Helical Gear Design." Fellows Corp., Mar./Apr. 1988.

"On the Interference of Internal Gearing." Yu, July/Aug. 1989.

Loads

"Centennial Anniversary: Lewis Bending Strength Equations — Investigation of the Strength of Gear Teeth." Lewis, Nov./Dec. 1992.

"A Computer Solution for the Dynamic Load, Lubricant, Film Thickness and Surface Temperatures in Spiral Bevel Gears." Chao, Baxter & Cheng, Mar./Apr. 1986.

"Comparative Load Capacity Evaluation of CBN-Finished Gears." Drago, May/June 1990.

"Controlling Tooth Loads in Helical Gears." Buckingham, Mar./Apr. 1986.

"Dynamic Loads in Parallel Shaft Transmissions — Part I." Lin, Huston & Coy, Mar./Apr. 1990.

"Dynamic Loads in Parallel Shaft Transmissions — Part II." Lin, Huston & Coy, May/June 1990.

"Helical Gear Mathematics: Formulas & Examples — Part I." Buckingham, May/June 1988.

"Helical Gear Mathematics: Formulas & Examples — Part II." Buckingham, July/Aug. 1988.

"Improvement in Load Capacity of Crossed Helical Gears." Shimokobe, Toyama & Qi-Jun, Jan./Feb. 1987.

"Influence of Relative Displacements between Pinion and Gear on Tooth Root Stresses of Spiral Bevel Gears." Winter & Paul, July/Aug. 1985.

"Longitudinal Load Distribution Factor of Helical Gears." Tobe & Inoue, July/Aug. 1985.

"Longitudinal Load Distribution Factor for Straddle- and Overhang-Mounted Spur Gears." Tobe & Inoue, July/Aug. 1987.

"Practical Analysis of Highly-Loaded Gears by Using the Modified-Scoring Index Calculation Method." Hirt, Weiss & Stockmaier, Sept./Oct. 1986.

"Scoring Load Capacity of Gears Lubricated with EP-Oils." Winter & Michaelis, Oct./Nov. 1984.

"Tolerance for Overload Stress." Diesburg, Mar./Apr. 1985.

"Tooth Contact Shift in Loaded Spiral Bevel Gears." Savage et al., Nov./Dec. 1992.

"Tooth Strength Study of Spur Planet Gears." Drago & Uppaluri, Sept./Oct. 1986.

Lubrication

"A Computer Solution for the Dynamic Load, Lubricant, Film Thickness and Surface Temperatures in Spiral Bevel Gears." Chao, Baxter & Cheng, Mar./Apr. 1986.

"Calculation of Slow Speed Wear of Lubricated Gears." Winter & Plewe, Nov./Dec. 1985.

"Cutting Low-Pitch-Angle Bevel Gears; Worm Gears & the Oil Entry Gap." Smith & Janninck, July/Aug. 1992.

"Effect of MoS_2 Films on Scoring Resistance of Gears." Terauchi, Nadano, & Kohno, July/Aug. 1986.

"Environmentally Safe Cutting Fluids for Industrial Cutting, Lubrication & Cleaning." Vandewalle, Jan./Feb. 1993.

"Improved Worm Gear Performance with Colloidal MoS_2-Containing Lubricants." Pacholke & Marshek, Nov./Dec. 1988.

"Influence of Lubricants on Gear Pitting & Micropitting Resistance." Winter & Oster, Mar./Apr. 1990.

"Into-Mesh Lubrication of Spur Gears with Arbitrary Offset Oil Jet — Part I." Akin & Townsend, May/June 1989.

"Into-Mesh Lubrication of Spur Gears with Arbitrary Offset Oil Jet — Part II." Akin & Townsend, July/Aug. 1989.

"Lubricant Jet Flow Phenomena in Spur and Helical Gears." Akin & Townsend, Jan./Feb. 1987.

"Lubrication of Gears — Part I." Errichello, Mar./Apr. 1991.

"Lubrication of Gears — Part II." Errichello, May/June 1991.

"Lubrication of Gears — Part III." Errichello, July/Aug. 1991.

"Scoring Load Capacity of Gears Lubricated with EP-Oils." Winter & Michaelis, Oct./Nov. 1984.

"The Effect of Lubricant Traction on Wormgear Efficiency." Murphy, et als., Jan./Feb. 1985.

Manufacturing

"Applying Process Control to Gear Manufacturing." Sebetic, Mar./Apr. 1992.

"Bevel Gear Manufacturing Troubleshooting Problems." Sebetic, Mar./Apr. 1991.

"CNC Gear Shaping." Sulzer, Mar./Apr. 1986.

"CNC Bevel Gear Generators and Flared Cup Gear Grinding." Krenzer, July/Aug. 1993.

"CNC Technology & the System-Independent Manufacture of Spiral Bevel Gears." Wiener, Sept./Oct. 1992.

"Cone Drive Double Enveloping Worm Gearing Design and Manufacturing." Loveless, Oct./Nov. 1984.

"Cutting Fluid Selection and Process Controls for the Gear Manufacturing Industry." Tripp, July/Aug. 1987.

"Estimating Hobbing Times." Endoy, July/Aug. 1989.

"Gear Manufacturing Methods — Forming the Teeth." National Broach, Jan./Feb. 1987.

"Give Your Gears a Break — Select the Right Coupling." Jakuba, May/June 1987.

"Hobbing Ridges; Crooked Teeth; Crown Shaving." Janninck & McVittie, Mar./Apr. 1992.

"Improving Gear Manufacturing Quality with Surface Measurement Technology." Moyer, Mar./Apr. 1993.

"The European Rack Shift Coefficient "X" for Americans." McVittie, July/Aug. 1993.

Materials

"Austempered Ductile Iron." Breen, Oct./Nov. 1984.

"Austempered Nodular Cast Irons." Janowak & Barr, Mar./Apr. 1985.

"Factors Influencing Fracture Toughness of High-Carbon Martensitic Steels." Sharma, Walter, Case & Breen, Jan./Feb. 1989.

"Finishing Gears by Ausforming." Amateau & Cellitti, Nov./Dec. 1987.

"Gear Material Quality: How to Judge It . . . Pitting: How to Prevent It." McVittie, Mar./Apr. 1993.

"Gear Hardness Technology." Broglie & Smith, Mar./Apr. 1992.

"Material Selection and Heat Treatment — Part I: Mechanical Properties." National Broach & Machine, July/Aug. 1985.

"Material Selection and Heat Treatment — Part II: Metallurgical Characteristics." National Broach & Machine, Sept./Oct. 1985.

"Production Testing of a Chromium-Free Carburizing Grade Gear Steel." Breen & Cameron, May/June 1989.

"Selection of Material and Compatible Heat Treatments for Gearing." Jones, May/June 1986.

"Surface Fatigue Life of CBN and Vitreous Ground Carburized and Hardened AISI 9310 Spur Gears." Townsend & Patel, Jan./Feb. 1990.

Mathematics

"Accurate and Fast Gear Trigonometry." Polder, Sept./Oct. 1990.

"Centennial Anniversary: Lewis Bending Strength Equations — Investigation of the Strength of Gear Teeth." Lewis, Nov./Dec. 1992.

"Contact Analysis of Gears Using a Combined Finite Element and Surface Integral Method." Vijayakar, July/Aug. 1993.

"Crowned Spur Gears: Optimal Geometry & Generation." Litvin, Zhang, Chaing, Coy & Handschuh, Sept./Oct. 1988.

"Determination of Gear Ratios." Orthwein, Aug./Sept. 1984.

"Finding Gear Teeth Ratios." Orthwein, Nov./Dec. 1985.

"Formula for Determining Gear Dimensions by Metric Pitch." July/Aug. 1986.

"Gear Tooth Profile Determination from Arbitrary Rack Geometry." Vijayakar, Sarkar & Houser, Nov./Dec. 1988.

"General Equations of Gear Cutting Tool Calculations." Bass, Nov./Dec. 1985.

"Helical Gear Mathematics: Formulas & Examples — Part I." Buckingham, May/June 1988.

"Helical Gear Mathematics: Formulas & Examples — Part II." Buckingham, July/Aug. 1988.

"Influence of Geometrical Parameters on the Gear Scuffing Criterion — Part I." Polder, Mar./Apr. 1987.

"Influence of Geometrical Parameters on the Gear Scuffing Criterion — Part II." Polder, May/June 1987.

"Line of Action: Concepts & Calculations." Tua & McElroy, Jan./Feb. 1993.

"Metric Conversions." July/Aug. 1986.

"Practical Analysis of Highly-Loaded Gears by Using the Modified-Scoring Index Calculation Method." Hirt, Weiss & Stockmaier, Sept./Oct. 1986.

"Rules and Formulae for Gear Sizes." Sept./Oct. 1986.

"Rules and Formulae for Worm Gearing, Strength of Bevel Gears and Strength of Gear Teeth." May/June 1987.

"SI Units — Measurements & Equivalencies." Jakuba, Sept./Oct. 1987.

"Use of Boundary Elements for Determination of the Geometry Factor." Vijayakar & Houser, Jan./Feb. 1988.

Misalignment

"Crowning: A Cheap Fix for Noise Reduction and Misalignment Problems and Applications." Young, Mar./Apr. 1987.

"Misalignment No Beauty in Gear Sets." McVittie, May/June, 1991.

Neural Nets

"Initial Design of Gears Using an Artificial Neural Net." Jeong, Kicher & Zab, May/June 1993.

Noise

"Automated Acoustic Intensity Measurements and the Effect of Gear Tooth Profile on Noise." Atherton, Pintz & Lewicki, Mar./Apr. 1988.

"Crowning: A Cheap Fix for Noise Reduction and Misalignment Problems and Applications." Young, Mar./Apr. 1987.

"Gear Noise and Making Silent Gears." Liu, Wu, Qian & Chen, Mar./Apr. 1990.

"Gear Noise and the Sideband Phenomonen." Dale, Jan./Feb. 1987.

"Gear Tip Chamfer and Gear Noise: Surface Measure of Spiral Bevel Gear Teeth." Janninck & Smith, July/Aug. 1993.

"Identification & Correction of Damaging Resonances in Gear Drives." El-Bayoumy, Aug./Sept. 1984.

"Identification of Gear Noise with Single Flank Composite Measurement." Smith, May/June 1986.

"Investigation into Gear Rattle Phenomena." Rust, Brandl & Thien, Sept./Oct. 1992.

"Relationship of Measured Gear Noise to Measured Gear Transmission Errors." Smith, Jan./Feb. 1988.

Pitting

"A Review of AGMA, ISO, and BS Gear Standards. Part I — Pitting." Walton, Shi & Taylor, Nov./Dec. 1990.

"A Review of AGMA, ISO, and BS Gear Standards. Part II — Pitting." Walton, Shi & Taylor, Jan./Feb. 1991.

"Gear Material Quality: How to Judge It . . . Pitting: How to Prevent It." McVittie, Mar./Apr. 1993.

"Predicted Effect of Dynamic Load on Pitting Fatigue Life for Low-Contact-Ratio Spur Gears." Lewicki, Mar./Apr. 1989.

"Surface Pitting Fatigue Life of Noninvolute, Low-Contact-Ratio Gears." Townsend, May/June 1991.

"Influence of Lubricants on Gear Pitting & Micropitting Resistance." Winter & Oster, Mar./Apr. 1990.

Planetary Gears

"KHV Planetary Gearing — Part I." Yu, Nov./Dec. 1987.

"KHV Planetary Gearing — Part II." Yu, Jan./Feb. 1988.

"Synthesis of Compound Planetary Gear Trains." Bagci, July/Aug. 1990.

"Tooth Strength Study of Spur Planet Gears." Drago & Uppaluri, Sept./Oct. 1986.

Plastic Gears

"Design and Manufacture of Machined Plastic Gears — Part I." Chen & Juarbe, May/June 1985.

"Design and Manufacture of Machined Plastic Gears — Part II." Chen & Juarbe, July/Aug. 1985.

"Maximum Surface Temperature of the Thermoplastic Gear in a Non-Lubricated Plastic/Steel Gear Pair." Gauvin, Girard & Yelle, Aug./Sept. 1984.

"Systematic Approach to Designing Plastic Spur and Helical Gears." Paquet, Nov./Dec. 1989.

Rolling

"Gear Finishing by Shaving, Rolling & Honing — Part 1." Dugas, Mar./Apr. 1992.

"Gear Finishing by Shaving, Rolling & Honing — Part 2." Dugas, May/June 1992.

Shaping

"CNC Gear Shaping." Sulzer, Mar./Apr. 1986.

"Gear Shaping Machines: CNC Development." Lange, Nov./Dec. 1985.

"Gear Generation Using Rack Cutters." Miller, Oct./Nov. 1984.

"Hard Cutting — A Competitive Process in High Quality Gear Production." Klein, May/June 1987.

"SPC Acceptance of Gear Hobbing & Shaping Machines." Cluff, Sept./Oct. 1991.

Sharpening

"Effects of Hob Quality & Resharpening Errors on Generating Accuracy." Cluff, Sept./Oct. 1987.

Shaving

"Gear Finishing by Shaving, Rolling & Honing — Part 1." Dugas, Mar./Apr. 1992.

"Gear Finishing by Shaving, Rolling & Honing — Part 2." Dugas, May/June 1992.

"Hobbing Ridges; Crooked Teeth; Crown Shaving." Janninck & McVittie, Mar./Apr. 1992.

"The Process of Gear Shaving." Dugas, Jan./Feb. 1986.

Shot Peening

"Effect of Shot Peening on Surface Fatigue Life of Carburized and Hardened AISI 9310 Spur Gears." Townsend & Zaretsky, Jan./Feb. 1986.

"Improved Gear Life through Controlled Shot Peening." Burrell, Sept./Oct. 1986.

"Optimum Shot Peening Specification — Part I." Lawerenz & Ekis, Nov./Dec. 1991.

"Optimum Shot Peening Specification — Part II." Lawerenz & Ekis, Jan./Feb. 1992.

Skiving

"Hard Gear Processing with Skiving Hobs." Loy, Mar./Apr. 1985.

"Using Hobs for Skiving." McElroy, May/June 1993.

Specifying

"Gear Inspection Chart Evaluation; Specifying Unusual Gear Sets." Smith & Janninck, Nov./Dec. 1991.

Spiral Bevel Gears

"A Computer Solution for the Dynamic Load, Lubricant, Film Thickness and Surface Temperatures in Spiral Bevel Gears." Chao, Baxter and Cheng, Mar./Apr. 1986.

"CNC Technology & the System-Independent Manufacture of Spiral Bevel Gears." Wiener, Sept./Oct. 1992.

"Gear Tip Chamfer and Gear Noise: Surface Measure of Spiral Bevel Gear Teeth." Janninck & Smith, July/Aug. 1993.

"Influence of Relative Displacements between Pinion and Gear on Tooth Root Stresses of Spiral Bevel Gears." Winter & Paul, July/Aug. 1985.

"Precision Forged Spiral Bevel Gears." Badawy, Raghupathi, Horvat & Ostberg, Aug./Sept. 1984.

"Pressure Angle Changes in the Transverse Plane for Circular Cut Spiral Bevel Gears." Huston & Coy, Sept./Oct. 1986.

"Synthesis of Spiral Bevel Gears." Litvin, Mar./Apr. 1991.

"Tooth Contact Shift in Loaded Spiral Bevel Gears." Savage et al. Nov./Dec. 1992.

"Tooth Root Stresses of Spiral Bevel Gears." Winter & Paul, May/June 1988.

Splines

"Advantages of Involute Splines As Compared to Straight Sided Splines." Tifco Spline, May/June 1985.

"Involute Splines." Och, Sept./Oct. 1990.

"Involute Spline Size Inspection." Janninck & Nielsen, Mar./Apr. 1985.

Spur Gears

"A Microcomputer Program to Calculate Spur Gears." Yelle, Gauvin and Nguyen, July/Aug. 1988.

"Basic Spur Gear Design." Janninck, Nov./Dec. 1988.

"Calculation of Spur Gear Tooth Flexibility by the Complex Potential Method." Cardou & Tordion, Sept./Oct. 1985.

"Computer-Aided Design of the Stress Analysis of an Internal Spur Gear." Hwang & Guenther, May/June 1988.

"Computer-Aided Spur Gear Tooth Design: An Application Driven Approach." Zarefar & Lawley, Nov./Dec. 1989.

"Crowned Spur Gears: Optimal Geometry &

Generation." Litvin, Zhang, Chaing, Coy & Handschuh, Sept./Oct. 1988.

"Effect of Shot Peening on Surfacing Fatigue Life of Carburized and Hardened AISI 9310 Spur Gears." Townsend & Zaretsky, Jan./Feb. 1986.

"Gear Tooth Scoring Design Considerations for Spur and Helical Gearing." Lynwander, May/June 1985.

"Grinding of Spur and Helical Gears." Rao, July/Aug. 1992.

"Into-Mesh Lubrication of Spur Gears with Arbitrary Offset Oil Jet — Part I." Akin & Townsend, May/June 1989.

"Into-Mesh Lubrication of Spur Gears with Arbitrary Offset Oil Jet — Part II." Akin & Townsend, July/Aug. 1989

"Longitudinal Load Distribution Factor for Straddle- and Overhang-Mounted Spur Gears." Tobe & Inoue, July/Aug. 1987.

"Lubricant Jet Flow Phenomena in Spur and Helical Gears." Akin & Townsend, Jan./Feb. 1987.

"Predicted Effect of Dynamic Load on Pitting Fatigue Life for Low-Contact-Ratio Spur Gears." Lewicki, Mar./Apr. 1989.

"Selection of a Proper Ball Size to Check an Involute Spur or Helical Gear Tooth." Reece & Van Gerpen, Sept./Oct. 1987.

"Spur Gear Fundamentals." Hindhede, Jan./Feb. 1989.

"Systematic Approach to Designing Plastic Spur and Helical Gears." Paquet, Nov./Dec. 1989.

"Tooth Strength Study of Spur Planet Gears." Drago & Uppaluri, Sept./Oct. 1986.

Standards

"A Review of AGMA, ISO, and BS Gear Standards. Part I — Pitting." Walton, Shi & Taylor, Nov./Dec. 1990.

"A Review of AGMA, ISO and BS Gear Standards. Part II." Walton, Shi & Taylor, Jan./Feb. 1991.

Statistical Process Control (SPC)

"Applying Process Control to Gear Manufacturing." Sebetic, Mar./Apr. 1992.

"SPC Acceptance of Gear Hobbing & Shaping Machines." Cluff, Sept./Oct. 1991.

Surface Temperatures

"A Computer Solution for the Dynamic Load, Lubricant, Film Thickness and Surface Temperatures in Spiral Bevel Gears." Chao, Baxter & Cheng, Mar./Apr. 1986.

"Maximum Surface Temperature of the Thermoplastic Gear in a Non-Lubricated Plastic/Steel Gear Pair." Gauvin, Girard & Yelle, Aug./Sept. 1984.

Tables (See also Basics, Mathematics)

"Base Pitch Tables." Janninck, Sept./Oct. 1992.

"SI Units — Measurements & Equivalencies." Jakuba, Sept./Oct. 1988.

"Useful Information." July/Aug. 1986.

Transmission Error

"Transmission Errors & Bearing Contact of Gears." Litvin, Zhang, Lee & Handschuh, July/Aug. 1990.

"Relationship of Measured Gear Noise to Measured Gear Transmission Errors." Smith, Jan./Feb. 1988.

Troubleshooting

"Bevel Gear Manufacturing Troubleshooting Problems." Sebetic, Mar./Apr. 1991.

"Identification & Correction of Damaging Resonances in Gear Drives." El-Bayoumy, Aug./Sept. 1984.

"Identification of Gear Noise with Single Flank Composite Measurement." Smith, May/June 1986.

"New Techniques for Aligning and Maintaining Large Ring Gears." Antosiewicz, Sept./Oct. 1985.

Wear

"Calculation of Slow Speed Wear of Lubricated Gears." Winter & Plewe, Nov./Dec. 1985.

"Classification of Types of Gear Tooth Wear — Part I." Faure, Nov./Dec. 1992.

"Classification of Types of Gear Tooth Wear — Part II." Faure, Jan./Feb. 1993.

"Comparing Surface Failure Modes in Bearings & Gears." Moyer, July/Aug. 1992.

"Effect of Shot Peening on Surfacing Fatigue Life of Carburized and Hardened AISI 9310 Spur Gears." Townsend & Zaretsky, Jan./Feb. 1986.

"Effect of MoS_2 Films on Scoring Resistance of Gears." Terauchi, Hadano, & Kohno, July/Aug. 1986.

"Gear Tooth Scoring Design Considerations for Spur and Helical Gearing." Lynwander, May/June 1985.

"Gear Inspection; Hob Wear Questions." Janninck, Mar./Apr. 1991.

"Influence of Geometrical Parameters on the Gear Scuffing Criterion — Part I." Polder, Mar./Apr. 1987.

"Influence of Geometrical Parameters on the Gear Scuffing Criterion — Part II." Polder, May/June 1987.

"Predicted Effect of Dynamic Load on Pitting Fatigue Life for Low-Contact-Ratio Spur Gears." Lewicki, Mar./Apr. 1989.

"Surface Fatigue Life of CBN and Vitreous Ground Carburized and Hardened AISI 9310 Spur Gears." Townsend & Patel, Jan./Feb. 1990.

"Surface Pitting Fatigue Life of Noninvolute, Low-Contact-Ratio Gears." Townsend, May/June 1991.

Worm Gears

"A New Method for Designing Worm Gears." Octrue, July/Aug. 1989.

"Coarse Pitch Worms." Sharma, May/June 1993.

"Cone Drive Double Enveloping Worm Gearing Design and Manufacturing." Loveless, Oct./Nov. 1984.

"Contact Surface Topology of Worm Gear Teeth." Janninck, Mar./Apr. 1988.

"Cutting Low-Pitch-Angle Bevel Gears; Worm Gears & the Oil Entry Gap." Smith & Janninck, July/Aug. 1992.

"Improved Worm Gear Performance with Colloidal MoS_2-Containing Lubricants." Pacholke & Marshek, Nov./Dec. 1988.

"Introduction to Worm Gears." Simonelli, Mar./Apr. 1993.

"Limitation of Worm and Worm Gear Surfaces to Avoid Undercutting." Kin, Nov./Dec. 1990.

"The Effect of Lubricant Traction on Wormgear Efficiency." Murphy et al., Jan./Feb. 1985.

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COMPANY INDEX

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3260 Tillman Drive, Bensalem, PA 19020. (800) 374-7736 or (215) 244-4900; FAX (215) 244-7954. Contact: Tom Farrell, Jr.
R. S. # A-47

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P.O. Box 1789, Amarillo, TX 79105 (806) 622-1273 FAX (806) 622-3258. Contact: Billy Pyeatt.
R. S. # A-11

AMERICAN PFAUTER, LIMITED PARTNERSHIP
1351 Windsor Road, Loves Park, IL 61111-4294. (815) 282-3000; FAX (815) 282-3075. Contact: Robert A. Dunlap.
R. S. # A-1

BASIC INCORPORATED GROUP
P.O. Box 36276, Los Angeles, CA 90036. (213) 933-0311 FAX (213) 933-7487. Contact: Terry Wolf.
R. S. # A-10

BOURN & KOCH MACHINE TOOL CO.
2500 Kishwaukee Street, Rockford, IL 61104. (815) 965-4013 FAX (815) 965-0019. Contact: Carl S. Eckberg.
R. S. # A-18

CIATEQ, A.C.
Calzada del Retablo No. 150, Queretaro, Qro., Mexico. 76150 (52) 42 16 38 08 FAX (52) 42 16 99 63. Contact: Juan Jauregui C.
R. S. # A-22

DIAMOND BLACK TECHNOLOGY, INC.
100 Somerset Drive, Conover, NC 28613. (800) 368-9968 FAX (704) 322-4636. Contact: Ann Spuller.
R. S. # A-13

DIANAMIC® ABRASIVE PRODUCTS, INC.
2566 Industrial Row, Troy, MI 48084. (810) 280-1185 FAX (810) 280-2733. Contact: George J. Collins.
R. S. # A-24

R. S. # A-24

FAIRLANE GEAR, INC.
P.O. Box 409A, Plymouth, MI 48170. (800) 837-1773 or (313) 459-2440 FAX (313) 459-2941. Contact: Bob Turke.
R. S. # A-7

GMI
6708 Ivandale Road, Independence, OH 44131. (216) 642-0230 FAX (216) 642-0231. Contact: Bill McElroy.
R. S. # A-51

HALIFAX RACK & SCREW CUTTING CO.
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R. S. # A-25

K.H. HUPPERT COMPANY
16850 South State St., South Holland, IL 60473-2881. (708) 339-2020 FAX (708) 339-2225. Contact: Gary Huppert.
R. S. # A-8

R. S. # A-29

JAMES TECHNOLOGIES CORPORATION
4732 Pearl St., Boulder, CO 80301. (303) 444-6337 FAX (303) 444-6561. Contact: Jim Richards.
R. S. # A-12

M & M PRECISION SYSTEMS CORP.
300 Progress Road, West Carrollton, OH 45449. (513) 859-8273 FAX (513) 859-4452. Contact: Ellen Raichle.
R. S. # A-6

MTM KÖNIG
Main-Tauber-Maschinenbau GmbH, Am Stammholz, Wertheim, Germany D97877. (49) 9342 876 14 FAX(49) 9342 876 25. Contact: Horst König.
R. S. # A-14

MERIT GEAR CORPORATION
3701 Durand Ave., Suite 327, Racine, WI 53401. (800) 75-MERIT FAX (414) 554-3310. Contact: Suzi Zierten.
R. S. # A-20

MITSUBISHI MACHINE TOOL USA, INC.
907 W. Irving Park Rd., Itasca, IL 60143. (708) 860-4222 FAX (708) 860-4233. Contact: Rick Reenan.
R. S. # A-50

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BROACHING EQUIPMENT

ELMASS NORTH AMERICA, INC.
N. 114 W. 19320 Clinton Dr., Germantown, WI 53022. (414) 255-5644 FAX (414) 255-6509. Contact: Markus Meinhardt.
R. S. # A-34

R. S. # A-19

CNC GRINDING WHEEL DRESSERS

NORMAC, INC.
Airport Road Industrial Park, Arden, NC 28704. (704) 684-1002 FAX (704) 684-1384. Contact: R. M. Bodie.
R. S. # A-15

GEAR BLANKS — BRONZE

ACCURATE SPECIALTIES INC.
N12 W24360 Bluemound Rd., Waukesha, WI 53188. (414) 547-5450 FAX (414) 547-5892. Contact: Greg Wilkey.
R. S. # A-38

GEAR CUTTING TOOLS

GMI
6708 Ivandale Rd., Independence, OH 44131. (216) 642-0230 FAX (216) 642-0231. Contact: Bill McElroy.
R. S. # A-51

R. S. # A-29

R. S. # A-35

R. S. # A-19

PFAUTER-MAAG CUTTING TOOLS, LIMITED PARTNERSHIP
1351 Windsor Rd., Loves Park, IL 61111. (815) 877-8900 FAX (815) 877-0264. Contact: Jerry D. Knoy.
R. S. # A-2

STARCUT SALES
P.O. Box 376, Farmington, MI 48332-0376. (313) 474-8200 FAX (313) 474-9518. Contact: Bill Maples.
R. S. # A-4

R. S. # A-37

GEAR FINISHING MACHINES

GMI
6708 Ivandale Rd., Independence, OH 44131. (216) 642-0230 FAX (216) 642-0231. Contact: Bill McElroy.
R. S. # A-51

MITSUBISHI MACHINE TOOL USA, INC.
907 W. Irving Park Rd., Itasca, IL 60143. (708) 860-4222 FAX (708) 860-4233. Contact: Rick Reenan.
R. S. # A-50

MOORE PRODUCTS CO.
Sumneytown Pike, Springhouse, PA 19477. (215) 646-7400 FAX (215) 283-6358. Contact: Matt Thompson.
R. S. # A-5

NATIONAL BROACH AND MACHINE CO.
17500 Twenty Three Mile Road, Macomb, MI 48044. (313) 263-0100 FAX (313) 263-4571. Contact: Ray Wagner.
R. S. # A-19

NIAGARA GEAR CORP.
941 Military Road, Buffalo, NY 14217-2590. (716) 874-3131 FAX (716) 874-9003. Contact: Dennis Klimko.
R. S. # A-23

NORMAC, INC.
Airport Road Industrial Park, Arden, NC 28704. (704) 684-1002 FAX (704) 684-1384. Contact: Ray Bodie.
R. S. # A-15

PARKER INDUSTRIES, INC.
1650 Sycamore Ave., Bohemia, NY 11716. (516) 567-1000 FAX (516) 567-1355. Contact: George Parker.
R. S. # A-9

PFAUTER-MAAG CUTTING TOOLS LIMITED PARTNERSHIP
1351 Windsor Road, Loves Park, IL 61111. (815) 877-8900 FAX (815) 877-0264. Contact: Jerry Knoy.
R. S. # A-2

REDIN CORPORATION
1817 18th Avenue, Rockford, IL 61104. (815) 398-1010 FAX (815) 398-1055. Contact: Fred Johnson.
R. S. # A-21

REISHAUER CORP.
1525 Holmes Road, Elgin, IL 60123. (708) 888-3828 FAX (708) 888-0343. Contact: Dennis Richmond.
R. S. # A-42

ROTO-TECHNOLOGY
351 Fame Road, Dayton, OH 45449-2388. (513) 859-8503 FAX (513) 859-0656. Contact: Esther Munsey
R. S. # A-17

RUSSELL, HOLBROOK & HENDERSON
Two North St., Waldwick, NJ 07463. (201) 670-4220 FAX (201) 670-4266. Contact: Kazunobu Agu.
R. S. # A-16

STAR CUTTER COMPANY
23461 Industrial Park Drive, Farmington Hills, MI 48335. (313) 474-8200 FAX (313) 474-9518. Contact: Bill Maples.
R. S. # A-4

GEAR FORMING MACHINES

R. S. # A-52

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1351 Windsor Rd., Loves Park, IL 61111-4294. (815) 282-3000 FAX (815) 282-3075. Contact: Robert A. Dunlap.
R. S. # A-1

R. S. # A-19

GEAR HOBBING MACHINES

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R. S. # A-1

CHUN YANG INDUSTRIAL CO., LTD.
No. 10 Lane 126, Sec. 3, Chung Yang Rd., Tu-Cheng Shiang, Taipei Hsien, Taiwan, R.O.C. 886-2-2603681 FAX 886-4-532-0394, 886-2-262-3025. Contact: Victor Wang.
R. S. # A-39

MITSUBISHI MACHINE TOOL USA, INC.
907 W. Irving Park Rd., Itasca, IL 60143. (708) 860-4222 FAX (708) 860-4233. Contact: Rick Reenan.
R. S. # A-50

GEAR INSPECTION EQUIPMENT

R. S. # A-49

M & M PRECISION SYSTEMS CORPORATION
300 Progress Rd., West Carrollton, OH 45449. (513) 859-8273 FAX (513) 859-4452. Contact: Ellen Raichle.
R. S. # A-6

R. S. # A-53

GEAR MEASURING MACHINES

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R. S. # A-47

R. S. # A-43

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R. S. # A-44

PILLAR INDUSTRIES
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IMPORT AGENTS

Lorenz Shaper Cutters:

STARCUT SALES

P.O. Box 376, Farmington, MI 48332-0376. (313) 474-8200 FAX (313) 474-9518. Contact: Pat Drumm.

R. S. # A-32

INSPECTION EQUIPMENT REPAIRS

PRECISE INSPECTION

27380 Gratiot Ave., Roseville, MI 48066. (313) 445-6959, (313) 775-3334 FAX (313) 775-3334 #7. Contact: W. Schippert.

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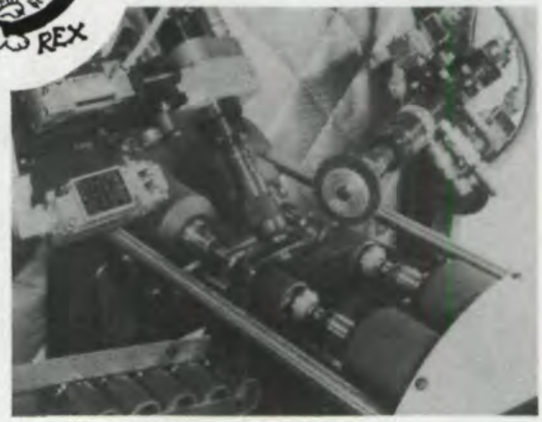

This Automatic Load/Unload (4) Track Pinion Deburr Machine, produces 1000 P/P per hour. Call Redin Specialists to increase your production.

• Automation	• Bevel	• Spur
• Tooth Radiusing	• Spiral	• Ring
• Grinding	• Pinion	• Hypoid
• Brushing	• Helical	• Spiral Bevel
• Cams	• Irregular Shapes any size	
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C O M I N G I N 1 9 9 4

ALL THE RIGHT MOVES

Introducing our newest column: People On The Move.

Beginning with our January/February, 1994, issue, we will be reporting on

- Promotions
- Moves to new companies
- Company moves to new locations

Don't miss any of the new moves; see *Gear Technology*'s next issue. If you have a move of your own you'd like to report, call us at 800-451-8166 or fax us at :

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all in one

GEAR DESIGN SOFTWARE

diseng v1.1
Is the first gear design software that really designs and not just calculates.

diseng v1.1
Is really easy to use in your PC, because it permits achieving high performance results since it is also a research tool for analyzing the influence of each single parameter variation in the results.

diseng v1.1
Also has preliminary dimensioning program presented as a spread sheet.

diseng v1.1
Has standard English and metric unit systems included

How does it work?

FIRST

You define for each parameter, such as ratio, center distance, pressure angle, etc., a convenient set of values that you are really able to use.

SECOND

You define your performance needs regarding Pitting Life, Bending Life, Scoring Probability, Reliability Level and Operating Conditions.

THIRD

You wait a few seconds until diseng© finds out the best solution within your particular possibilities.

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"Demo & Full Demo Disk Available"

diseng©

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CALENDAR

NOVEMBER 3-4

Vacuum Heat Treating & Brazing User Group Conference. Sponsored by Abar Ibsen Industries. The Holiday Inn, Bucks County, Trevose, PA. Sessions focusing on problem solving and information exchange for heat treaters and brazers. Contact Tom Farrell, (800) 374-7736.

NOVEMBER 25-29

EPM Vietnam '93, International Exhibition for Engineering, Production & Machinery. Tan Binh Sport & Exhibition Center, Ho Chi Minh City (Saigon) Vietnam. Sponsored by Vietnamese Chamber of Industry & Commerce and Hannover Fairs USA., Inc. Exhibits will cover a broad range of mechanical engineering products and services, including tools, cutting technology, measuring and testing equipment and surface treatment technology. Call Rachel Blumenthal (609) 987-1202.

NOVEMBER 28 - DECEMBER 3

ASME Winter Annual Meeting. Ernest N. Morial Convention Center, New Orleans, LA. Over 300 sessions, panels and lectures, many covering meeting theme — "Managing Technological Risks." Call ASME Meetings Dept. (212) 705-7795.

CALL FOR PAPERS
JANUARY 1, 1994 DEADLINE

ASME is sponsoring six simultaneous conferences on mechanisms, design automation, design theory, flexible assembly systems, computers in engineering, engineering data bases and related topics. The conference will be held on September 11-14, 1994, at the Hyatt Regency Hotel in Minneapolis, MN. Papers are being accepted for all six conferences now. Call Jeff Lenard, ASME Public Information, at (212) 705-8157 for more details.

APRIL 18-21, 1994

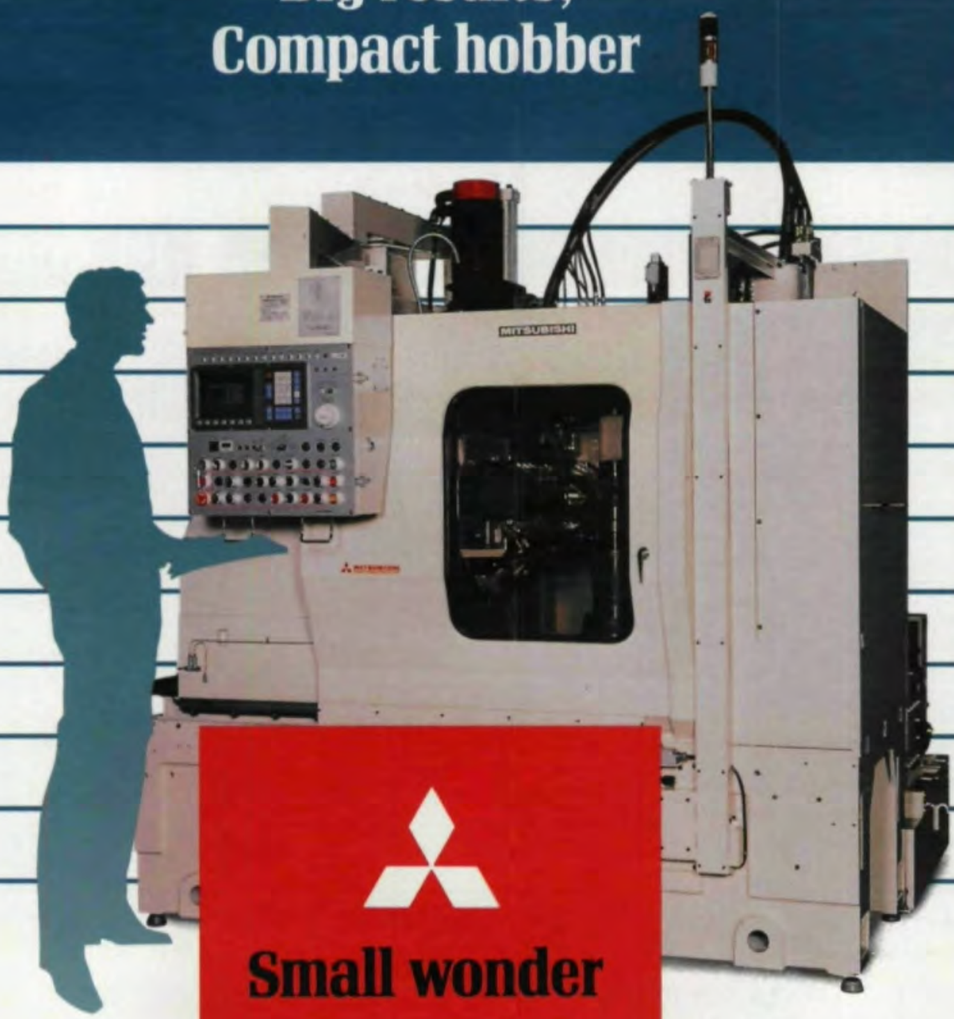
North American Material Handling Show and Forum. Cobo Hall, Detroit, MI. A comprehensive showcase of material handling equipment, systems and technologies, plus a concurrent educational forum on improving productivity in manufacturing and distribution. Contact Carol Miller at The Material Handling Industry of America, (800) 345-1815.

PENCIL US IN . . .

If your company or organization is planning an educational or trade show event that you think would be of interest to our readers, announce it in our Technical Calendar. Notices need to be in our hands by the 10th of the month two months prior to the issue date in which you wish your announcement to appear. Mail your announcement to:

Technical Calendar
Gear Technology
P.O. Box 1426
Elk Grove Village, IL 60009
or fax us at (708) 437-6618.

Big results, Compact hobber



Small wonder

No other company makes more gear hobbers, shapers and shavers than Mitsubishi. So it's no wonder no other gear hobber is as compact <u>and</u> as accurate as the new GC40CNC gear hobber.

Here are just four reasons why:

- Using finite analysis and kinematics of machine components, Mitsubishi design engineers developed a structure that is extremely rigid.
- Inside, it's a big machine with an optimized hob head assembly design that minimizes overhang and deflection—and maximizes cutting capability.
- A new Mitsubishi servo system delivers high accuracy synchronization between hob and table, using feed forward technology.
- Cutting capacities have been increased by boosting X- and Y-axis feedrates to 10 m/min and hob speed to 1,000 rpm.

To find out other great reasons why this new CNC gear hobber—with fully conversational CNC controls—is the most productive machine in its class (or for more information on the full line of Mitsubishi gear making machines), call write or circle the number below.

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FAX (802) 885-3745

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Spur, helical and bevel gears

Our gear hardening equipment includes 4 NATCO submerged process machines and 3 AJAX CNC-controlled gear scanning machines. We can also tool to meet any production need. Write for a free brochure.

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HELP WANTED

KOEPFER

Company growth of world leading gear equipment manufacturer has created the following positions from our Illinois facility:

Sales Engineer: Marketing of hobbing and related machinery.

Service Engineer: CNC and gear technology experience is needed.

Machine Tool Builder: Precision mechanical, hydraulic and electrical capabilities required.

Send Resume in confidence to:

JKS

Koepfer America Limited Partnership
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Telephone: 708-931-4121

PURCHASING AGENT: $60,000. Automotive Drive Line Components. Southeast. Bi-lingual German a plus.
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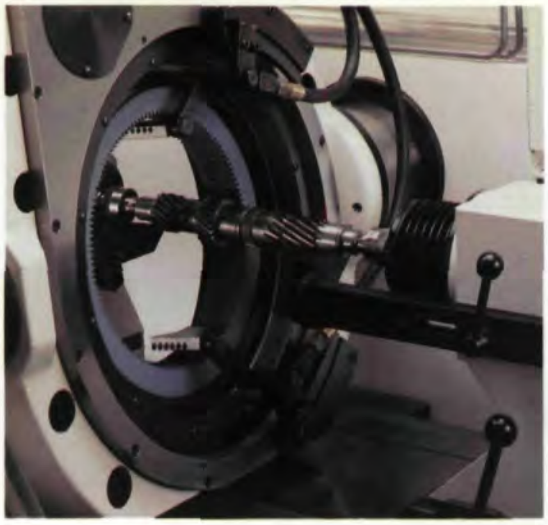
ENGINEERING MANAGER: $60,000. Enclosed Gear Boxes. Supervise 4. Design.
Contact Ann Hunsucker, Excel Associates, Inc.
P. O. Box 520, Cordova, TN 38088
or call (901) 757-9600. FAX (901) 754-2894.

To advertise in *Gear Technology* Call (708) 437-6604.

Rates: Line classified - $37.50 per line. 8 lines per inch. $300 minimum. Classified Display - per inch (3" min.) **1X** - $170, **3X**-$160, **6X** - $150. Type will be set to advertiser's layout or *Gear Technology* will set type at no extra charge.

Payment: Full payment must accompany classified ads. Send check or Visa/Mastercard/American Express number and expiration date to: *Gear Technology*, P. O. Box 1426, Elk Grove Village, IL, 60009. **Agency Commission:** No agency commission on classifieds. **Materials Deadline:** Ads must be received by the 25th of the month, two months prior to publication. **Acceptance:** Publisher reserves the right to accept or reject classified advertisements at his discretion.



WHO TAKES GEAR HONING TO AN UNCOMPROMISED FINISH?

Nobody but Reishauer. Obtain a high precision finish on the hardened tooth flanks of gears and pinions. RZR Series Honing machines utilize the oscillation (or plunge) process to achieve increased productivity without sacrificing superior finishes. Profiling of the hone ring is done with a diamond master gear matched to the workpiece specifications. Crowning along the lead is CNC controlled for consistent and repeatable accuracy.

So, before you're caught in a compromising position, hone in on the experts.

RZR Gear Honing Machine
Capacity:

Workpiece O.D.	9.44" (240 mm)
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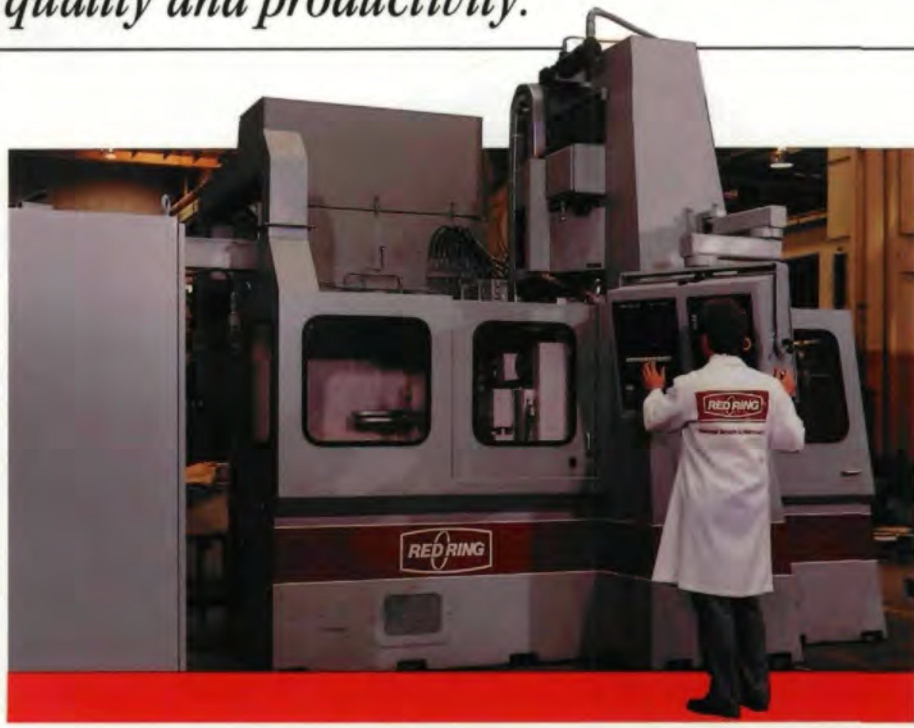
SF-SERIES CNC PRECISION GEAR GRINDERS FOR EXTERNAL AND INTERNAL SPUR AND HELICAL GEARS UP TO 36-IN. DIA.

Consistently higher accuracy, faster set-ups, and unmatched versatility to boost your quality and productivity.



The RED RING SF-series of grinders are the world's only full 6-axis CNC precision form gear grinders proven in four years of production.

FLEXIBILITY/VERSATILITY. They let you choose the best grinding method for the job, from aluminum oxide, ceramic aluminum oxide, CBN plated, or dressable CBN wheels. The SF grinders are capable of creep feed or conventional grinding. This level of versatility can produce optimum results on the widest range of jobs.

INCREDIBLY FAST SET-UPS. Part data input can be accomplished in approximately 15 minutes. Without the need for cams, templates and index plates, you typically cut set-up time to a fraction of the time required with conventional machines.

EASY PROFILE COORDINATE GENERATION. Our unique, user-friendly profile coordinate generation software (PCGS) provides prompts that ask the operator questions about the involute profile of the part. Built-in validity checking on all inputs confirms all data. Part profiling is accomplished faster than ever before.

AUTOMATIC WHEEL SIZE COMPENSATION. Grinding wheel speed and profile data are updated with every dress cycle, providing optimum profile accuracy, particularly on helical gears.

AUTOMATIC STOCK DIVIDING. This patented option allows the gear to be accurately positioned for optimum stock removal in a fraction of the time previously needed for stock dividing.

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