Carbide Rehobbing — A New Technology That Works!

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Many people in the gear industry have heard of skiving, a process wherein solid carbide or inserted carbide blade hobs with 15 – 60° of negative rake are used to recut gears to 62 Rc. The topic of this article is the use of neutral (zero) rake solid carbide hobs to remove heat treat distortion, achieving accuracies of AGMA 8 to AGMA 14, DIN 10-5 and improving surface finish on gears from 8 DP – 96DP (.3 module – .26 m.).

Early technology developed with Azumi skiving hobs yielded encouraging results. However, few people seemed to adopt this process in lieu of gear grinding. Among the drawbacks were the necessity of having extremely rigid hobbing machines and work fixturing, expensive tooth timing, centering devices, expensive cutters, and the difficulty of re-sharpening the cutters properly to maintain the correct involute.

Some of these problems have been eliminated by using zero-rake solid carbide hobs which are available from many of the major hob manufacturers. This eliminates the need to offset the diamond wheel when resharpening on a hob sharpener, reduces the initial cost of producing the cutter and increases cutter life. Another improvement is the common use of non-contact, electro-magnetic sensors which automatically divide the stock on the tooth flanks with extreme accuracy. If the quality of the gear is excellent initially and heat treat distortion is minimal, it is possible to recut gears with as little as .0015 – .003" over wires as a salvage method for gears which grew unexpectedly during heat treat.

Ideally gears should be roughed with protuberance hobs which have any desired profile modification built in. If the part is crowned, it may be beneficial to crown during roughing so that an even amount of stock is removed from the flanks, leaving a uniform case hardness depth. Helical gears often unwind during heat treat, and accommodation may be made to increase the helix angle. For fine pitch, we start with approximately 0°15' as an offset. Remember that if a protuberance rougher is used, it generally only produces the correct involute in a sometimes narrow range of teeth.

Our experience is limited to the carbide

GEAR DATA

Type of Gear: Spur
Pressure angle: 28°
Diametral Pitch: 12
Number of Teeth: 14
Pitch Diameter: 1.1667 [.0018 | A–B] P.D.
Max Allowable Eccentricity:
Total Composite Error .002 to Datum [A–B] with Master
(Backlash .004 Min. .996 Max with Master)
Mating Gear: P/N 3020-188 O.D. Max. Min.
No. of Teeth 14
Center Distance Min. 1.16655
Helix Angle: R. H. or L. H.
Lead: Nominal
Min. Root Fillet Radius: .0131
Class of Gear (Per SS-157): Class 5 [1]
Base Circle Radius: .5151
True Involute Form Diameter (T. I. F.): 1.0634
Involute Roll Angle to T.I.F. Dia.: 14° 41'
Involute Roll Angle to Outside Dia.: 45° 1'
Root Dia. .9465 Min. 1.0171 Max.
Dimension Over Pins 1.3569 – 1.3603
Measuring Pins Diameter: .144

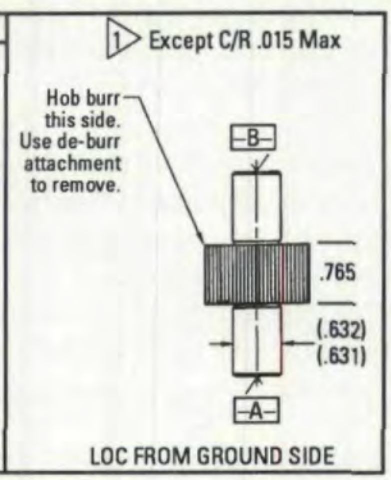

Fig.1 – Case 1

rehobbing of gears ranging from 8DP – 96DP and less than 4" (100 mm.) in diameter, although many people have skive-hobbed much coarser, larger gears to 40 mm module. In fact a number of manufacturers skive coarse pitch gears to reduce finish grinding times.

Remember that proper gear blank finishing is crucial for achieving high quality levels for carbide rehobbing, just as it is vital to gear grinding. Bore-type blanks should be honed or I.D.-ground, and faces should be parallel and perpendicular to the bore. Similarly, shafts should be cylindrically ground to provide true locating diameters to the centers for cutting and later inspection.

Since carbide can be susceptible to cracking, later vintage hobbing machines with backlash-eliminating features, power tailstock clamping and CNC controls multiply dramatically achievable production rates and accuracies as well as prevent hob damage. As reported in a January, 1993, paper, "Skive Hobbing Hardened Gears" by Hans Glatzeder, rigid machines can carbide rehob to 2/3 their capacity diameter and module (Ref. 1).

Cutting tools should be A or AA quality and preferably titanium carbo-nitride (TiCN) coated to improve lubricity. Either face or bore keys are suggested to increase drive rigidity. Typical carbides are ISO K10, K05, M15, M10 and P20 (Tables I – IV). Depending on pitch, stock removal, hardness and whether protuberance hobs were used to rough, surface speeds range from 90 – 340 m/min. Recommended stock removal is .002 – .006" (.05 – .15 mm.). Required quality may dictate a finishing pass. In this case it is beneficial to climb-cut on one pass and conventionally cut the other to reduce cutter wear and improve quality. Experimentation on helical gears is warranted to determine if opposite-hand hobbing; i.e., left-hand hob, right-hand gear or vice versa, will yield better results. Close observation of the cutter and gear quality will help determine shift and sharpening intervals. On fine and medium pitch gears, we expect at least 2000 pieces per hob or more, depending on hob size and part hardness, unless suffering a crash. Microfinish is determined by the number of flutes in the cutter versus the number of teeth in the gear, the pressure angle, feed rates,

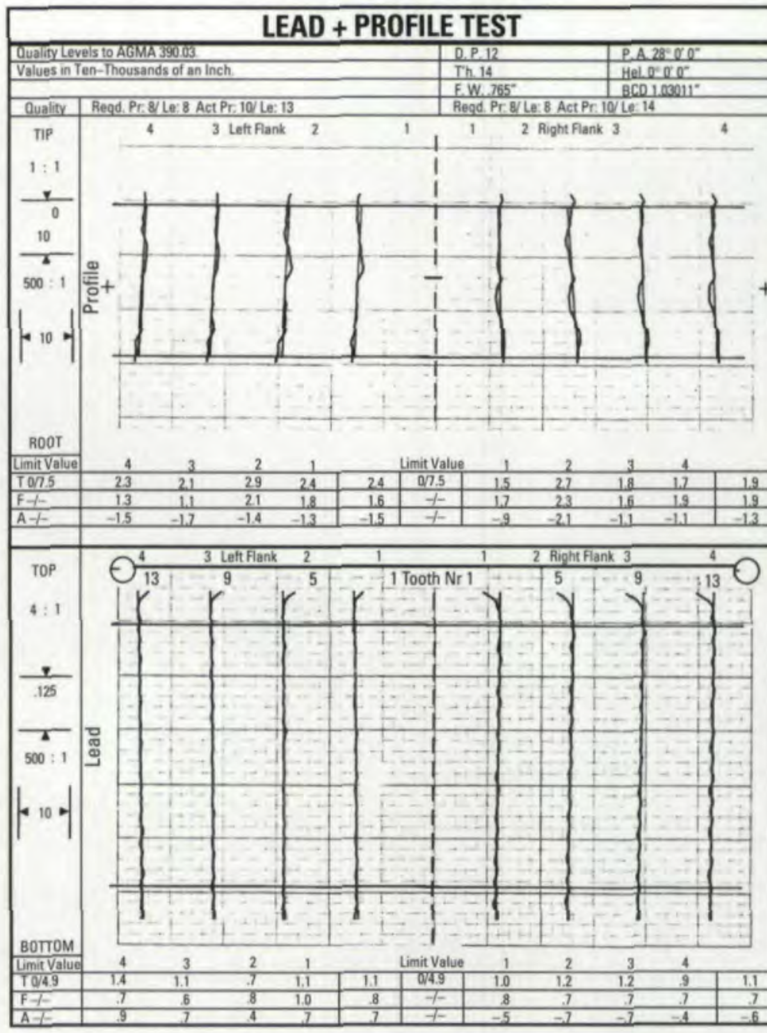

Fig.2 – Case 1

material cut, hardness and coolant. Surprisingly, carbide-hobbed finishes approach ground finshes, often around 16 microinches. Flank wear of .002 – .006" (.05 – .15 mm.) per hob flank is a suggested starting point in fine and medium pitches before shifting and sharpening. Because TiCN does not lend itself to recoating, and regrinding the hob profile is not easily done, we have not used recoating.

So far only recutting has been mentioned. It should be noted that many manufacturers are carbide hobbing from solid. In fine to medium pitches, this is practical in the 40 – 50 Rc range, especially where small quantities are involved, and hob spindle rpms may be reduced to under 100. Hobbing from the solid is generally more costly than carbide rehobbing rough hobbed gears due to tooling and machine time costs.

Most of our carbide rehobbing has been done on mechanical hobbers which realign the hob tangentially after the machine has been initialized with the home position for hob and

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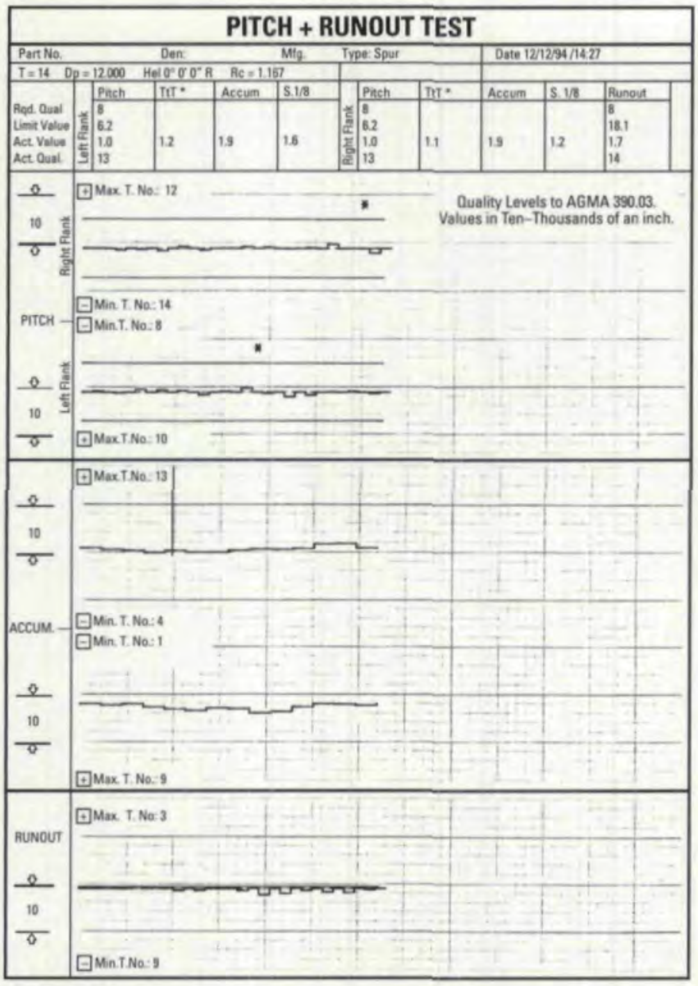


Fig.3 – Case 1

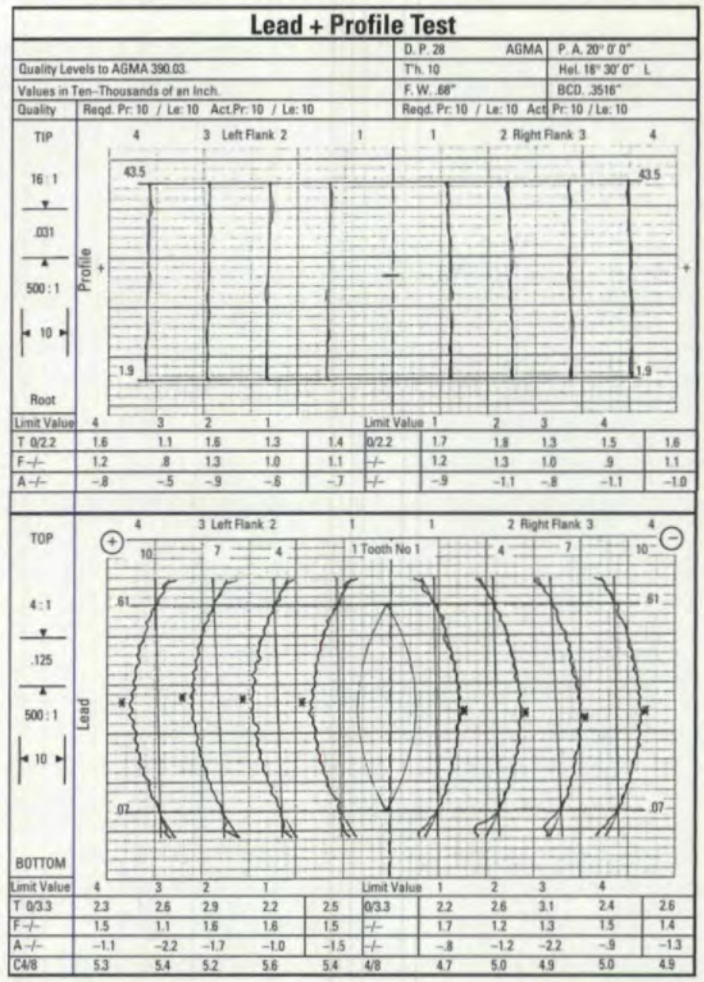


Fig.4 – Case 2

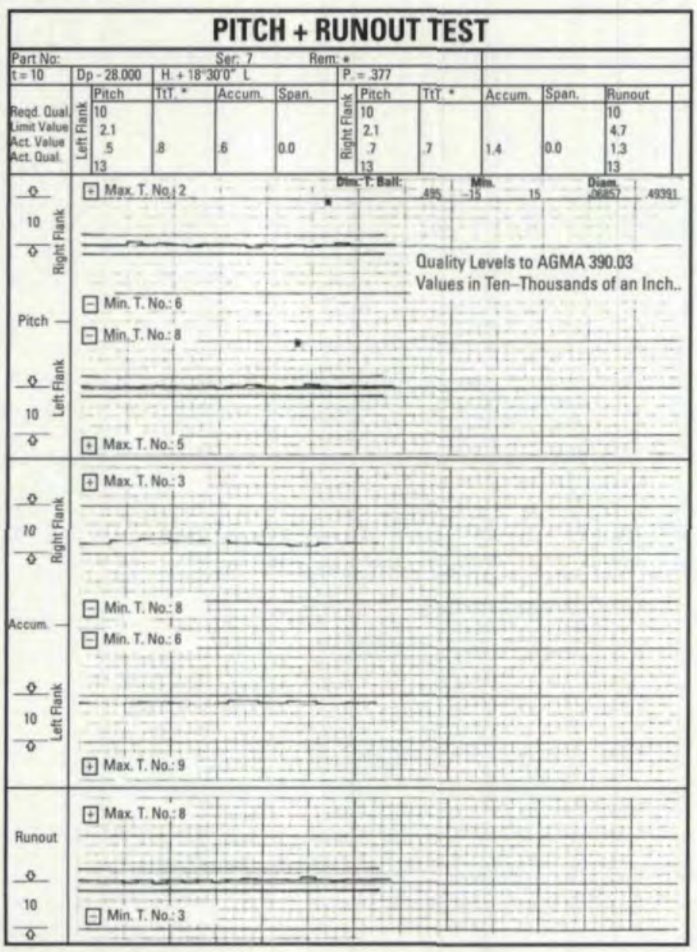
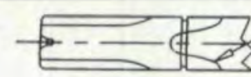


Fig.5 – Case 2



Item	Spur or Helical Gear Data	Specification	Insp.
1	Type	Helical	X
2	Normal diametral pitch	28	
3	Number of teeth	10	X
4	Normal pressure angle	20°	
5	Helix angle	18° 30'00"	
6	Hand of helix	Left	
7	Standard pitch diameter	.3766	
8	Whole depth	.0803	X
9	AGMA quality number	10	
10	Total composite tolerance	.001031	X
11	Tooth-to-tooth composite tolerance	.000712	X
12	Master part number		
13	Meas. over .06857 dia. (2) wires	.4965 – .4935	X
14	Lead	3.536026	
15	Lead tolerance	.000323	X
16	Profile tolerance	.000216	X
17	Roll angle (functional profile)	1.8943°	X
19	Outside dia. of gear (5)	.4715 ± .000 .006	X
20	Center distance (functional)	.96034	
21	Circular tooth thickness	.0677 – .0658	
22	Backlash	.003 – .0003	
23	Tooth form (see detail " ")		
25	Modification	.0115	
26	Base dia.	.3516	
27	Mating gear	699607	
28	Min root dia.	.305	
29	Pinion must have .0004 to .0008 crown		X

Fig.6 – Case 2

work piece stored from a setup part. Hob shift limits are established over a circular pitch range, shifting the hob in and out to realign from the timed position established by the proximity device located over the top of the workpiece. When the hob is thoroughly worn in a given area, the hob is shifted a full circular pitch and continues across the hob face. Care must be taken to cut reasonably good parts in roughing and to insure that no severe damage occurs in heat treat. If a CNC hobber can be used, better profile results are possible because the workpiece is rotated rather than shifting the hob, which may degrade the profile.

Following are some histories which should make a strong case for the cost-effectiveness of carbide rehobbing as a substitute for gear grinding. In fact, many applications would be impractical to grind because of wheel diameter and cost. Keep in mind this hobbing was done on non-CNC, mechanical hobbers, costing \$250,000 – \$350,000, versus gear grinders, which usually cost \$1,000,000.

Case History 1. Aerospace high pressure pump gear (Figs. 1–3). Fourteen teeth, 12 DP, 28° PA, .765" face width, spur, hardened to 55 – 60 Rc.

A. Rough cut-double cut, .050/.030" (1.27 – .76 mm.) feed at 350 rpm with a 2" (50 mm.) diameter hob-33/hr. Normal tooth thickness, .130/.132 (3.3 mm.).

B. Finish-cut 400 rpm, feed .015" (.38 mm.), 2" (50 mm.) diameter cutter, TiCn coated, production 14/hr. auto-loading.

Case History 2. Power tool application (Figs 4–6). Ten teeth, 28 DP, 20° PA, 18.58°, .68" (17.3 mm.) helical face width, hardened to 48 – 53 Rc, material 41L50.

A. Rough hobbed 800 rpm, .045" (1.14 mm.) feed, .070/.072" (1.6 mm.) Normal tooth thickness, 100/hr.

B. Finish crown hobbed 500 rpm, .025" (.63 mm.) feed, .0642/.0625" (1.6mm.) normal tooth thickness, 60/hr.

Case History 3. Aerospace application (Figs. 7-9). Forty teeth, 32 DP, 20° PA, .325" face spur material 431 cres, heat treat 210/245,000 PSI, AGMA 10.

A. Rough hob 900 rpm/.050 (1.27 mm.) feed, 1 7/8 diameter M42 hob TiN, production 100/hour.

B. Finish carbide TiCn, 530 RPM, .025"

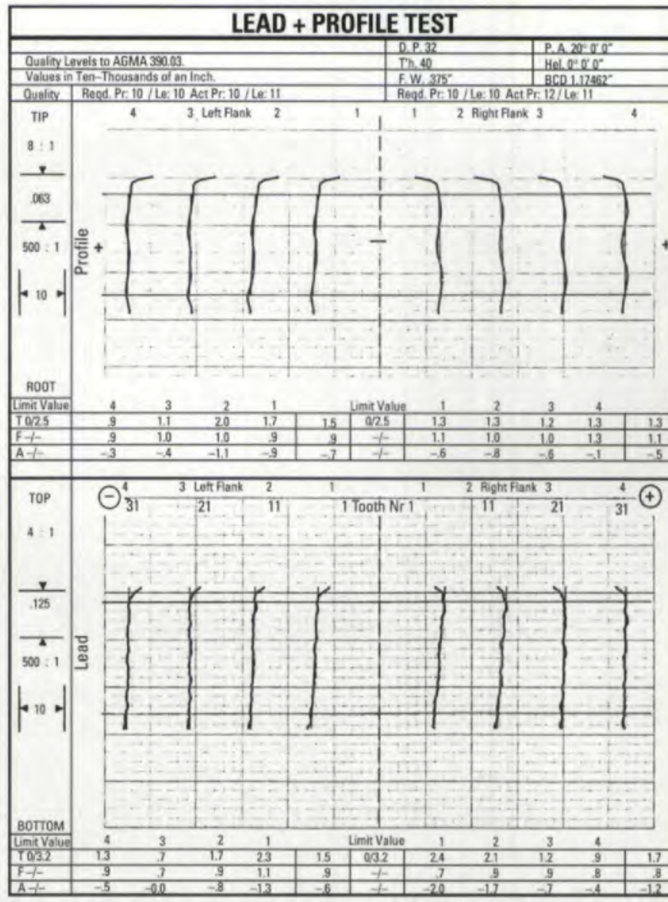


Fig.7 – Case 3

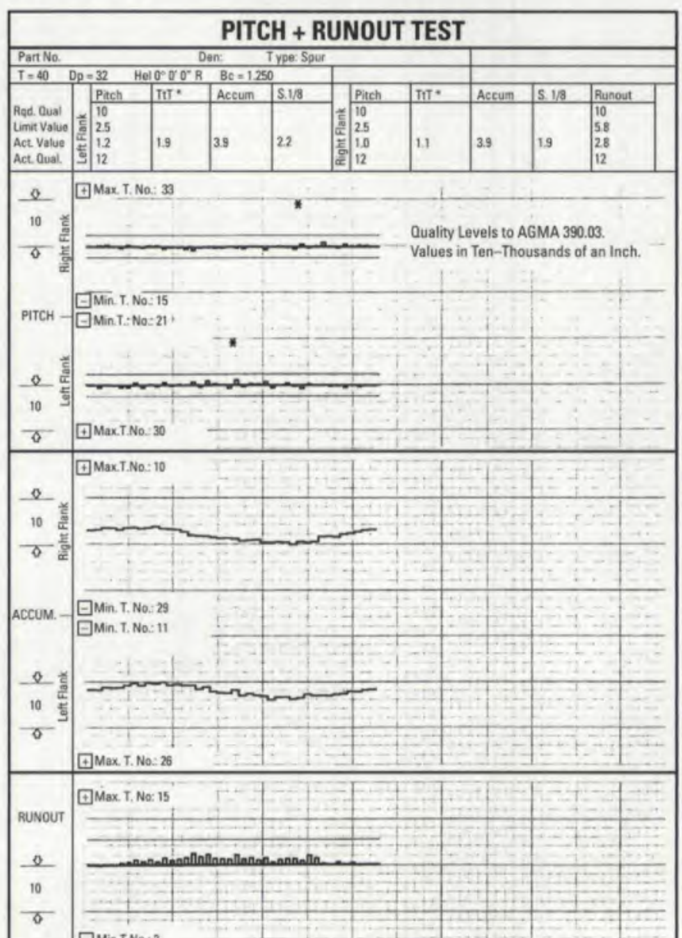


Fig.8 – Case 3

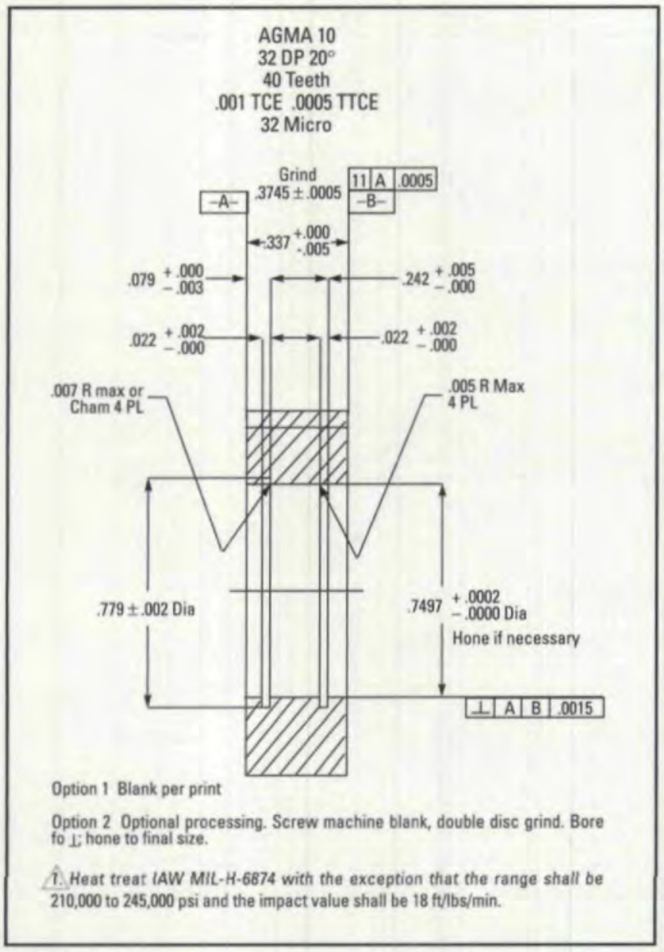


Fig.9 – Case 3

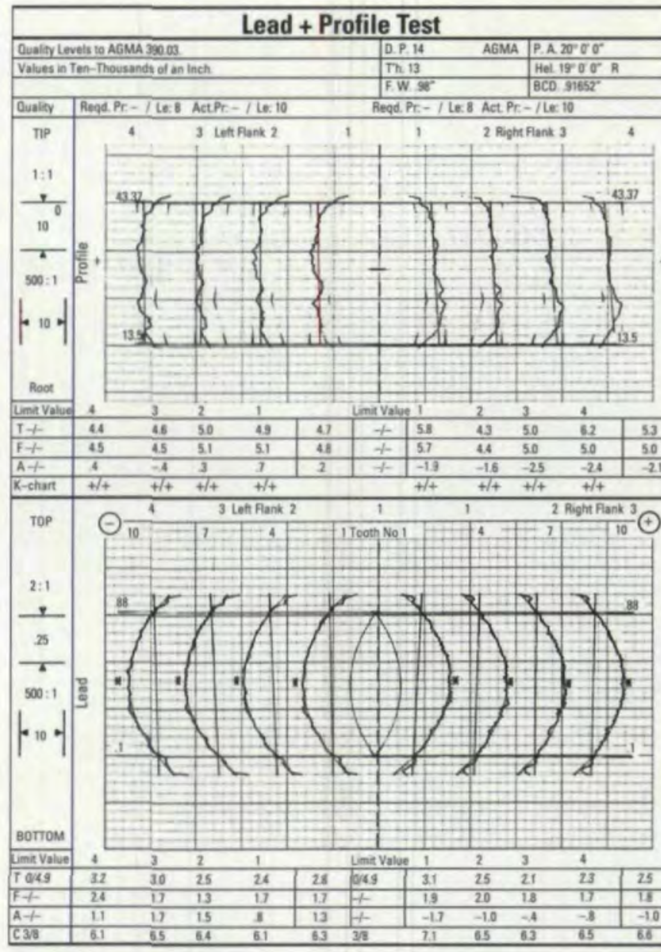


Fig.10 – Case 4

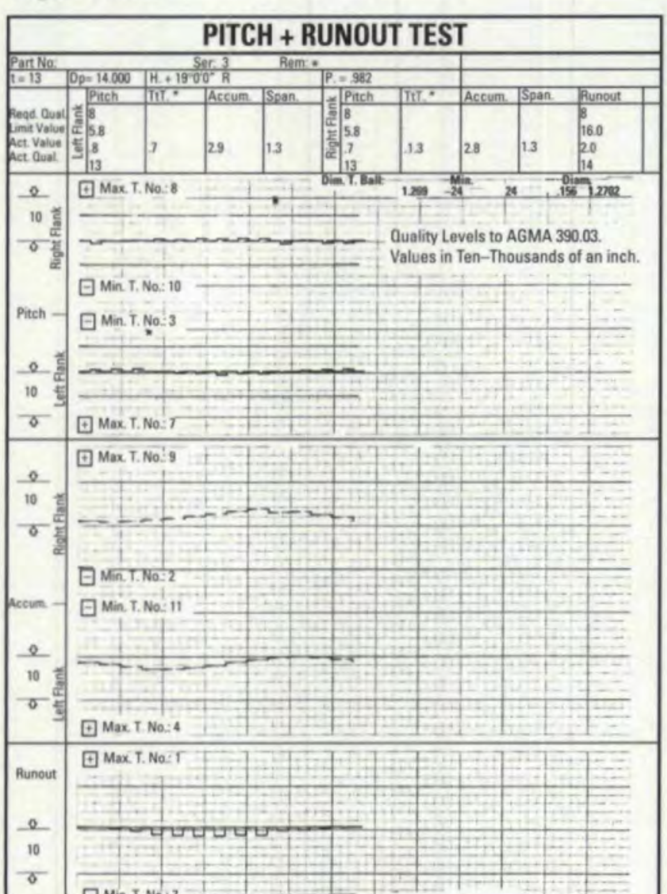


Fig.11 – Case 4

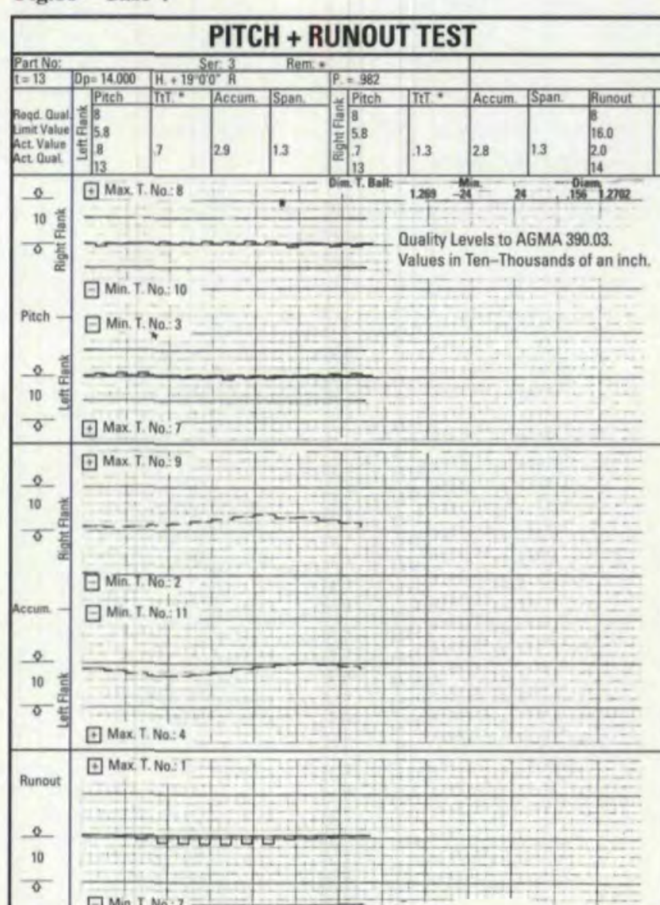


Fig.12 – Case 5

(.64 mm.) feed, 1 7/8 hob diameter, 28/hr.

Case History 4. Lift truck motor armature (Figs. 10–11). Thirteen teeth, 14 DP, 20° PA, 18.83° helical, .97 (24.6 mm.) face width, 86L20 material, induction hardened gear 58 – 63 Rc.

A. Rough hob 1" diameter hob, 800 rpm, .040 feed, 67/hr. Normal tooth thickness, .1406/.1387.

B. Finish hob 350 rpm, .025 (.64 mm.) feed, crowned, .0002/.001" (.005 – .025 mm.) 24/hr.

Case History 5. Lift truck armature shaft. (Figs. 12-13). Thirteen teeth, 14 DP, 20°PA, 14.75° helix, face 1.3" (33 mm.), crown-hobbed to AGMA 8.

A. Rough hob 600 rpm, .055" (1.4 mm.) feed, 1-7/8" (47.6 mm.) diameter hob TiCn, 45/hr.

B. Finish hob 325 rpm, .025" (.64 mm.) feed, 1-7/8" (47.6 mm.) diameter cutter TiCn 17/23/64. Normal tooth thickness, .1233/.1208 (3.1 mm.).

C. 14T, 16/32DP, 30°PA spline, 2.12" (53.8 mm.) face-finish splined, 22/48 Rc core hardness with carbide TiCN 1-7/8" (47.6 mm.) diameter hob, 34/hr.

For variation, Fig. 14 depicts a cast tooth form pump gear re-hobbed in alloy C

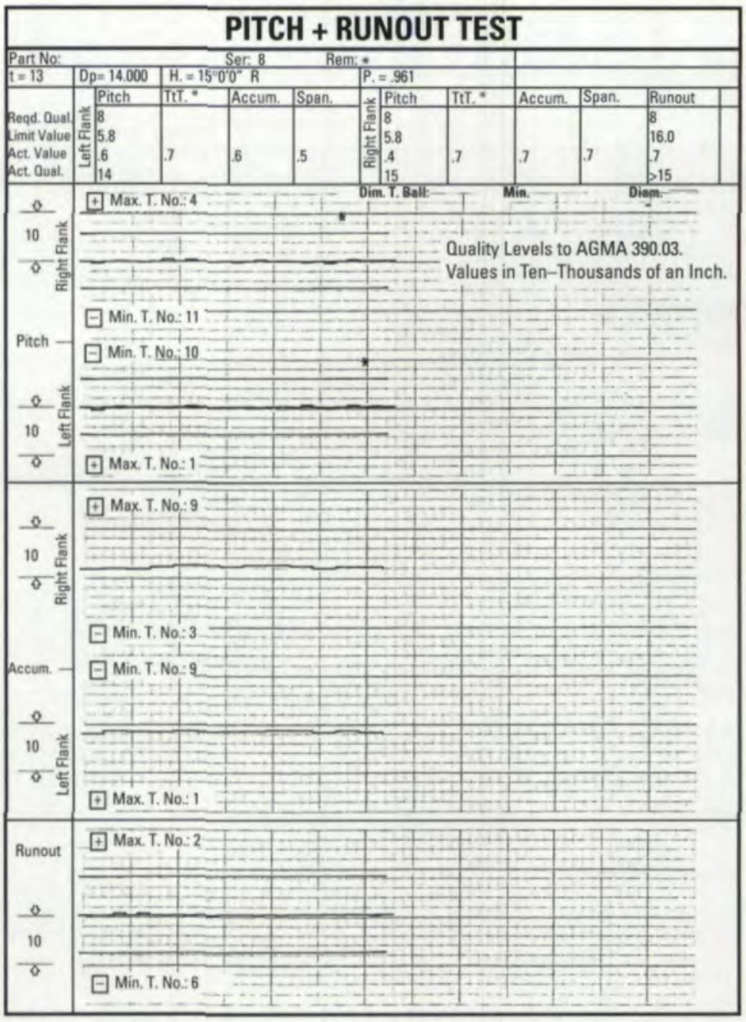


Fig.13 – Case 5

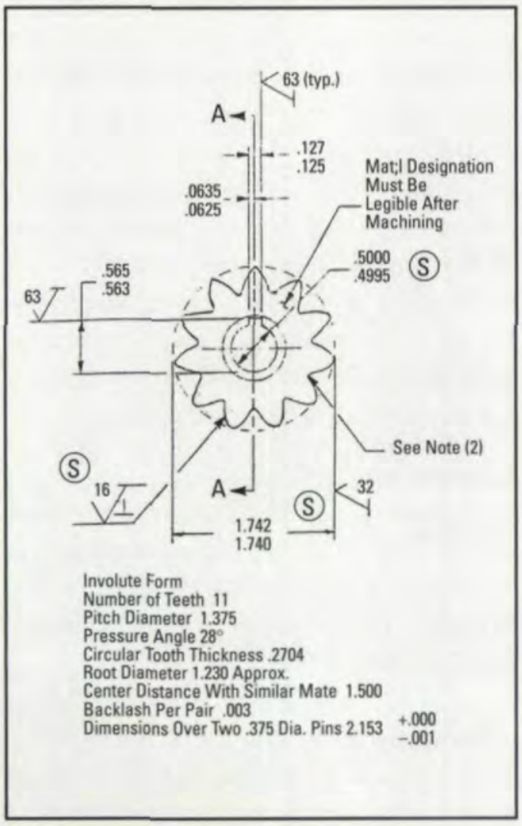


Fig.14

Table I

ISO	Rockwell Hardness	Deflection Resistence	W	Co	Ti	Ta	C
P20	90	90	60 83	5 10	5 15	0 15	6 9
M10	91.5	100	70 86	4 9	3 11	0 11	6 8
M15	89.5 93	120 220	75 95	5 9	0 10	0 12	5 7
K05	89 93	150 230	85 97	3 8	0 3	0 7	5 7
K10	90.5	120	84 90	4 7	0 1	0 2	5 6

Table II

Feed Module (DP)	Rough mm (in)	Finish mm (in)
> 12 [< 2]	3 – 4mm/rev (.120 – .160"/rev)	2 – 3mm/rev (.080 – .120"/rev)
> 12 [< 2]	2 – 3.5mm/rev (.008 – .140"/rev)	1.5 – 2.5mm/rev (.060 – .100"rev)

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Table III

Hardness HCR	Speed mm/min (in/min)
50–55	70 + 90 (220 – 290)
55–60	60 + 70 (190 – 220)
60–65	50 + 60 (160 – 190)

Table IV

Module DP	Speed mm/min (in/min)
1 + 5 (5 – 25)	60 + 90 (190 – 290)
6 + 12 (2 – 4)	50 + 70 (160 – 220)
> 12 (<2)	30 + 50 96 – 160)

Hastalloy. This presented a problem for the electromagnetic sensor, since this material is non-magnetic.

Tables I–IV (Ref. 2) define typical carbide grades, liberal feed rates for roughing and finishing and suggested speeds versus hardness and speed versus module. We tend to be more conservative with our speed and feeds to save hob wear and improve quality.

In conclusion, carbide rehobbing is an extremely economical approach to removing distortion caused by heat treatment. Besides approaching gear ground quality levels and finishes, carbide rehobbing can be used with small hobs capable of approaching blend-cut shoulders, which larger grinding wheels, including double helicals, cannot reach. Hardware cost is fractional, since the same machine can be used for roughing and finishing and mass production is readily obtainable with automatic loading. This process is a viable alternative to gear grinding. ■

References:

1. Glatzeder, Hans. "Skive Hobbing Hardened Gears," Liebherr Versahntechnik GMBH.
2. McElroy, William E. "Using Hobs for Skiving: A Pre-Finish and Finishing Solution." *Gear Technology*, May/June, 1993.

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