BACK TO BASICS...

Rotary Gear Honing

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Rotary gear honing is a hard gear finishing process that was developed to improve the sound characteristics of hardened gears by:

1. Removing nicks and burrs.
2. Improving surface finish.
3. Making minor corrections in tooth irregularities caused by heat-treat distortion.

The process was originally developed to remove nicks and burrs that are often encountered in production gears because of careless handling. Further development work with the process has shown that minor corrections in tooth irregularities and surface finish quality improvement can be achieved. These latter improvements can add significantly to the wear life and sound qualities of both shaved and ground hardened gears.

Gear honing does not raise tooth surface temperature, nor does it produce heat cracks, burned spots or reduce skin hardness. It does not cold work or alter the microstructure of the gear material, nor does it generate internal stresses.

Honing can be applied to both external and internal spur and helical gears utilizing a variety of specialized types of honing machine tools. Both taper and crown honing operations can be carried out if desired.

How the Process Works

The process uses an abrasive-impregnated, helical gear-shaped tool. This tool is generally run in tight mesh with the hardened work gear in crossed-axes relationship under low, controlled center distance pressure.

The work gear is normally driven by the honing tool at speeds of approximately 600 surface ft. per minute. During the work cycle, the work gear is traversed back and forth in a path parallel to the work gear axis. The work gear is rotated in both directions during the honing cycle. The process is carried out with conventional honing oil as a coolant.

The honing tool is a throw-away type that is discarded at the end of its useful life. The teeth are thinned as the tool wears. This tooth thickness reduction can continue until root or fillet interference occurs with the work gear. Then the O.D. of the hone can be reduced to provide proper clearance.

Eventually, thinning of the hone teeth also results in root intereference with the outside diameter of the work gear. When this condition occurs, the hone is generally considreed to be at the end of its useful life. In some isolated cases, it has been found practical to re-cut the hone root diameter with a grinding wheel to provide additional hone life.

Usually the amount of stock removed from the gear tooth by honing ranges from 0.0005" to 0.002" measured over pins.

The production rate at which honing operations can be carried out depends on the pitch diameter and face width of the work. A gear 1" diameter by 1" width can be honed in approximately 15 seconds. A gear 24" in diameter by 3" face width will require approximately 10 minutes honing time. Of course, honing of salvage gears requires longer cycles.

External Gear Honing Machines

A typical 24" external gear honing machine has the motor-driven honing tool mounted at the rear of the work spindle. The work spindle is mounted on a tilting table that can be positioned to provide four selective modes of operation.

The first mode is called loose backlash, where the hone and work gear are positioned in loose backlash operation on a fixed center distance. This method is sometimes utilized to slightly improve surface finish only, primarily on fine pitch gears with minimum stock removal.

The second mode of operation is called zero backlash. Here the work gear is positioned in tight mesh with the honing tool. The table is locked in fixed center distance location with a pre-selected hone pressure. This method is sometimes used to provide maximum gear tooth runout correction with minimum stock removal.

The third and most generally applied mode of operation is called constant pressure. The work gear is held in mesh with the honing tool at a constant pressure. This method removes nicks and burrs and provides maximum surface finish improvement in a minimum time.

The fourth mode of operation is called differential pressure. A pre-selected low pressure is present between the hone and the low point of an eccentric gear, and a pre-selected increased amount of pressure is present between the hone and the high point of eccentricity. This method has all of the desirable features of the constant pressure method plus the ability to slightly correct eccentricity. The amount of eccentricity in the gears with differential pressure honing may cause the hone to wear faster than the constant pressure method.

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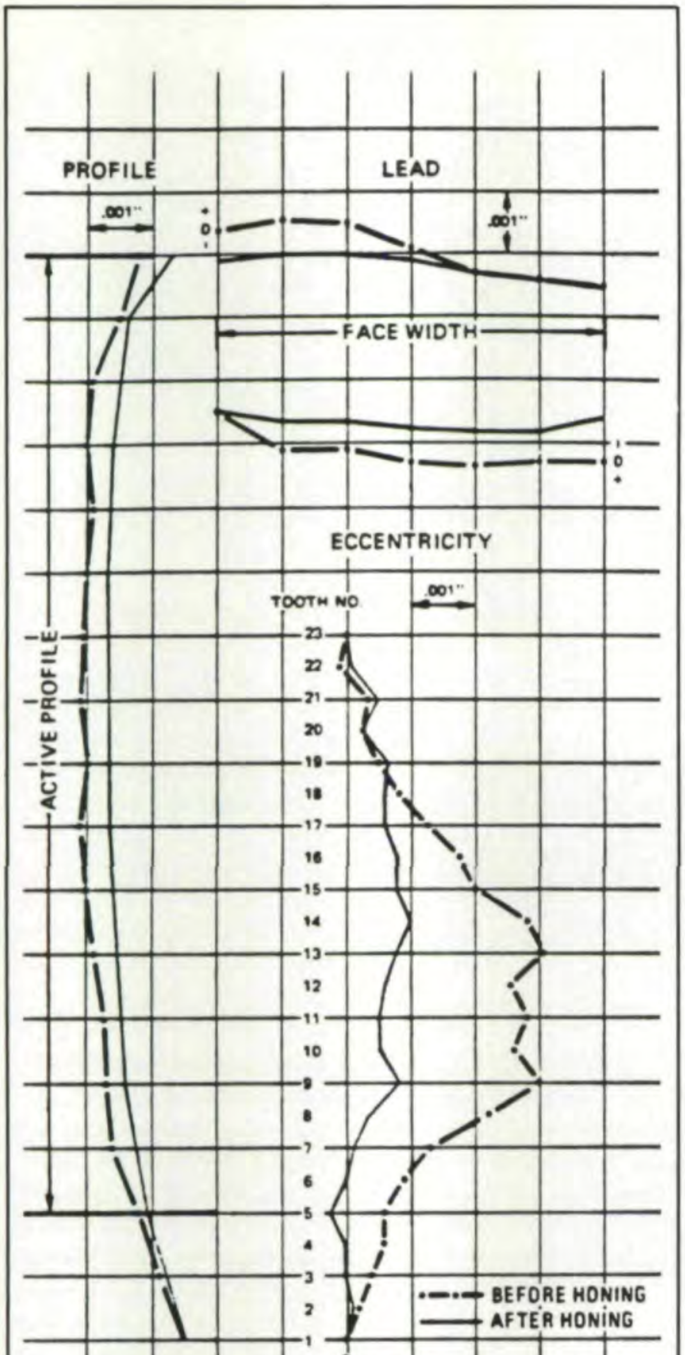

Fig. 1 – Improvement in tooth accuracy achieved by honing a shaved helical truck transmission gear.

Rotary Gear Honing Tools

Honing tools are a mixture of plastic resins and abrasive grains such as silicon carbide, that is formed in a precision mold. They are made in a wide variety of mix numbers with grits ranging from 60 to 500, to suit special production and part requirements.

Honing tools are divided into three different types for three different applications.

1. The standard type honing tool is made in a variety of resin and abrasive mixes for gears that have been shaved and heat treated. It removes nicks and burrs, improves tooth spacing and runout and can provide surface finishes down in the 8 to 14 μ range.

2. The "AA" ground honing tool, similar to the standard type tool, has precision tooth forms. All critical dimensions on this tool are held within .0002". It is used on ground hardened gears to improve spacing and runout and provide surface finishes in the 8 to 10 μ range.

3. The polishing type honing tool is a flexible, porous polyurethane tool that will bring the surface finish down to the 4 to 6 μ range for total contact on ground or shaved gear teeth that have been previously honed. Polishing action is achieved by using an abrasive liquid compound during the finishing process.

Honing tools are made in diameters ranging from 3½" (for internal gears) to 14" with face width from 1/2" to 2". Most gear hones are made with approximately 9" diameter.

Selection of the proper honing tool depends on the tooth finishing method, the gear material, the honing application requirements and machine capacities.

Honing Shaved Gears

Traditionally, tooth surface finishes in the range of 25 to 40 μ have been provided by the rotary gear shaving operation. The honing process, because it is not basically a heavy stock removal or tooth correction process, *cannot* substitute for gear shaving, which is performed on the soft gear. In fact, the tendency of a hone to charge a gear under 40 Rockwell C hardness with abrasive particles makes honing of soft gears a questionable application.

However, because a gear has to be heat treated, a process that usually roughens the tooth surface to a degree, the honing process tends to restore the hardened tooth surface finish to its original shaved condition and actually improves it. In all cases, the honed surface finish is better than the surface finish before honing. (Fig. 1).

To hone production gears, economy dictates that one grit
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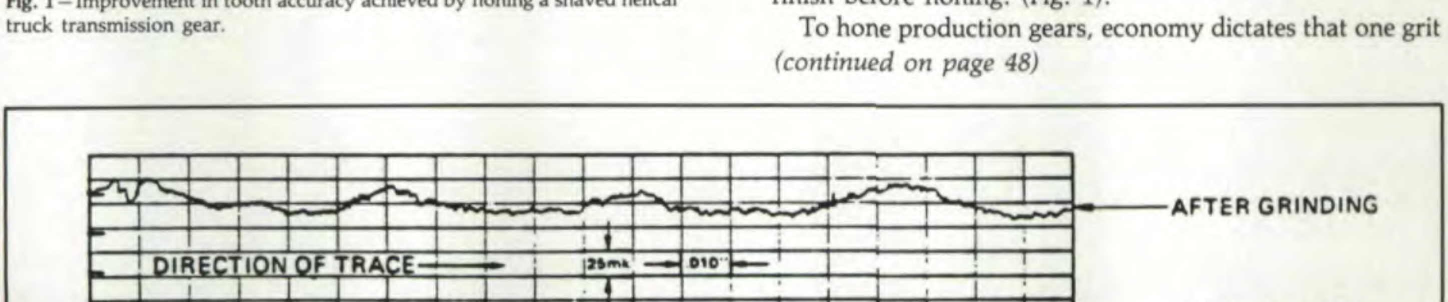

Fig. 2 – Proficorder checks of ground gear teeth before and after honing.

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of tool and a relatively short honing cycle be used. What is produced in the way of surface finish, then, represents a compromise. First, the honing tool must remove nicks and burrs; then it should make minor tooth corrections that will improve sound level and wear life. The improvement in surface finish, *which is in reality* a by-product of the honing process, is a valuable adjunct which will help promote long wear life as well as improving sound characteristics.

Honing Gound Gears

In the aerospace industry, gears are traditionally operated at high speeds under heavy loads. They are usually cut, heat treated and ground to provide tooth surfaces (usually of sophisticated modified forms) of the highest order of accuracy. However, tests with exotic surface measuring equipment have shown that ground surfaces have a jagged, wavy profile that will not support heavy loads or wear long unless costly break-in procedures are carried out.

Ground tooth surfaces usually have a surface finish in the 16 to 32 μ range. Honing with type "AA" honing tools can *bring this surface finish down to the 8 to 10 μ range* (Fig. 2). In one 39-tooth, 5-D.P., 20° P.A., 7.800" P.D. spur helicopter drive gear, honing of the gear teeth down to 8 μ surface finish increased wear life by 1,000% and increased load carrying capacity by 30%. Other tests by the gearing industry have shown 100% load carrying capacity increases by honing ground layers.

Acknowledgement:
Presented at the SME Gear Processing and Manufacturing Clinic, November 11-13, 1986, Schaumburg, Illinois

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Comparison of DIN and AGMA Qualities

A closer comparison between the various tolerance systems is beyond the scope of a simple table, for the corresponding quality fields never coincide exactly; moreover the various national standards do not make comparable adjustments to gear error tolerances to allow for the influence of the gear diameter and size of pitch: a given class in one standard can, in certain ranges of diameter and pitch, cover several classes of another standard.

A comparison between AGMA run-out tolerances and the equivalent DIN has been omitted, due to the differences in definition. AGMA Quality Classes for lead tolerances have been included in spite of minor differeces in definition.

	Reference diameter											
Adjacent pitch error and difference between adjacent pitches	up to 15.8 in. (up to 400 mm)	DIN	2	2	3	3	4	5	5	6	7	8
		AGMA			15	15	13	12	12	11	10	9
	over 15.8 in. (over 400 mm)	DIN	2	2	2–3	2–3	3–4	4–5	4–5	5–6	6–7	7–8
		AGMA	15	15	14–15	14–15	13	12	12	11	10	9
Total profile error		DIN	2	2	3	3	4	5	5	5	6	6
		AGMA						14–15	14–15	14–15	13–14	13–14
Maximum accumulated pitch error		DIN	3	3	4	5	6	7	5	6	7	8
Radial run-out		DIN	3	4	5	5–6	6	7	5	6	7	8
Total composite error (double flank)		DIN			5	6	7	8	6	7	8	9
		AGMA				12	11–12	10–11	12	11–12	10–11	9
Tooth-to-tooth composite error	up to 15.8 in. (up to 400 mm)	DIN			5	5	6	7	6	7	8	9
	over 15.8 in. (over 400 mm)	DIN			4–5	4–5	5–6	6–7	5–6	6–7	7–8	8–9
Total tooth alignment error	up to 15.8" (400 mm), $P \geqq 4$ ($m \leqq 6$)	DIN	1	1	1	2	2	3	3	3	4	4
	up to 15.8" (400 mm), $P<4$ ($m>6$)	DIN	2	2	2	3	3	4	4	4	5	5
	over 15.8" (400 mm), $P \geqq 4$ ($m \leqq 6$)	DIN		2	2	3	3	4	4	4	5	5
	over 15.8" (400 mm), $P<4$ ($m>6$)	DIN		3	3	4	4	5	5	5	6	6