BACK TO BASICS...

Good Gears Start With Good Blanks

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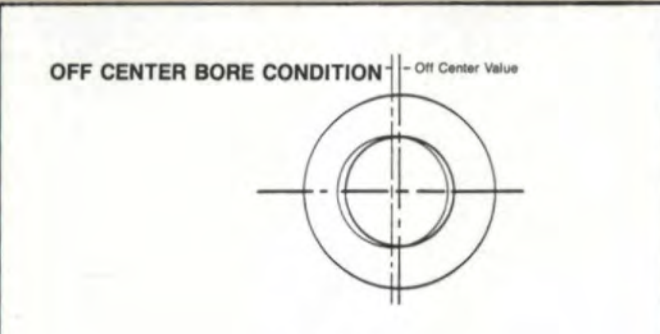

Fig. 1

Introduction

The quality of the finished gear is influenced by the very first machining operations on the blank. Since the gear tooth geometry is generated on a continuously rotating blank in hobbing or shaping, it is important that the timed relationship between the cutter and workpiece is correct. If this relationship is disturbed by eccentricities of the blank to its operating centerline, the generated gear teeth will not be of the correct geometry. During the blanking operations, the gear's centerline and locating surfaces are established and must be maintained as the same through the following operations that generate the gear teeth. **This centerline of the manufacturing operations must also be the same as the operating centerline of the gear as it is used.** (See Fig. 1.)

Gear Blank Design

The gear design engineer can assist in assuring good quality finished parts by designing gear teeth on well proportioned blanks. The configuration of the blank should be one that allows the workpiece to be supported just inside the root diameter of the gear teeth during cutting operations. Another consideration in the blank is to avoid thin cross section areas between the gear teeth and the operating bearing area that may warp or distort unevenly during heat treatment. A well proportioned blank with the adequate locating area and uniform cross section compared to a poor blank design is shown in Fig. 2. The poor design has very little support material behind the gear teeth and a thin web cross section. This blank is an extreme example that would be difficult to locate accurately for hobbing and shaving. It would also be distorted considerably during hardening.

Gear Blank Inspection

During the blanking operation, adequate gaging must be done to insure that the locating surfaces of the blank are maintained perpendicular and concentric to the centerline of the gear. **It is good manufacturing practice to do finish turning and facing operations on the blank prior to cutting the gear teeth.** In the case of a hole type gear, the blank should be finish cut on the locating face or faces, and the bore finish cut perpendicular to the face and concentric to the outside diameter. Typical tolerances for an automotive blank 25 mm thick and 100 mm outside diameter would be:

1. Locating face squareness to bore 0.01 mm to 0.02 mm.
2. Outside diameter concentricity to bore 0.12 mm maximum.
3. Bore size tolerance for 25 mm bore 0.01 mm to 0.02 mm.
4. Bore size taper tolerance for 25 mm bore 0.005 mm to 0.008 mm.

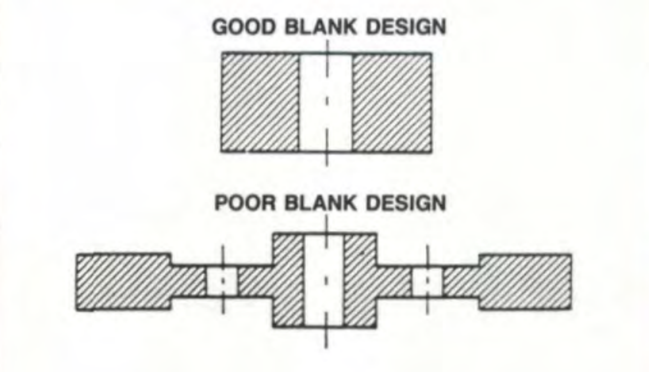

Fig. 2

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Table 4-1—Typical Gear Blank Tolerances*

Blank Dia. In.	Face Runout In.	Hole Size In.	Hole Taper In./In.	Hole Roundness In.-Max	O.D. In.-Max.	O.D. Runout In.
Up to 1, 1-in. Thick	0.0003-0.0005	0.0003-0.0006	0.0002-0.0003	0.0002-0.0003	0.003	0.003
1 to 4, up to 1-in. Thick	0.0004-0.0008	0.0005-0.001	0.0002-0.0003	0.0003-0.0005	0.005	0.005
4 to 8	0.0006-0.0012	0.0008-0.0012	0.0002-0.0003	0.0004-0.0006	0.005	0.007
8 to 12	0.001-0.002.	0.001-0.0015	0.0002-0.0003	0.0005-0.0007	0.005	0.008

*Tolerances for Specific Gears Should be Selected in Accordance with Quality Requirements.

Fig. 3

SAMPLE PINION GEAR BLANK CHECK

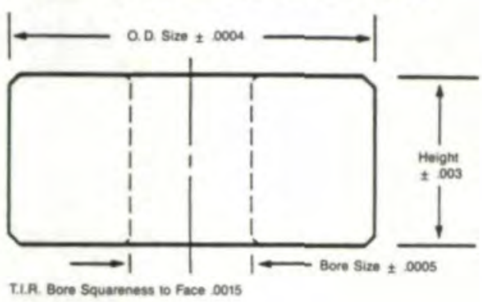


Fig. 4

INTERNAL GEAR BLANK SAMPLE CHECK

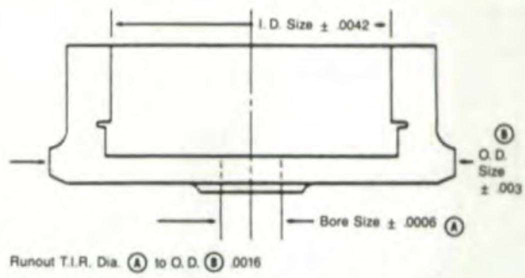


Fig. 5

BASIC ARBOR FOR CHECKING PINION BLANK

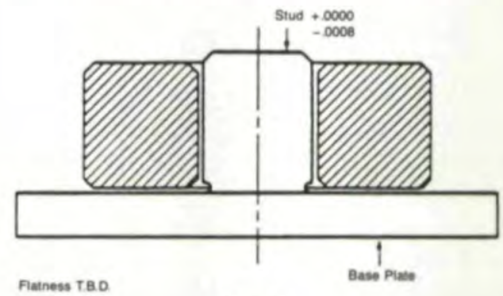


Fig. 6

Fig. 3 is a table of different gear blank tolerances. Fig. 4 is a sample pinion gear blank, while Fig. 5 is a sample internal gear blank.

The blank tolerances should be specified by the manufacturing engineer separately from the finished part print tolerance. Gaging fixtures with precision indicators should be supplied for the machine operator's use to check alignments, concentricities and perpendicular accuracies of locating surfaces to the centerline of the blank. The gaging fixtures should be placed at each finish turning machine for constant use by the machine operator.

Fig. 6 illustrates basic arbor for checking pinion blanks, while Fig. 7 is a photograph of a fixture to check face runout and O.D. runout.

The bores or bearing journals should be inspected at their finish machining stages using air gages or precise indicator gages. It is important to check both the size of the bore or bearing journal and its configuration. A tapered or out-of-round condition will result in poor workholding efficiency if the blank is driven by clamping in the bore or on the bearing journal during the gear generating process. Fig. 8 illustrates various bore configurations to check.

When production rates are high, automatic gaging is used to check each blank for size, concentricity and perpendicular locating surfaces. The automatic gaging of each blank is the most precise method of gear blank gaging. The operator's influence is removed from the gaging operation and all decisions are made by the instrument. There is also the advantage with automatic gaging that all elements are checked by the gage at a high rate of speed.

Metallurgical Considerations

Various types of materials and metal preparation are used for gear blanks; specifically, forgings, castings, cold forming or basic bar stock. In the case of cold forming, sometimes an in-process heat treatment may be necessary to improve part machinability. Also, if a part has been turned on very high speed equipment, work hardening may be experienced, and again, in-process heat treatment may be required. There are various other examples, such as making a blank readily machinable for hole broaching, but having poor tool life when the gear teeth are generated. Each individual process will have to be experimented with, and experience will ultimately determine if either metallurgical change is called for or an in-process heat treatment should be employed.

Gear Blank Related Errors

The errors caused by gear blank inaccuracies can be illustrated by assuming that a perfectly aligned hobbing machine with accurate tooling is used to cut gears from random blanks. The gear blanks are simple hole type flat gears that are clamped in the bore and located on the faces. Presenting a gear blank to the precision hobbing machine with the bore accurate for size and shape, but the locating faces not perpendicular to the bore centerline, will result in the gear blank wobbling during the hobbing operation. The inaccuracy of the locating faces causes the centerline of the bore to be skewed from the generating centerline of the hobbing machine. The resulting lead inspection would produce a chart that shows high lead variation. If tooling, specifically the hob, is improperly mounted to an extreme runout condition, a part with excessive involute error could be produced, as illustrated in Fig. 9.

Presenting a gear blank to the hobbing machine with excessive concentricity error between the outside diameter and the bore centerline will result in uneven cutting load around the blank. The resulting gear teeth will then show a like concentricity error when a red line check is performed on the teeth; that is, when the teeth are checked from the centerline of the bore and/or rolled with a master gear.

Presenting a blank to the hobbing machine with an oversize bore will result in poor clamping in the bore. The blank will then have a tendency to slip on the arbor, resulting in mutilated or off lead gear teeth as shown in Fig. 10.

In the case where the blank is centralized on the bore and clamped on its faces, the blank centerline will be shifted off the centerline of the hobbing machine. The subsequent concentricity check of the gear teeth to the centerline of the bore will show excessive concentricity error.

In the high volume production of gears, such as in the automotive industry, different locating areas are used, specifically in pinion hobbing. Here the fixture holds the piece

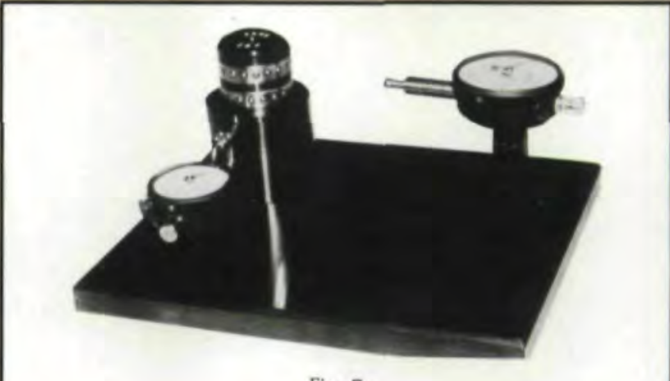


Fig. 7

VARIOUS BORE CONDITIONS

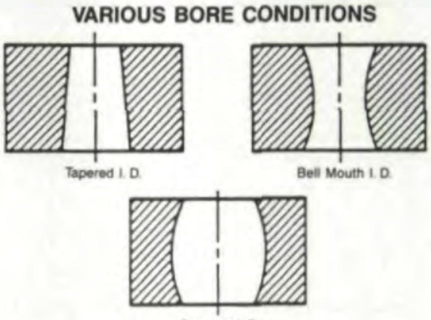


Fig. 8

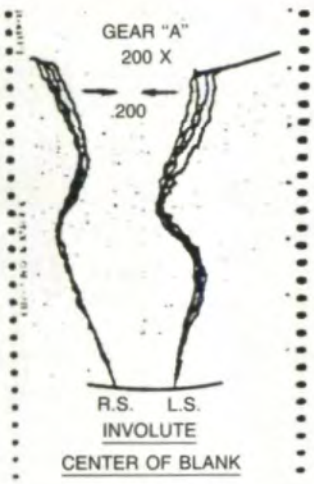


Fig. 9

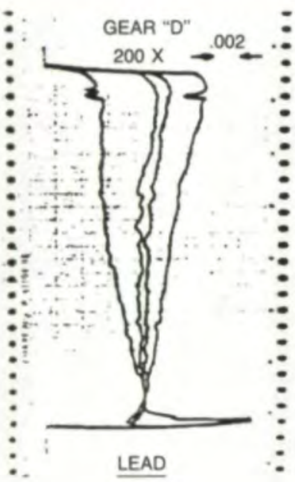


Fig. 10

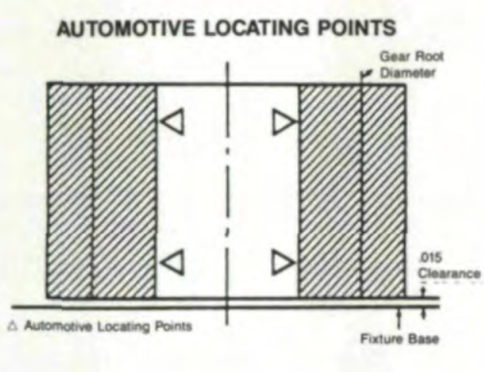


Fig. 11

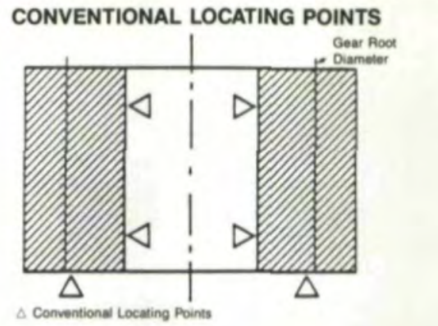


Fig. 12

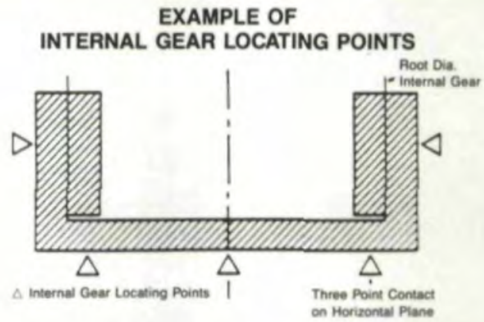


Fig. 13

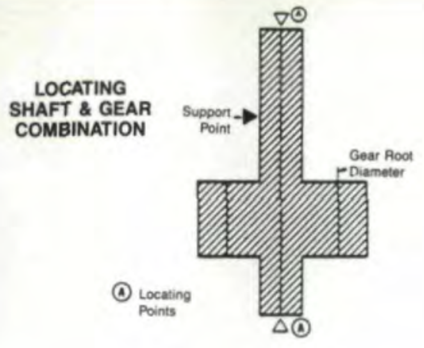
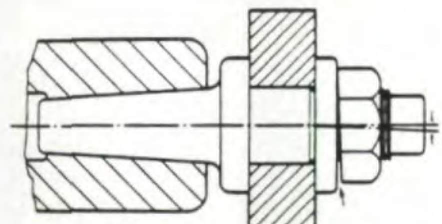
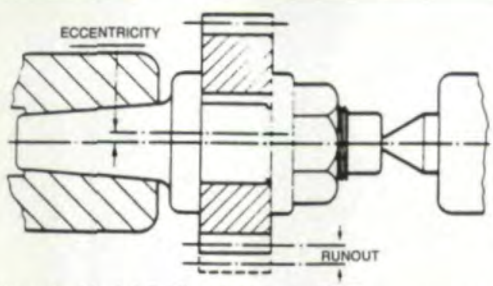


Fig. 14



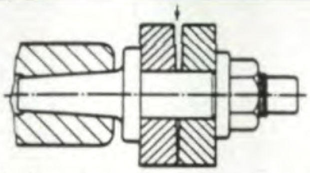
Lock-up nut is not square to holding plate. Therefore, arbor is bent.

Fig. 15



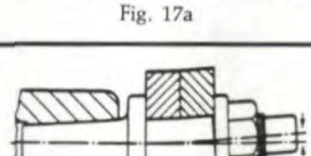
Oversize blank I. D. Therefore, part will have gear runout.

Fig. 16



Blanks not squarely mounted. Results in lead, involute and concentricity errors.

Fig. 17a



Bent arbor results in lead, involute and concentricity errors.

Fig. 17b

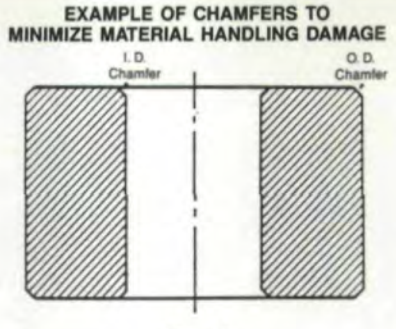


Fig. 18

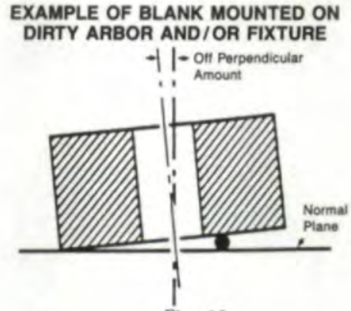


Fig. 19

part in the bore only and does not locate on the face area. (See Fig. 11.) The conventional method is to locate the piece part on the bore as well as the lower face, as illustrated in Fig. 12. Locating points for internal gears are shown in Fig. 13, while locating points for shaft and gear combination are shown in Fig. 14.

Several examples of improperly mounted gear blanks are illustrated in Figs. 15 through 17.

Another point that must be considered is material handling abuse. The gear blanks should be designed with adequate chamfers at the outside diameter edges and locating surface corners. (See Fig. 18.) Nicks, burrs, dirt and any other foreign material on the locating and clamping surfaces will cause the part centerline to skew, resulting in lead variations and excessive concentricity errors. (See Fig. 19.)

Summary

The quality of the finished gear is affected by the quality of the blank on which the gear teeth are cut. The operating centerline is the centerline from which the gear is designed to run; therefore, once a manufacturing centerline is established, it must remain the same as the operating centerline.

Good gear practice by the design engineer is helpful to the manufacturing engineer in producing high quality gears at lower manufacturing costs. The manufacturing engineer must remember that all errors in the locating surfaces and clamping surfaces of the blank are reflected in the quality of the finished gear. Good inspection and quality control procedures will result in early detection of bad blanks. The poor blanks can then be removed from the system before subsequent expensive operations are performed on them.