

New Opportunities with Molded Gears

by: R.E. Kleiss, A.L. Kapelevich and N.J. Kleiss Jr.,
Kleiss Gears, Inc.

American Gear Manufacturers Association



TECHNICAL PAPER

New Opportunities with Molded Gears

**Roderick E. Kleiss, Alexander L. Kapelevich and N. Jack Kleiss Jr.,
Kleiss Gears, Inc.**

[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

Molded gearing includes plastic and powder metal injection molded gears as well as powder metal sintered gears. Near-net forged gears may also share some unique similarities and opportunities as well. This type of manufacturing offers some particularly intriguing opportunities for the gear designer, and also some challenges not usually encountered with cut gears. The challenges are often related to the mechanical properties of the material. Proper steel, cut and hardened correctly, is hard to beat for strength. Ordinary attempts to replace steel gears with the molded variety are usually doomed to failure.

On the other hand, molded gears can offer some material properties not achievable with cut gears, including unique advantages in weight, noise, modulus, self-lubrication, magnetism, chemical resistance, and most appealing low cost. The challenge is to make them survive the demands put upon them. For instance, thermoplastic gears, when placed under continuous high load, will melt. This is a phenomenon not shared with any metal counterpart. The goal must be to make a weaker material appear stronger. The unique tools that are available to the molded gear designer are concentrated in the method of manufacture. When the proper mold is constructed and combined with the optimized molding process, a remarkably consistent and uniform gear can be continuously manufactured. The construction of this molded tooling can be almost completely CAD based. Traditional gear cutting processes are almost never used to develop the mold cavities.

Unique tooth geometry that might be difficult or even impossible to achieve with cut gears can be applied to molded gears matter-of-factly. This paper will investigate two types of gears that we have designed, molded, and tested in plastic. The first is an asymmetric mesh, the second is an orbiting transmission. The asymmetric gears have dissimilar 20° and 48° pressure angles while the orbiting gear set works with a 65° pressure angle. Both transmissions have higher load potential than traditional design approaches.

Copyright © 2001

American Gear Manufacturers Association
1500 King Street, Suite 201
Alexandria, Virginia, 22314

October, 2001

ISBN: 1-55589-788-6

New Opportunities with Molded gears

Rod Kleiss, President, Kleiss Gears

Alex Kapelevich, Principal Engineer, Kleiss Gears

N. Jack Kleiss Jr., Consultant, Kleiss Engineering

Molded gears share some very basic similarities with cut metal gears, principally the involute gear shape and a need for precise design, manufacturing, and inspection. They also diverge from cut metal gears in some very significant ways. The design of the gears and mold tool construction usually does not require or employ any traditional gear cutting techniques. Spur gear molds are almost invariably made utilizing a wire Electrical Discharge Machine (EDM) which is capable of producing any 2-dimensional and even some slightly 3-dimensional shapes with surface accuracy on the order of a single micron. Helical cavities are cut using electrode EDM's. These electrodes can be made with end mills having gear profiles wire EDM'd into their cutting edges, or by using high-speed surface generation on a 4-axis CNC mill. The difficulty of using traditional gear cutting techniques is most often due to the required physical geometry of the cavity. Since most molded gears will shrink from the mold, the mold cavity must be adjusted for enlarged base pitch, tooth thickness, major, and minor diameters. Form grinding electrodes is an option, but standard hob generation is almost never suitable. Additionally, very few electrodes will be needed to generate the mold cavities. Gear houses tend to shy away from such small jobs that will only infrequently be repeated.

Still, the options left open to the molded gear designer are quite extensive To achieve

an effective transmission design, every available tool and resource is usually required. First of all is the design of the gears themselves. As with many design constraints, space is usually at a premium with large expected loads. The danger with molded plastic gears especially is heat. Plastic gears melt, and as temperature increases, their modulus of elasticity decreases and they get even weaker. Constant duty cycles under heavy loading is one of the most difficult designs to achieve successfully with plastic molded gears. Using exotic materials with higher heat capacity brings along its own set of problems. Quite often these materials will be brittle, or difficult to mold accurately, or just too expensive to be cost competitive with high speed gear cutting. Most successful plastic gear designs will be molded with basic engineering thermoplastics such as nylon or acetal.

Molded Gear Design

One of the biggest opportunities for the molded gear designer is the design of the gears themselves. Since the spur tooling can be generated with wire EDM, any 2-dimensional shape that can be drawn, can usually be produced, and even adjusted mathematically for shrinkage before being cut. There are only 8 variables required to completely describe a symmetrical spur gear mesh design. Figure 1 is a screen dump of our design approach to this task.

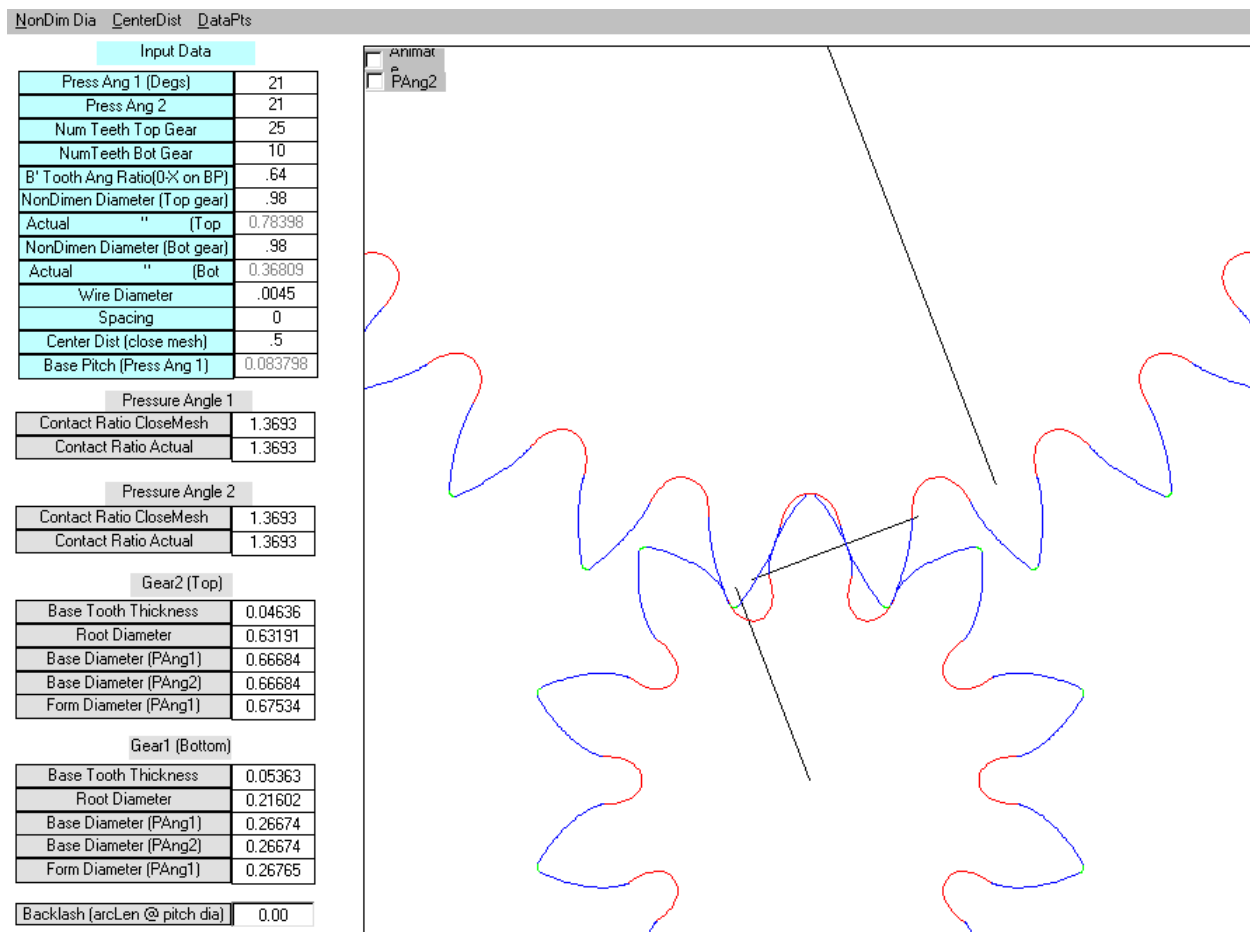


Figure 1 Typical spur gear design

The input data field in the upper left-hand corner of Figure 1 shows the required information to complete this design. For symmetric gears the operating pressure angle will be the same in both directions. The numbers of teeth in each gear is followed by the tooth thickness of one of the gears. In this case tooth thickness is defined as a non-dimensional ratio to the base pitch of the drive pinion. The outside diameter of both gears is required as well as the wire diameter of the EDM that will cut the cavities. This will cause the tips of each gear to be rounded, which will affect both the contact ratio and the formation of the mating gear's root geometry. Finally, either center distance of the mesh or the base pitch is required to physically size the gears. With

these minimum inputs the rest of the gear features are produced by generation from the principal features.

In this case, the outside diameters of the gears are designed to 98% of the theoretical maximum diameter possible. A slight undercut is generated by the gear to the pinion. This gives the effect of a bonus tolerance on contact ratio, since the contact ratio will not begin to decrease until the gears have separated beyond the undercut condition. Tooth thickness can be adjusted visually and then checked with traditional methods to assure balanced strength. Working pressure angles can be increased or decreased to optimize any particular feature. Similar results can be attained with shaper