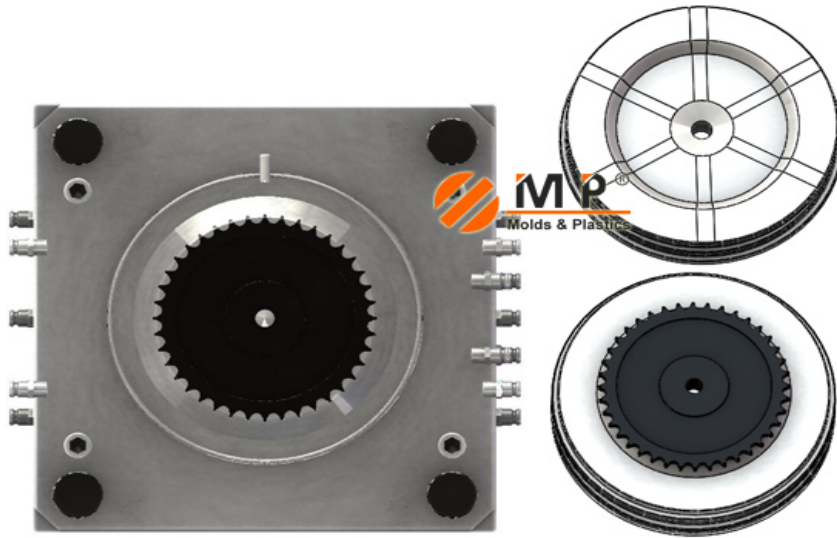


How to make Molded Gear

Molded plastic gears have very little in common with machined gears other than the fact that both use the involute for conjugate action. The differences are quite fundamental. Machined gears are cut to size with specialized machinery designed specifically for the task. Molded gears are formed in gear cavities that are usually cut with wire Electrical Discharge Machines (EDM). These cavities are sized so that the molded gear will shrink to the proper size after molding. One cavity might be expected to form more than a million molded gears.



**A molding insert tool along side the molded gear
And the gear cavity**

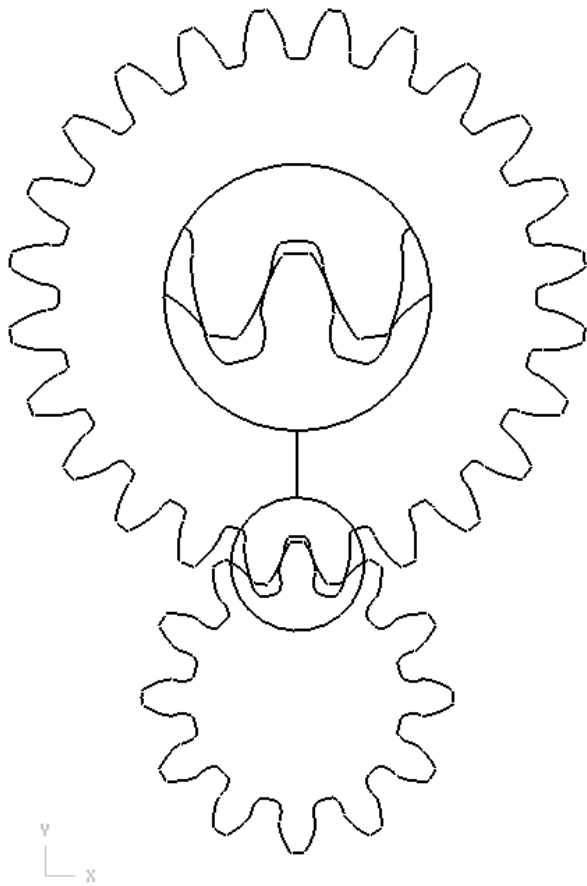
A gear cutting manufacturer is charged with the task of cutting gears within tolerance with every piece made. The gear mold is charged with the task of making one nearly perfect gear cavity and then processing each gear from that cavity within tolerance for every piece made. This small but significant difference leads to many other variations. The differences begin as soon as the choice for molded gears is made.

Design

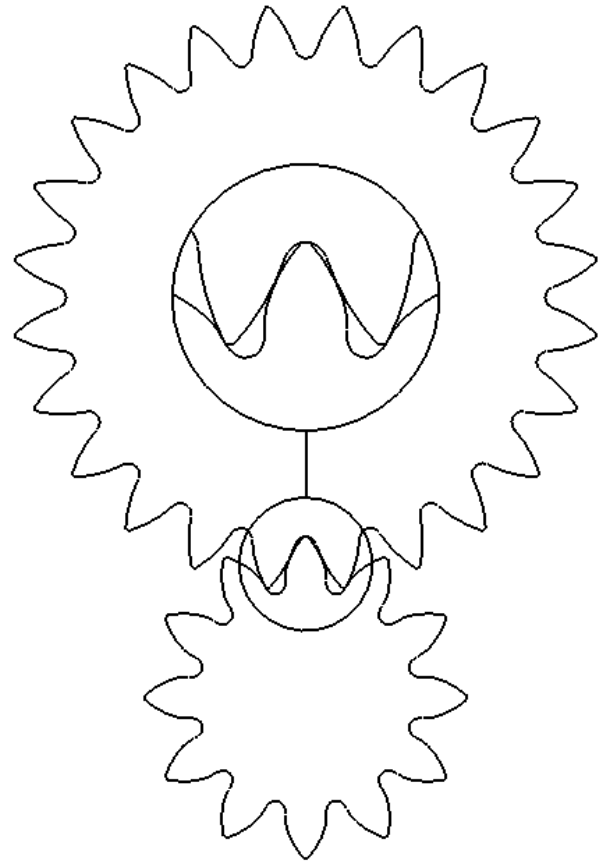
Molded gears invariably must operate in molded housings. This single fact has significant consequences. Molded housings and the shafts in them are rarely going to have the precision tolerances that a machined transmission can provide. The housings and gears will shrink and expand due to moisture and temperature, perhaps at different rates. The strength, hardness, and even efficiency of the plastic material will also vary due to local conditions. Surface tooth temperatures will rise under load, which affects plastic properties. All of these variables and more dictate a need for custom design of gear teeth.

The advantage the plastic gear designer has is in the application. Most plastic transmissions are unique. A gear mesh can be designed strictly for its intended function with a single mating gear. Additionally, the molded gear can be optimized with very little regard for tooling.

Wire EDM's can generate machined patterns with the precision of CAD. A gear cavity can be made with micron tolerances. Given the fact that traditional hobs are not required, Diametral Pitch or Module are unimportant specifications. The involute base circle is the variable of importance. Pressure angles can be adjusted in an analog fashion to balance strength and depth of tooth engagement. Custom designed gears will offer a great improvement in performance, quietness, and allowable tolerances than standard gearing.



Standard Gear set



Shape Formed Gear set

Shared Attributes:

Center Distance: .75 inches minimum
 Gear Ratio: 2 to 1 (24 to 12 teeth)

Differences:

Standard Gears: 24 Diametral Pitch 20 Degree pressure angle .06545 Tooth Thickness (both gears) Max contact ratio: 1.15 Max center distance variation: +.022 inches	Shape Formed Gears: .11865 Base Pitch 25 Degree operating pressure angle .070 pinion tooth thk'ns/.061 gear tooth thkn's Max contact ratio: 1.59 Max center distance variation: +.032 inches
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Comparison of Standard Gear Mesh to Custom Shape Formed Gears



Molded gears can be made in many forms and varied sizes.

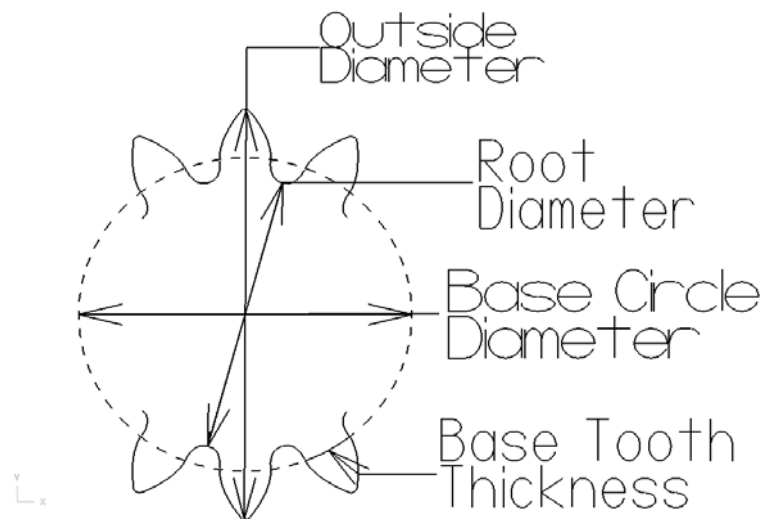


Very Fine Pitch Gear

The Gear Molding Tool

With the gear mesh designed and toleranced, the next step is tool construction. Gear tooling must be precise with excellent thermal stability, hardened sleeves and surfaces, exact gear cavity formation, and designed for high-pressure injection molding. The gear cavity itself must be specifically designed for the selected molding material.

There is no way to accurately predict the actual shrinkage for molded plastic gears in a specific application. This is due to a number of factors. Most importantly, plastic does not shrink from the cavity in an isotropic fashion. The main body of the gear will shrink in a manner that may be similar to manufacturer's estimations, but the individual tooth is surrounded by steel and its cooling pattern will differ from the macroscopic pattern of the larger mass.



Distinct shrink rates for general plastic gears

A good method to determine shrink requires a two-step approach. Shrink factors are estimated for the gear in question. After the tool is made and the first gears are molded, they are then profile inspected for exact involute geometry. The individual shrink rates are then determined, a new cavity is made to the measured shrink and the final gear geometry is properly sized. Only profile inspection will be able to accurately determine involute shrinkage. Gear roll testing may give some idea of shrinkage anomalies, but it can also give misleading indications.

Sometimes heavily glass filled material is selected for gears due to its low shrink rate. Shrinkage then becomes less of an issue in mold design. This approach can also cause its own problems. Unfilled engineering resins such as nylon and acetal mold into very precise shapes, albeit with shrinkage. Glass filled materials will have knit lines where injection flow fronts merge. These knit lines can cause distortion at the tooth surface as well as localized weak spots on the gear. Glass filled gears will generally be much more abrasive during their life than equivalent unfilled gears. Generally, filler should only be used when a specific need has been established that outweighs potential problems.

Mold Processing

All molding is not equivalent. All molding machines are not equivalent. Gears require mold processing that is exact and repeatable. In general, virgin resin is used for high accuracy gears. Even with virgin resin, the material must be of correct dryness, its melt temperature must be controlled exactly and repeatably. Injection pressures must be established precisely. The interaction of the mold tool and process control must also be taken into account.

As plastic is injected at high temperature and pressure, the melt must displace air in the gear cavity. Vent paths must be created to allow air to escape, but must be thin enough to stop the resin from venting as well. If the vents are too small, gas will be trapped and burning could result. If the vents are too big, plastic melt will flow through and cause flash on the part.

It is often advisable for the gearing customer to visit the molding facility before placing the final order. Just a cursory inspection of molding equipment, general plant cleanliness, inspection capabilities, and personnel, can help to evaluate their potential for successful molding and control. For instance, it will be very difficult to mold precision gears in a non-temperature controlled environment. Molding precision gears in 90% humidity at 100°F is fraught with difficulty.

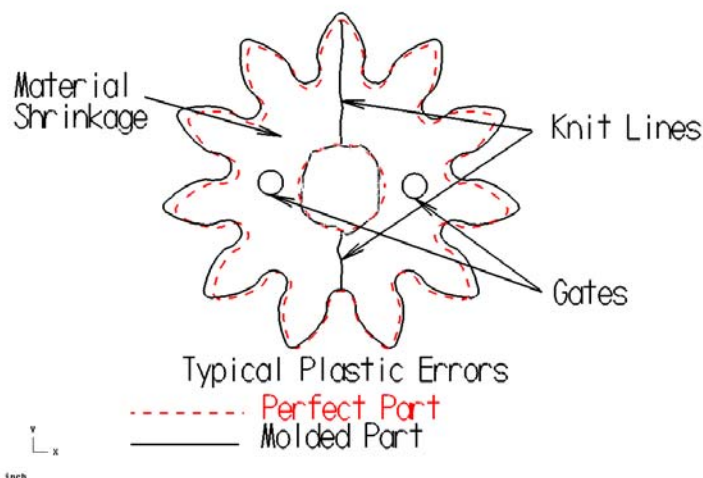
Inspection

Over the years gear inspection has been refined to discover most errors that trouble cut gearing. A profile scanning inspection of the involute profiles is usually done for only a few teeth around the gear. Metal gears are produced on turning machinery and patterns can be expected from tooth to tooth. Plastic molded gears can have large solitary errors anywhere on any surface of the gear. Furthermore, the molding process can introduce a much different kind of error than in traditional manufacture.

Since any molded gear will shrink, the involute profile is a target, not a given value. Whether one considers Diametral Pitch, Module, base pitch, pressure angle or any other involute feature as the controlling geometry, this feature will be a variable in the actual part. It is necessary to set realistic tolerances for these truly variable features.

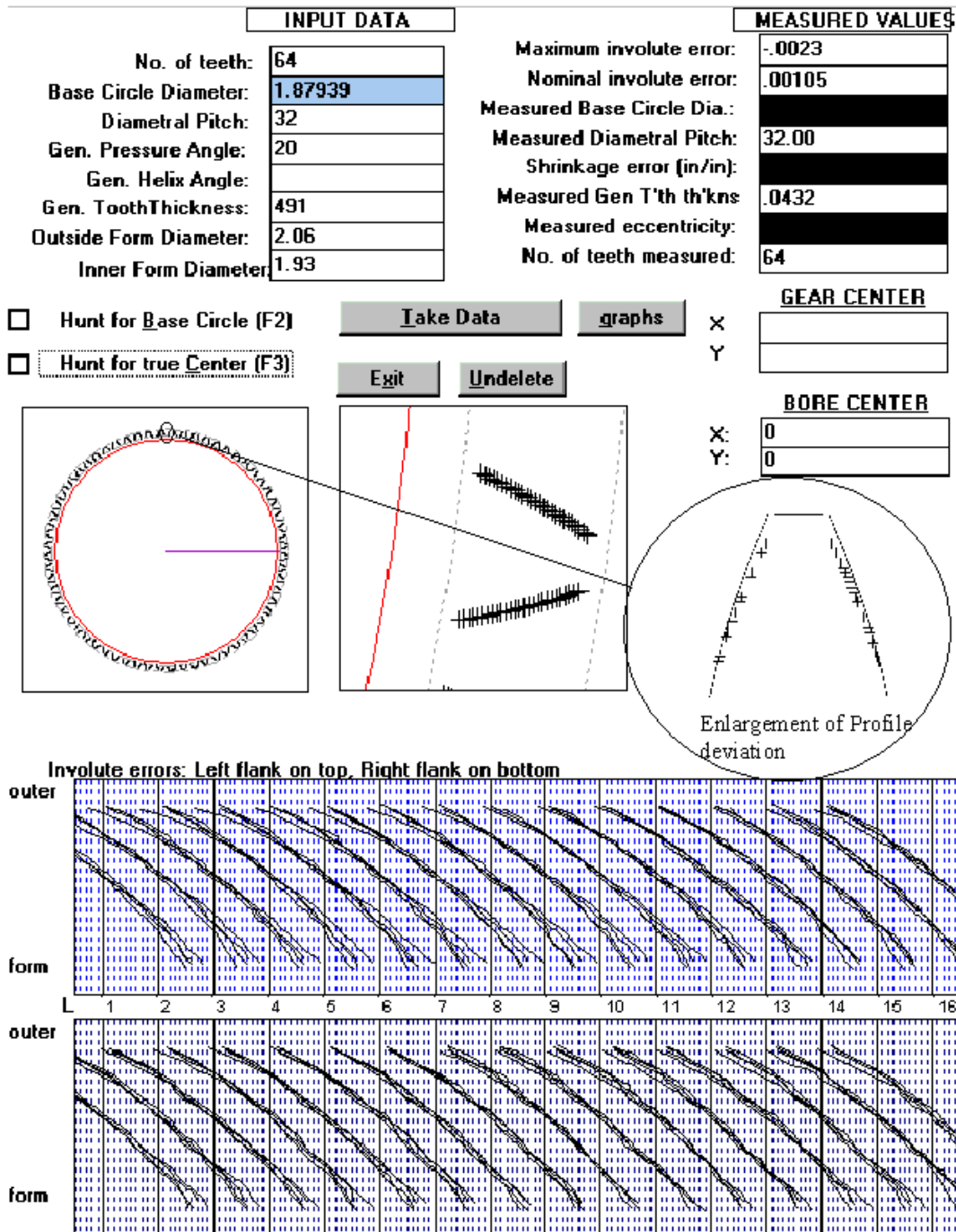


The Involute Shrinkage of a Molded Gear



Typical errors in a Molded Part

The only way to be certain that a plastic molded gear is within tolerance is by scanning the involute profile and determining the actual physical geometry of the gear. The molded part can be completely out of specification and still give acceptable roll test results. Below is a profile inspection of such a gear. The involute base circle was very far off the defined value. The gear had 64 teeth and a master used to measure the gear had 64 teeth. With such a large number of meshing teeth in roll testing, there was almost no tooth-to-tooth error. The gear simply appeared large, even though the base circle was small. The molder thinned the teeth, brought the gear into good specification with a roll test, and supplied parts to the customer. The parts immediately failed when meshed with a cut metal gear of correct size.



Badly Shrunk Plastic Molded Gear

To prevent this type of error the gear must be completely specified with each variable toleranced. One such method is recognized by the AGMA in the recently completed Information guide for Inspection of Molded Plastic Gears.

NUMBER OF TEETH	
BASE PITCH (BASIC DIMENSION)	
BASE CIRCLE DIAMETER	+/-
BASE CIRCLE TOOTH THICKNESS	+/-
ROOT DIAMETER**	+/-
OUTSIDE DIAMETER	+/-
INVOLUTE FORM DIAMETER	max
TIP RADIUS	max
CENTER DISTANCE WITH MASTER GEAR	Tbd
MASTER GEAR SPECIFICATION	Tbd
TOOTH-TO-TOOTH COMPOSITE ERROR	max
PROFILE FORM TOLERANCE (fi)	max

****ROOT TROCHOID MUST BE DIRECTLY GENERATED
(RE: AGMA STANDARD 1006-A97 APPENDIX F)**

OPERATING DATA

NOMINAL OPERATING DIAMETRAL PITCH	
NOMINAL OPERATING MESH ANGLE	
NOMINAL OPERATING TOOTH THICKNESS	

Suggested Gear Data Specification for Molded Gears

In this approach the base circle geometry of the gear is used as the fundamental control. The indirect specification of Diametral Pitch and Pressure Angle are included in the operating data field as a reference for traditional analysis.

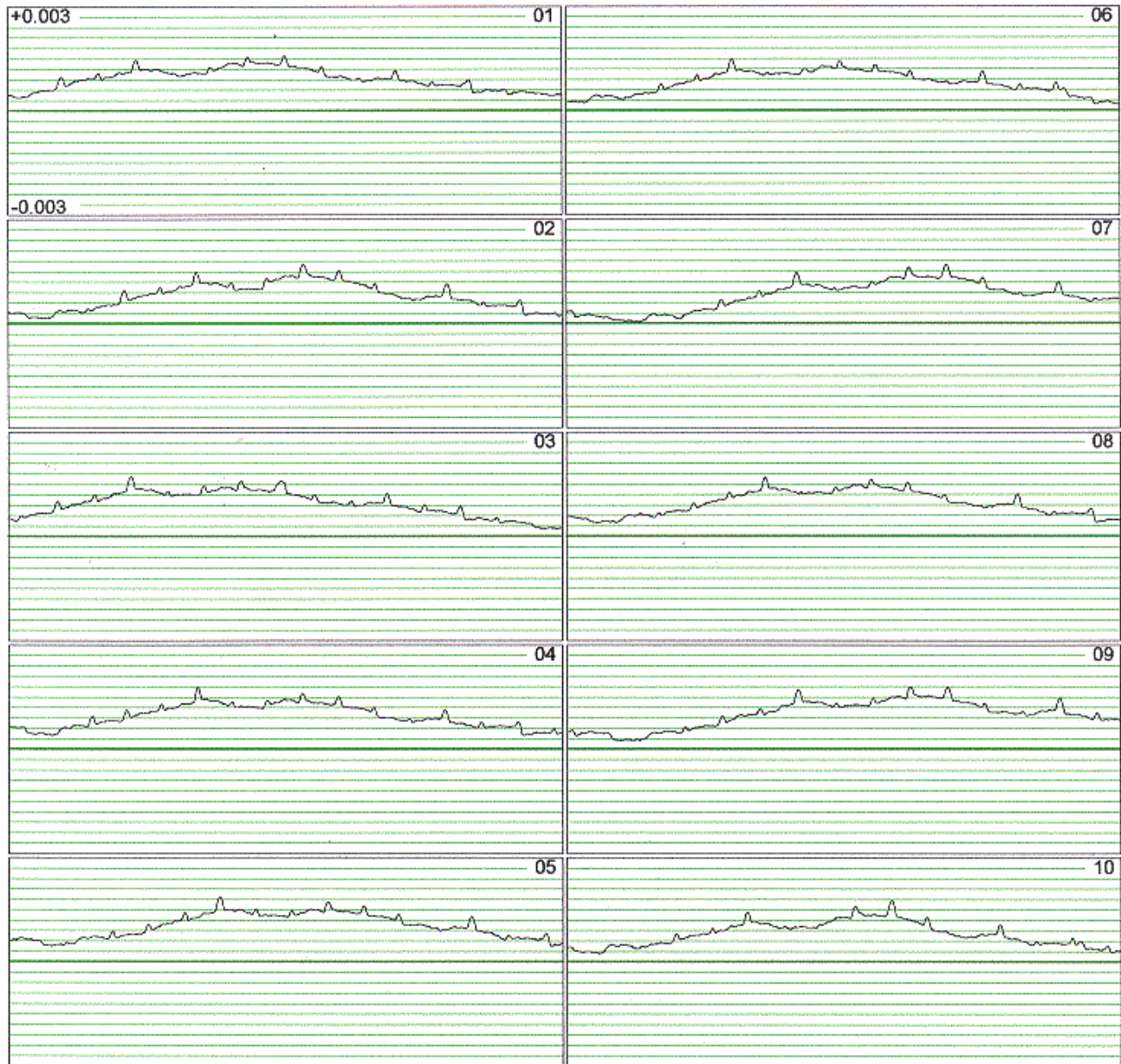
Gear roll testing is almost always the best way to assure consistency of the molded part in production. Rather than simply describe allowable Total Composite Error (TCE) or Tooth-to-Tooth error (TTE), the actual center distance with a given master can be specified with indicated +/- tolerances. This will provide an easy method to assure that the gears are molding the same day after day. Roll tests of sample gears can be gathered to assure both the general form and the absolute size of the gears are within tolerance. Roll testing for plastic gears is more like establishing a roll test signature and confirming that the parts conform to that signature day after day.

GEAR DATA

Gear #Teeth: 16
 DP/phi/Tn: 32/25/.0456
 Master #Teeth: 64
 Master T'th Thk'ns: .04935
 Center Distance: 1.2465
 Part Bore: .1895
 Gage Blocks: 0.9018
 Master Gear ID: 124203
 File: 10821-3
 Date: 8/21/01
 Force(Oz): 4
 Yscale(inch): +/- 0.003 inches
 Xscale(revs): 1

STATISTICAL DATA

Trace #	Minimum	Maximum	Mean	TCE
01	0.00038	0.00157	0.00092	0.00119
02	0.00016	0.00170	0.00080	0.00154
03	0.00021	0.00172	0.00094	0.00151
04	0.00040	0.00179	0.00095	0.00139
05	0.00046	0.00187	0.00104	0.00142
06	0.00018	0.00148	0.00080	0.00129
07	0.00004	0.00170	0.00080	0.00166
08	0.00040	0.00169	0.00096	0.00129
09	0.00023	0.00180	0.00101	0.00157
10	0.00024	0.00177	0.00081	0.00153
Min	0.00004	0.00148	0.00080	0.00119
Max	0.00046	0.00187	0.00104	0.00166
Mean	0.00027	0.00171	0.00090	0.00144
STD DEV	0.00013	0.00011	0.00009	0.00015



1 Revolution(s)

Typical Roll Test Signature of 10 Molded Gears

The future for plastic molded gears is quite promising. Materials are improving greatly. Molding machinery is becoming more accurate. Inspection equipment is now capable of measuring these unique parts with great precision. In the future, plastic can be expected to replace metal gears in lighter duty applications. They are and will continue to find uses in areas that cannot be served by metal gears.

In order to reach these new potentials, every step must be taken correctly and every advantage exploited. The result will be a remarkable new generation of power transmission products.

Pls let' s know if you have any question. Have a good day!

Best regards,

Luis Lu

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