Feature Article

Plastic Gear Process Modeling and Manufacturing

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Research Program Organization

A new effort in plastic gearing has been initiated as a joint program between the Gear Lab, headed by Dr. Don Houser in Mechanical Engineering, and CAPCE. Each partner brings their expertise to the goal of improving the accuracy and performance of injection molded plastic gears. Current sponsors include Ticona Plastics, Xerox, Kodak, ABA-PGT, and Shell Chemical.

Plastic gears have become increasingly common in varieties of consumer products. They are generally lighter and less noisy than their metal counterparts and are well suited for mass production using a net-shape process such as injection molding. Plastic gears are used extensively in printers, scanners, copy machines, paint mixing equipment, and in home appliances. Whether used for power transmission or for timing applications, high quality gears are desired and often necessary for good product performance. It is generally true that gear quality is a strong function of the molding process itself.

Current Research Goal

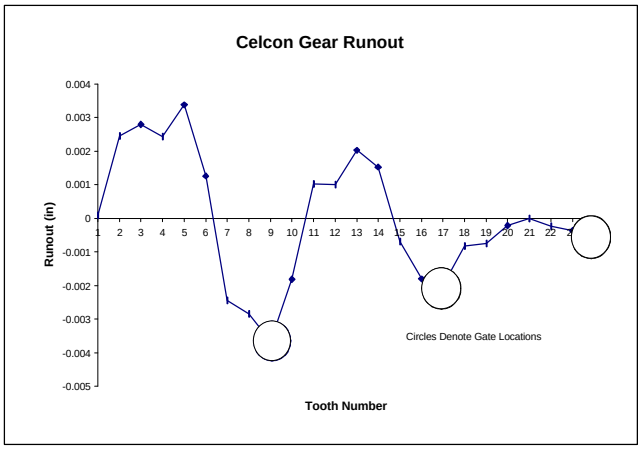
The overall goal is to quantify the effects of different manufacturing variables to predict the final gear geometry and form. The focus of the current research is to examine and quantify:

- the effect of different materials and gating configurations on:
  - tooth profile error along the face width
  - runout error
  - The effect of these on gear noise and PPTE.
- the ability to simulate and predict:
  - flow line locations
  - flow orientation
  - molded-in stresses
- shrinkage and warpage.

Research Results to Date

One defect that is present in molded gears arises due to the gating of the part and the mold fills with polymeric material. The figure below shows data taken from a gear that was recently molded using three gates located symmetrically about the gear axis. As can be seen, this gear exhibited a strong variation in geometry depending on the location of the gear teeth relative to the gates. The figure shows **gear runout** (a measure of the 'out-of-round' of the gear's pitch circle diameter from tooth to tooth). At locations near the gates, which are marked with circles on the plot, values for runout are all local minimums; locations between the gates are local maximums. Thus, it can be said that the runout of this gear is strongly dependent on the gating configuration used to produce it. This variation leads to a poor quality gear, since it increases transmission error and thus increases the gear noise produced. It is a goal of the research to quantify this effect using a test stand recently built exclusively for plastic gears.

Another problem associated with plastic gearing arises from shrinkage effects. Normally in injection molding, a part is packed after filling by keeping an elevated pressure at the gates. As the part shrinks, additional molten material is injected to reduce the overall shrinkage of the part. In gears, however, this is difficult because the web of the gear (the area between the bore of the gear and the gear teeth) is typically made thinner than the gear teeth themselves. This is commonly done in an attempt to keep all sections of the gear with the same nominal wall thickness. This thin portion freezes before the gear teeth, acting to cut off the gear teeth from the beneficial effects of the packing pressure. One expected outcome will be a set of guidelines for the best ratio of web thickness to rim thickness based on the face width to pitch circle diameter of the gear.



One result of this reduced ability to pack the part is shrinkage across the face width of the teeth. Below is a plot of lead variation, that is the deviation from the involute shape across the facewidth of the gear. This shape variation of the teeth has an effect on gear noise, but its exact nature is yet to be determined. This shape also requires the gear tooth to carry load at the edges of the tooth and not across the entire face width. This accelerates the wear of the teeth and reduces the load capacity of the gear.

Work has started on the modeling, molding, and testing of these gears. We would like to thank Don Ellis of ABA-PGT for donating a modular mold for the use of this research effort.