Program for Involute Equation to Develop Spur Gears on Pro/E Software

Sandeep Singal

In effect, this article continues a previous *Gear Technology* article, "Modeling Gears In Pro/Engineer," published in the January/February 1999 issue. The previous article discussed drawing involute gear teeth using a program built into the Pro/E software.

However, the program does not include the effect of the "profile shift" in the involute equation. The outside diameter and root diameter needed as input data may be obtained from the article "Profile Shift in External Parallel-Axis Cylindrical Involute Gears," published in *Gear Technology*, in its November/December 2001 issue.

For true modeling of spur gears, especially in terms of gear tooth profile, it is very important to include the effects of profile shift.

The technique depends on generating the involute curve in such a fashion so it is formed exactly symmetrical about one of the planes and a mirror image of the curve can be formed by using the mirror commands. The technique can be automated so all parameters—like number of teeth, correction factor, module, pressure angle, outside diameter and root diameter—are already present and ready for input. That way, a person can generate another gear just by changing the input parameters.

Reference for generation of this involute equation is taken from the June 1980 edition of *Gear Cutting Tools*, published by Verzahntechnik Lorenz GmbH & Co., Ettlingen, Germany.

The procedure given here is based on the following assumptions:

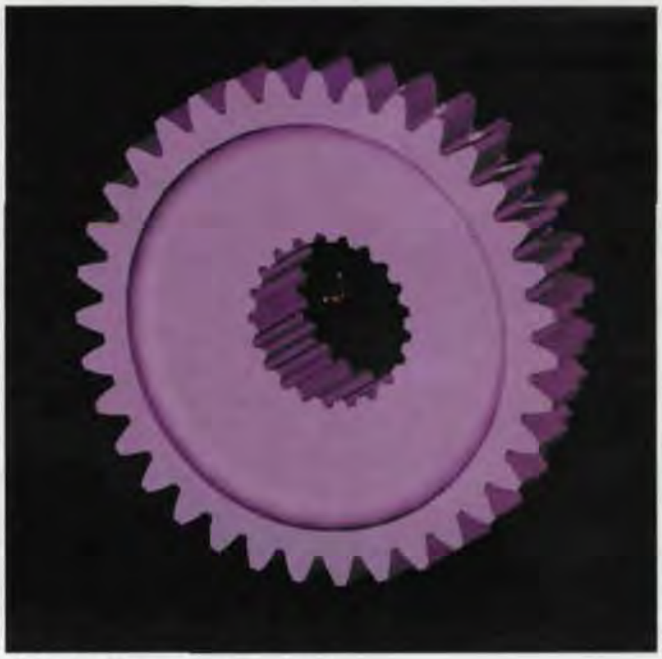
- Only spur gears are considered,
- Tooth thinning for backlash is ignored,
- Tooth profile protuberance for grinding relief is ignored,
- Tooth profile is not undercut, and
- Root fillet is approximated with a circular curve joining the involute and root circle.

The step-by-step procedure for generation of the involute is as follows:

- Step 1: Create the three Default Datum planes using the commands Feature, Create, Datum, Plane, Default.
- Step 2: Create the protrusion, taking into account that the gear's outer diameter is known. To create the protrusion, use the commands Feature, Create, Solid, Protrusion, Revolve.

(Note: The Extrusion command also can be used.)

- Step 3: Create the coordinate system for generation of the involute equations using the commands Feature, Create,



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Datum, Coord sys, 3 Planes. (Note: Refer to the three default datum planes created in Step 1; take care that the Z-axis has to be in the direction of the gear's center axis.)

• Step 4: Generate the involute profile of one tooth flank. To do this, use the commands Feature, Create, Datum, Curve, From Equation, Choose Cylindrical, and use the just-created coordinate system.

At this point, there will be a window in which the involute equation will need to be written. The equation will need the following input data: number of teeth (not), pressure angle (pangle), module (m), correction factor of the gear under consideration (x), outside diameter (od) and root diameter (rd). These data will change with each specific gear to be drawn.

As an example, the following input data will be used:

```
  not = 46
pangle = 20
    m = 3
    x = 0.55
   od = 146.7
   rd = 133.8
```

The equation is as follows:

```
pcd = not*m
bcd = pcd*cos(pangle)
rbase = bcd/2
tt = (((3.141592654)*m)/2)
    + (2*m*x*tan(pangle))
k = bcd*((tt/pcd)
    + ((tan(pangle)
    – ((pangle
    *(3.141592654)))/180)))
gamma =
    (((bcd*(3.141592654))
    – (not*k))/(not*2))
    *(360/(bcd
    *(3.141592654)))
r = rbase/(cos(t*40))
inv = tan(t*40) – (((t*40)
    *(3.141592654))/180)
theta = (((inv*180)
    /(3.141592654))
    + gamma)
z = 0
```

The output is:

pcd = Pitch Circle Diameter
bcd = Base Circle
rbase = Base Circle Radius
tt = Tooth Thickness at the pcd
k = Tooth Thickness at the bcd
gamma = Basically, this is my own term for calculation of the angle subtended by the end point of the start of involute profile from the base circle diameter towards the gear center. (Note: This is an important parameter, which helps generation of the involute profile exactly at a point where, if we take a mirror image of the profile, then both generated profiles will create the exact space width in the gear tooth.)

r = This calculates the r function for involute profiles in terms of cylindrical coordinates.

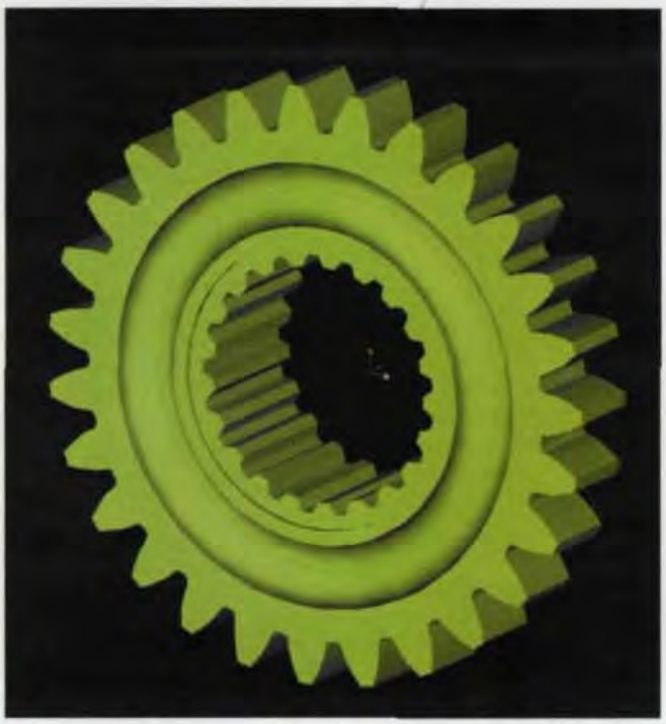
inv = This is tan(α) – α, where α = the pressure angle in radians.

theta = This calculates the theta function for involute profiles in terms of cylindrical coordinates.

t = Pro/E internal variable, which varies from 0 to 1

z = the gear axis (For the program, the axis has to be zero.)

(Note: This program will generate involute profiles up to 40°, only as the variable "t" given in the output for r and inv is 40°. However, this



function can be changed to any extent based on individual requirements.)

This step will generate an involute profile curve, which will be found at an angle with respect to one of the Datum planes.

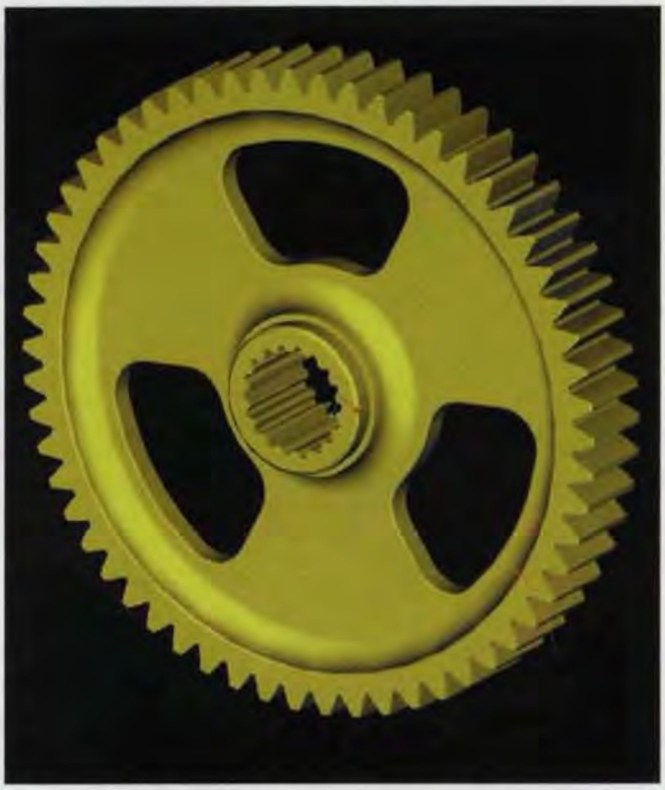
• Step 5: To create a mirror image of this datum curve about the plane, use the commands Feature, Copy, Mirror, Dependent. Select the curve and say Done, then choose the Datum plane along which the curve is to be mirrored.

• Step 6: To create the cut using the already generated curves, use the commands Feature, Create, Solid, Cut, Extrude. Choose the plane containing the datum curves as the Sketching plane. Use Geometry Tools in the Sketcher mode. Use the edges of the datum curves. Use Outer Diameter as the boundaries of the cut. Also, draw the root circle radius for closing the boundary. Extrude the cut along the entire face width. This procedure should be restricted to gears without undercut. The involute can be joined with the root circle by giving a suitable value for the fillet radius. For this example, the value is 0.8 mm. The gear designer can choose how to join the profile with the root circle diameter.

After Step 6, one tooth space will have been created. From here, any method for the gear generation can be used. In this case, the method used was as follows:

• Step 7: Create another cut using the Copy command. Use the commands Feature, Copy, Move, Dependent, Done, Rotate. Select the center axis as the axis around which to rotate. For the rotation angle, put 360/number of teeth as the input and say Done.

• Step 8: Generate the entire gear using the Pattern command. Use the commands Feature and Pattern, using the just-copied cut as the feature for the pattern. This step will show various dimensions on the just-copied cut. Select the



rotation angle given in Step 7, and fill in the same value, i.e. 360/number of teeth. Afterward, the program will ask for the number of features in the pattern. Give it a value that is one tooth less than the number of teeth. One tooth is subtracted because one cut—the original one—is already there.

This completes generation of a spur gear with the actual involute profile using nominal values, but without the actual profile being produced in the root fillet area. Helical gears also can be generated, but the involute equation is slightly different.

This program can be converted into parametric form, in which only input values are needed to completely generate a gear.

A number of gears used in tractor transmissions were checked. The gears had modules in the range of 3–5.75 mm. The accuracy observed on the values for diameter over pins and measurement over number of teeth varied in the range of 1–4 microns. Therefore, these steps can be used to reliably generate spur gears. ○

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