A parametric modeling of spur gear using ProEngineer

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Abstract — Teeth of spur gear have commonly involute profile. The circle from which the involute is derived is called the base circle. The pitch circle diameter of gear has a relation with module of spur gear and number of teeth. Similarly, other dimensions of spur gear have direct or indirect relation with module, number of teeth and pressure angle. In other words, parameters like module, number of teeth and pressure angle decide the shape and size of a spur gear. A procedure to make parametric model of spur gear using ProEngineer Wildfire 5.0 is described in this paper.

I. INTRODUCTION

Gears are common components in many mechanical designs, but the surface profile of the gear teeth is relatively difficult to draw accurately. Since gears are normally either purchased components, or else fabricated with standard cutters, they are often not drawn in exact detail, but simply as circular blanks without the teeth cut out. One may require detailed finite element analysis of a gear set, or perhaps may need to fabricate gears with a rapid prototyping machine. Either of these will require an exact CAD model of the tooth geometry, and approximate methods will not always meet the requirements.

II. GEAR TERMINOLOGY

(1) **Pitch circle**: An imaginary circle that contacts the pitch circle of any other gear with which it is in mesh.

(2) **Pitch diameter (D)**: The diameter of the pitch circle.

(3) **Number of teeth (N)**: The number of teeth on the gear.

(4) **Diametral pitch (P)**: The number of teeth of a gear per inch of its pitch diameter.

(5) **Module (m)**: The ratio of pitch diameter to the number of teeth. It is reciprocal of the diametral pitch. The pitch diameter is specified either in inches or millimeters.

(6) **Pressure angle (a)**: The angle through which forces are transmitted between meshing gears. It is either 14.5°or 20°. It defines the geometry of the gear tooth and also determines the diameter of the base circle.

(7) **Addendum (a)**: The Radial distance from the pitch circle to the top of the gear tooth.

(8) **Dedendum (b)**: The Radial distance from the pitch circle to the bottom of the tooth space.
III. THE INVOLUTE CURVE

It is known that involute gears are the most widely used in practice, being preferred over cycloidal and circular profile gears. The involute gears have the active flanks of their teeth shaped as involute curves of a common circle, called base circle. The involute of a circle is obtained by attaching an inextensible string to this given circle, and tracing its free end as it is wound or unwound onto the base circle. Fig. 2 illustrates this concept, where BT represents the string, while the involute curve is the locus generated by the free end point T of the string.

![Fig.2 The Involute Curve of a Circle of Radius r](image)

The following scalar equations are used to define involute:

\[
\begin{align*}
X &= r_b \sin C - r_b \cos C \cdot \pi C \\
Y &= r_b \cos C + r_b \sin C \cdot \pi C
\end{align*}
\]

Involute of spur gear is drawn from its base circle (refer Table 2 for relation of radius of base circle). This involute profile is either extended or trimmed to root circle (refer Table 2 for the relation). The radius of root circle is less than that of base circle for number of teeth \(Z\) is less than or equal to 42\(^{[3]}\). To complete the profile of tooth in ProEngineer, the involute should be extended or trimmed. Hence, there should be two parametric models for the spur gear: one for less than or equal to 42 teeth and other for greater than 42 teeth. Here, this issue has been approached in a different way. A spline is drawn which joins the center of base circle and six point on involute profile (Fig. 5). It is also compared that there is no difference between involute profile drawn by this method and spline drawn by joining six points on involute.

IV. MODELING THE SPUR GEAR IN PRO/ENGINEER

First, open a new part file and create the basic gear parameters as shown in Table 1 using Tools\(\rightarrow\)Parameters. These basic gear parameters determine all other parameters that define the gear tooth profile (or alternatively, the profile of the spaces between the gear teeth). The other gear parameters, shown in Table 2, are defined in terms of relationship to the basic parameters (Fig. 3) using Tools\(\rightarrow\)Relations.

<table>
<thead>
<tr>
<th>Sr. no</th>
<th>Parameter</th>
<th>Relationship</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>(p)</td>
<td>(\pi \times m)</td>
<td>Pitch of the teeth on a straight generative rack.</td>
</tr>
<tr>
<td>2.</td>
<td>(h_a)</td>
<td>(m)</td>
<td>Addendum</td>
</tr>
<tr>
<td>3.</td>
<td>(h_f)</td>
<td>if (m&gt;1) (h_f = 1.25 \times m) else (h_f = 1.4 \times m)</td>
<td>Dedendum</td>
</tr>
<tr>
<td>4.</td>
<td>(r_p)</td>
<td>(m \times Z/2)</td>
<td>Radius of the pitch circle.</td>
</tr>
<tr>
<td>5.</td>
<td>(r_a)</td>
<td>(r_p + h_a)</td>
<td>Radius of the outer circle.</td>
</tr>
<tr>
<td>6.</td>
<td>(r_f)</td>
<td>(r_p - h_f)</td>
<td>Radius of the root circle.</td>
</tr>
<tr>
<td>7.</td>
<td>(r_b)</td>
<td>(r_p \times \cos(a))</td>
<td>Radius of the base circle.</td>
</tr>
<tr>
<td>8.</td>
<td>(r_c)</td>
<td>(m \times 0.38)</td>
<td>Radius of the root concave corner.</td>
</tr>
<tr>
<td>9.</td>
<td>(X_C)</td>
<td>(r_b \times (\sin(C \times \pi) - \cos(C \times \pi)) \times C \times \pi)</td>
<td>X coordinates of the involute tooth profile</td>
</tr>
<tr>
<td>10.</td>
<td>(Y_C)</td>
<td>(r_b \times (\cos(C \times \pi) + \sin(C \times \pi)) \times C \times \pi)</td>
<td>Y coordinates of the involute tooth profile</td>
</tr>
<tr>
<td>11.</td>
<td>(R_o)</td>
<td>(r_b \times a \times \pi / 180)</td>
<td>Radius of the osculating circle of the involute curve, on the pitch circle.</td>
</tr>
<tr>
<td>12.</td>
<td>(C)</td>
<td>(\sqrt{\frac{1}{\cos^2 a} - 1} / \pi)</td>
<td>Angle of the point of the involute that intersects the pitch circle.</td>
</tr>
<tr>
<td>13.</td>
<td>(\phi)</td>
<td>(\tan^{-1} \left(\frac{X_C}{Y_C}\right) + 90\times Z)</td>
<td>Rotation angle used for making a gear symmetric to the ZX plane</td>
</tr>
</tbody>
</table>
Defining Part Relation

Defining Axis and Datum Plane

For creating involute profile, X, Y, and Z axes are created first and then the datum planes using these axes. The X axis is an intersection between Top and Front planes. Y and Z axes are also created as specified in Table 3. Then datum planes are created which pass through the axis and make an angle with the primary reference planes as shown in Table 3. This angle is the rotation angle that makes the gear symmetric.

<table>
<thead>
<tr>
<th>Axis /Datum plane</th>
<th>Reference plane 1 (Select)</th>
<th>Value</th>
<th>Reference plane 2 (Select)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X_AXIS</td>
<td>Top plane</td>
<td>-</td>
<td>Front plane</td>
</tr>
<tr>
<td>Y_AXIS</td>
<td>Front plane</td>
<td>-</td>
<td>Right plane</td>
</tr>
<tr>
<td>Z_AXIS</td>
<td>Right plane</td>
<td>-</td>
<td>Top plane</td>
</tr>
<tr>
<td>DATUM_1</td>
<td>Right plane (offset)</td>
<td>abs((\phi))</td>
<td>Z-axis (through)</td>
</tr>
<tr>
<td>DATUM_2</td>
<td>Datum1 (offset)</td>
<td>90°</td>
<td>Z-axis (through)</td>
</tr>
<tr>
<td>DATUM_3</td>
<td>Right plane (offset)</td>
<td>180/Z</td>
<td>Z-axis (through)</td>
</tr>
</tbody>
</table>

Defining Datum Points

Now, click on sketch tool and select Front plane as sketching plane and Datum1 as reference with right orientation. Create six points in first quadrant and give following relations in Tools \(\rightarrow\) Relations. The resultant sketch is shown in Fig. 4. These points are created parametrically for different values of C.

\[
\begin{align*}
X_1 &= rb \* (\sin(0^\circ \pi) - \cos(0^\circ \pi) \* 0^\circ \pi) \\
Y_1 &= rb \* (\cos(0^\circ \pi) + \sin(0^\circ \pi) \* 0^\circ \pi) \\
X_2 &= rb \* (\sin(0.1^\circ 180) - \cos(0.1^\circ 180) \* 0.1^\circ \pi) \\
Y_2 &= rb \* (\cos(0.1^\circ 180) + \sin(0.1^\circ 180) \* 0.1^\circ \pi) \\
X_3 &= rb \* (\sin(0.2^\circ 180) - \cos(0.2^\circ 180) \* 0.2^\circ \pi) \\
Y_3 &= rb \* (\cos(0.2^\circ 180) + \sin(0.2^\circ 180) \* 0.2^\circ \pi) \\
X_4 &= rb \* (\sin(0.3^\circ 180) - \cos(0.3^\circ 180) \* 0.3^\circ \pi) \\
Y_4 &= rb \* (\cos(0.3^\circ 180) + \sin(0.3^\circ 180) \* 0.3^\circ \pi) \\
X_5 &= rb \* (\sin(0.4^\circ 180) - \cos(0.4^\circ 180) \* 0.4^\circ \pi) \\
Y_5 &= rb \* (\cos(0.4^\circ 180) + \sin(0.4^\circ 180) \* 0.4^\circ \pi) \\
X_6 &= rb \* (\sin(0.5^\circ 180) - \cos(0.5^\circ 180) \* 0.5^\circ \pi) \\
Y_6 &= rb \* (\cos(0.5^\circ 180) + \sin(0.5^\circ 180) \* 0.5^\circ \pi)
\end{align*}
\]

Note: Change the name of all dimensions as per requirements. Click on dimension and press the tab “properties” and change.

\[
\begin{align*}
X_1 &= rb \* (\sin(0^\circ \pi) - \cos(0^\circ \pi) \* 0^\circ \pi) \\
Y_1 &= rb \* (\cos(0^\circ \pi) + \sin(0^\circ \pi) \* 0^\circ \pi) \\
X_2 &= rb \* (\sin(0.1^\circ 180) - \cos(0.1^\circ 180) \* 0.1^\circ \pi) \\
Y_2 &= rb \* (\cos(0.1^\circ 180) + \sin(0.1^\circ 180) \* 0.1^\circ \pi) \\
X_3 &= rb \* (\sin(0.2^\circ 180) - \cos(0.2^\circ 180) \* 0.2^\circ \pi) \\
Y_3 &= rb \* (\cos(0.2^\circ 180) + \sin(0.2^\circ 180) \* 0.2^\circ \pi) \\
X_4 &= rb \* (\sin(0.3^\circ 180) - \cos(0.3^\circ 180) \* 0.3^\circ \pi) \\
Y_4 &= rb \* (\cos(0.3^\circ 180) + \sin(0.3^\circ 180) \* 0.3^\circ \pi) \\
X_5 &= rb \* (\sin(0.4^\circ 180) - \cos(0.4^\circ 180) \* 0.4^\circ \pi) \\
Y_5 &= rb \* (\cos(0.4^\circ 180) + \sin(0.4^\circ 180) \* 0.4^\circ \pi) \\
X_6 &= rb \* (\sin(0.5^\circ 180) - \cos(0.5^\circ 180) \* 0.5^\circ \pi) \\
Y_6 &= rb \* (\cos(0.5^\circ 180) + \sin(0.5^\circ 180) \* 0.5^\circ \pi)
\end{align*}
\]
Finishing Spur Gear

Create the gear blank by extruding the circle of diameter $R_A$ that corresponds to the outer diameter of gear. Since only the portion of involute curve above the root circle is required, trim the lower portion of spline and extrude it to cut the gear blank (Fig. 6).

Create the rotational pattern of the cut portion of the gear with number of copies equal to the number of teeth. Fillet the gear teeth at the root diameter using round tool to reduce the root fillet stress.

VI. CONCLUSION

The parametric model is capable of creating spur gears with different modules and number of teeth by modifying the parameters and regenerating the model. Sets of gears having the same module and pressure angle can be created and assembled together. It is possible to carry out finite element analysis such as contact stresses between gear teeth pair and effect of root fillet radius on the root stresses.

VII. REFERENCES