Program 60-1442—Pin (Ball) Measurement—Internal Involute Gears

Introduction

This model calculates the measurement between pins or balls for internal involute spur and helical gears. This measuring system is used extensively for gears and splines and is a very accurate method for control of space width and tooth thickness. By using different size pins (or balls) a rough check can also be made of the involute profile. If the number of teeth in the gear is even, the pins or balls will be opposite each other. The measuring contact points will be on a centerline of the gear. If the number of teeth is odd the pins or balls will not be opposite each other and the measuring contact points will not be on a centerline of the gear.

For cylindrical involute gears, spur or helical, the measuring pins or balls will have their centers on the ball helix of the gear. The ball helix is the location of the center of the ball that is free to roll in the tooth space of the gear. The problem of finding the measurement between pins or balls for a given space width or tooth thickness and pin or ball diameter then becomes a problem of finding the distance between the ball helixes. For spur gears and splines, pins may be used for the measurement. For helical gears and splines it is necessary to use balls. The balls MUST be constrained to the plane of rotation of the gear (transverse plane).

The model calculates the diameter of a recommended pin or ball that should be suitable for the gear being measured. In some cases the pin or ball may not project below the inside diameter of the gear. If this proves to be a problem, a larger pin or ball can usually be found that will project below the inside diameter and still achieve proper contact on the tooth flank. Many internal splines and some gears will require flats on the pins to avoid contact at the major diameter. The closest “standard” pin to the recommended pin is found and given in the Power User form or in the TK Solver Variable Sheet. If you have the space width or tooth thickness and want to solve for the size between pins, the recommend pin and the closest “standard” pin can be found before an actual measuring pin size is entered. If the internal gear is spur, the tooth thickness can be measured by measuring the span between tooth flanks separated by a specified number of spaces. This can be done with an internal vernier or by optical means. This procedure is analogous to span measurement over a specified number of teeth on an external gear.
Examples

Example 1

This example was selected to demonstrate how to find the size between pins given the space width, and to find the space width and tooth thickness given the measured size between pins.

The example is an odd tooth spur gear that does not have a “standard” pitch or space width.

First we will find the measurement between pins and the span measurement when we know the normal space width at the reference pitch diameter. (The reference pitch diameter is the diameter found by dividing the number of teeth by the transverse pitch.)

We have the following data available:

- Number of teeth
- Normal Diametral Pitch
- Normal Pressure Angle
- Helix Angle
- Inside Diameter*
- Major (Root) Diameter*
- True Involute Form Diameter*
- Normal Space Width (or Tooth Thickness)

* These values are not necessary to obtain a size between pins but are required for the model to check the contact diameter of the pins or balls and to create a plot of the tooth.

Open a new analysis in 60-1442 and enter the known data in the data input form. When the red message appears at the bottom of the form, click the radio button for “Space Width,” and follow the subsequent sequence for data entry. The interface will advise you of inputs required for plots and other purposes.

The completed form is shown in Figure 1-1. The solved model inputs and outputs are shown in Report 1-1.
Fig. 1-1

Integrated Gear Software (60-1442)

Enter Values
- Number of teeth: 29
- Normal module: 3.527778 mm
- Normal diametral pitch: 7.200000 1/in
- Normal pressure angle: 20.000000 deg
- Nominal helix angle at root pitch 7.900000 seg
- True involute form 2.2947 in

Diameter
- Inside diameter: 3.7900 in
- Major diameter: 4.3750 in

Tooth Thickness
- External tooth thickness: n/a
- External tooth thickness at root: n/a

Measurement Between Pins or Balls
- Measurement between two pins: n/a
- Measurement between two balls: n/a

Space width
- Normal space width at root: 0.2064 in
- Minimum space at root: 0.2064 in

Enter Pin Value
- Actual pin (or test) diameter: 0.24000 in

Spacers Spanned
- Actual number of spacers spanned: n/a

Save Measurement
- Min recommended spaces spanned: n/a
- Recommend number of spaces spanned: n/a
- Max recommended spaces spanned: n/a

Please select either 'Tooth Thickness', 'Measurement between pins or balls', 'Space width' or 'Span Size'

Report 1-1

Model Title: Program 60-1442
Unit System: US

Plot Ball / Teeth? y
Number of teeth 29
Normal diametral pitch 7.200000 1/in
Normal module 3.527778 mm
Normal pressure angle 20.000000 deg
Nominal helix angle 0.000000 deg
Pointed tooth diameter Below BD in
Inside diameter 3.7900 in
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>True involute form dia TIF (Opt)</td>
<td>4.2847 in</td>
</tr>
<tr>
<td>Major diameter</td>
<td>4.3750 in</td>
</tr>
<tr>
<td>Reference pitch diameter</td>
<td>4.0278 in</td>
</tr>
<tr>
<td>Base diameter</td>
<td>3.7849 in</td>
</tr>
<tr>
<td>Transverse diametral pitch</td>
<td>7.200000 1/in</td>
</tr>
<tr>
<td>Transverse module</td>
<td>3.527778 mm</td>
</tr>
<tr>
<td>Transverse pressure angle</td>
<td>20.000000 deg</td>
</tr>
<tr>
<td>Normal space width at Ref PD</td>
<td>0.2094 in</td>
</tr>
<tr>
<td>Normal tooth thickness at Ref PD</td>
<td>0.2269 in</td>
</tr>
<tr>
<td>Normal base pitch</td>
<td>0.4100 in</td>
</tr>
<tr>
<td>Transverse base pitch</td>
<td>0.4100 in</td>
</tr>
<tr>
<td>Transverse space width at Ref PD</td>
<td>0.2094 in</td>
</tr>
<tr>
<td>Transverse tooth thickness at Ref PD</td>
<td>0.2269 in</td>
</tr>
<tr>
<td>Recommended pin (or ball) diameter</td>
<td>0.23333 in</td>
</tr>
<tr>
<td>Closest standard inch series pin</td>
<td>0.24000 in</td>
</tr>
<tr>
<td>Closest standard metric series pin</td>
<td>6.0000 mm</td>
</tr>
<tr>
<td>Actual pin (or ball) diameter</td>
<td>0.24000 in</td>
</tr>
<tr>
<td>Measurement between two pins/balls</td>
<td>3.6303 in</td>
</tr>
<tr>
<td>Radius from center to one pin/ball</td>
<td>1.8180 in</td>
</tr>
<tr>
<td>Axial pitch</td>
<td>--- in</td>
</tr>
<tr>
<td>Lead</td>
<td>--- in</td>
</tr>
<tr>
<td>Base helix angle</td>
<td>0.0000 deg</td>
</tr>
<tr>
<td>Ball path helix angle</td>
<td>0.0000 deg</td>
</tr>
<tr>
<td>Radius to center of pin</td>
<td>1.9380 in</td>
</tr>
<tr>
<td>Pressure angle at center of pin</td>
<td>0.2172 rad</td>
</tr>
</tbody>
</table>
Model Title: Program 60-1442  
Unit System: US  

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Involute of PA at center of pin</td>
<td>0.0035 rad</td>
</tr>
<tr>
<td>Pressure angle at pin/ball contact</td>
<td>0.2768 rad</td>
</tr>
<tr>
<td>Diameter at pin/ball contact</td>
<td>3.9347 in</td>
</tr>
</tbody>
</table>

**SPAN MEASUREMENT (SPUR GEARS)**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min Recommended Spaces Spanned</td>
<td>3</td>
</tr>
<tr>
<td>Recommended Spaces Spanned</td>
<td>4</td>
</tr>
<tr>
<td>Max Recommended Spaces Spanned</td>
<td>5</td>
</tr>
<tr>
<td>Actual Number of Spaces Spanned</td>
<td>4</td>
</tr>
<tr>
<td>Distance Between Tooth Flanks</td>
<td>1.4832 in</td>
</tr>
<tr>
<td>Mean Measuring Contact Diameter</td>
<td>4.0651 in</td>
</tr>
</tbody>
</table>

Notice that the recommended pin is output along with the closest “standard” pin—in this case, .24000 inches.

Tables of “standard” inch series pins and metric pins (not balls) are available in the TK Solver model. The table names are, respectively, “std_pin”, Table 1 below, and “std_pin_m”, Table 2 below.
Table 1

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<tr>
<th>Element</th>
<th>Pitch, P</th>
<th>1.92/P</th>
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<td>0.00864</td>
<td>0.00840</td>
<td>0.00720</td>
</tr>
</tbody>
</table>
In Example 1 the model has solved for the radius from the center of the gear to one pin and the measurement between two pins.

Figure 1-2 is plot of the pin in contact with the tooth; it is the “ball” plot listed in the TK Solver model Plot Sheet or in the drop-down Plot List in the Object Bar. We can see that the pin extends below the inside diameter, is well below the major diameter and contacts the teeth below the TIF diameter. (The model checks for these possible problems numerically and if there had been a problem you would have been notified.)

<table>
<thead>
<tr>
<th>Element</th>
<th>mm</th>
<th>mm</th>
<th>mm</th>
</tr>
</thead>
<tbody>
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<td>1</td>
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<td>2.25</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>2.5</td>
<td>6.5</td>
<td>20</td>
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<td>4</td>
<td>2.75</td>
<td>7</td>
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</tr>
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<td>5</td>
<td>3</td>
<td>7.5</td>
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<td>6</td>
<td>3.25</td>
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<td>28</td>
</tr>
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<td>7</td>
<td>3.5</td>
<td>9</td>
<td>30</td>
</tr>
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<td>8</td>
<td>3.75</td>
<td>10</td>
<td>35</td>
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<tr>
<td>9</td>
<td>4</td>
<td>10.5</td>
<td>40</td>
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<td>10</td>
<td>4.25</td>
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</tr>
<tr>
<td>13</td>
<td>5.25</td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>
Now we will use the model to find the space width or tooth thickness when given the measurement between pins. In this case it is only necessary to enter the measurement to one pin or the measurement between two pins and solve the model. We have left the numerical data the same so that you can see that we get the same tooth thickness and measured size any direction we choose to go.

In the data entry form, click the radio button for “Measurement Between Pins or Balls” and follow the subsequent sequence to enter the data shown in Figure 1-3. The solved model is shown in Report 1-3.
Fig. 1-3

Model Title: Program 60-1442
Unit System: US

Plot Ball / Teeth? y
Number of teeth 29
Normal diametral pitch 7.200000 1/in
Normal module 3.527778 mm
Normal pressure angle 20.000000 deg
Nominal helix angle 0.000000 deg
Pointed tooth diameter Below BD in
Model Title : Program 60-1442
Unit System: US

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside diameter</td>
<td>3.7900 in</td>
</tr>
<tr>
<td>True involute form dia TIF (Opt)</td>
<td>4.2847 in</td>
</tr>
<tr>
<td>Major diameter</td>
<td>4.3750 in</td>
</tr>
<tr>
<td>Reference pitch diameter</td>
<td>4.0278 in</td>
</tr>
<tr>
<td>Base diameter</td>
<td>3.7849 in</td>
</tr>
<tr>
<td>Transverse diametral pitch</td>
<td>7.200000 1/in</td>
</tr>
<tr>
<td>Transverse module</td>
<td>3.527778 mm</td>
</tr>
<tr>
<td>Transverse pressure angle</td>
<td>20.000000 deg</td>
</tr>
<tr>
<td>Normal space width at Ref PD</td>
<td>0.2094 in</td>
</tr>
<tr>
<td>Normal tooth thickness at Ref PD</td>
<td>0.2269 in</td>
</tr>
<tr>
<td>Normal base pitch</td>
<td>0.4100 in</td>
</tr>
<tr>
<td>Transverse base pitch</td>
<td>0.4100 in</td>
</tr>
<tr>
<td>Transverse space width at Ref PD</td>
<td>0.2094 in</td>
</tr>
<tr>
<td>Transverse tooth thickness at Ref PD</td>
<td>0.2269 in</td>
</tr>
<tr>
<td>Recommended pin (or ball) diameter</td>
<td>0.23333 in</td>
</tr>
<tr>
<td>Closest standard inch series pin</td>
<td>0.24000 in</td>
</tr>
<tr>
<td>Closest standard metric series pin</td>
<td>6.00000 mm</td>
</tr>
<tr>
<td>Actual pin (or ball) diameter</td>
<td>0.24000 in</td>
</tr>
<tr>
<td>Measurement between two pins/balls</td>
<td>3.6303 in</td>
</tr>
<tr>
<td>Radius from center to one pin/ball</td>
<td>1.8180 in</td>
</tr>
<tr>
<td>Axial pitch</td>
<td>--- in</td>
</tr>
<tr>
<td>Lead</td>
<td>--- in</td>
</tr>
<tr>
<td>Base helix angle</td>
<td>0.0000 deg</td>
</tr>
<tr>
<td>Ball path helix angle</td>
<td>0.0000 deg</td>
</tr>
<tr>
<td>Radius to center of pin</td>
<td>1.9380 in</td>
</tr>
</tbody>
</table>
**Model Title:** Program 60-1442  
**Unit System:** US

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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<tbody>
<tr>
<td>Pressure angle at center of pin</td>
<td>0.2173 rad</td>
</tr>
<tr>
<td>Involute of PA at center of pin</td>
<td>0.0035 rad</td>
</tr>
<tr>
<td>Pressure angle at pin/ball contact</td>
<td>0.2768 rad</td>
</tr>
<tr>
<td>Diameter at pin/ball contact</td>
<td>3.9347 in</td>
</tr>
</tbody>
</table>

**SPAN MEASUREMENT (SPUR GEARS)**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min Recommended Spaces Spanned</td>
<td>3</td>
</tr>
<tr>
<td>Recommended Spaces Spanned</td>
<td>4</td>
</tr>
<tr>
<td>Max Recommended Spaces Spanned</td>
<td>5</td>
</tr>
<tr>
<td>Actual Number of Spaces Spanned</td>
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</tr>
<tr>
<td>Distance Between Tooth Flanks</td>
<td>in</td>
</tr>
<tr>
<td>Mean Measuring Contact Diameter</td>
<td>in</td>
</tr>
</tbody>
</table>
**Example 2**

Example 2 is a 57 tooth helical gear for which we want a measurement between balls.

Figure 2-1 is the completed data input form and Report 2-1 is the solved model after entering the known data. Since we are using balls instead of pins we will assume that we have only fractional inch precision balls available and use 5/32 inch balls, as this is the closest 1/32-inch series ball to the recommended size of .168 inch.

**Fig. 2-1**
### Model Title: Program 60-1442

#### Unit System: US

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<thead>
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<th>Property</th>
<th>Value</th>
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<tr>
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<td>57</td>
</tr>
<tr>
<td>Normal diametral pitch</td>
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</tr>
<tr>
<td>Normal module</td>
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</tr>
<tr>
<td>Normal pressure angle</td>
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</tr>
<tr>
<td>Nominal helix angle</td>
<td>35.000000 deg</td>
</tr>
<tr>
<td>Pointed tooth diameter</td>
<td>6.5194 in</td>
</tr>
<tr>
<td>Inside diameter</td>
<td>6.7200 in</td>
</tr>
<tr>
<td>True involute form dia TIF (Opt)</td>
<td>7.1700 in</td>
</tr>
<tr>
<td>Major diameter</td>
<td>7.2130 in</td>
</tr>
<tr>
<td>Reference pitch diameter</td>
<td>6.9584 in</td>
</tr>
<tr>
<td>Base diameter</td>
<td>6.2097 in</td>
</tr>
<tr>
<td>Transverse diametral pitch</td>
<td>8.191520 1/in</td>
</tr>
<tr>
<td>Transverse module</td>
<td>3.100767 mm</td>
</tr>
<tr>
<td>Transverse pressure angle</td>
<td>26.824000 deg</td>
</tr>
<tr>
<td>Normal space width at Ref PD</td>
<td>0.1590 in</td>
</tr>
<tr>
<td>Normal tooth thickness at Ref PD</td>
<td>0.1552 in</td>
</tr>
<tr>
<td>Normal base pitch</td>
<td>0.2902 in</td>
</tr>
<tr>
<td>Transverse base pitch</td>
<td>0.3423 in</td>
</tr>
<tr>
<td>Transverse space width at Ref PD</td>
<td>0.1941 in</td>
</tr>
<tr>
<td>Transverse tooth thickness at Ref PD</td>
<td>0.1894 in</td>
</tr>
</tbody>
</table>
UTS Integrated Gear Software

Model Title : Program 60-1442
Unit System: US

Recommended pin (or ball) diameter 0.16800 in
Closest standard inch series pin --- in
Closest standard metric series pin --- mm
Actual pin (or ball) diameter 0.15625 in
Measurement between two pins/balls 6.7749 in
Radius from center to one pin/ball 3.3888 in
Axial pitch 0.5477 in
Lead 31.2200 in
Base helix angle 31.9997 deg
Ball path helix angle 34.9047 deg
Radius to center of pin 3.4669 in
Pressure angle at center of pin 0.4611 rad
Involute of PA at center of pin 0.0357 rad
Pressure angle at pin/ball contact 0.4781 rad
Diameter at pin/ball contact 6.9938 in

Note that as the model was being solved a warning appeared that the balls did not extend below the inside diameter. This condition would make it difficult (nearly impossible with finer pitches) to measure the distance between the ball without contacting the inside diameter.

Figure 2-2 is the “ball” plot for this model. The section in the plot is through the plane of rotation (transverse plane) where the ball is in contact with one of the teeth. The dashed circle is the circle on the ball through the contact point. The solid circle is in front of the section and is the actual diameter of the ball. We can see that the ball does not extend below the inside diameter.
Let's try to correct the problem by using a larger ball size of 3/16 inch.
**UTS Integrated Gear Software**

**Fig. 2-3**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of teeth</td>
<td>57</td>
</tr>
<tr>
<td>Normal module</td>
<td>2.540000 mm</td>
</tr>
<tr>
<td>Normal diametral pitch</td>
<td>10.000000 1/in</td>
</tr>
<tr>
<td>Normal pressure angle</td>
<td>22.500000 deg</td>
</tr>
<tr>
<td>Nominal helix angle</td>
<td>35.000000 deg</td>
</tr>
<tr>
<td>Pointed tooth diameter</td>
<td>6.5194 in</td>
</tr>
<tr>
<td>Inside diameter</td>
<td>6.7200 in</td>
</tr>
<tr>
<td>True involute form dia TIF (Opt)</td>
<td>7.1700 in</td>
</tr>
</tbody>
</table>

**Report 2-3**

**Model Title :** Program 60-1442

**Unit System:** US

Plot Ball / Teeth? y

Number of teeth 57
Normal diametral pitch 10.000000 1/in
Normal module 2.540000 mm
Normal pressure angle 22.500000 deg
Nominal helix angle 35.000000 deg
Pointed tooth diameter 6.5194 in
Inside diameter 6.7200 in
True involute form dia TIF (Opt) 7.1700 in
Model Title: Program 60-1442
Unit System: US

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major diameter</td>
<td>7.2130 in</td>
</tr>
<tr>
<td>Reference pitch diameter</td>
<td>6.9584 in</td>
</tr>
<tr>
<td>Base diameter</td>
<td>6.2097 in</td>
</tr>
<tr>
<td>Transverse diametral pitch</td>
<td>8.19520 1/in</td>
</tr>
<tr>
<td>Transverse module</td>
<td>3.100767 mm</td>
</tr>
<tr>
<td>Transverse pressure angle</td>
<td>26.824000 deg</td>
</tr>
<tr>
<td>Normal space width at Ref PD</td>
<td>0.1590 in</td>
</tr>
<tr>
<td>Normal tooth thickness at Ref PD</td>
<td>0.1552 in</td>
</tr>
<tr>
<td>Normal base pitch</td>
<td>0.2902 in</td>
</tr>
<tr>
<td>Transverse base pitch</td>
<td>0.3423 in</td>
</tr>
<tr>
<td>Transverse space width at Ref PD</td>
<td>0.1941 in</td>
</tr>
<tr>
<td>Transverse tooth thickness at Ref PD</td>
<td>0.1894 in</td>
</tr>
<tr>
<td>Recommended pin (or ball) diameter</td>
<td>0.16800 in</td>
</tr>
<tr>
<td>Closest standard inch series pin</td>
<td>--- in</td>
</tr>
<tr>
<td>Closest standard metric series pin</td>
<td>--- mm</td>
</tr>
<tr>
<td>Actual pin (or ball) diameter</td>
<td>0.18750 in</td>
</tr>
<tr>
<td>Measurement between two pins/balls</td>
<td>6.6587 in</td>
</tr>
<tr>
<td>Radius from center to one pin/ball</td>
<td>3.3307 in</td>
</tr>
<tr>
<td>Axial pitch</td>
<td>0.5477 in</td>
</tr>
<tr>
<td>Lead</td>
<td>31.2200 in</td>
</tr>
<tr>
<td>Base helix angle</td>
<td>31.9997 deg</td>
</tr>
<tr>
<td>Ball path helix angle</td>
<td>34.5738 deg</td>
</tr>
<tr>
<td>Radius to center of pin</td>
<td>3.4244 in</td>
</tr>
<tr>
<td>Pressure angle at center of pin</td>
<td>0.4355 rad</td>
</tr>
<tr>
<td>Involute of PA at center of pin</td>
<td>0.0298 rad</td>
</tr>
<tr>
<td>Pressure angle at pin/ball contact</td>
<td>0.4563 rad</td>
</tr>
<tr>
<td>Diameter at pin/ball contact</td>
<td>6.9174 in</td>
</tr>
</tbody>
</table>
This change takes care of the problem. Figure 2-4 shows the “ball” plot of the ball in contact with the tooth.

*Fig. 2-4*