Gear Hobbing Simulation Software

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1. Gear hobbing modelling and simulation

Gear is fixed in the model (Figure 1.1.). Hob is rotating around its axis and moving around gear along helical trajectory. The model produces cutting only in one tooth space.

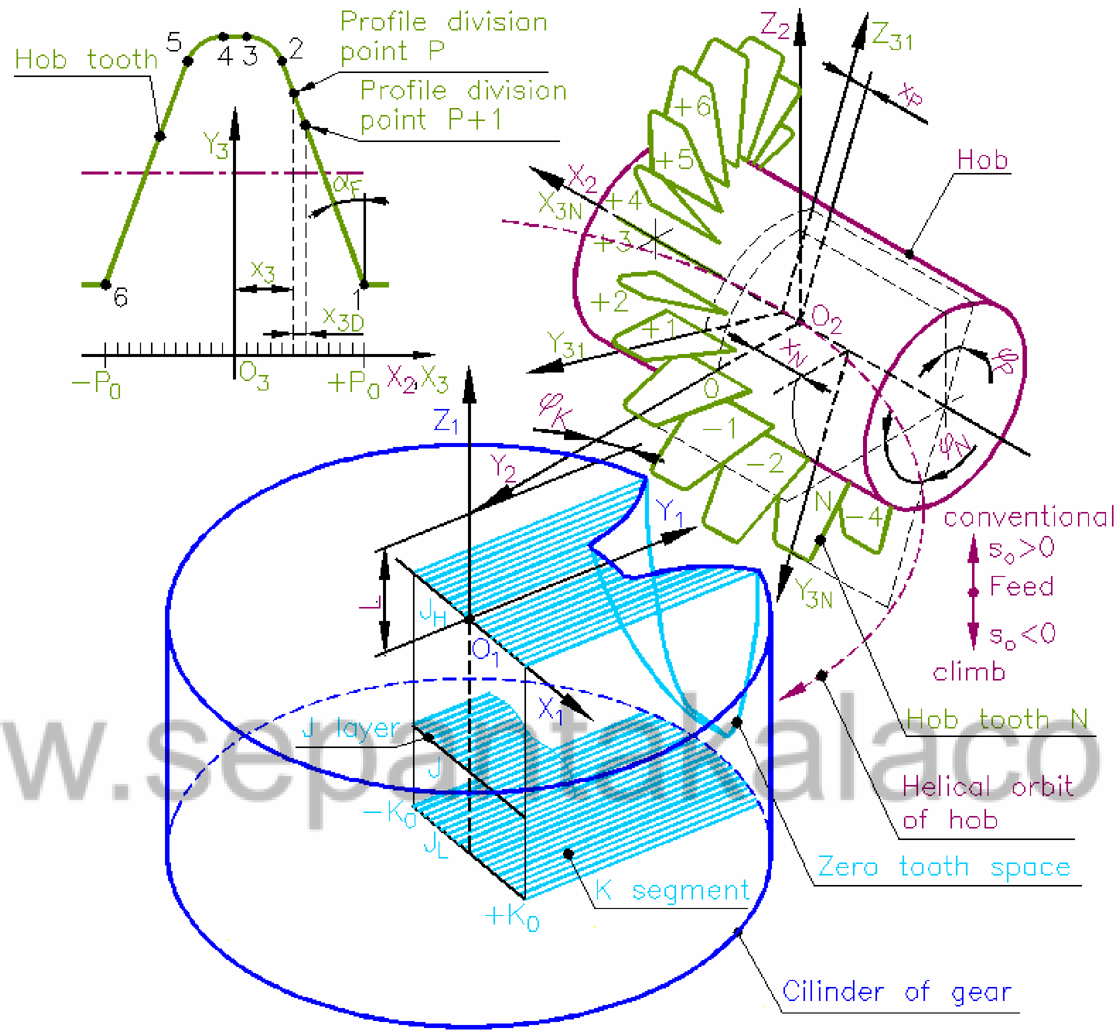


Figure 1.1

This tooth space is filled with J layers from J_H to J_L. Each layer is filled with K parallel segments, which numbers are from $-K_0$ to $+K_0$. Finished surface errors are calculated in point of the ideal tooth space surface.

The cutting simulation is executed in following. Hob teeth N in series are moving across the tooth space. Boundaries of hob teeth edges are divided into P points at the even distances x_{3D} between them. Each hob tooth boundary cuts tops of layer K segments. The top lengths of cut out segments are recalculated to cutting thicknesses. Random cutting thicknesses are interpolated into teeth boundary points.

Using the model of cylindrical gear hobbing we can calculate the following:

- - finished tooth space surface error distribution,
- - cut out volume for each hob tooth;
- - cutting thickness, cutting length for each hob tooth boundary point;
- - cutting forces and torque in gear and hob coordinate systems.

Parameters of gear hobbing model are:

Common:
- Module
- Pressure angle

Spur or helical gear:
- Numbers of teeth
- Helix angle (right or left hand)
- Profile shift coefficient
- Material

Helix hob:
- Outside radius
- Number of gashes
- Number of treads
- Tip roundness coefficient
- Hob right or left hand

Cutting:
- Feed (conventional or climb)

1.1 Design of gear hobbing model

Digital model of gear hobbing was designed. Systems of axes are selected and relation between them is determined. The gear is fixed in $X_1Y_1Z_1$ coordinate system. The hob with its $X_2Y_2Z_2$ coordinate system revolves around gear axis Z_1 and own axis X_2. Cutting is simulated only in one gear tooth space (zero tooth space) (Figure 1.2.).

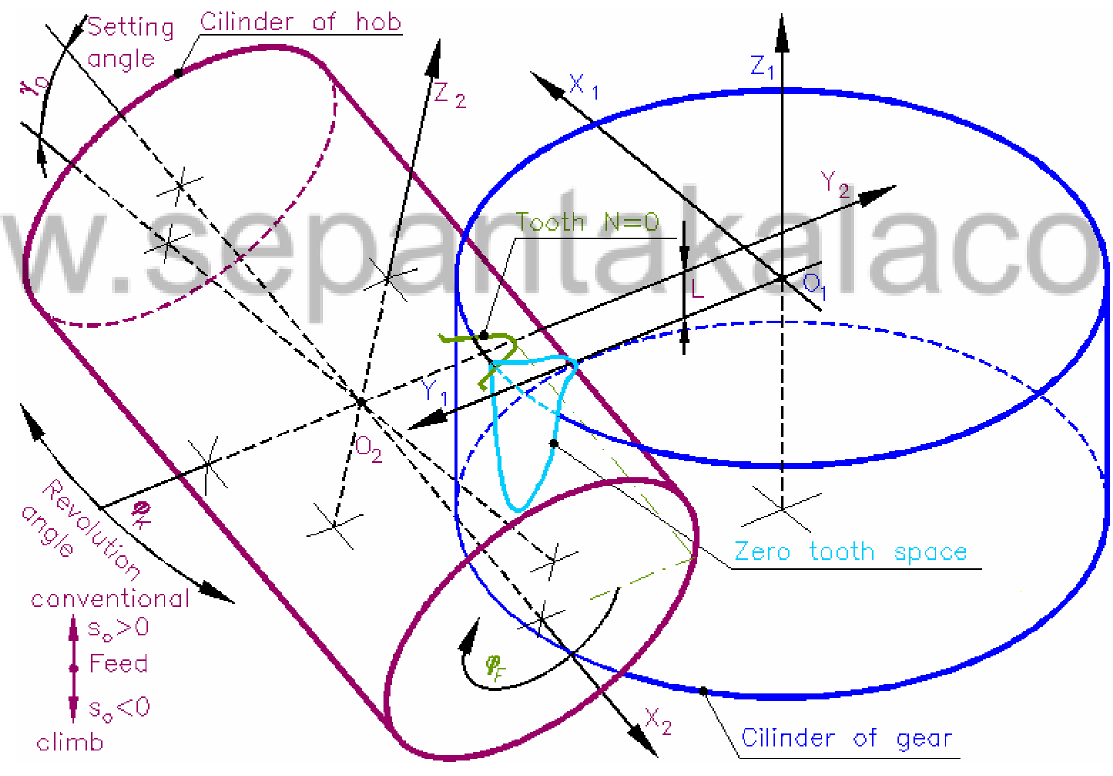


Figure 1.2

Each hob tooth has serial number N and own $X_{3N}Y_{3N}Z_{3N}$ coordinate system. Straight gashes are used in this model (Figure 1.3.).

Hob tooth boundary is divided in several straight lines and curves. All profile boundaries are divided in points P. Numbers of P points are from $-P_0$ to $+P_0$. The distance between division points is x_{3D} and this value depends on number of P points. Maximum 401 division points can be used in program of this model (Figure 1.4.). Using this number of points you can get maximum simulation precision.

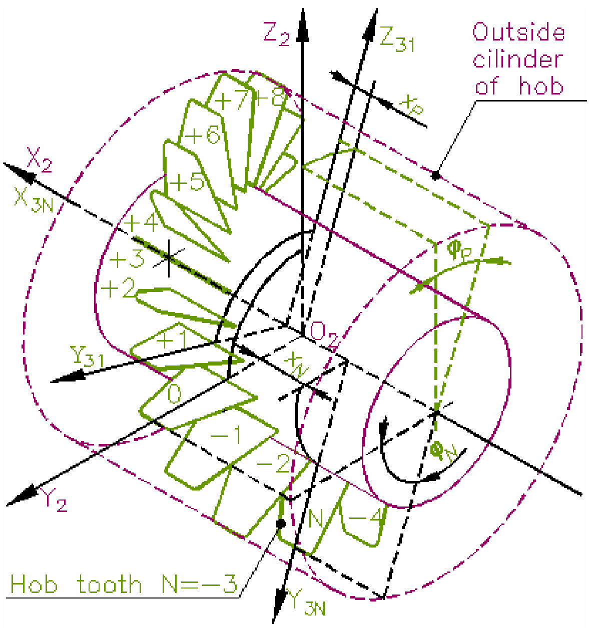


Figure 1.3

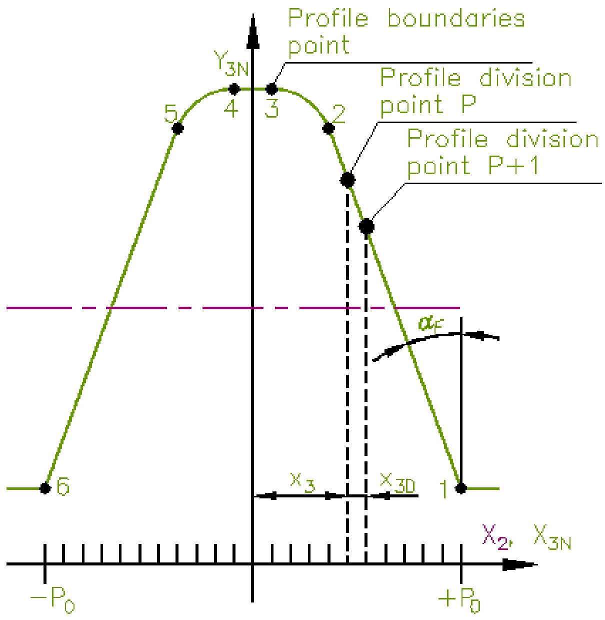


Figure 1.4

Number of the first cutting hob tooth is T_F and of the last - T_L. These numbers are calculated from cutting zone, which is a common for hob and gear bodies (Figure 1.5.).

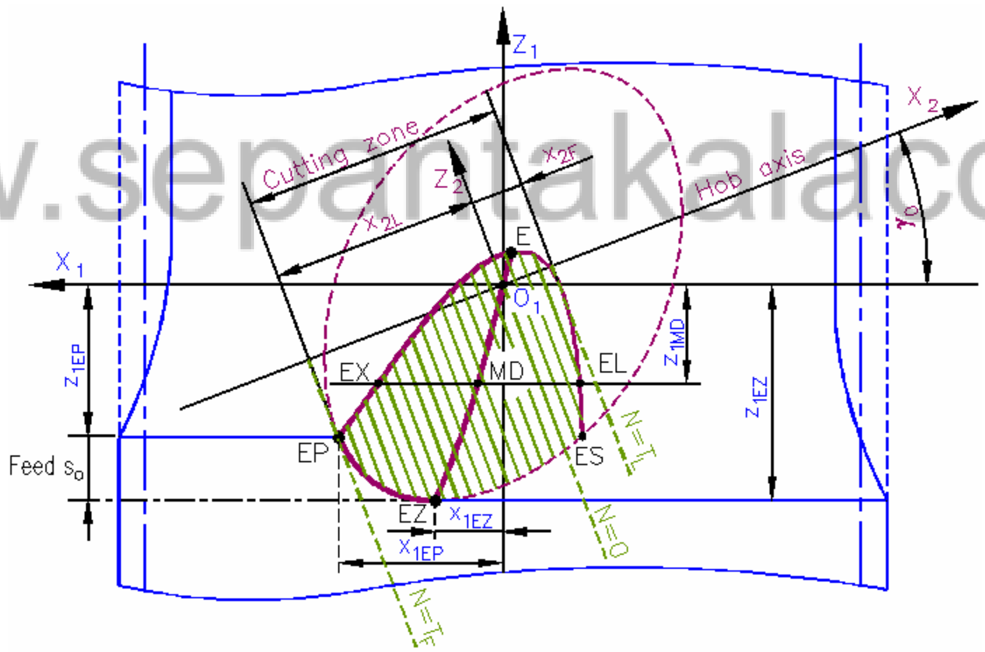


Figure 1.5

Zero tooth space of gear is filled with J layers (Figure 1.6.). Numbers of J layers are from J_H to J_L.

Each J layer is divided in to K parallel straight segments. Numbers of K segments are from $-K_0$ to $+K_0$ (Figure 1.7.). Maximum 401 segments can be used in program of this model.

Density of segments and layers depend on simulation purpose. 60-200 segments on layers are used for simulation of cutting forces. Ideal tooth space surface is prepared for simulation of cutting precision using 300 - 400 segments on layers.

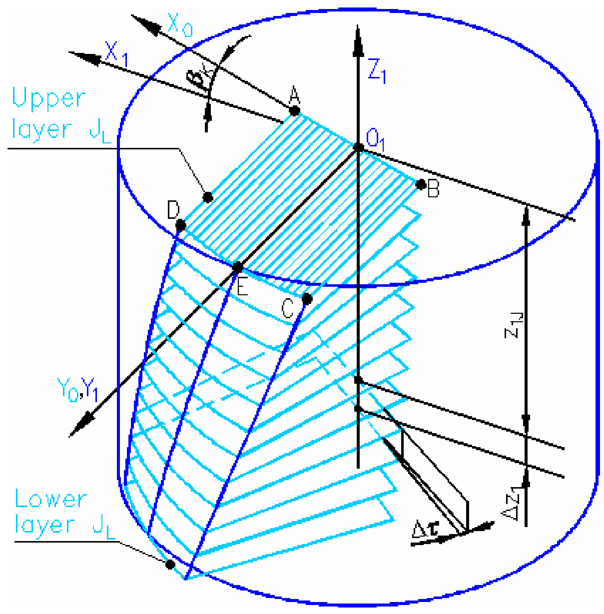


Figure 1.6

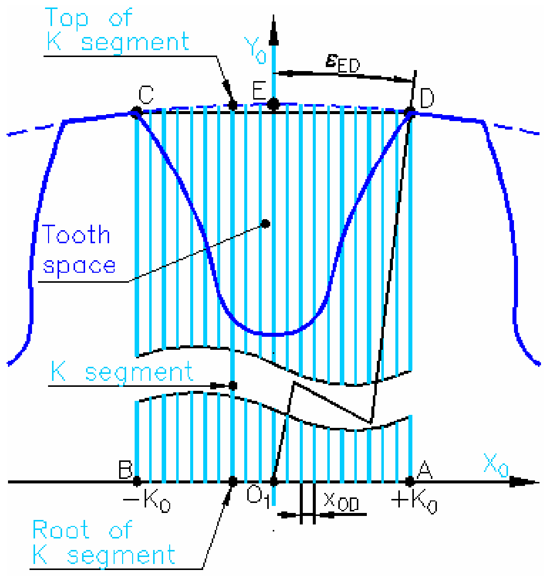


Figure 1.7

NOTES:

- Numbers of layer segments *K* and hob tooth profile division points *P* are variables and the simulation time depends on them.

1.2 Simulation of gear hobbing

The method of gear hobbing was designed. Cutting simulation is executed in following. Hob teeth *N* in series are moving across *J* layers in zero tooth space. The boundary of each hob *N*-th tooth cuts the tops of *K* segments in *J* layer. Simulation is divided into two stages. In the first stage cutting is simulated for hob, which is revolved back one revolution around gear. The second stage is simulation of real cutting process.

Coordinate of *C* point is 3D coordinate of intersection between hob tooth boundary and *JK* segment. This coordinate is calculated using special algorithm (Figure 1.8.).

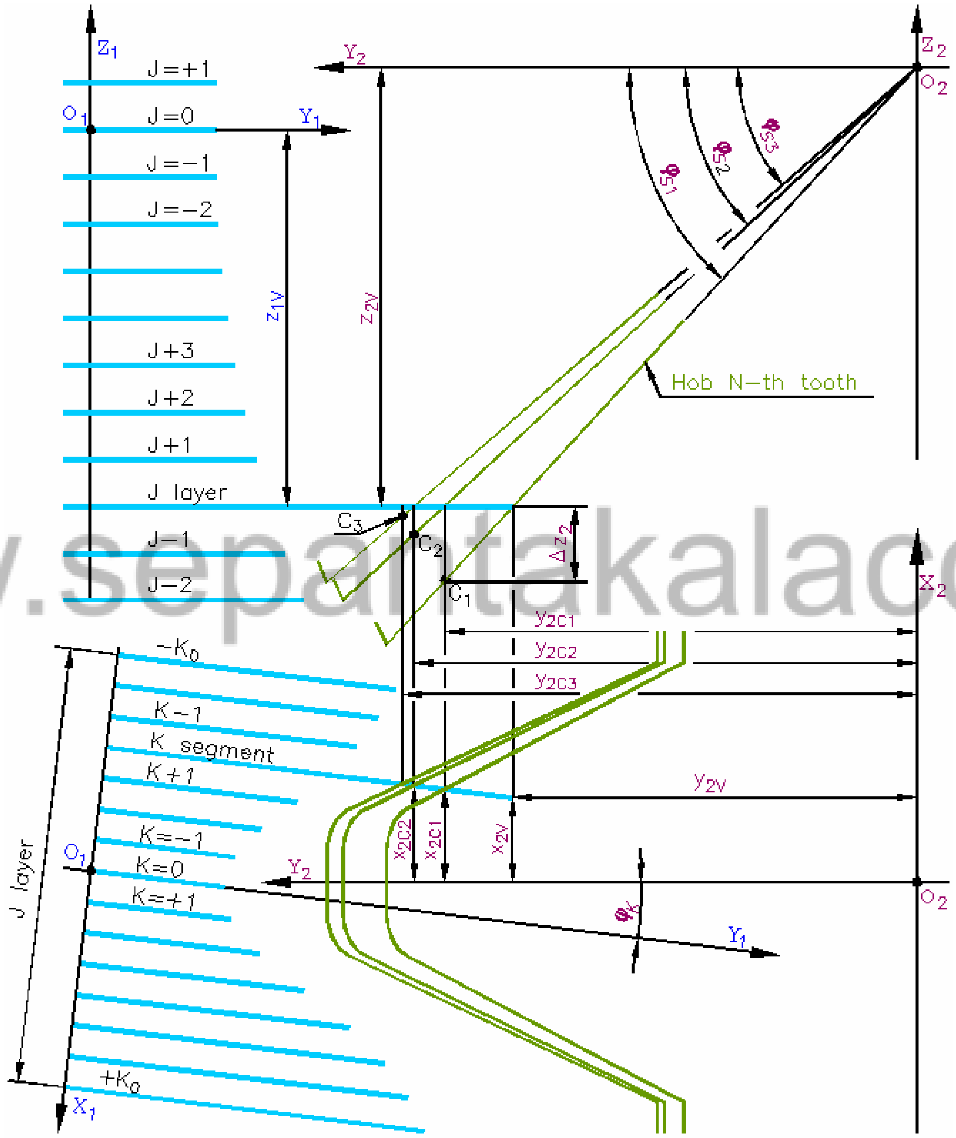


Figure 1.8

Length of cutout *JK* segments top is *CV*. This length is recalculated to length *CD* which is perpendicular to tooth boundary in *C* point (Figure 1.9.).

CD is cutting thickness in *C* point. Starting and ending points (in these points *CD* is equal zero) of cutting boundary are defined by using floating *JK* segment (Figure 1.10.).

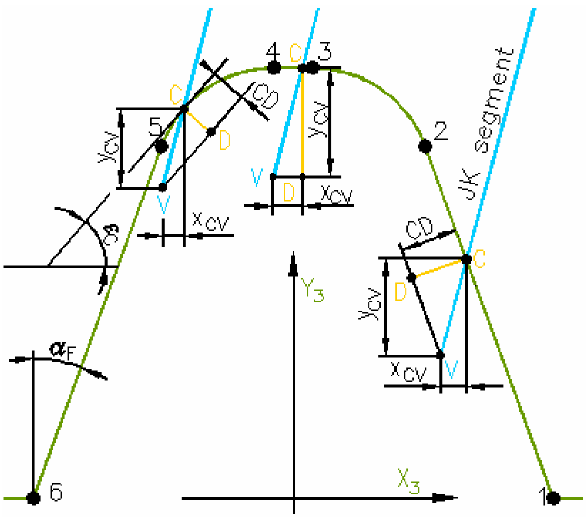


Figure 1.9

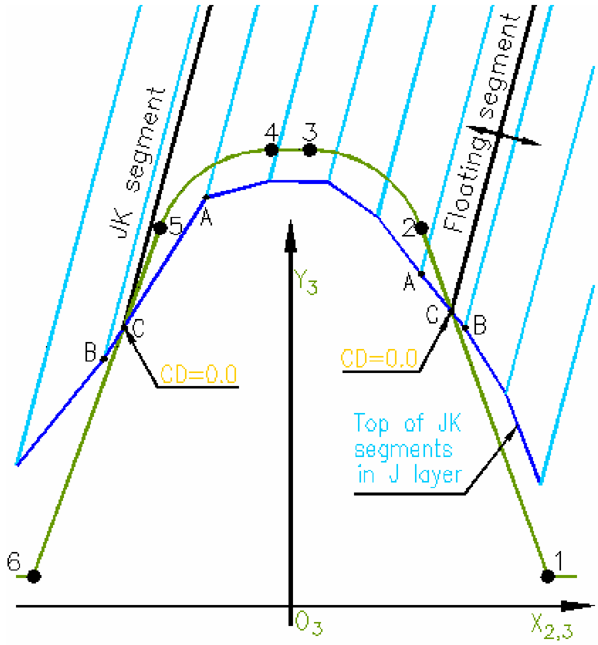


Figure 1.10

Random cutting thicknesses *CD* are interpolated into hob profile discrete points *P* and into hob revolution angle discrete positions *H* (Figure 1.11.).

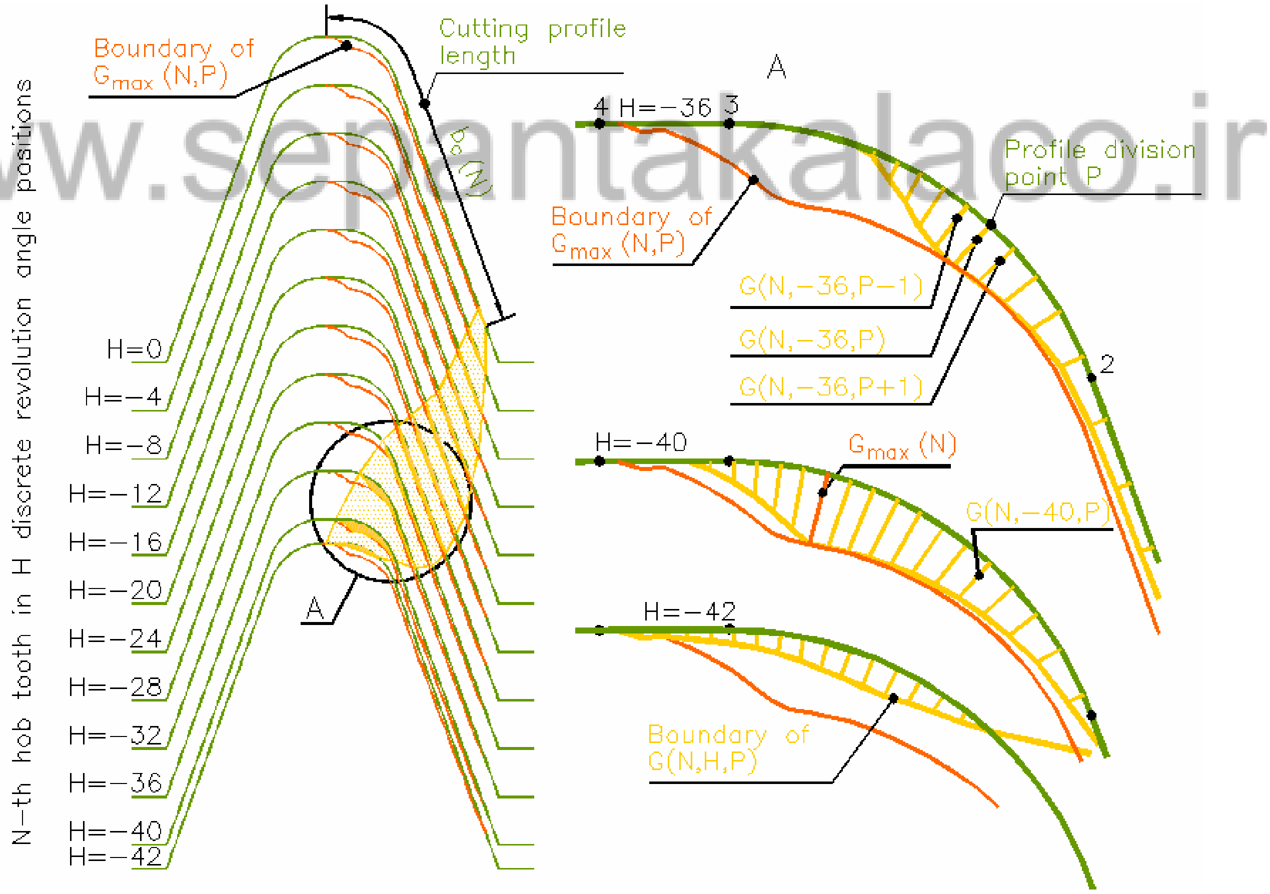


Figure 1.11

Maximum 2048 hob revolution angle *H* division points can be used in program of this model. Discrete function *G*(*N*,*H*,*P*) is the first result of simulation. Another discrete function is $Y_1(N,J,K)$, which describes coordinates of *JK* segments top after cutting with each *N*-th hob tooth (Figure 1.12.).

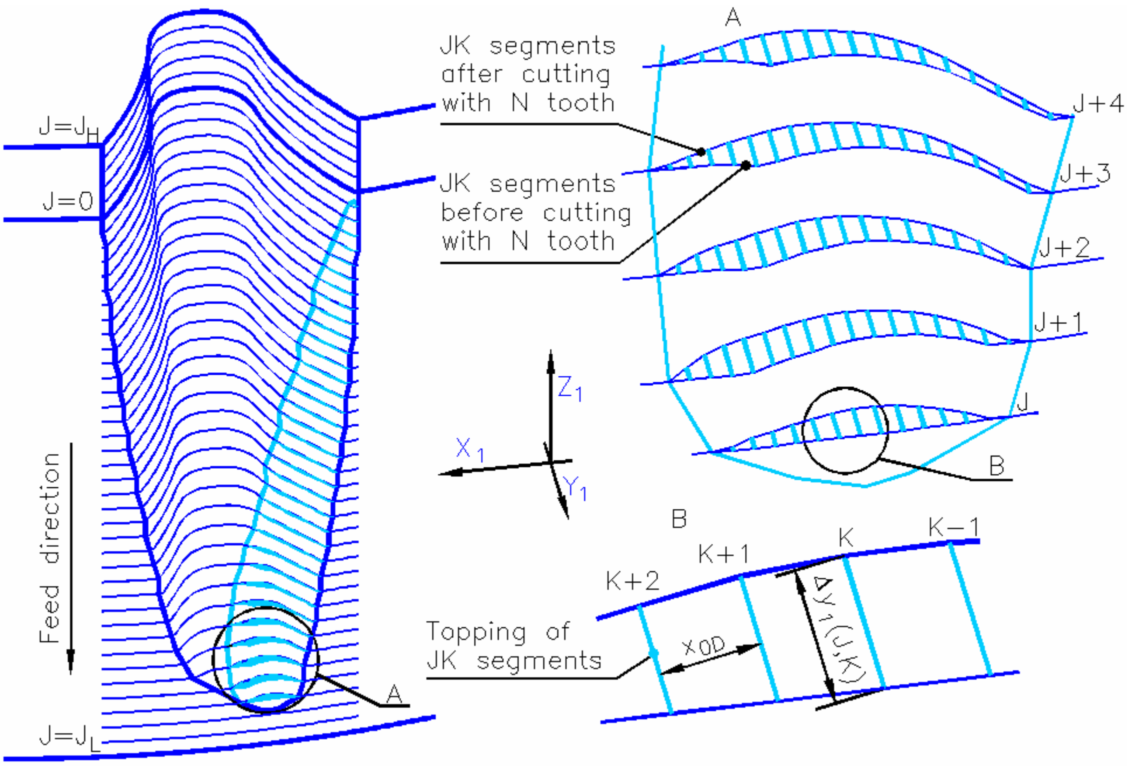


Figure 1.12

1.3 Simulation of finished tooth space surface

The method of gear hobbing error distribution in finished tooth space surface was designed. Arguments of discrete function $Y_1(T_L,J,K)$ are coordinates of *JK* segments tops after cutting with all hob teeth. In *JK* point profile error *f*(*J*,*K*) is the length of perpendicular from *JK* segment top to reference curve (Figure 1.13.).

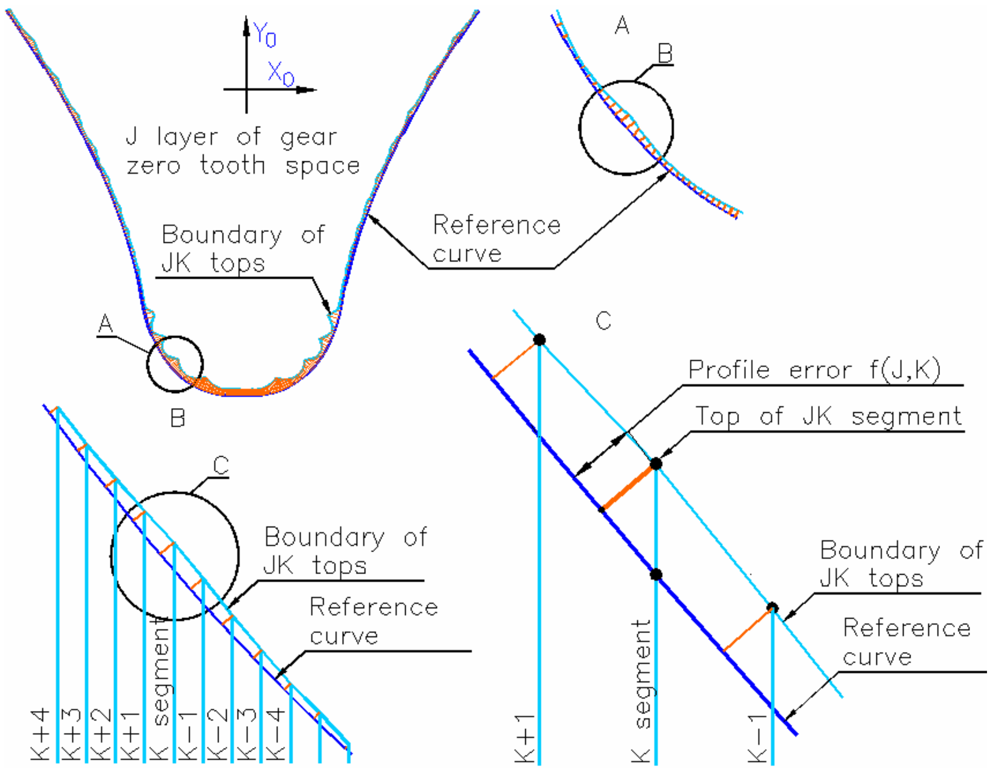


Figure 1.13

Arguments of discrete function $Y_1(T_L,J,K)$ can show how profile error is distributed in gear tooth space (Figure 1.14.). There are two kinds of profile errors: involutes flank profile error $f_E(J,K)$ and root curve profile error $f(J,K)$. Values of f_{Emax} and f_{max} are maximum profile errors.

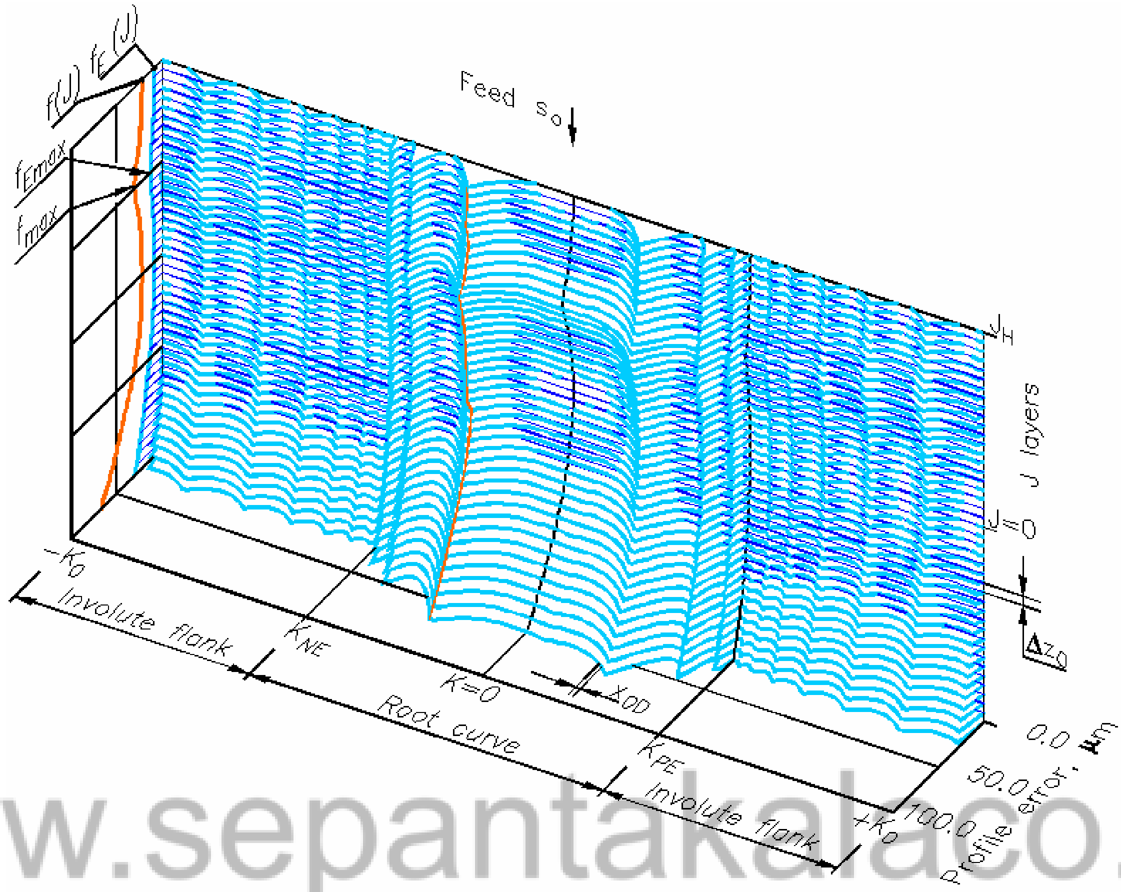


Figure 1.14

1.4 Simulation of Gear Hobbing Geometrical Size

The simulation method of maximum geometrical cutting size in gear hobbing was designed. This method is applicable for calculation of cutting thickness, length, cutout absolute and relative volumes. Discrete function $G(N,H,P)$ is the result of simulation. This function describes cutting thickness of N hob tooth P point at H revolution angle of hob. These cutting thicknesses can be shown graphically (Figure 1.15.).

These new functions are composed from discrete function $G(N,H,P)$:

- $G_{max}(N,P)$ - maximum cutting thicknesses of each N-th hob tooth in P profile points;
- $L(N,P)$ - cutting way of each N-th hob tooth in P profile points;
- $Q(N,P)$ - relative cutout volume (cutout volume divided by distance between P points) of each N-th hob tooth in P profile points;
- $b_c(N)$ - hob tooth cutting boundary length.

These functions for each hob tooth can be shown graphically. For example:

- Figure 1.16 - hob tooth with P point, which has global maximum cutting thicknesses G_{max};
- Figure 1.17 - hob tooth with P point, which has global maximum relative cutout volume Q_{max};
- Figure 1.18 - hob tooth with P point, which has global maximum cutting way L_{max}.

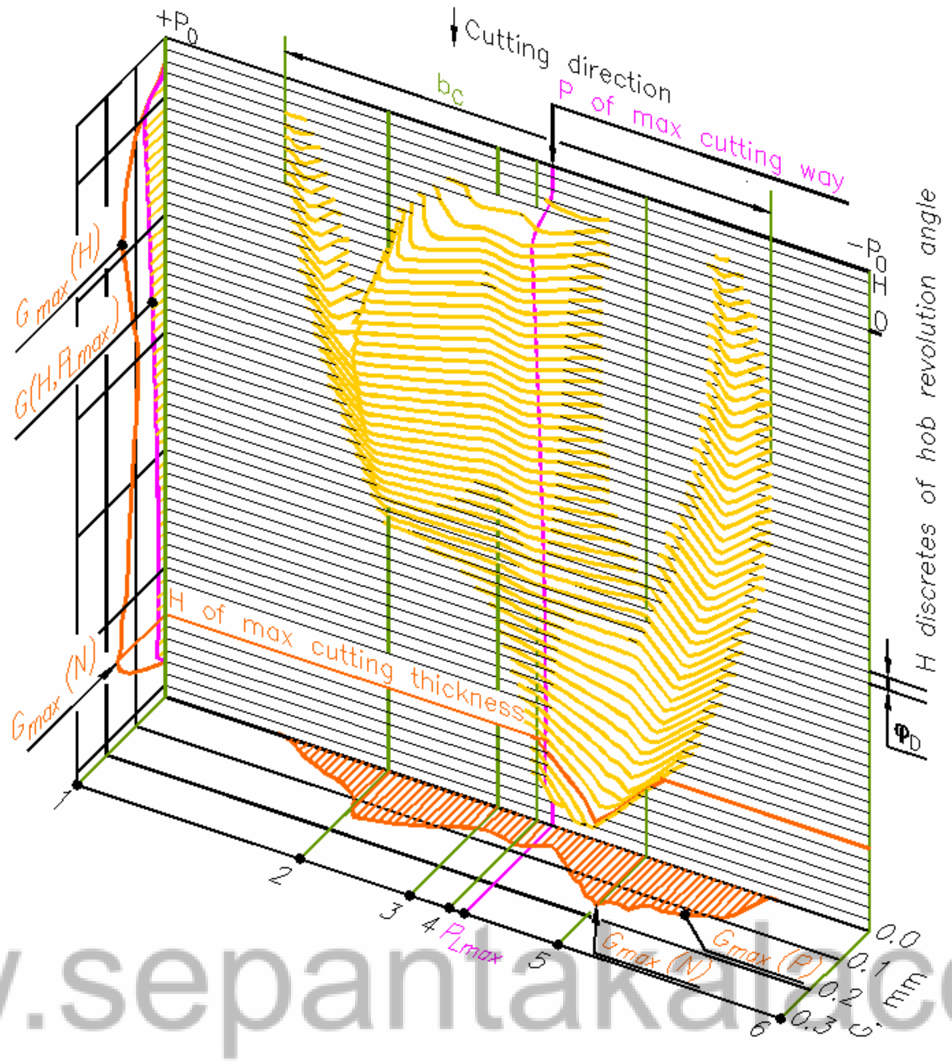


Figure 1.15

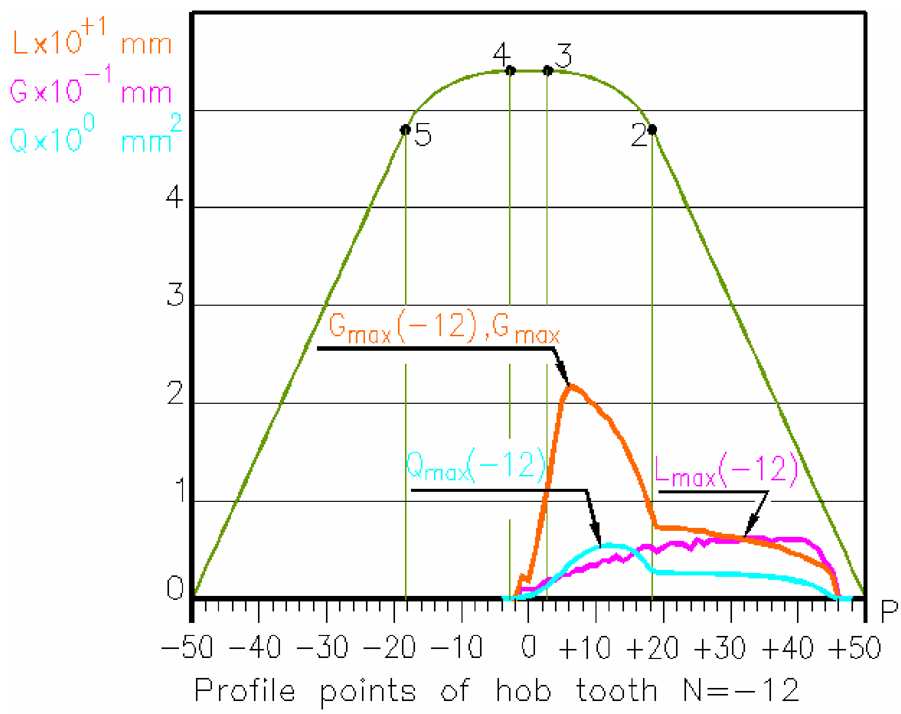


Figure 1.16

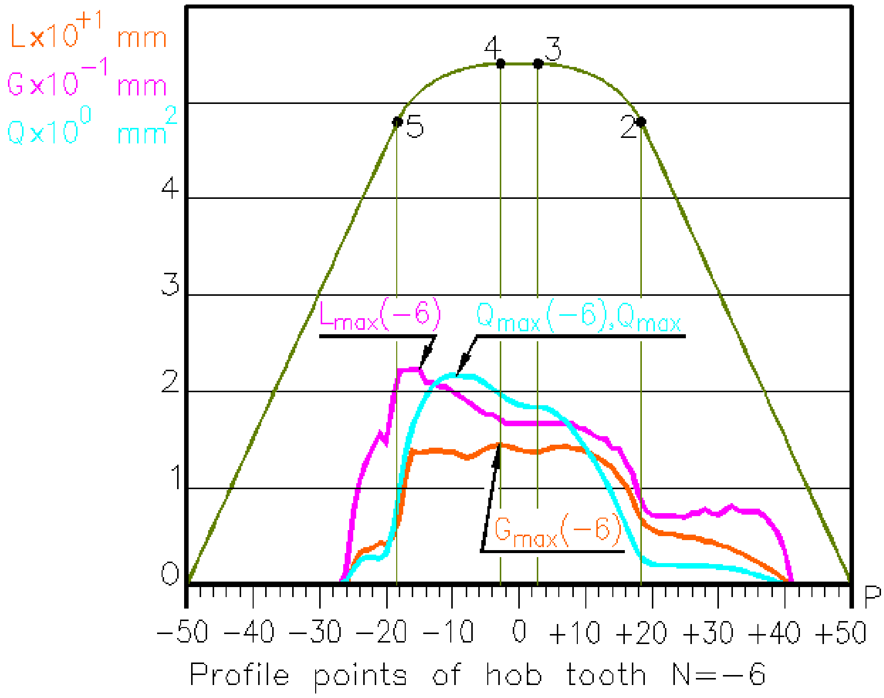


Figure 1.17

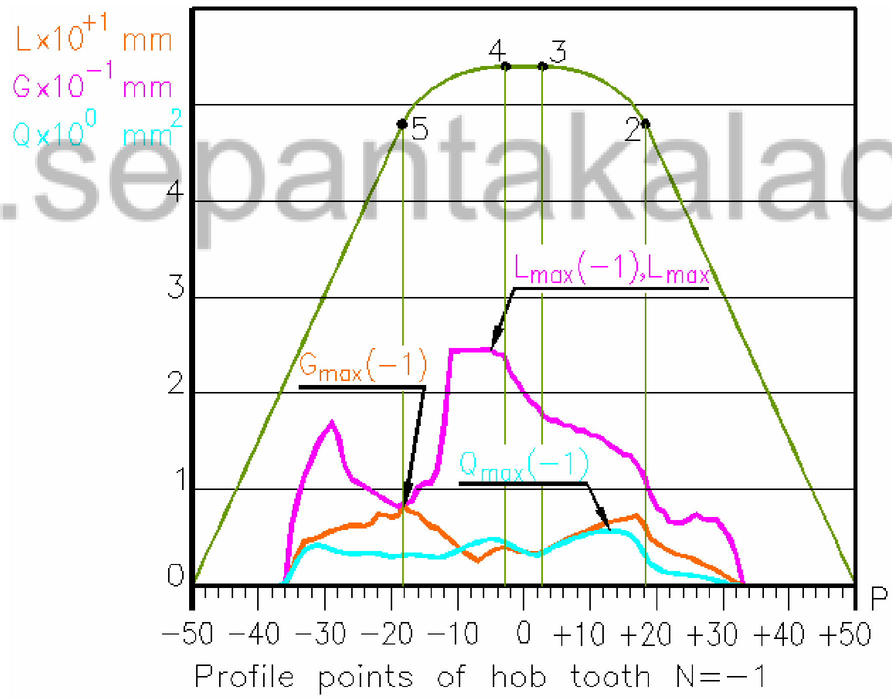


Figure 1.18

Global maximum functions $G_{max}(N)$ and $W_{Pmax}(N)$ are composed from discrete functions $G_{max}(N,P)$ and $Q(N,P)$. Summary of gear hobbing geometrical size simulation can be shown graphically (Figure 1.19.).

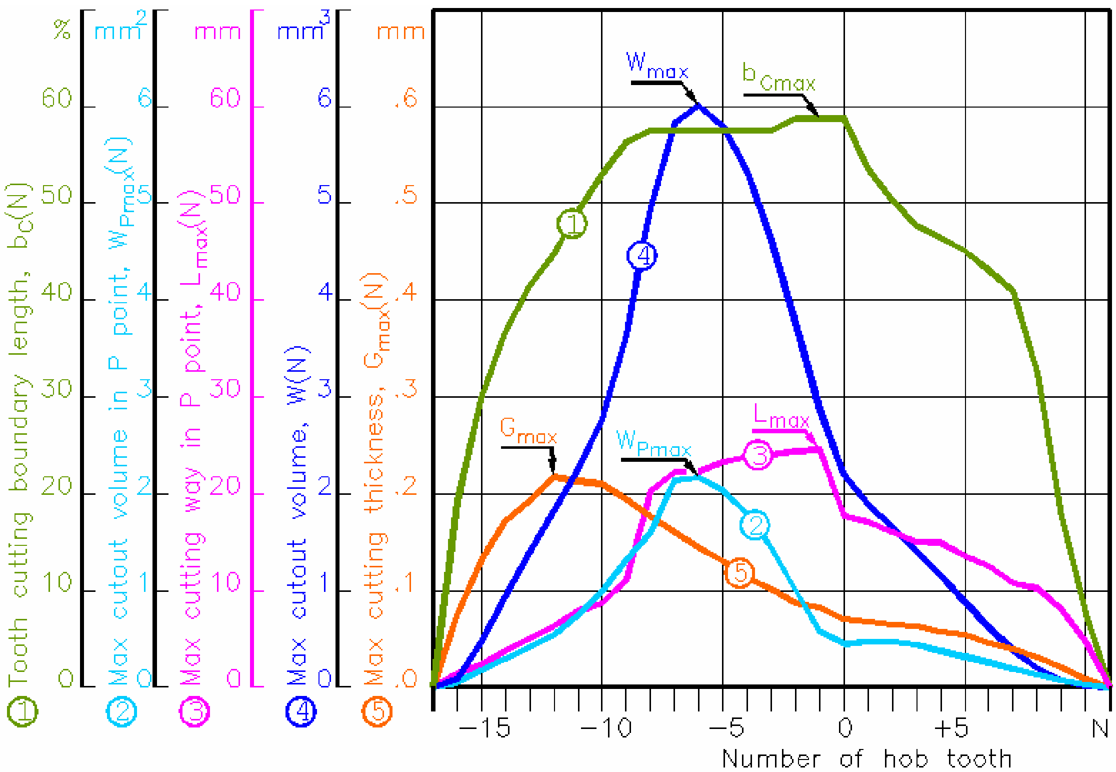


Figure 1.19

1.5 Simulation of gear hobbing forces

Calculation method of relations between gear hobbing forces, torque and angle of hob rotation was designed. The discrete area between cutting thicknesses *G*(*P*) and *G*(*P*+1) is used for calculation of elementary forces. Two vectors are calculated for each discrete area (Figure 1.20.).

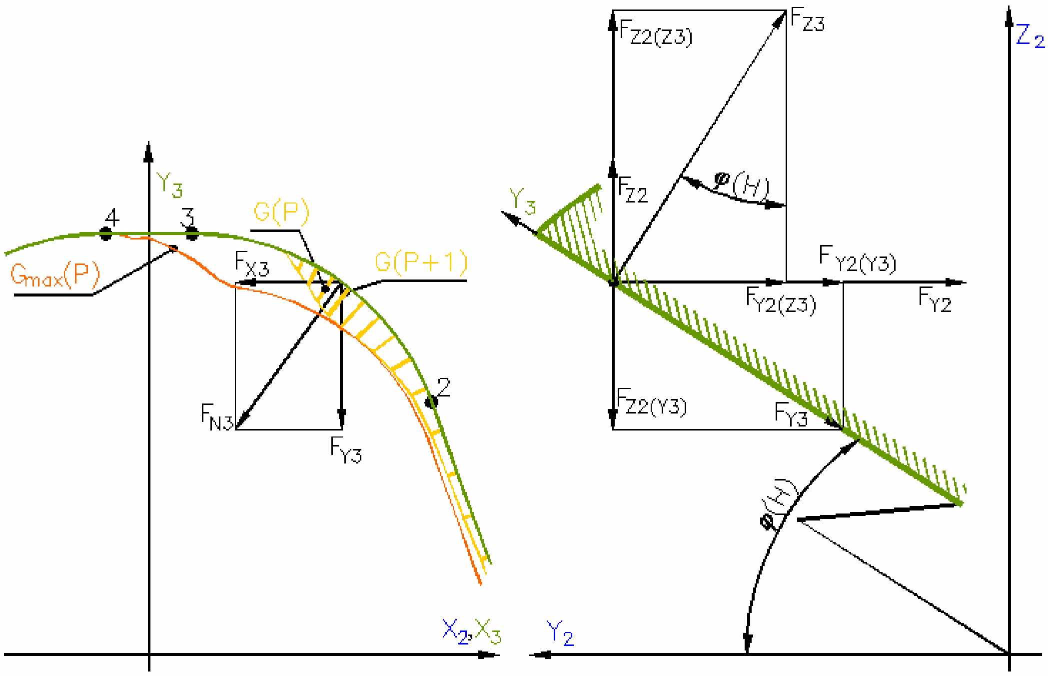


Figure 1.20

An $F = C \cdot t^a$ equation was used for force F_{Z3} calculation: F – cutting force in one mm of cutting edge, t – cutting thickness, values of coefficients C and a are shown in table.

Material of gear	Hardness, HB	Coefficient for function	
		C	*a*
Plain carbon steel	HB≤197	1165.21	0.6442
	HB 198-229	1285.63	0.6446
	HB>229	1528.65	0.6443
Alloy steel	HB≤197	1660.03	0.6764
	HB≤198-229	1767.01	0.6704
	HB>229	1954.87	0.6706
Gray iron	HB≤180	983.42	0.6431
	HB>180	1023.82	0.6116
Ductile iron		830.17	0.6077

Vectors of cutting forces and torque are calculated by adding forces vectors of each discrete area. Forces and torque of one hob tooth are shown in figure 1.21.

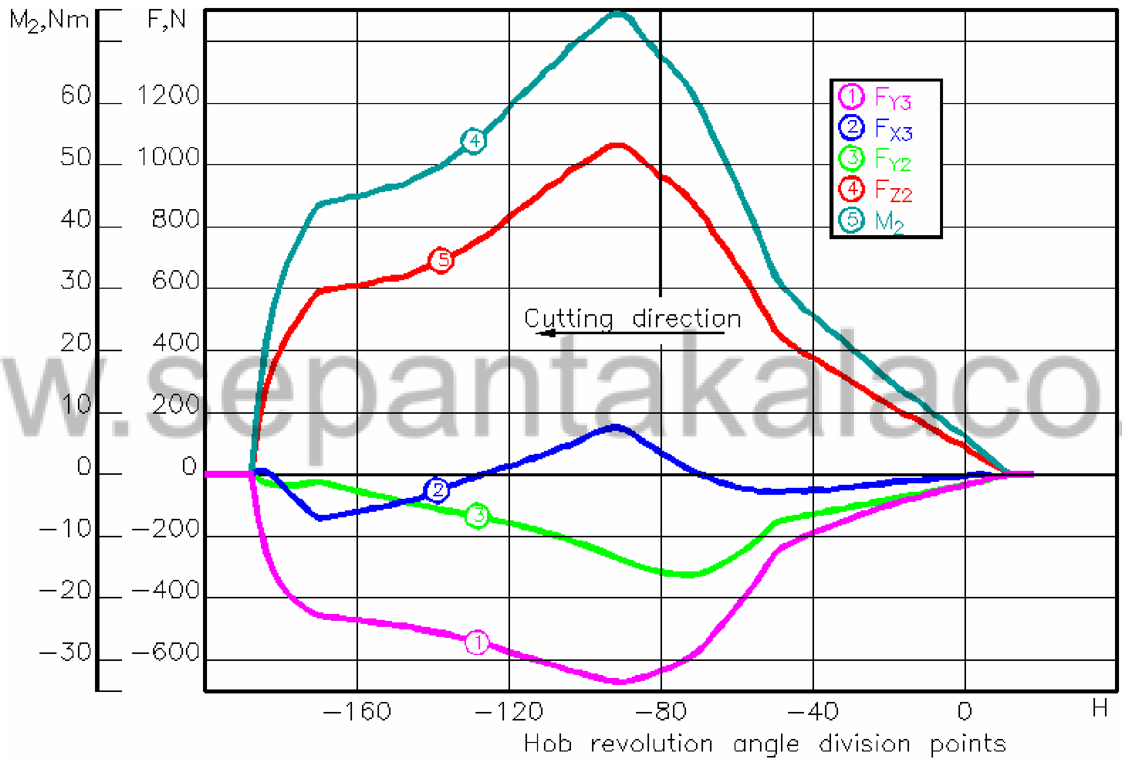


Figure 1.21

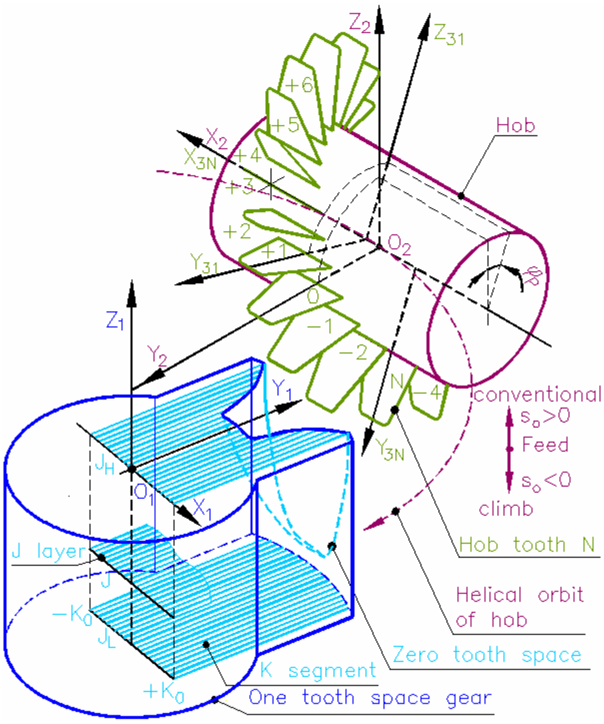


Figure 1.22

The cutting simulation is executed only in one zero tooth space of gear. It is very good for measure of real cutting forces (Figure 1.22.). All cutting forces and torque in this case are shown in figure 1.23.

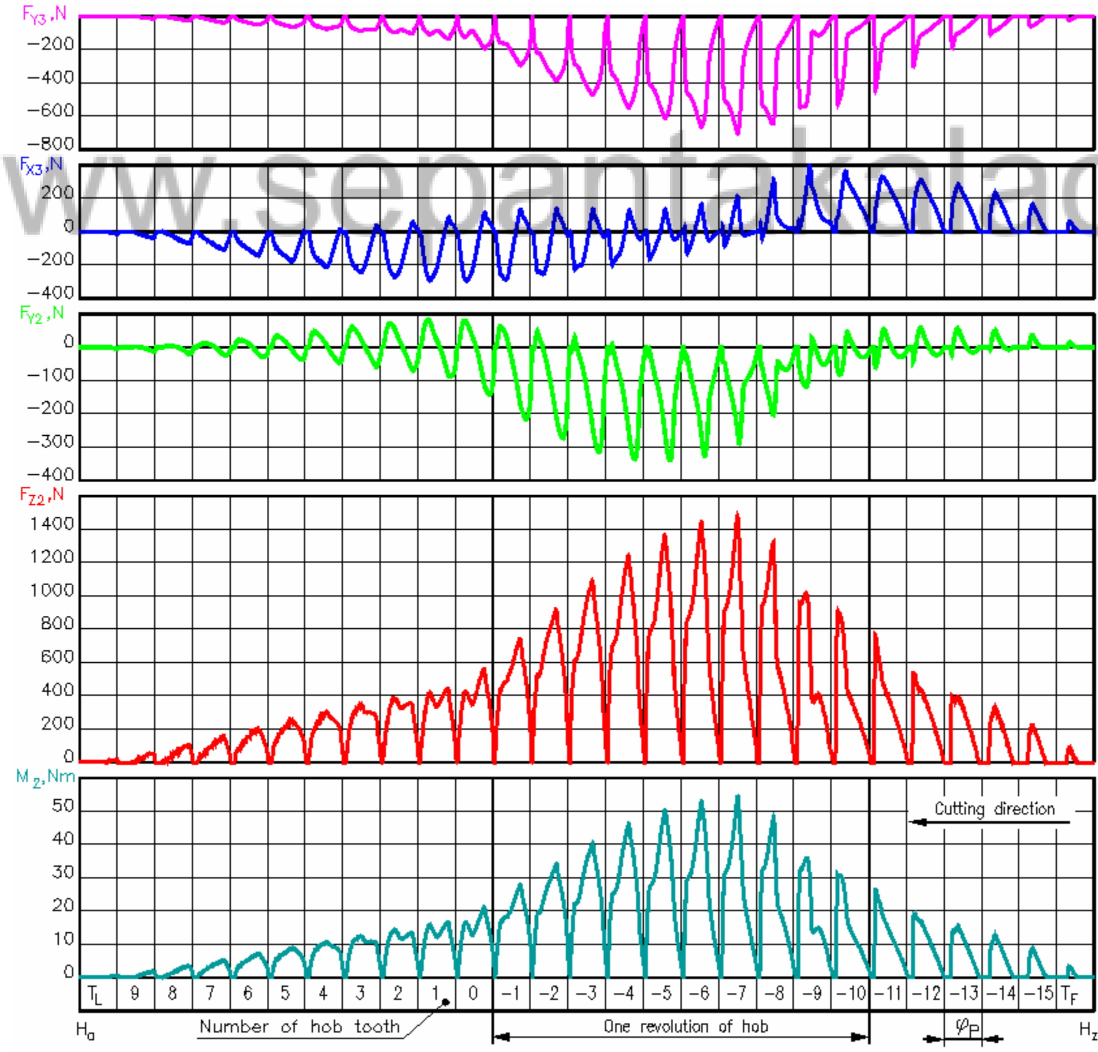


Figure 1.23

Digital gear hobbing model presents relations of the forces in both coordinate systems of the gear and the hob. Full cutting forces and torque are shown in figure 1.24.

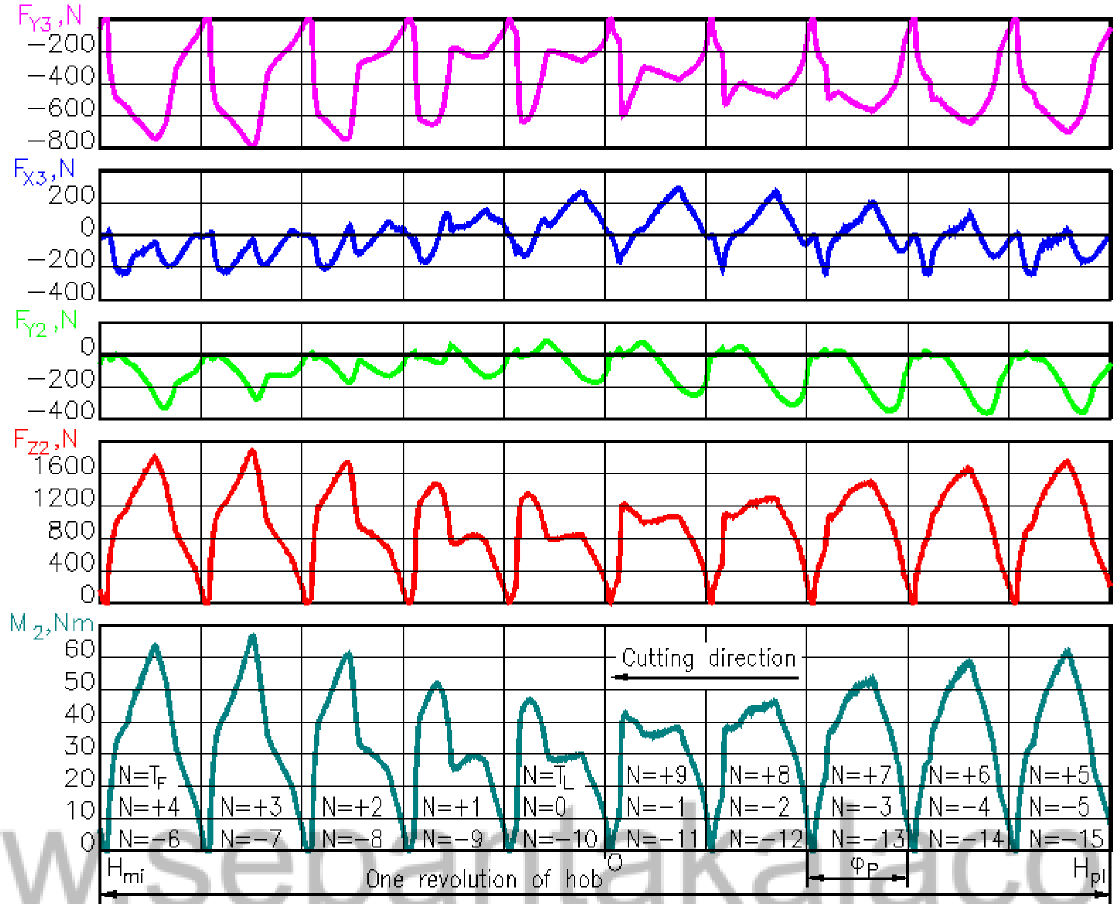


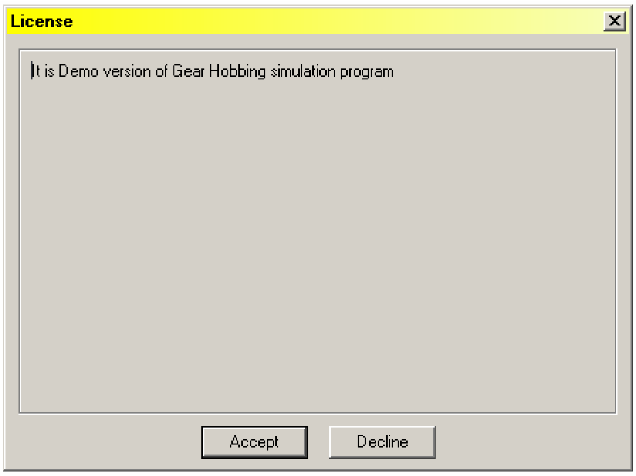
Figure 1.24

2. Software of gear hobbing simulation

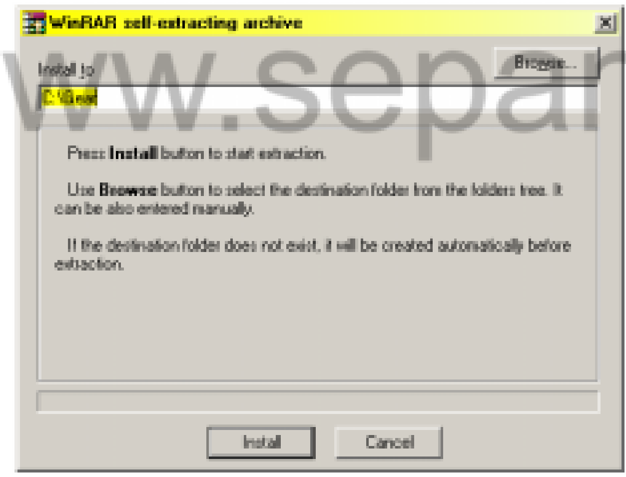
The main function of gear hob simulation program is to calculate forces, cutting precision cutout volumes and other cutting parameters.

2.1 Program installation

Run downloaded **Gear.exe** file. It is self extracting archive file.



If yours downloaded file is demo version, you will see **License** dialog box on screen. Click **Accept** button.



The program must be installed in **C:\gear folder**. Click **Install**.

After installation you can see shortcut to this program on desktop:

Double click mouse right button on this icon will activate program.

2.2 Work with program

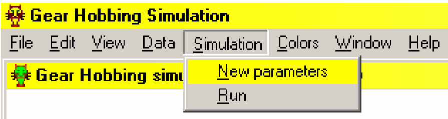


Figure 2.1

1. For new simulation click **Simulation** menu to select **New Parameters**.

2. On **Data** menu click **Parameters**. In **Parameters for gear hobbing** dialog box you can change:

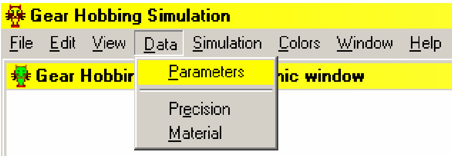


Figure 2.2

module, pressure angle, number of gear tooth, gear helix angle (left or right hand), profile shift coefficient, hob tooth tip roundness coefficient, profile angle, hob outside diameter, number of gashes, number of treads and feed (climb or conventional).

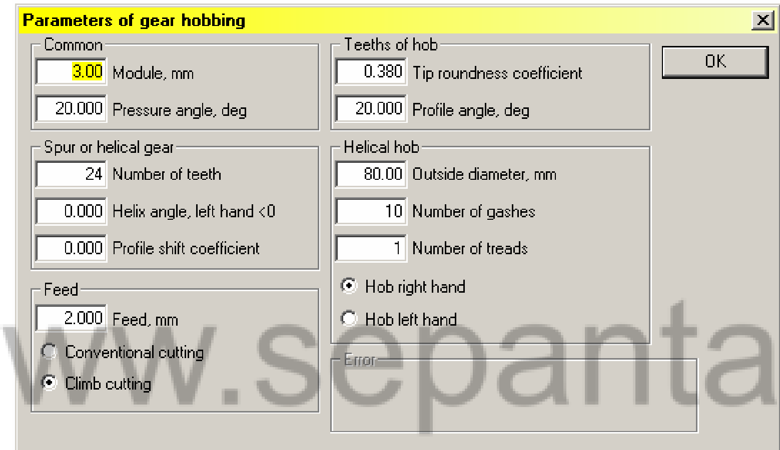
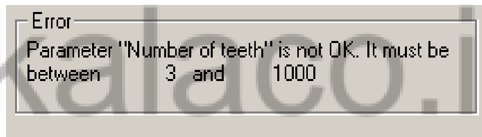


Figure 2.3

3. The value of each numerical parameter must be in interval of legal values.

Area **Error** is disable. If one of parameter is outside of legal interval in **Error** area, you can see min and max value of bad parameter:



Minimum and maximum values of parameters:

From	To	Parameter:
0.01	100.0	Module, mm
5.0	40.0	Pressure angle, deg
3	1000	Number of gear teeth
-45.0	45.0	Gear helix angle, left hand <0
-1.0	1.0	Profile shift coefficient
0.0	1.0	Hob tooth tip roundness coefficient
5.0	45.0	Profile angle, deg
0.05	45000.0	Hob outside diameter, mm
1	20	Number of gashes
1	5	Number of treads
0.001	20.0	Feed, mm/rev (climb or conventional)

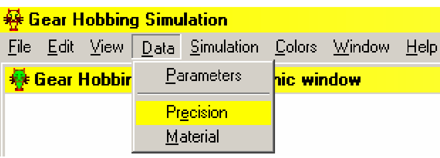


Figure 2.4

4. On **Data** menu click **Precision**. In **Precision of simulation** dialog box you can change **NK** (number of segments in layer), **NF** (number of hob tooth division points), **NA** (number of hob revolution angle division points).

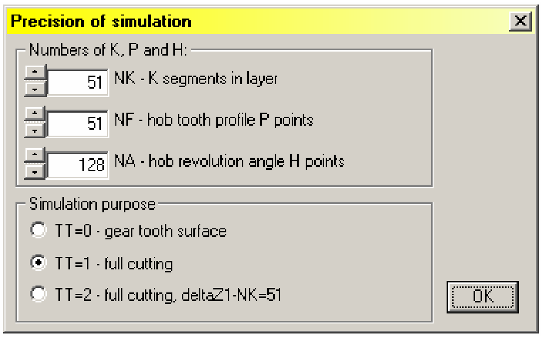


Figure 2.5

5. The time of simulation depends on these parameters. You can simulate with low precision for various parameters of hob or cutting. Also you can use maximum values of precision for simulation with good collection of hob and cutting parameters.

NOTE. Only odd numbers are using for **NK** and **NF**.

Minimum and maximum values of precision parameters:

From:	To:	Parameter:
21	401	NK - number of segments in layer
21	401	NF - number of hob tooth division points
16	2048	NA - number of hob revolution angle division points

For real cutting simulation you must select TT=1 (distance between layers is proportional to distance between segments) or TT=2 (distance between layers is fixed). TT=2 is used when you want to explore gear tooth surface errors.

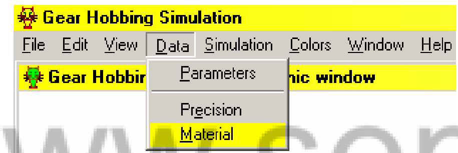


Figure 2.6

6. On **Data** menu click **Material**.

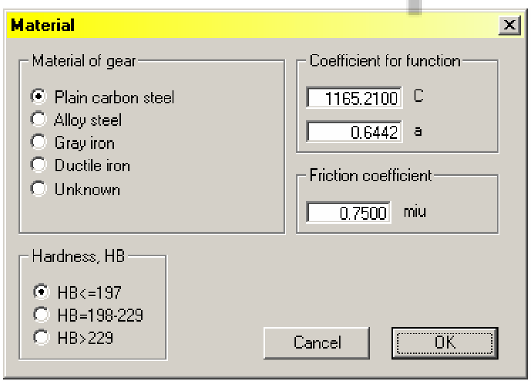


Figure 2.7

7. Gear material can be selected in **Material** dialog box. You can select **Unknown** if you have another gear material. In this case you must write values of **C** and **a** coefficients:

Coefficient **miu** is coefficient of friction between hob tooth and gear cutout material.

NOTE. After simulation you can change selected gear material. Program will recalculate cutting forces with new gear material.

NOTE. After simulation **Parameters for gear hobbing** and **Precision of simulation** dialog boxes are disable. For new parameters click **Simulation** and select **New parameters**.

2.3 Simulation

Parameters and precision are selected for simulation.

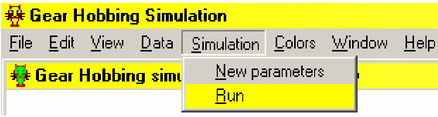
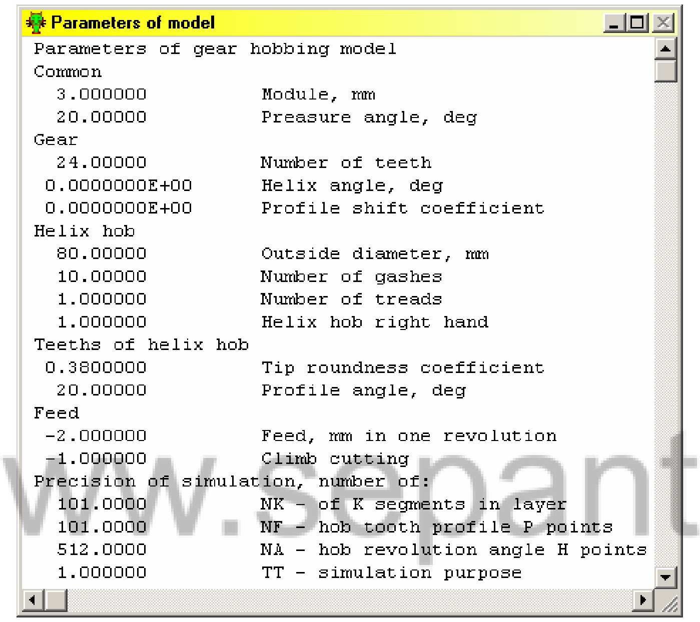


Figure 2.8

5. For simulation click **Simulation** menu and select **Run**.

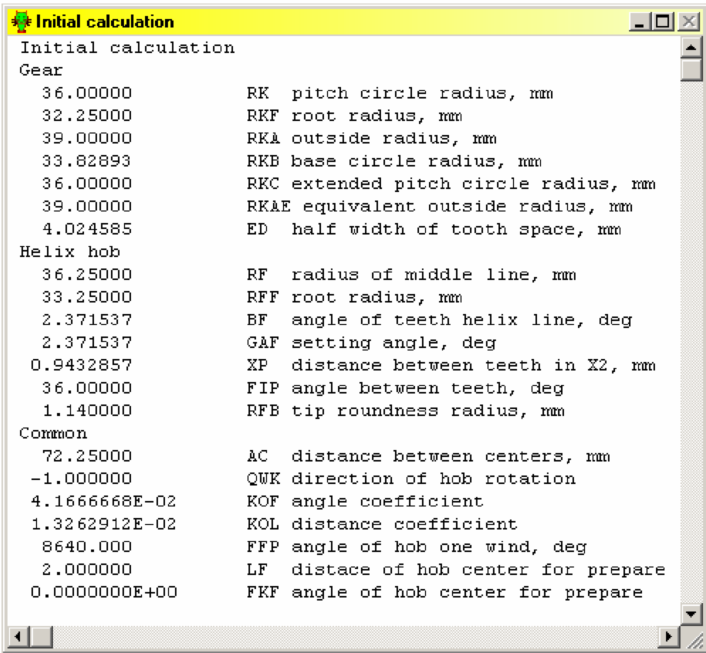
On screen you can see some text windows, which will appear in series. All text from these windows is in **C:\gear\model.txt** file.




```
Parameters of gear hobbing model
Common
  3.000000          Module, mm
  20.00000          Preasure angle, deg
Gear
  24.00000          Number of teeth
 0.0000000E+00      Helix angle, deg
 0.0000000E+00      Profile shift coefficient
Helix hob
  80.00000          Outside diameter, mm
  10.00000          Number of gashes
  1.000000          Number of treads
  1.000000          Helix hob right hand
Teeths of helix hob
 0.3800000          Tip roundness coefficient
  20.00000          Profile angle, deg
Feed
 -2.000000          Feed, mm in one revolution
 -1.000000          Climb cutting
Precision of simulation, number of:
  101.0000          NK - of K segments in layer
  101.0000          NF - hob tooth profile P points
  512.0000          NA - hob revolution angle H points
  1.000000          TT - simulation purpose
```

Figure 2.9

All parameters for simulation with measurement units are in window **Parameter of gear hobbing model**.




```
Initial calculation
Gear
  36.00000          RK   pitch circle radius, mm
  32.25000          RKF  root radius, mm
  39.00000          RKA  outside radius, mm
  33.82893          RKB  base circle radius, mm
  36.00000          RKC  extended pitch circle radius, mm
  39.00000          RKAE equivalent outside radius, mm
  4.024585          ED   half width of tooth space, mm
Helix hob
  36.25000          RF   radius of middle line, mm
  33.25000          RFF  root radius, mm
  2.371537          BF   angle of teeth helix line, deg
  2.371537          GAF  setting angle, deg
 0.9432857          XP   distance between teeth in X2, mm
  36.00000          FIP  angle between teeth, deg
  1.140000          RFB  tip roundness radius, mm
Common
  72.25000          AC   distance between centers, mm
 -1.000000          QWK  direction of hob rotation
 4.1666668E-02      KOF  angle coefficient
 1.3262912E-02      KOL  distance coefficient
  8640.000          FFP  angle of hob one wind, deg
  2.000000          LF   distace of hob center for prepare
 0.0000000E+00      FKF  angle of hob center for prepare
```

Figure 2.10

Various intermediate values are in window **Initial calculation**.

```
Profile of helix hob tooth
Profile of helix hob tooth [PrfPri]
 6.9021218E-02        X3D distance between P points, mm
 -2.745124            KPO coefficient of flank heel
  42.72359            MPO coefficient of flank origin
  16.14553            SAM length of tooth boudary, mm
  50.00000            PO number of last profile point
Coordinates of profile division points 1-6
   i          Xp(i)          Yp(i)
  1       3.45106        33.25000
  2       1.26540        39.24990
  3       0.19324        40.00000
  4      -0.19324        40.00000
  5      -1.26540        39.24990
  6      -3.45106        33.25000
  7       0.19324        38.86000
  8      -0.19324        38.86000
  9       0.99216        40.00000
```

Figure 2.11

Some calculated parameters for hob tooth points are in **Profile of helix hob tooth** window.

X3D is distance between *P* points in hob tooth. This distance depends on selected *NK*.

P0 – number of last profile point;

Xp(i), **Yp(i)** - coordinates of profile division points (Figure 4).

```
Cutting zone
Points of cutting zone [ZonePri]
Point EZ
  1.077267            X1EZ
 -22.27734            Z1EZ
 -1.998165            X2EZ
 -22.21368            Z2EZ
Point EP
  10.69761            X1EP
 -20.27734            Z1EP
  21.93029            X1M width of ellipse
```

Figure 2.12

Geometrical parameters of cutting zone are in **Cutting zone** window (Figure 5).

```
Distances and numbers
Teeth of hob, zero tooth space      [GhnumPri]
Numbers for hob teeth
  8.072443            X2F length of cutting zone (ingoing)
 -11.48213            X2L length of cutting zone (outgoing)
 -17.00000            NRF number for first cutting tooth
  14.00000            NRL number for last cutting tooth
  12.00000            NP  number of profile producing teeth
 -17.00000            TF  number for first cutting tooth
  14.00000            TL  number for last cutting tooth
  1.000000            QN  direction for numbers of teeth
  32.00000            TM  number of cutting teeth
  18.00000            TO  index for numbers shift
Zero tooth space of gear
 0.3683901            ZOF
-6.5030158E-02        ZOL
  1.368390            ZOU
 -22.27871            ZOD
 8.0491699E-02        XOD distance between K segments
  50.00000            KO  last number of K segment
 0.2760849            Z1D distance between J layers
 0.0000000E+00        DT  angle between J layers
  6.000000            JH  number for upper J layer
 -82.00000            JL  number for bottom J layer
  89.00000            JM  number of layers
  83.00000            JO  index for number shift
Cutting angles
  5.000000            FH  upper cutting angle
 -51.00000            FL  lower cutting angle
 1.2271847E-02        FD  angle between H discretes
  57.00000            FM  number of H discretes
  52.00000            FO  index for number shift
```

Figure 2.13

Parameters, which are calculated from cutting zone geometry, are in **Distance and numbers** window:

TF – number of first cutting hob tooth;

TL - number of last cutting hob tooth (Fig. 3);

X0D – distance between *K* segments in layer (Fig. 4);

K0 – last number of *K* segment;

Z1D – Δz_1 distance between two *J* layers;

JH – number of upper *J* layer;

JL – number of bottom *J* layer (Fig. 6).

Message Window appears on screen after initial calculations. Gear hobbing simulation is divided into phases. Gear zero tooth space is prepared in the first phase. In the next step program searches for number of first cutting tooth. The second phase is real cutting simulation. Numbers of cutting tooth from T_F to T_L will appear in **Message Window**. Time of simulation depends on simulation precision.

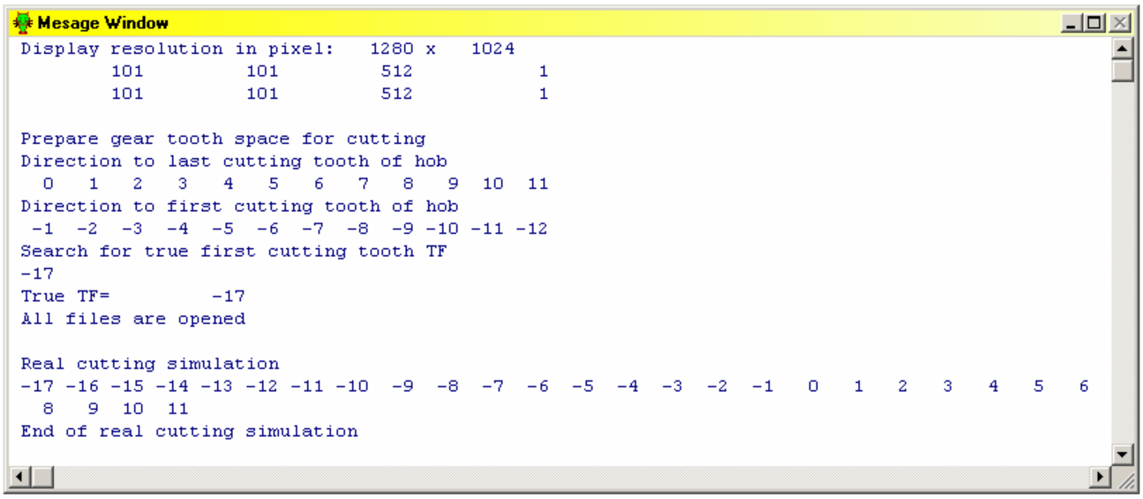


Figure 2.14

Successful simulation presents message **End of real cutting simulation** in **Message Window**.

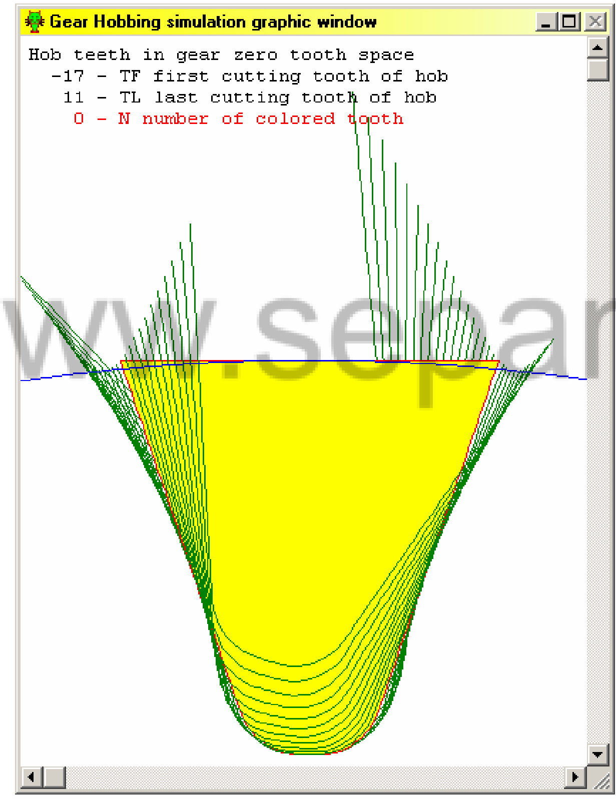


Figure 2.15

Gear Hobbing simulation graphic window becomes active. In this window you can see Hob teeth in gear zero tooth space picture.

Chapter "Control tool" describes how to select necessary picture and control image size, location and other features.

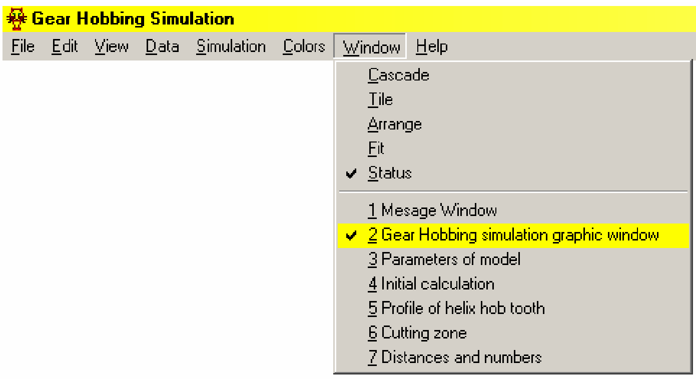


Figure 2.16

Click **Window** menu and select **Gear Hobbing simulation graphic window** or another necessary text window.

Note: Gear Hobbing simulation graphic window is active after simulation.

2.4 Control tools

You can select any text window or graphic window after the ending of simulation. Any picture can be scaled, moved or rotated in graphic window. Numerical values of cutting thickness, forces and others results of simulation are placed in the left top corner of graphic window. All this you can do with control tools, which are common for all pictures in graphic window.

2.4.1 Select drawing

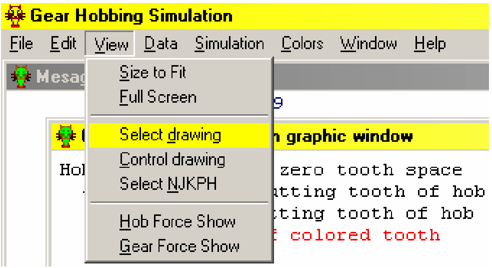


Figure 2.17

Any graphical results of simulation can be selected in two manners:

- On **View** menu click **Select drawing**;
- click mouse right button in graphic window.

Select necessary graphic result of simulation in **Graphic selector** dialog box.

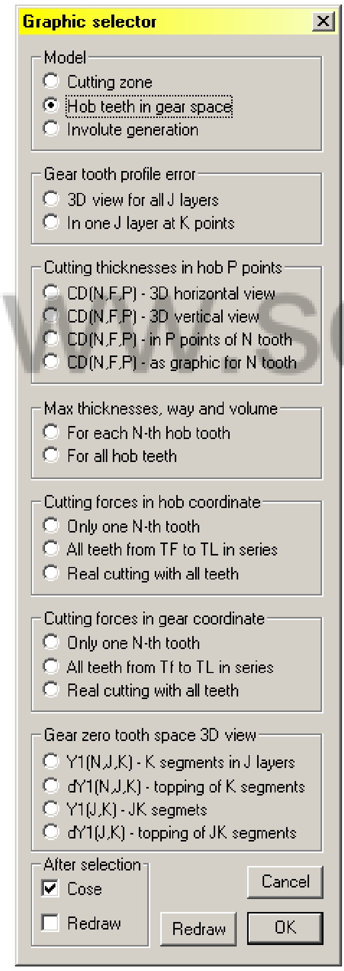


Figure 2.18

Model

Cutting zone (Fig. 1.5, 2.31)
Hob teeth in gear space (Fig. 2.15, 2.23, 2.24, 2.32)
Involute generation (Fig. 2.33)

Gear tooth profile error

3D view for all J layers (Fig. 1.14, 2.34)
In one J layer at K points (Fig. 1.13, 2.35)

Cutting thicknesses in hob P points

CD(N,F,P) – 3D horizontal view (Fig. 1.15, 2.36, 2.37, 2.38)
CD(N,F,P) – 3D vertical view (Fig. 1.15, 2.39)
CD(N,F,P) – in P points of N-th tooth (Fig. 1.9, 1.10, 1.11, 2.40)
CD(N,F,P) – as graphic for N-th tooth (Fig. 1.9, 1.10, 1.11, 2.41)

Max thicknesses, way and volume

For each N-th hob tooth (Fig. 1.16, 1.17, 1.18, 2.42)
For all hob teeth (Fig. 1.19, 2.43)

Cutting forces in hob coordinates

Only one N-th tooth (Fig. 1.21, 2.44)
All teeth from TF to TL in series (Fig. 2.47)
Real cutting with all teeth (Fig. 2.48)

Cutting forces in gear coordinates

Only one N-th tooth (Fig. 2.49)
All teeth from TF to TL in series (Fig. 1.22, 1.23, 2.52)
Real cutting with all teeth (Fig. 1.24, 2.53)

Gear zero tooth space in 3D view

Y1(N,J,K) – K segments in J layers (Fig. 1.6, 1.7, 1.12, 2.54)
dY1(N,J,K) – topping of K segments (Fig. 1.6, 1.7, 1.15, 2.55)
Y1(J,K) – JK segments (Fig. 1.6, 1.7, 1.22, 2.56)
dY1(J,K) – topping of JK segments (Fig. 1.6, 1.7, 2.57)

There are two check boxes in **After selection** area. This dialog box will close automatically if **Close** is checked. Otherwise use **OK** or **Cancel** buttons. Selected graphic will appear in window immediately, if **Redraw** is checked. Otherwise use **Redraw** button.

2.4.2 Picture control tools

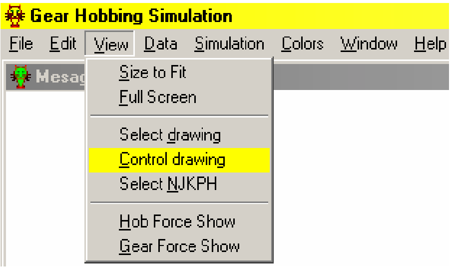


Figure 2.19

View of graphical window can be changed in **Drawing Control** dialog box. To open this dialog box:

- On **View** menu click **Drawing control**;
- Click mouse left button in graphical window.

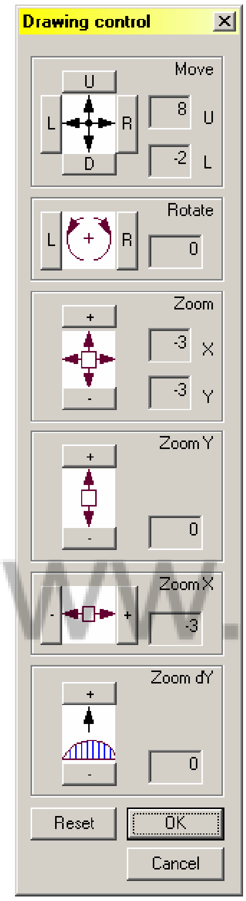


Figure 2.20

Use buttons to move, scale, scale X, scale Y or rotate graphical view. Boxes with numbers are in left side of each area. Every time pushed button increases or decreases value of number in box. Click **Reset** button to apply default control parameters of picture.

Move – move picture Up, Down or Left, Right. Buttons Left and Down decrease value of number in box.

Rotate – rotate picture clockwise (R) or counterclockwise (L). It is available only in 3D pictures. Picture is rotated around vertical Z axes.

Zoom – enlarge (+) or curtail (-) picture in X and Y directions.

ZoomY - enlarge (+) or curtail (-) picture only in Y direction.

ZoomX - enlarge (+) or curtail (-) picture only in X direction.

Zoom dY - enlarge (+) or curtail (-) one element of picture. For example, you can scale length of cutout K segments in picture topping of K segments (Figure 2.55).

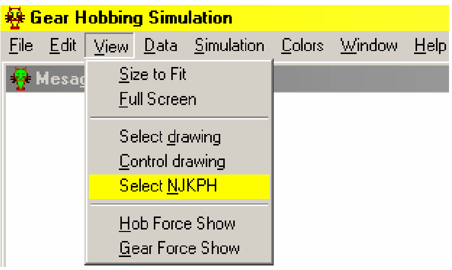


Figure 2.21

You can select or change some parameters for each graphical view.

For this purpose open **Select parameter** dialog box:

- On **View** menu click **Select NJKPH**;
- hold **Shift** key and click mouse left button in graphical window.

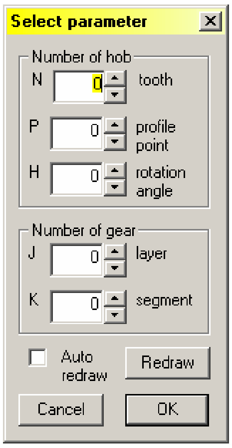


Figure 2.22

N – number of hob tooth. You can change this number from T_F (first cutting tooth) to T_L (last cutting tooth). See figures 1.3, 1.5 and 2.13, 2.43.

P – number of hob tooth profile point. You can change this number from $-P_0$ to $+P_0$. See figures 1.4, 2.11. X3D is the distance between P points in hob tooth.

H – number of hob revolution angle discrete. You can change this number from F_H to F_L. See figures 1.11, 1.15, 2.13, 2.52. FD is the angle between H points.

J – number of layer. You can change this number from J_H to J_L. See figure 1.1, 1.6, 1.12, 1.14, 2.54, 2.55, 2.56, 2.57. Z1D – Δz_1 distance between two J layers;

K – number of K segment. You can change this number from $-K_0$ to $+K_0$. See figures 1.1, 1.7, 2.13. X0D is the distance between P points in hob tooth.

Note. These numbers are common for all pictures in graphic window.

Note. Element or object, which number can be changed, is marked with separate color in picture. These numbers always are shown in the left upper corner of graphic window. Active hob tooth has colored boundary and its area is filled with color in figures 2.23 and 2.24.

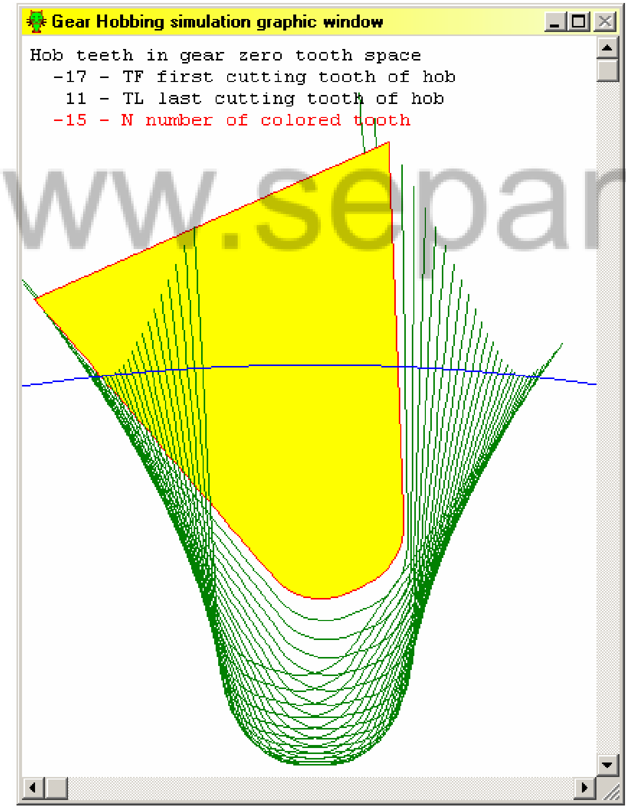


Figure 2.23

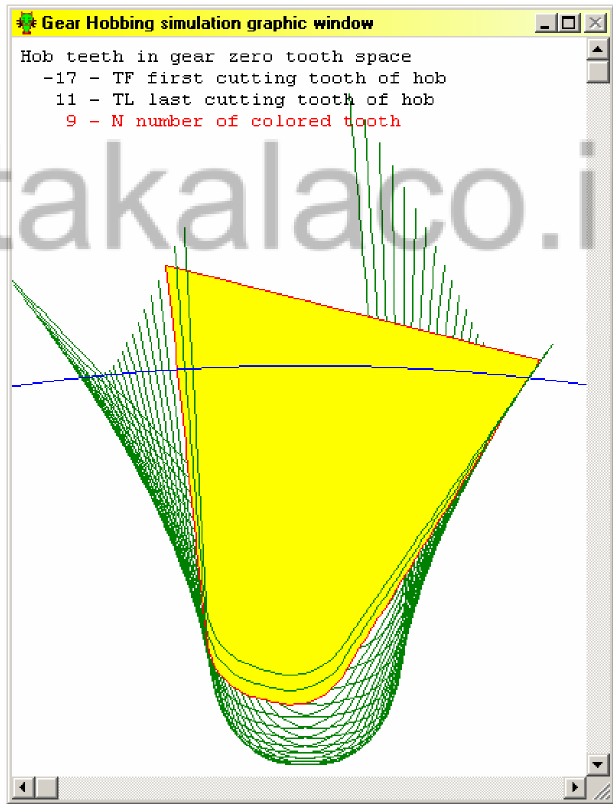


Figure 2.24

2.4.3 Color tools

In all graphical windows colors of all lines can be changed in **Colors for lines** dialog box.

Figure 2.25

To open it click **Lines** on **Colors** menu.

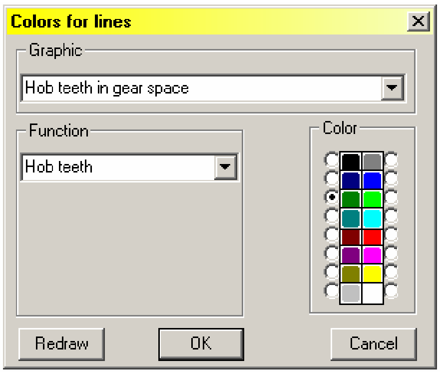


Figure 2.26

In area **Graphics** you can select desired picture by name. In area **Function** you can select desired line by function name. In area **Colors** you can select one of shown color.

Push **Redraw** button after all colors have been selected.

Push **OK** button if colors are good. Otherwise you can continue colors selection.

For example.

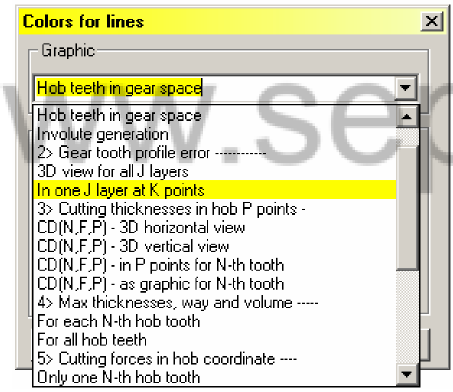


Figure 2.27

Open **Graphic** list and in **2> Gear tooth profile error** section select **In one J layer at K points**.

All pictures names are in the same order as it is presented in **Graphic selector** dialog box.

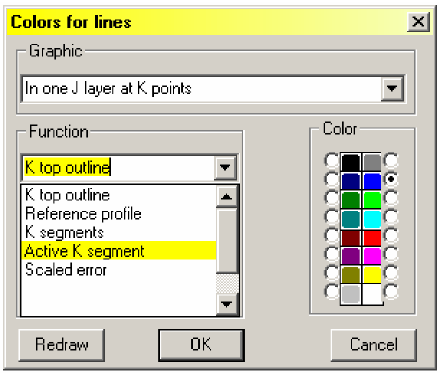


Figure 2.28

Open **Function** list and select **Active K segment**. Each picture has different amount of lines.

Background color of graphic window and color of text can be changed in **Background colors** dialog box.

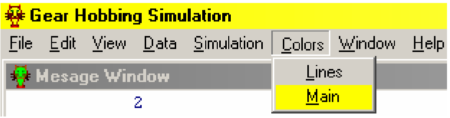


Figure 2.29

To open it click **Main** on **Colors** menu.

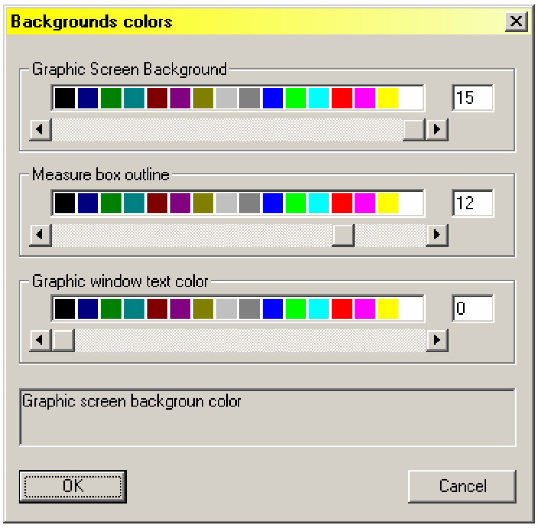


Figure 2.30

There are three sliders for color selection.

Graphic Screen Background color is white by default. Use this color if you want print graphic pictures.

Some pictures have measure box. Values of active element or elements are in that box. You can select color for measure box outline.

Each picture has the text in the left upper corner of graphic screen. Color of main text is black by default. Some text lines are colored in function color.

2.5 Results of simulation

All results of gear hob simulation are presented in **Gear Hobbing simulation graphic window**. Any picture can be selected in **Graphic selector** dialog box (click mouse right button in graphic window).

2.5.1 Cutting zone

Cutting zone shows area, in witch hob teeth are cutting gear body. See figure 1.5 for more details.

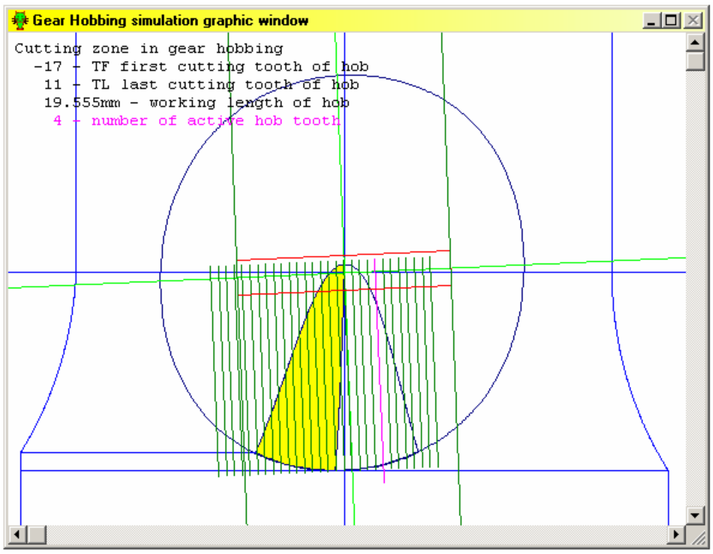


Figure 2.31

Center lines of hob teeth are green. Line of active hob tooth is colored in magenta. Number of this tooth is in the left upper corner of window. This number can be changed in **Select parameter** dialog box (hold **Shift** key and click mouse left button in graphical window) with **N** button.

Size and position of picture can be changed in **Drawing control** dialog box (click mouse left button in graphical window). Buttons **Move**, **Zoom**, **Zoom X**, and **Zoom Y** are available.

2.5.2 Hob teeth in gear space

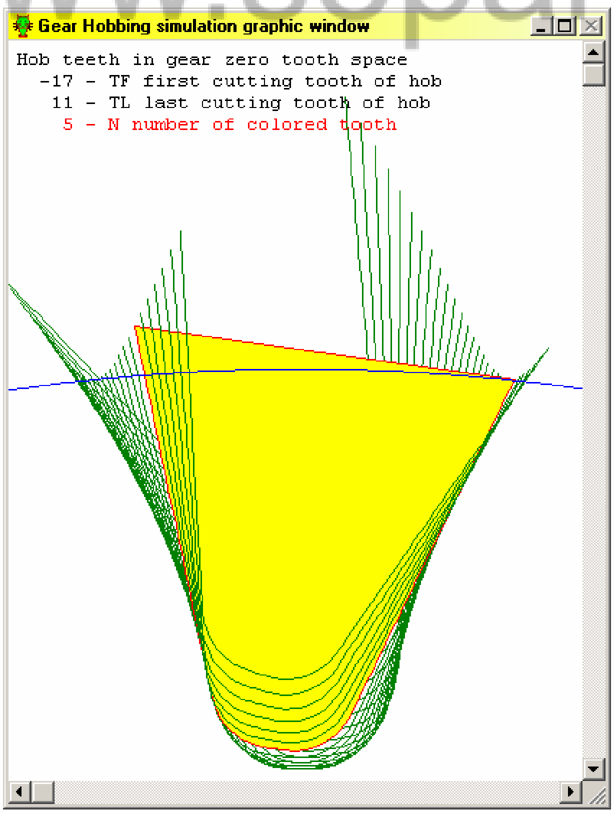


Figure 2.32

Boundaries of all hob teeth are in gear zero space. One of tooth boundary lines is in red and it is filled with color – it is active hob tooth. Number of this tooth is in the left upper corner of window. This number can be changed in **Select parameter** dialog box (hold **Shift** key and click mouse left button in graphical window) with **N** button.

Size and position of picture can be changed in **Drawing control** dialog box (click mouse left button in graphical window). Buttons **Move**, **Zoom**, **Zoom X** and **Zoom Y** are available.

2.5.3 Involute generation

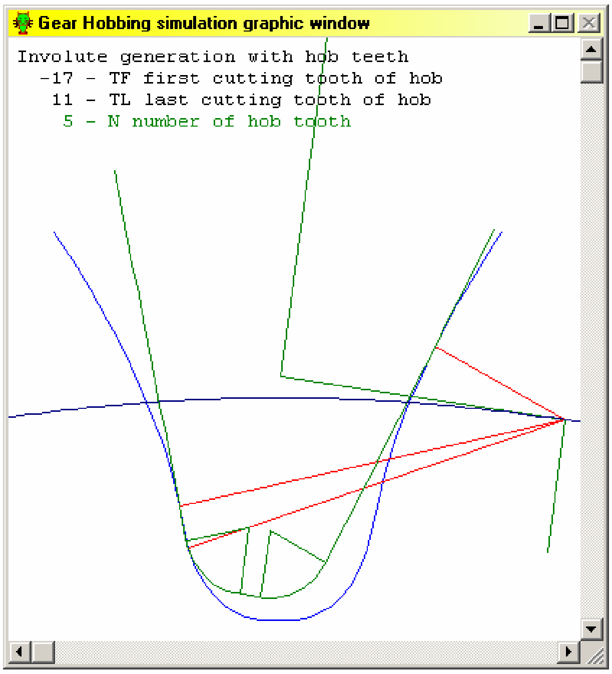


Figure 2.33

Involute and gear tooth root curve generation with hob teeth.

Red lines are perpendiculars from rolling center on pitch cylinder to tooth boundary.

Number of hob tooth is in the left upper corner of window. This number can be changed in **Select parameter** dialog box (hold **Shift** key and click mouse left button in graphical window) with **N** button.

Size and position of picture can be changed in **Drawing control** dialog box (click mouse left button in graphical window). Buttons **Move**, **Zoom**, **Zoom X** and **Zoom Y** are available.

2.5.4 Gear tooth profile error 3D view

There are two kinds of profile errors - involutes flank profile error and root curve profile error. Green lines are outline of profile error - involutes flank profile error $f_E(J,K)$ and root curve profile error $f(J,K)$. Values of f_{Emax} and f_{max} are shown on the left wall of diagram. For more details see figure 1.14. Values of errors are shown in the left upper corner of window.

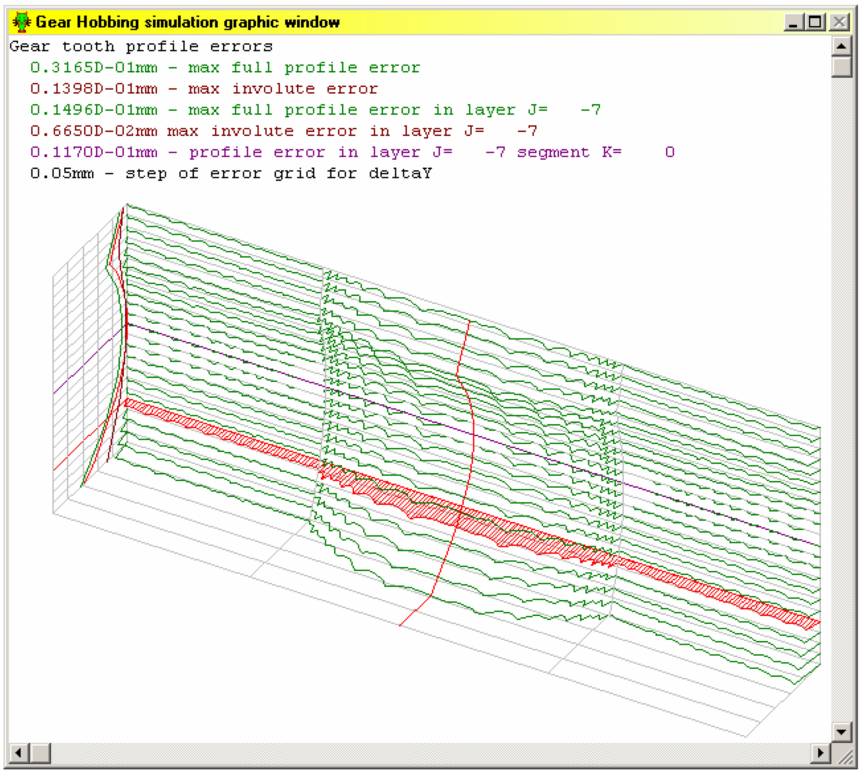


Figure 2.34

Numbers of active *J* layer and *K* segment can be changed in **Select parameter** dialog box (hold **Shift** key and click mouse left button in graphical window) with **J** and **K** button. Active layer is red by default.

Size and position of picture can be changed in **Drawing control** dialog box (click mouse left button in graphical window). Buttons **Move**, **Zoom**, **Zoom X are Zoom Y** are available.

Diagram can be rotated with **Rotate** buttons.

Error outlines can be scaled with **Zoom dY** button.

2.5.5 Gear tooth profile error in one J layer

Gear tooth profile error in one *J* layer. Cyan lines are perpendiculars from top of each *K* segment to reference curve. For more details see figure 1.13.

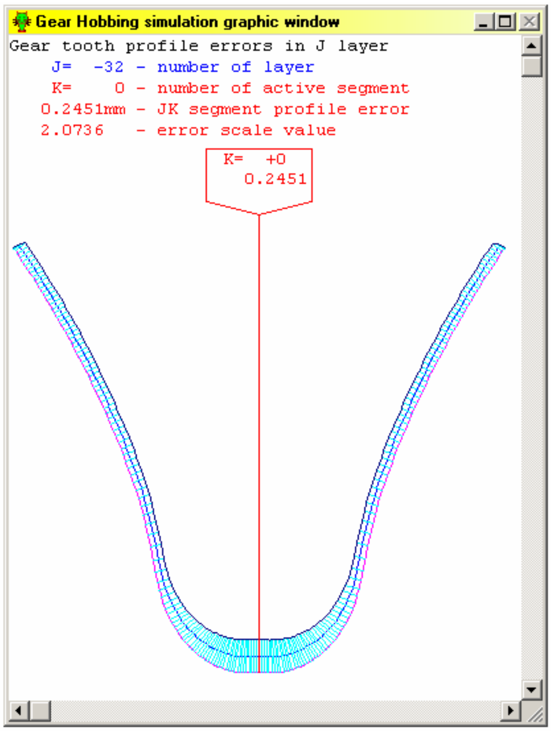


Figure 2.35

Numbers of active *J* layer and *K* segment can be changed in **Select parameter** dialog box (hold **Shift** key and click mouse left button in graphical window) with **J** and **K** button.

Number of active *K* segment and profile error value are shown in measure box.

Size and position of picture can be changed in **Drawing control** dialog box (click mouse left button in graphical window). Buttons **Move**, **Zoom**, **Zoom X** and **Zoom Y** are available.

Error outlines can be scaled with **Zoom dY** buttons.

2.5.6 Cutting thicknesses in hob P points, horizontal view

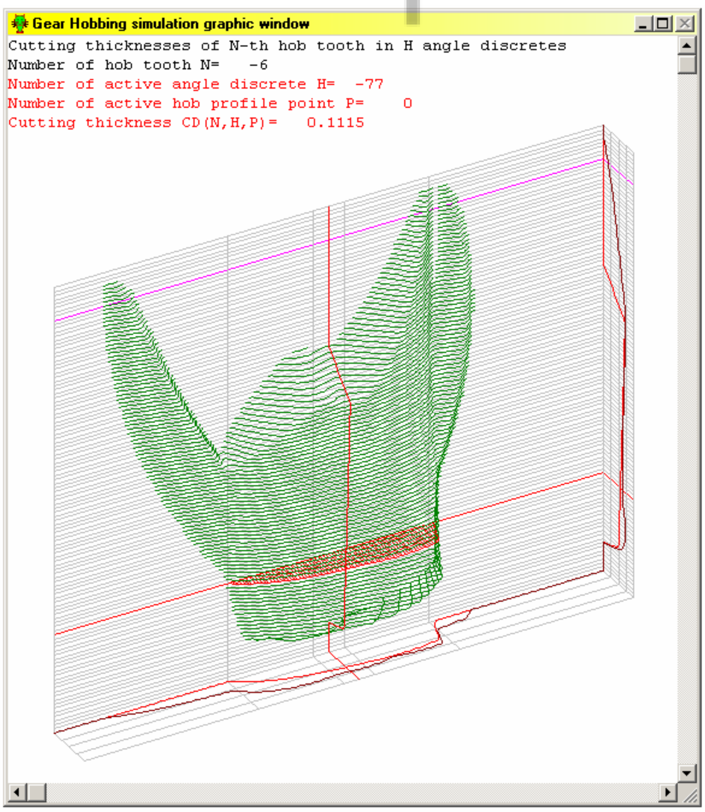


Figure 2.36

Cutting thicknesses of each hob tooth *P* points in *H* revolution angle discrete are shown as 3D diagram. For more information see figure 1.15.

Numbers of hob tooth *N*, active *H* angle and *P* point can be changed in **Select parameter** dialog box (hold **Shift** key and click mouse left button in graphical window) with **N**, **H** and **P** buttons.

Cutting thicknesses of active angle discrete *H* are colored in red. For example cutting thicknesses of hob tooth which:

- cutout max volume from gear body (fig. 2.36);
- cut most deeply (fig. 2.37);
- has *P* point with max cutting way (fig. 2.38).

Size and position of picture can be changed in **Drawing control** dialog box (click mouse left button in graphical window). Buttons **Move**, **Zoom**, **Zoom X** and **Zoom Y** are available.

Diagram can be rotated with **Rotate** buttons. Cutting thicknesses can be scaled with **Zoom dY** buttons.

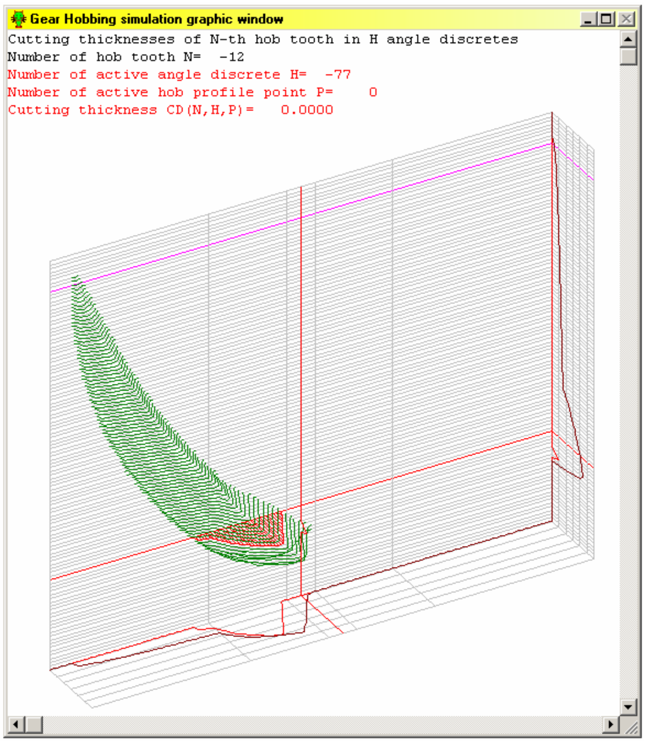


Figure 2.37

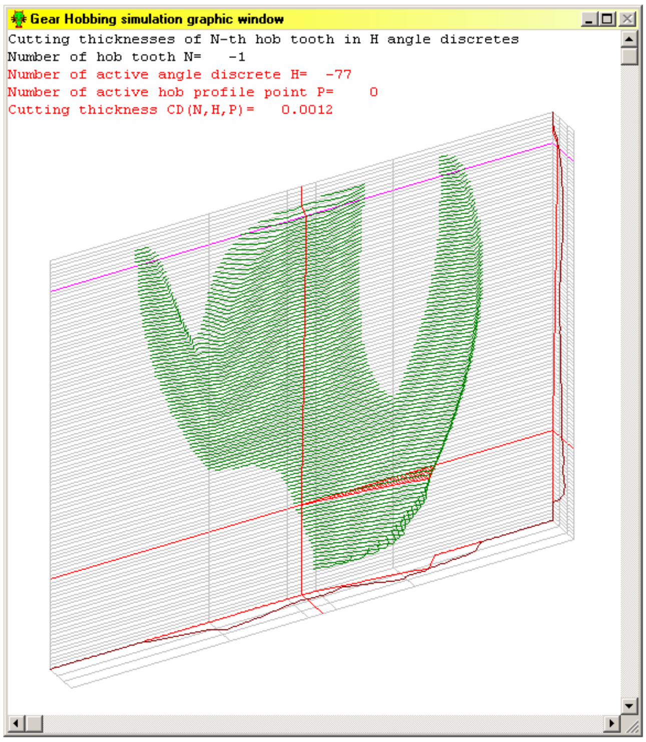


Figure 2.38

2.5.7 Cutting thicknesses in hob P points, vertical view

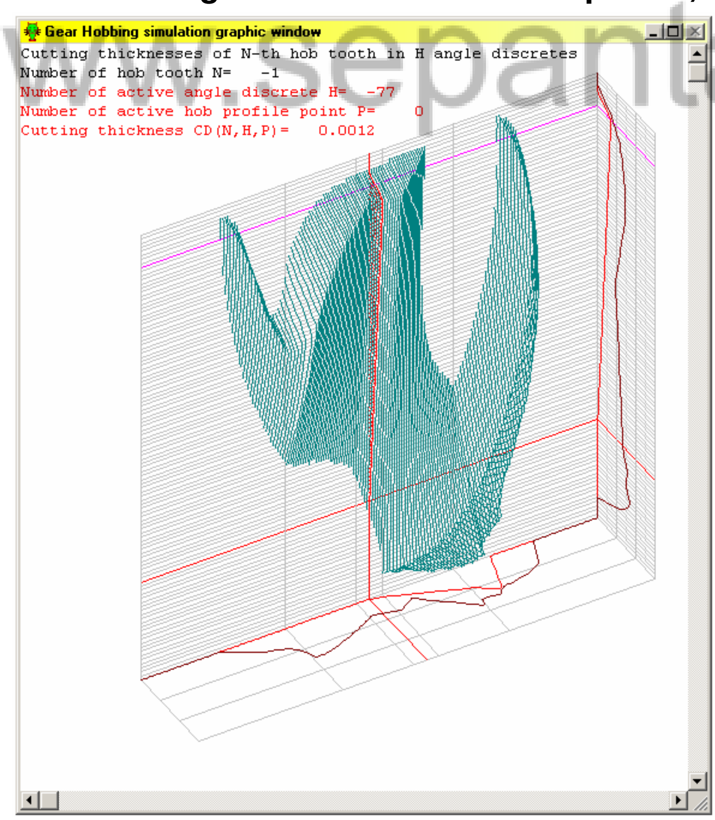


Figure 2.39

Cutting thicknesses of each hob tooth *P* points in *H* revolution angle discrete are shown as 3D diagram. It is the same as above pictures, but cutting thicknesses outline is drown vertically through *P* points.

2.5.8 Cutting thicknesses in P points of N-th tooth

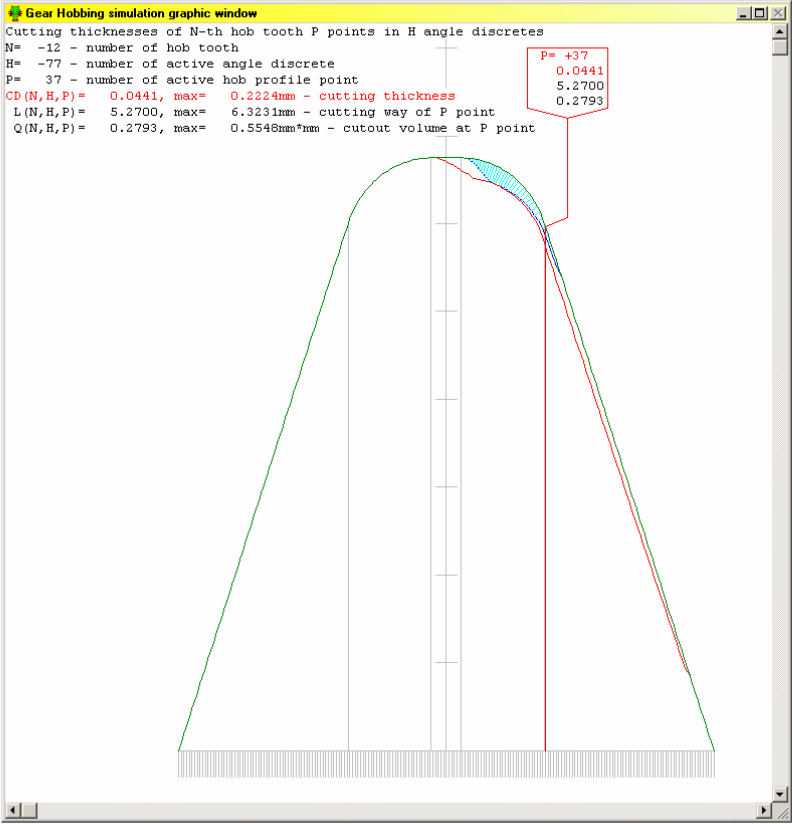


Figure 2.40

Cutting thicknesses of each hob tooth points *P* in one hob revolution angle discrete *H*. For more information see figures 1.11, 1.16, 1.17 and 1.18.

Numbers of hob tooth *N*, active *H* angle and *P* point can be changed in **Select parameter** dialog box (hold **Shift** key and click mouse left button in graphical window) with **N**, **H** and **P** buttons.

Size and position of picture can be changed in **Drawing control** dialog box (click mouse left button in graphical window). Buttons **Move**, **Zoom**, **Zoom X** and **Zoom Y** are available. Cutting thicknesses can be scaled with **Zoom dY** buttons.

Red curve shows max cutting thicknesses with this *N*-th hob tooth.

2.5.9 Cutting thicknesses as graphic in P points of N-th tooth

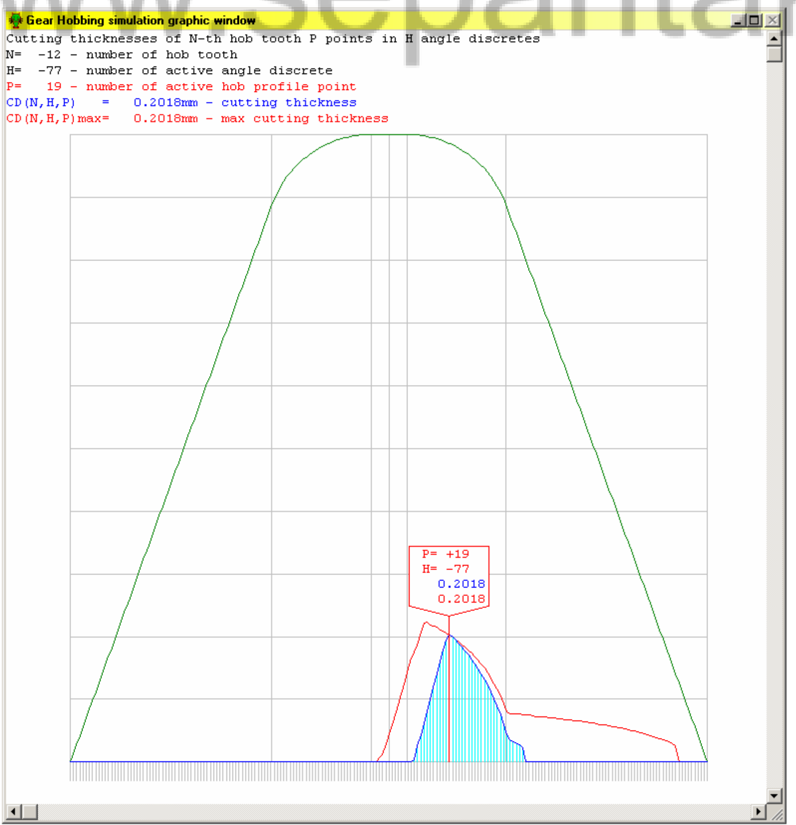


Figure 2.41

Cutting thicknesses (blue outline) of each hob tooth points *P* in one hob revolution angle discrete *H* and max cutting thicknesses (red outline). For more information see figures 1.11, 1.16, 1.17 and 1.18.

Number of hob tooth *N*, active *H* angle and *P* point can be changed in **Select parameter** dialog box (hold **Shift** key and click mouse left button in graphical window) with **N**, **H** and **P** buttons.

Size and position of picture can be changed in **Drawing control** dialog box (click mouse left button in graphical window). Buttons **Move**, **Zoom**, **Zoom X** and **Zoom Y** are available.

Red curve shows max cutting thicknesses with this *N*-th hob tooth.

2.5.10 Max thicknesses, way and cutout volume for each N-th hob tooth

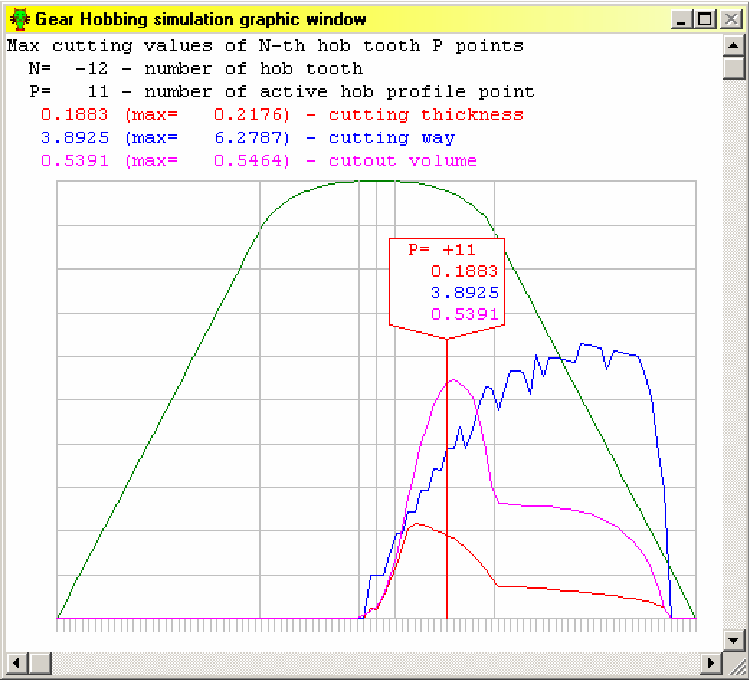


Figure 2.42

Max cutting thicknesses (red), cutting way (blue) and cutout volumes (magenta) in each hob *N*-th tooth boundary point *P*.

Numbers of hob tooth *N* and *P* point can be changed in **Select parameter** dialog box (hold **Shift** key and click mouse left button in graphical window) with **N** and **P** button.

Size and position of picture can be changed in **Drawing control** dialog box (click mouse left button in graphical window). Buttons **Move**, **Zoom**, **Zoom X** and **Zoom Y** are available.

Number of active *P* point, values of max cutting thicknesses (red), cutting way (blue) and cutout volumes (magenta) are shown in measure box.

2.5.11 Max thicknesses, way and cutout volume for all hob teeth

There are summary results of simulation. Max values of cutout volume, cutting thickness, cutting way, cutout volume at *P* point and cutting boundary length are shown for all hob teeth. For more details see figure 1.19.

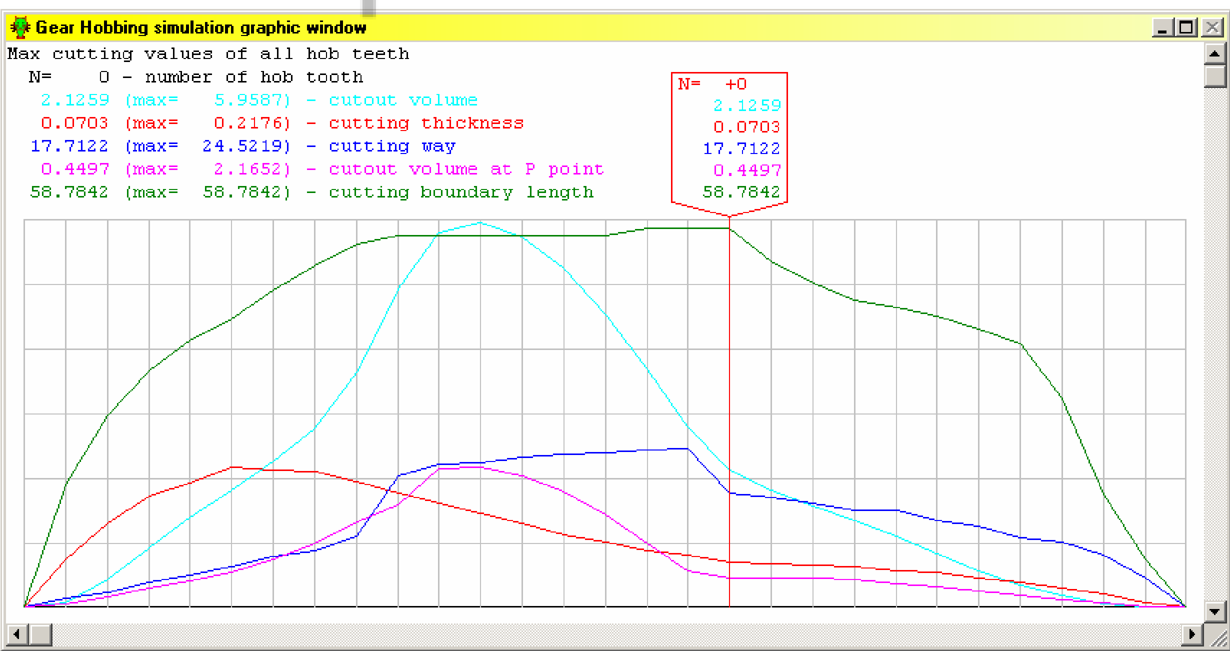


Figure 2.43

Number of hob tooth *N* can be changed in **Select parameter** dialog box (hold **Shift** key and click mouse left button in graphical window) with **N** button. Size and position of picture can be changed in **Drawing control** dialog box (click mouse left button in graphical window). Buttons **Move**, **Zoom**, **Zoom X** and **Zoom Y** are available.

2.6 Cutting forces in hob coordinate

Cutting forces can be shown for one hob tooth, for all hob teeth in series and as real cutting forces in hob coordinate system.

2.6.1 Forces of one N-th hob tooth

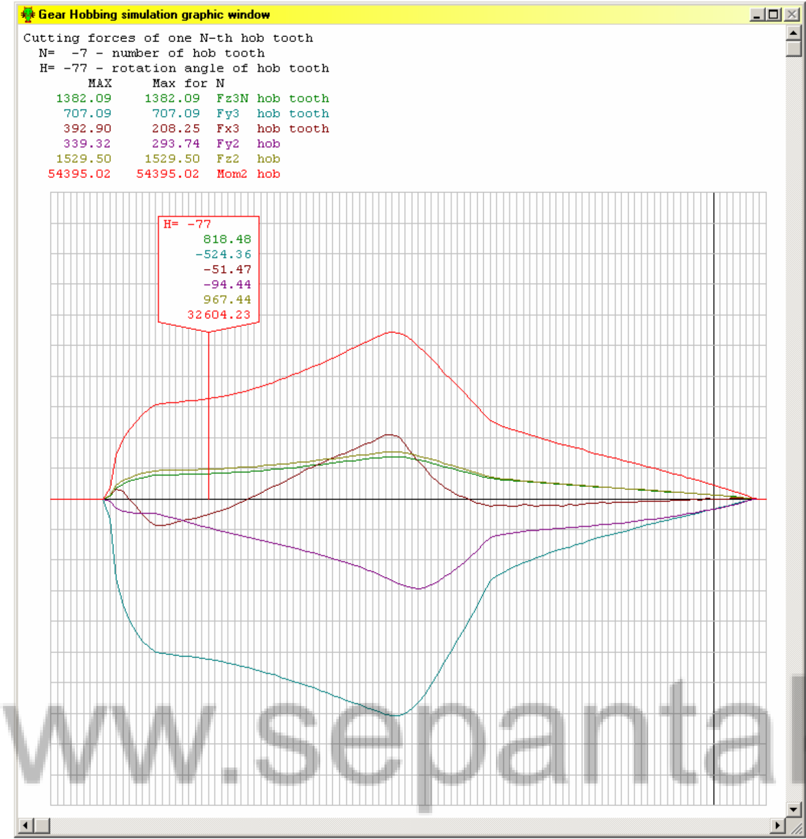


Figure 2.44

Only of one *N*-th tooth cutting forces and torque are shown in this picture. For more details see figures 1.20 and 1.21.

Numbers of hob tooth *N* and hob rotation angle discrete *H* can be changed in **Select parameter** dialog box (hold **Shift** key and click mouse left button in graphical window) with **N** and **H** button.

Size and position of picture can be changed in **Drawing control** dialog box (click mouse left button in graphical window). Buttons **Move**, **Zoom**, **Zoom X** and **Zoom Y** are available.

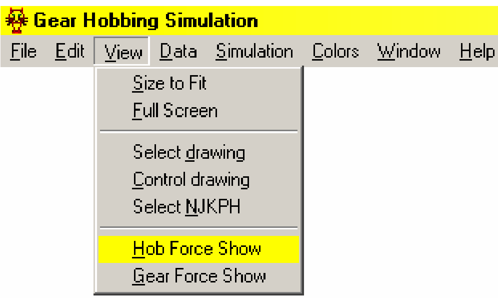


Figure 2.45

You can control which forces or torque to show in picture.

Select **View** menu and click **Hob force Show** or hold **Ctrl** key and click right mouse button.

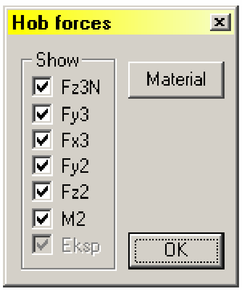


Figure 2.46

Click on desired check box in **Show** area. Program redraws picture automatically.

Push **OK**, when you have selected all curves in picture.

2.6.2 Forces of all hob teeth from TF to TL in series

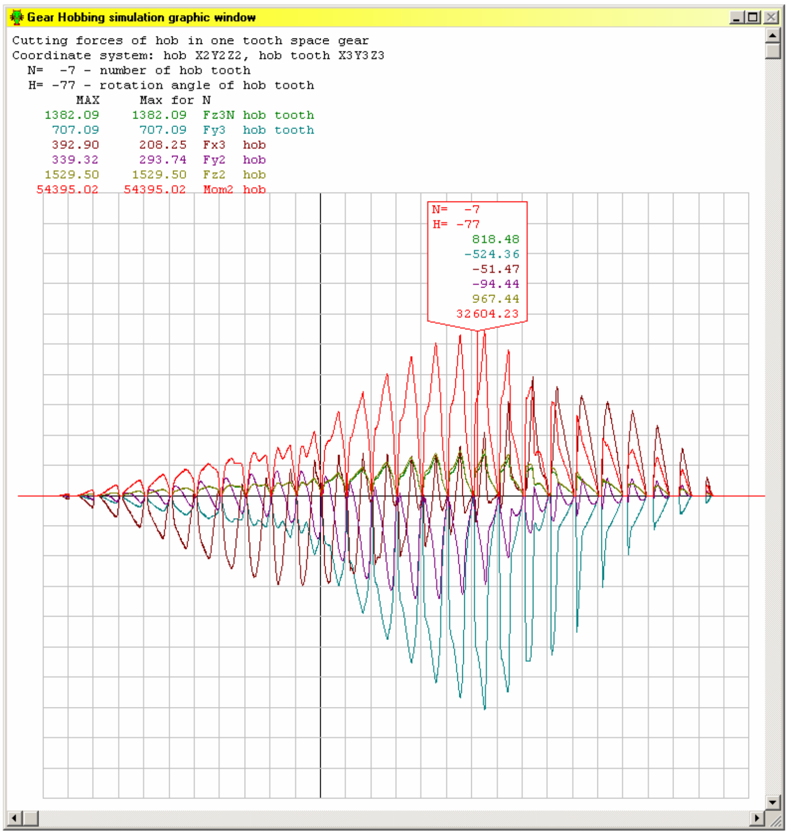


Figure 2.47

For more details see figures 1.22 and 1.23.

Numbers of hob tooth *N* and hob rotation angle discrete *H* can be changed in **Select parameter** dialog box (hold **Shift** key and click mouse left button in graphical window) with **N** and **H** buttons.

Size and position of picture can be changed in **Drawing control** dialog box (click mouse left button in graphical window). Buttons **Move**, **Zoom**, **Zoom X** and **Zoom Y** are available.

What to show you can select in **Hob forces** dialog box (hold **Ctrl** key and click right mouse button).

2.6.3 Forces of real cutting with all hob teeth

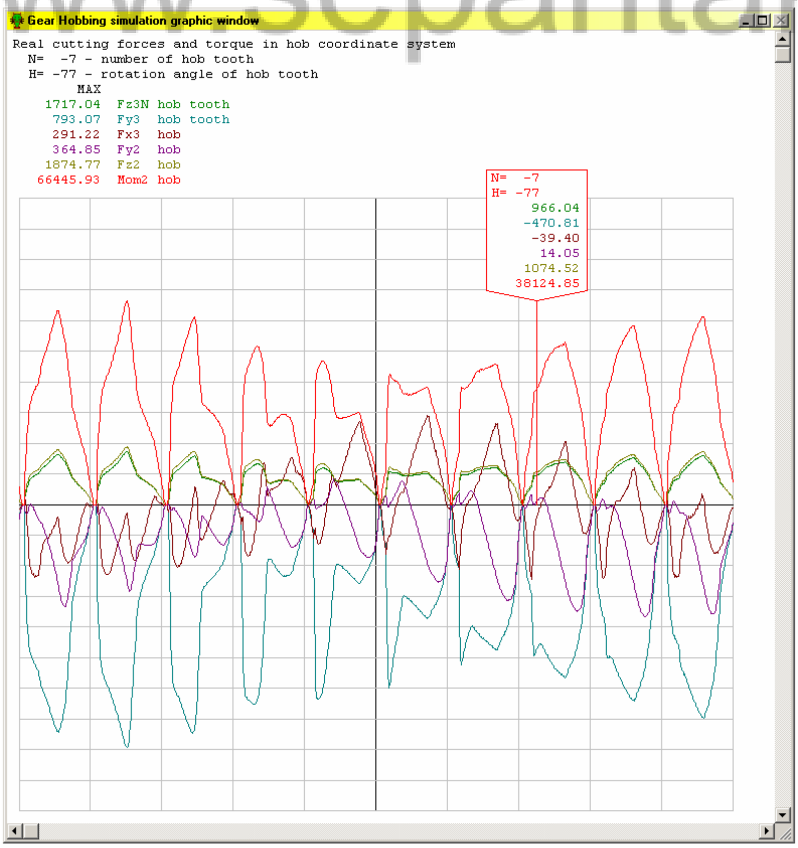


Figure 2.48

For more details see figure 1.24.

Numbers of hob tooth *N* and hob rotation angle discrete *H* can be changed in **Select parameter** dialog box (hold **Shift** key and click mouse left button in graphical window) with **N** and **H** button.

Size and position of picture can be changed in **Drawing control** dialog box (click mouse left button in graphical window). Buttons **Move**, **Zoom**, **Zoom X** and **Zoom Y** are available.

What to show you can select in **Hob forces** dialog box (hold **Ctrl** key and click right mouse button).

2.7 Cutting forces in gear coordinates

Cutting forces can be shown for one hob tooth, for all hob teeth in series and as real cutting forces in gear coordinate system.

2.7.1 Forces of one N-th hob tooth

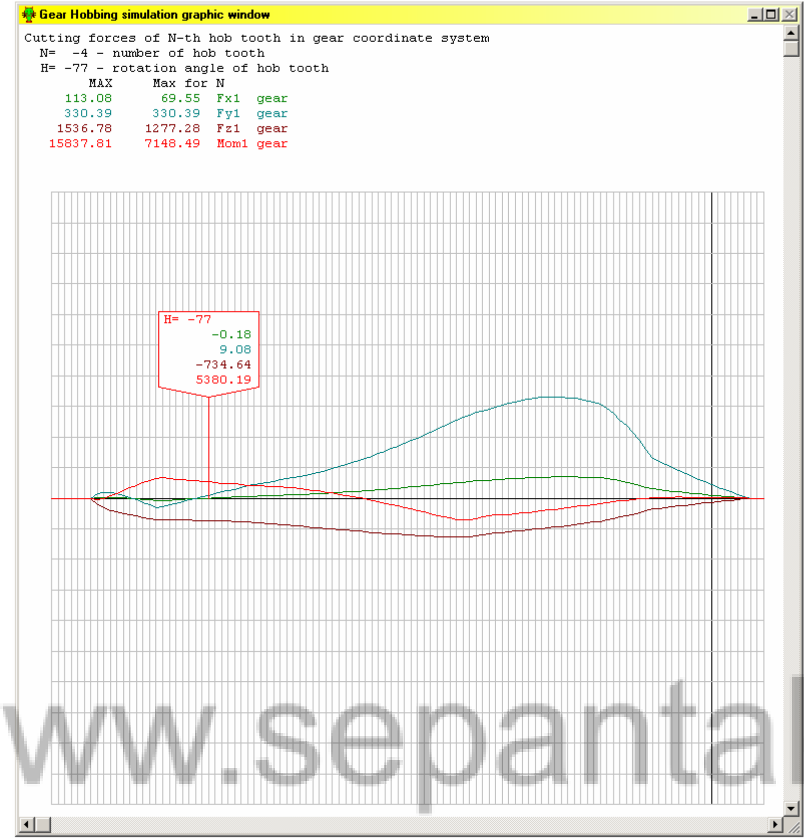


Figure 2.49

Only of one *N*-th tooth cutting forces and torque in gear coordinate system are shown in this picture. For more details see figures 1.1 and 1.2.

Number of hob tooth *N* and hob rotation angle discrete *H* can be changed in **Select parameter** dialog box (hold **Shift** key and click mouse left button in graphical window) with **N** and **H** button.

Size and position of picture can be changed in **Drawing control** dialog box (click mouse left button in graphical window). Buttons **Move**, **Zoom**, **Zoom X** and **Zoom Y** are available.

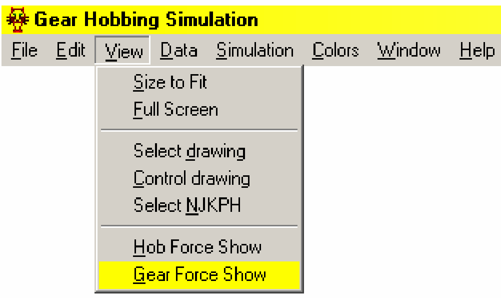


Figure 2.50

You can control which forces or torque to show in picture.

Select **View** menu and click **Gear force Show** or hold **Ctrl** key and click right mouse button.

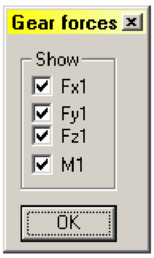


Figure 2.51

Click on desired check box in **Show** area. Program redraws picture automatically. Push **OK,** when you have selected all curves in picture.

2.7.2 Forces of all hob teeth from TF to TL in series

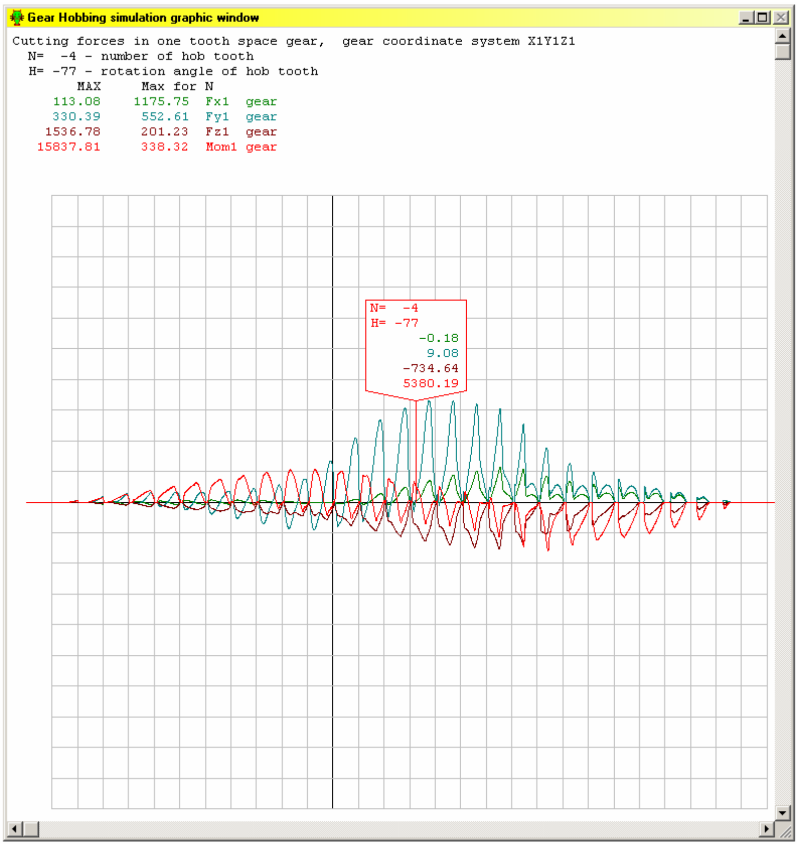


Figure 2.52

Numbers of hob tooth *N* and hob rotation angle discrete *H* can be changed in **Select parameter** dialog box (hold **Shift** key and click mouse left button in graphical window) with **N** and **H** button.

Size and position of picture can be changed in **Drawing control** dialog box (click mouse left button in graphical window). Buttons **Move**, **Zoom**, **Zoom X** and **Zoom Y** are available.

What to show you can select in **Gear forces** dialog box (hold **Ctrl** key and click right mouse button).

2.7.3 Forces of real cutting with all hob teeth

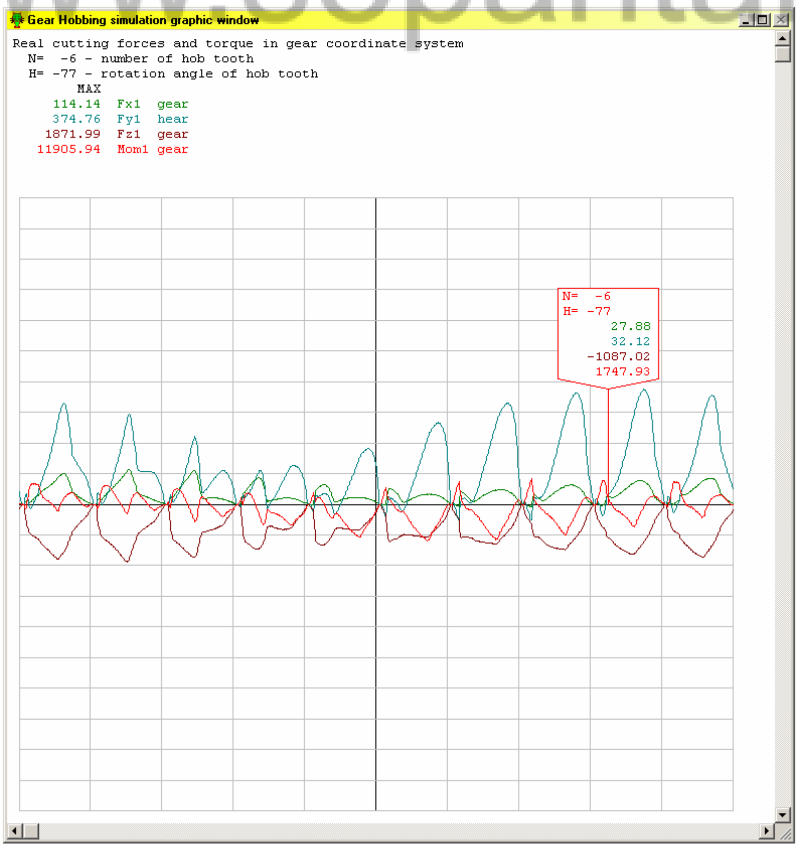


Figure 2.53

Numbers of hob tooth *N* and hob rotation angle discrete *H* can be changed in **Select parameter** dialog box (hold **Shift** key and click mouse left button in graphical window) with **N** and **H** buttons.

Size and position of picture can be changed in **Drawing control** dialog box (click mouse left button in graphical window). Buttons **Move**, **Zoom**, **Zoom X** and **Zoom Y** are available.

What to show you can select in **Gear forces** dialog box (hold **Ctrl** key and click right mouse button).

2.8 Gear zero tooth space in 3D view

Picture of **Y1(N,J,K)** shows top points of *K* segments in all *J* layers and cutout *K* segments with *N*-th hob tooth. Picture of **dY1(N,J,K)** shows cutout with *N*-th hob tooth tops of *K* segments in all *J* layers. For more details see figure 1.12.

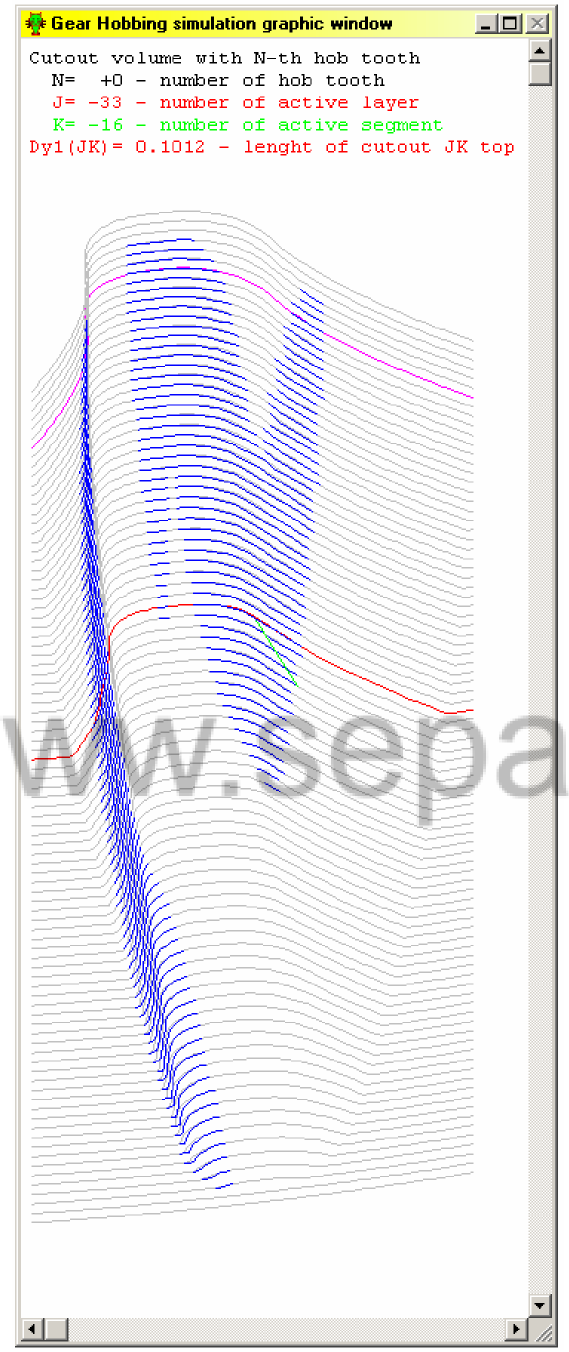


Figure 2.54

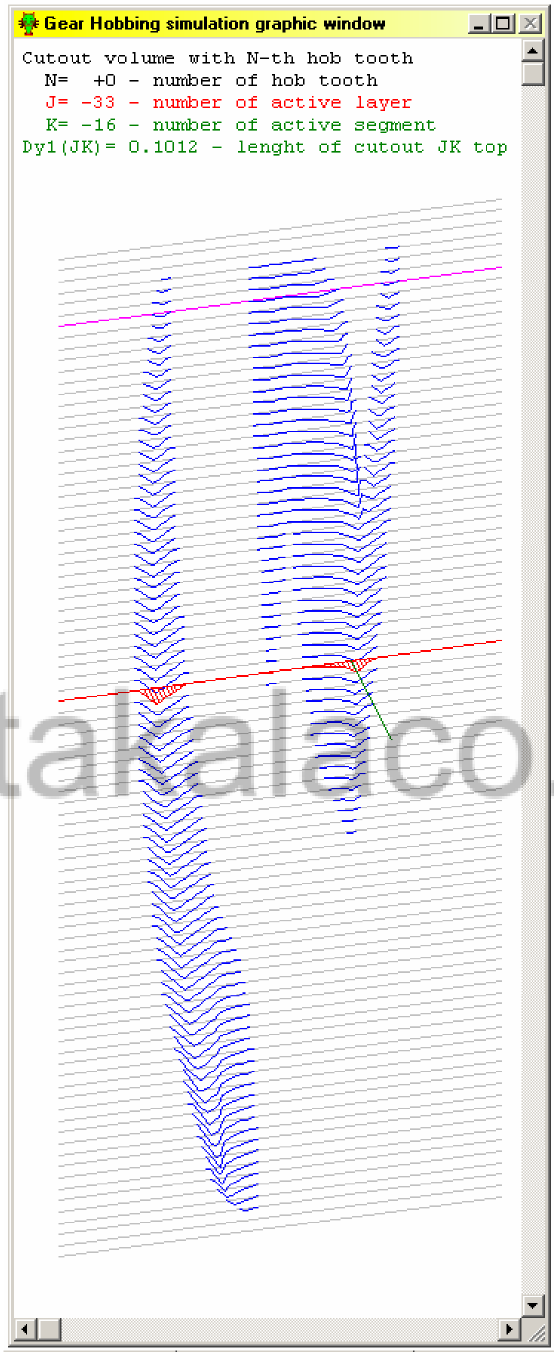


Figure 2.55

Numbers of hob tooth *N*, active *J* layer and *K* segment can be changed in **Select parameter** dialog box (hold **Shift** key and click mouse left button in graphical window) with **N**, **J** and **K** buttons. Active *J* layer is colored in red.

Size and position of picture can be changed in **Drawing control** dialog box (click mouse left button in graphical window). Buttons **Move**, **Zoom**, **Zoom X** and **Zoom Y** are available. Picture can be rotated with **Rotate** buttons. Topping of *K* segments can be scaled with **Zoom dY** buttons.

Picture of **Y1(J,K)** shows top points of *K* segments in all *J* layers and cutout *K* segments with all hob teeth.

Picture of **dY1(J,K)** shows cutout with all hob teeth tops of *K* segments in all *J* layers.

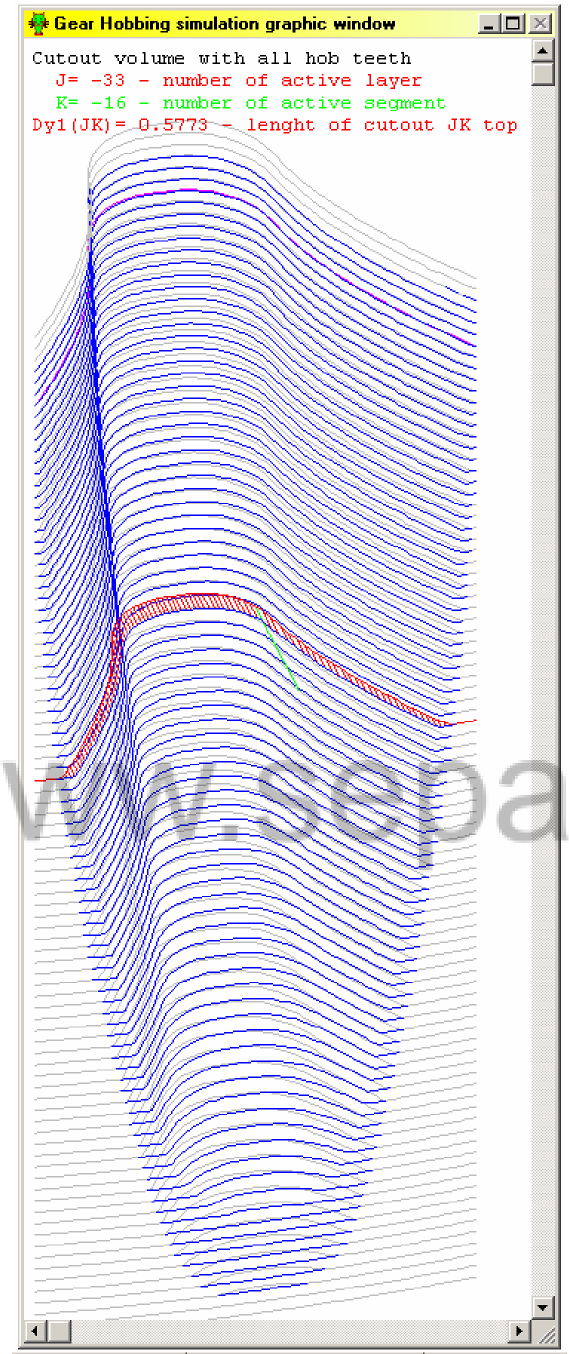


Figure 2.56

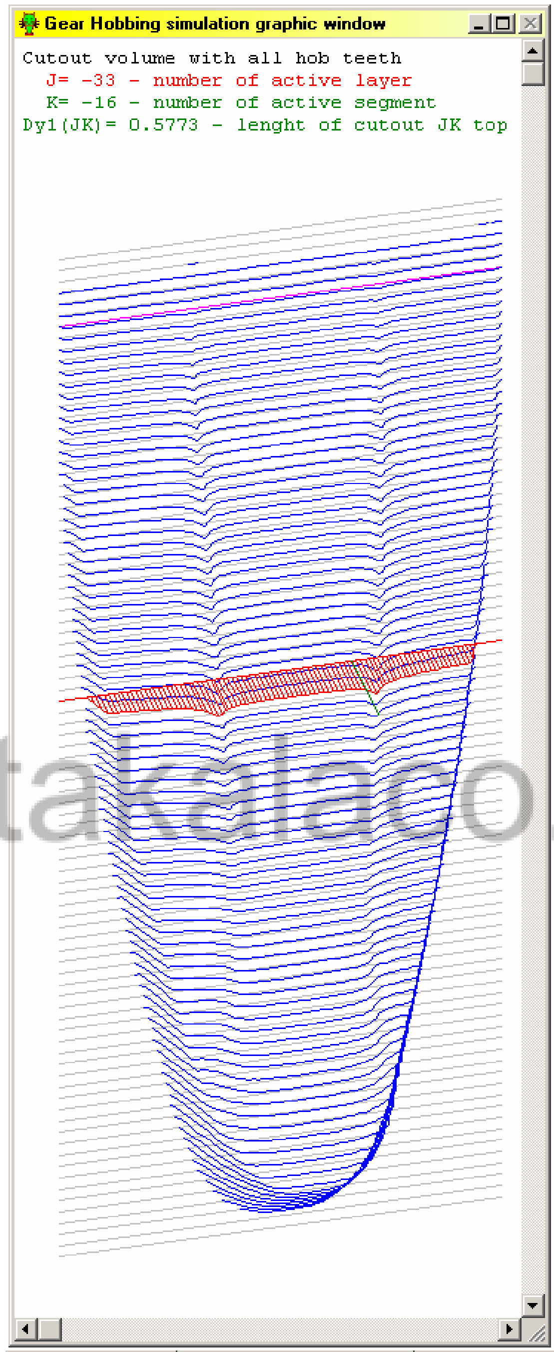


Figure 2.57

Active *J* layer and *K* segment can be changed in **Select parameter** dialog box (hold **Shift** key and click mouse left button in graphical window) with **J** and **K** buttons. Active *J* layer is colored in red.

Size and position of picture can be changed in **Drawing control** dialog box (click mouse left button in graphical window). Buttons **Move**, **Zoom**, **Zoom X** and **Zoom Y** are available. Picture can be rotated with **Rotate** buttons. Topping of *K* segments can be scaled with **Zoom dY** buttons.