

[42] Skiving cutter design system (English ver.)

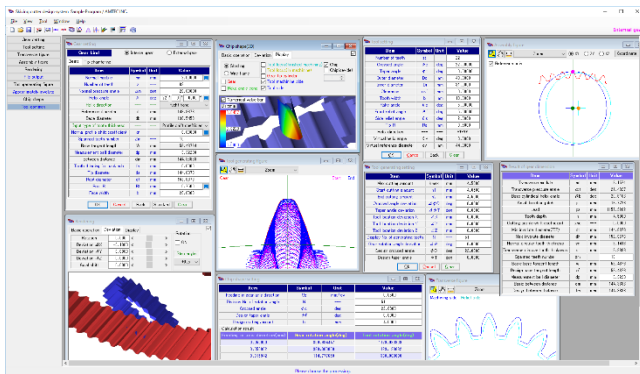


Fig.42.1 Skiving cutter design system

42.1 Abstract

Power Skiving, a type of gear cutting method for cylindrical gears (external gears, internal gears), has passed 100 years since the patent was established in 1910. However, in recent years, this construction method has been reviewed and special machines have been sold both in Japan and overseas. In addition, gear processing is not a gear cutting machine, but in recent years, spiral bevel gears and special gears are also being machined at machining centers (catalog (vol.16), page 41 pictures).

Power skiving can be processed with a high-performance machining center if the tool mounting angle (crossing angle, taper angle) and even the tool tooth profile are decided. The Skiving cutter design system is a software that can generate a tooth form of a tool (pinion cutter) from gear specifications and tool mounting angle. In addition, the generated blade shape can be generated as an approximate involute blade shape. Fig.42.1 shows the whole screen.

42.2 Software structure

Table 42.1 shows the configuration of the Skiving cutter design system. ○ in Table 42 is included in the basic software, ◎ is optional.

Applicable gear: involute flat, helical gear (external gear, internal gear)

Table 42.1 software structure

| No. | Item | Page | Structure |
|-----|------------------------------|-------|-----------|
| 1 | Gear dimension | 42.3 | ○ |
| 2 | Tool dimension | 42.4 | ○ |
| 3 | Tooth profile (gear, tool) | 42.5 | ○ |
| 4 | Setting software (2D) | 42.6 | ○ |
| 5 | Tooth profile rendering | 42.7 | ○ |
| 6 | Generating profile | 42.8 | ○ |
| 7 | Tooth profile-output | 42.9 | ○ |
| 8 | Approximate involute profile | 42.10 | ○ |
| 9 | design data | — | ○ |
| 10 | Chip shape | 42.12 | ◎ |
| 11 | Tool reviewing | 42.13 | ◎ |
| 12 | Chamfering (R, C) | 42.14 | ◎ |

○ : included in the basic software, ◎ : optional software

42.3 Gear dimensions

When the work gear is an internal gear, the gear specifications are set as shown in Fig.42.2 and Fig.42.3. The dislocation coefficient has a direct input method, a tooth thickness, and an over ball (between ball) dimension. An example of an external gear is shown in 42.11.

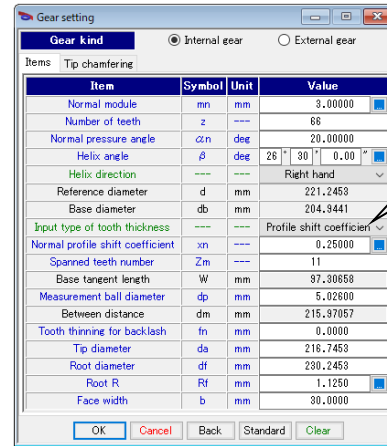


Fig.42.2 Gear specification (internal gear)

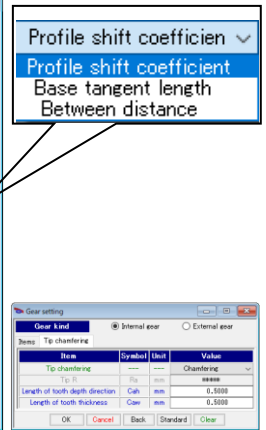


Fig.42.3 Chamfer

| Item | Symbol | Unit | Value |
|-------------------------------------|------------|------|-----------|
| Transverse module | mt | mm | 3.3522 |
| Transverse pressure angle | α_t | deg | 22.1316 |
| Base cylindrical helix angle | β_b | deg | 24.7897 |
| Axial direction pitch | pt | mm | 21.1224 |
| Lead | pz | mm | 1394.0798 |
| Tooth depth | h | mm | 6.7500 |
| Cutting profile shift coefficient | xnc | --- | 0.2500 |
| Min involute diameter(TIF) | dt | mm | 217.7453 |
| Max involute diameter | dh | mm | 228.9901 |
| Normal circular tooth thickness | sn | mm | 4.1664 |
| Transverse circular tooth thickness | st | mm | 4.6556 |
| Spanned teeth number | zm | --- | 11 |
| Basic base tangent length | w | mm | 97.3068 |
| Design base tangent length | w' | mm | 97.3068 |
| Measurement ball diameter | dp | mm | 5.0280 |
| Basic between distance | dm | mm | 215.9708 |
| Design between distance | dm' | mm | 215.9708 |

Fig.42.4 dimensions

42.4 Tool dimensions

The specifications of the machining tool (pinion cutter) are shown in Fig.42.5. Here is an example when the tolerance angle during machining is set to $\phi_c = 20^\circ$ with respect to the helix angle of the gear of 26.5° . Figures 42.5a and 42.5b show the shape, position and clearance angle of the cutter, respectively.

In this software, a tool is attached at an intersection angle ϕ_c and a taper angle ϕ_t , and a tool edge shape when machining the gear of Fig. 42.2 is generated considering the rake angle and side clearance angle. For pinion cutters during helical gear machining, side rake angle (blade angle) is not given so that blade grinding is easy.

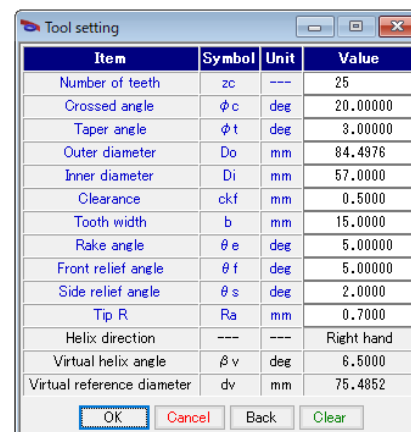


Fig.42.5 Tool specifications

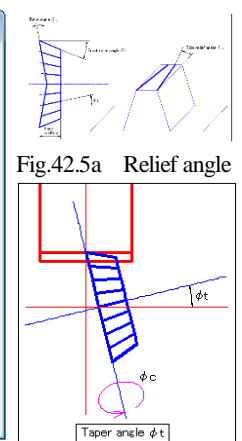


Fig.42.5a Relief angle

Fig.42.5b Cutter position

42.5 Tooth profile (gear; tool)

The gear tooth profile is shown in Fig. 42.6, and the pinion cutter blade shape is shown in Fig.42.7. The blue wire type shown in Fig. 42.7 is the blade shape of the machined end face of the pinion cutter shown in Fig. 42.8, and the light blue line shows the blade shape of the upper face of the pinion cutter. The tooth profile has enlargement, reduction, distance measurement function.

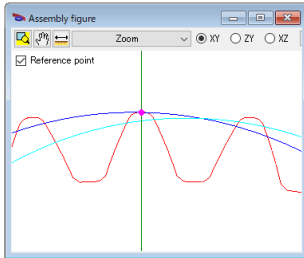


Fig.42.6 Tooth profile

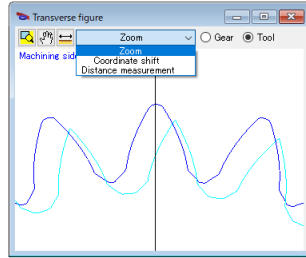


Fig.42.7 Pinion cutter

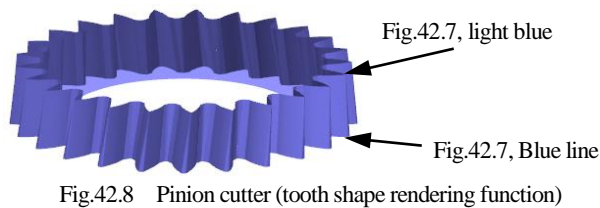
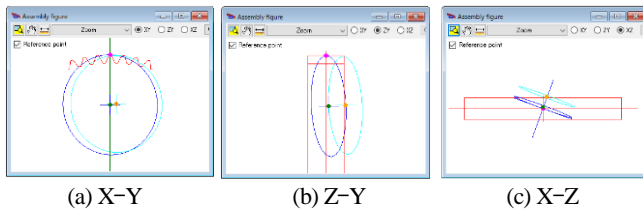


Fig.42.8 Pinion cutter (tooth shape rendering function)

42.6 Assembly drawing (2D)

Figure 42.9 shows the assembly chart. As shown in Fig. 42.10, the tool point (A, B, C) of the machining coordinate value has the center of the gear as (0, 0, 0) origin.



(a) X-Y

(b) Z-Y

(c) X-Z

Fig.42.9 Assembly drawing

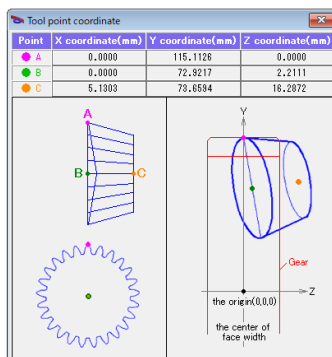


Fig.42.10 Machining coordinate value

42.7 Tooth profile rendering

In the tooth shape rendering (Fig. 42.12 - 42.15), it is possible to check the engagement between the gear and the pinion cutter. As an auxiliary function, there is a function to move and rotate the tool in the X, Y, Z direction. Therefore, as shown in Fig.42.13, it is possible to check the relationship between the tool and the meshing (cutting) of the tool while turning the tool blade. In addition, it is possible to display only the pinion cutter as shown in Fig.42.15.

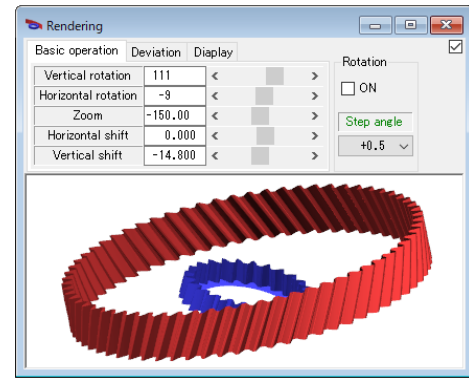


Fig.42.11 Tooth profile rendering

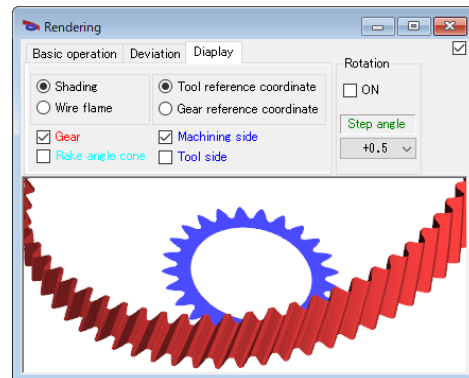


Fig.42.12 Tool cutting end face (cutting edge) and gear

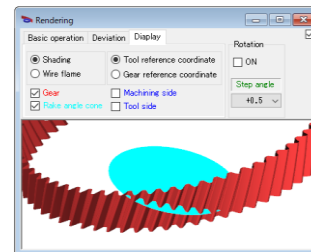


Fig.42.13 Rake angle cross section

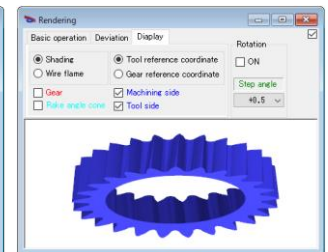


Fig.42.14 Pinion cutter

42.8 Tooth creation drawing

Fig. 42.15 shows the setting screen of the tooth creation diagram. Here, Fig. 42.16 shows the tooth creation Fig. When the cutting depth of the tool during roughing is 5 mm and the cutting depth of the finish is 6.75 mm.

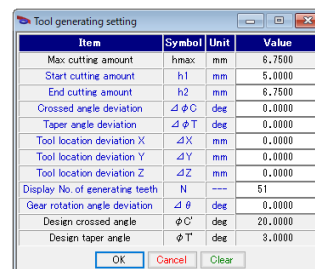


Fig.42.15 Creation setting

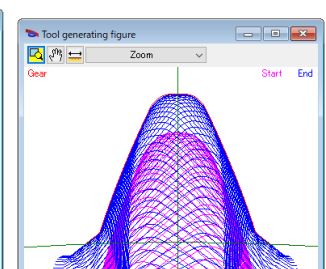


Fig.42.16 Tooth profile

42.9 Tooth profile file output

You can output the gear tooth form and the tool blade shape as DXF file and IGES file. Fig. 42.17 shows the tooth profile output setting screen, and Fig. 42.18 shows the tool CAD drawing example.

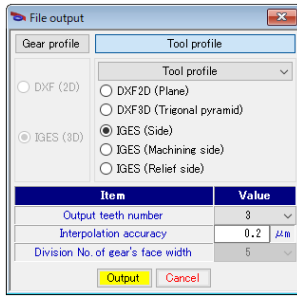
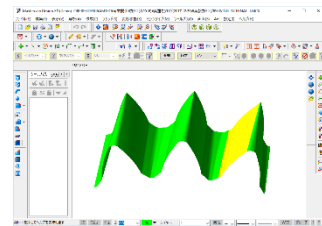
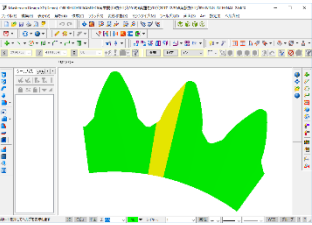


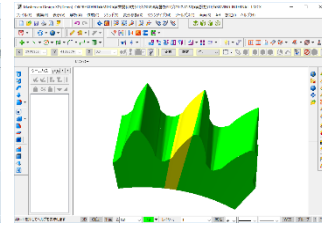
Fig.42.17 Output setting



(a) Blade (side)



(b) Blade (front)



(c) Blade (file merger)

Fig.42.18 CAD drawing example (3D-IGES)

42.10 Approximate involute blade shape

Since the blade shape generated in Figure 42.18 can be approximated as an involute, it can be easily handled when ordering (manufacturing) a tool. For the blade shape of Fig. 42.18 in this example, as shown in Fig. 42.19, the pressure angle can be approximated by $\alpha_n = 20.6265^\circ$ and the helix angle by $\beta = 8^\circ 30'$ in the case of the left cutting edge. As shown in Fig.42.20, the difference between the approximate blade shape and the theoretical blade shape is as small as 0.0007 mm in the vicinity of the cutting edge of the cutter.

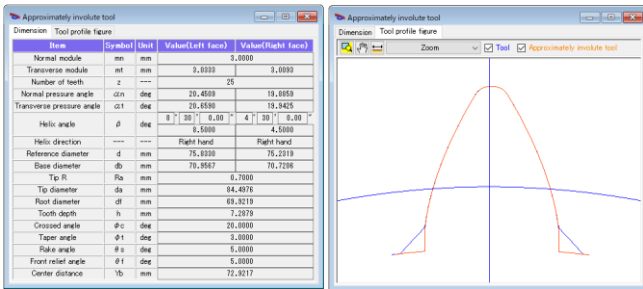


Fig.42.19 Involute approximate blade shape

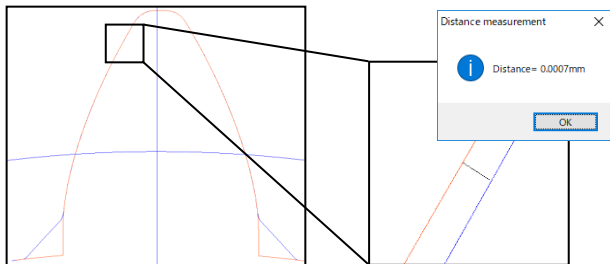


Fig.42.20 Difference in approximate shape of involute (distance measurement)

42.12 Chip shape (option)

Figures 42.22 to 42.24 show the chip shape when skiving is performed under the processing conditions in Figure 42.21. In the machining condition of Fig. 42.21, you can set the feed amount, crossing angle and cutting amount of the tool arbitrarily. The chip shape shown in Fig. 42.22 and Fig. 42.23 shows the shape until one blade of the tool finishes cutting for the first time. Fig.42.24 shows the state of the gear and rake face, and Fig.42.25 shows the 2D cutting thickness by 100 times.

| Item | Symbol | Unit | Value |
|--------------------------------|-----------|--------|---------|
| Feeding in gear axis direction | V_z | mm/rev | 0.0500 |
| Division No. of rotation angle | N | — | 51 |
| Crossed angle | ϕ_c' | deg | 20.0000 |
| Design taper angle | ϕ_t' | deg | 3.0000 |
| Design cutting amount | h | mm | 6.7500 |

| Calculation result | | |
|-------------------------------|--------------------------|--------------------------|
| Feeding in axis direction(mm) | Gear rotation angle(deg) | Tool rotation angle(deg) |
| 0.050000 | 359.987088 | 950.400000 |
| 0.050002 | 360.000000 | 950.434088 |
| 0.018939 | 136.358746 | 360.000000 |

Fig.42.21 Cutting conditions

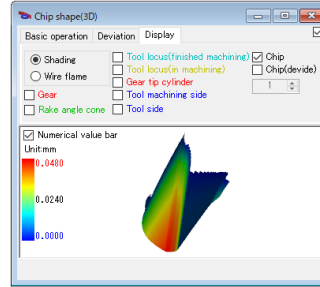


Fig.42.22 Chip shape

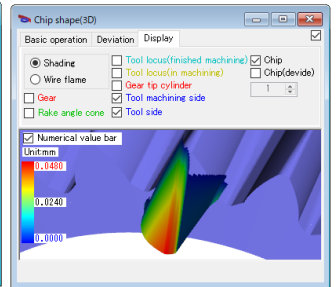


Fig.42.23 Gear and chip shape

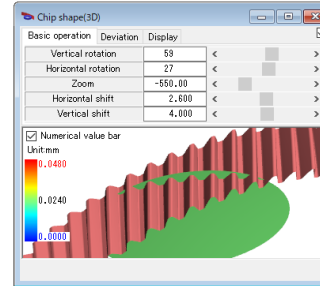


Fig.42.24 Gears and rake faces

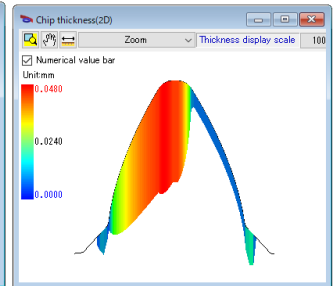


Fig.42.25 Cutting thickness

At **Chip thickness value(CSV)** in the cutting condition (Fig. 42.21), the chip shape can be output to the csv file as shown in Fig.42.24.

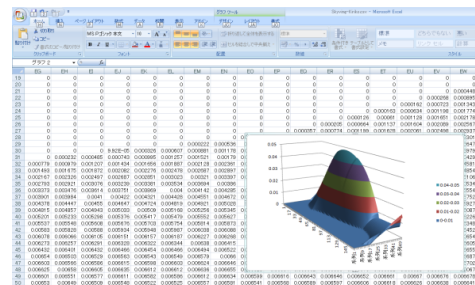


Fig.42.24 Cutting thickness (csv file)

42.13 Tool sharing calculation (option)

When machining a gear different from Fig. 42.2 with the tool of Fig. 42.18, calculate how much you can share with this tool. The gear of Fig. 42.25 has the same pressure angle as the gear module of Fig. 42.2, but the number of teeth and the helix angle are different. Also, if the mounting angle of the tool is shown in Fig. 42.26, Fig. 42.27 and Fig. 42.28 can be displayed. Then, if we compare the portion of Fig. 42.28 with the tooth profile of the gear specification (Fig. 42.25), we see that the difference is 1.2 μm as shown in Fig.42.29. Similarly, measuring the left tooth surface is 0.7 μm .

As shown above, by adjusting the intersection angle and taper angle even if the tool is different from the target gear, it is possible to minimize

the tooth profile error so it is possible to share tools. However, in the case of this example, they match very well, but there are cases where they do not agree well depending on specifications and conditions. And it is also possible to analyze the tooth shape rendering table shown in Fig. 42.26 (Fig.42.27) and the chip shape (Fig.42.22) based on the processing condition (Fig.42.21).

Here we showed examples of internal gears, but external gears can be calculated in the same way. In addition, tool sharing is calculated on the 2nd screen as shown in Fig.42.30.

| Item | Symbol | Unit | Value |
|----------------------------------|------------|------|---------------------------|
| Normal module | m_n | mm | 3.00000 |
| Number of teeth | z | --- | 88 |
| Normal pressure angle | α_n | deg | 20.00000 |
| Helix angle | β | deg | 25 * 0 0.00 * |
| Helix direction | --- | --- | Right hand |
| Reference diameter | d | mm | 291.2918 |
| Base diameter | d_b | mm | 270.3085 |
| Input type of tooth thickness | --- | --- | Profile shift coefficient |
| Normal profile shift coefficient | x_n | --- | 0.25000 |
| Spanned teeth number | Z_m | --- | 14 |
| Base tangent length | W | mm | 124.96513 |
| Measurement ball diameter | d_p | mm | 5.02300 |
| Between distance | d_m | mm | 286.02907 |
| Tooth thinning for backlash | f_n | mm | 0.0000 |
| Tip diameter | d_a | mm | 286.7918 |
| Root diameter | d_f | mm | 300.2918 |
| Root R | R_f | mm | 1.1250 |
| Face width | b | mm | 30.0000 |

Fig.42.25 Gear specification (tool sharing)

| Item | Symbol | Unit | Value |
|--------------------|----------|------|----------|
| Crossed angle | ϕ_c | deg | 18.00000 |
| Design taper angle | ϕ_t | deg | 3.00000 |

Fig.42.26 Tool set angle

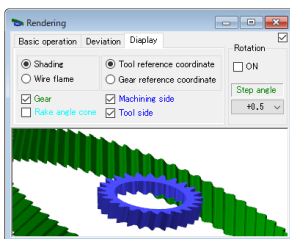


Fig.42.27 Rendering

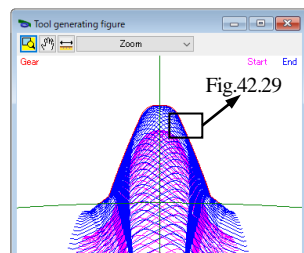


Fig.42.28 Creating tooth profile

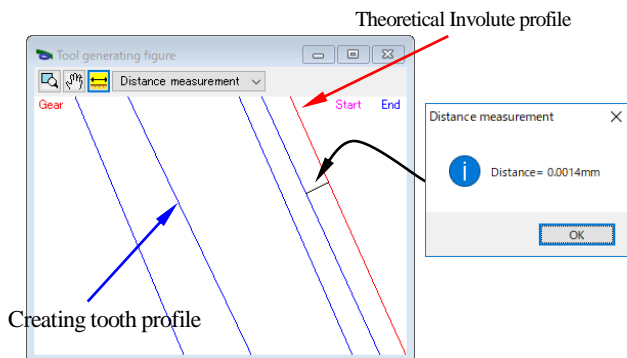


Fig.42.29 Distance measurement

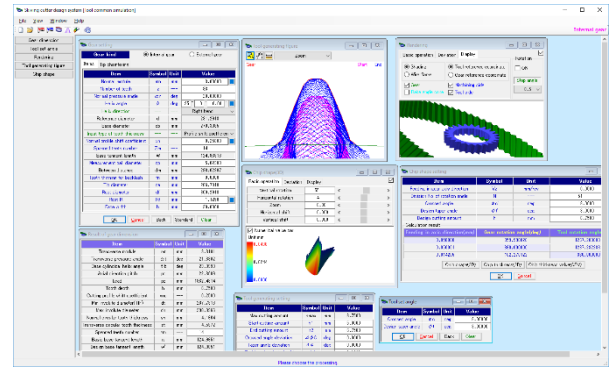


Fig.42.30 Tool shared screen

42.14 External gear example

Like the internal gear, the external gear calculates the tool edge shape, the chip shape, and the involute approximate shape. Calculation examples are shown in Fig.42.31 ~ 42.43.

| Item | Symbol | Unit | Value |
|----------------------------------|------------|------|---------------------------|
| Normal module | m_n | mm | 3.00000 |
| Number of teeth | z | --- | 25 |
| Normal pressure angle | α_n | deg | 20.00000 |
| Helix angle | β | deg | 25 * 0 0.00 * |
| Helix direction | --- | --- | Right hand |
| Reference diameter | d | mm | 82.7530 |
| Base diameter | d_b | mm | 76.7922 |
| Input type of tooth thickness | --- | --- | Profile shift coefficient |
| Normal profile shift coefficient | x_n | --- | 0.25000 |
| Spanned teeth number | Z_m | --- | 5 |
| Base tangent length | W | mm | 41.75623 |
| Measurement ball diameter | d_p | mm | 5.30300 |
| Over ball distance | d_m | mm | 91.50713 |
| Tooth thinning for backlash | f_n | mm | 0.0000 |
| Tip diameter | d_a | mm | 90.2533 |
| Root diameter | d_f | mm | 76.7533 |
| Basic rack root R | R_f | mm | 1.1250 |
| Face width | b | mm | 30.0000 |

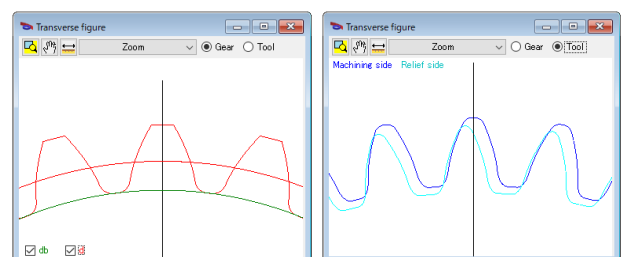
Fig.42.31 Gear specification (without chamfer)

| Item | Symbol | Unit | Value |
|-------------------------------------|------------|------|----------|
| Transverse module | m_t | mm | 3.3101 |
| Transverse pressure angle | α_t | deg | 21.8802 |
| Base cylindrical helix angle | β_b | deg | 23.9990 |
| Axial direction pitch | p_t | mm | 22.3069 |
| Lead | p_z | mm | 557.5231 |
| Tooth depth | h | mm | 6.7500 |
| Cutting profile shift coefficient | x_{nc} | --- | 0.2500 |
| Min involute diameter(TIP) | d_t | mm | 78.0391 |
| Max involute diameter | d_h | mm | 90.2533 |
| Normal circular tooth thickness | s_n | mm | 5.2583 |
| Transverse circular tooth thickness | s_t | mm | 5.0019 |
| Spanned teeth number | Z_m | --- | 5 |
| Basic base tangent length | w | mm | 41.7562 |
| Design base tangent length | w_d | mm | 41.7562 |
| Measurement ball diameter | d_p | mm | 5.3030 |
| Basic over ball distance | d_m | mm | 91.5071 |
| Design over ball distance | d_{m1} | mm | 91.5071 |

Fig.42.32 Gear specifications

| Item | Symbol | Unit | Value |
|----------------------------|------------|------|-----------|
| Number of teeth | z_c | --- | 39 |
| Crossed angle | ϕ_c | deg | -20.00000 |
| Taper angle | ϕ_t | deg | 3.00000 |
| Outer diameter | D_o | mm | 123.4552 |
| Inner diameter | D_i | mm | 96.4181 |
| Clearance | ckf | mm | 0.7500 |
| Tooth width | b | mm | 10.0000 |
| Rake angle | θ_e | deg | 5.00000 |
| Front relief angle | θ_f | deg | 5.00000 |
| Side relief angle | θ_s | deg | 2.0000 |
| Tip R | R_a | mm | 1.1250 |
| Helix direction | --- | --- | Left hand |
| Virtual helix angle | β_v | deg | 5.0000 |
| Virtual reference diameter | d_v | mm | 117.4469 |

Fig.42.33 Tool specifications



(a) Gear Tooth Profile

(b) Pinion cutter

Fig.42.34 Tooth Profile

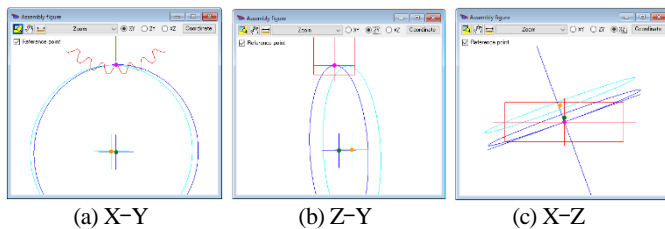


Fig.42.35 Assembly drawing

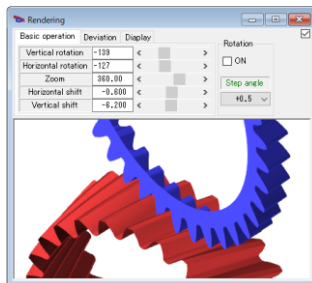


Fig.42.36 Rendering

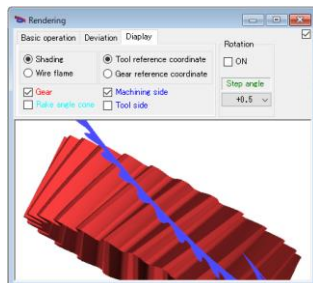


Fig.42.37 Cutting Edge

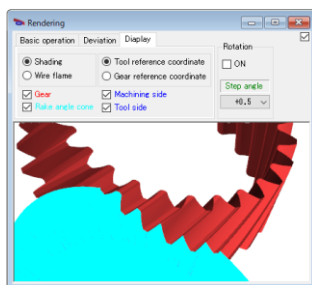


Fig.42.38 Rake angle cross section

Fig.42.39 Setting of tooth

| 項目 | 記号 | 単位 | 数値 |
|---------|-----------------|-----|----------|
| 最大切込量 | hmax | mm | 6.7500 |
| 開始切込量 | h1 | mm | 6.0000 |
| 終了切込量 | h2 | mm | 6.7500 |
| 交差角誤差 | $\Delta \phi C$ | deg | 0.0000 |
| テーパー角誤差 | $\Delta \phi T$ | deg | 0.0000 |
| 工具位置誤差X | ΔX | mm | 0.0000 |
| 工具位置誤差Y | ΔY | mm | 0.0000 |
| 工具位置誤差Z | ΔZ | mm | 0.0000 |
| 削成刃表示個数 | N | --- | 51 |
| 歯車回転角誤差 | $\Delta \theta$ | deg | 0.0000 |
| 設計交差角 | $\phi C'$ | deg | -20.0000 |
| 設計テーパー角 | $\phi T'$ | deg | 3.0000 |

Fig.42.39 Setting of tooth

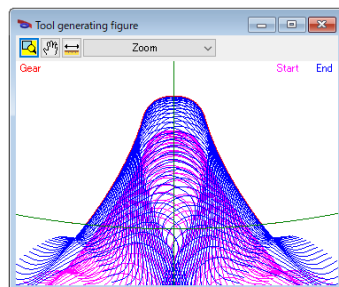


Fig.42.40 Creation of tooth profile

Fig.42.41 Involute approximate blade shape

| Item | Symbol | Unit | Value(Left face) | Value(Right face) |
|---------------------------|------------|------|------------------|-------------------|
| Normal module | m | mm | 3.0000 | 3.0000 |
| Transverse module | mt | mm | 3.0041 | 3.0225 |
| Number of teeth | z | --- | 39 | 39 |
| Normal pressure angle | α_n | deg | 19.3057 | 20.3157 |
| Transverse pressure angle | α_t | deg | 19.3059 | 20.4557 |
| Helix angle | β | deg | 0.7011 | 0.7011 |
| Helix direction | --- | --- | Left hand | Left hand |
| Reference diameter | d | mm | 117.1898 | 117.8788 |
| Base diameter | db | mm | 110.1229 | 110.4485 |
| Tip S | Ra | mm | 1.1250 | 1.1250 |
| Tip diameter | da | mm | 123.4552 | 123.4552 |
| Root diameter | df | mm | 108.3574 | 108.3574 |
| Tooth depth | h | mm | 7.5400 | 7.5400 |
| Crossed angle | ϕc | deg | -20.0000 | -20.0000 |
| Taper angle | ϕt | deg | 3.0000 | 3.0000 |
| Rake angle | ϕr | deg | 5.0000 | 5.0000 |
| Front relief angle | ϕf | deg | 100.0197 | 100.0197 |
| Center distance | a | mm | 100.0197 | 100.0197 |

Fig.42.41 Involute approximate blade shape

Fig.42.42 Cutting conditions

| Item | Symbol | Unit | Value |
|--------------------------------|-----------|--------|----------|
| Feeding in gear axis direction | Vz | mm/rev | 0.0500 |
| Division No. of rotation angle | N | --- | 51 |
| Crossed angle | $\phi c'$ | deg | -20.0000 |
| Design taper angle | $\phi t'$ | deg | 3.0000 |
| Design cutting amount | h | mm | 6.7500 |

| Calculation result | | |
|-------------------------------|--------------------------|--------------------------|
| Feeding in axis direction(mm) | Gear rotation angle(deg) | Tool rotation angle(deg) |
| 0.050000 | -380.032286 | 230.769231 |
| -0.045996 | 380.000000 | -230.748537 |
| 0.076000 | -561.850366 | 380.000000 |

Fig.42.42 Cutting conditions

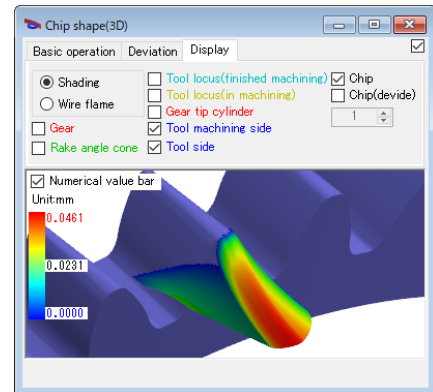


Fig.42.43 Gear and chip shape (external gear)

42.15 Chamfer C, R (option)

If it is necessary to chamfer teeth of a gear, you can give a chamfer shape to the tool. As shown in Fig.42.44, chamfering of gear specifications in Fig.42.2 can select C face and R face.

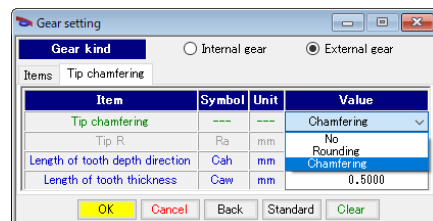


Fig.42.44 Chamfer setting

42.16 HELP function

You can use the [HELP] function if you want to know the operation method. If you have unknown contents as shown in Fig.42.46, you can select the table of contents of Fig.42.46 by pressing [F1] with that screen active as shown in Fig.44.45.

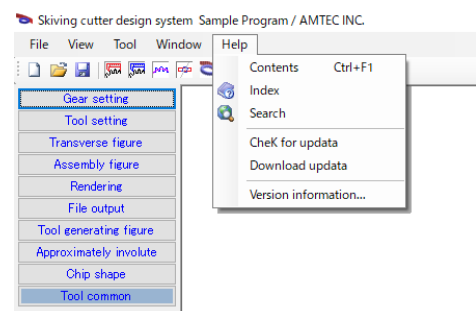


Fig.42.45 Help function

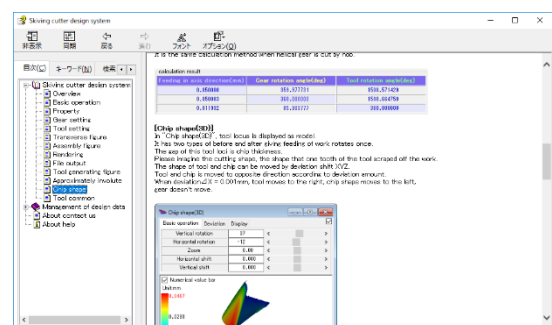


Fig.42.46 Explanation (example of chip)