## [47] Strain wave gearing design system



Fig.47.1 Strain wave gearing design system

### 47.1 Overview

Strain wave gearing design system is a software that generates wave gear tooth profile, based on basic rack or tool (hob). Meshing of the generated tooth profile and rendering can be displayed, and also 2D-DXF file output can be generated. Overall display is shown in Table 47.1.

### 47.2 Software configuration

Strain wave gearing design system configuration is shown in Table 47.1.

Table 47.1    Software Configuration

| No. | Item | Figure | |
|---|---|---|---|
| 1 | Basic rack | | 47.3 |
| | Tool（HOB） | ----- | 47.12 |
| | Type of Ring | | ----- |
| 2 | Tool dimension | ----- | 47.12 |
| 3 | Gear dimension | 47.4 | 47.12.2 |
| 4 | Tooth profile | 47.5 | 47.12.3 |
| 5 | Tooth modification | 47.6 | ----- |
| 6 | 2DTooth profile | 47.7 | 47.12.3 |
| 7 | Tooth rendering | 47.8 | 47.12.3 |
| 8 | FEM-Analysis | 47.9 | 47.12.4 |
| 9 | Hertzian stress | 47.10 | 47.12.4 |
| 10 | Output (Tooth profile) | 47.11 | 47.12.5 |
| 11 | Design-data management | 47.13 | |

### 47.3 Basic Rack（Property）

Basic rack (cup type) is shown in Figure 47.2. As basic rack can be chosen between full depth tooth, low tooth and special tooth, Initialize is used to set up special tooth with $\alpha=25°$, $h_{ac}=0.8$, $h_{fc}=1.05$, $r_c=0.375$. After basic rack is specified, actual basic rack can be displayed as shown by Figure 47.3, by clicking Tooth profile (Hob-based tooth profile is shown in Figure 47.12)
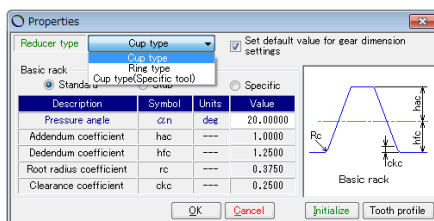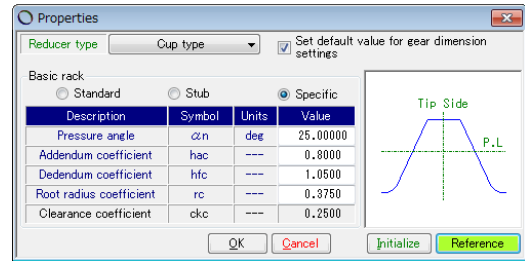


Fig.47.2    Basic rack（Cup type）



Fig.47.3    Property and basic rack（Cup type）

### 47.4 Dimension

Dimension display is shown in Figure 47.4 by using the example with $m_n=0.3$, $z_{FS}=100$, $z_{CS}=102$. Although the addendum modification coefficient is shown as $x_n=0.2$, it can be set to any value. Also, tip R can be defined all the way to the addendum pointed limit. In basic rack root R, the value specified in Figure 47.2 is taken as the standard value, but it can be defined all the way to the established limit of basic rack profile. The input range is shown below.

Module　　　　　:　$0 < m_n < 10$
Number of teeth　:　$10 < z_{FS} \leqq 1000$, $z_{FS}+2 < z_{CS} \leqq 1000$
Profile shift　　　:　$-2 < x_n < +3$
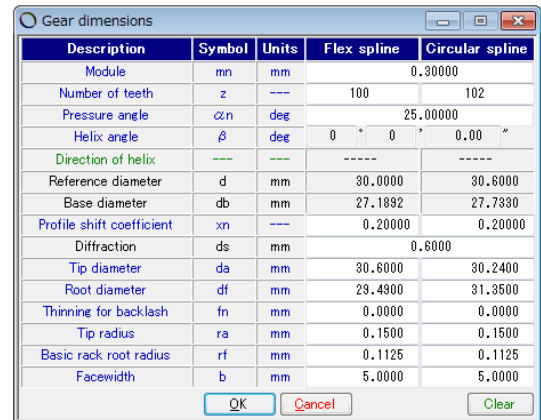Face width　　　　:　$0 < b < 1000$



Fig.47.4    Gear dimensions

### 47.5 Tooth profile calculation

The tooth profile calculation setup display is shown in Figure 47.5. Flex spline thickness, device outer diameter and number of divisions for tooth profile calculation set-up can be specified. After setting the values, click OK to proceed to tooth profile calculation.



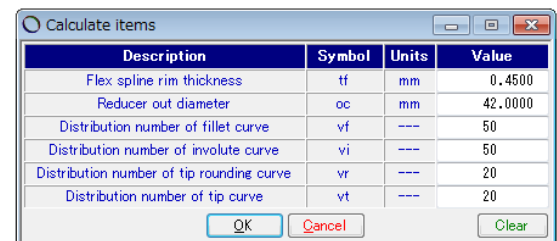Fig.47.5    Tooth Profile Set-up

### 47.6 Tooth profile modification

Generated flex spline tooth profile can be modified as shown in Figure 47.6. Tooth profile can be specified either by line of action or diameter, while the magnification of the tooth profile modification can be selected from 50, 100, 200, 300, 400, 500, 1000.

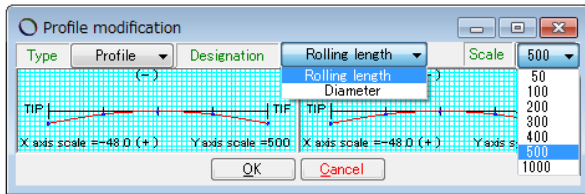204　　　　　　　　　　　　　AMTEC　www.amtecinc.co.jp

Fig.47.6　Tooth Profile Modification

The tooth profile modification can be applied by track-bar (shown at the center of Figure 47.7) and table-entry on the right hand side of the screen. In Figure 47.7, tooth profile is shown with 9 divisions, but it can be specified up to 50 divisions. Also, connection of the tooth profile can be spline (as shown by this example) or straight line connection. Moreover, numerical value can be entered into the template figure as shown in Figure 47.8.
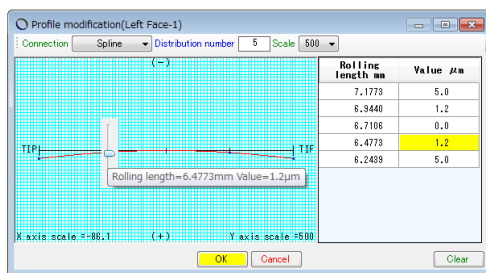

Fig.47.7　Profile modification setup
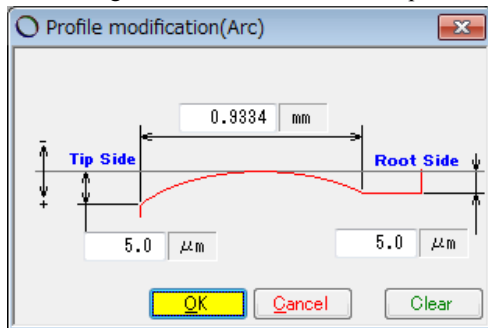

Fig.47.8　Profile modification setup (Template)

## 47.7　Tooth Profile Figure (2D)

Generated tooth profile can be displayed as shown in Figure 47.9. Enlarged sections [A] to [D] are shown in Figure 47.10. Also, distance can be measured as shown in Figure 47.11. Moreover, rotation-related tooth profile meshing can be checked by rotation ☐ Rotation in right hand corner of Figure 47.9.
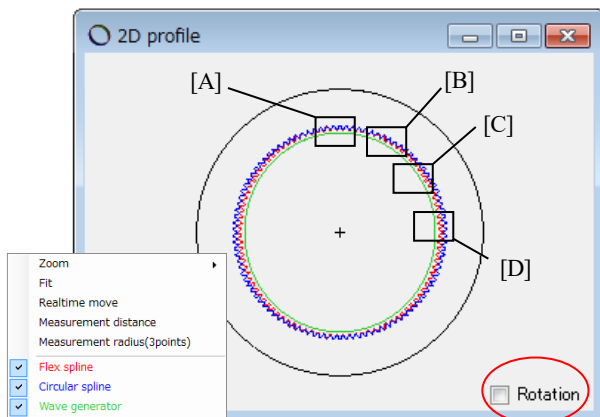

Fig.47.9　Tooth Profile & Supplemental Feature
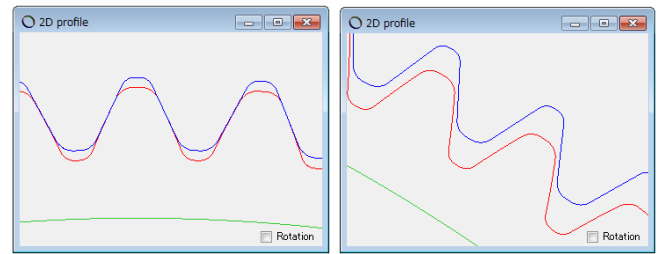

(a) Section[A]　　　　　　(b) Section [B]
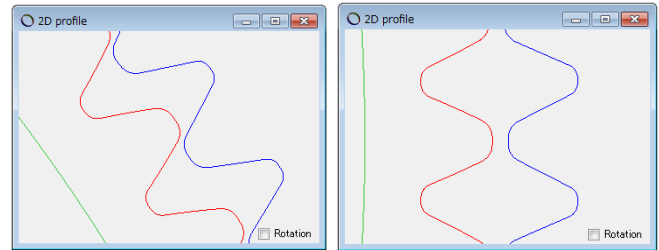

(c) Section [C]　　　　　　(d) Section [D]
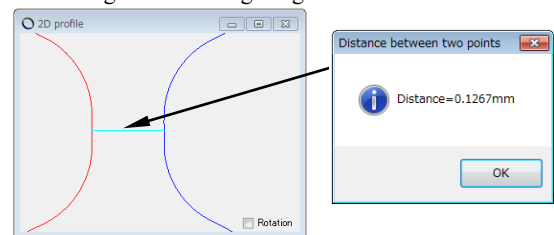Fig.47.10　Enlarged figure at each section


Fig.47.11　Distance measurement

## 47.8　Rendering

Tooth profile can be displayed as shown in Figure 47.12. This rendering can be enlarged, reduced and rotated by using ☐ Rotation .
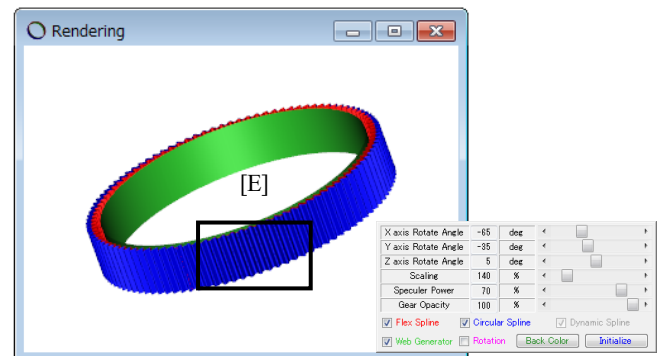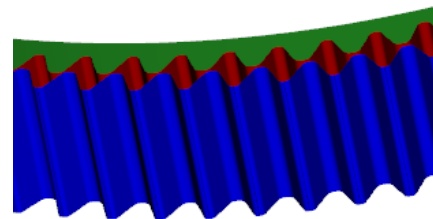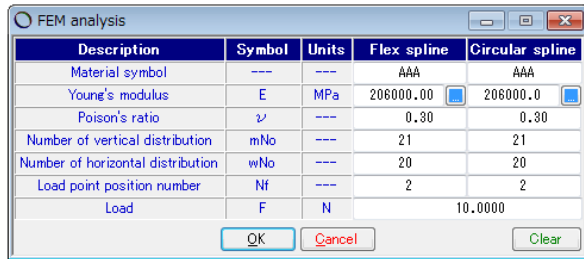

Fig.47.12　Rendering and supplemental form


Fig.47.13　Rendering enlargement[E]

## 47.9　FEM Analysis (2D)

When load is applied to teeth, root stress in the teeth can be calculated. FEM analysis setup display is shown in Figure 47.14, but in FEM analysis, material is symbols only, as it is based on longitudinal elastic modulus and Poisson's ratio. Vertical division number and horizontal

division number can be specified arbitrarily. The position of the load (2 in the example: the second node from the tooth tip), less than 2 in the vertical division number can be specified. For the load applied in this case, please set the value per designer's intension.


Fig.47.14　FEM analysis setup

FEM analysis results are shown in Figure 47.15 to 47.20. The analysis items are $\sigma x$ $\sigma y$ $\tau xy$ $\sigma 1$ $\sigma 2$ $\sigma$ $\delta d$ , and flex spline max main stress is found to be $\sigma_{1max}$=24.0MPa as shown in Figure 47.15. Also, displacement figure is shown in Figure 47.17 while stress summary (selective results only) is shown in Figure 47.18.
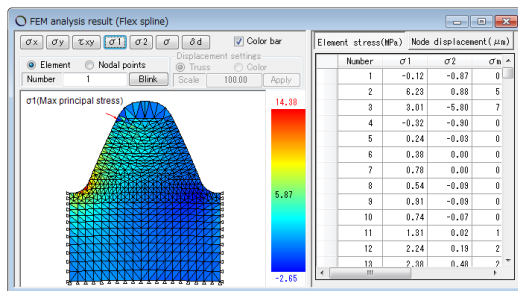

Fig.47.15　Flex Spline, $\sigma_{1max}$=14.4MPa
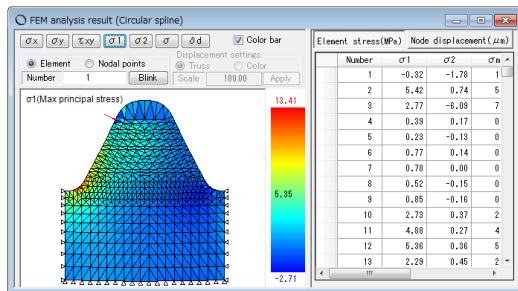

Fig.47.16　Circular spline, $\sigma_{1max}$=13.4MPa


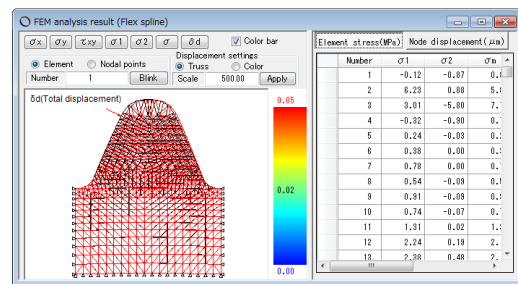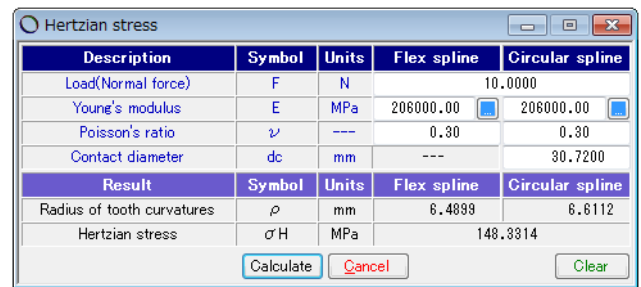Fig.47.17　Flex Spline displacement, $\delta$max=0.08μm


Fig. 47.18　Stress Summary (selective results)

## 47.10　Tooth contact stress

The calculation of Hertzian stress acting on tooth surface is shown in Figure 47.19. The purpose of this feature is to compare the Hertzian stress due to tooth profile differences, so the load acting on one tooth should be designer's intended value.
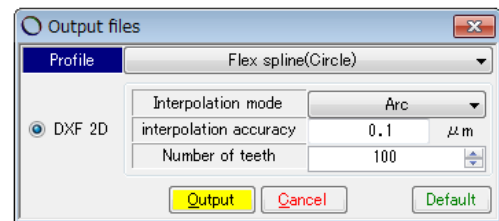

Fig.47.19　Hertzian Stress

## 47.11　Tooth profile output

The resulting F/S (perfect circle), F/S (ellipse) and C/S tooth profile output can be generated. F/S tooth profile output display is shown in Figure 47.20 while CAD drawing sample is shown in Figure 47.21.


Fig.47.20　F/S Tooth profile output setup


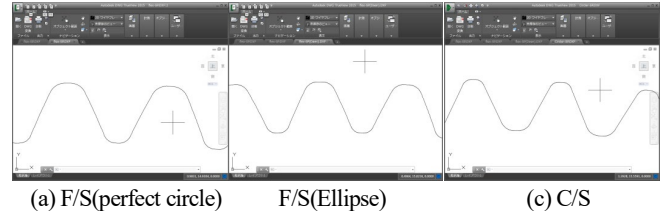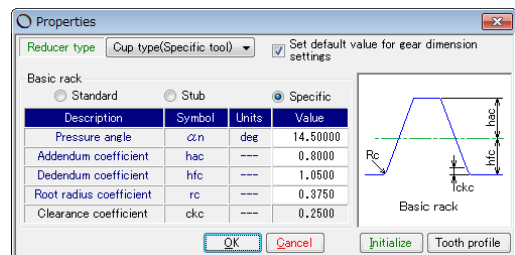(a) F/S(perfect circle)　　　F/S(Ellipse)　　　(c) C/S
Fig.47.21　CAD Drawing sample

## 47.12　Tooth profile made by hob
### 47.12.1　Hob dimensions

When hob blade profile is known, the hob profile can be defined by selecting cup Cup type(Specific tool) in reducer type property in Figure 47.32.


Fig.47.32　Property, Cup type (Special tool)

Hob dimension input sample is shown in Figure 47.33. In this sample, pitch=0.9425 is used to achieve module 0.3, but any value can be specified. After input entry, true hob profile can be displayed by clicking profile Tooth profile . The hob profile is based on gear front surface.
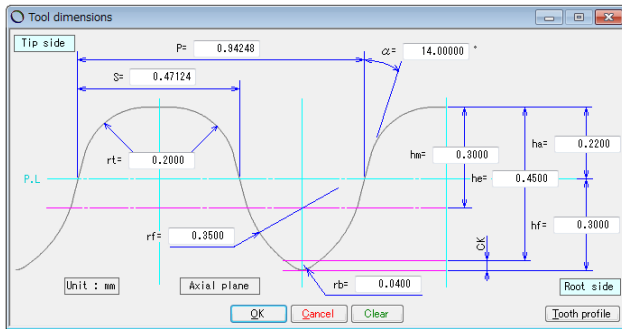
　　　　　　　　　　AMTEC　www.amtecinc.co.jp
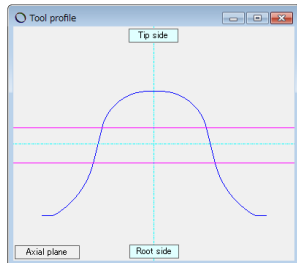
Fig.47.33　Hob dimensions


Fig.47.34　Hob profile

## 47.12.2　Gear Dimensions

In Figure 47.4, module was entered, but module, pressure angle and root diameter cannot be entered in Figure 47.35 because pitch is already entered in Figure 47.33 (background is grayed out).



| Description | Symbol | Units | Flex spline | Circular spline |
|---|---|---|---|---|
| Module | mn | mm | 0.30000 | |
| Number of teeth | z | --- | 100 | 102 |
| Pressure angle | $\alpha$n | deg | 14.00000 | |
| Helix angle | $\beta$ | deg | 0 ° 0 ' 0.00 " | |
| Reference diameter | d | mm | 30.0001 | 30.6001 |
| Profile shift coefficient | xn | --- | 0.0000 | 0.0000 |
| Diffraction | ds | mm | 0.60000 | |
| Tip diameter | da | mm | 30.4601 | 30.3001 |
| Root diameter | df | mm | 29.5601 | 31.2001 |
| Clearance | c | mm | 0.0700 | 0.0700 |
| Thinning for backlash | fn | mm | 0.0000 | 0.0000 |
| Facewidth | b | mm | 5.0000 | 5.0000 |
| Pin diameter | dp | mm | 0.5000 | 0.5000 |

Fig. 47.35　Gear dimensions

## 47.12.3　Tooth profile

After gear dimensions are specified, tooth profile calculation is performed based on rim thickness and outer diameter as shown in Figure 47.36.



| Description | Symbol | Units | Value |
|---|---|---|---|
| Flex spline rim thickness | tf | mm | 0.4500 |
| Reducer out diameter | oc | mm | 42.0000 |

Fig.47.36　Rim thickness and outer diameter

After tooth profile calculation is completed, transverse tooth profile can be displayed as shown in Figure 47.37. However, tooth profile modification cannot be performed when it is based on hob. Since C/S tooth profile is generated to mesh with F/S tooth profile, both gears are contacting without any gaps as shown in the enlarged view of [E] in

Figure 47.37. Also, there is 22μm of gap between tooth tips in [F], and there is 2.6μm of gap between teeth in [G]. The clearance is 0.07mm as shown in Figure 47.40, and F/S tip area is found to be arc-shape of 0.359mm as calculated in Figure 47.41. When gear is specified as over-pin, tooth profile and pin are contacting as shown in Figure 47.42, and F/S contact diameter is found to be $d_c$=33.01mm.
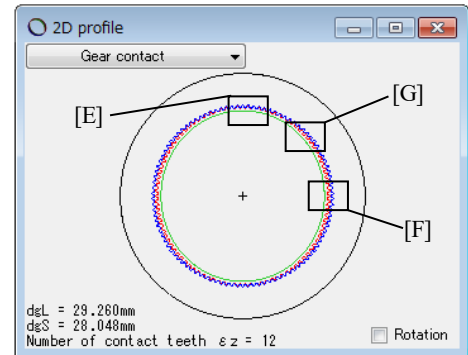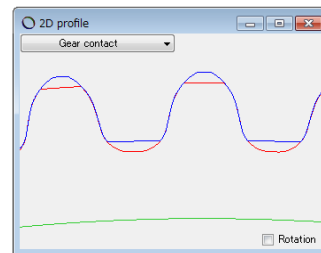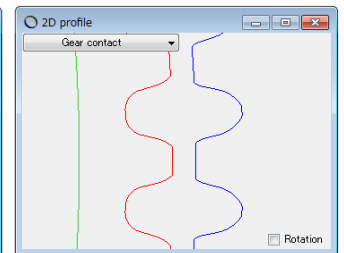


dgL = 29.260mm
dgS = 28.048mm
Number of contact teeth $\varepsilon$z = 12

Fig.47.37　Tooth profile



(a) [E] section　　　　(b) [F] section
Fig. 47.38　Enlarged tooth profile
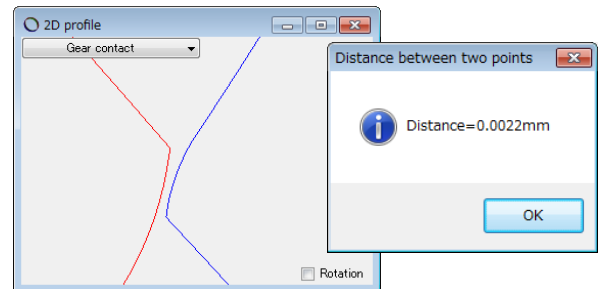

Distance=0.0022mm
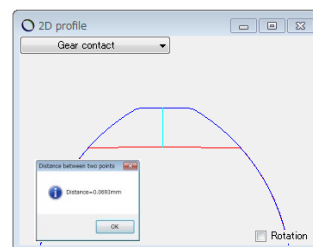
Fig.47.39　Enlarged tooth profile [G] section, distance measurement


Fig.47.40　Distance measurement　　Fig.47.41　Arc measurement
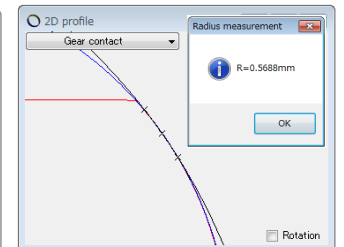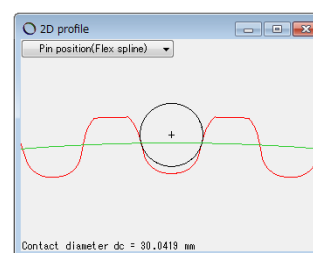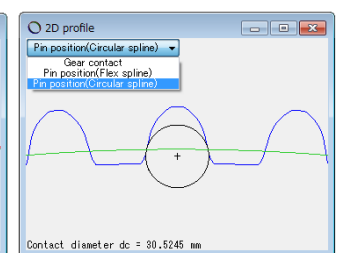


Contact diameter dc = 30.0419 mm　　Contact diameter dc = 30.5245 mm

(a) F/S & Pin　　　　(b) C/S & Pin
Fig.47.42　Pin positions

After tooth profile is generated, tooth profile rendering can be displayed as shown in Figure 47.43. This figure can be rotated just like 2D tooth profile, while changing observation angle in the supplemental form.
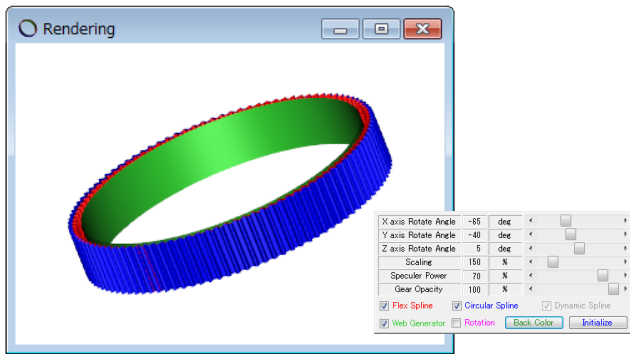

Fig.47.43　Rendering & supplemental form

## 47.12.4　FEM analysis & Hertzian stress

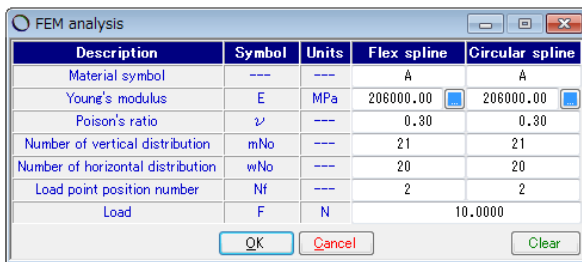Analysis results are shown in Fig.47.44 to Fig. 47.47.
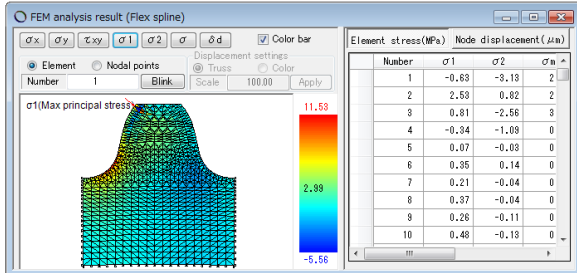

Fig.47.44　FEM analysis setup
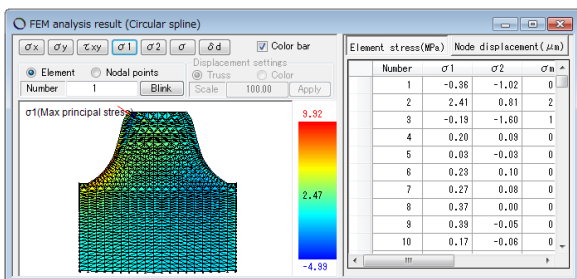

Fig.47.45　Flex spline, $\sigma_{1max}$=11.5MPa


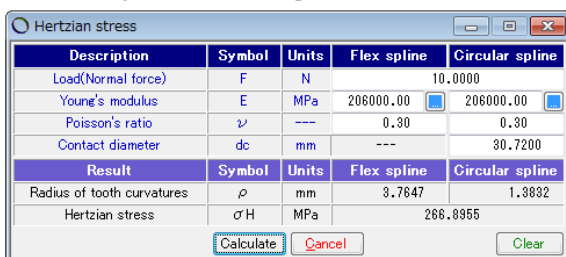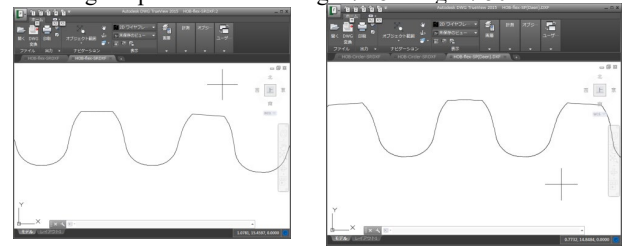Fig.47.46　Circular spline, $\sigma_{1max}$=472MPa


Fig.47.47　Hertzian stress

## 47.12.5　CAD drawing sample

Drawing samples are shown in Fig. 47.48 to Fig. 47.50.


F/S(circle)　　　F/S(ellipse)
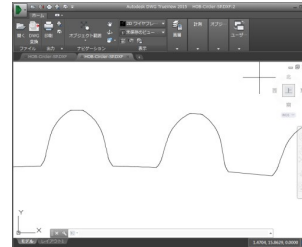Fig.47.48　CAD drawing sample,


Fig.47.50　CAD drawing sample, C/S

## 47.13　Design data management

Design data can be managed as shown in Figure 47.51, while it can be also imported and exported as shown in Figure 47.52.
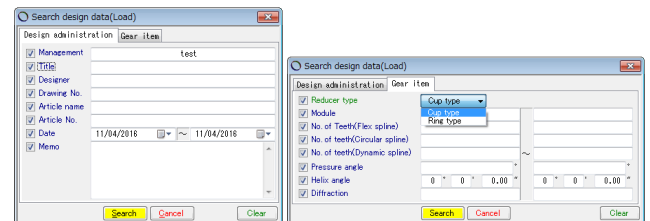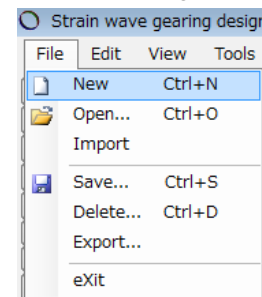

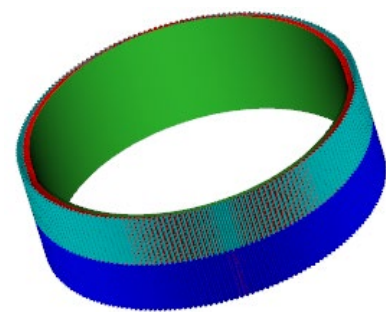Fig.47.51　Design data management


Fig.47.52　File management


Fig.47.53 Ring type, $m$=0.15, $z_1$=$z_3$=200, $z_2$=204

◆日本語版カタログは別途お申しつけください.