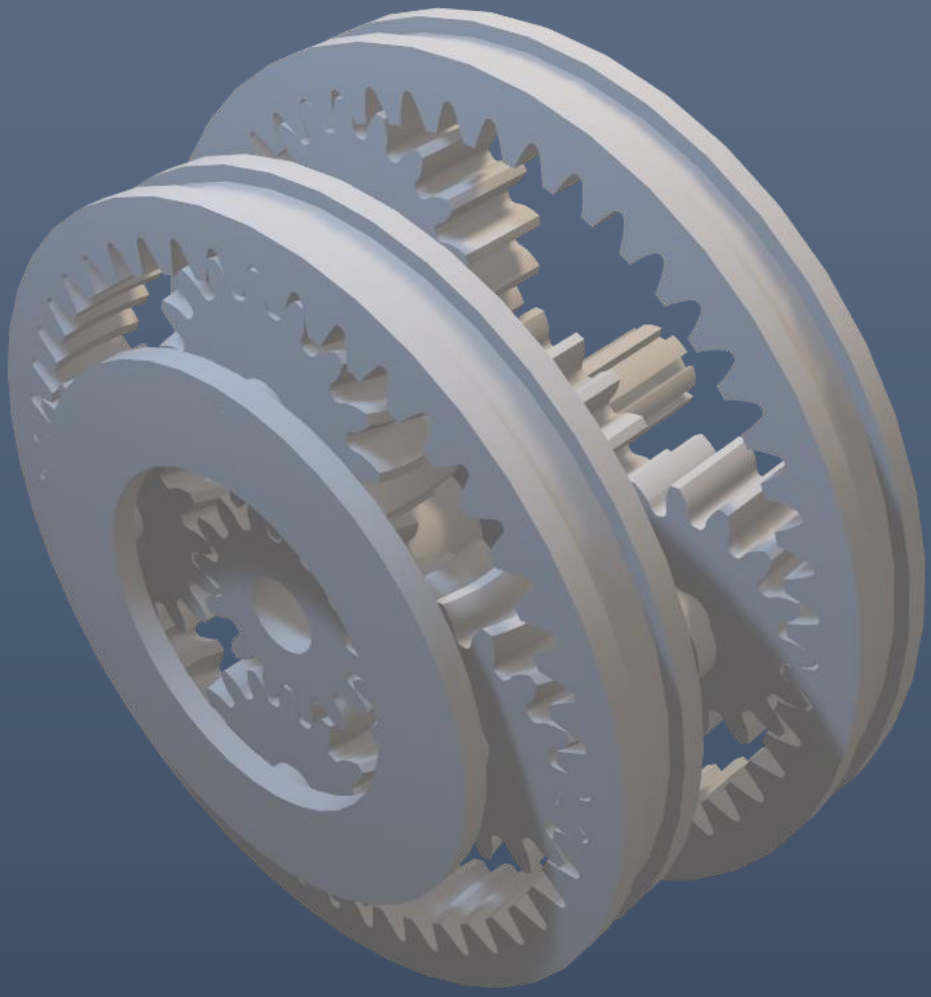
2021



Planetary Gear Maker

USER GUIDE

MARCIN SZYDŁOWSKI

SHWIVEL | https://www.shwivel.com

Table of Contents

DISCLAIMER 2

1. Description 3

Application 3

Parameters 4

UI parameters 4

Real-time calculated parameters 6

2. Installation and uninstallation 8

Windows 8

Mac OS 9

Problems 9

3. Running and managing the plugin 10

4. User interface 12

First run 12

Tooltips 13

Common elements 14

Tabs and specific functions 18

Main parameters 19

Modifications' tab 25

Option's tab 31

Information tab 36

5. Components' properties 37

Calculated parameters 37

Motion links' formulas 38

6. Additional information 45

Sensitive data 45

Runtime directory 45

Errors 45

Invoices 45

Discounts 46

Known problems 46

Support and contact 46

7. Table of figures 47

8. Table of tables 48

DISCLAIMER

Presented program should be used only for educational purposes or for creating 3D models for hobby additive printing or other proof of concepts. Models prepared by this program are very accurate and they are created due to mathematical formulas but the program itself does not perform any analysis such as checking strength, durability, or interferences.

Please make sure that the necessary validation and post-actions are done before releasing this onto production, especially when you want to make such elements by expensive CNC machines. Author of this plugin is not responsible for any damage to machines and injuries sustained due to improper use of models created by this program or due to independent modifications of the program.

Description of settings provided by the program are described later. Samples on how to perform interference, sections, and motion study is shown on the *YouTube* channel. There are also many other videos about basic operations like combining, cutting bodies, or modifying and post-processing them. If you have a specific case which needs further analysis, you can ask about it by the email in the *Support and contact* section at the end of this document.

1. Description

Application

The plugin creates planetary gears as a single stage or many stages for various set of parameters. Program lets to choose shape of teeth, system of module, dimensioning of module, units and much more. Document contains instruction how to install the plugin, full description of an interface, how to work with it and how to manage settings.

Parameters

Section describes parameters used in the program.

UI parameters

Table contains ranges of options accessed by the user interface.

Table 1. Ranges of options.

Name	Symbol	Range			
		(mm)	(in)	(°)	-
module	m	0.25 … 50	1/128 … 2		
diametral pitch	DP				0.25 … 160(1)
circular pitch	CP		0.1 … 20		
pressure angle	α			14.5 … 25	
teeth shape					straight, helical, double helical, herringbone, arc
module system					axial (A), normal (N)
Gear hand					RH, LH
helix angle	β			10 … 45	
groove width	w_{gr}	0 … t(2)			
groove depth	d_{gr}				
fillet radius	r_{hf}	0 … m(3)			
cutter radius	r_c	0.75t … 10000(4)	0.75t … 400(4)		
clearance factor	f_c				0.1 … 0.25(5)
thickness	t	0.5 … 2000	1/64 … 80		
sun teeth number	z_s				8 … 100
planet teeth number	z_p				6 … 210
planet's number	N				1 … n_p(6)
ring teeth numer	z_r				20 … 520
great diameter	d_g	0 … 10000(7)	0 … 400(7)		
profile shifting type					zero, auto, manual

sun profile shift factor	x_s				-1 … 1
planet profile shift factor	x_p				
ring profile shift factor	x_r				
sun backlash[8]	j_s	-0.2 … 0.2	-1/32 … 1/32		
planet backlash	j_p				
ring backlash	j_r				
sun taper factor	f_{ts}				0 … 0.5[9]
planet taper factor	f_{tp}				
relief type[10]					tangent arc, line
sun relief width	w_{rs}	0 … $0.45s_a$			
sun relief height	h_{rs}	0 … < $0.5m$			
planet relief width	w_{rp}	0 … $0.45s_a$			
planet relief height	h_{rp}	0 … < $0.5m$			
edge finishing type					height-width, height-angle, equal size, radius
edge finishing height	h_{ef}	0 … m[11]			
edge finishing width	w_{ef}	0 … $\min\{0.5w, m\}$[11]			
edge finishing angle	γ_{ef}			5 … 40	
edge finishign radius	r_{ef}	0 … $\min\{0.5w, m\}$[11]			
edge finishing sides					right, left, both
sun hole diameter	d_{hs}	0 … 1000[12]	0 … 40[12]		
planet hole diameter	d_{hp}				
stage distance	l_s	0 … 1000[13]	0 … 40[13]		
displayed units					mm, in
module dimensioning					m, DP, CP
angle format					decimal, HMS
numbers precision	$pr.$				0 … 6

(1) all non-integer values within the range are possible,

(2) available for double-helical sun and planet gears; depends on thickness of gear and hole diameter if applied,

(3) available for herringbone gears,

(4) available for arc gears,

(5) in case of ring gear or gears with very small or even non existing root area clearance can be smaller because of fillet,

(6) limited by number of teeth of gears and case when they are interfere with each other,

(7) available for ring gear; limited by root diameter and depth of groove if gear is double-helical,

(8) all backlashes are normal,

(9) available for sun and planets,

(10) available for sun and planets and when there are no other modifications ($x = j = f_t = 0$),

(11) values can be greater but then teeth have no head surfaces,

(12) available for sun and planets; limited by root diameter and depth of groove if gear is double-helical,

(13) not available for first stage.

Real-time calculated parameters

When settings are changed, they automatically trigger calculation of radial parameters of gears. These parameters are displayed in the *Dimensions* group which is described in the *Main parameters – gear* subsection. Table below describes meaning of these parameters.

Table 2. Real-time calculated parameters.

Group	Symbol	Meaning
Sun gear	d	pitch diameter
	d_w	working pitch diameter
	d_{wps}	working pitch diameter between sun and planet
	d_b	base diameter
	d_a	outside diameter
	d_f	root diameter
	α_{wsp}	working pressure angle between sun and planet
Sun top land parameters	α_a	outside pressure angle
	θ_a	half of top land angle
	s_a	top land thickness
Planet gear	d	pitch diameter
	d_w	working pitch diameter
	d_{wps}	working pitch diameter between planet and sun
	d_{wpr}	working pitch diameter between planet and ring
	d_b	base diameter
	d_a	outside diameter
	d_f	root diameter
	α_{wsp}	working pressure angle between sun and planet
	α_{wpr}	working pressure angle between planet and ring
Planet top land parameters	α_a	outside pressure angle
	θ_a	half of top land angle
	s_a	top land thickness
Ring gear	d	pitch diameter
	d_w	working pitch diameter
	d_{wpr}	working pitch diameter between planet and ring
	d_b	base diameter
	d_a	outside diameter
	d_f	root diameter
	d_g	great diameter
	α_{wpr}	working pressure angle between planet and ring

Ring top land parameters	α_f	outside pressure angle
	θ_f	half of top land angle
	s_f	top land thickness
Center distance	a_x	center distance
	a_{xsp}	center distance between sun and planet(1)
	a_{xpr}	center distance between planet and ring(1)

(1) different than a_x for automatic or manual profile shifting.

2. Installation and uninstallation

Before you download the installer, please switch to the proper OS which you use. Buttons shown below should be visible on the product's website under the title of the plugin:

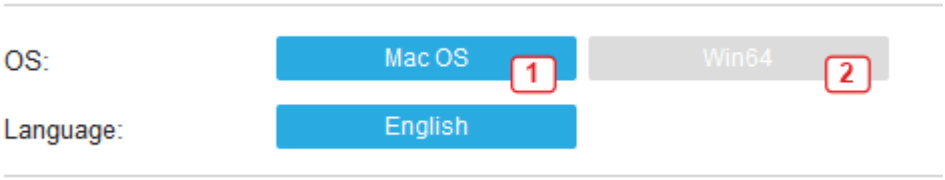


Figure 1. Active OS for downloading installer - Mac OS in this case.

Chosen system is marked by the blue color so in this case a Mac OS **(1)** is active. For choosing Windows you need to click the gray button **(2)**.

Mac OS installer should have **.pkg* format whereas Windows installer **.msi*.

Windows

Installation

Installer should run automatically when you downloaded it from Autodesk® App Store. If not, you need to run it by double-click or selecting it and pressing *Enter*.

Installer is not digitally signed so file, especially when there is a new version of the plugin, can trigger Antiviruses or UAC. When such information about non-trusted file is displayed, try to proceed the operation by clicking *More options* button or make the security rule for the program.

Uninstallation

Exit the Fusion 360™ if you are currently running it and:

- rerun the plugin's installer and select the *Uninstall* button.

or

- go to the *Control Panel\Programs\Programs and Features*, find the plugin, select it, and click the *Uninstall* button.

Mac OS

Installation

Installer should run automatically when you downloaded it from Autodesk® App Store. If not, you need to run it by double-click or selecting it and pressing *Enter*.

Uninstallation

Exit the Fusion 360™ if you are currently running it, go to the *./ApplicationsPlugins* folder and select the app bundle of the plugin, then:

- then drag the bundle to the *Trash* or right-click and select *Move to Trash*

or

- select the app bundle and then hit *Command+Delete* to move the app to *Trash*.

Problems

- You have Windows but accidentally downloaded installer for Mac OS

    1. Unpack the *Content* folder from the **.pkg* file – it can be done, for example, by *7-Zip* package manager;
    2. Change the name of the *Content* folder to *Pluginname*;
    3. Move this folder to the *C:\Users\[YOUR USER NAME]\AppData\Roaming\Autodesk\ApplicationPlugins*
    4. Run the plugin[1] or restart Fusion 360™.

    Note: this cannot be done in Mac OS.

- You have Mac OS but plugin is not visible after installation

    1. Unpack the *Content* folder from the **.pkg* file – it can be done, for example, by *Suspicious* package manager;
    2. Change the name of the *Content* folder to *Pluginname*;
    3. Copy it to the *~/Library/Application Support/Autodesk/Autodesk Fusion 360/API/AddIns*
    4. Run the plugin or restart Fusion 360™.

[1] Next section explains how to do this.

3. Running and managing the plugin

Plugin is designed to work with the newest version of Fusion 360™ and works only with tabbed UI. When installation went properly, plugin should be shown in the *GEARS* **(1)** panel of *SHWIVEL* **(2)** tab of *DESIGN* **(3)** workspace:

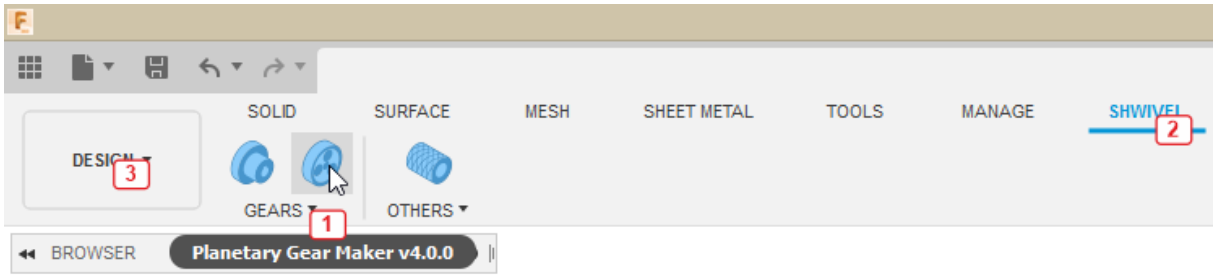


Figure 1. Where to find the plugin.

Then, plugin is ready to work and for run it, you need to click the icon or position in the *OTHERS* panel.

If the plugin is not visible but you know the installation went without errors, first check if the plugin is accessed by the Fusion 360™ and try to start it manually. For managing plugins, you need to run the *ADD-INS* **(1)** window of the *TOOLS* **(2)** tab as shown in the next image. By clicking the name of the plugin in *Add-Ins* **(3)** tab you can stop it **(5)**, run it **(6)** or turn off **(4)** if you don't want to start it automatically with the Fusion 360™. You can get the location of the main script **(8)** by expanding the *Details* **(7)** button. This location can also be opened by pressing the *Plugin folder* **(98)** button which is described in the *Information tab* subsection.

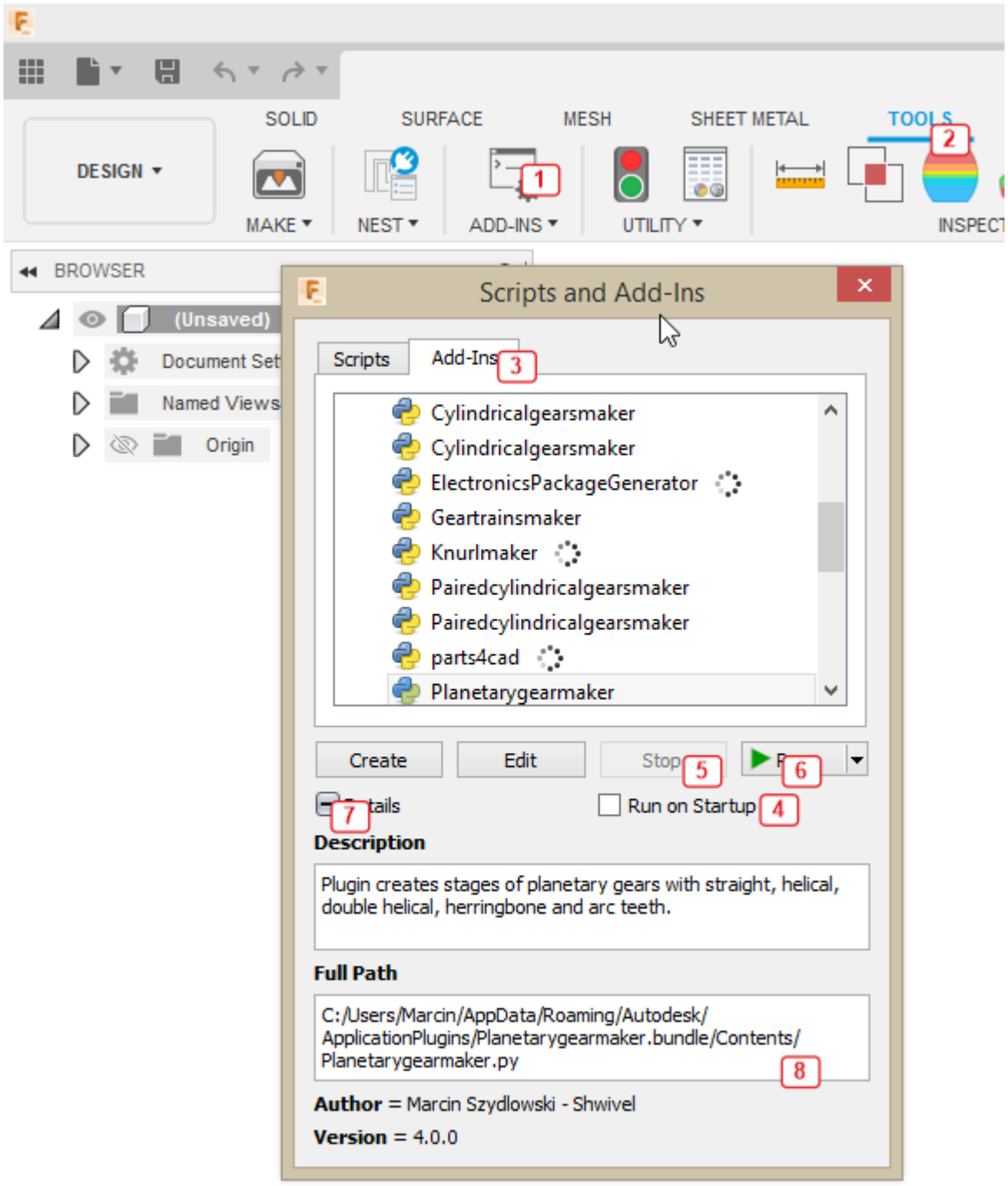


Figure 2. Managing the plugin. Add-in should be visible in the My Add-Ins tree.

4. User interface

This section describes functions available on user interface (UI) and how to work with the plugin.

First run

When you run the program for the first time, window should look similar to this:

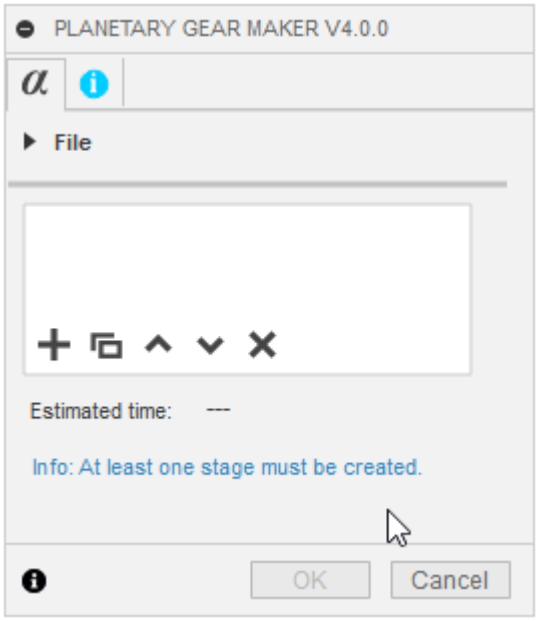


Figure 3. Plugin's window at first run.

At the default, size of the window is the same as other plugins or tools available in Fusion so it may be very narrow and cause difficult access to settings. To change this, window can be resized by dragging the lower-right corner as shown in the next image.

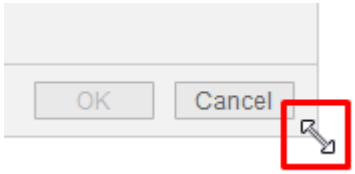


Figure 4. Resizing window.

Tooltips

Most of the inputs contains tooltips and images for displaying quick help-balloons explaining the meaning of parameter or setting. For showing it, mouse cursor must be hovered for a second over the input. Image shows an example of this feature for module:

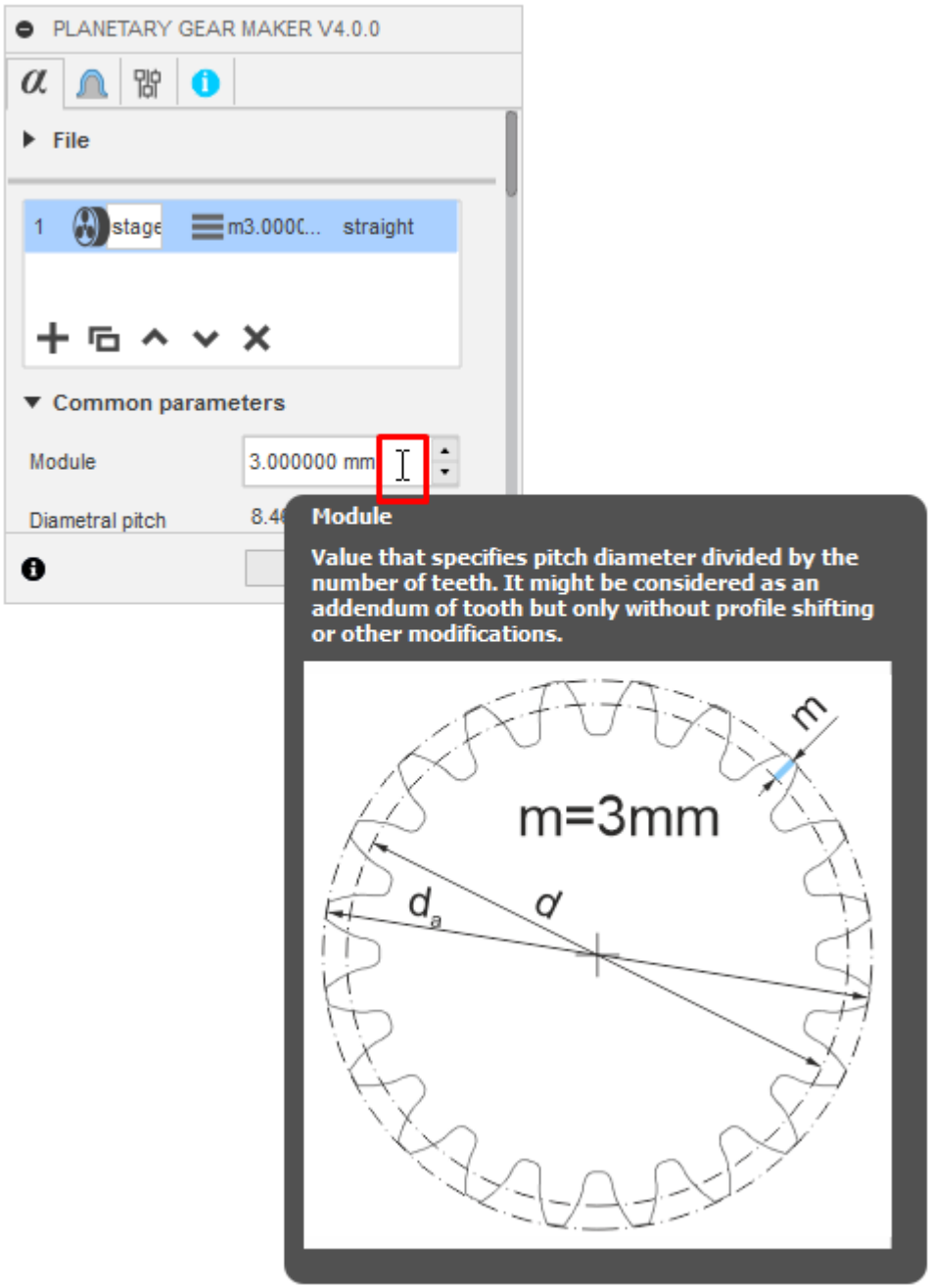


Figure 5. An example of toolclip shown when the mouse cursor is hovered over the input.

Common elements

Common elements of UI are visible and accessed always[2].

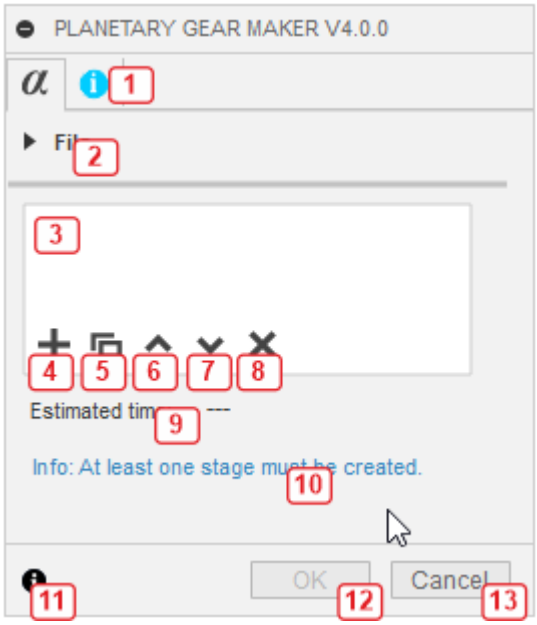


Figure 6. Common elements.

tabs strip **(1)** – used for splitting settings and organize them as groups.

File **(2)** – menu which provides saving, loading and reset setting which means fast delete (clear) all created stages.

Figure 7. File group.

Save **(14)** – saves settings as JSON file to the chosen location.

Load **(15)** – loads settings.

Reset **(16)** – deletes all stages.

File name **(17)** – path to the file which was loaded[3].

[2] Messages **(10)** are usually hidden. It is described later.
[3] When there are unsaved changes, this text is market by *(*)*

table of stages **(3)** – list of all stages.

Add stage **(4)** – clicking this button creates a new stage[4].

Copy stage **(5)** – copies selected stage and add it at the end of list.

Move up **(6)** – moves selected stage one position up.

Move down **(7)** – moves selected stage one position down.

Delete stage **(8)** – deletes selected stage.

Estimated time **(9)** – shows estimated time needed for creating stages; the more runs, the better estimates; when program cannot find similar settings, no estimation is displayed.

Messages **(10)** – shows information why something is happening or can not be done; messages that relate to stages are visible only when that stage is selected; there are three types of messages:

information **(blue color)** – only one information in this plugin that the list of stages is empty; it prevents the process from being started,

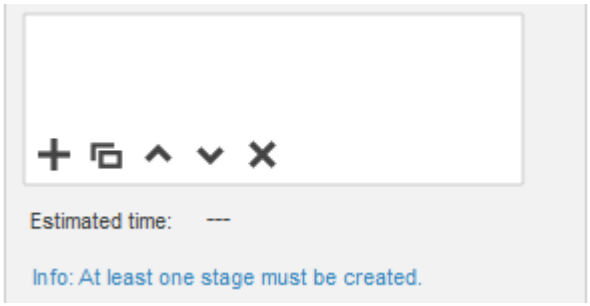


Figure 8. Information.

[4] Newly created stage has always default values and is placed at the bottom of the list.

warning **(gold)** – describes that the parameters may disqualify stages to use, ex. too many planets to be placed evenly without interference with the ring gear's teeth, but still possible to manufacture,

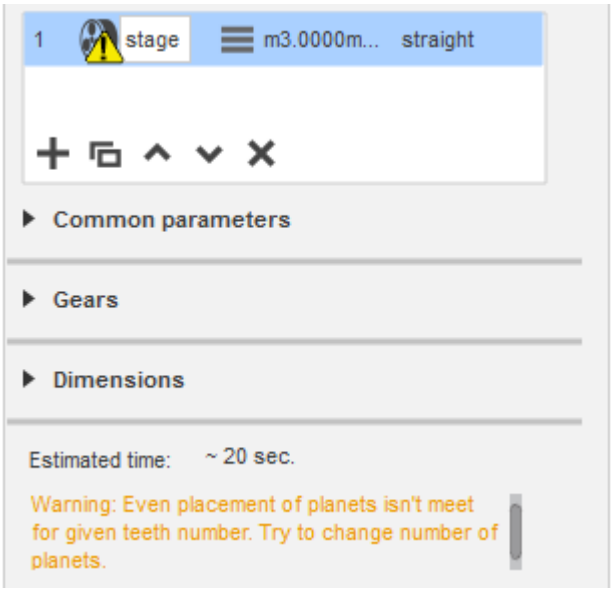


Figure 9. Warning – placement of planets causes interference with the ring gear's teeth, but process can be started.

error **(red)** – describes the error which can be related with the specific stage (wrong configuration of settings – marked by the exclamation mark) or range of parameter; if the error is related with the range of parameter, the wrong value of parameter will be erased when other stage is selected; stage error prevents further actions till error will be fixed, even when the invalid stage is not selected:

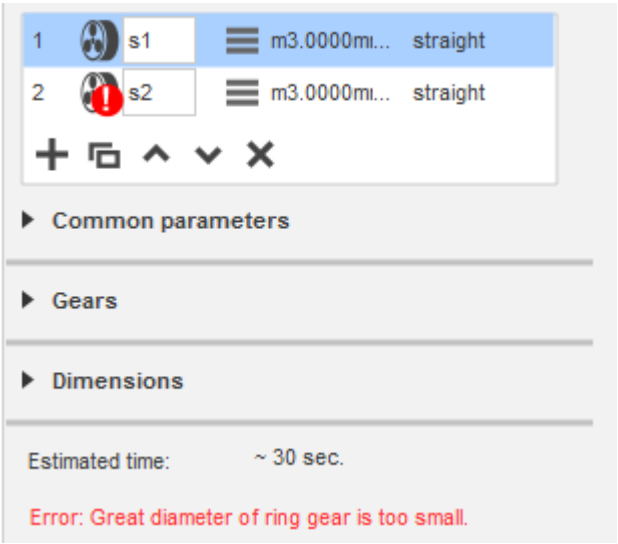


Figure 10. Error – invalid stage prevents start of the process.

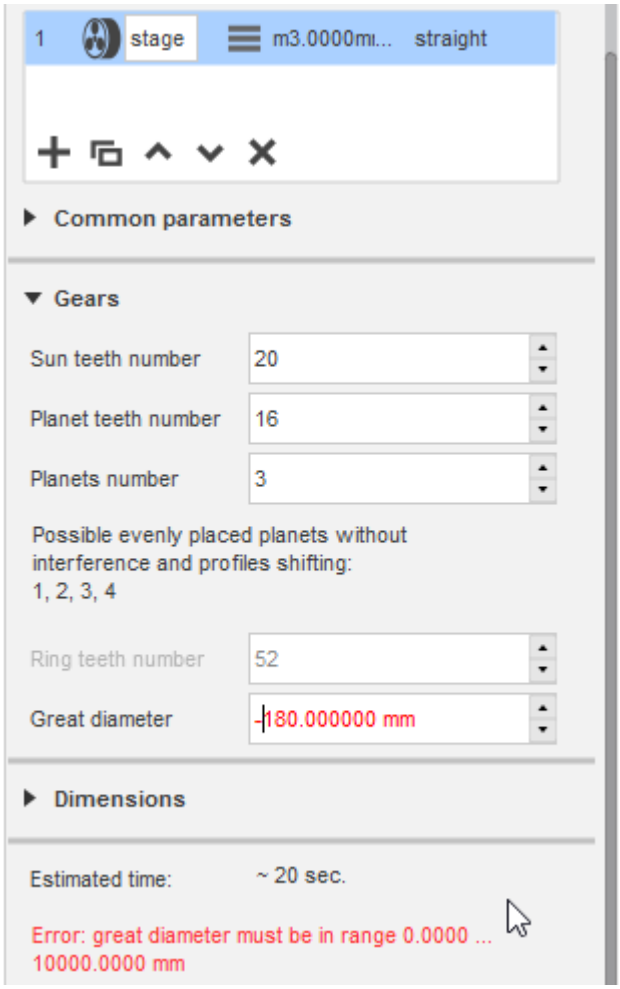


Figure 11. Error – invalid value prevents start of the process.

Information **(11)** – opens basic documentation in the default web browser.

OK **(12)** – starts creating stages; it is active when list is not empty, and all stages are valid; all invalid stages are marked by exclamation marks.

Cancel **(13)** – cancels changing settings and temporary hides the plugin's window.

Tabs and specific functions

Interface is divided into four tabs, but two middle ones are invisible when the list of stages is empty.

Figure 12. Tabs.

Main parameters **(18)** – settings of most important parameters of stages.

Modifications **(19)** – additional settings like profile shifting, tapering, backlash, etc.; it is visible when stage is selected.

Options **(20)** – units, decimal places, module dimensioning, design, joints, axis, preview; it is visible when stage is selected.

Information **(21)** – documentation, links, checking updates.

Main parameters

Parameters are displayed when the stage **(22)** is selected.

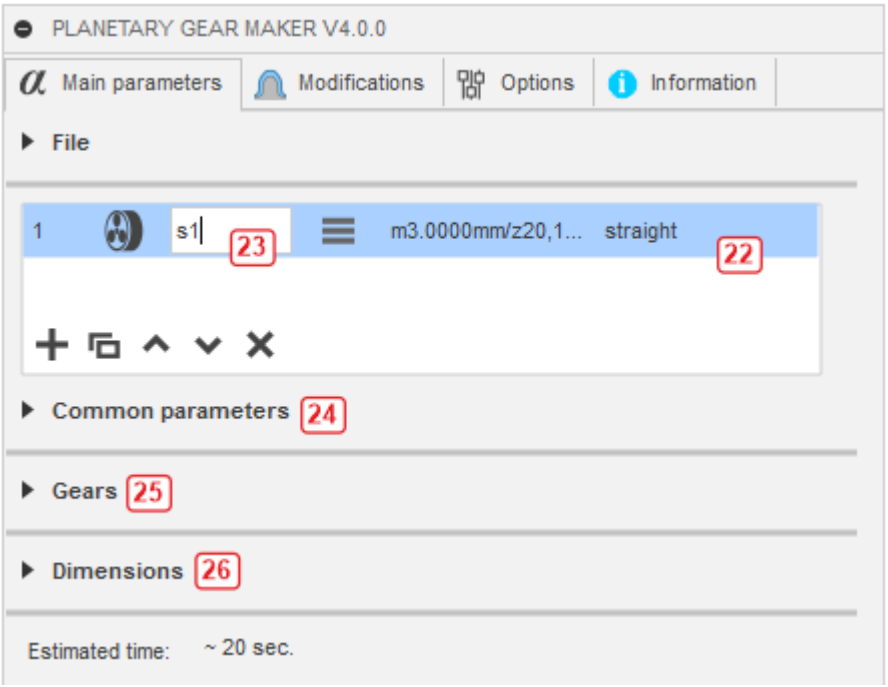


Figure 13. Main parameters.

Name of stage **(23)** – field for setting stage's name.

Common parameters **(24)** – main and other parameters common for sun, planets, and the ring gears within a stage.

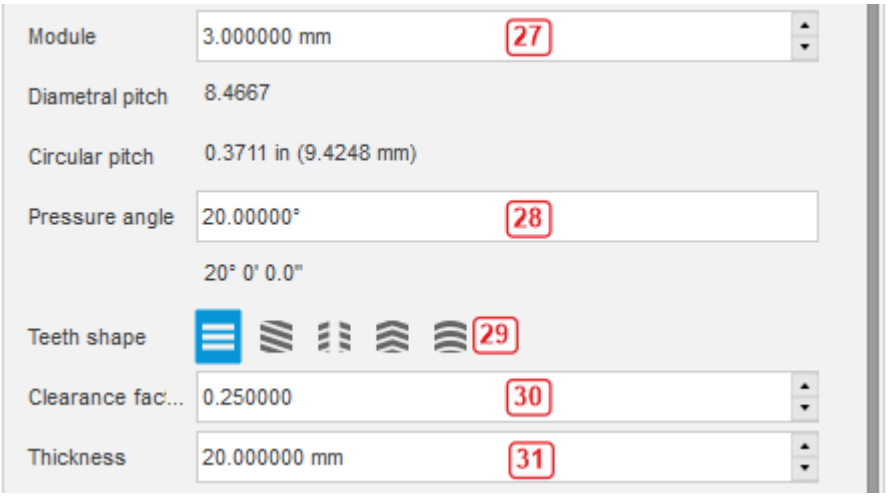


Figure 14. Common parameters.

Module **(27)** – module (m), in millimeters or inches[5]; corresponding diametral pitch (DP) and circular pitch (CP) are displayed below this input; there is also possible to switch dimensioning between module, DP, CP[6].

Pressure angle **(28)** – pressure angle (α); it can be entered as decimal or HMS format[7]; corresponding HMS or decimal value is displayed below the input.

Teeth shape **(29)** – shape of teeth: straight (default), helical, double helical, herring-bone, arc.

Clearance factor **(30)** – factor (f_c) which denotes amount of space between root and head of teeth of matched gears; clearance (c) equals $f_c m$.

Thickness **(31)** – thickness (t) of all gears in selected stage.

Options for helical gears

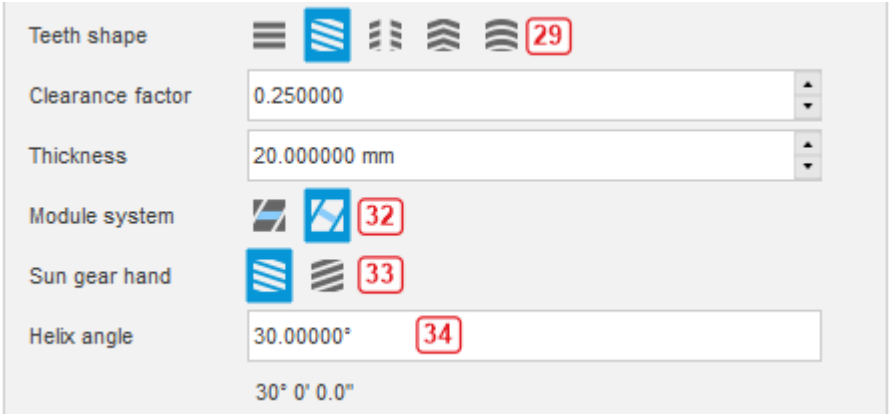


Figure 15. Options for helical gears

[5] All scalar inputs with defined units can be switched between millimeters and inches.
[6] Both switching between units and dimensioning is described later.
[7] All angular inputs can be switched between decimal or HMS format.

Module system **(32)** – module system of gear: axial (A), normal (N - default).

Sun gear hand **(33)** – direction of teeth of the sun gear: right (RH - default), left (LH); direction of planets and ring gears' teeth is opposite.

Helix angle **(34)** – helix angle of teeth.

Options for double-helical gears

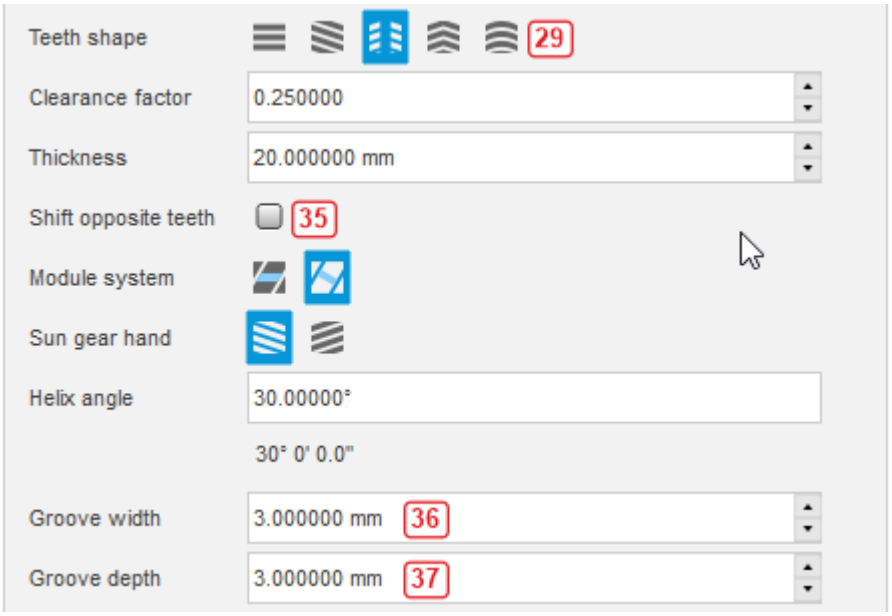


Figure 16. Options for double-helical gears.

Shift opposite teeth **(35)** – when this option is checked, teeth on opposite sides are placed alternately.

Groove width **(36)** – width of groove (w_g).

Groove depth **(37)** – depth of groove (d_{gr}).

Options for herringbone gears

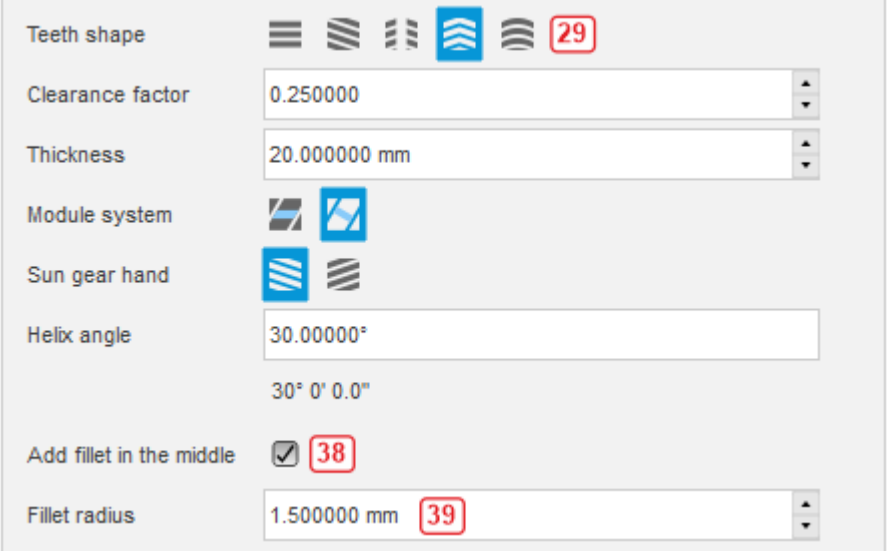


Figure 17. Options for herringbone gears.

Add fillet in the middle **(38)** – when this option is checked, transition in the middle part of tooth is smooth.

Fillet radius **(39)** – radius of fillet (r_{hf}).

Options for arc gears

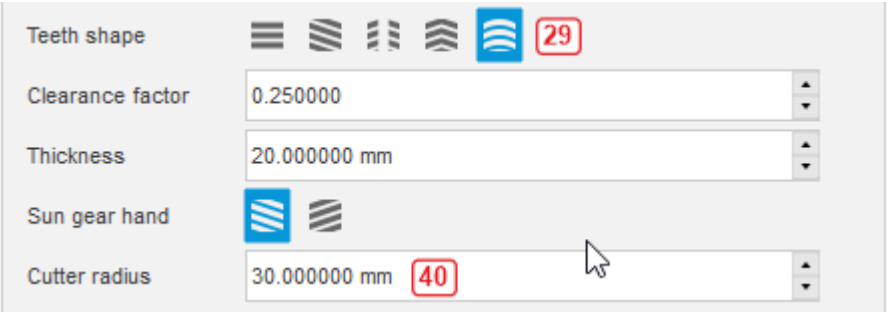


Figure 18. Options for arc gears.

Cutter radius **(40)** – radius of cutter (r_c).

Gears **(25)** – settings for number of teeth, planets, and great diameter of the ring gear.

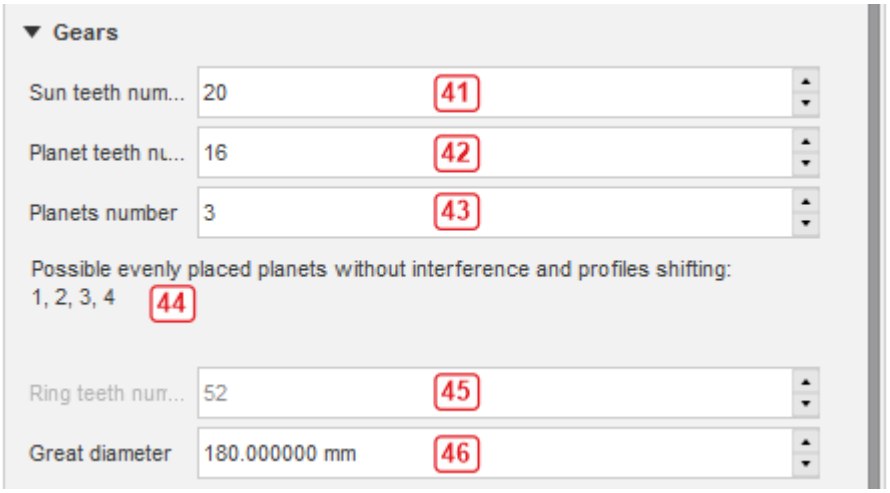


Figure 19. Gears' group.

Sun teeth number **(41)** – number of sun gear's teeth (z_s).

Planet teeth number **(42)** – number of planet gear's teeth (z_p).

Planets number **(43)** – number of planets (N).

Possible evenly placed planets number **(44)** – information about possible numbers of planets for given configuration of sun, planet and ring gears' teeth which guarantee no interference with the ring gear.

Ring teeth number **(45)** – number of ring gear's teeth (z_r); it's enabled only for *Manual ring teeth number* mode of the profile shifting[8].

Great diameter **(46)** – great diameter of the ring gear (d_g).

Dimensions **(26)** – radial dimensions of gears in selected stage; this section is visible on every tab; meaning of symbols is described in the *Real-time calculated parameters*.

[8] Profile shifting is described later in the subsection about modifications.

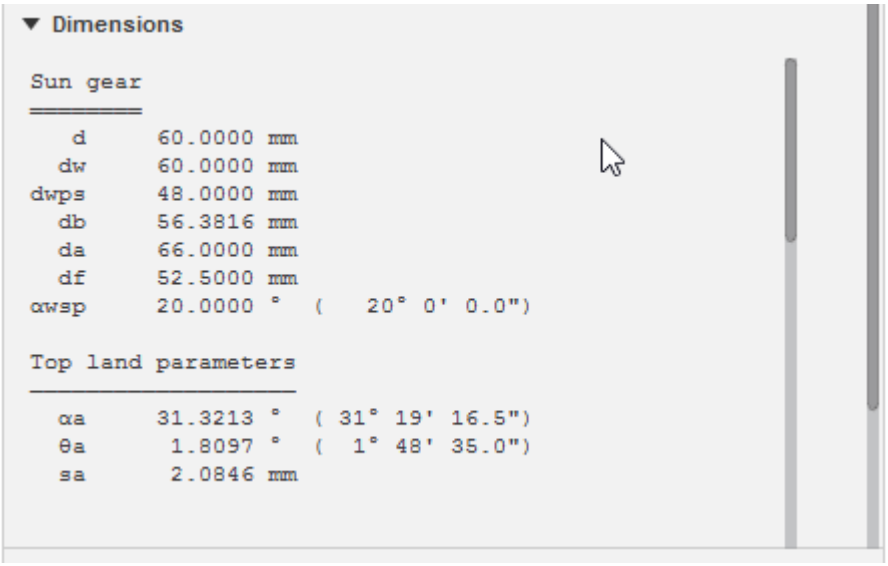


Figure 20. Real-time calculated parameters.

Modifications' tab

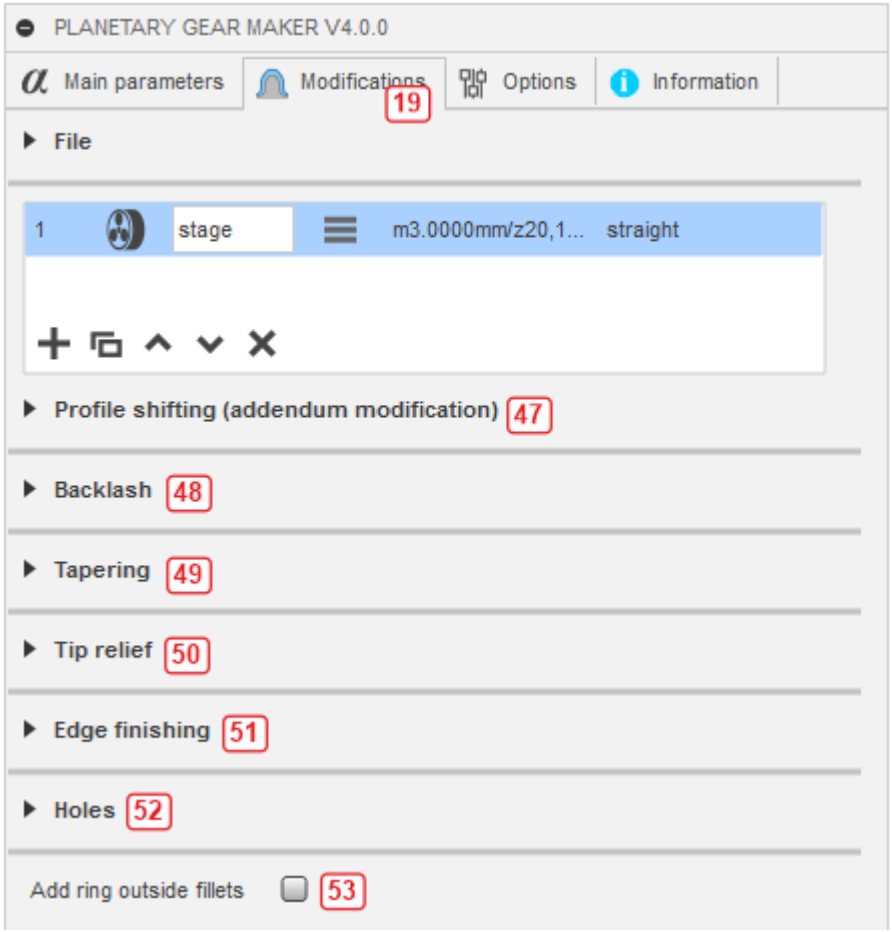


Figure 21. Modification's tab.

Profile shifting (addendum modification) **(47)** – modifications of teeth's profiles.

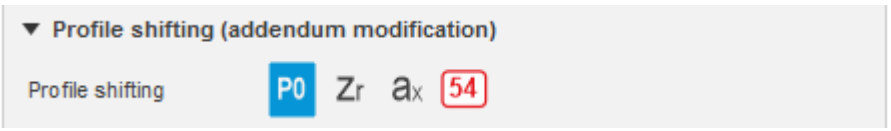


Figure 22. Profile shifting modes – P0.

Profile shifting **(54)** – mode of profile shifting; values of coefficients cannot be changed manually:

- *P0* **(x_s, x_p, x_r = 0)** – no profile shifting is applied to the gears within a selected stage and number of ring gear's teeth are minimal and cannot be changed.
- Z_r **(manual ring teeth's number)** – user can change the number of ring gear's teeth (at most 2 teeth more than minimal value) and coefficients and center distance **(55, 56, 57, 58)** are calculated automatically.

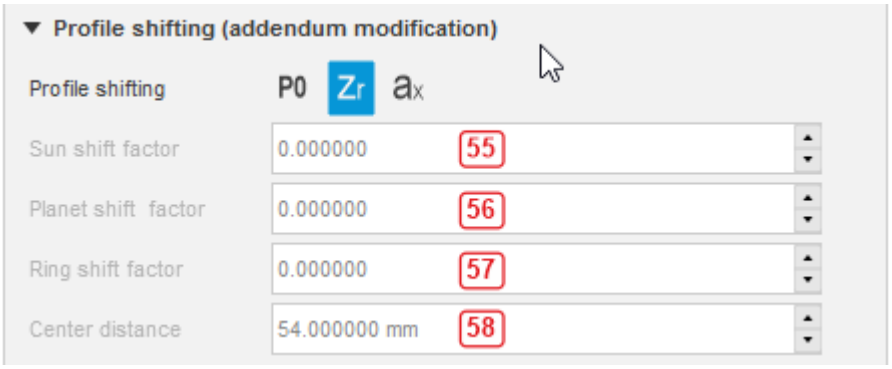


Figure 23. Profile shifting modes – z_r.

- a_x **(manual center distance)** – user can change the center distance **(58)** and coefficients are calculated automatically.

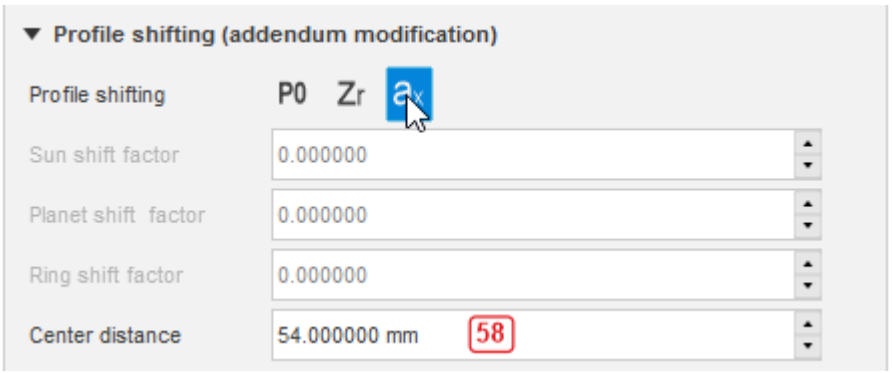


Figure 24. Profile shifting modes – a_x.

Backlash **(48)** – normal backlashes.

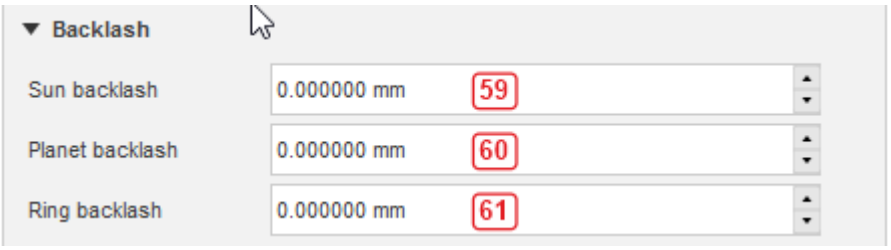


Figure 25. Backlashes.

Sun backlash **(59)** – backlash of sun gear (j_s).

Planet backlash **(60)** – backlash of planet gears (j_b).

Ring backlash **(61)** – backlash of ring gear (j_r).

Taper factor **(49)** – taper factors of sun and planets gears.

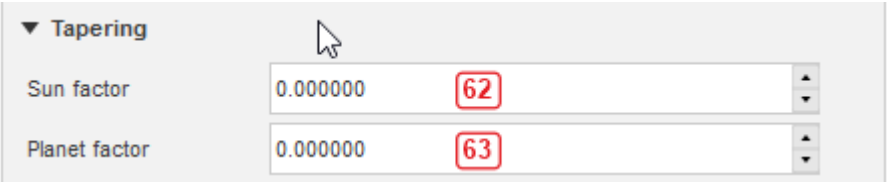


Figure 26. Taper factors.

Sun factor **(62)** – taper factor of sun gear (f_{ts}).

Planet factor **(63)** – taper factor of planet gears (f_{tp}).

Tip relief **(50)** – tip relief of sun and planet gears.

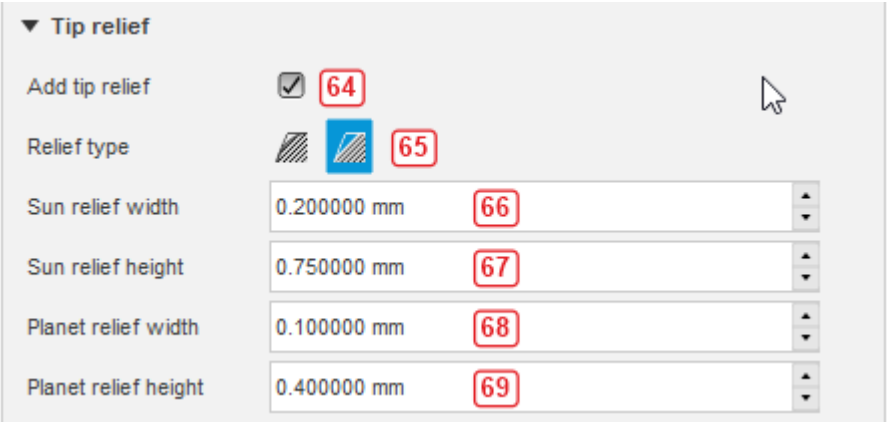


Figure 27. Tip reliefs.

Add tip relief **(64)** – if this option is checked, tip relief is applied; available only when profile shift factor, backlash and taper factor are 0.

Relief type **(65)** – type of relief: smooth (arc tangent to the flank) or line (default).

Sun relief width **(66)** – width of sun gear's relief (w_{trs}).

Sun relief height **(67)** – height of sun gear's relief (h_{trs}).

Planet relief width **(68)** – width of planet gear's relief (w_{trs}).

Planet relief height **(69)** – height of planet gear's relief (h_{trs}).

Edge finishing **(51)** – modifications of side edges of teeth.

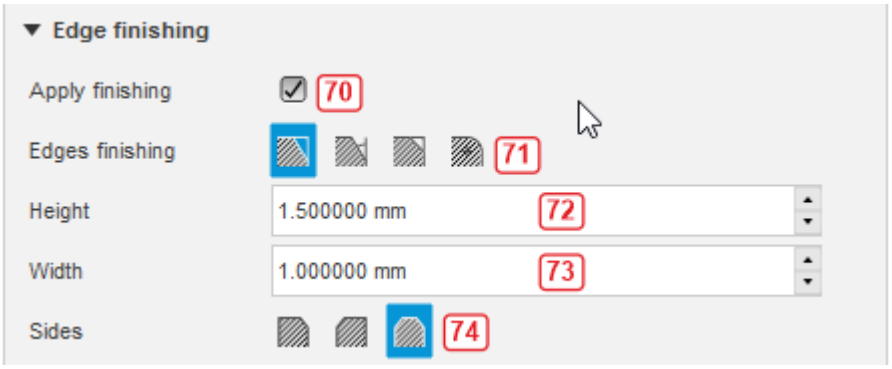


Figure 28. Edge finishing: height-width.

Apply finishing **(70)** – if this option is checked, side edges of gear are finished.

Edges finishing **(71)** – type of finishing: height-width (default), height-angle, equal-size, radius.

Height **(72)** – height of finishing (h_{ef}).

Width **(73)** – width of finishing (w_{ef}); available only for height-width mode.

Sides **(74)** – sides of finishing: right, left, both (default).

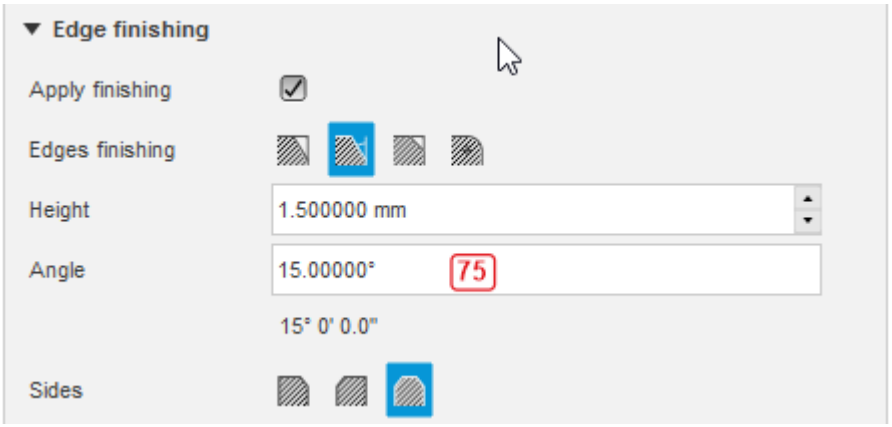


Figure 29. Edge finishing: height-angle.

Angle **(75)** – angle of finishing (a_{ef}).

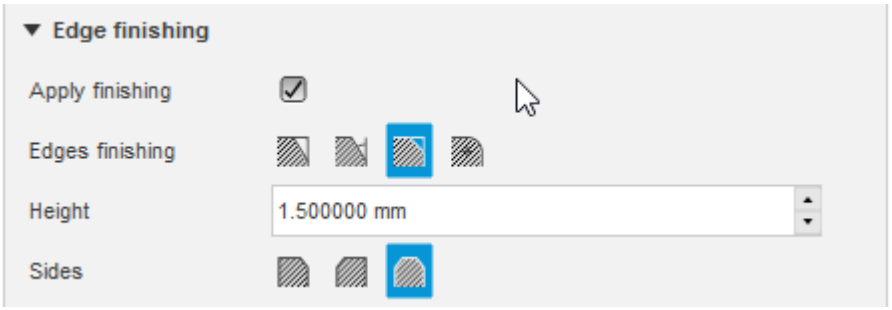


Figure 30. Edge finishing: equal sides.

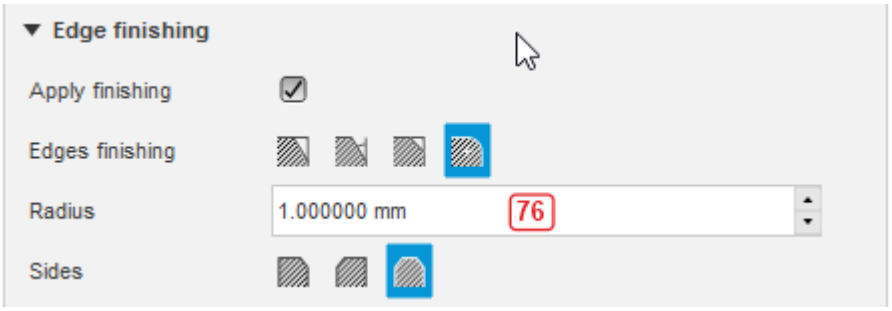


Figure 31. Edge finishing: radius.

Radius **(76)** – radius of finishing (r_{ef}).

Holes **(52)** – defining holes for sun and planet gears.

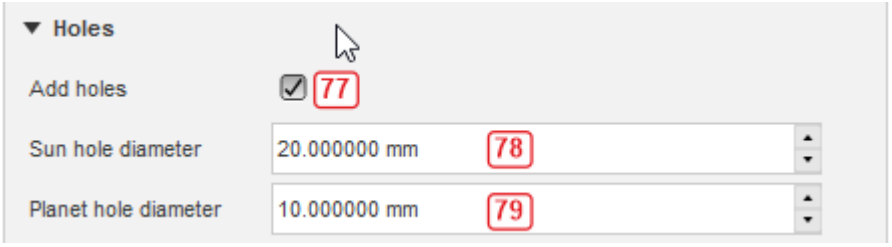


Figure 32. Holes options.

Add holes **(77)** – if this option is checked hole is added to sun and planets.

Sun hole diameter **(78)** – diameter of hole of sun gear (d_{hs}).

Planet hole diameter **(79)** – diameter of hole of planet gear (d_{hp}).

Outside fillets **(53)** – applies fillets to ring gear's teeth at outside diameter.

There is also one more group available when the selected stage **(104)** isn't first:

Stage distance **(105)** – options about distance between the selected and previous stage.

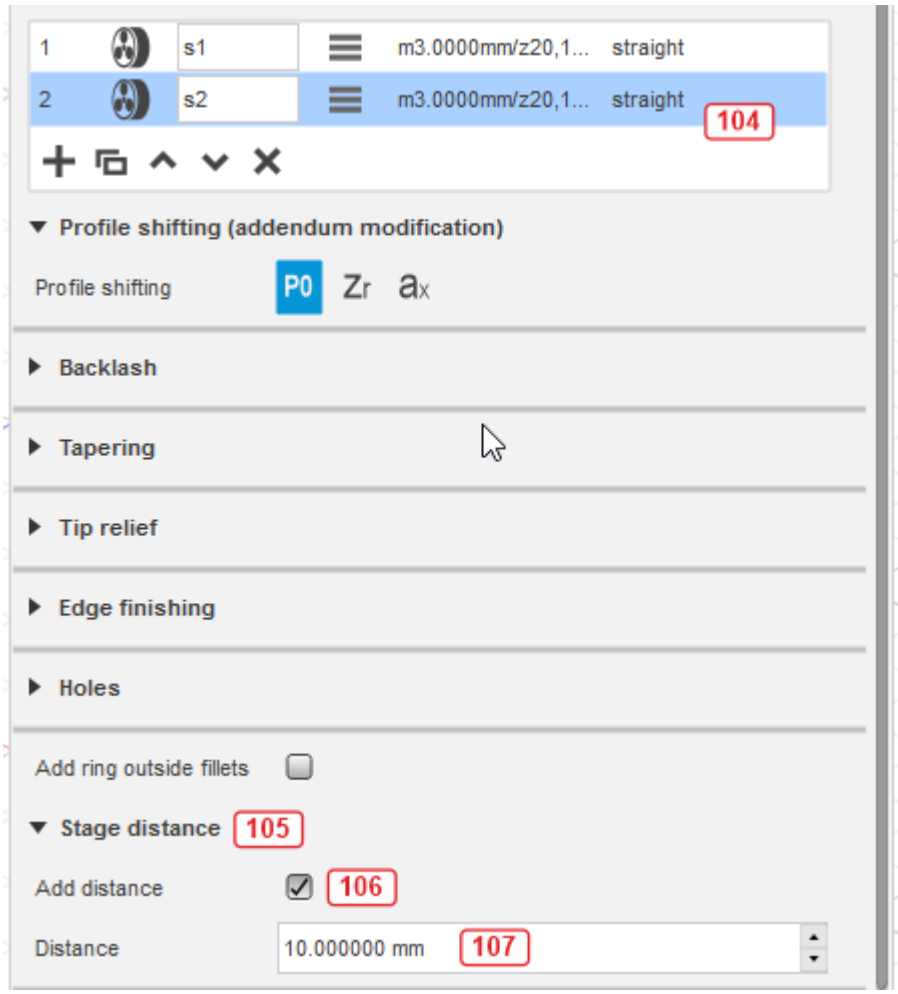


Figure 33. Options of distance between stages which are available if the selected stage isn't first.

Add distance **(106)** – if checked, distance between the selected and previous stage is added.

Distance **(107)** – value of distance (l).

Option’s tab

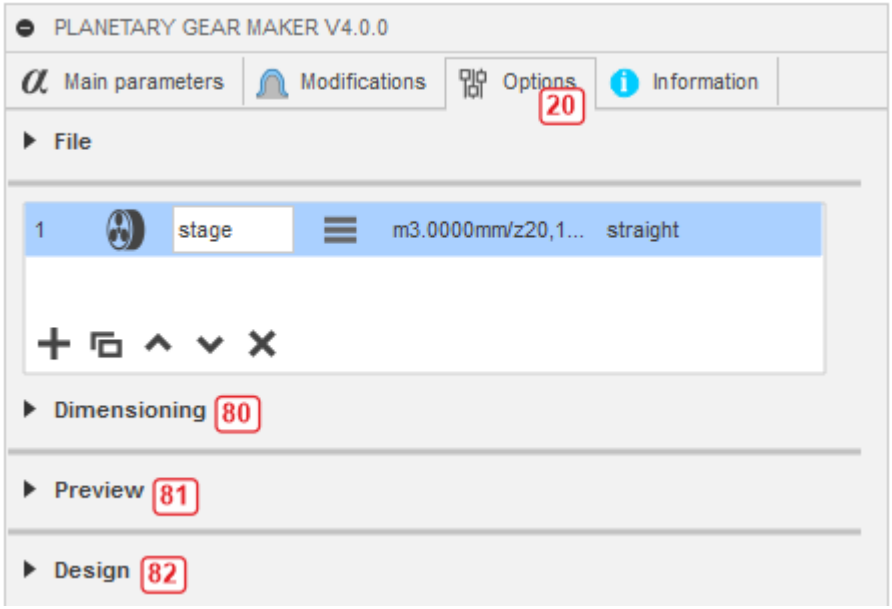


Figure 34. Option’s tab.

Dimensioning **(80)** – settings for units, dimensioning of module, format of angles, precision of displaying numbers.

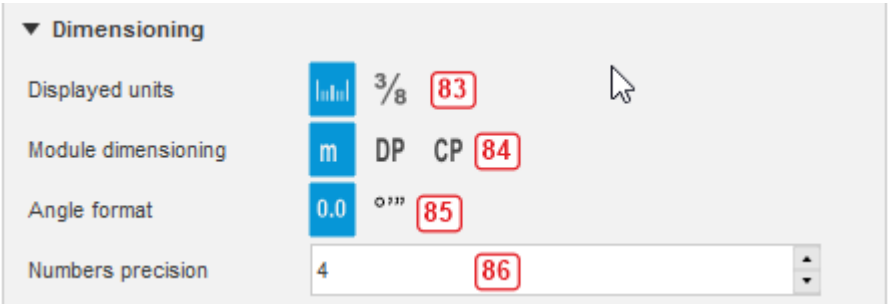


Figure 35. Dimensioning.

Displayed units **(83)** – options for changing units: millimeters (default) or inches.

Module dimensioning **(84)** – options for changing type of dimensioning between: module (default), diametral pitch, circular pitch; it is possible to display millimeters units for DP and CP.

Angle format **(85)** – options for changing way how angular values are set: as decimal (default) or HMS.

Numbers precision **(86)** – number of decimal digits for displaying values; it doesn’t change precision of inputs.

Preview **(81)** – settings of preview, used for displaying models of stages before they are created.

Figure 36. Preview options.

Show preview **(87)** – if this option is checked, preview of stages is shown.

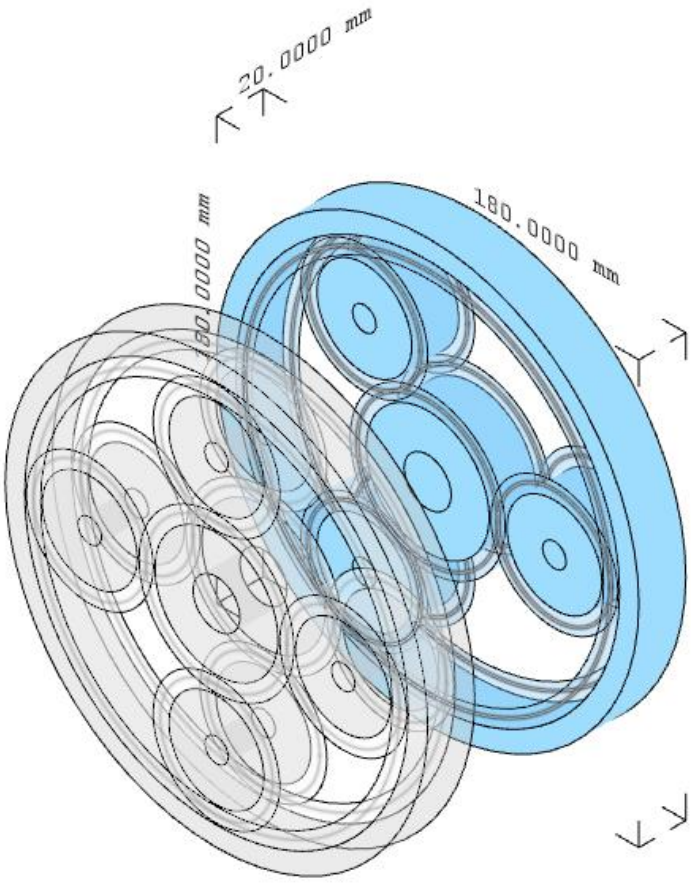


Figure 37. Sample preview of two stages: selected (blue) and the second one (grayed).

Show teeth shape **(88)** – if this option is checked, shape of teeth is shown on gears.

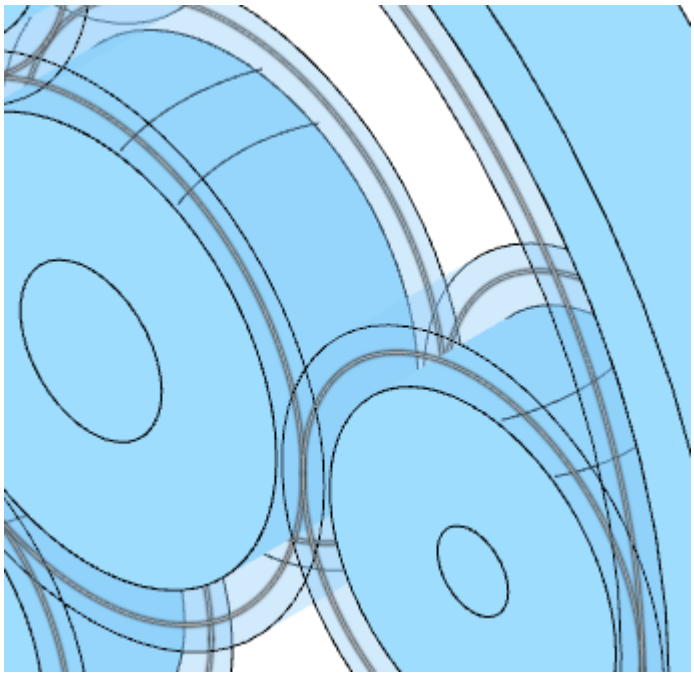


Figure 38. Sample preview of teeth's shape.

Show bounding box **(89)** – if this option is checked, minimum bounding box is drawn around the selected stage.

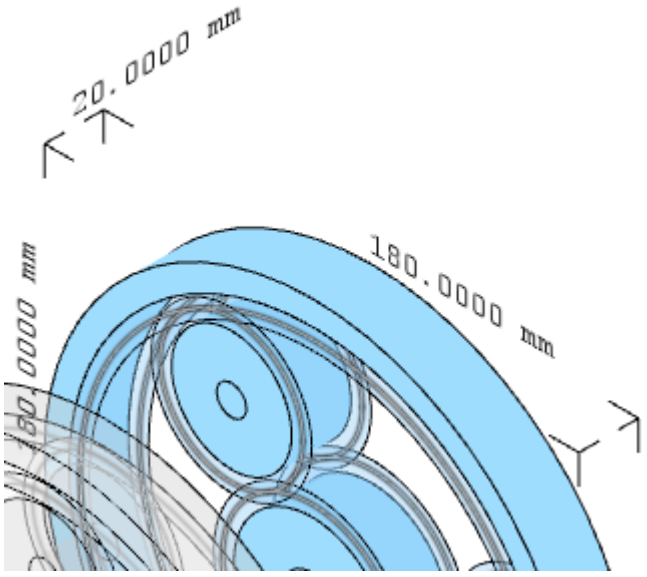


Figure 39. Bounding box around the selected stage.

Continuous edges **(90)** – if this option is checked, edges of bounding box are drawn as lines, otherwise only corners are marked.

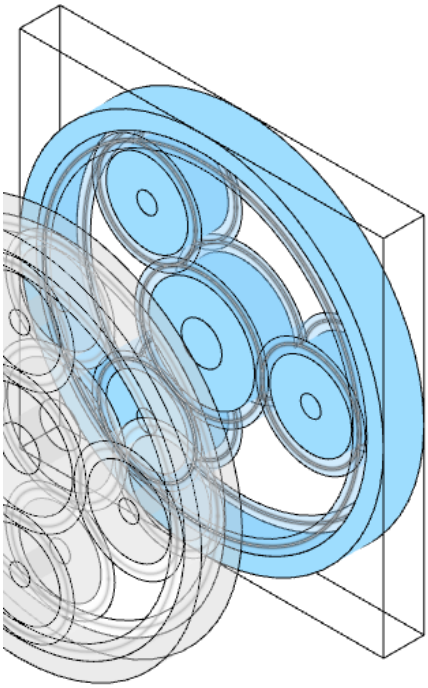


Figure 40. Bounding box with continuous lines.

Show dimensions **(91)** – if this option is checked, dimension of bounding box are drawn.

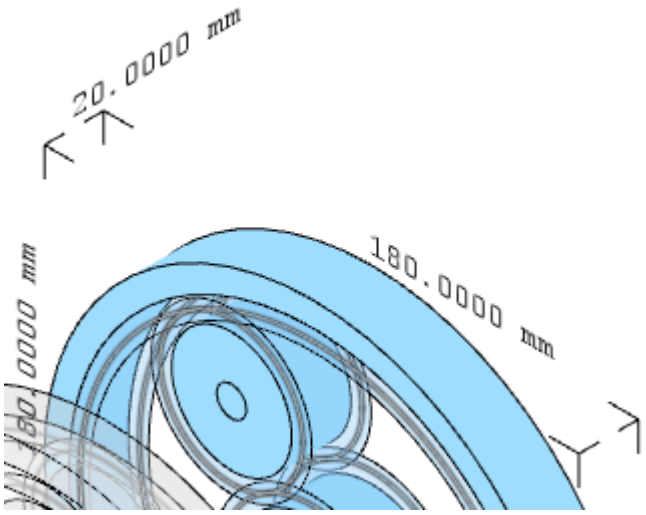


Figure 41. Dimensions of bounding box.

Show selected stage only **(92)** – if this option is checked, only selected stage is drawn.

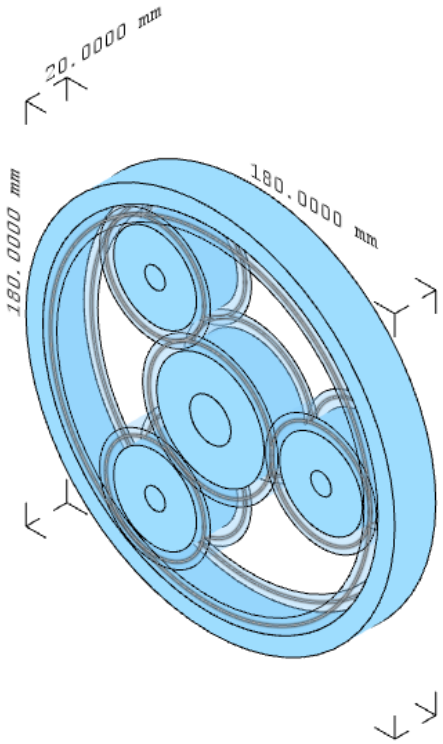


Figure 42. Selected stage only.

Design **(82)** – adding joint, rotation axis, mode of creating (current document or a new one).

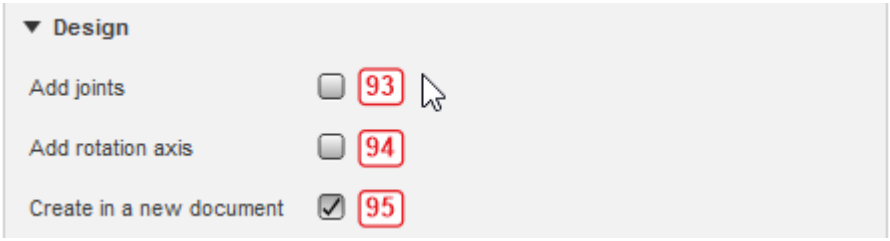


Figure 43. Design options.

Add joints **(93)** – adds revolution joins to created gears.

Add rotation axis **(94)** – adds axes of rotation to created gears.

Create in a new document **(95)** – creates stages in a new document[9].

[9] Capturing history (timeline features) in parametric design doesn't work in newly created document. Components must be moved to another design.

Information tab

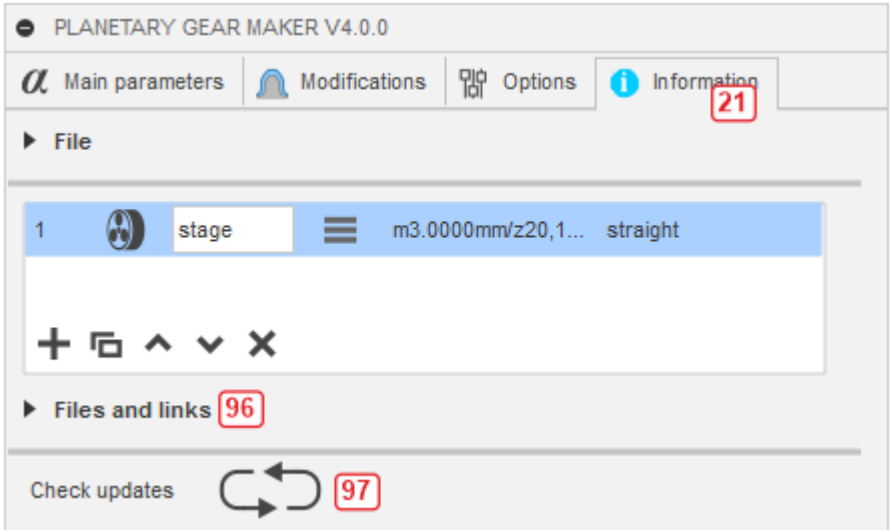


Figure 44. Information tab.

Files and links **(96)** – links to files used by the plugin and to documentation.

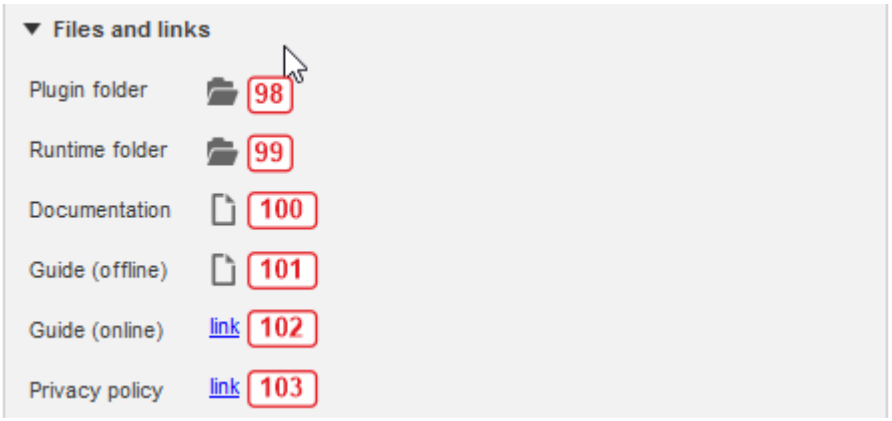


Figure 45. Holes options.

Plugin folder **(98)** – opens root directory of the plugin.

Runtime folder **(99)** – opens runtime directory of the plugin.

Documentation **(100)** – opens basic documentation, the same as on the website but available offline.

Guide (offline) **(101)** – opens this guide offline by the default PDF reader.

Guide (online) **(102)** – redirects to this guide by default web browser.

Privacy policy **(104)** – privacy policy (only online).

Check updates **(97)** – button for checking updates.

5. Components' properties

This section describes parameters available in components' which may be useful in later designing using prepared gears.

Calculated parameters

Each gear component contains parameters saved in its description. For getting them, stage component must be expanded, and properties of a specific gear must be entered.

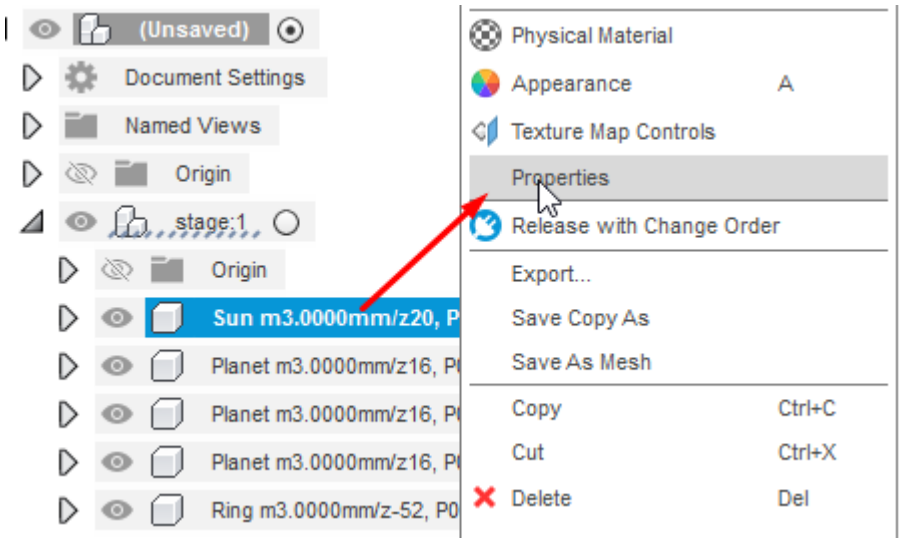


Figure 46. Properties of gear, in this case - sun.

Next step is to copy content of description and paste it to some text editor.

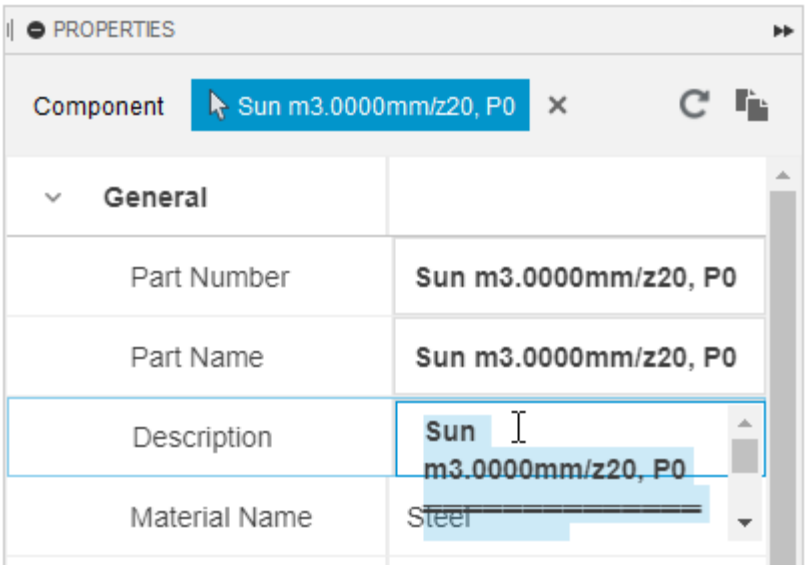
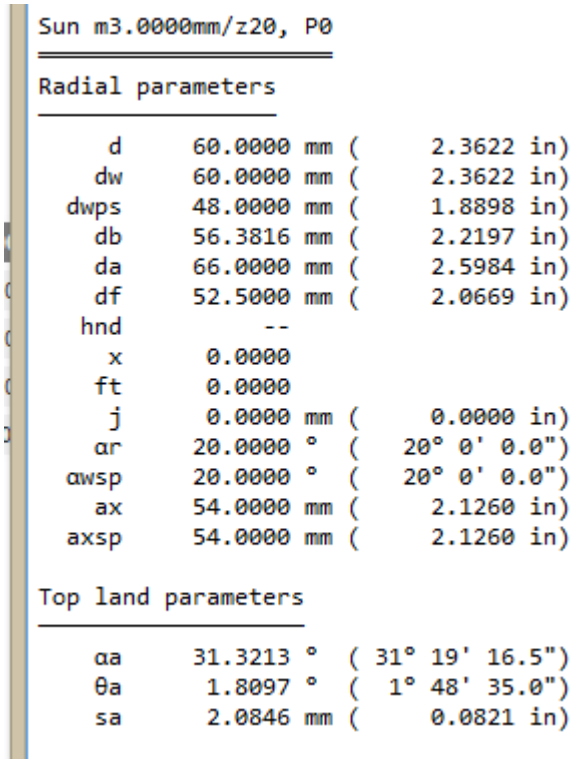


Figure 47. Content of the component's description.



```
Sun m3.0000mm/z20, P0
═══════════════════

Radial parameters
─────────────────

     d      60.0000 mm (      2.3622 in)
    dw      60.0000 mm (      2.3622 in)
  dwps      48.0000 mm (      1.8898 in)
    db      56.3816 mm (      2.2197 in)
    da      66.0000 mm (      2.5984 in)
    df      52.5000 mm (      2.0669 in)
   hnd           --
     x       0.0000
    ft       0.0000
     j       0.0000 mm (      0.0000 in)
    αr      20.0000 °  (   20° 0' 0.0")
  αwsp      20.0000 °  (   20° 0' 0.0")
    ax      54.0000 mm (      2.1260 in)
  axsp      54.0000 mm (      2.1260 in)

Top land parameters
───────────────────

    αa      31.3213 °  ( 31° 19' 16.5")
    θa       1.8097 °  (  1° 48' 35.0")
    sa       2.0846 mm (      0.0821 in)
```

Figure 48. Calculated parameters pasted to the text editor.

Meaning of all parameters is described in the *Real-time calculated parameters* subsection.

Motion links' formulas

Motion links defines movement behavior between components, in this case, gears. For checking how the elements are move, motion links need to be defined but it's not straightforward. Formula for the second component must be transformed for getting proper ratio between elements. Plugin automatically calculates and saves such formulas, so user don't need to do this.

For showing where to find, how to get proper formula, and how to use it in a real example, a single stage has been prepared. Additionally, there is a carrier for holding all planets.

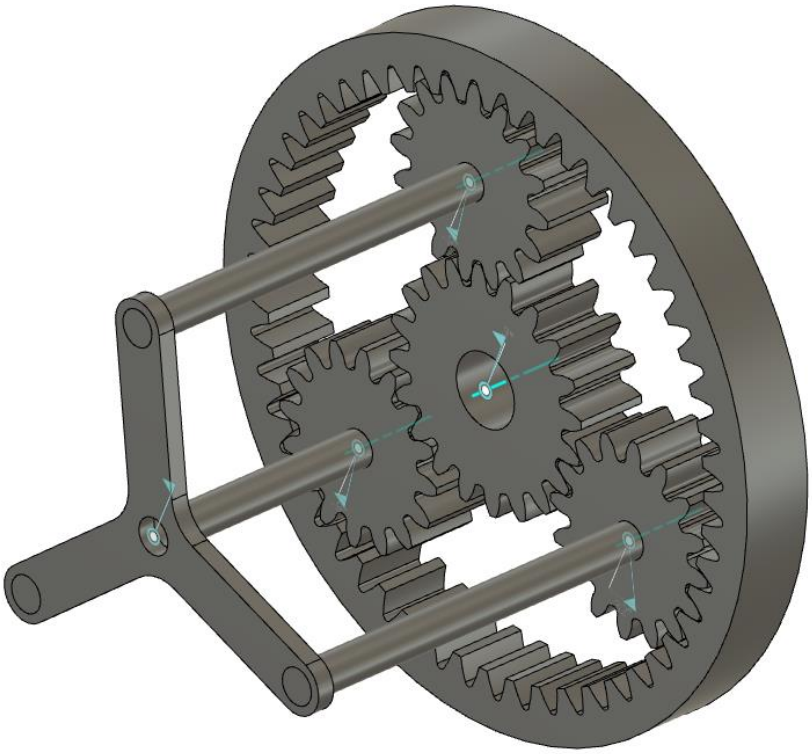


Figure 49. Single stage with carrier and revolution joints.

Motion link formulas are also contained in descriptions of components but in this case, they are in stages' components:

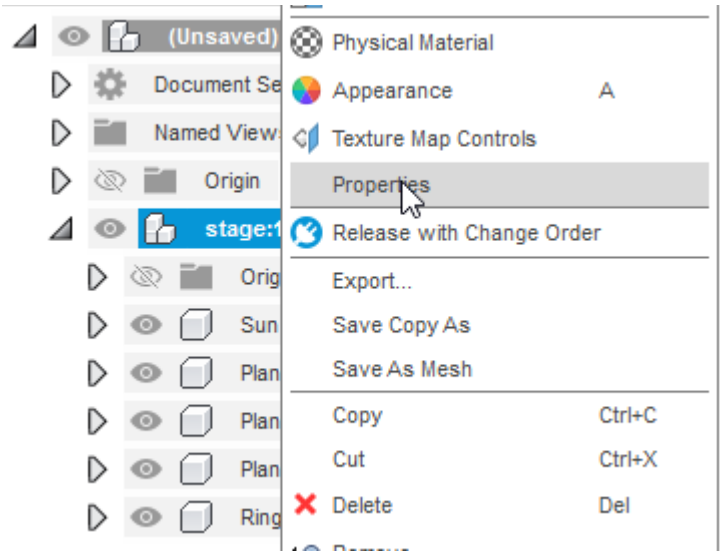


Figure 50. Properties of stage.

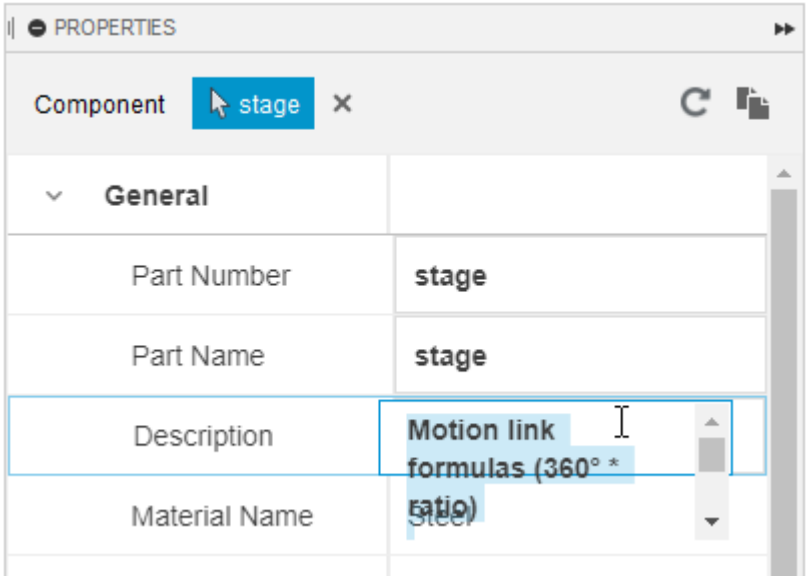


Figure 51. Motion link formulas contained in description.

Motion link formulas (360° * ratio)

input	grounded	output	formula
sun	carrier	ring	360*(-20/52)
sun	carrier	planet	360*(-20/16)
sun	ring	carrier	360*(20/(52+20))
sun	ring	planet	360*(-52*20/(16*(52+20)))
carrier	sun	ring	360*(1+20/52)
carrier	sun	planet	360*(20/16)
carrier	ring	sun	360*(1+52/20)
carrier	ring	planet	360*(-52/16)
ring	sun	carrier	360*(1/(1+20/52))
ring	sun	planet	360*(20/(16*(1+20/52)))
ring	carrier	sun	360*(-52/20)
ring	carrier	planet	360*(52/16)

Figure 52. Motion link formulas pasted to the text editor.

Table contains twelve rows, each for specific input gear, grounded element, and output gear. Grounded element ensures that it won't move, and other elements will orbit around its center. In this example, we assume that the third and fourth cases are needed to be simulated in the design: sun as input gear, ring stationary, and carrier with planets move:

input	grounded	output	formula
sun	carrier	ring	360*(-20/52)
sun	carrier	planet	360*(-20/16)
sun	ring	carrier	360*(20/(52+20))
sun	ring	planet	360*(-52*20/(16*(52+20)))
carrier	sun	ring	360*(1+20/52)
carrier	sun	planet	360*(20/16)
carrier	ring	sun	360*(1+52/20)
carrier	ring	planet	360*(-52/16)
ring	sun	carrier	360*(1/(1+20/52))
ring	sun	planet	360*(20/(16*(1+20/52)))
ring	carrier	sun	360*(-52/20)
ring	carrier	planet	360*(52/16)

Figure 53. Third formula: sun input, ring stationary, carrier output.

Ring gear needs to be grounded:

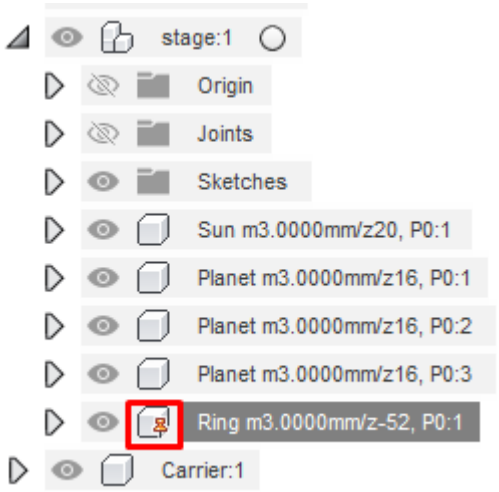


Figure 54. Grounded ring.

Motion link needs to be defined between joints of sun and carrier components and formula needs to be pasted in the second (output) field:

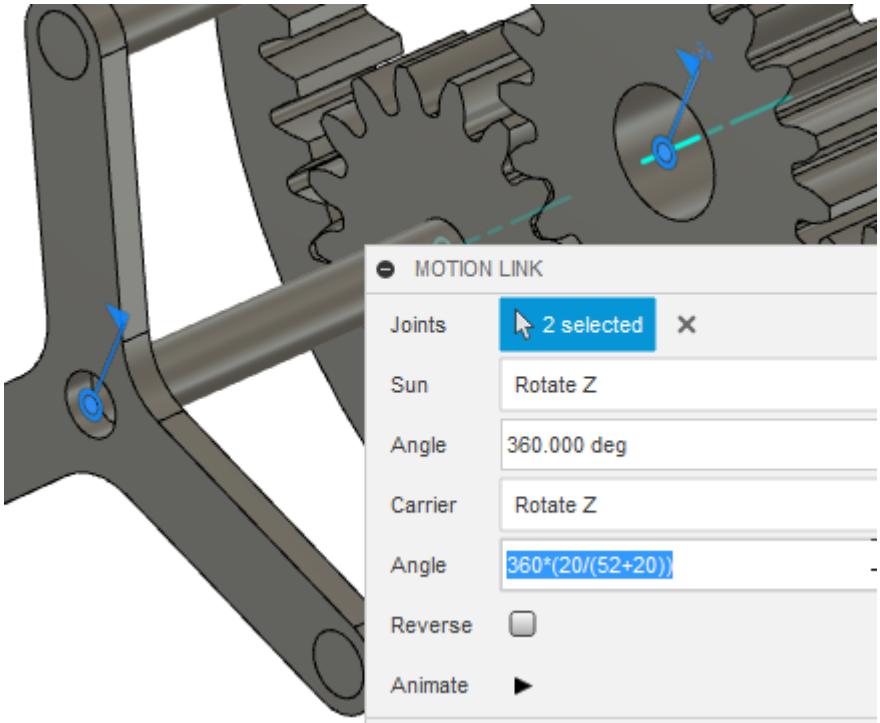


Figure 55. Defining motion link between sun and carrier – formula is pasted in the carrier's (output) field.

The same process will be repeated for planets:

input	grounded	output	formula
sun	carrier	ring	360*(-20/52)
sun	carrier	planet	360*(-20/16)
sun	ring	carrier	360*(20/(52+20))
sun	ring	planet	360*(-52*20/(16*(52+20)))
carrier	sun	ring	360*(1+20/52)
carrier	sun	planet	360*(20/16)
carrier	ring	sun	360*(1+52/20)
carrier	ring	planet	360*(-52/16)
ring	sun	carrier	360*(1/(1+20/52))
ring	sun	planet	360*(20/(16*(1+20/52)))
ring	carrier	sun	360*(-52/20)
ring	carrier	planet	360*(52/16)

Figure 56. Fourth formula: sun input, ring stationary, planet output.

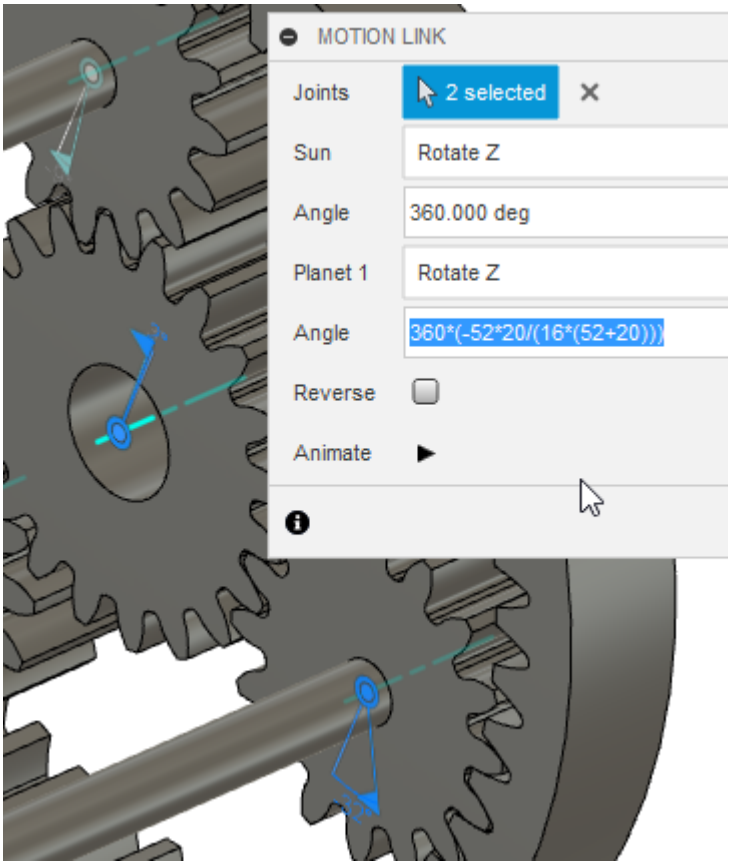


Figure 57. Defining motion link between sun and planet (must be repeated for every planet if needed.

Now, when sun gear's component will be rotated, carrier and planet(s) will rotate too.

Note: motion links' formulas work properly for joints which have the same direction of rotation for all gears (CW or CCW but not together). If at least one joint of mounted component has opposite direction, then gear will be rotating backwards after applying formula. Presented example shows such situation:

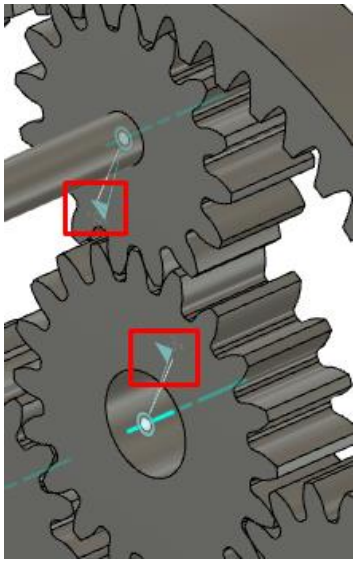


Figure 58. Opposite direction of joints: sun – CCW, planets – CW.

A simple solution for this is to add a "-" sign in the beginning of the formulas for planets as outputs:

Motion link formulas (360° * ratio)

input	grounded	output	formula
sun	carrier	ring	360*(-20/52)
sun	carrier	planet	360*(-20/16) remove "-"
sun	ring	carrier	360*(20/(52+20))
sun	ring	planet	360*(-52*20/(16*(52+20))) remove "-"
carrier	sun	ring	360*(1+20/52)
carrier	sun	planet	360*(20/16) add "-"
carrier	ring	sun	360*(1+52/20)
carrier	ring	planet	360*(-52/16)
ring	sun	carrier	360*(1/(1+20/52))
ring	sun	planet	360*(20/(16*(1+20/52))) add "-"
ring	carrier	sun	360*(-52/20)
ring	carrier	planet	360*(52/16) add "-"

Figure 59. Opposite direction of joints – solution.

6. Additional information

Sensitive data

Apart from version checking, no other Internet communication is done by the plugin. User data which are stored (only in case of errors) are paths of directories. This is a natural consequence of how the logging stores stack trace of errors. It is a normal and common behavior in all programming languages and technologies, and it helps to search the cause of error in files and to find solutions.

Runtime directory

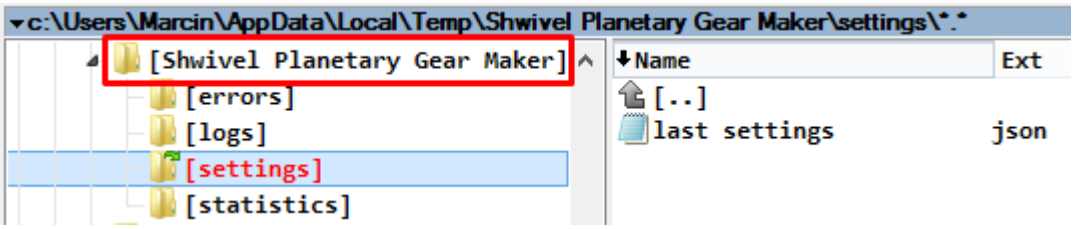


Figure 60. Runtime directory – example on Win machine.

Plugin uses a runtime directory located in the temporary folder of your system's directory. If your user does not have read/write permissions to this directory, files will not be created but you will be informed (on the *Information* tab) what you should do. Files created and used by the plugin are:

last settings.json - contains settings of last used parameters; it is useful when you want to repeat operation for the same values without setting all the fields once again,

stats.json - contains times of executions used for estimating time,

Error_YYMMDD_HHmmss.json, Stacktrace_YYMMDD_HHmmss.txt - contains information about errors and it is used for fixing them.

Errors

In case of errors, information about them is saved in the *Errors* folder of the plugin. You can easily check the content of the files using the simplest text editors. These files may be very useful for fixing errors and they need to be attached to the mail to the support.

Invoices

If you purchased the program as an entrepreneur, please send the following data to get an invoice maximum to the 15th day of the next month after the month of the purchase:

- Name of product,
- Date of purchase,
- Name of company/institution/buyer,
- Address,
- Your VAT number (in case of the company).

As a private individual you can request for an invoice 3 months after the month of purchase. Mail is in the *Support and contact* section.

Discounts

Discount is available in case of buying a necessary number of licenses but first, they need to be bought. After that, you need to send an email which provide the name of application you bought and the number of licenses. Discount will be returned to the same PayPal account which was used for buying the plugins.

Table 3. Discount.

Number of licenses	Discount
1-3	0%
4-10	10%
10-20	25%
>50	50%

Known problems

Most of the problems are described in the *Problems* subsection of

Installation and **uninstallation** section. If you encounter and error linked with specific set of parameters, please use the mail from the *Support and contact* section to explain and describe your problem.

Support and contact

Mail: shwivel360@gmail.com

Response would take at most a day or two.

7. Table of figures

Figure 1. Where to find the plugin. 10
Figure 2. Managing the plugin. Add-in should be visible in the My Add-Ins tree. 11
Figure 3. Plugin's window at first run. 12
Figure 4. Resizing window 12
Figure 5. An example of toolclip shown when the mouse cursor is hovered over the input. 13
Figure 6. Common elements. 14
Figure 7. File group 14
Figure 8. Information 15
Figure 9. Warning – placement of planets causes interference with the ring gear's teeth, but process can be started 16
Figure 10. Error – invalid stage prevents start of the process. 16
Figure 11. Error – invalid value prevents start of the process. 17
Figure 12. Tabs 18
Figure 13. Main parameters. 19
Figure 14. Common parameters. 20
Figure 15. Options for helical gears 20
Figure 16. Options for double-helical gears. 21
Figure 17. Options for herringbone gears 22
Figure 18. Options for arc gears. 22
Figure 19. Gears' group. 23
Figure 20. Real-time calculated parameters. 24
Figure 21. Modification's tab. 25
Figure 22. Profile shifting modes – P0 25
Figure 23. Profile shifting modes – z_r. 26
Figure 24. Profile shifting modes – a_x 26
Figure 25. Backlashes. 26
Figure 26. Taper factors 27
Figure 27. Tip reliefs. 27
Figure 28. Edge finishing: height-width 28
Figure 29. Edge finishing: height-angle. 28
Figure 30. Edge finishing: equal sides 29
Figure 31. Edge finishing: radius 29
Figure 32. Holes options. 29
Figure 33. Options of distance between stages which are available if the selected stage isn't first. 30
Figure 34. Option's tab. 31
Figure 35. Dimensioning. 31
Figure 36. Preview options 32
Figure 37. Sample preview of two stages: selected (blue) and the second one (grayed). 32
Figure 38. Sample preview of teeth's shape. 33
Figure 39. Bounding box around the selected stage 33
Figure 40. Bounding box with continuous lines 34
Figure 41. Dimensions of bounding box. 34

Figure 42. Selected stage only. 35
Figure 43. Design options. 35
Figure 44. Information tab. 36
Figure 45. Holes options. 36
Figure 46. Properties of gear, in this case - sun. 37
Figure 47. Content of the component's description. 37
Figure 48. Calculated parameters pasted to the text editor. 38
Figure 49. Single stage with carrier and revolution joints. 39
Figure 50. Properties of stage. 39
Figure 51. Motion link formulas contained in description. 40
Figure 52. Motion link formulas pasted to the text editor. 40
Figure 53. Third formula: sun input, ring stationary, carrier output. 41
Figure 54. Grounded ring. 41
Figure 55. Defining motion link between sun and carrier – formula is pasted in the carrier's (output) field. 42
Figure 56. Fourth formula: sun input, ring stationary, planet output. 42
Figure 57. Defining motion link between sun and planet (must be repeated for every planet if needed. 43
Figure 58. Opposite direction of joints: sun – CCW, planets – CW. 43
Figure 59. Opposite direction of joints – solution. 44
Figure 60. Runtime directory – example on Win machine. 45

8. Table of tables

Table 1. Ranges of options. 4
Table 2. Real-time calculated parameters. 6
Table 3. Discount. 46