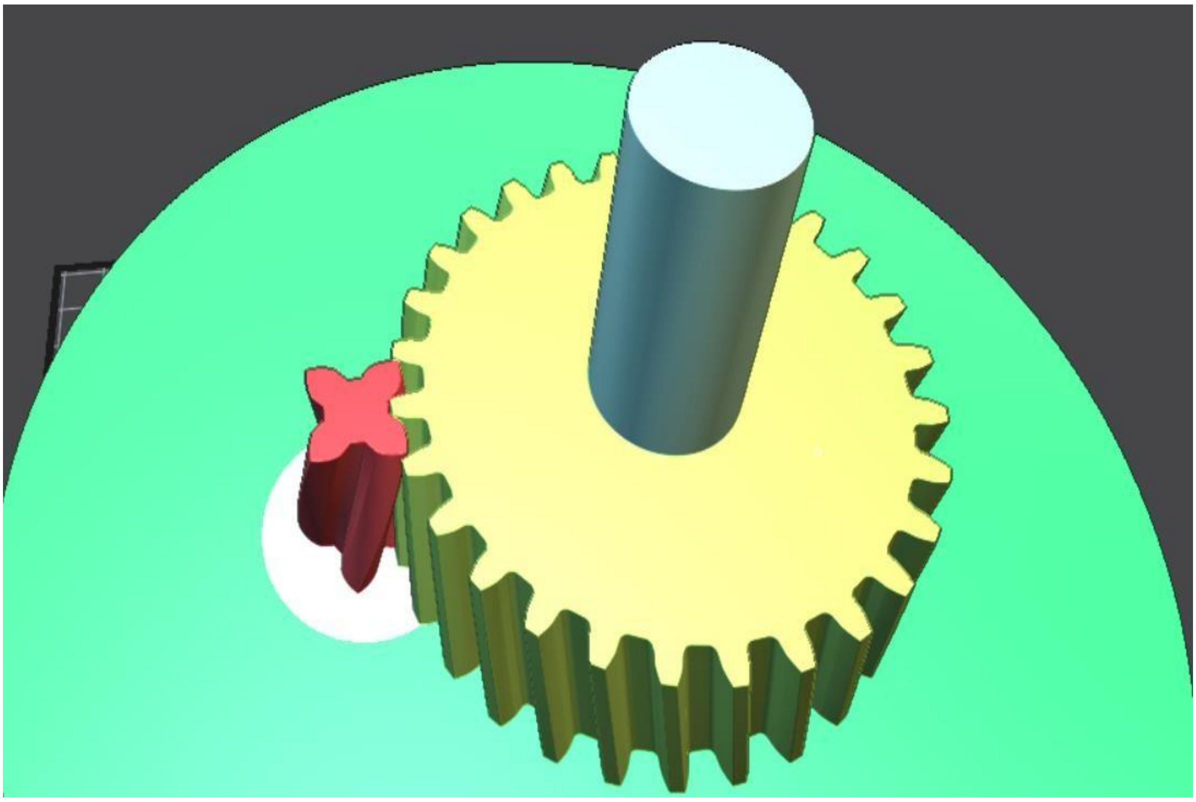
Case Study Cyber-Physical Production System

Using AM

Instructions to Print the High Ratio Evoloid Drive



Group: Gear Mechanism Using AM

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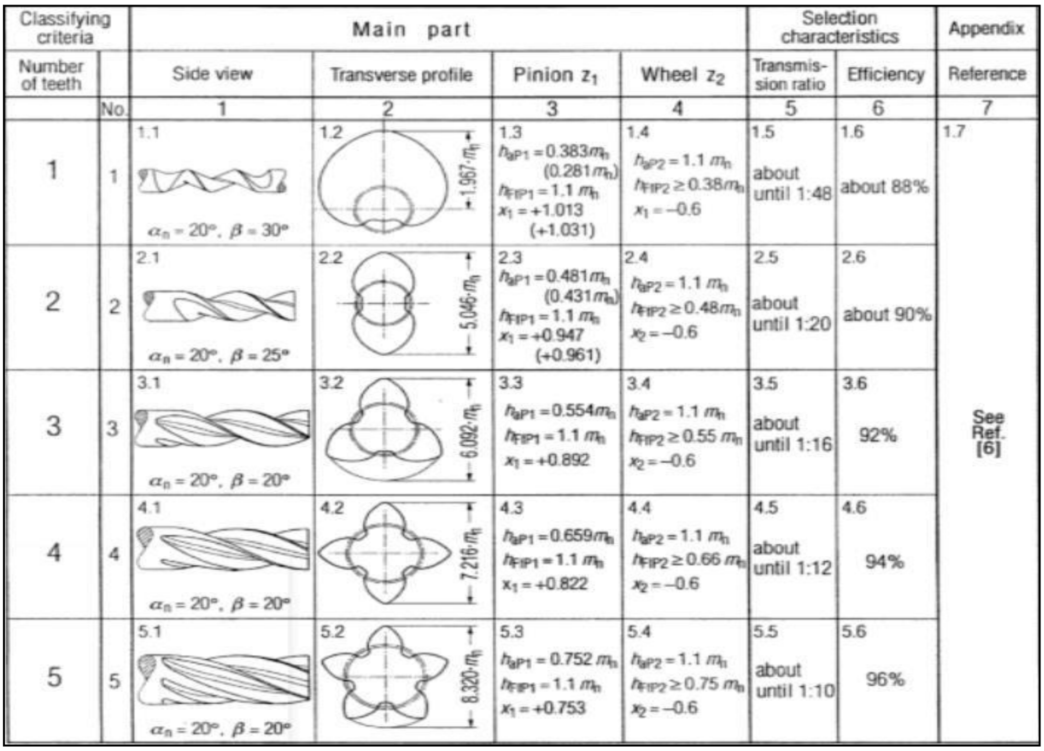
1 Introduction

Evoloid drive systems are helical cut pairs of gears with number of teeth less than 7 at the pinion or driver enabling the design of compact powerful gears. This system has high load capacity, and it can achieve a high gear ratio in a single stage. For more information, visit the Technical Report “Involute Gearing: Evoloid Drive with High Gear Ratio”.

- In this document, necessary information to replicate the display model(high gear ratio evoloid drive) with AM with the help of Lua script in IceSl is stated.
- Evoloid Gears are helical cut pairs of gears with number of teeth less than 7 at the pinion which in turn allows to attain a high gear ratio in a single stage.
- Users can easily modify the Evoloid drive by changing the UI box Input parameters like number of teeth on pinion and gear, module, helix angle, face width, profile shift, addendum and dedendum modification coefficients of both pinion and gear.
- Users should provide the input variables like pressure angle, helix angle, number of teeth on pinion, profile shift and addendum, dedendum modification coefficients for both pinion and gear according to the table for different high gear ratio. ***(Chakarabarthi)***
- We assume that the user has sufficient knowledge about AM, Lua and IceSl.
- The LUA script description along with the STL file generation is also included in this document.



Classifying criteria		Main part				Selection characteristics		Appendix
Number of teeth		Side view	Transverse profile	Pinion z_1	Wheel z_2	Transmission ratio	Efficiency	Reference
	No.	1	2	3	4	5	6	7
1	1	1.1 $\alpha_n = 20°$, $\beta = 30°$	1.2 $1.967 \cdot m_n$	1.3 $h_{aP1} = 0.383 m_n$ $(0.281 m_n)$ $h_{FfP1} = 1.1\ m_n$ $x_1 = +1.013$ $(+1.031)$	1.4 $h_{aP2} = 1.1\ m_n$ $h_{FfP2} \geq 0.38 m_n$ $x_1 = -0.6$	1.5 about until 1:48	1.6 about 88%	1.7
2	2	2.1 $\alpha_n = 20°$, $\beta = 25°$	2.2 $5.046 \cdot m_n$	2.3 $h_{aP1} = 0.481 m_n$ $(0.431 m_n)$ $h_{FfP1} = 1.1\ m_n$ $x_1 = +0.947$ $(+0.961)$	2.4 $h_{aP2} = 1.1\ m_n$ $h_{FfP2} \geq 0.48 m_n$ $x_2 = -0.6$	2.5 about until 1:20	2.6 about 90%	
3	3	3.1 $\alpha_n = 20°$, $\beta = 20°$	3.2 $6.092 \cdot m_n$	3.3 $h_{aP1} = 0.554 m_n$ $h_{FfP1} = 1.1\ m_n$ $x_1 = +0.892$	3.4 $h_{aP2} = 1.1\ m_n$ $h_{FfP2} \geq 0.55\ m_n$ $x_2 = -0.6$	3.5 about until 1:16	3.6 92%	See Ref. [6]
4	4	4.1 $\alpha_n = 20°$, $\beta = 20°$	4.2 $7.216 \cdot m_n$	4.3 $h_{aP1} = 0.659 m_n$ $h_{FfP1} = 1.1\ m_n$ $x_1 = +0.822$	4.4 $h_{aP2} = 1.1\ m_n$ $h_{FfP2} \geq 0.66\ m_n$ $x_2 = -0.6$	4.5 about until 1:12	4.6 94%	
5	5	5.1 $\alpha_n = 20°$, $\beta = 20°$	5.2 $8.320 \cdot m_n$	5.3 $h_{aP1} = 0.752\ m_n$ $h_{FfP1} = 1.1\ m_n$ $x_1 = +0.753$	5.4 $h_{aP2} = 1.1\ m_n$ $h_{FfP2} \geq 0.75\ m_n$ $x_2 = -0.6$	5.5 about until 1:10	5.6 96%	

Figure 1:Evoloid drive input parameters with respect to different high gear ratio values
(Chakarabarthi)

2 IceSL Software

IceSL is an advanced tool which helps in designing complex models for 3D printing. The app comes with a slicer that generates precise instructions to be used by all sorts of printers. Modelling in IceSl is done with the help of Lua Script. Modelling of the different shapes are done with customization of parameters. The application comes with two different software, namely the Forge and Slicer. Slicer is a tool that focuses on generating accurate instructions for the printer, the Forge is where we can design and customise models. For more information visit [IceSL (loria.fr)].

3 Input parameters

The first step in creating an Evoloid drive in IceSL is to define the basic parameters for the gear. Some of these parameters are user defined and the other parameters are derived from the inputs given. Through the tweak box the user can change the parametric values to analyse the variations in the model. There are two gears designed in the script so that the user must change the parameter of both gears. The important thing is that parameters like number of teeth ,helix angle, pressure angle, profile shift, addendum and dedendum modification coefficients of both pinion and gear should be according with the table values (***Chakarabarthi***).For more information about how to create a tweak box visit [Scripting language · Wiki · mfx / IceSL documentation · GitLab (inria.fr)].

The input parameters needed for gear design are defined as a user interface in the following way:

```
--Input parameters needed for gear design

z1=ui_number("Number of Teeth on pinion",4,2,6)
                      --input for number of teeth on pinion/driver,in an evoloid drive where number of teeths on the pinion less than 5 or 7 (The
pinion/driver gear comprising less tooth contributes to the high possible transmission ratios)

z2=ui_number("Number of Teeth on external_gear",28,24,36)
                       --input for number of teeth on external_gear


m_t=ui_number("module",3,1,50)
                    -- Gear module

alpha_t=ui_numberBox("Pressure angle (Degrees)",20)
                   --pressure angle in degrees

Face_width=ui_number("Face Width(mm)",30,1,50)                --Gear Face Width

x_coef_2=ui_scalar("profile_shift_external_gear(mm)",-0.6,-2,2)
               --profile shift factor for external_gear(external_gear should have a negative profile shift coefficient),values as per table

x_coef_1=ui_scalar("profile_shift_Pinion(mm)",.822,-2,2)
               --profile shift factor for Pinion(pinion should have a positive profile shift coefficient),values as per table

h_ap_1=ui_scalar("addendummodifcoef_Pinion(mm)",0.659,-2,2)--addendum modification coefficient of pinion,values as per table

h_fp_1=ui_scalar("dedendummodifcoef_Pinion(mm)",1.1,-2,2)--dendendum modification coefficient of pinion,values as per table

h_ap_2=ui_scalar("addendummodifcoef_gear(mm)",1.1,-2,2)----addendum modification coefficient of gear,values as per table

h_fp_2=ui_scalar("dedendummodifcoef_gear(mm)",.66,-2,2)--dendendum modification coefficient of gear,values as per table

Rotation=math.floor(ui_scalar("evoloid drive rotation",0,0,360))
          --rotation in which the pinion gear rotating with the external gear)

helix_angle_value=ui_scalar("helix angle(Degrees)",20,20,45)
        -- helix angle of evoloid drive
```

Figure 2:Input parameters for gear design *(Chakarabarthi)*

The tweak box explained in detail below:

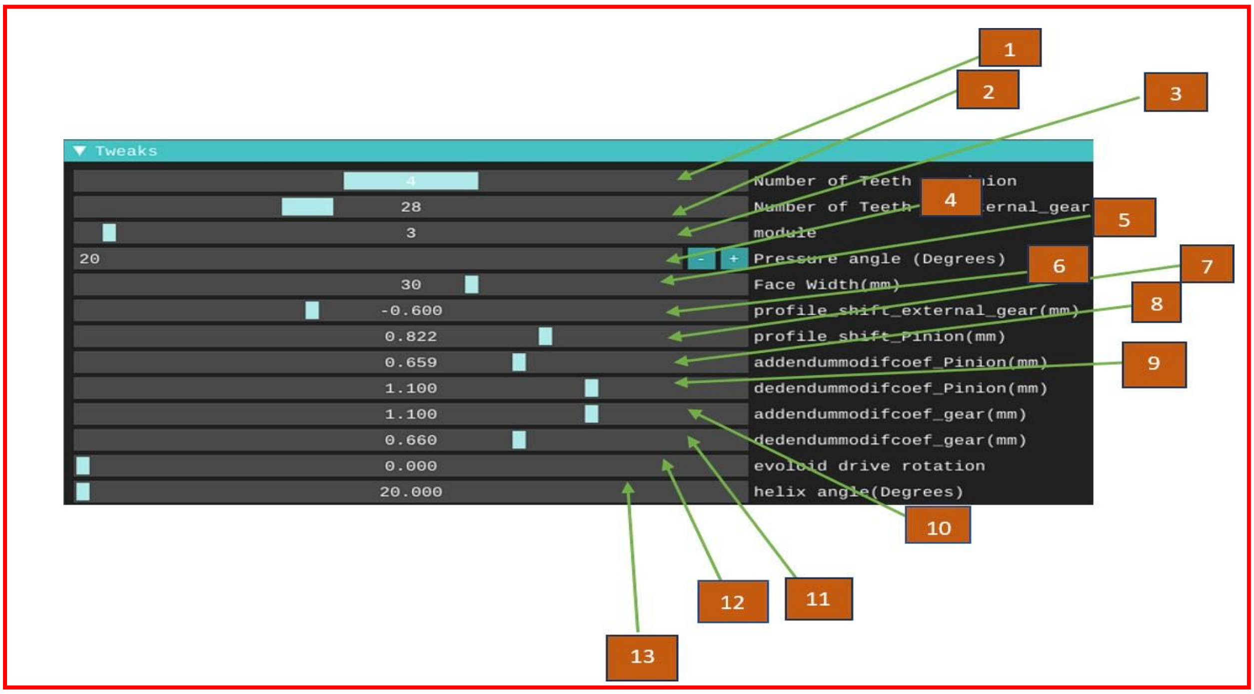


Figure 2.1:Tweak box for the input parameters needed for gear design ***(Chakarabarthi)***

As shown above, users can easily modify the model by changing the input parameters in the tweak box. Each number here represents the input data and described below in detail.

1. For the evoloid drive the number of teeth on the pinion should be less than seven. less number of teeth provide high gear ratio. Slide the slider to change the number of teeth on pinion, values as per the table .
2. With this option users can change the number of teeth on big gear, values as per the table.
3. With this option users can change the module of both gears which make the gears bigger /smaller
4. Slide the slider to change the pressure angle of both gears. values as per the table.
5. With this option users can change the face width/thickness of both gears
6. Slide the slider to change the profile shift of big gear, values as per the table.
7. Slide the slider to change the profile shift of pinion/gear with a small number of teeth, values as per the table.
8. With this option users can change the addendum modification coefficients of Pinion, values as per the table.
9. With this option users can change the dedendum modification coefficients of Pinion, values as per the table.
10. With this option users can change the addendum modification coefficients of big gear, values as per the table.

11. With this option users can change the dedendum modification coefficients of big gear, values as per the table.
12. Slide the slider to rotate both gears so that meshing takes place.
13. With this option users can change the helix angle of both gears, values as per the table.

4 Script Description

We have parametrically designed the high gear ratio evoloid drive mechanism consisting of a big gear and a pinion with small number of teeth. The assembly consists of meshing of both pinion and big gear where the gears are helical toothed. To get the proper mesh, the input parameters should follow the table values ***(Chakarabarthi)***. Important steps in creating the model are described below.

- **Step 1:** Defined the input parameters for the gear design by UI variables. Line number 14-46.[For more information check the Lua code].
- **Step 2:** Created a function called **gear()[**line number 52-178] to generate the involute full spur gear profile and inside the function we have created many sub functions.[For more information check the Lua code].sub functions are described below.

1. **function involute(r_b, angle)[**line number 114-116]-this involute function generates the involute tooth geometry which gives x and y components of points in return
2. **function involute_mirror(involut_points)**[line number 119-121]-this function gives the mirror points of any contour concerning the y-axis
3. **function curve(r_1,r_2)**[line number 95-97]-this function responsible to find the right angle between both sides of the Gear
4. **function point_rotate(ang, points)**[line number 144-146]-this function responsible for the rotation of whole tooth around z axis
5. **function circle(a,b,r,th)**[line number 148-150]-function to create a circle
6. **function slope(contour)**[line number 109-111]-this function find the slope of at the of contour
7. **function extrude(Contour, angle, dir_v, scale_v, z_steps)**[line number 183-236]-this function extrudes the gear at a helix angle ***(Prof.Dr.Ing.Stefan Scherbarth)***.
8. **function helicalangle(Face_width,z,m_t,helix_angle_value)**[line number 239-243]-function to calculate the helix angle
9. **function gearangle(m_t,x_coef,alpha_t,z)**[line number 254-257]-this function calculate angle of both sides of tooth
10. **emit(translate(0,-d_p/2,0)*Evoloid_gear,10)**[line number 287]-emitting the big gear
11. **emit(translate(0,-d_p/2,-Face_width)*rotation_2*difference(shaft,cube),12)**[line number 293]-emitting the shaft for big gear

12. **emit(translate(0,-value_1*2.53,-Face_width-6)*difference(casing_base,hole_cylinder),19)[**line number 300]-emitting the casing base [For more information check the Lua code].

- **Step 3:** Finally, by using the extrude function(Code Line number 182-235,***(Prof.Dr.Ing.Stefan Scherbarth)*** we can extrude the gear at a helix angle so that helical gear can be generated. Then emitting both gears. Important is input parameters like number of teeth, helix angle, pressure angle, addendum and dedendum, profile shift factors should be based on the table. [For more information check the Lua code]

The Lua code has been included with many comments so that users can easily understand the above steps in detail while checking the code.

5 Output

The output of our Lua script in IceSL is shown below:

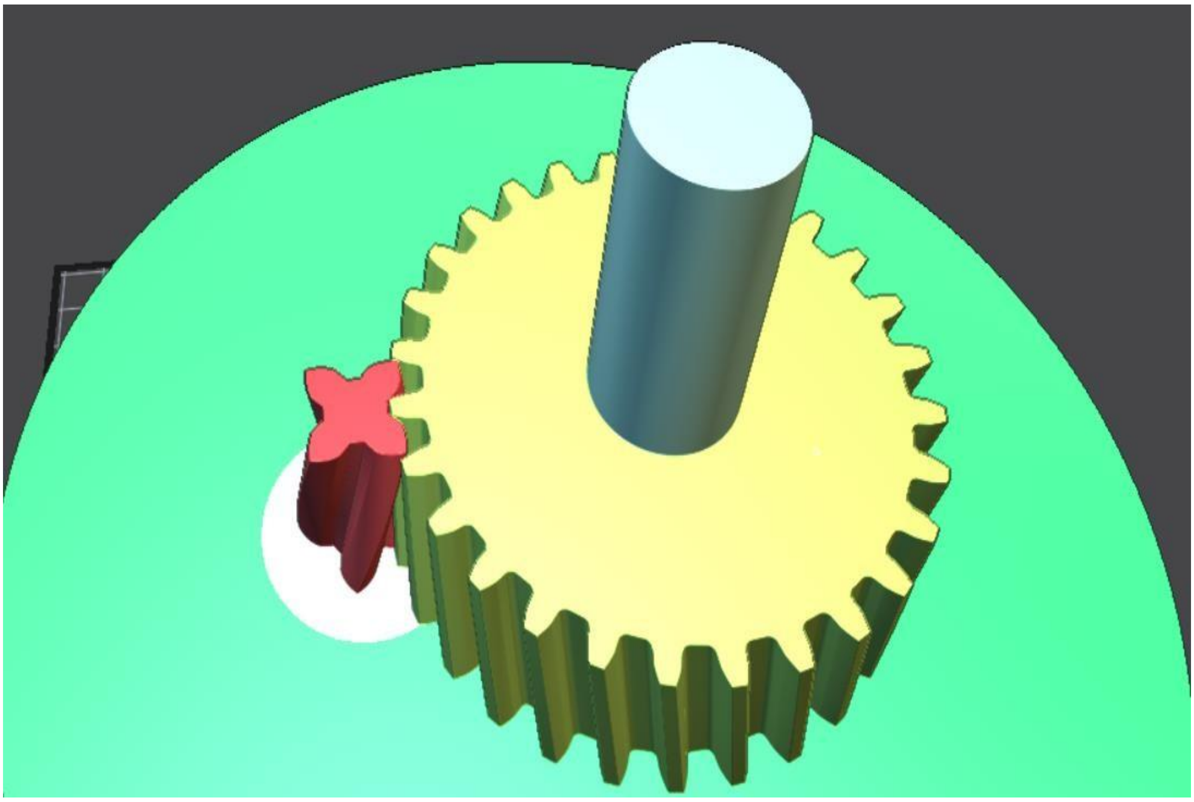


Figure 3:High Ratio Evoloid drive assembly

6 STL file generation and Slicing

To print the evoloid drive assembly, first the user must generate an STL file. For more information user can check here,[Slicing settings (loria.fr)]. In a nutshell user can create an STL file as shown below,

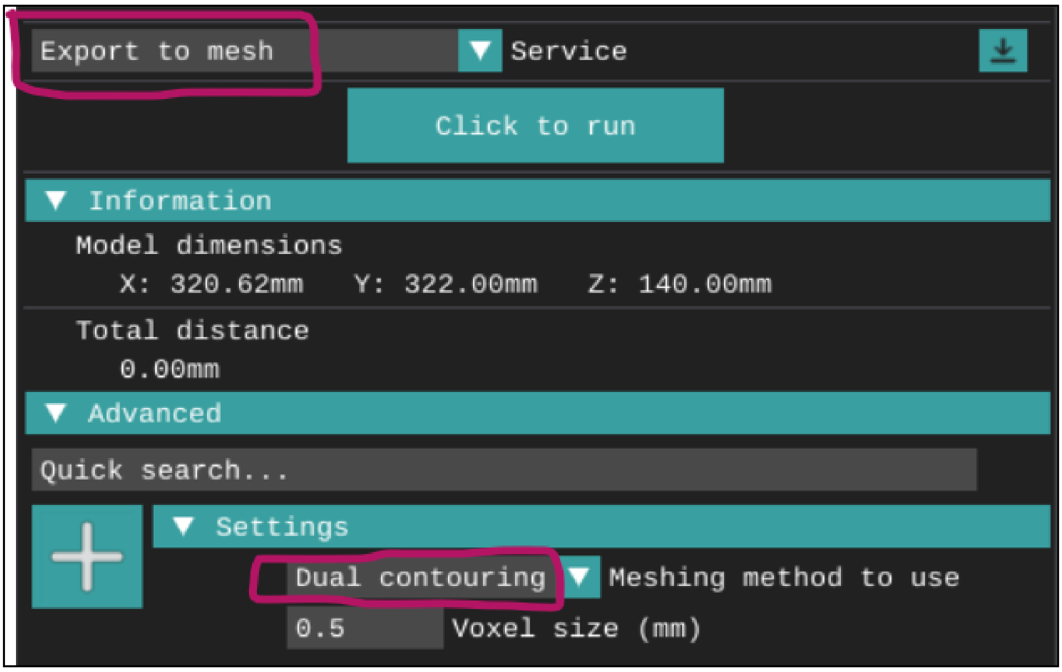


Figure 4:STL file generation

- User needs to select "Export to mesh" under the service tab.
- User needs to choose "Dual contouring" under the tab Meshing method to use.
- User can change the Voxel size

After the STL file generation, the user must slice it to generate the G-code. Before that user must select the printer, material etc. From the settings user can change many factors. After generating the G-code user can check the print time(build time),number of layers and many more.

7 Assembly Description

Part list:

1. Big Gear
2. Pinion
3. Shaft for Big gear
4. Shaft for Pinion
5. Casing for the assembly
6.Bolts/Nuts

- The high gear ratio Evoloid drive mechanism can be printed by the user by following the instructions. For the Assembly, a part list is also stated above so that the user can assemble the mechanism.
- The Big Gear and pinion are mounted on the casing using the 4 bolts so that the user needs to drill holes. A shaft is also mounted on the slot of the big gear. For the pinion shaft to fit the pinion in the casing we must cut the casing or drill a hole in casing.

8 Credits

- Chakarabarthi, A. (n.d.). Engineering Design Synthesis: Understanding, Approaches and Tools. .[Engineering Design Synthesis: Understanding, Approaches and Tools - Google Books]
- Gmbh, M.-K. (n.d.).
- Prof.Dr. Ing. Stefan.Scherbarth, P. (n.d.). for the extrude function in the Lua script (Code Line number 182-235),[For more information check the Lua code]