3D SolidWorks Tutorial

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INTRODUCTION - 3D DESIGN SOFTWARE

There are a few different kinds of 3D design software available for use by RIT students. The preferred software for compatibility with the 3D printers is Inventor. This software can be downloaded for free by students from the internet. SolidWorks is another software that can be found on RIT computers in Mechanical Engineering. Both of these programs use similar vocabulary and functions, so after learning one software, it is not difficult to transition to another. The basic operations are either identical or very similar with only minor nuances between programs.

Above graphics from software websites.
Software is available in the PC labs owned by the Mechanical Engineering Department. You can use these PC’s (except sometimes when a class/lab is being taught). You can sign on with your RIT user account and password. PC labs in GLE-2260 and ENG-1535.
Click on Part
WORKSPACE

Draw your part here.

Workspace. See some notes on next page.
SET UNITS AND GRID

First set units and Grid
Select Options, Document Properties, Units (Custom) and change to microns, Kg, m³

Then set Grid/Snap
SELECT PLANE… START SKETCH

When you start a sketch you will be asked to select a plane…click on it. Select one of the 3 planes on which to draw your sketch. Here the Top Plane is selected.
CHANGE VIEWS AND BANNERS

Middle mouse button lets you zoom in/out and rotate the view

Top banner can be symbols or tabs, click on small arrow on left

Tools banner is shown under top banner.

Note: you can select visible tabs by right clicking on any of the existing tabs and selecting the tabs you want shown.
To draw a 100um by 40um rectangle. Click Sketch and Corner Rectangle. Then zoom in on the origin symbol using the middle mouse button (roll towards you) so that the 100um size rectangle can be seen once defined. Then click on the dot at the origin and drag to the other corner (approximate dimensions). The exact dimensions can be set in the parameters box on the left. When that object is correct click on the green check mark.
The sketch might look like this. Actually four lines. The dimensions can be displayed on the sketch. See next page.
SMART DIMENSION

The length of selected lines can be displayed by clicking on Smart Dimension and then on a line in the sketch. The length and other properties can be modified during this operation.
To convert the 2D sketch into a 3D object select Features > Extrude Boss/Base. Set the height in the properties box on the left. Click on the green check box when done.
2D EXTRUDE TO 3D AND Y DIMENSION SET TO 2um

The result of the conversion of the 2D sketch into a 3D object select Features > Extrude Boss/Base is shown here where the thickness was set to 2 microns.
INSERTING A SPLIT

In preparation for applying a force or temperature you may need to split the 3D object. For example if you plan to add a force to one end of the structure you need to create a split near one end of the object. See next pages.

Split can also help shape more complex bodies.
Sketch a line then... Select Insert on the top banner (use little arrow to get tabs) then Features, then Split. Then select the object and the line that defines the cut. Be sure to uncheck [ ] Consume cut body. Then cut part... see dialog box and result on the next page.
Be sure to uncheck the [ ] Consume cut Bodies

When done click the green check mark
Be sure to uncheck the [ ] Consume cut Bodies

When done click the green check mark
A line has been drawn and a split created shown on the right end.
**STUDY (SIMULATION)**

Apply Material
Fixtures to support structure
External Loads

Create Mesh
Run This Study
### PROPERTIES OF Si, Al, SiO₂, Si₃N₄

<table>
<thead>
<tr>
<th>Property</th>
<th>Silicon</th>
<th>Aluminum</th>
<th>SiO₂</th>
<th>Si₃N₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (g/cm³)</td>
<td>2.33</td>
<td>2.7</td>
<td>2.5</td>
<td>3.1</td>
</tr>
<tr>
<td>Thermal Expansion (E-6/(°C))</td>
<td>2.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal Conductivity (w/(m°C))</td>
<td></td>
<td>149</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young’s Modulus (GPa)</td>
<td>112</td>
<td>68</td>
<td>73</td>
<td>385</td>
</tr>
<tr>
<td>Shear Modulus (GPa)</td>
<td>70</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poisson Ratio</td>
<td></td>
<td>0.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield Strength (GPa)</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tensile Strength (GPa)</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

More

still working on these entries
Create a new folder (such as MEMS) in the Custom Materials folder. Copy Silicon from the Silicons folder and put it the folder created and name it Polysilicon. Click on Polysilicon, enter Thermal Coefficient of expansion 2.33E-6/°K. Apply Close.
You can select either of the two objects or both. Which you can work with. For example the blue area can have its material set to poly silicon, or add a force.
ADDING FORCE TO A SURFACE AND FIXTURE

Force = 10uN
CREATE FINITE ELEMENT ANALYSIS (FEA) MESH
DISPLACEMENT SOLUTION

Red indicates 1E-3mm or 1um
Von Mesis - STRESS RESULTS

Red indicates stress = 36MPa

Von Mesis stress
Richard von Mises

von Mises, von Mises Yield Criterion

von Mises, an applied mathematician forced to leave Germany in 1933, came to Harvard in 1939. He gave the first university course on powered flight in 1913, and made and piloted a 600-horsepower aircraft for the Austrian army.

von Mises developed a criterion for the yield stress of ductile materials that employs the total distortional strain energy in the sample. Originally developed for mathematical convenience, the model provides a better fit to data obtained on ductile samples than the Tresca criterion. Written in terms of the principal stresses this criterion states that yield will occur when:

$$\sigma_M = \left( \frac{1}{2} \left[ (\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 \right] \right)^{0.5}.$$ 

The value of $\sigma_M$ can be obtained from a uniaxial yield stress determination since for uniaxial tension $\sigma_1 = \sigma_y =$ yield stress, and $\sigma_2 = \sigma_3 = 0$, so that $\sigma_M = \sigma_y$. The term in the square root is also proportional to the shear stress on the octahedral planes of the coordinate system defined by the principal axes.
# CALCULATIONS

### Maximum displacement $Y_{\text{max}}$ for given force ($F$)

$$Y_{\text{max}} = \frac{F L^3}{3EI}$$

$$I = \frac{bh^3}{12}$$

### Maximum Stress for given force ($F$)

$$\sigma_{x=0} = \frac{F L h}{2I}$$

### Material Properties

<table>
<thead>
<tr>
<th>Material</th>
<th>Silicon</th>
<th>Oxide</th>
<th>Nitride</th>
<th>Aluminum</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Youngs Modulus</td>
<td>1.90E+11</td>
<td>7.30E+10</td>
<td>3.85E+11</td>
<td>6.80E+10</td>
<td>N/m²</td>
</tr>
<tr>
<td>Density</td>
<td>2.30E+03</td>
<td>2.50E+03</td>
<td>3.10E+03</td>
<td>2.70E+03</td>
<td>Kg/m³</td>
</tr>
<tr>
<td>Ultimate Strength</td>
<td>1.40E+10</td>
<td>1.60E+10</td>
<td>2.80E+10</td>
<td>6.80E+10</td>
<td>N/m²</td>
</tr>
</tbody>
</table>

ADDING ANIMATION
Select Simulate > Plot Tools > Animate
OTHER STRUCTURES OF INTEREST

- Complex Cantilever
- Diaphragms
- Chevron
- Hot Arm
- Cold Arm
- Thermal Actuator
- Thermal Actuators
- Fixed Points in Red
OTHER STRUCTURES OF INTEREST

Springs

Fixed Points in Red

Multilayer Different Materials

Simple Bridge
REFERENCES

1. Solid Works website help.
2. Dr. Fuller’s Tutorial on 3D printing. See webpage
1. Duplicate the drawing and evaluation of a simple cantilever with different dimensions.
2. Draw and evaluate one of the structures on page 30.