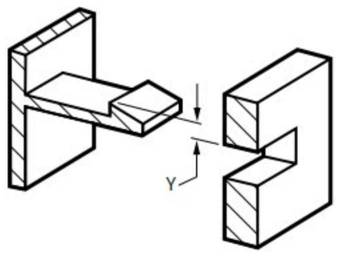
Snap Fit Design

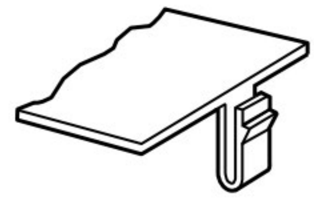
Best practices For Additive Manufacturing Processes

Common Examples

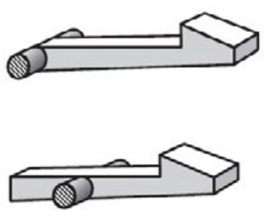


Cantilever

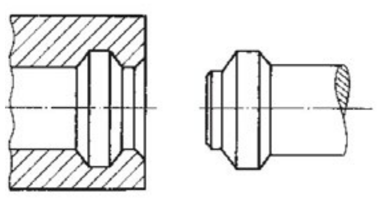
L-Shaped Cantilever



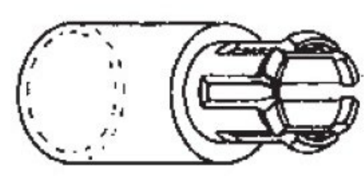
U-Shaped Cantilever



Torsion (Inseparable, and Separable)



Annular



Discontinuous annular snap joint
Also called: Segmented Cantiever in circular format

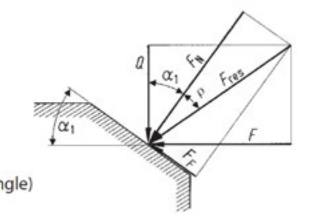
Snap-fit parts allow assembly without tools for thermoplastic components that fit together. They can be permanent or removable, depending on the design and material pairing criteria.

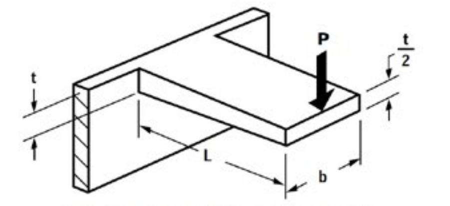
Additive Manufacturing (AM) affords oportunities for useful application of snap-fit geometry in prototyping attachment modes often associated with injection molding processes. While there are few tooling costs associated with part production through AM processes, it is still necesary to consider build orientation and material selection when designing snap-fits to optimize part integrity and function.

Important considerations when implementing a snap-fit joint are material resilience and elasticity, permitted strain, deflection, clearances and build orientation to prevent staircase effects.

Applied Forces

Q = Deflection force
F = Assembly force
F_N = Normal force
F_F = Friction force
F_{res} = Resultant force
α_1 = Joining angle (lead-in angle)
ρ = Friction angle





II) Uniform Width, Height Tapers to t/2 at Free End

Stiffness: $k = \frac{P}{Y} = \frac{Eb}{6.528}\left(\frac{t}{L}\right)^3$

Strain: $\mathrm{E} = 0.92 \left(\frac{t}{L^2}\right) Y$

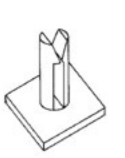
Where:
E = Flexural Modulus
P = Force
Y= Deflection
b = Width of Beam

For more on strain calculation, check out the BASF Snap-Fit DesignGuide in the resources section

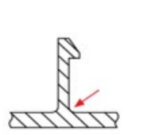
Cantilever Snap-Fit

- Successful design must find a balance between integrity of the assembly (stays latched) and strength of the cantilever beam (doesn't degrade with repeated stress).
- The depth of the overhang defines the amount of deflection during assembly.
- A cantilever beam with a deep overhang can make the unit secure, but it also puts more strain on the beam during assembly and disassembly.
- The overhang typically has a gentle ramp on the entrance side and a sharper angle on the retraction side.
- A small angle at the entrance side helps toreduce the assembly effort.
- A sharp angle at the retraction side (hook) makes disassembly very difficult or impossible depending on the intended function.
- Locators help the user to align the parts and guide the movement until a snapping sound indicates that the connection is made
- Tapering the beam helps reduce strain on the material and allows more deflection without permanent deformation of the beam material
- Choose the direction of deflection independently of the given joining direction if it works better with build orientation
- Consider the amount of deflection carefully - Large deflection amounts may cause delamination in FDM beam structures
- Stress concentrations are typically found in sharp corners, try to fillet joints to reduce strain

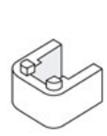
Design to Reduce Material Loading



2-sided snap for tight spaces



fillet joints at base of cantilever

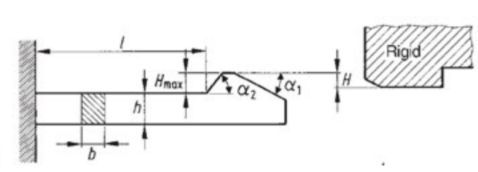


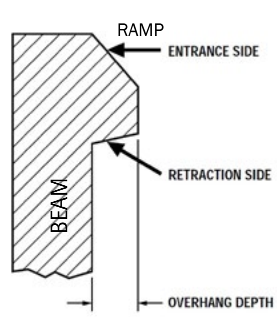
Alignment Features/ Locators

Taper beam

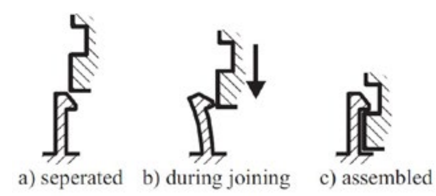
Angles and Clearance Dimensions

α_1 = Joining angle
α_2 = Retaining angle
b = Breadth of cross section (hook breadth)
h = Height of cross section
l = Snap-fit length
H = Snap-fit height (undercut)

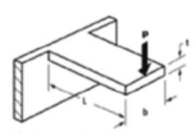




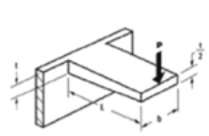
Deflection



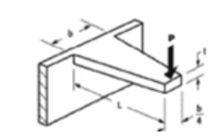
Increase flexibility by removing material



Uniform cross section

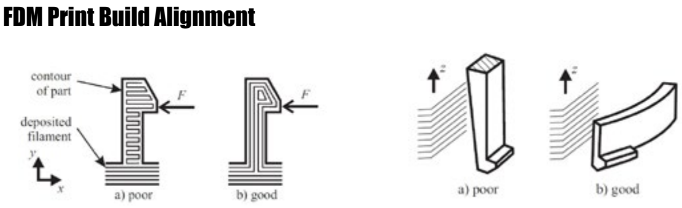


Taper beam height



Taper beam width

FDM Print Build Alignment



During snap-fit joining the material is stressed along the stronger directions of the anisotropic material and the notches between layers have less impact on the durability of the cantilever beam. Consider extrusion head tool path in configuring design elements and build orrientation to yield highest level of part integrity.

Useful Terms

Anisotropic - varying in magnitude according to the direction of measurement.
Beam - in a cantilever snap-fit, the often tapered portion of the design that bends to allow the snap to function
Hook - the angle of the snap that secures the beam when the feature is fully engaged
Overhang - the length of the hook that secures the snap
Ramp - small angle on the entrance side of the hook that allows for easier assembly
Staircase effect - alignment of part geometry that creates jagged edge along angled surfaces in the z axis of the build - creates friction and may cause binding during part assembly
Deflection - amount of travel the beam exhibits during assembly
Creep - gradual deformation where components are under stress

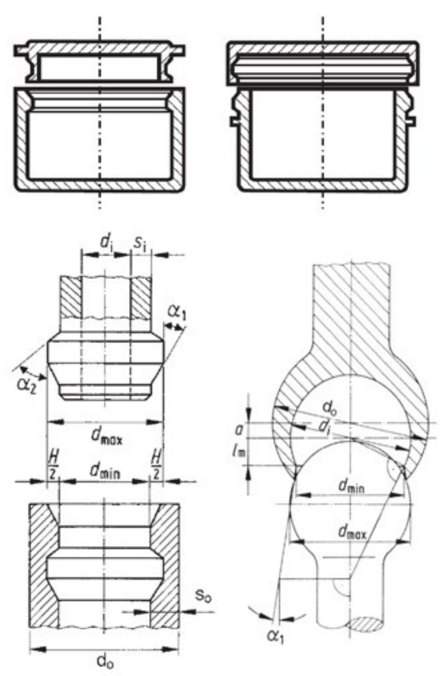
Annular Snap Fit

Annular or circular snap-fits are rotationally symmetrical and involve multiaxial stresses. Annular snap- fits rely on the elastic properties of thermoplastic to expand and compress to allow limited clearances to expand to assemble parts. Thermoplastic material selection criteria must include elastic properties to allow circumference to compress or elongate.

Clearance - difference between greatest diameter and smalest diameter. If producing on FDM equipment design clearance of .012" (.35mm)

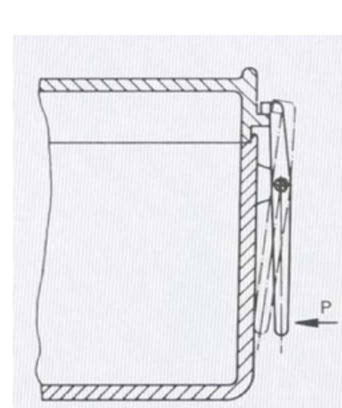
Wall thickness on the outer deflecting (flexing) part. For FDM production not thicker than .075" (1.9 mm)

Dimensions and their designations in cylindrical annular snap-fit joints
d_{max} = Greatest diameter, d_{min} = Smallest diameter } of the snap-fit joint
d_o = Outer diameter, s_o = Wall thickness } of the outer part
d_i = Inner diameter, s_i = Wall thickness } of the inner part



Torsion Snap Fit

Torsion snap-fits rely on rotation about an axis that is fixed in location. Some torsion designs use a removable design like a see-saw - A push on the free end of the beam lifts the hook and releases the joint.



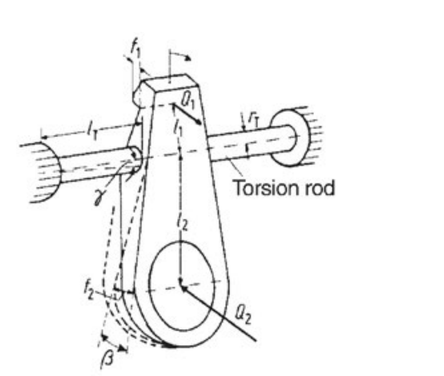


Figure 8.7 Dimensions and their designations in torsional snap-fit joints
l_T = Length, r_T = Radius } of torsion rod
β = Torsion angle
γ = Twisting angle
$l_{1,2}$ = Lever arm lengths
$f_{1,2}$ = Elastic excursions
$Q_{1,2}$ = Deflection forces

References
1. Designing with Plastics, Gunter Erhard
Leseprobe 2, Weitere Informationen oder Bestellungen unter
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ISBN 3-446-22590-0

2. Design Guidelines for Additive Manufactured Snap-Fit Joints
Christoph Klahn*, Daniel Singer, Mirko Meboldt
Inspire AG, Leonhardstrasse 21, 8092 Zurich, Switzerland

3. BASF Snapfit guidelines, 2007

4. Troughton, Michael J., and Institute of Welding International. Handbook of Plastics Joining : A Practical Guide, Elsevier Science & Technology Books, 2008. ProQuest Ebook Central, https://ebookcentral-proquest-com.proxy1.lib.tju.edu/lib/philau/detail.action?docID=428695.

5. Bayer Material Science LLC, Snap-fit joints for plastics - a design guide,
Pittsburg (2013).

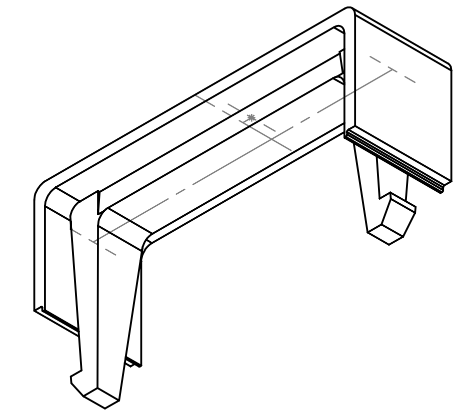
Type of design \ Shape of the cross section		A Rectangle	B Trapezoid	C Ring segment	D Irregular cross section
(Permissible) deflection	1 Cross section constant Over the length	$y = 0.67 \cdot \frac{\varepsilon \cdot l^2}{h}$	$y = \frac{a+b_{(1)}}{2a+b} \cdot \frac{\varepsilon \cdot l^2}{h}$	$y = K_{(2)} \cdot \frac{\varepsilon \cdot l^2}{r_2}$	$y = \frac{1}{3} \cdot \frac{\varepsilon \cdot l^2}{c_{(2)}}$
	2 All dimensions in direction y, e.g., h or Δr, decrease to One-half	$y = 1.09 \cdot \frac{\varepsilon \cdot l^2}{h}$	$y = 1.64 \cdot \frac{a+b_{(1)}}{2a+b} \cdot \frac{\varepsilon \cdot l^2}{h}$	$y = 1.64 \cdot K_{(2)} \cdot \frac{\varepsilon \cdot l^2}{r_2}$	$y = 0.55 \cdot \frac{\varepsilon \cdot l^2}{c_2}$
	3 All dimensions in direction z, e.g., b and a, decrease to one-quarter	$y = 0.86 \cdot \frac{\varepsilon \cdot l^2}{h}$	$y = 1.28 \frac{a+b_{(1)}}{2a+b} \cdot \frac{\varepsilon \cdot l^2}{h}$	$y = 1.28 \cdot K_{(2)} \cdot \frac{\varepsilon \cdot l^2}{r_2}$	$y = 0.43 \cdot \frac{\varepsilon \cdot l^2}{c_{(2)}}$
Deflection force	1,2,3	$P = \overbrace{\frac{bh^2}{6}}^{Z} \cdot \frac{E_s \varepsilon}{1}$	$P = \overbrace{\frac{h^2}{12} \cdot \frac{a^2 + 4ab_{(1)} + b^2}{2a+b}}^{Z} \cdot \frac{E_s \varepsilon}{1}$	$P = Z_{(4)} \cdot \frac{E_s \varepsilon}{1}$	$P = Z_{(4)} \cdot \frac{E_s \varepsilon}{1}$

Subscript numbers in parenthesis designate the note to refer to.

Symbols

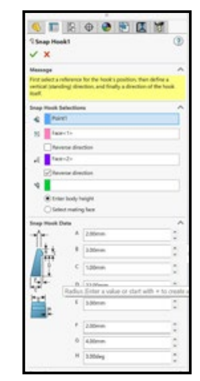
y = (permissible) deflection (=undercut)
E = (permissible) strain in the outer fiber
at the root; in formulae: E as absolute value = percentage/100 (see Table 2)
l = length of arm
h = thickness at root
b = width at root
c = distance between outer fiber and neutral fiber (center of gravity)
Z = section modulus Z = I c, where I = axial moment of inertia
Es = secant modulus (see Fig. 16)
P = (permissible) deflection force
K = geometric factor (see Fig. 10)

Scoring:
Engagement - how difficult is it to seat the snap correctly
Disengagement - how difficult is it to disassemble the snap
Integrity - how well does it hold

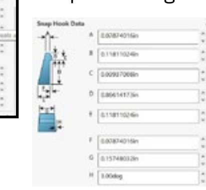


All test snap hooks shared same height and the same receiving slot for continuity

Snap Hook Beam length overall .866" (22 mm)

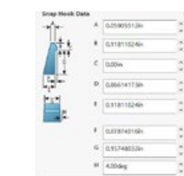


Beam
Thickness
Initial: .118" (3.0mm)
Terminal: .079" (2.0mm)
Width
Initial: .157" (4.0mm)
Taper: 3 deg
Overhang: .079" (2.0mm)
Ramp: .118" (3.0mm)
Snap hook height: .039" (1.0mm)



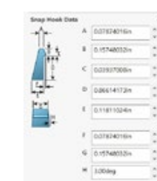
score
Engagement: 3
Disengagement: 4
Integrity: 4

Beam
Thickness
Initial: .118" (3.0mm)
Terminal: .059" (1.5mm)
Width
Initial: .157" (4.0mm)
Taper: 4 deg
Overhang: .079" (2.0mm)
Ramp: .118" (3.0mm)
Snap hook height: .0" (0mm)



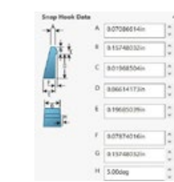
score
Engagement: 3
Disengagement: 4
Integrity: 3

Beam
Thickness
Initial: .118" (3.0mm)
Terminal: .079" (2.0mm)
Width
Initial: .157" (4.0mm)
Taper: 3 deg
Overhang: .079" (2.0mm)
Ramp: .157" (4.0mm)
Snap hook height: .039" (1.0mm)



score
Engagement: 3
Disengagement: 3
Integrity: 4

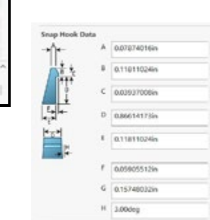
Beam
Thickness
Initial: .197" (5.0mm)
Terminal: .071" (1.8mm)
Width
Initial: .157" (4.0mm)
Taper: 5 deg
Overhang: .079" (2.0mm)
Ramp: .157" (4.0mm)
Snap hook height: .02" (.5mm)



score
Engagement: 3
Disengagement: 2
Integrity: 5

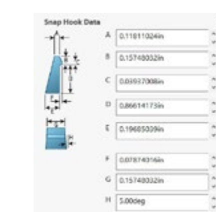
Beam
Thickness
Initial: .118" (3.0mm)
Terminal: .079" (2.0mm)
Width
Initial: .157" (4.0mm)
Taper: 3 deg

Ramp: .118" (3.0mm)
Snap hook height: .039" (1.0mm)



score
Engagement: 4
Disengagement: 4
Integrity: 4

Beam
Thickness
Initial: .197" (5.0mm)
Terminal: .118" (3.0mm)
Width
Initial: .157" (4.0mm)
Taper: 5 deg
Overhang: .079" (2.0mm)
Ramp: .157" (4.0mm)
Snap hook height: .039" (1.0mm)



score
Engagement: 3
Disengagement: 1
Integrity: 5