Design and Analysis of Snap Fit Joint with Design Calculator

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ABSTRACT

Structural elements that are required to have high deformability should be designed so that they are capable of withstanding the flexural or torsional loads associated with the application. Two examples of such designs common in parts made from polymeric materials are snap-fit or interlocking joint elements and elastic elements. Snap fits are the simplest, quickest & most cost-effective method of assembling two parts. When designed properly, parts with snap-fits can be assembled and disassembled numerous times without any adverse effect on the assembly Intension of our project was to replace the screws used on the PCB's in any electronic device. We have design a cantilever snap-fit joint with reference of dimensions taken from a PCB (motherboard) of a laptop. We have formulated the design procedure for various components of snap-fit in excel sheet, wherein we could further develop different design of each component for different payloads, thus we have partially made a universal program to develop any (of this type) snap-fit. The design was calculated analytically and the model has been prepared using SOLIDWORKS. The analysis of snap-fit or was carried out using analytical and software using ANSYS software. Snap-fits are also the most environmentally friendly form of assembly because of their ease of disassembly, making components of different materials easy to recycle. A snap-fit device is provided for joining two parts of any shape together by fitting, perpendicularly to their junction surfaces, at least one element projecting from the junction surface of one of the parts, after slight deformation thereof, into a recess in the junction surface of the other part and engagement of the projection element, by resilient return thereof, on a surface portion of the recess. Basically, a moulded undercut on one part engages a mating lip on the other. This method of assembly is uniquely suited to thermoplastic materials due to flexibility, high elongation and ability to be moulded into complex shapes. Although snap-fits can be designed with many materials, the ideal material is thermoplastic because of its high flexibility and its ability to be easily and inexpensively moulded into complex geometries.

Keywords*: Snap Fit Joint, Design, Design Calculator.*

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1. INTRODUCTION

A Snap-fit (Integral Attachment Feature) is an assembly method used to attach flexible parts, usually plastic, to form the final product by pushing the parts interlocking components together. There are a number of variations in snap fits, including cantilever, torsional and annular. Snap fits are an alternative to assembly using nails or screws, and have the advantages of speed and no loose parts. Snap fit connectors can be found in everyday products such as battery compartment lids, Snap fasteners and Pens. Snap-together connectors have been used for thousands of years. The first ones were metal. Some of the oldest snap-fits found are snap fasteners, or buttons, developed for the Chinese Terracotta army. Metal snap fasteners, spring clips, and other snap-type connectors are still in broad use today. With the development of new flexible yet springy materials, such as moulded plastic, and new manufacturing processes, many new variations in these types of connectors have been invented, and are commonly called snap-fits. They can be found in on our phones, laptops, keys, and other household devices. Engineers have studied and developed these snap-fits, creating formulae concerning the amount of deflection allowed on the components, amount of torque one can take, and the amount of space one can allow in order to be detached.

Production of snap fit molds of the parts is created and hot liquid plastic is poured into the molds. The molds contain the shape of the parts and the snapping component built in. However, one major risk when the cooling of the mold finishes is the product shrinking causing errors in the attachment parts. Building a snap-fit design requires more precise engineering than a screw or nail assembly, and is often more expensive. When snap-fits are being made, the producer needs to determine where the stresses of the parts will be applied to when assembled, or they break will during assembly. The high production costs are due to the amount of calculation and precision that must be done in

order to create a strong snap-fit. The design of the Snap-fit determines what it can be used for. There are three main types of snap-fits: annular, cantilever, and torsional. Most snap-fit joints have a common design of a protruding edge and a snap-in area. The specific name of the snap-fit is usually named after the type of stress or strain it utilizes; the torsional snap-fit uses torque to hold parts in place.

1.1 NEED FOR THE WORK

Customers want their laptops to be thin, light weight, durable and of course, stylish. To produce these "ultra-notebooks", manufacturers need an equally advanced material. Fortunately, they can turn to high-performance reinforced polycarbonates and polycarbonate blends to bring the next generation of laptops to market. Snap-fits are used to replace screws in the PCB's or motherboards. Since the screws used in motherboards can sometime lead to grounding issues, Grounding is act of short-circuiting due to contact of metal parts with your system. So, using plastic part instead can avoid short-circuiting. Sometimes un-screwing a motherboard gets tough from standoff, making the screws to rotate at the same position

2. DESIGN CONCEPT

Snap-fit joints are widely used in the industry as a simple, economical and quick way of connecting two parts. The joints consist of one male and one female part. The temporary bending of the cantilever hook allows the fit of two pieces, using the material's elasticity property. After the joining operation, the pieces return to a stress-free state. The geometrical parameters of the parts define the force needed to assemble or disassemble it and the separable or inseparable characters of the joints. The joint is mainly designed according to the mechanical load during assembly and its corresponding assembly force.

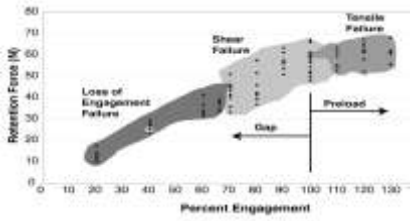
Rudimentary design is provided by the snap-fit manufacturers such as BASF (BASF 2007) or Bayer (Bayer Material Science LLC 2000). Based on the assumption of the Euler-Bernoulli beam theory, the design variables for the joints are the following:

Height of the cantilever beam t,

Length of the cantilever L,

Width of the cantilever b,

Undercut Y.



Given the maximal permissible strain of the material ε, the maximal deflection for a cantilever with rectangular and constant cross section is:

$$Y(\max) = 0.67\frac{\varepsilon L^2}{t(\text{base})}$$

For a cantilever snap joint with decreasing height to one-half at the tip over the length the 0.67 factor becomes 1.09.

During the assembly, the deflection force P at the tip of the cantilever at Ymax is given by:

$$P(\text{deflection}) = \frac{bh^3}{6}\frac{E\varepsilon}{L}$$

Where E is the modulus of the material and b the width of cantilever. More information on the design of cantilever snap joint can be found at (BASF 2007) or derived from the beam theory of a cantilever beam with point load at the tip.

The force necessary to assemble the joint, called mating force, depends on the friction coefficient of the material μ, the insertion angle and the deflection force. Both the deflection and friction force have to be overcome by the mating force:

$$F(\text{mating}) = P\left[\frac{\mu + \tan\alpha}{1 - \mu\tan\alpha}\right]$$

The same equation can be used to determine the separation force of the joint where the insertion angle alpha has to be replaced by the retention angle beta. A value of 90° for the retention angle gives the maximal retention force. Furthermore, a study from Luscher (Luscher 1995) shows that the retention force not only depends on the retention angle but on the Percentage of Engagement (PE) as well. The engagement is the depth of insertion in the undercut of the mating part. A hook fully in contact with its mating part would have a PE of 100 per cent. The PE defines the failure mode and thus the maximal retention force. Finally, the stress concentration at the root of the cantilever should be reduced by adding a fillet radius.

3. DESIGN CALCULATION

3.1 MATERIAL SELECTION

From circuit breakers to renewable energy products, polycarbonate helps the electrical industry bring its technologies to the market to meet the high demand for durable, rugged performance. [8]
Thermoplastics for electrical applications must offer reliable insulation properties, safe operation, high mechanical property profile and protection from electric shock.

	ABS+PC	POLYSULPHONE	RADEL-r	PETG
MAX TEMPERATURE (deg celcius)	105	174	182	70
COST ($ / kg)	8.37	26.98	56.75	5
TENSILE YIELD STRENGTH (MPa)	51	70	69.6	50
FLEXURAL YIELD STRENGTH (MPa)	75	106	91	70
FLEXURAL MODULUS (MPa)	2410	2600	2400	2075

Polycarbonate + acrylonitrile butadiene styrene (PC+ABS) blends exhibit an excellent balance of properties, most notably high toughness – even at cold temperatures – rigidity, dimensional stability, excellent creep resistance, low moisture absorption and good heat resistance. Polycarbonate's high mechanical strength, heat resistance and outstanding electrical insulation properties makes it the material of choice.

3.2 FORMULATION FOR INSERTION FORCE

3.2.1 Determine the insertion force:

The dimensioning of the snap-fit is done for the deflection Y, to which the hook moves in order to go past the interference. The deposition of the forces acting on element one, at this point is shown in fig
Considering from the figure
P :- Horizontal Force
W :- Insertion Force
N :- Normal Force
Y :- Horizontal Deflection Necessary for the hook to go past the interference

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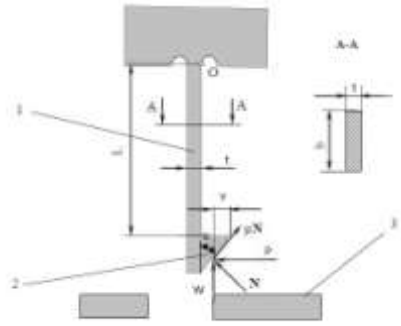

Figure 0-1: Forces on cantilever snap fit

The horizontal force (P) acting during the deflection equal to:

$$P = N\cos\alpha - \mu N\sin\alpha$$
$$= N[\cos\alpha - \mu\sin\alpha]$$

Resolving Vertical Force Yield.

$$W = N\sin\alpha + \mu N\cos\alpha$$
$$= N[\sin\alpha + \mu\cos\alpha]$$

Eliminating N from above equation given

$$W = P\left[\frac{\mu + \tan\alpha}{1 - \mu\tan\alpha}\right]$$

The Snap Fit when regarded as the cantilever then the horizontal deflection Y is

$$Y = \frac{PL^3}{3EI}$$

Where

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

After replacing 'P' we get,

$$Y = \frac{WL^3}{3EI}\left[\frac{1 - \mu\tan\alpha}{\mu + \tan\alpha}\right]$$

Hence the insertion force 'W' is

$$W = \frac{EbY}{4}\frac{1}{\left(\frac{L}{t}\right)^3}\left[\frac{1 - \mu\tan\alpha}{\mu + \tan\alpha}\right]$$

3.2.2 Determination of stress when joining the parts:

The dimensioning of Snap-Fit also requires determining the stress at the point when the beam experiences strain.The stress must not exceed the yield strength for the material.The stress for such type of cantilever is

$$\sigma = \frac{My}{I}$$

M is the bending moment,

M = P.L

Y is the half depth of the beam,

$$y = \frac{t}{2}$$

I is the Moment of inertia

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

$$\sigma = \frac{PLt}{2I} = \frac{WLt}{2I}\left[\frac{1 - \mu \tan\alpha}{\mu + \tan\alpha}\right]$$

$$\sigma = \frac{3EYt}{2L^3}$$

From the above formula, we can see stress is independent of the width 'b'.

3.3 CAD MODEL

3.2.1 2D Model

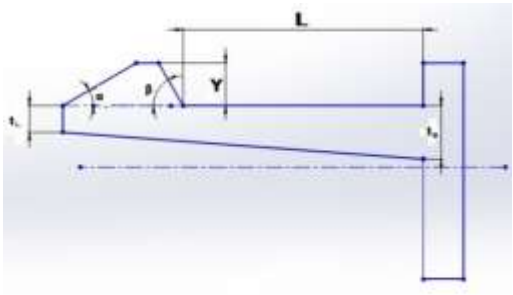

Figure 3.2.1 Snap-fit 2D model

t_0 Thickness of the cantilever beam at base end,

t_L Thickness of the cantilever beam at catch end,

L Length of the cantilever beam,

b Width of the cantilever beam,

Y Undercut,

α Angle of insertion,

β Angle of retention.

3.4 RESULT & DISCUSSION

SR. NO.	NAME OF PART	CALC. VALUES	C/S AREA mm^2	MATERIAL STRENGTH MPa	STRESS (CALC. & ANSYS REPORT) MPa
1	Permissible deflection(Y)	0.66217 mm	-	-	-
2	Permissible deflection force(P)	5.36 N	-	-	-
3	Assembly force(W)	8.12 N	-	-	-
4	Retention force(W')	89.22 N	-	-	-
5	Beam at section 1-1	-	2	75	72.3
6	Beam at catch end (section 0-0)	-	1	51	46.538

The bending stress at the section 1-1 of the cantilever beam, after calculation is well within the range of the flexural strength of the material.

The shear stress at the section 0-0 of the cantilever beam, after ansys analysis is within the range of the tensile strength of the material.Thus snap-fits made from the selected material and under the given boundary conditions can replace screws in the fixing PCB'S to the laptop base.

3. CONCLUSION

Snap-fits solve the problem of creating an inexpensive component that can be quickly and easily joined with another piece. With the need of lighter laptops, ease in removal and attachment of the internal parts, screw replacement such as snap-fit is considered. Few geometrical conditions are already known such as the distance between the PCB and laptop base, and the PCB hole diameter. The cantilever type of snap-fit is selected for the application. When permanent assembly is considered, there is just one deformation, so the strain cannot exceed the above-mentioned strain. In the case of a sloped beam, stress is reduced as it is widely distributed throughout the cantilever. Therefore, the stress concentration and fastening force is relatively reduced. Selecting the material which can withstand maximum temperature, Thermoplastics are selected as they are ideal material for snap-fits because they have the flexibility and resilience necessary to allow for numerous assembly and disassembly operations. On the basis of material properties and geometrical values, thickness, permissible deflection (Y), permissible deflection force (P), assemble force (W), retention force (W') is calculated and the stress obtained is compared with the flexural strength of the material. Further an ansys report is obtained and project is validated with the obtained shear stress and given tensile strength of the material.

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