Modeling SCME Microcantilever Using Solidworks

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SCME
Support Center for Microsystems Education

Modeling SCME Microcantilever Using Solidworks

Abstract - This presentation will show how to model SCME microcantilevers in support of MEMS education. The resonant mode of vibration of various cantilever beams supplied in the SCME microcantilever kits will be evaluated to see how the resonant mode of vibration of a cantilever beam is influenced by mass, modulus of elasticity, and beam dimensions using the 3D CAD software Solidworks.

SCME - Microcantilever Model Kit

This kit supports the Microcantilever Learning Module.

The Microcantilever Model Kit allows students to investigate the motion of a dynamic cantilever under varying masses and various dimensions in order to determine the relationship that expresses the resonant frequency of a cantilever as a function of mass or size. This activity simulates the dynamic mode of operation for microcantilevers used in MEMS sensors.

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Solidworks

A solid modeling computer-aided design and computer-aided engineering computer program that runs primarily on Microsoft Windows. While it is possible to run SolidWorks on MacOS, it is not supported by SolidWorks. SolidWorks is published by Dassault Systèmes. *Wikipedia*

Microcantilever Model Kit

This kit contains most of the materials for the Microcantilever Model Activity in Book 2 of the Microcantilever Learning Module. This activity provides participants an opportunity to explore the motion of a cantilever under a varying mass and to determine the relationship that expresses the resonant frequency of a cantilever as a function of mass. This activity simulates the dynamic mode of operation for microcantilevers used in MEMS sensors.

Review of the Kit
to get the kit

login to www.scme-support.org and then go to
Educational Materials>Order Kits and select
*** CLICK HERE FOR PRICING AND TO ORDER ***
You would select
8A - Microcantilever Model Kit which cost 225.00

The kit includes the following cantilevers:

6 - 3cm wide, 3mm thick, 60cm long sticks of density 1 (D1)
6 - 3cm wide, 3mm thick, 60cm long density 2 (D2 – colored sticks)
3 - 6cm wide, 3mm thick, 60cm long D1
3 - 9cm wide, 3mm thick, 60cm long D1
3 - 3cm wide, 6mm thick, 60cm long D1
3 - 3cm wide, 13mm thick, 60cm long D1

Also 6 C-clamps and 36 binder clips

Microcantilever Model Kit

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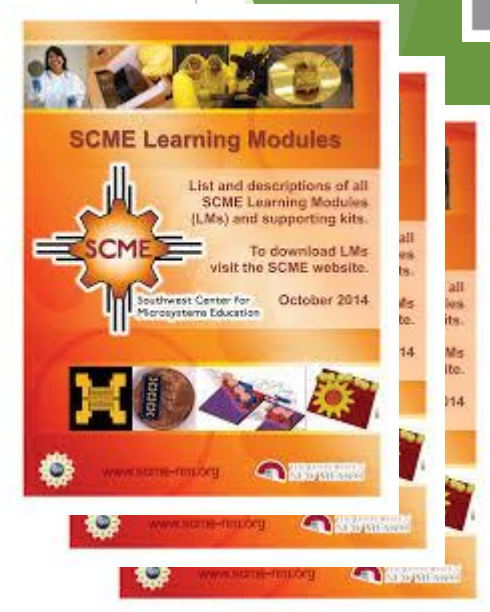
Review of the Kit
to get the educational material

login in to https://scme-support.org/ and then go to EDUCATIONAL MATERIALS>MEMS Applications>Microcantilevers and from here select "Microcantilevers for Instructors" and/or "Microcantilevers for Participants"

A Bit of Dynamic Theory[1]

$$\omega_0 = \sqrt{\frac{k}{m}}$$

Natural Frequency

$$k = \frac{Et^3 w}{4l^3}$$

Spring Constant

The natural frequency (ω_0) of a cantilever is related to its spring constant, k and mass, m. For a rectangular cantilever beam the spring constant (k) is a function of

E = Young's modulus of Elasticity (a property of the material)

t = thickness

w = width

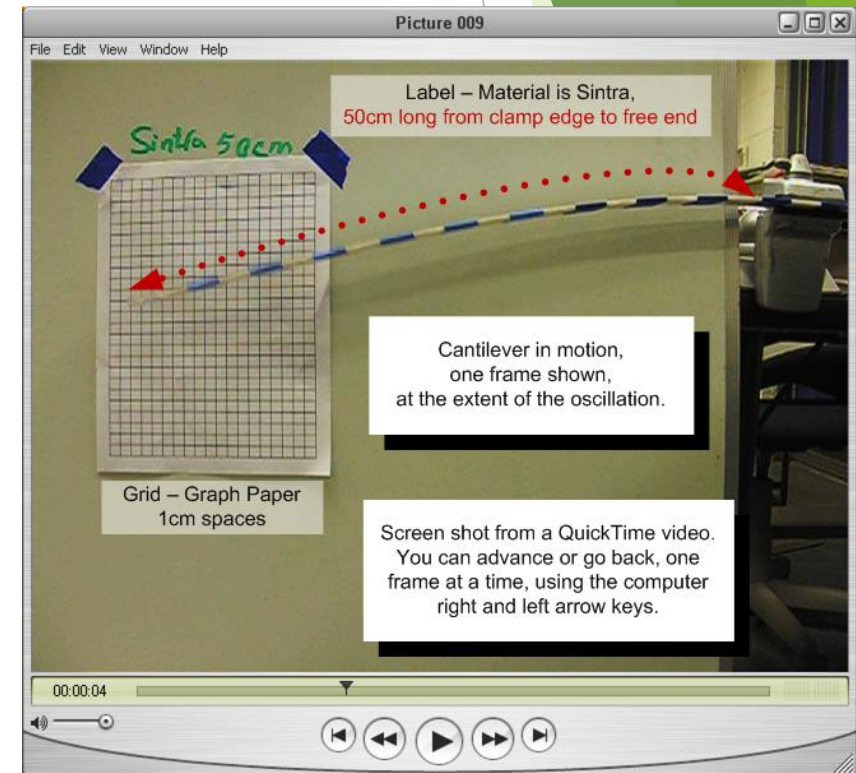*l = length*

1 – SCME presentation on "HOW DOES A CANTILEVER WORK?"

Young's Modulus of Elasticity

E = 9.6GPa for Sintra, a type of PVC Foam. This was determined assuming a 1.4g/cm^3 density, 3mm thickness, 50cm length, 5cm width and measuring a 2.5Hz resonant frequency for this cantilever at this length.

The Experiment

Step 1 - Set up cantilever
Step 2 – Set up camera
Step 3 - Record cantilever specifications
Step 4 - System Calibration
Step 5 - Create a data table
Step 6 - Record cantilever oscillations with no mass
Step 7 - Record cantilever oscillations with added mass
Step 8 - Determine the natural resonant frequency of the cantilever system
Step 9 - Record your data
Step 10 - Repeat steps 7 – 9
Step 11 - Plot your data
Step 12 - Complete the documentation requirements
Step 13 - Answer all of the Post-Activity Questions and turn in with the report.

The Calculations

The natural frequency (ω_0) of a cantilever is related to its spring constant, k and mass, m. For a rectangular cantilever beam the spring constant (k) is a function of the dimensions of the beam: thickness, width and length.

E = Young's modulus of Elasticity (a property of the material) = 9.6GPa
t = thickness = 3mm
w = width = 3cm
l = length = 50cm
ρ *= 1.4g/cm^3*
ω_0 *= sqrt(k/m) = 15.7rads/sec = 2.5 Hz*

$$\omega_0 = \sqrt{\frac{k}{m}}$$

Natural Frequency

$$k = \frac{Et^3 w}{4l^3}$$

Spring Constant

Solidworks (the Simulation)

Step 1 - In Solidworks draw a cantilever beam with a length of 50cm, a width of 3cm and a thickness of 3mm. This basic shape will be used for all of the simulations. The result will be a drawing that looks like a wood plank or a diving board. In our case we drew a Center Rectangle on the Front Plane of 3mm by 3cm and Extruded Boss Base 50cm.
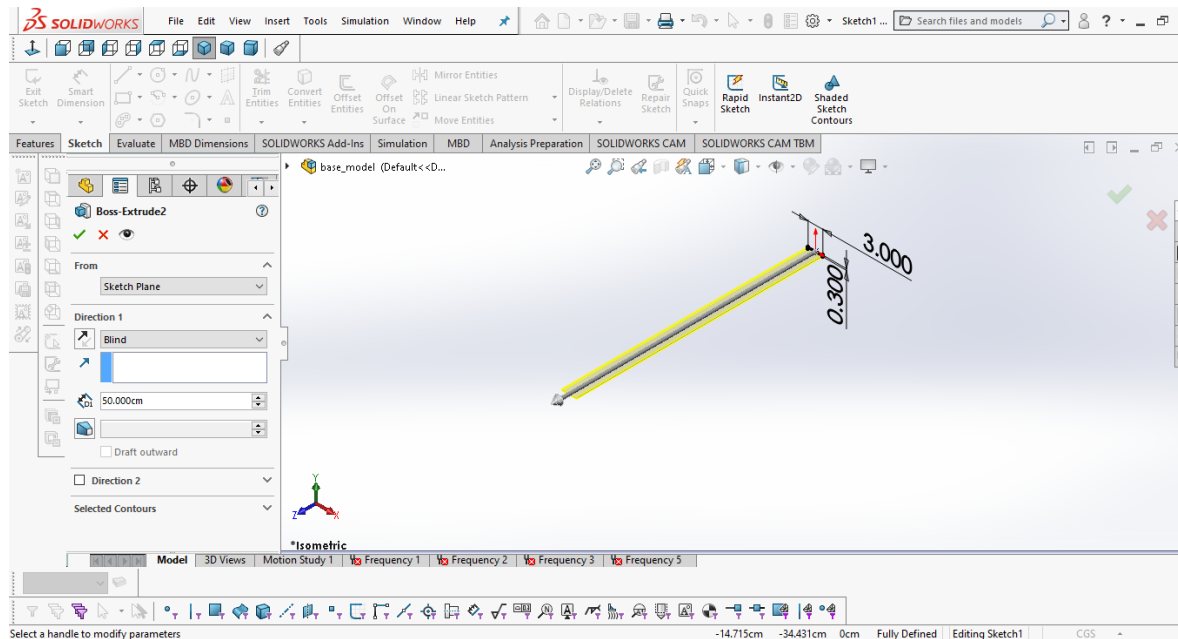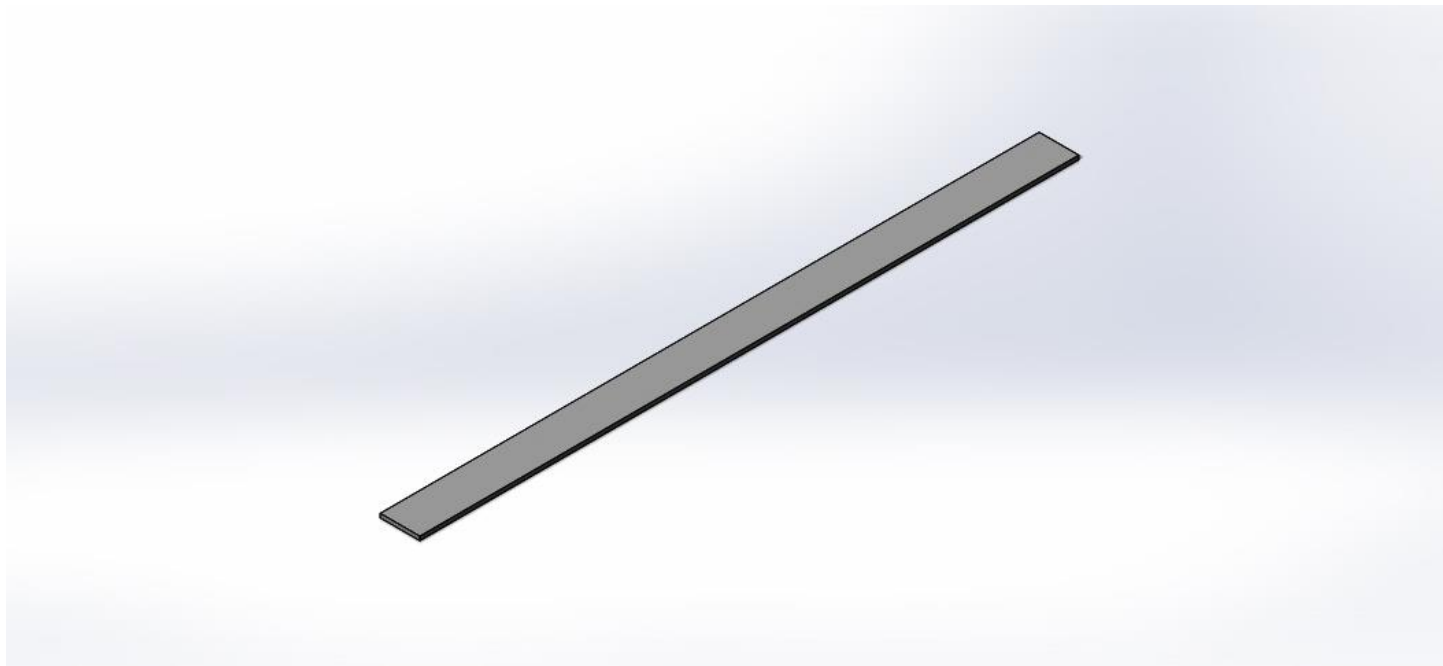
Solidworks (the Simulation)

A *Frequency Analysis* will be run to determine the *resonant mode* of vibration for the cantilever beam. The basic shape will be needed for each beam you will be evaluating. The beam is shown in a 3D isometric view which is commonly used for CAD drawings.
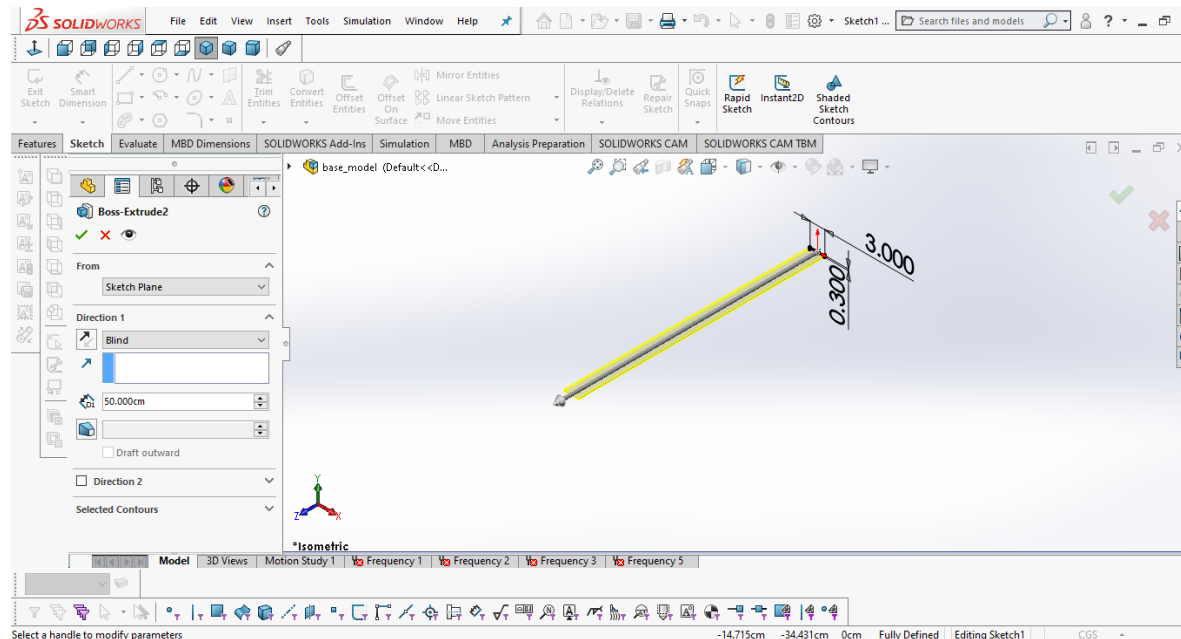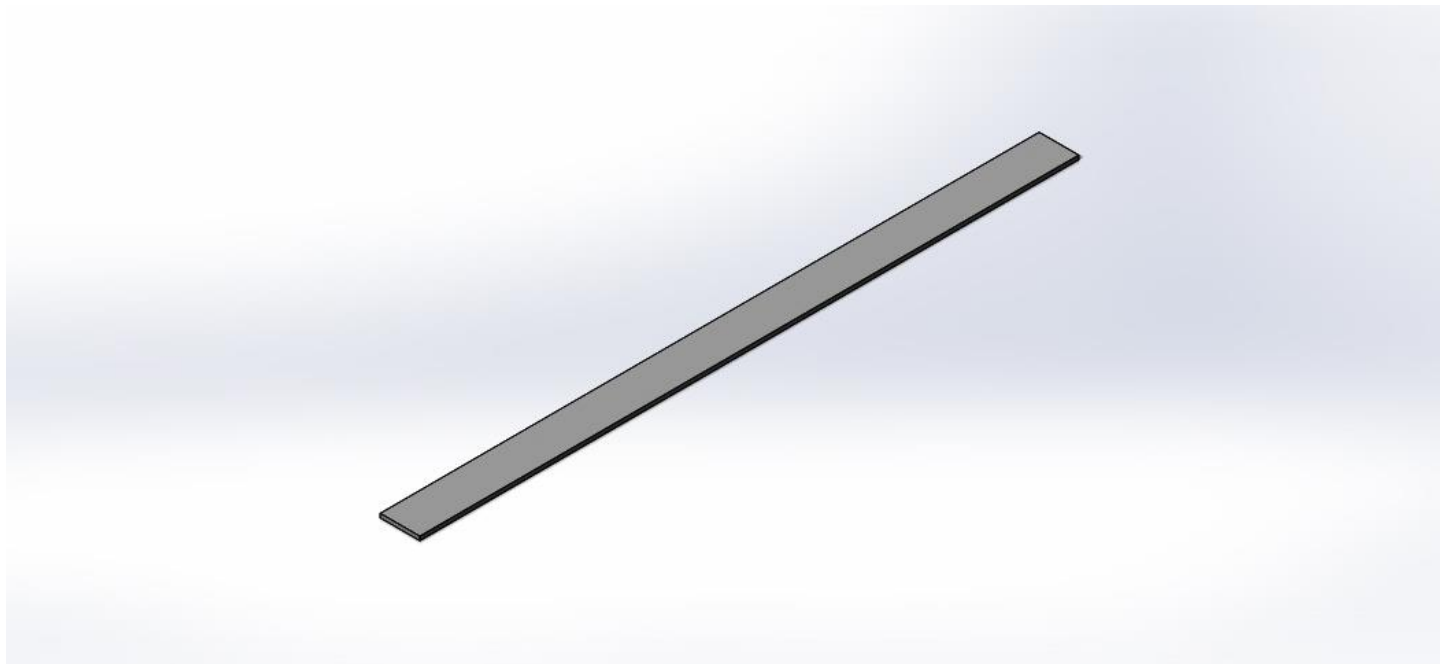
Solidworks (the Simulation)

Step 2- Start the setup for the *Frequency Analysis Simulation*. You may need to turn on the simulation option to see this tab. This option will use the physical dimensions of the cantilever beam and the material properties defined in the SCME literature for Sintra's material density, ρ, and Young's Modulus of Elasticity, **E.**

Solidworks (the Simulation)

According to the SCME documents, Sintra has a Young's Modulus of Elasticity (E) of 9.6GPa and a density (ρ) of 1.4gr/cm^3. This information needs to be added to Solidworks as a custom material with E = 9.6e9 N/m^2 and ρ = 1400 kg/m^3

Model

Solidworks (the Simulation)

Step 3 - Simulation of Cantilever Beam using Solidworks (video)
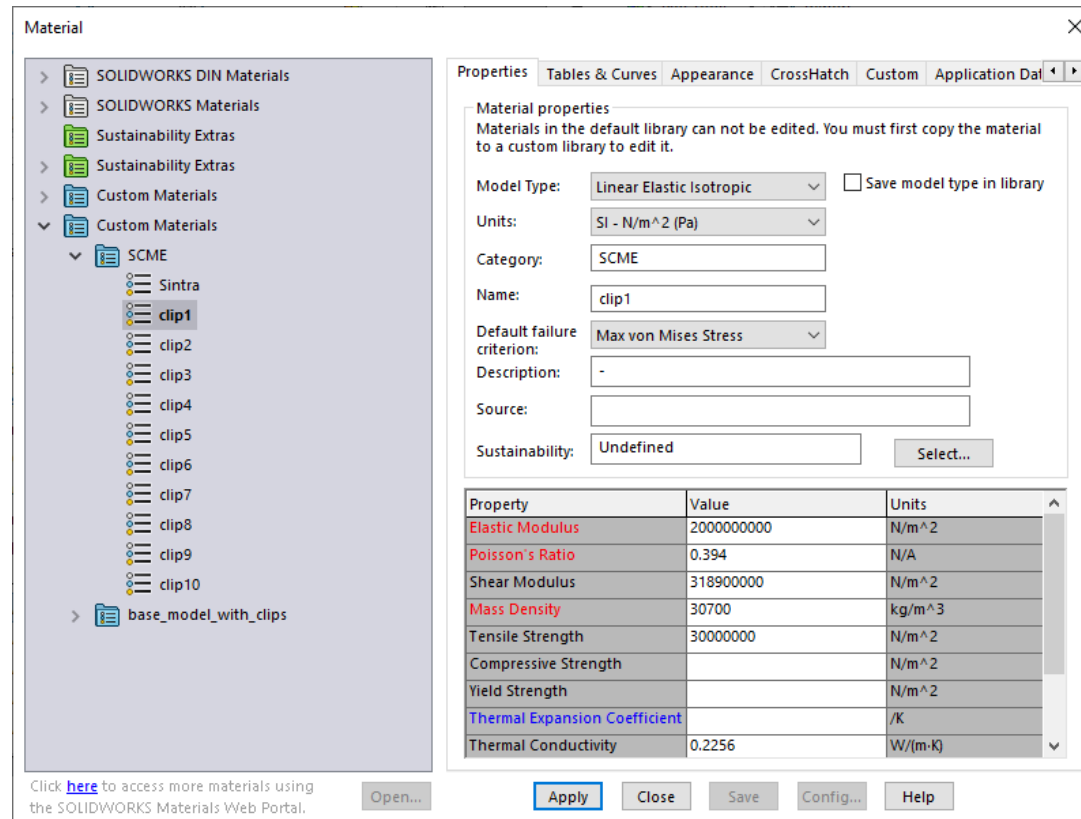https://www.youtube.com/watch?v=EpiBEctMf18&t=7s

Solidworks (the Simulation)

Step 4 – Determine the required density of a 3cm x 3mm x 3mm volume that would have a mass equal to each clip set, i.e. 1 clip, 2 clips …10 clips and add 10 new custom materials to the database. The assumption is that each clip weighs 8.28 grams. The spreadsheet below shows how the density was determined for each mass.

Clip Volume	cm
w =	3
t =	0.3
l =	0.3
clip volume =	0.270 cm^3
clip volume =	270.0E-9 m^3

# Clips	gr	kgr	ρ = kg/m3
1	8.28	0.00828	30.7E+3
2	16.56	0.01656	61.3E+3
3	24.84	0.02484	92.0E+3
4	33.12	0.03312	122.7E+3
5	41.40	0.04140	153.3E+3
6	49.68	0.04968	184.0E+3
7	57.96	0.05796	214.7E+3
8	66.24	0.06624	245.3E+3
9	74.52	0.07452	276.0E+3
10	82.80	0.08280	306.7E+3

Calculations

Solidworks (the Simulation)

Add these materials to the database. Then all you will need to do is add a small 3cm x 3mm x 3mm cuboid (box) to the end of the cantilever beam.

Model

Solidworks (the Simulation)

Step 5- Simulation of Cantilever Beam using Solidworks (video)
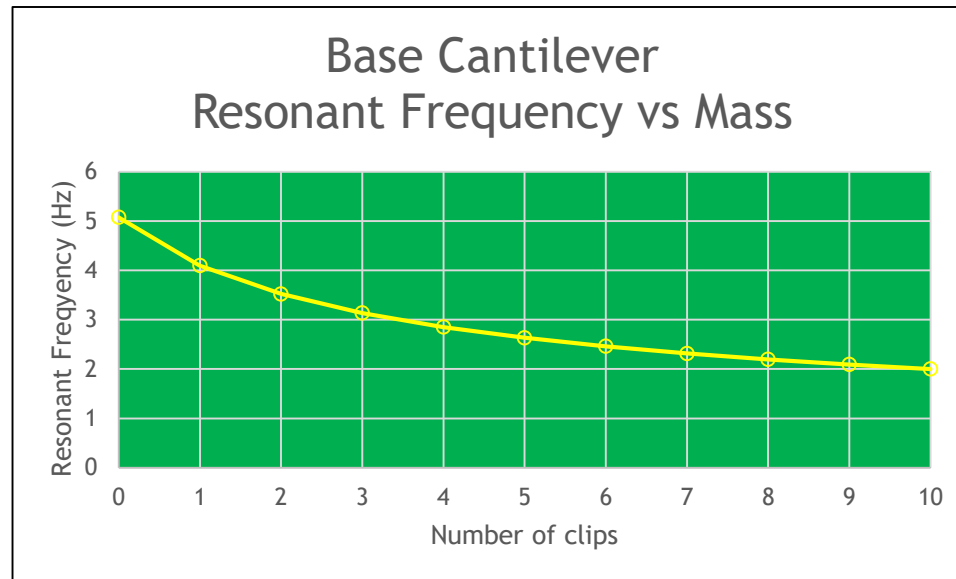https://www.youtube.com/watch?v=bI0_NV0D1Es

Solidworks (the Results)

Step 6 – Results of *Frequency Analysis Simulation* shows that as mass is added the resonant mode of vibration of the decreases, i.e. there is an inverse relationship between mass and resonant frequency.

no of clips	Resonant Frequency
0	5.0763
1	4.0951
2	3.5224
3	3.1355
4	2.8528
5	2.6354
6	2.4605
7	2.3163
8	2.1952
9	2.0909
10	2.0002

Base Cantilever
Resonant Frequency vs Mass

Results

Solidworks (help)

Helpful YouTube Links

Solidworks Simulation: Frequency analysis. Part 1/2
https://www.youtube.com/watch?v=A3hh_SBkE0c

Solidworks Simulation: Frequency analysis. Part 2/2
https://www.youtube.com/watch?v=PFD99R38XoE

Questions?

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