Musical Acoustics

Home Laboratory 1: Glass Harp

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Students

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Ex1

Generate a 3D model of the Wineglass.

Point a:

Geometry

The procedure used to build the wineglass inside Comsol is the following:

- A 3D component is added
- The 2D shape is drawn via quadratic Bezier curves and Polygons as in Fig.1
- The resulting shape is rotated around the vertical axis to obtatin a 3D shape
- The shape is finally converted to a solid object as in Fig.2a

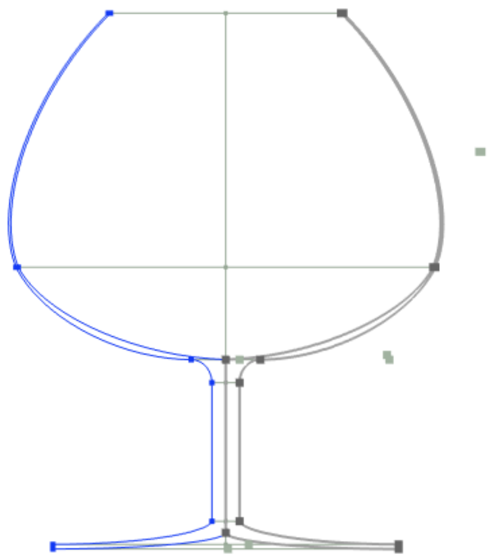

Figure 1: Work plane of the wineglass.

Materials

The material of the wineglass is defined starting from a blank material with the following properties:

- Young's Modulus: $E = 73.1GPa$
- Density: $\rho = 2203\frac{kg}{m^3}$
- Poisson's Ratio: $\nu = 0.17$

The material is then added to the component.

(a) (b)

Figure 2: 3D model and meshed 3D model for the wineglass.

Mesh

Given the similarity to the geometry of the tuning fork the first approach was to apply a combination of free triangular and swept mesh to the glass by splitting the glass in three parts: base, stem and cup each made in their own workplane. However after some experimentation, with both swept meshes and differently sized meshes we decided to use a free tetrahedral fine mesh applied to the whole domain. This choice is due to the fact that we wanted to get a good amount of detail everywhere in the domain since we didn't have any starting data or technical knowledge to base our choices off of. The results are the ones seen in Fig.2b.

Point b:

Solid Mechanics

The physics used for the simulation of eigenmodes is Solid Mechanics: an add-on for Comsol which brings an interface made for analysis on structural and solid mechanics. Through this a pinned boundary condition is set for the whole base of the glass by adding a fixed constraint for it.

Study

A study node is then added. Through this node it is possible to study the eigenmodes of the glass and their associated eigenfrequencies. In particular it is requested to find the first 20 eigenmodes. The results are shown in Table.1 and in Fig.3.

Mode	1	2	3	4	5	6	7	8	9	10
Freq.(Hz)	74.072	74.098	127.68	257.52	257.53	447.38	447.62	713.96	713.96	980.41
Mode	11	12	13	14	15	16	17	18	19	20
Freq.(Hz)	1350.8	1351.1	2142.5	2142.5	3062.8	3062.8	4084.9	4084.9	5177.4	5178

Table 1: **Eigenfrequencies of the first twenty modes**

By taking a look at the modeshapes we see that some only happen in the cup, while the stem is still and doesn't contribute, while others include the bending of the stem. The first eigenmode is

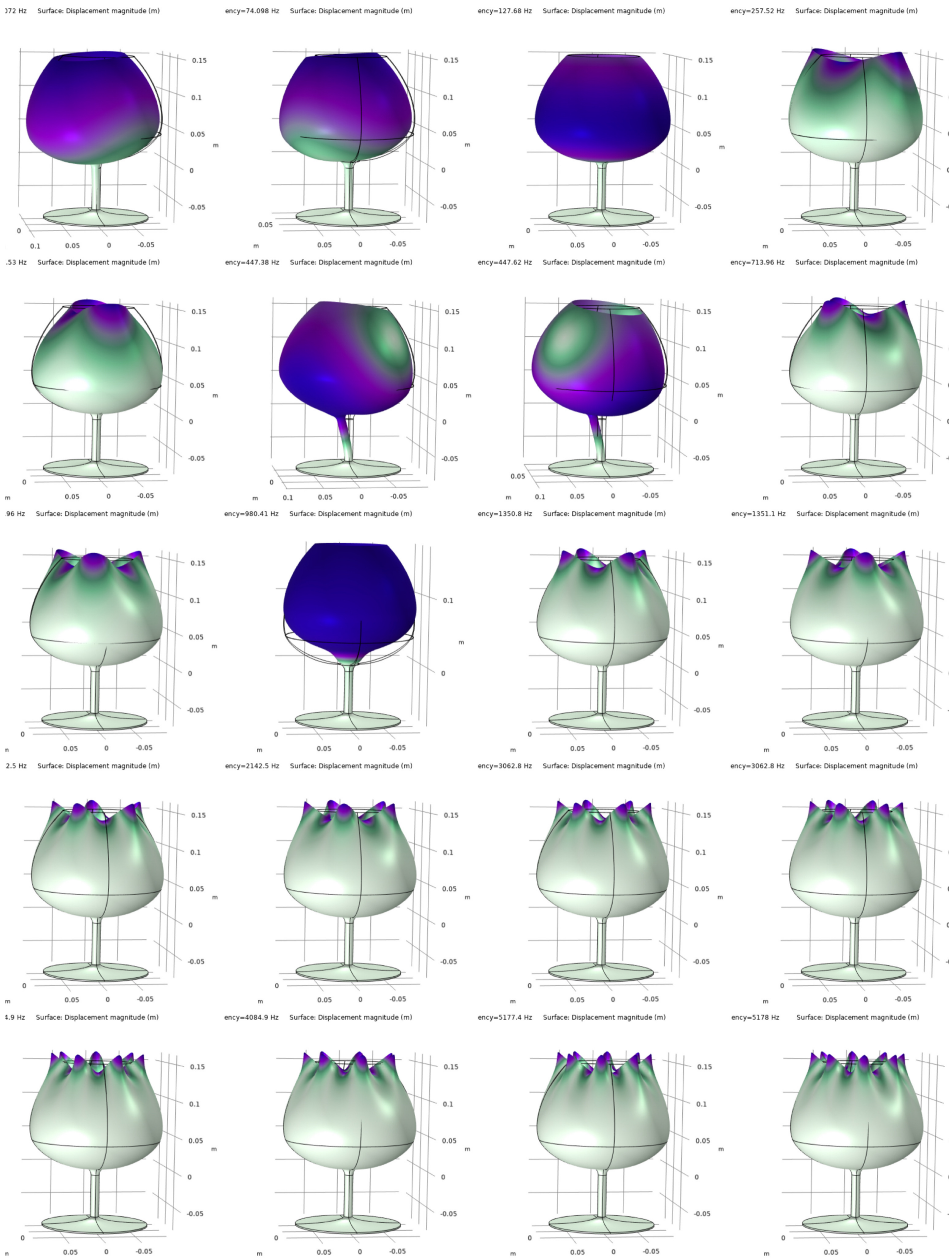

Figure 3: First 20 eigenmodes of the wineglass.

a bending mode and we could think of the associated $74Hz$ eigenfrequency as the fundamental frequency for the sound radiated by the wineglass. From further research[1] we see that the mode which is usually considered the fundamental, as far as sound radiation is concerned, is the one where the cup move in such a way that the top aperture becomes elliptic which, in our case, would be the mode at around $257Hz$.

[1] Jundt, G., Radu, A., Fort, E., Duda, J., Vach, H.,& Fletcher, N. (2006). Vibrational modes of partly filled wine glasses. The Journal of the Acoustical Society of America, 119(6), 3793-3798.

(a) (b)

Figure 4: 2D model and meshed 2D model for the wineglass.

Ex2

Point a:

Geometry

The procedure to build the geometry is the same as for Ex1 so we can import the workplane in a new axisymmetric component and convert it to a solid as shown in Fig.4a.

Material

The same material was used as in the 3D model case.

Mesh

An user-controlled, free triangular mesh is added using the fine model to the entire wineglass, see Fig.4b.

Point b:

Solid Mechanics

The Solid Mechanics physics is added and the same boundary conditions are applied as in Ex.1.

Study

Through the study node the first 20 eigenmodes and associated eigenfrequencies are obtained as shown in Tab.2 and Fig.5.

Point c:

The study is repeated but with the circumferential mode extension applied. The results are shown in Tab.3 and in Fig.6.

Mode	1	2	3	4	5	6	7	8	9	10
Freq.(Hz)	976.95	5349.3	7551	9062	9675.9	10136	10621	11174	11762	12417
Mode	11	12	13	14	15	16	17	18	19	20
Freq.(Hz)	13251	13630	14301	15500	16844	17980	18957	19484	21277	23263

Table 2: **Eigenfrequency of the first twenty modes. Axisymmetric**

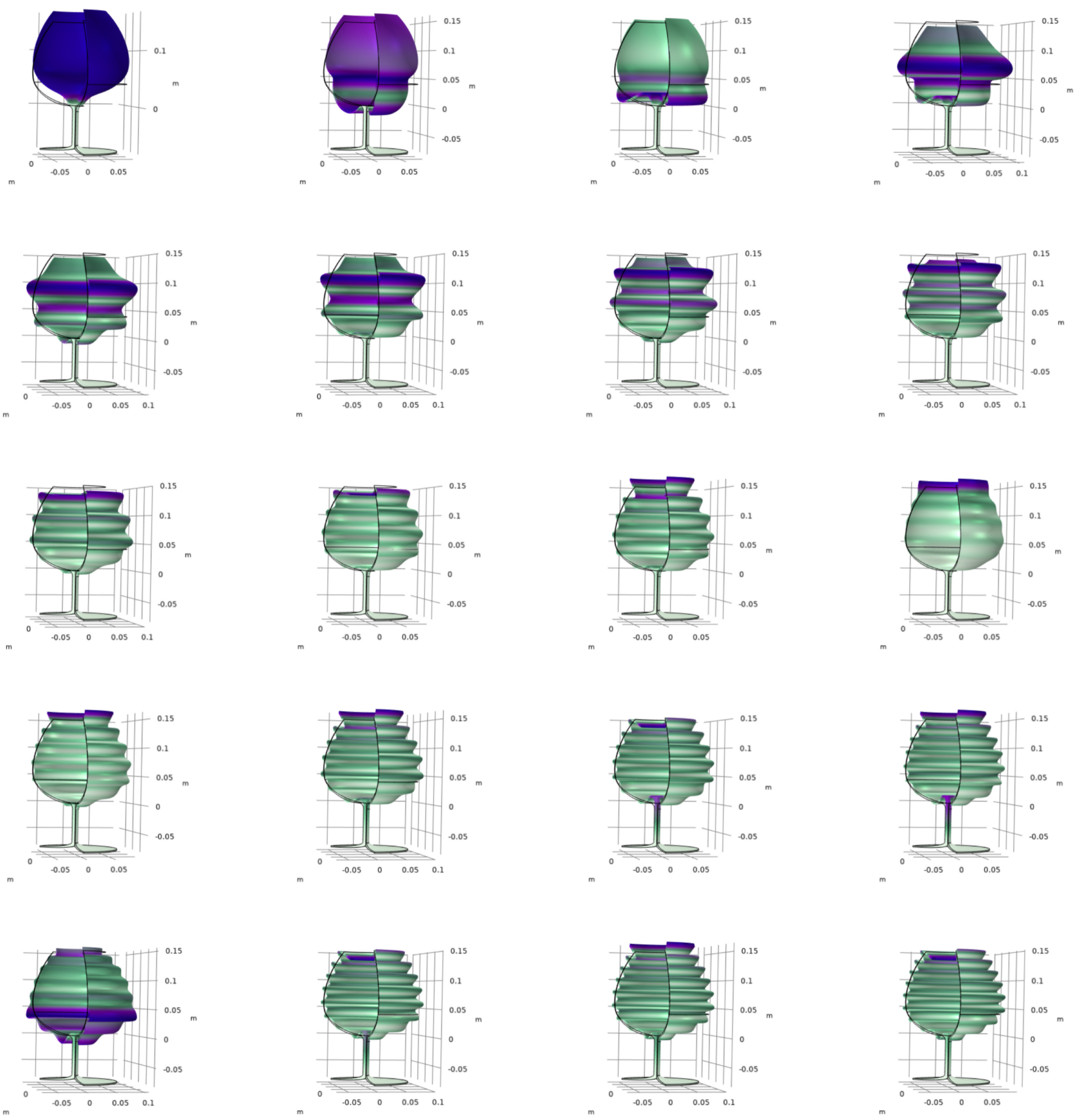

Figure 5: First 20 eigenmodes of the wineglass using 2D axysimmetric model.

Point d:

Looking at the results some useful information can be deduced. The axisymmetrical model enables us to get fast results (the computation time is much smaller compared to the full 3D model) but only the axisymmetrical modes are computed. In particular the only mode in common between the two studies is the one at $976Hz$. By adding the circumferential mode extension it is possible to also get the torsional modes that make the glass rotate around its axis. In particular we see from the results that the eigenmode at $127Hz$ is also found with this

Mode	1	2	3	4	5	6	7	8	9	10
Freq.(Hz)	127.48	976.95	5349.3	7551	9062	9675.9	10136	10621	11174	11762
Mode	11	12	13	14	15	16	17	18	19	20
Freq.(Hz)	12417	12928	13251	13630	14301	15500	16844	17980	18957	19484

Table 3: **Eigenfrequency of the first twenty modes. Axisymmetric with circumferential mode extension**

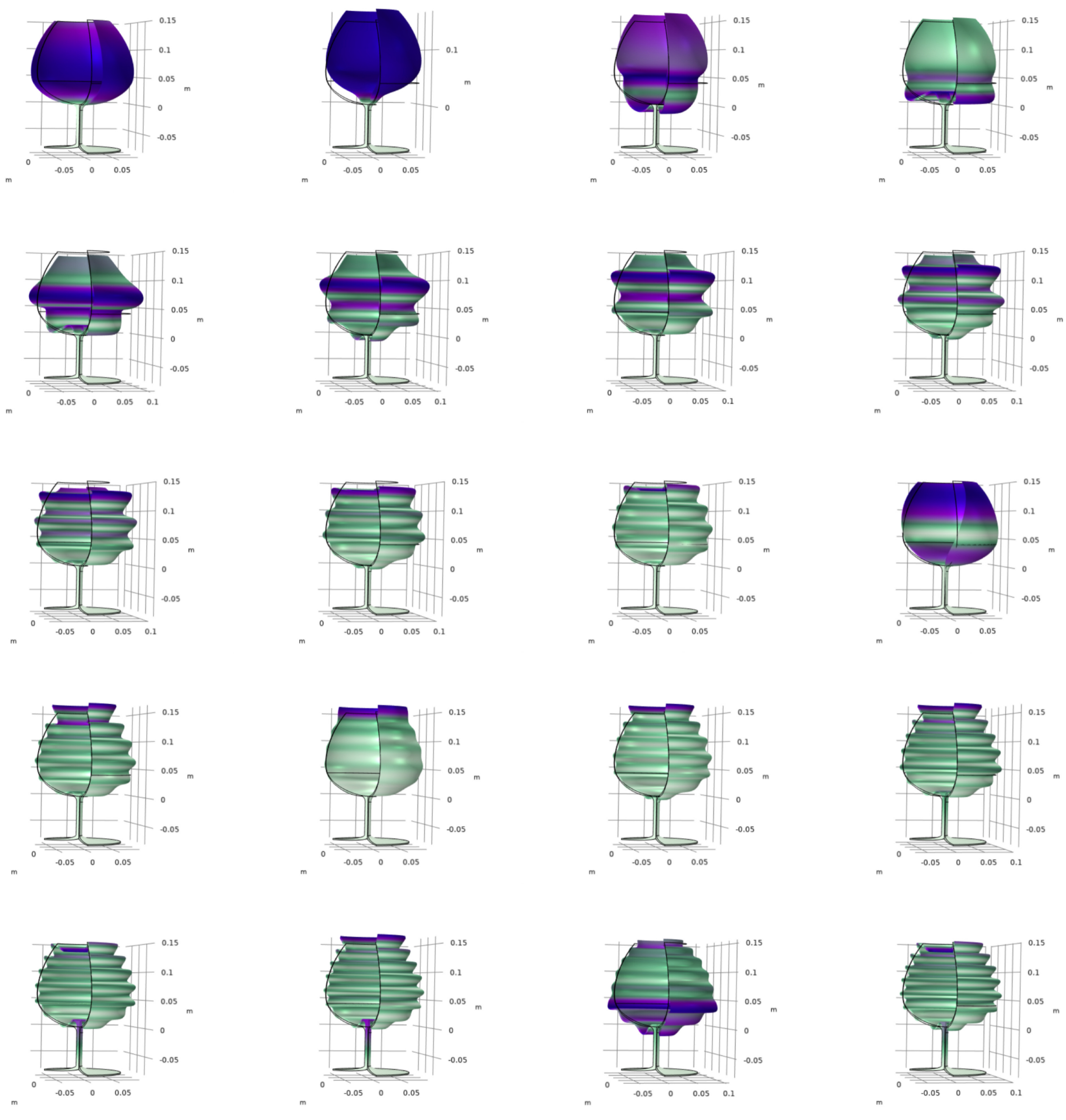

Figure 6: First 20 eigenmodes of the wineglass using 2D axysimmetric model with circumferential mode extension.

new model. These results tell us that an axisymmetric model can be useful if, for example, we are working on a complex structure that would need days of computation to finish a full 3D study on. This way we get a good approximation of the behaviour of the system which can then be checked against experimental results to make sure that the model accurately represents the real object currently under study.