

Model created in COMSOL Multiphysics 6.4

Shape Optimization of a Tuning Fork

Introduction

This model extends the model *Tuning Fork* in the COMSOL Multiphysics Application Library by adding a second study, in which the Parametric Sweep is replaced by an Optimization study node. The prong length $L_p = L + \pi R_b/2$, where L is the straight cylindrical part and R_b is the prong base radius, is determined by minimizing the objective function $(f - 440 \text{ Hz})^2$, where f is the fundamental frequency of the fork. The result agrees with that found in the original model version. For a detailed description of the model geometry and setup, see *Tuning Fork* in the COMSOL Multiphysics Application Library.


Application Library path: Optimization_Module/Shape_Optimization/
tuning_fork_shape_optimization

Modeling Instructions

ROOT

In this model version you determine the prong length by using an **Optimization** study node.

APPLICATION LIBRARIES

- 1 From the **File** menu, choose **Application Libraries**.
- 2 In the **Application Libraries** window, select **COMSOL Multiphysics > Structural Mechanics > tuning_fork** in the tree.
- 3 Click  **Open**.

Add a parameter for scaling the prong length using the **Deformed Geometry** interface, so that the problem can be solved using gradient based optimization.

GLOBAL DEFINITIONS

Parameters |


- 1 In the **Model Builder** window, under **Global Definitions** click **Parameters** |.
- 2 In the **Settings** window for **Parameters**, locate the **Parameters** section.

3 In the table, enter the following settings:

Name	Expression	Value	Description
scaleZ	1	1	Z scaling

COMPONENT 1 (COMPI)

Prescribed Deformation 1

- 1 In the **Physics** toolbar, click  **Deformed Geometry** and choose **Prescribed Deformation**.
- 2 Select Domains 1 and 3 only.
- 3 In the **Settings** window for **Prescribed Deformation**, locate the **Prescribed Deformation** section.
- 4 Specify the dx vector as


0	X
0	Y
Zg*(scaleZ-1)	Z

The Zg variable refers to the z-component in the geometry frame.

DEFINITIONS


Define a **Global Variable Probe** to keep track of the prong length in the material frame.


Scaled Prong Length

- 1 In the **Definitions** toolbar, click  **Probes** and choose **Global Variable Probe**.
- 2 In the **Settings** window for **Global Variable Probe**, type Scaled Prong Length in the **Label** text field.
- 3 In the **Variable name** text field, type scaledL.
- 4 Locate the **Expression** section. In the **Expression** text field, type L*scaleZ.

To keep the results of the parametric study, add a second study with an **Eigenfrequency** step set up the same way as before.

ADD STUDY

- 1 In the **Home** toolbar, click  **Add Study** to open the **Add Study** window.
- 2 Go to the **Add Study** window.
- 3 Find the **Studies** subsection. In the **Select Study** tree, select **General Studies** > **Eigenfrequency**.

- 4 Click the **Add Study** button in the window toolbar.
- 5 In the **Home** toolbar, click  **Add Study** to close the **Add Study** window.


STUDY 2

Step 1: Eigenfrequency

- 1 In the **Settings** window for **Eigenfrequency**, locate the **Study Settings** section.
- 2 Select the **Desired number of eigenfrequencies** checkbox. In the associated text field, type 1.
- 3 In the **Search for eigenfrequencies around shift** text field, type 440.


Now, add optimization. The **BOBYQA** solver is generally the fastest of the derivative-free solvers when the objective function is smooth.

General Optimization

- 1 In the **Study** toolbar, click  **Optimization** and choose **General Optimization**.
- 2 In the **Settings** window for **General Optimization**, locate the **Optimization Solver** section.
- 3 From the **Method** list, choose **IPOPT**.
- 4 Locate the **Objective Function** section. In the table, enter the following settings:

Expression	Description	Evaluate for
$(\text{freq}-440[\text{Hz}])^2$		Eigenfrequency

Next, add the control parameter. You can choose between the global parameters defined in your model. In this case, use the scaling parameter.

- 5 Locate the **Control Variables and Parameters** section. Click  **Add**.
Specify a length scale and suitable bounds.
- 6 In the table, enter the following settings:


Parameter	Initial value	Scale	Lower bound	Upper bound	Unit
scaleZ (Z scaling)	1	1	0.8	1.2	

The setup is now complete.

- 7 In the **Study** toolbar, click  **Compute**.

RESULTS

Probe Plot Group 2

I Click the  **Zoom Extents** button in the **Graphics** toolbar.


The default plot shows the eigenmode that corresponds to the optimized value of the cylinder length L .

Objective Probe Table 3

The optimized value of the cylinder length can be seen in the Objective Table:

The resulting cylinder length is close to 7.91 cm, which agrees with the value determined using a parametric sweep.

Probe Plot Group 2

Click the  **Zoom Extents** button in the **Graphics** toolbar.