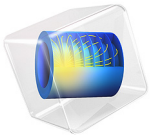

Shape Optimization of a Tuning Fork

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 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

1 In the **Model Builder** window, under **Global Definitions** click **Parameters 1**.

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 (COMP1)

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 **Add Study** 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** check box. 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.

Optimization

1 In the **Study** toolbar, click **Optimization** and choose **Optimization**.

2 In the **Settings** window for **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
`(freq-440[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 name	Initial value	Scale	Lower bound	Upper bound
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

1 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.