Course: ENG ME 360

Assignment: Bell Design

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Date: 8th May 2022

## Goal of this exercise:

The goal of this assignment is to create a Solidworks Bell model. Then use Solidworks frequency simulation tool to find the natural frequency of the bell values, or in other words find frequencies at which bell could resonate and produce sounds. Then MATLAB code and natural frequency values of the bell would be used to create a sound of the bell. Those sound files are attached on the webpage and can be downloaded.

## Constraints:

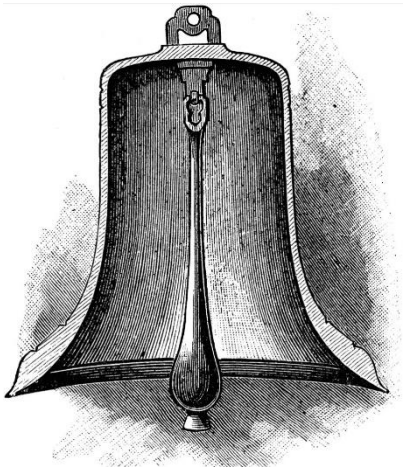

*Figure 1: Bell cross section*

Bell's bottom radius should be 1 meter diameter and cross-section shape should look like figure 1.

## Design decisions and justification:

Solidworks will be used to create the bell model. First step is to use sketch from picture option in Solidworks. Figure 1 below illustrates the inputting of the picture and making it appropriate size.

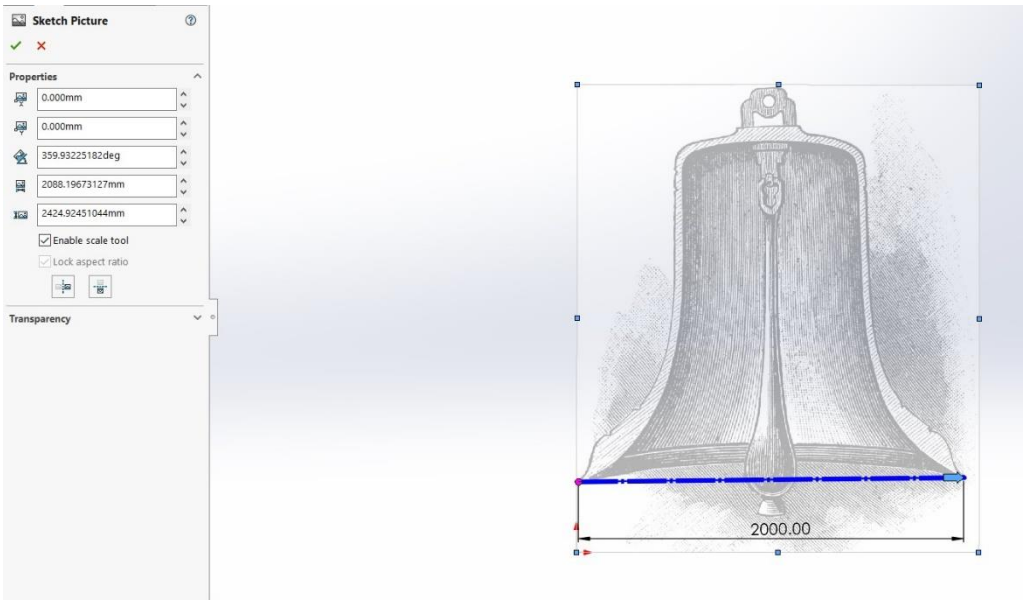


*Figure 2: appropriate size picture in Solidworks.*

Second step is tracing the bell picture using Spline feature. Figure 2 illustrates the step. In this step we create a cross-section of the bell and add a axis of rotation.

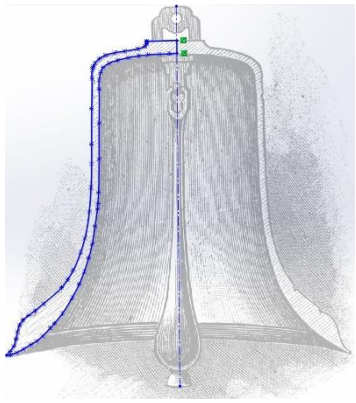

*Figure 3: Cross-section of the Bell*

Third step, illustrated in figure 4 is to revolve cross-section about the axis of rotation to get the bell's 3D shape.

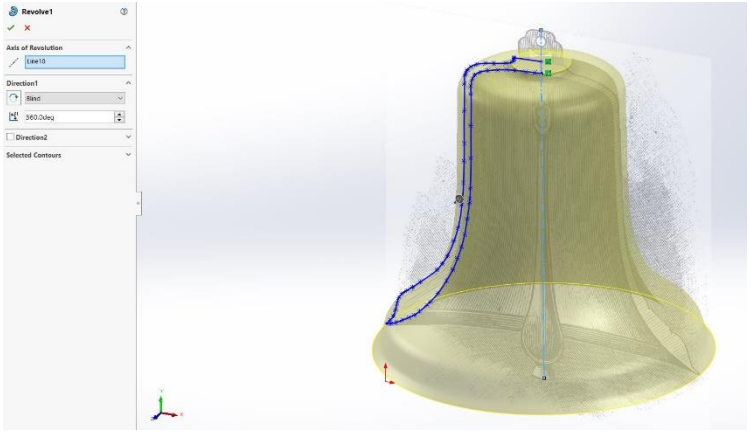


*Figure 4: 3D Shape of the bell.*

Fourth and final step of the design is to create a top feature that will be used as fixture in the simulation. Figure 5 illustrates the dimensions for the feature.

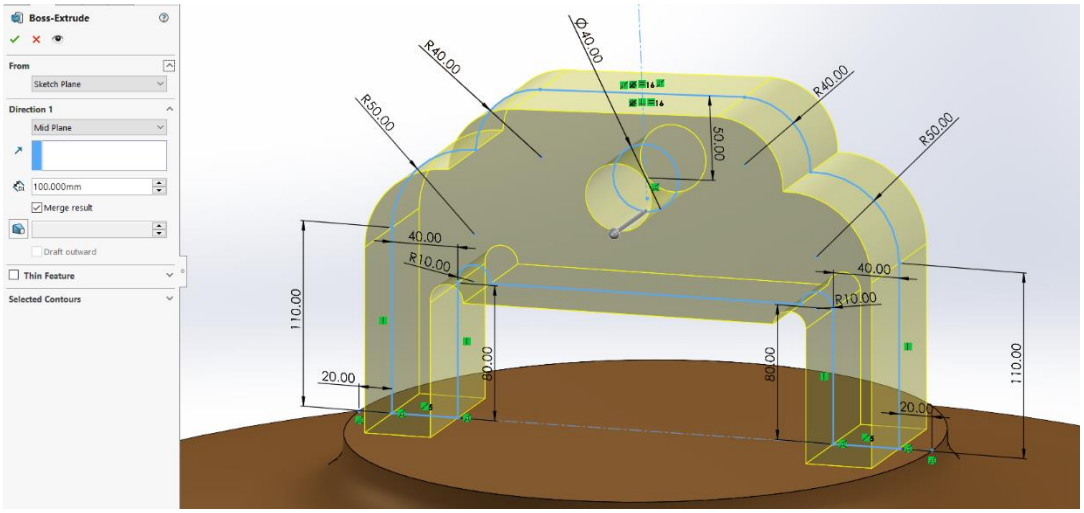


*Figure 5: dimensions for the top feature*

Material selection: Aluminium Bronze (because it is wildly used material for the bell models)

The 3-D model now is fully dimensioned, and we can proceed to the simulation.

## Analysis:

To accomplish Solidworks natural frequency simulation we need to apply fixtures (illustrated in figure 6) and mesh the bell illustrated in figure 7.

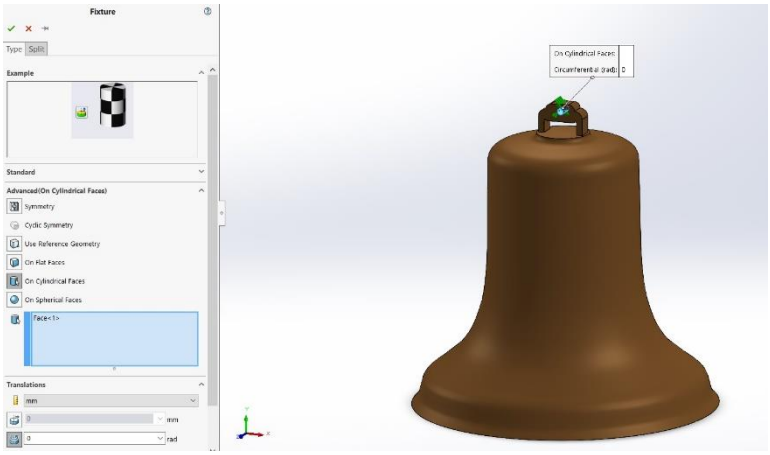


*Figure 6: Fixtures*

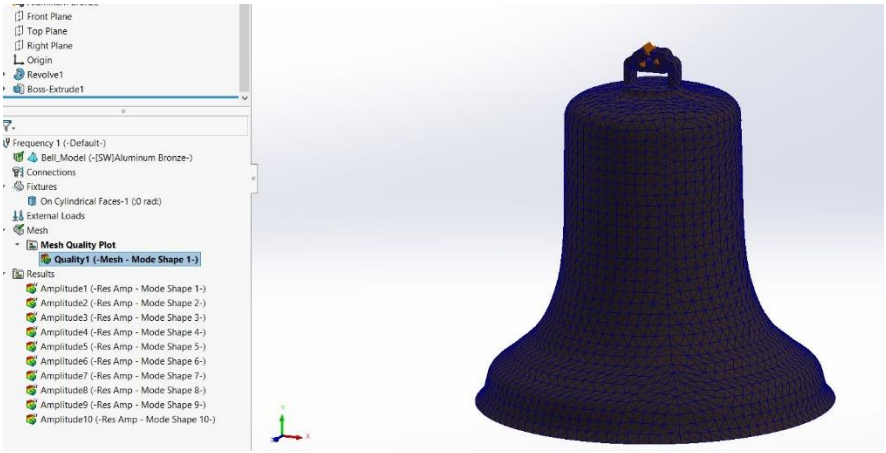


*Figure 7: Mesh*

Typical Solidworks result for the deformation is shown in figure 8.

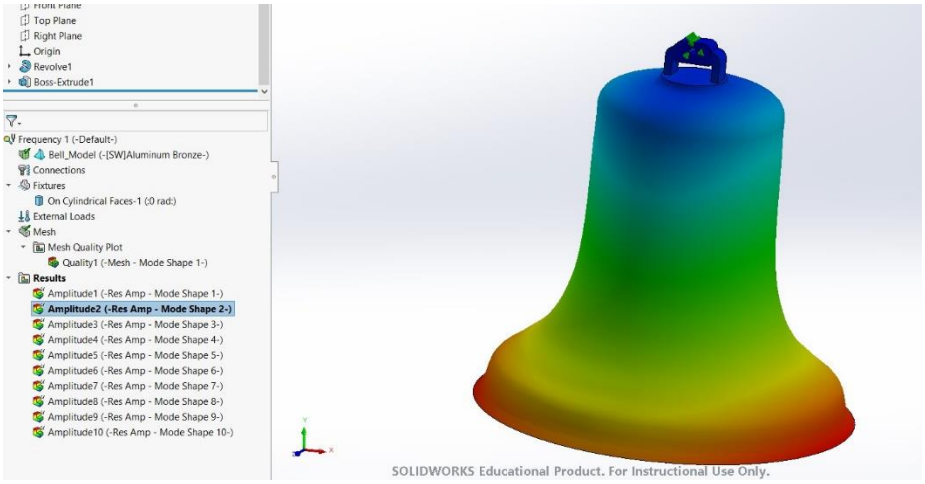


*Figure 8: Result of Solidworks simulation*

In this simulation we got 10 different natural frequency results. I have summarized the values in the table below.

| # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Frequency (Hz) | 0 | 5.77 | 6.1042 | 11.402 | 69.145 | 111.68 | 146.93 | 146.93 | 163.6 | 163.6 |

*Table 1: Natural frequency values for the bell from simulation.*

Now we are going to wright a MATLAB code that will simulate a sound of the designed bell. Our sound wave value will be calculated using formula:

$$y = e^{-dampling \times t} \times \left(\sum_{n=1}^{10} sin(2\pi f(n)t)\right)$$

Where:

$t$ – time (s)

$f(n)$ – natural frequency parameter from the table

$dampling$ – is the damping parameter depending on how fast energy is lost to the environment. We use the value: -2.

Our MATLAB code is shown in figure 9:

```
1 -  f = 100; % Tone frequency [Hz]
2 -  fs = 48000; %Sampling frequency rate [Hz] {must be greater then 2*f}
3 -  t_max = 5;
4 -  dt = 1/fs;
5 -  t = (0:dt:t_max);
6 -  y = exp(-2*t).*(sin(2*pi*0*t)+sin(2*pi*5.77*t)+sin(2*pi*6.1042*t)+sin(2*pi*11.402*t)+sin(2*pi*69.145*t)...
7        +sin(2*pi*111.68*t)+sin(2*pi*146.93*t)+sin(2*pi*146.93*t)+sin(2*pi*163.6*t)+sin(2*pi*163.6*t));
8
9 -  sound(y,fs)
10 -  plot(t,y),
11 -  xlabel('Time(s)'), ylabel('The sound')
12 -  title('')
13 -  filename = 'Bell_audio.mp4'
14 -  audiowrite(filename,y,fs)
```

*Figure 9: MATLAB code:*

Lines 1-8 generate a data set for the sound using the formula shown above.

Line 9 plays sound

Lines 10-12 plot the data illustrated in figure 10

Lines 13-14 write the data to mp4 file. You could find the file on my webpage.

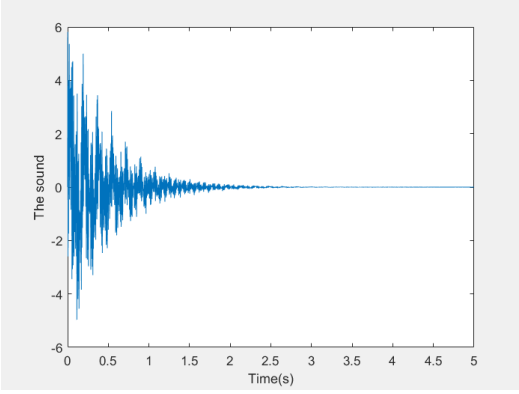


*Figure 10: Bell sound plot*

## Modeling and optimizations:

Model is not very precise. Uncertainties into the sound result were introduced since the very beginning. When making Solidworks 3-D model, the sketch from picture option was used, what made the model not precise. Next fixtures were vaguely introduced the real bell would have another fixture which is hard to model in Solidworks. Next our MATLAB code done on the level of performing the idea. We could model the sound using better techniques.

## Conclusions:

The exercise is useful as a playground and motivational exercise but not as a real-life modeling. It illustrates how many different useful parameters could be achieved in Solidworks simulations. The output sound could be recognized as a bell sound. Our mission is accomplished.