MECH 410 Lab 5: Design Optimization Using NX FEA Structural Analysis

Aidan Sarkozy - V00937139
Colm Molder - V00937879
Blaine Tubungbanua - V00918128

Oct 23, 2023

Table of Contents

1 Objective

The objective of this lab is to understand numerical optimization and its applications within SIEMENS NX. This lab will also provide relevant examples of how a sensitivity study can be utilized to select design parameters to modify. The optimization will be performed on an FEA study, where the FEA study will be used as a constraint on which to base the optimization simulation.

2 Description of Assignment

During CAD design, a model with specific dimensions is initially created to meet the design objectives. This model may not be the ideal shape as small changes in these dimensions can alter the performance and function of the design. Maximizing/minimizing certain variables while maintaining specific constraints requires iterative FEA/CFD simulations. These variables can be changed manually with new simulations run for each change. But to save time, software such as NX provides optimization tools that automatically run many simulations and produce ideal parameters. This lab seeks to showcase these tools by optimizing a bearing housing's rib thickness while minimizing its overall weight.

A common first step in CAD optimization is to perform a sensitivity study. A sensitivity study computes the rates of change of an objective with respect to a design parameter. It outputs the relevance of changing a design variable on the overall objective. For this lab, it is important to determine which aspects of the base would have the greatest effect on the model's weight. To do this, a sensitivity study is performed where the two design variables were the side rib's thicknesses and the base's width. The objective or "watch value" is the bearing housing's mass. The analysis provides a contribution percentage of each variable to the objective.

The assignment proceeds by running the same FEA simulation performed in laboratory 3. This consists of applying a 2000Nm torque to the front face of the bearing housing model while the base is fixed. Once the FEA has been set up and run, a geometry optimization simulation can be initiated by right-clicking on the sim file. The optimization setup is split into 5 tabs. The first tab is selecting the optimization type which is set to optimize. The second tab is the objective tab, allowing users to select the reason for the optimization. In this case, the objective is to minimize the overall model's weight. The third tab is for defining the constraints, where users select parameters that are to be maintained for all iterations. For this lab, the maximum von Mises stress is given an upper limit of 150MPa to provide a safety factor of 2.5 for the 380MPa yielding strength of G60 cast iron steel. The fourth tab sets the design variables which are to be altered. The thickness of the rib perpendicular to the cylinder of the bearing housing is selected as the design variable. It is given an upper limit of 10mm and a lower limit of 5mm.

3 Illustrations and Procedure

First, to determine the merits of an optimization study on the bearing housings bracket, a sensitivity study was completed. This study compared two parameter variations, the thickness of the rib, and the width of the rib, and the parameter's impact on the overall mass of the housing. The parameters in question are shown in figures 1 and 2.

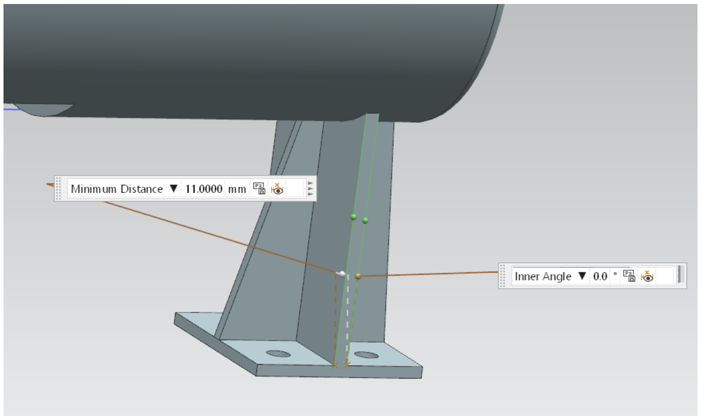

Figure 1: Parameter 1, rib thickness

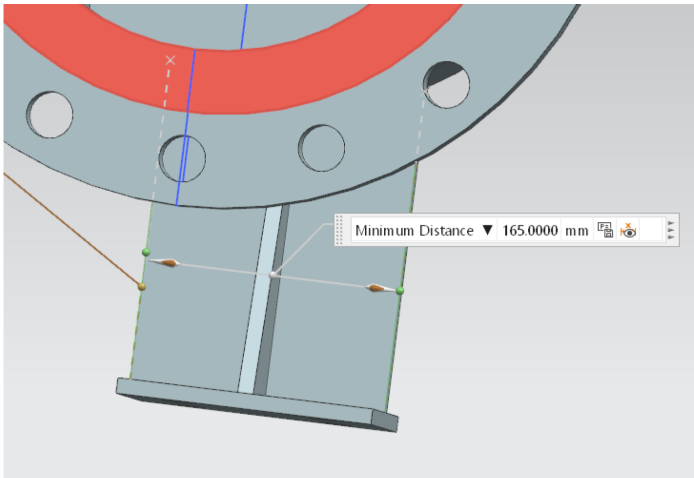

Figure 2: Parameter 2, Rib Width

Conducting the sensitivity analysis, the relationship between these parameters and the overall mass of the housing is determined. This is plotted in figure 3.

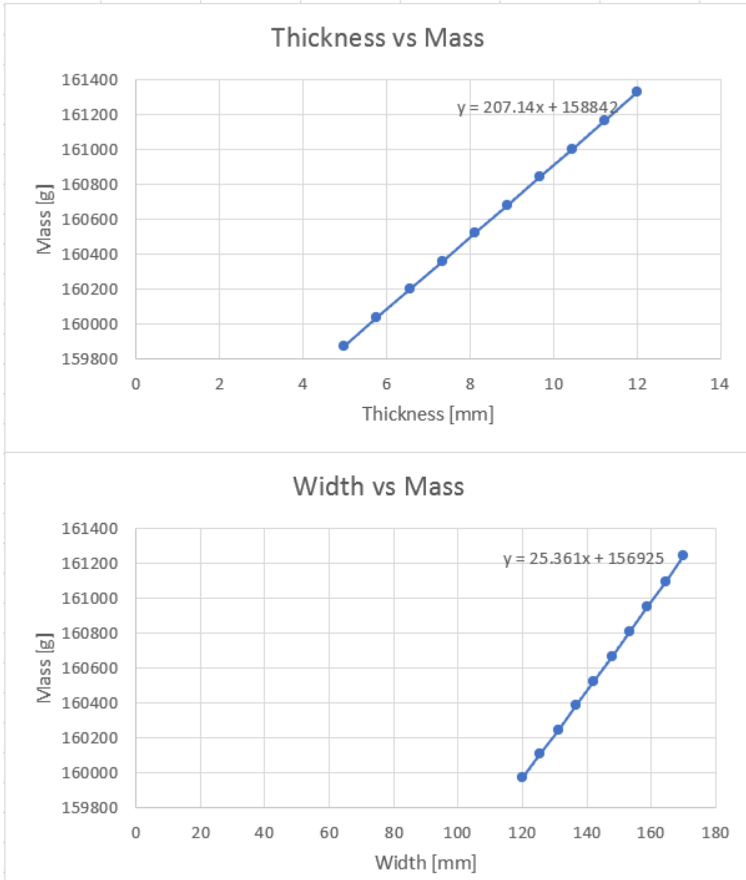

Figure 3: Parameter Variation Comparison with Housing Mass

The rib thickness trend has a slope of 207.14 [g/mm], while the rib width trend has a slope of 25.361 [g/mm]. This indicates that the rib thickness has a stronger impact on the overall weight of the housing. A change in thickness of 1mm results in a weight reduction of 207.14g, while a change in the width by 1mm results in a weight reduction of only 25.36g. Geometrically, this is reasonable, as changing the thickness changes the extrusion length of a large cross section, while changing the width changes the extrusion length of a small cross section.

With the sensitivity study completed, an optimization study was conducted on the thickness of the rib, maintaining a von mises stress below 150 MPa. The initial step was to conduct an FEA study. This was done by first simplifying the part by removing holes, meshing, applying loading and constraints, and running the study. For more technical details on the FEA setup and results, consult Lab 3 [2].

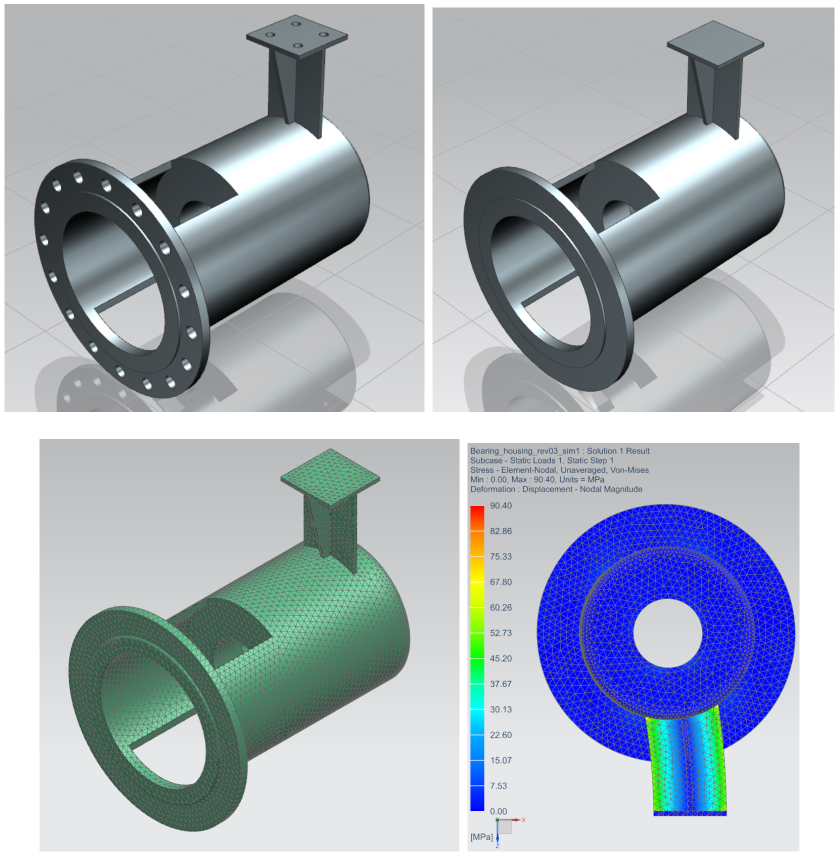

Figure 4: FEA Analysis

Next, as previously discussed, the objective, design variable, and design constraint were set and the optimization was run. The results of the six iterations of varying the rib thickness are seen below in Table 1.

Table 1: Objective, Design variable, and Constraint Values during Optimization Analysis

Iteration Number	**0**	**1**	**2**	**3**	**4**	**5**
Objective Result: Weight [N], Minimize	1476.71	1474.79	1467.37	1468.25	1467.97	1468.11
Design Variable: Rib thickness [mm], between 5-10mm	10	9	5.16	5.64	5.49	5.56
Design Constraint: Stress [Mpa], under 150MPa	90.396	98.375	155.69	146.29	146.69	145.08

The weight vs design cycle is seen plotted below in Figure 5.

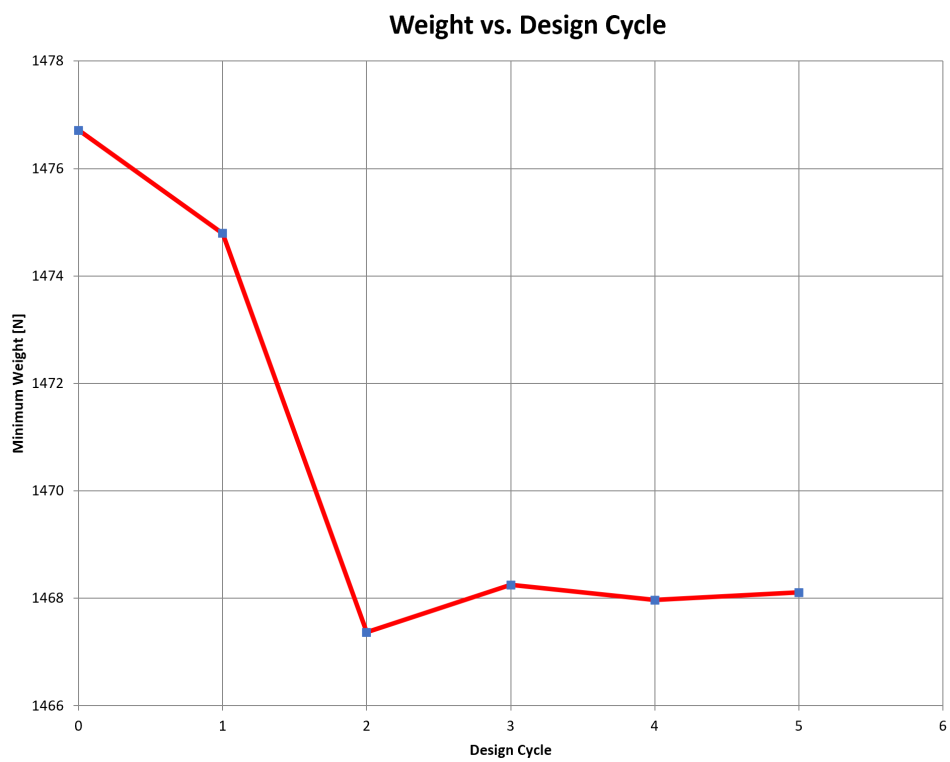

Figure 5: Weight Vs Design Cycle

The convergence of rib thickness to an optimized value is seen below in a plot of design cycle vs rib thickness (Figure 6).

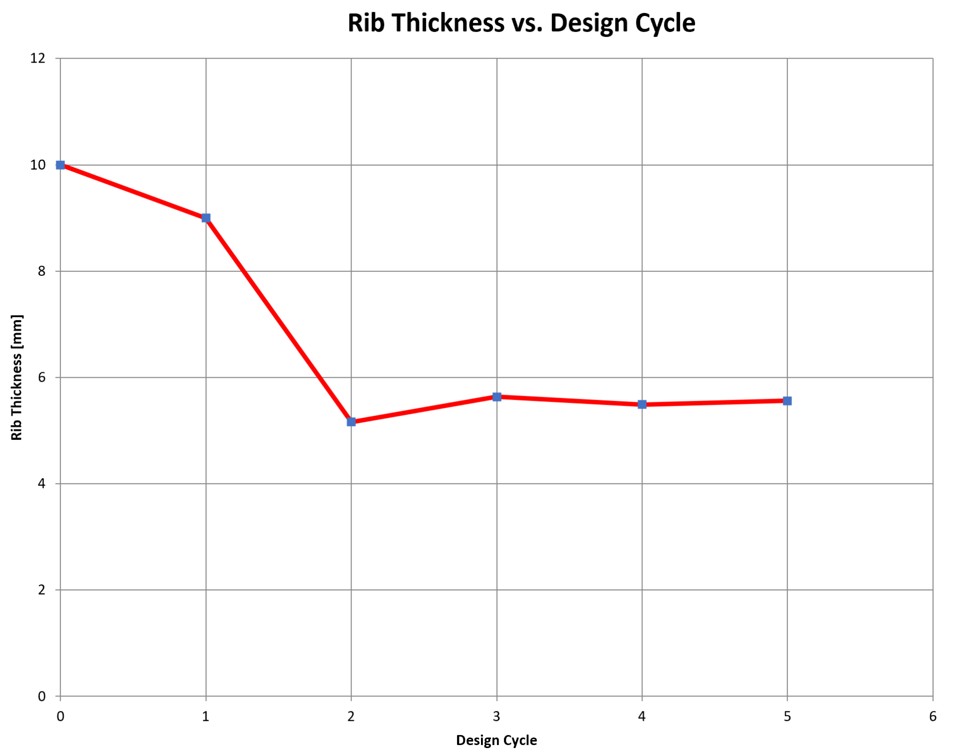

Figure 6: Rib Thickness Vs Design Cycle

Finally, the updated rib to match the ideal thickness of 5.56 mm is seen below. This thickness minimizes weight while ensuring a stress value below 150MPa.

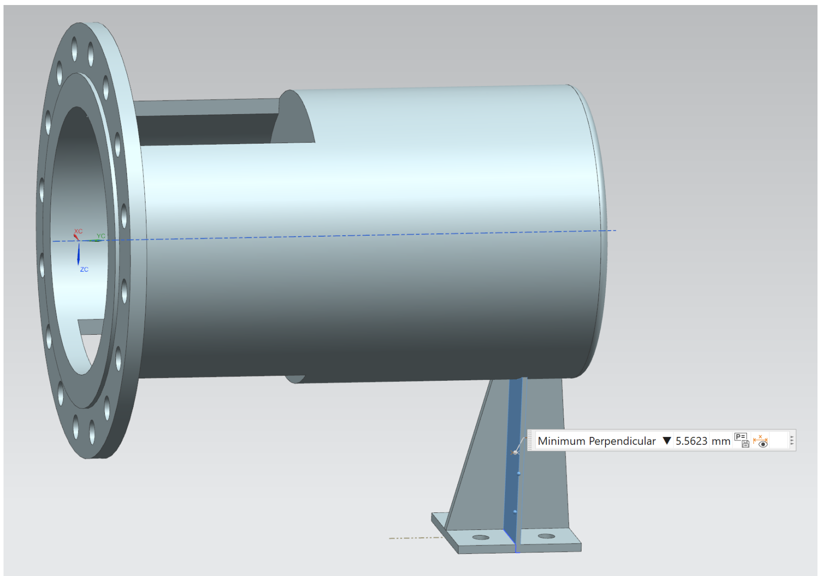

Figure 7: Optimized Rib

Discussion

The optimal thickness was determined to be 5.5623mm, resulting in a mass reduction of 1477 to 1468, saving 9 grams, or 0.6% weight savings. With the optimal thickness determined, the rib thickness should be increased to the closest stock material size, to ease manufacturability, and maintain the prescribed safety factor. Examining the assembly, the stand is likely constructed from a flat bar, welded together, and welded to the revolve.

It is somewhat illogical to perform this optimization study on the weakest point of the assembly, lowering the safety factor further, and only achieving a weight reduction of 0.6%, when there are stronger parts of the assembly that have even higher safety factors that should be lowered. For example, the thickness of the cylindrical portion has an extremely high safety factor, thus unnecessary weight. This type of optimization should be conducted such that the stress in the rest of the part approaches the desired safety factor and thus no excess material is used.

Summary

In this lab, a sensitivity study was conducted, examining the sensitivity of the housing mass to the variation of the thickness of the rib stand, and the width of the rib stand. The rib thickness was found to be more influential, so an FEA was conducted to obtain an automated method to determine von mises stress throughout the entire part. With the FEA completed, an optimization study was conducted, varying the thickness of the rib, and re-calculating the FEA to ensure compliance with a constraint of Von Mises stress and the cast iron material used for the part. It was discovered that 5.56mm was the optimal thickness for the rib to minimize weight while maintaining a safety factor of 2.5.

Design optimization is a very interesting topic and one that is definitely useful for engineers. As an engineer, the goal is always to optimize our design and having software that is able to help accomplish that is a very powerful tool. One aspect that should not be taken for granted is setting up a proper FEA/CFD simulation. Without a properly set up simulation, the outcome of an optimization study will provide inaccurate values. This can prove disastrous if an improper dimension is chosen and the part is no longer able to function as designed. But when done correctly, the improvements can be extremely fruitful. Benefits include strength increase, weight reduction, and most notably cost reduction.

References

[1] University of Victoria, 'MECH 410 Laboratory 3 Manual', Zuomin Dong, Siyang Steven Liu, Chon Him Lawrence Wong

[2] University of Victoria. 'MECH 410 Lab 3 Report', Aidan Sarkozy, Blaine Tubungbanua, Colm Molder