Lab #2
Static Analysis of an L-Bracket

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Department of Mechanical Engineering

ME 37100 Computer Aided Design
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Abstract

In a static analysis of a L-Bracket, mesh control was applied to the sharp edge (no filet with a 90-degree angle) of the geometry to see the effects of element size on the max von Mises stress. Mesh of increasingly smaller element size should allow for more precise reading of the

max Stress, however, such mathematical model used in the FEA analysis resulted in a diverging value. A filet of various radius is then applied to the corner to determine the effects of radius size. radius of 0 mm, 5 mm, 10 mm and 15 mm we're tested and increasing radius size was found to have decreased the maximum vin Mises stress experienced by the bracket. The Stress concentration factor was calculated from the results, with the larger radius displaying the least amount of concentrated stress.

Introduction

FEA has many applications for the use of everyday products. Designing tools to be used can be done easily through such software. In this lab, an exploration of ways to increase the accuracy of the FEA of an L-Bracket is introduced through the use of mesh control.

An L-bracket, in its simplest form is comprised of two rectangular shapes joined together to provide simple support from users such as camera leverage to shelf support. However, due to the sharp edge introduced by the joined geometry, an increased localized stress (SCF) can pose a problem as increased load is applied. Simple ways to fix this issue as seen in this lab is to introduce a filet at the edge.

Mesh control is a technique seen in FEA as a way to increase accuracy without having to increase computational time by increasing the total element count throughout the entire studied specimen. Based on the knowledge of SCF and how stress can localize at areas of support. By specifically applying higher mesh count in such areas, the accuracy of reading can be determined without applying the same mesh throughout the member in areas of less varied stress gradients.

Theoretical background

The formula for the stress concentration factor (k) is as follows:

$$k = \frac{\sigma_{max}}{\sigma_{nom}} \text{ (Equation 1)}$$

Where the nominal stress can be found using:

$$\sigma_{nom} = \frac{Mc}{I} \text{ (Equation 2)}$$

M = the moment using the applied load of 1000 N at a distance of 80 mm from the fixed end. The moment of inertia is then calculated using:

$$I = \frac{1}{12}bh^3$$

With a base (b) of 30 mm and a height (h) of 20 mm.

Manual Analysis and Calculations

Study	Size of Elements Along The Edge (mm)	Max Resultant Displacement (mm)	Max von Mises Stress (MPa)
mesh 1	4.76	0.247323	79.4801
mesh 2	2.4	0.248106	104.6896
mesh 3	1.2	0.248346	129.7099
mesh 4	0.6	0.248379	142.2498
mesh 5	0.3	0.248502	190.3168

Table 1: Tabulated data (size of elements along edge, max resultant displacement and max von Mises stress) Of different mesh control on the sharp edge of the L-bracket, as seen in the first portion of the lab.

Study	Max element size (mm)	Minimum element size (mm)	Nodal value max von Mises Stress (MPa)	Element value max von Mises Stress (MPa)
Round edge (2mm radius)	5	1	117.3352	101.6325

Table 2: data obtained from the first part of lab of the 2mm radius filet on the edge comparing values of max von mises stress from nodal vs element values.

The stress concentration factor calculations for the different filet radius is calculated below using equations 1-3.

$$I = \frac{1}{12}(30)(20)^3$$

$$I = 20{,}000\ mm^4$$

$$\sigma_{nom} = \frac{8000*10}{20{,}000}$$

$$\sigma_{nom} = 40\ MPa$$

The value of the SCF is then calculated using equation 1 and the results of the SCF for the different radius is seen in table 3.

Filet radius along edge (mm)	Maximum size of Elements Along The Edge (mm)	Minimum size of elements Along The Edge (mm)	Max Resultant Displacement (mm)	Max von Mises Stress (MPa)	SCF

0	5	1	0.248	85.797	2.145
5	5	1	0.241	79.977	1.999
10	5	1	0.2328	62.108	1.55
15	5	1	0.227	57.141	1.43

Table 3: Tabulated data (size of elements along edge, max resultant displacement and max von Mises stress) Of different radius of filet on edge of the L-bracket, as seen in the second portion of the lab.

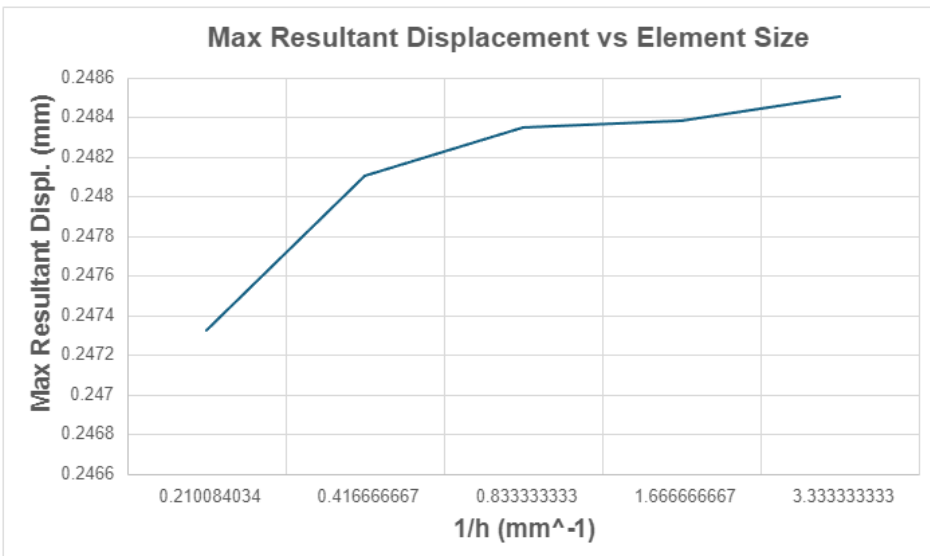

Table 4: Max resultant displacement vs element size of the sharp edge of the L bracket. H represents the element size.

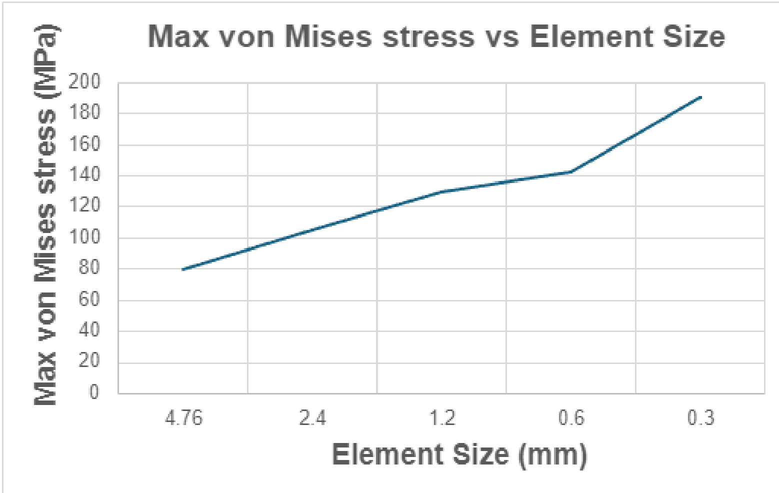

Table 5: Max von Mises Stress vs element size of the sharp edge of the L bracket.

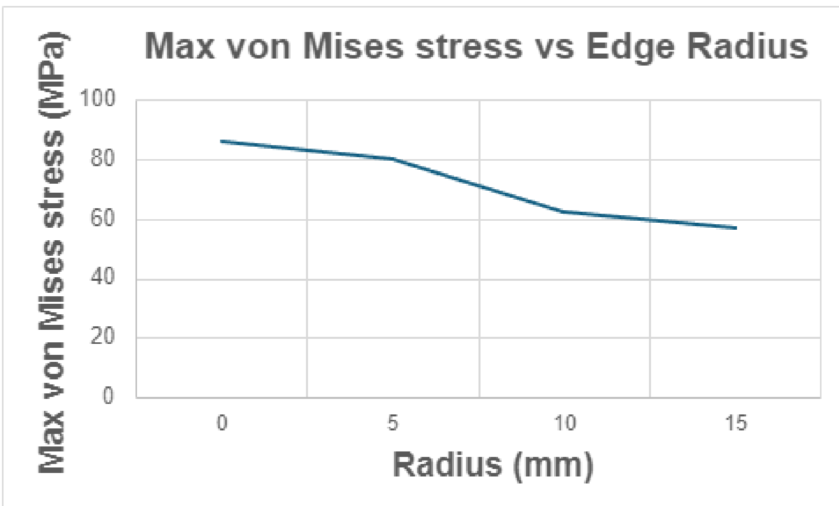

Table 6: Max von Mises Stress vs radius of the edge of the L bracket.

Graphical Demonstrations of SolidWorks Results

In the first portion of the lab, different settings are used to determine its effects on the calculated max von Mises stress. First, using a sharp edge, different mesh controls are used to determine how the stress value will change based on more elements along the sharp edge. Then, a filet is introduced and taking the max von Mises stress is compared with using nodal vs Element values. For this portion of the lab, the element size growth ratio of 1.5

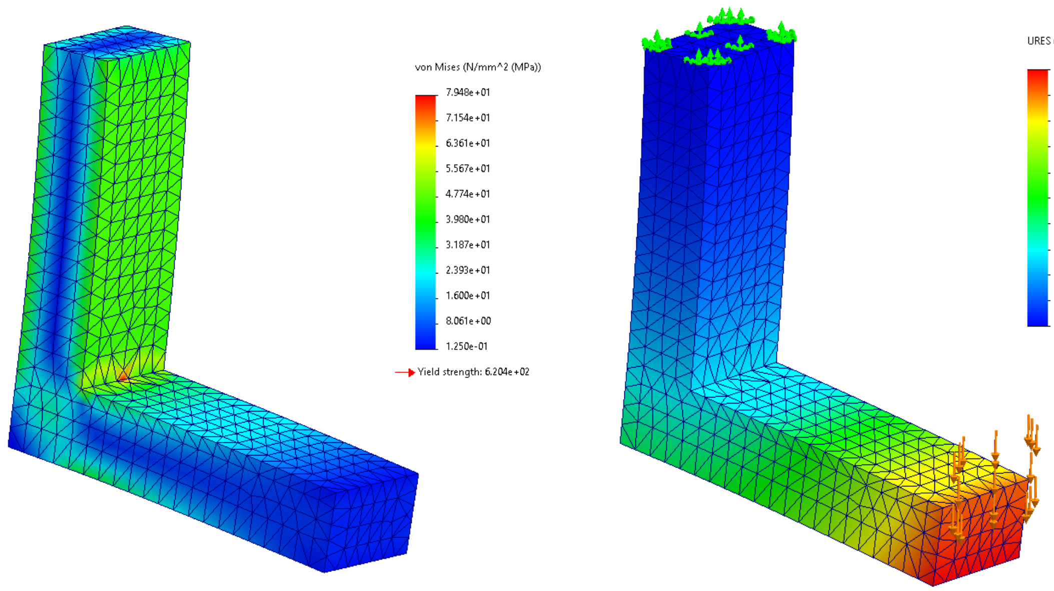

Figure 1: L-Bracket (A) Stress Plot on the left and (B) Displacement plot on the right with mesh setting corresponding to mesh 1 in Table 1.

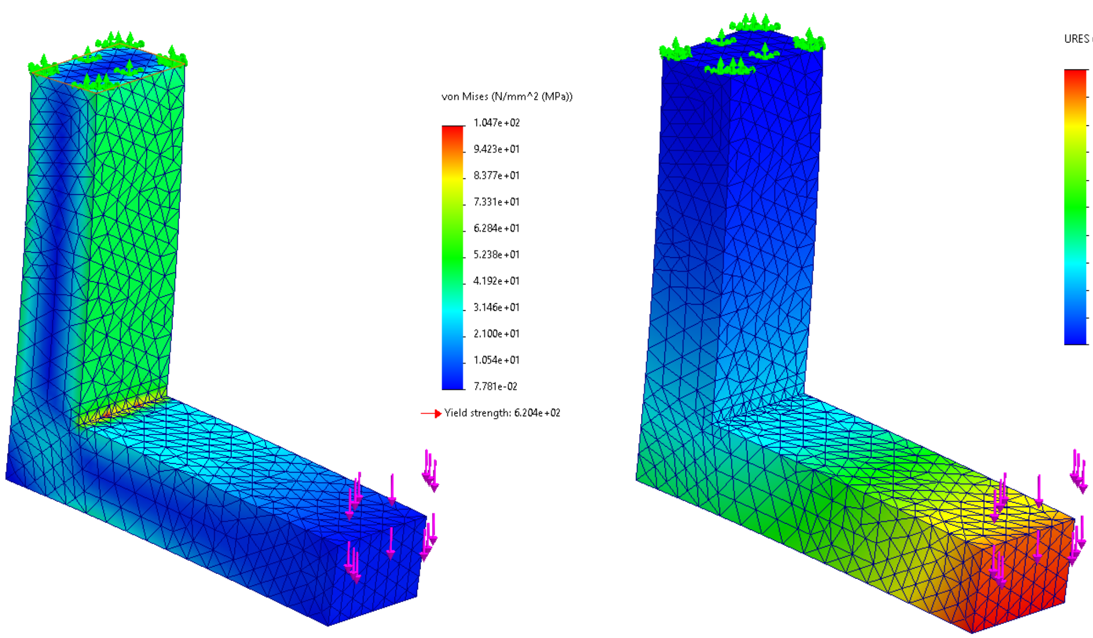

Figure 2: L-Bracket (A) Stress Plot on the left and (B) Displacement plot on the right with mesh setting corresponding to mesh 2 in Table 1.

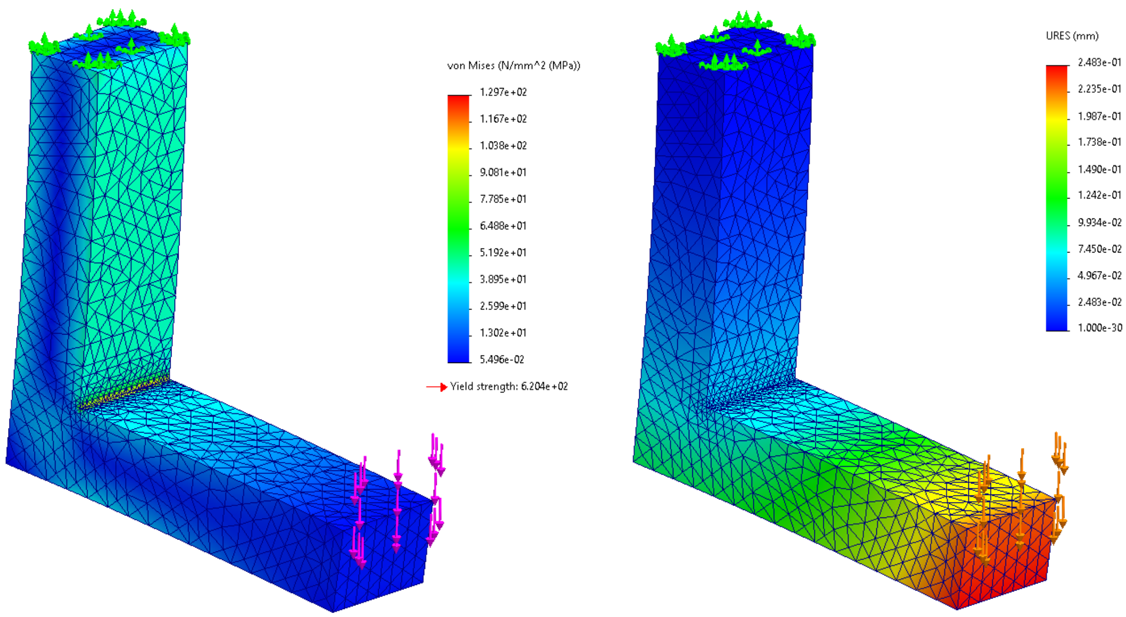

Figure 3: L-Bracket (A) Stress Plot on the left and (B) Displacement plot on the right with mesh setting corresponding to mesh 3 in Table 1.

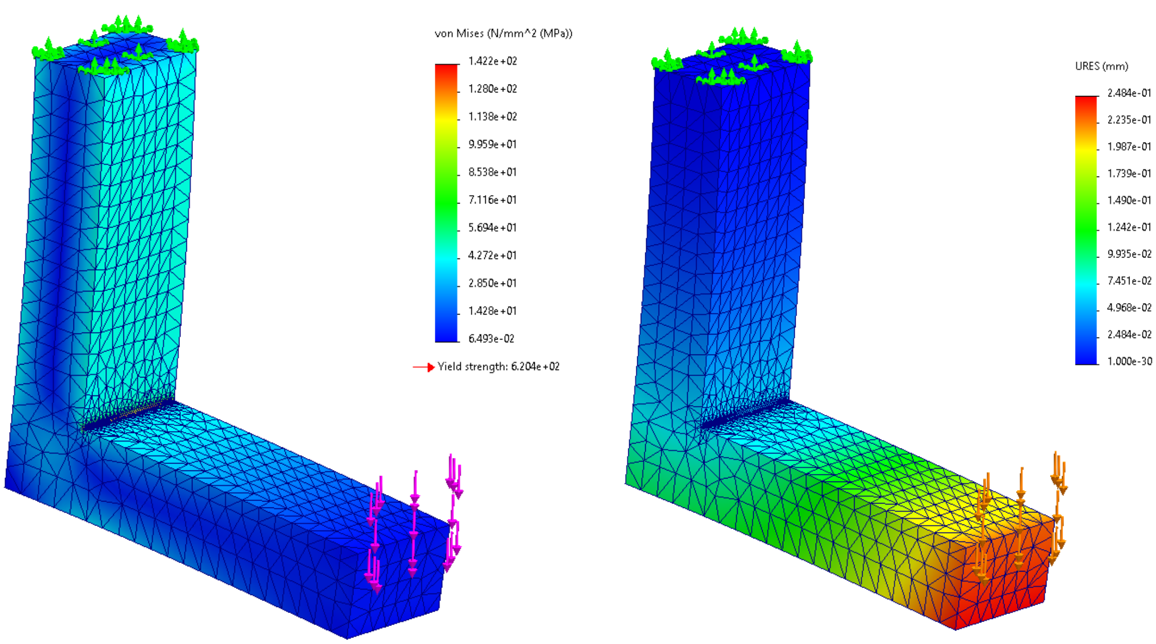

Figure 4: L-Bracket (A) Stress Plot on the left and (B) Displacement plot on the right with mesh setting corresponding to mesh 4 in Table 1.

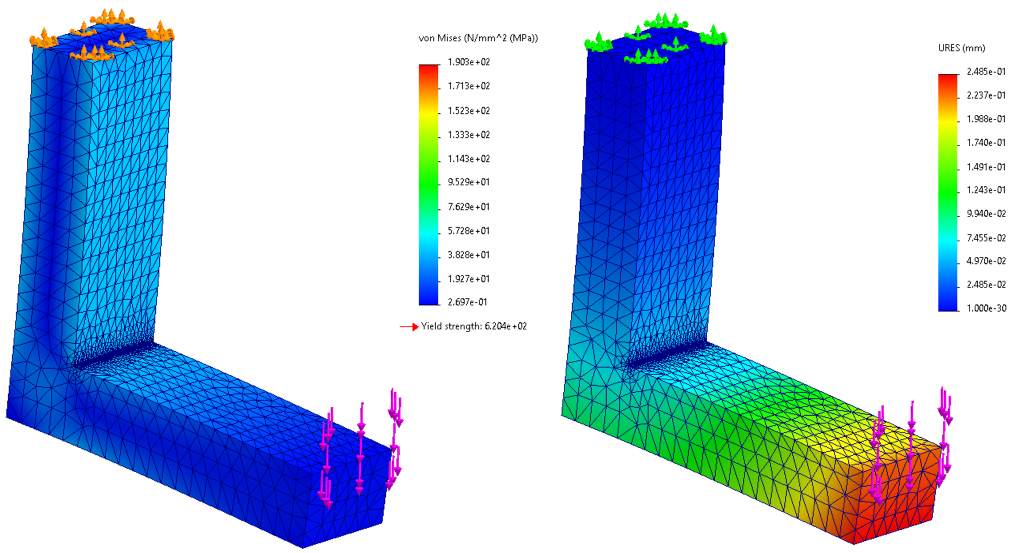

Figure 5: L-Bracket (A) Stress Plot on the left and (B) Displacement plot on the right with mesh setting corresponding to mesh 5 in Table 1.

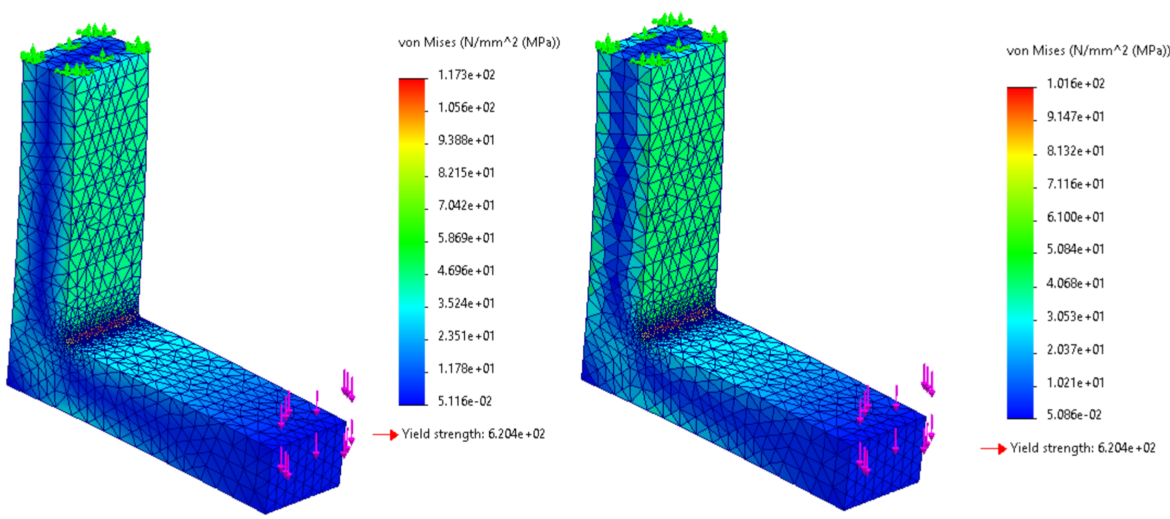

Figure 6: L-Bracket (A) Stress Plot from nodal values on the top left, (B) Stress Plot from element values on the top right with mesh setting corresponding to round edge in Table 2.

In the second portion of the lab, different filet radius is plotted to determine the effects on the max von Mises stress. The element size growth ratio used in this portion of the lab is 1.4.

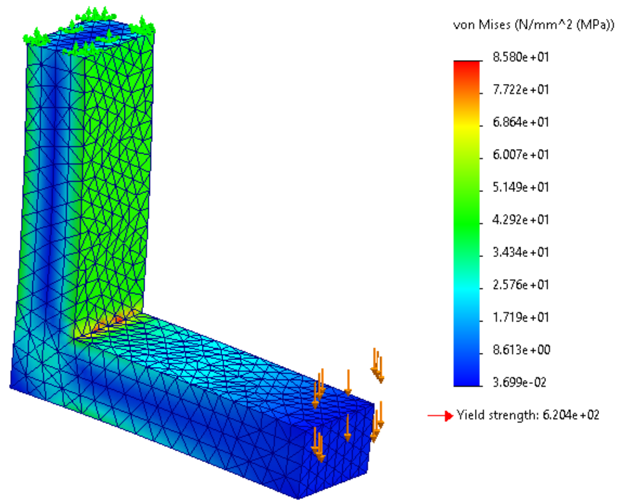

Figure 7: L-Bracket Stress Plot of a 0 mm radius filet with mesh setting corresponding to round edge in Table 3.

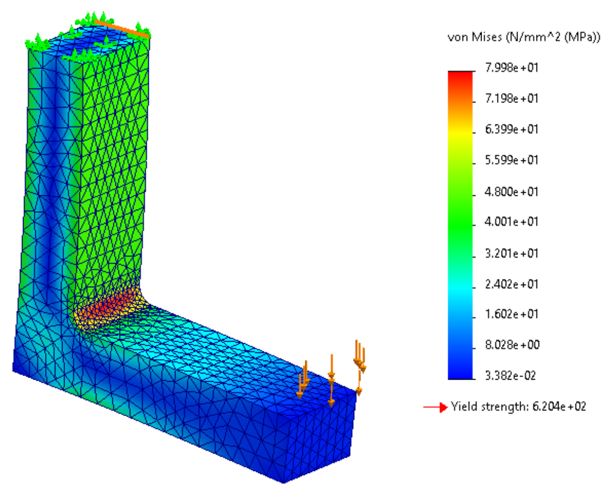

Figure 8: L-Bracket Stress Plot of a 5 mm radius filet with mesh setting corresponding to round edge in Table 3.

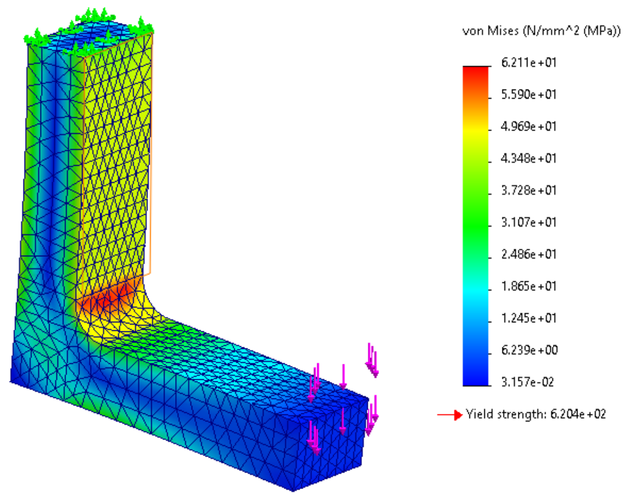

Figure 9: L-Bracket Stress Plot of a 10 mm radius filet with mesh setting corresponding to round edge in Table 3.

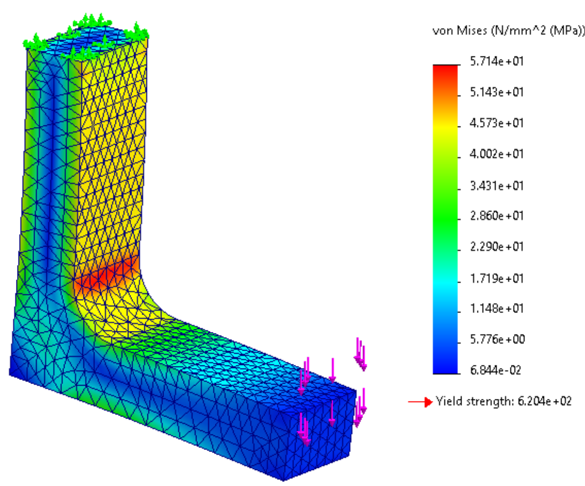

Figure 10: L-Bracket Stress Plot of a 15 mm radius filet with mesh setting corresponding to round edge in Table 3.

In the third portion of the lab, a comparison of the stress plots along the sharp edge and 15 mm radius filet at the edge is compared. The figure below shows the stress vs the nodal value along the edge and its corresponding line of values.

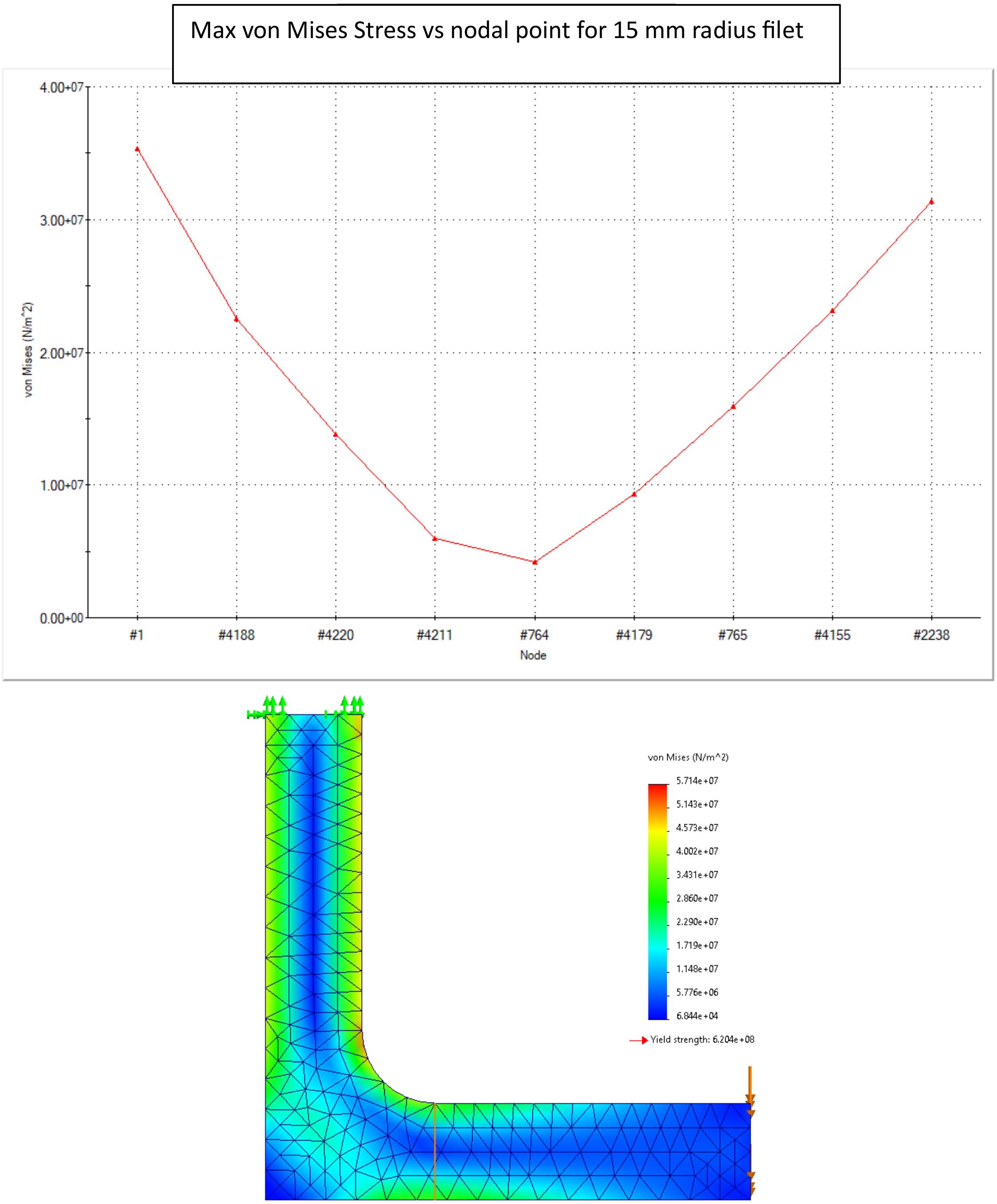

Figure 11: (A) Max von Mises Stress v nodal points of a 15 mm filet on the edge of the L-bracket plotted in 1st image along (B) the 20mm width line highlighted in orange in the 2nd image. Mesh settings corresponding to 0 mm radius in table 3.

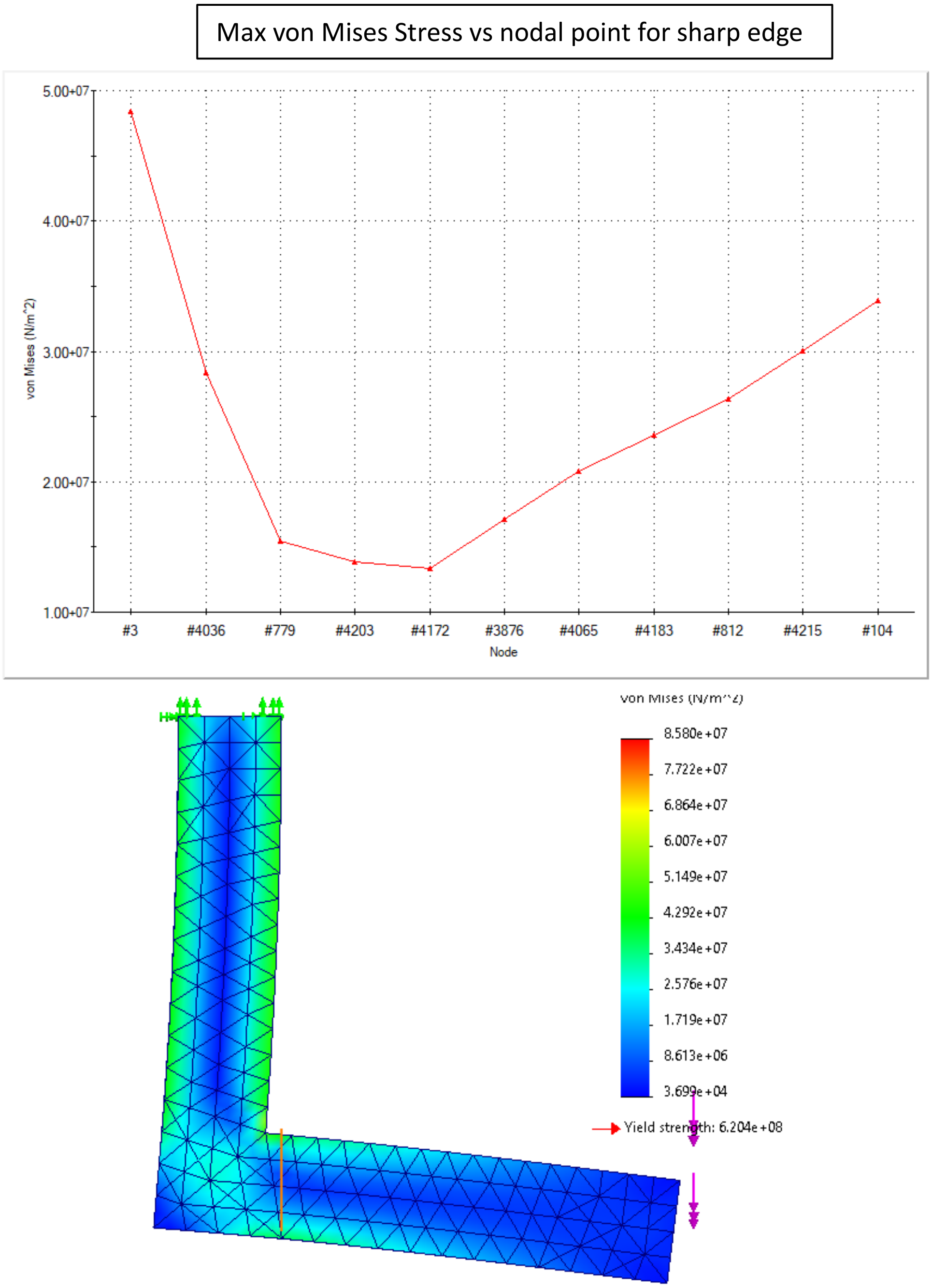

Figure 12: (A) Max von Mises Stress v nodal points of a sharp edge on the L-bracket plotted in 1st image along (B) the 20mm width line highlighted in orange in the 2nd image. Mesh settings corresponding to 15 mm radius in table 3.

Discussion and Interpretation of Results

Mesh control plays a critical role in the accuracy of the desired resultant parameters. In the first portion of the lab, mesh control was used around the sharp edge of the L-bracket to determine the role of smaller element sizes in improving accuracy. Although mesh control is a important tool needed to help determine more accurately values of stress in a localized area, in the use of a sharp edge, such mesh control is proven to be an ineffective tool. In table 5, it can be seen that as the element size of the mesh around the sharp edge, the max von Mises stress is increasing without any sight of convergence. This is because the finite element model used in the study does not align with the expected results at a sharp edge. Such a mathematical model used for the FEA would signify a diverging value rather than reaching a more accurate result. It can also be seen that mesh control was not needed with the displacement plots due to the insignificant change to along the edge. From table 4, it can be seen that the change in displacements is in the 5^{th} power, so further refinement at that edge was not necessary.

Nodal values of stress and element value of stress are compared using the radius of 2 mm on the edge of the bracket. It can be that the element value is smaller than that of the nodal value as seen in table 2. Such difference is used to determine the proper sizing of elements in the determining the mesh settings. As seen in figure 6, though the values differ, the overall stress scales and distribution can be to match, therefore letting users confirm that their mesh settings are accurate, saving the need to test for stress convergence as done with varying mesh controls.

The Filet radius added to the edge of the L-bracket was done to determine the changes to SCF. As per the results in table 3, the increase in the filet radius lowered the SCF values (table 6). SCF are the localized stresses that can help to determine areas of failure. By lowering the geometric irregularities and smoothing the flow of stress along the area, an increase filet radius can in turn reduce stress concentrations. As seen in figures 7-10, as the radius increased, the maximum stress can be seen going down as the load is spread on more area across the bracket. In comparing the stress plots along the 20 mm width, it can be observed that the sharp edge plt reached a larger max stress with a sharp edge (figure 12) as opposed to a gradual decline with smaller max stress (figure 11) with stress recovering more by the end of the width. Such results can explain that the radius along the edge creates a distribution of the stress along other [arts of the bracket. Whie the sharp edge experiences more stress along the edge, other parts of the bracket do not hold as much as seen with the 15 mm filet.

Conclusions

This lab looked to find the importance of mesh control and its proper usage. Before using mesh control, one must first determine areas of significance. However, from this lab, it can be seen that aligning the proper model use is important to obtain useful, converging results as seen with mesh control applied on the sharp edge. A method to confirm mesh control accuracy without testing for convergence is determined by comparing nodal and element-based values of the parameter in question over varying mesh sizes. Various radiuses along an edge of the L-bracket is used to compare the stress distributions and SCF along the critical points. It was determined that the larger radius can create less SCF along the edge. While this result can be applied for the use of L-brackets manufacturing, it must also be noted that the extra radius filet would increase the cost of production.

References

[1] Engineering Analysis with SolidWorks Simulation 2024, by Paul Kurowski (2024), ISBN-10: 1630576298.
[2] A First Course in the Finite Element Method, Enhanced Edition, 6th Ed., by Daryl Logan (2022), ISBN-10: 0357884140
[3] *Stress concentration: Mitigating risk factors in Design Engineering*. Neural Concept. (n.d.). https://www.neuralconcept.com/post/stress-concentration-mitigating-risk-factors-in-design-engineering#:~:text=Stress%20concentration%20occurs%20when%20there%27s%20a%20localized%20increase,material%2C%20causing%20it%20to%20concentrate%20at%20specific%20points.