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Effect of Fillet Radius of the Shaft On Von Mises Stress

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ABSTRACT: Circular components called shafts transfer force from one area of a machine to another. The way the components function together is altered when a tip is placed on a shaft. It is frequently used in engineering designs to ensure that the entire structure is strong, distribute stress, and increase wear resistance. It has smooth edges. tension gradients are divided by the shaft split, reducing the likelihood that tension may accumulate in one area and result in an early break. The importance of wear strength is demonstrated by the fact that this part of the design is extremely crucial for applications involving moving or spinning loads. Additionally, fillets facilitate easier load movement, which reduces the likelihood of cracks forming and spreading. In summary, mechanical systems perform better and last longer when fins are incorporated into the shaft design. The paper discusses a heavy shaft with a 5 Nm force on one end. It's set on the other side. A36 steel, AISI hot rolled bar, and stainless steel 316L are the three materials used. Each has a fillet radius of 0.25 mm, 0.5 mm, 1 mm, 1.5 mm, or 3 mm. SolidWorks can be used to create and inspect the shaft component. According to the findings, von Mises produces the most stress at the smallest fillet radius and the least amount at the smallest fillet radius.

KEYWORDS: Von mises, fillet radius, distribute stress

I. INTRODUCTION

The most crucial component of mechanical transportation systems is the shaft. They facilitate the transfer of power, torque, and motion. Shafts are used in anything from delicate products like coffee makers to massive machinery like cars, tanks, and airplanes.

A shaft's mechanical properties and strength are significantly altered when fillets are added. Fillet joints, which unite the shaft to other components in a curved or concave manner, aid in more uniform load distribution. This crucial work spreads stress and reduces the likelihood of failures brought on by fatigue.

Fillets make shafts stronger and less likely to twist and bend. A well-made fillet is an important part of mechanical and engineering design that can make a shaft work better and last longer.

The researcher in this study presents innovative and refined equations developed from sampling computational finite element simulations and subsequent regression analysis.

The new equations are easy to use, accurate, and give a new perspective on how the notch effect works in shaft design. [1].

This study suggests a technique for enhancing the dimensions of shoulder filleted shafts with relief grooves subjected to axial loads. The goal is to lower the stress concentration at the shoulder fillet and groove roots, which will increase the fatigue life. The method uses a special tool that combines the SQP optimization algorithm with a parametric model to figure out stress. We guess how long the shafts will last until they get tired, both with and without relief grooves. The innovation incorporates an optimization technique to determine the optimal design of relief grooves, employing an interface between MATLAB® and ANSYS. Future improvements and uses of this technology must have the right safety features. [2].

The study examines the stress concentration factor (SCF) of a shoulder filleted shaft/round bar under bending stresses. We use ANSYS 19.0 workbench software to do finite element analysis (FEA) on seven different shapes with different D/d ratios. The results show that the theoretical and FEA results are the same when the D/d ratios are lower. However, when D/d ratios are higher, the results are different. As the D/d ratios go up, the SCFs go down [3].

In this paper the objective of this research is to identify the most effective fillet shape for a shouldered shaft or plate, aiming to minimize the maximum equivalent stress and the findings indicate that stress concentration factors approaching one are attainable, even in bars with substantial cross-sectional variations. Additionally, the area occupied by the optimal fillets is considerably smaller compared to circular or elliptical configurations [4].

In this study, the researcher used 5 shaft parts to connect the mechanical equipment. The fillet radius at the shafts is 1mm, the concentration factor (kts) is 1.7, and the shaft material is AISI1040 with a yield stress of 415 MPa. The von Mises stress of the rotating shaft is 32.858 Mpa [5].

The authors explore the relationship between the shape of fillets in mechanical components subjected to multiple in-plane loading cases, and their effect on stress and deformation [6].

The article probably talks about how important it is to know about stress concentration factors in filleted shafts so that mechanical parts that have to deal with tension and bending loads can be designed safely and effectively. The goal of the paper is to give new and useful information about stress concentration factors for filleted shafts under tension and bending loads [7].

The authors propose a method for enhancing the geometries of structures under mechanical loads through dynamic programming. Their method breaks the structure down into smaller parts and finds the best way to arrange the material in each part to minimize the building's compliance, while keeping in mind limits on the amount of material used and the stress levels that are allowed.

The authors show that their method works by using it on a few examples, such as designing a cantilever beam and a plate with a hole that is bent. In general, the study gives a good way to solve problems in the area of structural optimization [8].

Researchers are providing useful insights and design data for optimizing the forms of shoulder fillets in flat plates under various loading circumstances, which could help improve the performance and structural integrity of engineering applications [9].

II. GEOMETRY OF THE LOADED SHAFT

The shafts are crafted in two interlinked segments: one with a 20 mm diameter, the other at 10 mm. Fillet values (0.25, 0.5, 1, 1.5, 3) mm vary for each simulation. The torque applied remains constant at 5 Nm. Materials chosen for the shafts include A36 Steel, AISI Hot Rolled Bar, and Stainless Steel 316L.).

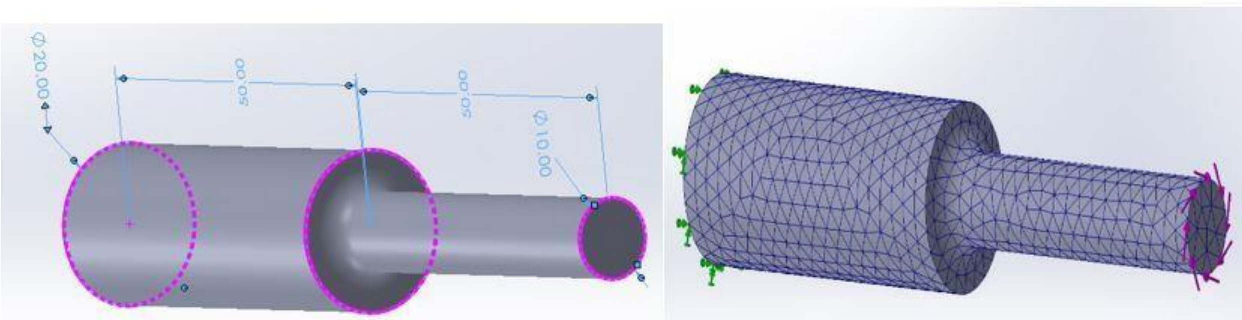

Figure 1. Design and mesh of loaded shift

III. MATHEMATICAL CALCULATIONS

The formulation of shear stress can be calculated by using formula as shown below:

$$\tau = Kts \frac{16\,T}{\pi D^{\wedge}3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

The value of von mises can be found by using the formulation below:

$$\sigma von = \sqrt{[(\sigma x)^{\wedge}2 - \sigma x * \sigma y + (\sigma y)^{\wedge}2 + 3(\tau xy)^{\wedge}2]} \quad \ldots\ldots\ldots\ldots 2$$

The value of σx = 0

The value of σy = 0

Therefore, the von mises can be found as a result:

$$\sigma von = \sqrt{3(\tau xy)^{\wedge}2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

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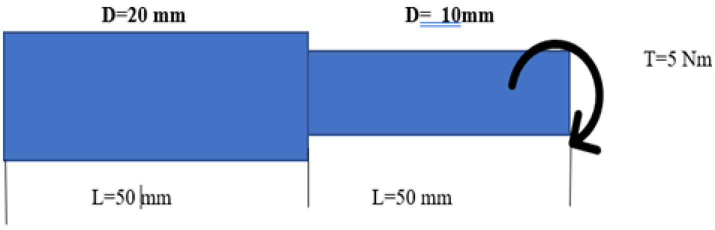

Figure 2. design shift

IV. STRESS CONCENTRATION FACTOR

The stress concentration factor (Kts) serves as a dimensionless measure indicating the degree of stress concentration within a mechanical component. It is defined as the ratio of the maximum stress in the part to a reference stress.

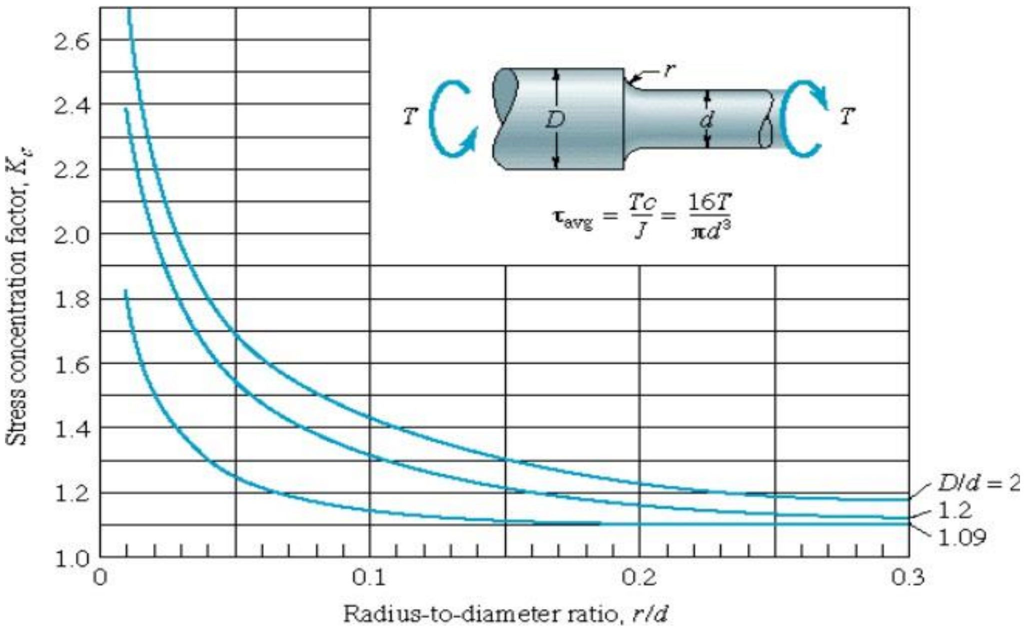

Figure 3. Stress concertation factor (10)

IV.I ANALYSIS OF THE LOADED PART

The examination of a component, subjected to a 5 Nm load on one side and fixed on the other, was conducted through design and simulation in SolidWorks 2022. Three ductile materials with yield stresses of 170 MPa, 180 MPa, and 250 MPa were employed. The simulation results closely align with the calculated values

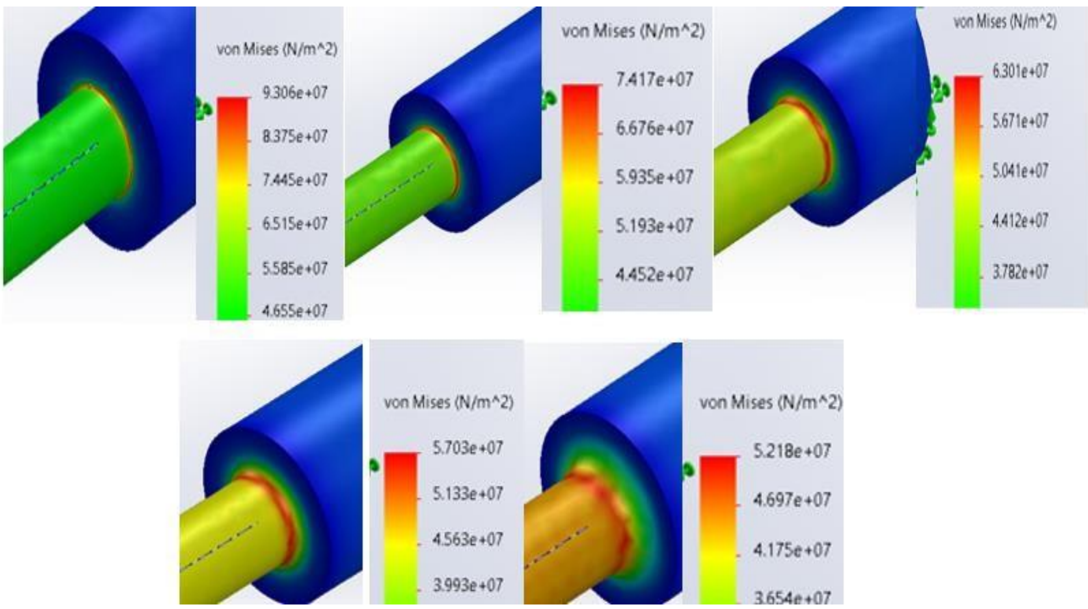

Figure 4. Amount of von mises with different fillet values (A 36 STEEL, 25 Mpa)

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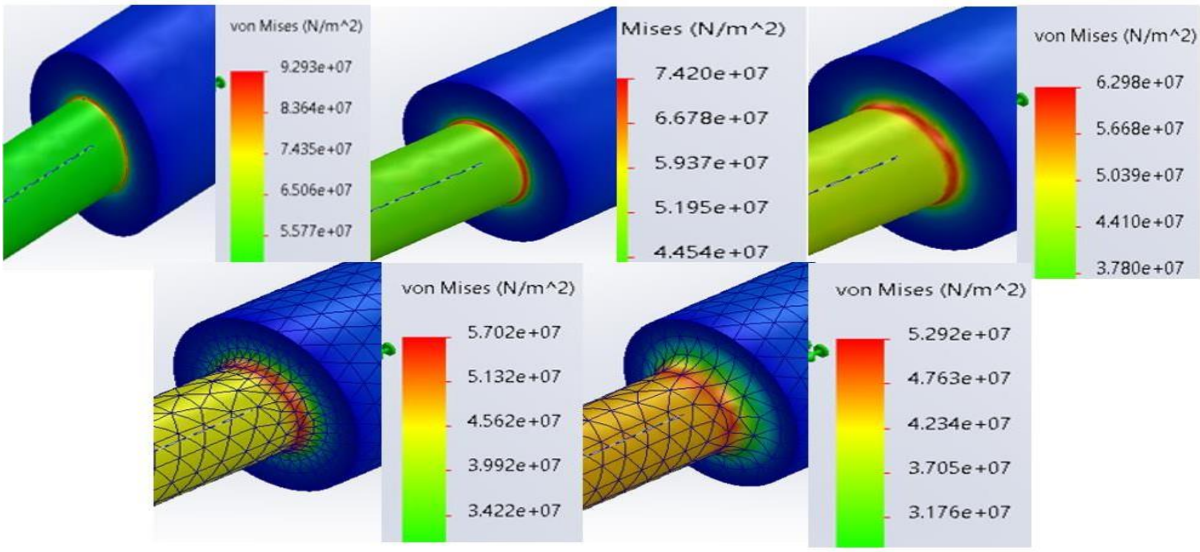

Figure 5. Amount of von mises with different fillet values (AISI1010 STEEL, 180Mpa

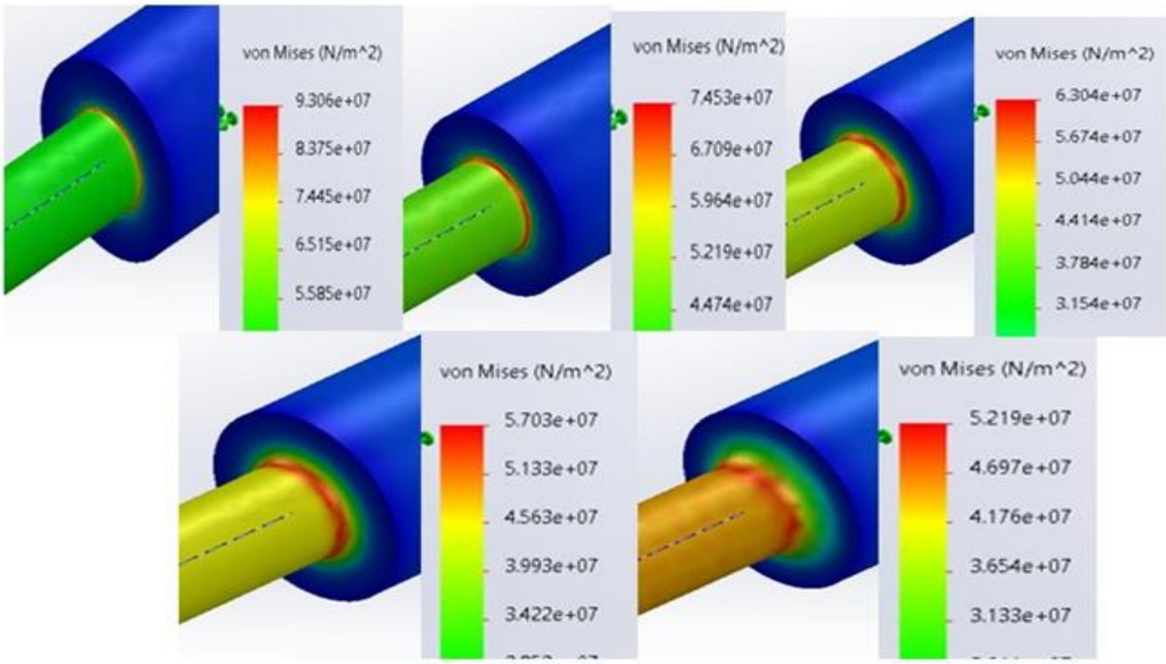

Figure 6. Amount of von mises with different fillet values (AISI316 170Mpa

Table 1. Material of Steel A36, Sy=250 Mpa

No	Fillet(mm)	Von-mises calculation	Calculation (FOS)	Von-misses analysis (Mpa)	ANALYSIS (FOS)
1	0.25	95.71	2.61	93.08	2.7
2	0.5	74.98	3.33	74.17	3.4
3	1	63.513	3.93	63.01	3.4
4	1.5	58.22	4.26	57.03	4.4
5	3	52.92	4.72	52.18	4.8

Table 2. Material of AISI, hot rolled bar, Sy=180 Mpa

No	Fillet(mm)	Von-mises calculation	Calculation (FOS)	Von-misses analysis (Mpa)	ANALYSIS (FOS)
1	0.25	95.709	1.88	92.93	1.9
2	0.5	74.98	2.4	74.2	2.4
3	1	63.513	2.8	62.98	2.9

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4	1.5	58.22	3.08	57.02	3.2
5	3	52.92	3.4	52.92	3.4

Table 3. Material of AISI Stainless steel 316L, hot rolled bar, Sy=170 Mpa

No	Fillet(mm)	Von-mises calculation	Calculation (FOS)	Von-misses analysis (Mpa)	ANALYSIS (FOS)
1	0.25	95.71	1.77	92.06	1.8
2	0.5	74.98	2.26	74.53	2.3
3	1	63.513	2.67	63.04	2.7
4	1.5	58.22	2.919	57.03	3
5	3	52.92	3.212	52.19	3.3

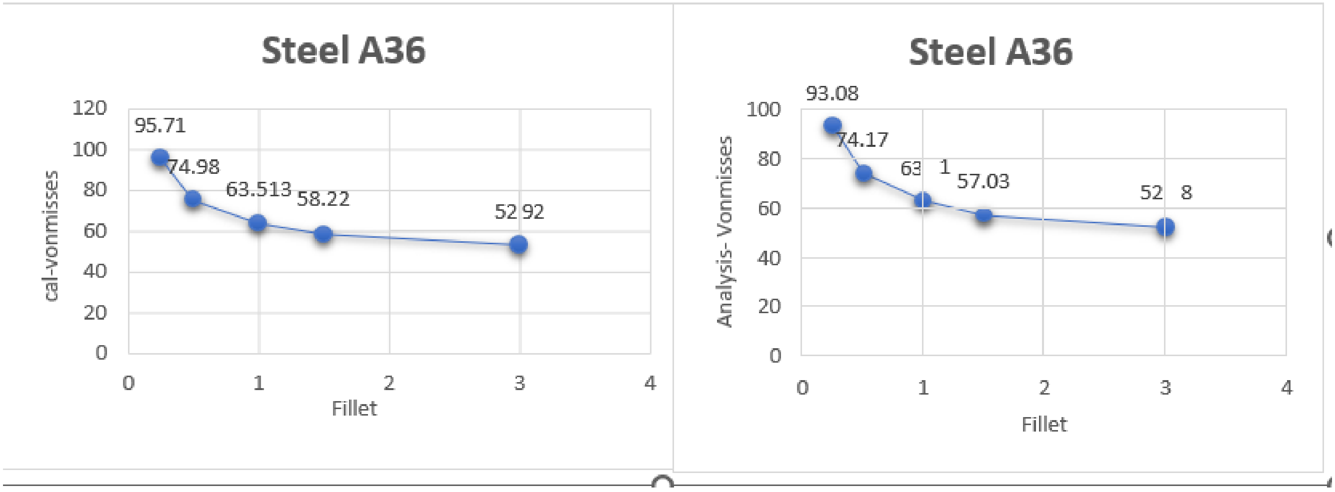

Figure 7. Curve of calculation -Analysis of A36 STEEL

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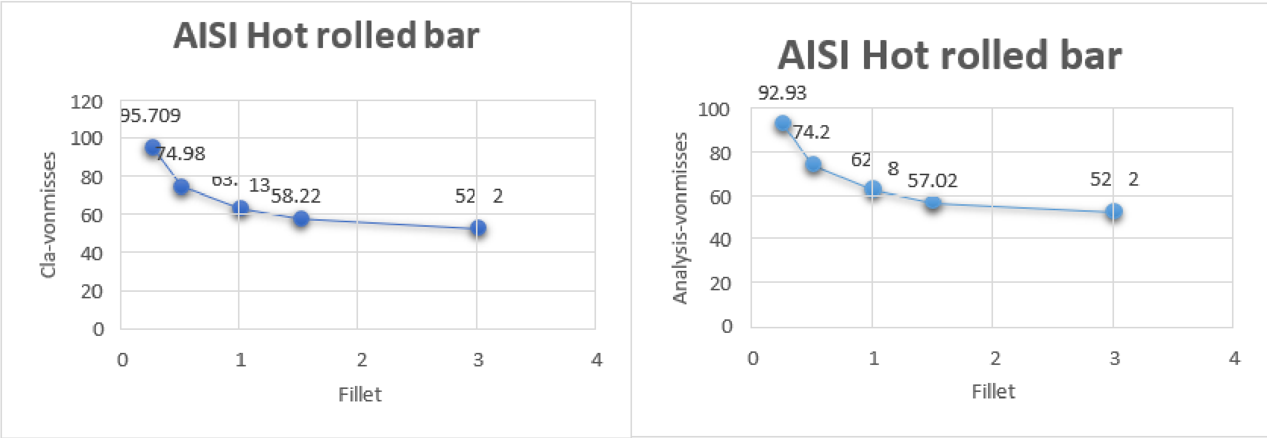

Figure (8) Curve of calculation -Analysis of AISI Hot rolled bar

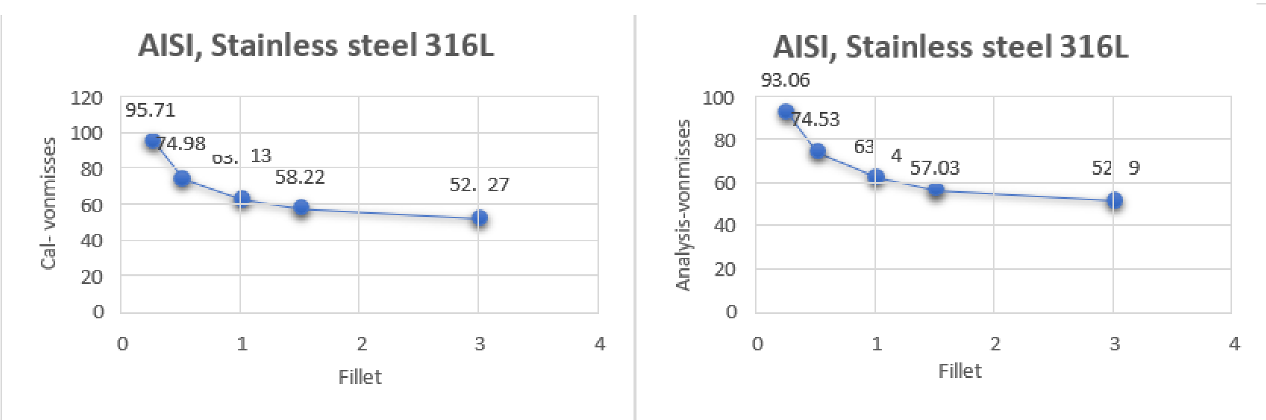

Figure (9) Curve of calculation -Analysis of AISI Stainless steel 316L

V. CONCLUSIONS

This study shows how the effect of fillet radius is very strong in the stress distribution and structural performance of torsionally loaded shafts. Computer simulations verify that a reduced fillet radius is linked to a high stress concentration, thus increasing the possibility of material failure. On the other hand, a larger fillet radius is an effective way of preventing von Mises stress by redistributing the load applied to the shaft more uniformly. The comparison of the materials covered A36 steel, AISI hot-rolled steel, and stainless steel 316L demonstrate a stable pattern, meaning that the fillet geometry has a stronger decisive impact on the stress reduction than is the choice of material under the same loading conditions. In this regard, it is advisable to consider the inclusion of higher fillet radii in the construction of shafts which are prone to rotating or dynamic loads in order to increase the durability, prevent the development of cracks and increase the service life of mechanical components

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5) Figure 6.5 Stress concentration factor for round bar with fillet. (c) Torsion. [Adapted from Collins (1981).] Text Reference: Figure 6.5, page 225
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