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Design Analysis Pillowblock Strength of Rotogravure Gearbox Uses Catia V5 Software

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displacement
safety factor

Abstract

The pillowblock has not been tested to determine the von Mises stress, displacement and safety factor values. The aim of this research is to analyze the results of the Pillowblock design analysis using the finite element method using CATIA V5 software.The research method used in this research is an experimental method. In this study, the independent variable used was variations in the thickness dimensions of the Rotogrvure Pillowblock Gearbox. The variations used are Pillowblock Close 1 with varying thicknesses (5 mm, 4 mm, 6 mm, 7 mm), Pillowblock Close 2 with varying thicknesses (6 mm, 5 mm, 7 mm, 8 mm) and Pillowblock Equipment with varying thicknesses (5 mm, 4 mm, 6 mm, 7 mm), the material used is ST 40 with a rotary bending load (bearing load). Tests were carried out using the fenite element method (FEM) to determine the value of von Mises stress, displacement and safety factor. The analysis results show that variations in pillowblock thickness have a high level of effectiveness and efficiency and have a safety factor value of ≥ 2, found in the Pillowblock Close 1 T4 (7 mm) with a von Mises stress value of 0.349 MPa, displacement 0.000046 mm, safety factor 787.96. Pillowblock Close 2 R4 (8 mm) with a von Mises stress value of 0.430 MPa, displacement 0.000062 mm, safety factor 639.24, and Pillowblock Equipment P4 (7 mm) with a von Mises stress value of 2.504 MPa, displacement 0.000312, safety factor 109.82.

1 Introduction

As time goes by, the industrial world continues to experience rapid development. This is supported by the increasing development of science and demands for a higher quality of life, for example in the printing and manufacturing industries. One of the industries engaged in the printing and manufacturing sector is CV Surya Cipta Inti Pratama (CIP). CV Surya CIP Semarang is a printing and assembly coMPany that specifically operates in the business of providing machines, designing and building spare parts related to bundling printing [1].

The rotogravure gearbox is one of the products produced by CV Surya CIP. The rotogravure gearbox functions to transfer rotational power from the drive motor to the printing machine. This gearbox has various components, one of which is the pillowblock. In this case, the pillowblock design in this rotogravure gearbox has not been scientifically tested and computerized. Pillowblock bearing is a component that functions to receive loads, both radial and thrust, as well as a shaft support [2].

The finite element method is one option that can be used to help test the strength of the design structure. The finite element method is a computational method used to obtain solutions to boundary value or numerical problems [3].

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This method is still very relevant and widely used by researchers to conduct their research. FEM (Fenite Element Method) is an analysis method that can determine static and dynamic loading values [4]. CATIA (Computer Aided Three-Dimensional Interactive Application) is an application that can be used in 3D programming, both design and analysis [5]. Therefore, this study uses CATIA software to assist the design, planning and analysis process on pillowblock components. The results of the analysis using CATIA software are in the form of von mises stress values, displacement, and safety factors, where from these results the design strength can be determined in withstanding a load that occurs and the design safety value.

Based on the description above, the purpose of this study is to analyze the initial pillowblock design by utilizing the finite element method in CATIA V5 software to determine the strength of the pillowblock structure in the form of von mises stress values, displacement and safety factors, which will later be used to design a new design (redesign) that is effective and efficient based on the study conducted.

2 Research Methods

The analysis process using the finite element method is carried out by varying the pillowblock design structure to produce von mises stress, displacement and safety factor values. The standard safety factor value allowed in this study is 2.0. The input rotational speed of the rotogravure gearbox is 1500 rpm with an electric motor power of 26.81 HP, while the material used in the design of the eccentric shaft and docta components is ST 40 carbon steel with the specifications shown in Table 1.

Table 1. ST 40 Carbon Steel Specifications

Properties	Value
Young Modulus	2.1e+011 N/m^2
Poisson Raito	0.27
Density	7700 kg/m^3
Thermal Expansion	1.17e-005_Kdeg
Yield s\Strenght	2.75e+008 N/m^2

Research Specimen Dimensions

The initial pillowblock design was based on the design of CV. Surya CIP Semarang. The pillowblock design variations of Tutup 1, Tutup 2, and Perlengkapan have structures with larger dimensions than the initial pillowblock design. Increasing the component dimensions will have an iMPact on the strength of the structure and the safety of the components in receiving the load. The size and dimensions of the initial pillowblock design are shown in Figure 1-4.

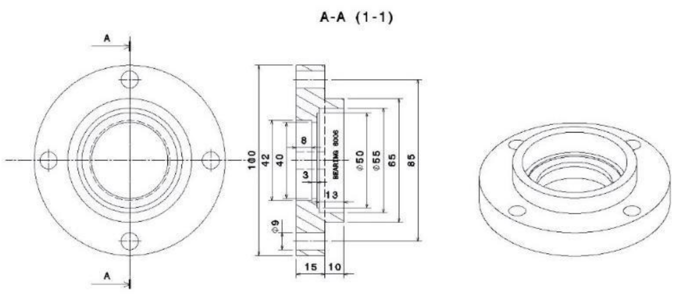

Figure 1. Initial Design of Pillowblock Cover 1

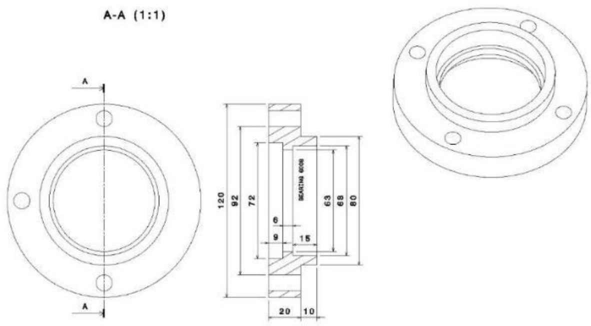

Figure 2. Initial Design of Pillowblock Cover 2

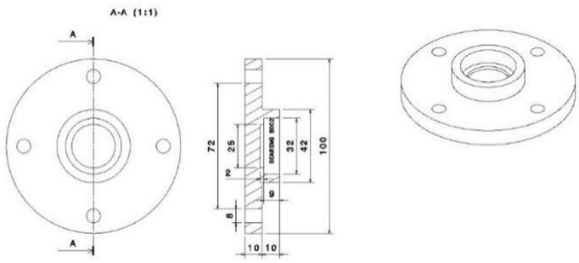

Figure 3. Initial Design of Pillowblock Equipment

Distributed Loading

1. Pillowblock Cover 1

   Based on previous research, pillowblock cover 1 receives a load from the gearbox axle 2, the force load received by the pillowblock is 93.87 Nm while this load is received by two pillowblocks cover 1 with the following load distribution:

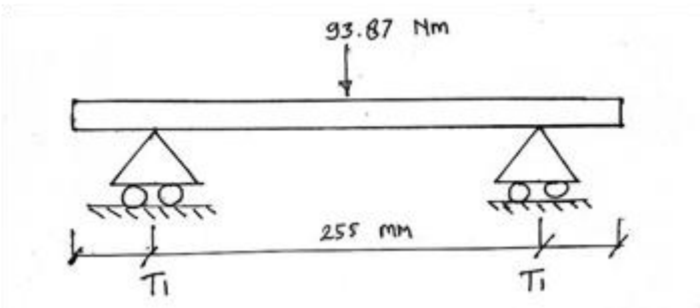

Figure 4. Distributed Loading Cover 1

   So the calculation of the distributed load is as follows:

   $T1 = T1 = \frac{W}{2} = \frac{93.87\ Nm}{2} = 48.935\ Nm$

   $W = 93.87\ Nm$

   T1 = T1 = Load on Pillowblock Close 1

2. Pillowblock Cover 2

Based on research related to pillowblock cover 2, the load received is the gearbox axle load of 153,606 Nm while the load received by pillowblock cover 2 is as follows:

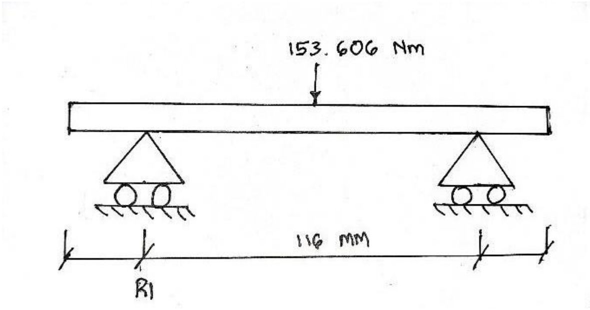

Figure 5. Distributed Loading Cover 2

$R1 = B = \frac{W}{2} = \frac{153.606\ Nm}{2} = 76.803\ Nm$

$W = 153.606\ Nm$

R1 = Load on Pillowblock Cover 2

B = Load on the middle flat gearbox

3. Pillowblock Equipment

Referring to previous research, the load received by the pillowblock equipment is 565,308 Nm [6], therefore the distributed load received by the pillowblock equipment is as follows:

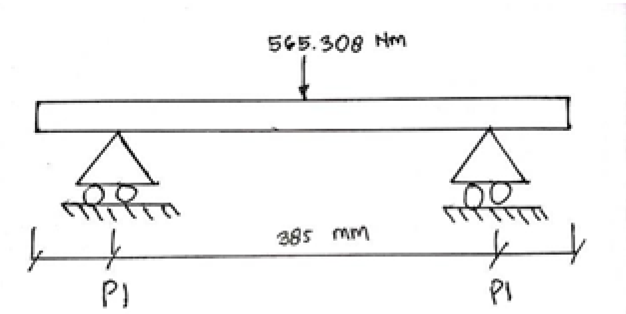

Figure 6. Distributed Loading of Equipment

$P1 = P1 = \frac{W}{2} = \frac{565.308\ Nm}{2} = 282.654\ Nm$

W = 565,308 Nm

P1 = P1 = Load on the Pillowblock equipment

Von Mises Stress

Von Mises stress is a stress that can cause failure in materials that receive triaxial stress, resulting in strain energy from the loading model given when approaching the yield point. Failure of a pillowblock material is cracking, wear, fracture, corrosion and so on. This failure in a material will occur if [6]:

$$\sigma' \geq \frac{Sy}{\eta} \quad (1)$$

Description:

Sy: tensile yield strength (MPa)
η: safety factor
σ′: von mises stress

Displacement

Displacement/deflection is a change in shape in the workpiece in the y direction (vertical) due to the loading given to the workpiece [7]. Displacement can be known if deformation occurs in the workpiece. Regardless of how much force is applied to the material, the material will still experience changes in shape and structural dimensions. This actual change can be divided into two types, namely plastic and elastic changes in shape. Increasing the load on the material that has experienced the highest strength is impossible, because in this condition the material has experienced a total change in shape or total deformation.

Safety Factor

The safety factor is a factor used to assess so that the preparation of machine components is guaranteed to be safe with low component dimensions. The safety factor value is said to be successful if it has a value above 1.0 to avoid structural failure. The formula for determining the safety factor value obtained is as follows [8].

$$\eta = \frac{Sy}{\sigma_e} \qquad (2)$$

Description:

η: safety factor
Sy: yield strength (MPa)
σe: von Mises stress (MPa)

3 Result and Discussion

3.1 Pillowblock Cover Component Analysis Results 1

Testing using the finite element method carried out on the pillowblock Cover 1 component using CATIA V5 software with dimensional variations produced test data in Table 2.

Table 2. Simulation Results Pillowblock Close 1

Code	Thickness dimension (mm)	Statis Analysis		
		Von Mises Stress (MPa)	Displacement (mm)	Safety Factor
T1	5	0.401	0.000067	685.78
T2	4	0.486	0.000083	565.84
T3	6	0.360	0.000053	763.88
T4	7	0.349	0.000046	787.96

Description:

T1: Cover 1 Initial Design
T2: Cover 1 Variation 1

T3: Cover 1 Variation 2
T4: Cover 1 Variation 3

Referring to the simulation results in Table 2 and Figure 7-14 shows that the variation of dimensions on the pillowblock Cover 1 produces different stress values for each dimension variation. The highest von mises stress value is found in T2 with a value of 0.486 MPa. While the lowest von mises stress is P4 with a value of 0.349 MPa.

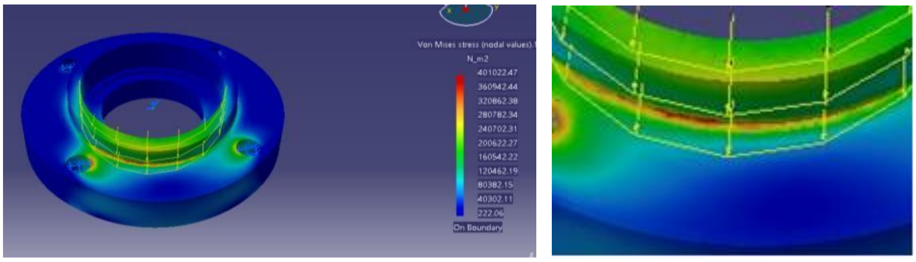

Figure 7. Von Mises T1

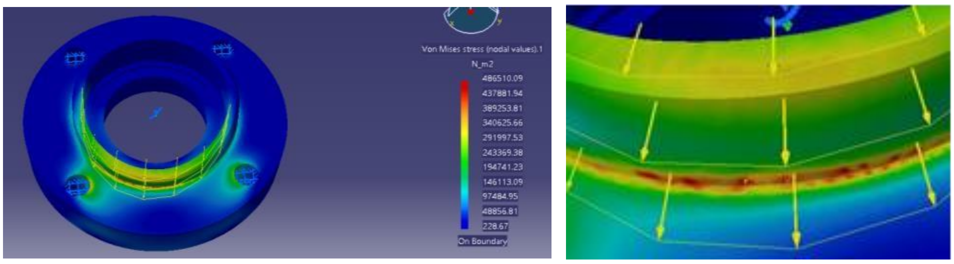

Figure 8. Von Mises T2

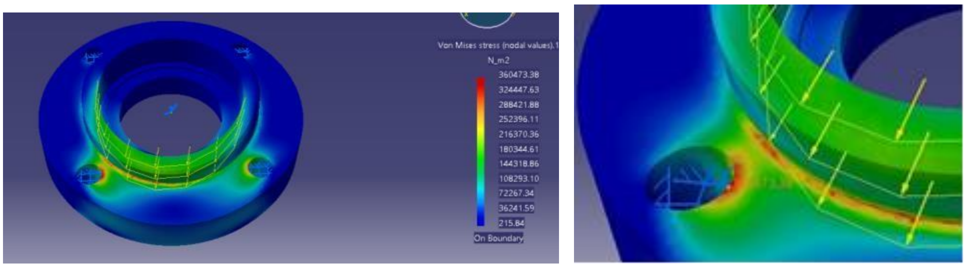

Figure 9. Von Mises T3

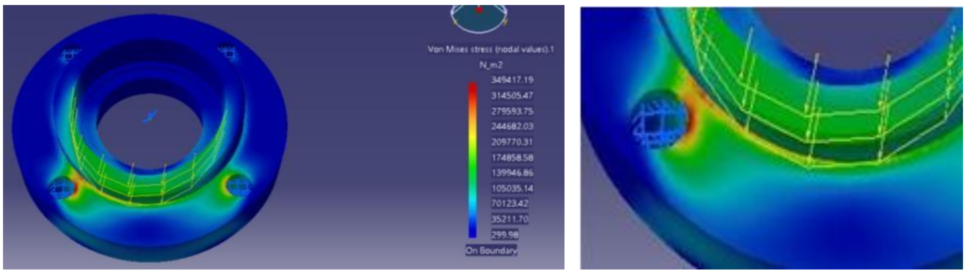

Figure 10. Von Mises T4

Based on the simulation results, it is known that the displacement value on the Close 1 pillowblock, the highest value is found in T2 with a displacement value of 0.000083 mm. while the lowest displacement value is found in T4 with a displacement value of 0.000046. it can be concluded that the lower the von mises stress value, the lower the displacement value. In addition, dimensional variations can also affect the displacement value, the larger the dimension, the smaller the resulting displacement value will be.

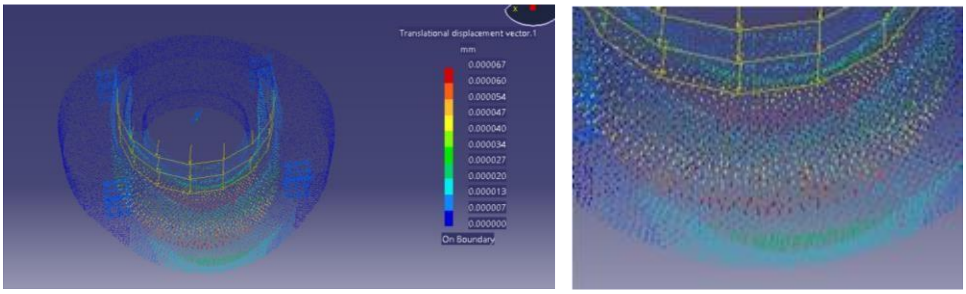

Figure 11. Displacement T1

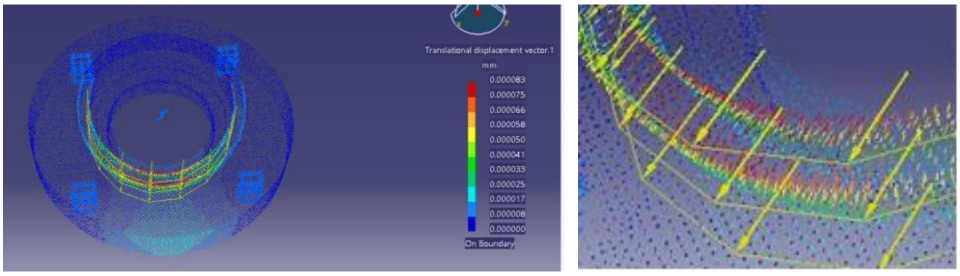

Figure 12. Displacement T2

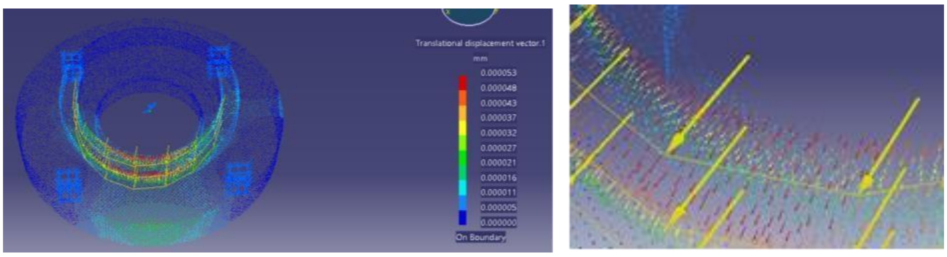

Figure 13. Displacement T3

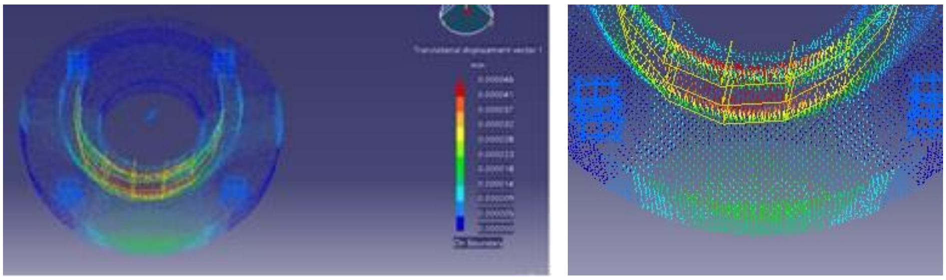

Figure 14. Displacement T4

The safety factor value is obtained based on calculations using equation 6 where the yield strength value of the ST 40 material per von mises stress produced so that the highest value is obtained at T4 with a safety factor value of 787.96. while the lowest safety factor value is at T2 with a value of 565.84. it can be concluded that the higher the von mises stress value, the lower the safety factor value produced.

3.2 Pillowblock Cover Component Analysis Results 2

Testing using the finite element method carried out on the pillowblock Cover 2 component using CATIA V5 software with dimensional variations produces test data in Table 3.

Table 3. Pillowblock Cover Simulation Results

Code	Thickness dimension (mm)	Statis Analysis		
		Von Mises Stress (MPa)	Displacement (mm)	Safety Factor
R1	5	0.424	0.000078	648.58
R2	4	0.460	0.000093	597.82
R3	6	0.430	0.000069	639.17
R4	7	0.430	0.000062	639.24

Description:

R1: Cover 2 Initial Design
R2: Cover 2 Variation 1
R3: Cover 2 Variation 2
R4: Cover 2 Variation 3

Referring to the simulation results in Table 3 and Figure 15-22 shows that the variation of dimensions on the Cover 2 pillowblock produces different stress values for each dimension variation. The highest von mises stress value is found in R2 with a value of 0.460 MPa. While the lowest von mises stress is R4 with a value of 0.430 MPa

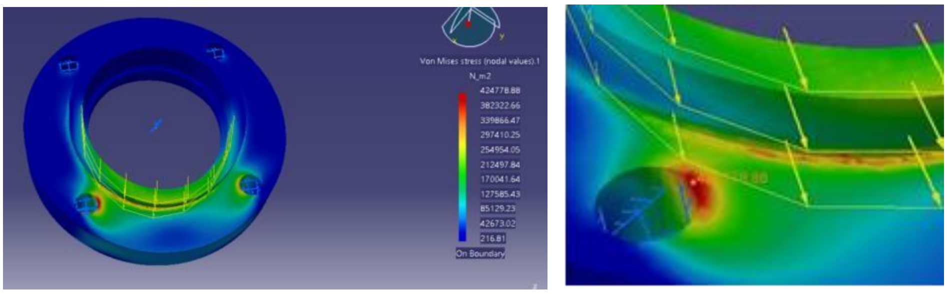

Figure 15. Von Mises R1

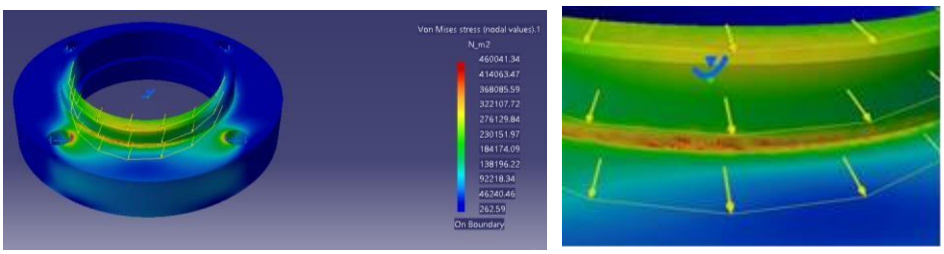

Figure 16. Von Mises R2

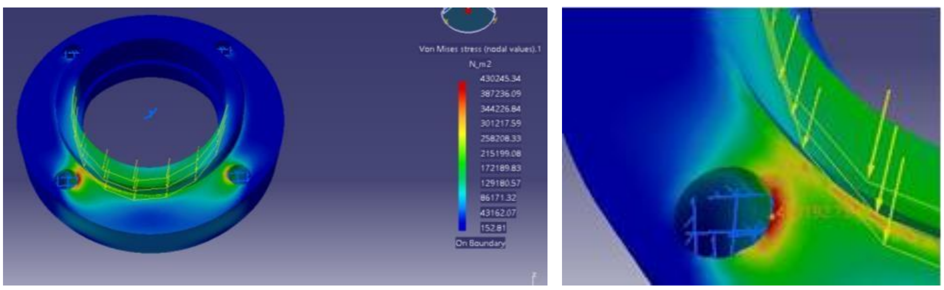

Figure 17. Von Mises R3

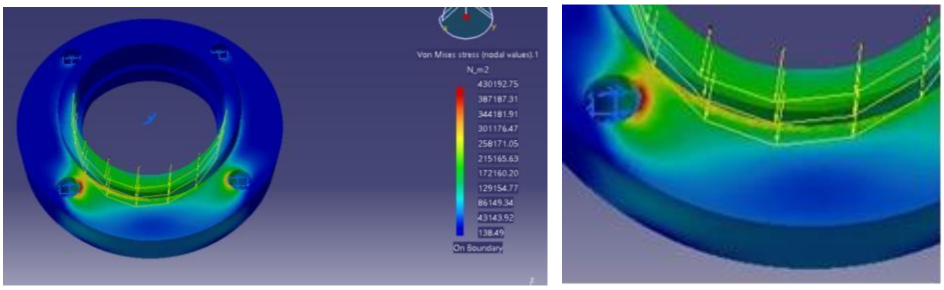

Figure 18. Von Mises R4

Based on the simulation results, it is known that the displacement value on the Close 1 pillowblock, the highest value is found in R2 with a displacement value of 0.000093 mm. while the lowest displacement value is found in R4 with a displacement value of 0.000062. it can be concluded that the lower the von mises stress value, the lower the displacement value. In addition, dimensional variations can also affect the displacement value, the larger the dimension, the smaller the resulting displacement value will be.

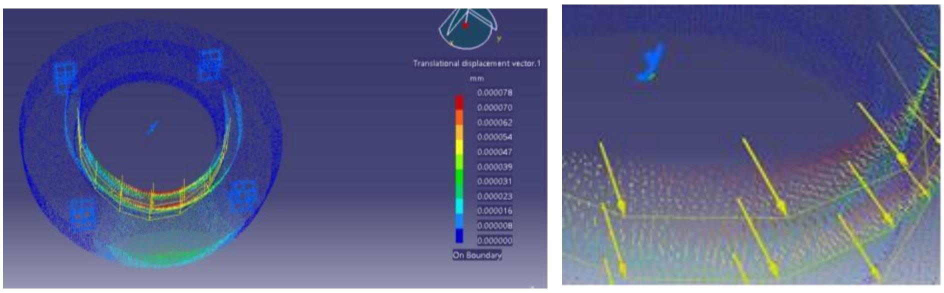

Figure 19. Displacement R1

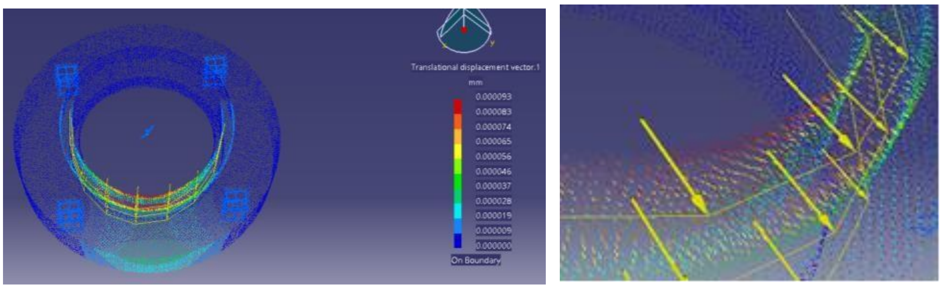

Figure 20. Displacement R2

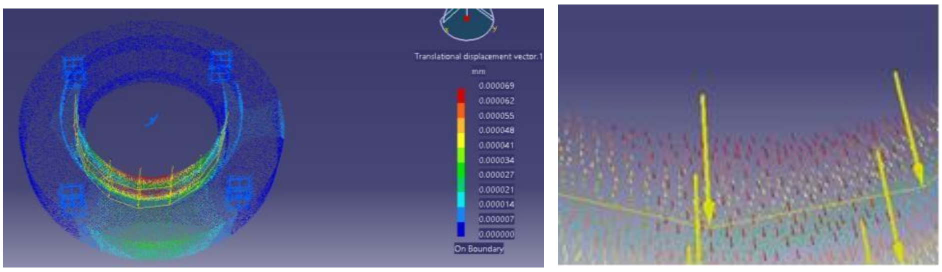

Figure 21. Displacement R3

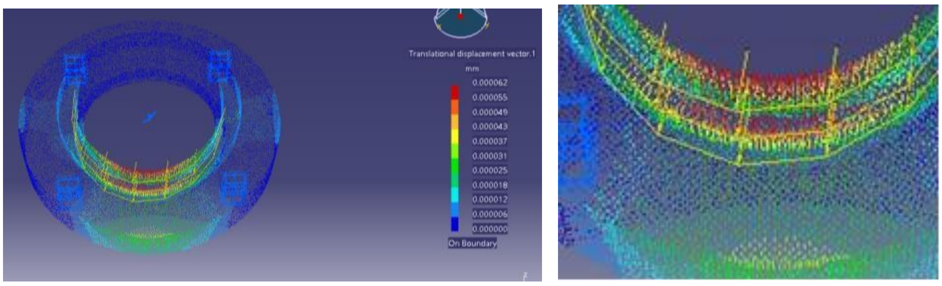

Figure 22. Displacement R4

The safety factor value is obtained based on calculations using equation 2 where the yield strength value of the ST 40 material per von mises stress produced so that the highest value is obtained at R4 with a safety factor value of 639.24. while the lowest safety factor value is at R2 with a value of 597.82. it can be concluded that the higher the von mises stress value, the lower the safety factor value produced.

3.3 Results of Analysis of Pillowblock Equipment Components

Testing using the finite element method carried out on the pillowblock components of the Equipment using CATIA V5 software with variations in dimensions produces test data in Table 4.

Table 4. Pillowblock Equipment Simulation Results

Code	**Thickness dimension (mm)**	**Statis Analysis**		
		Von Mises Stress (MPa)	**Displacement (mm)**	**Safety Factor**
R1	5	3.406	0.000464	80.73
R2	4	4.464	0.000608	61.60
R3	6	2.901	0.000372	91.79
R4	7	2.504	0.000312	109.82

Description:

P1 : Initial Design Equipment
P2 : Variation Equipment 1
P3 : Variation Equipment 2
P4 : Variation Equipment 3

Referring to the simulation results in Table 4 and Figures 23-30, it shows that the variation of dimensions in the Equipment pillowblock produces different stress values for each dimension variation. The highest von mises stress value is found in P2 with a value of 4,464 MPa. While the lowest von mises stress is P4 with a value of 2,504 MPa.

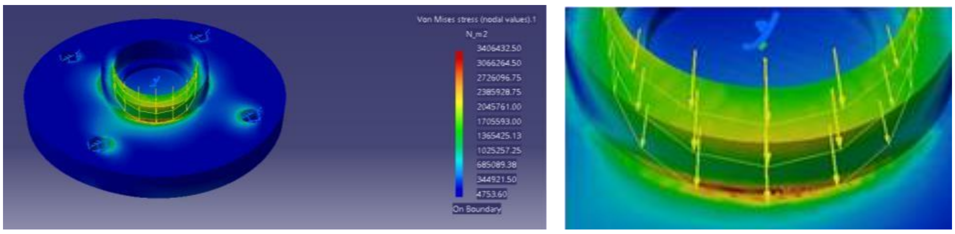

Figure 23. Von Mises P1

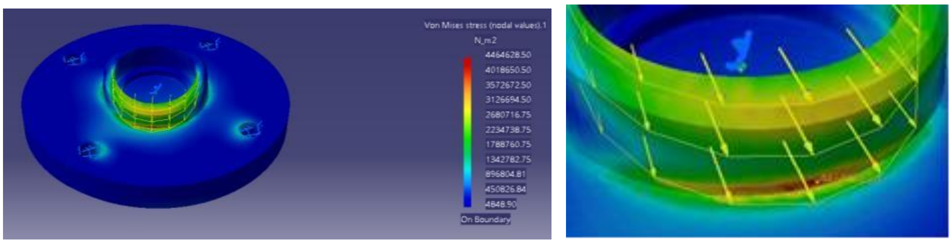

Figure 24. Von Mises P2

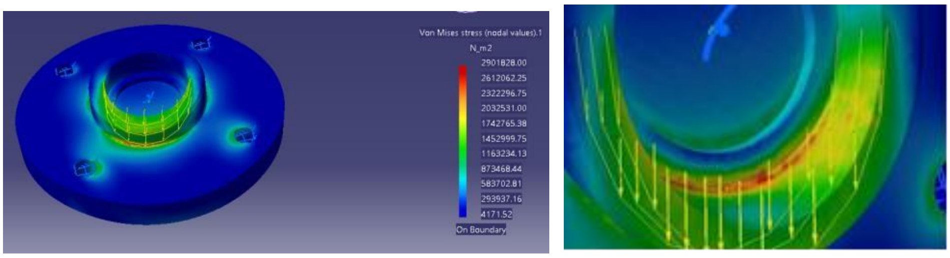

Figure 25. Von Mises P3

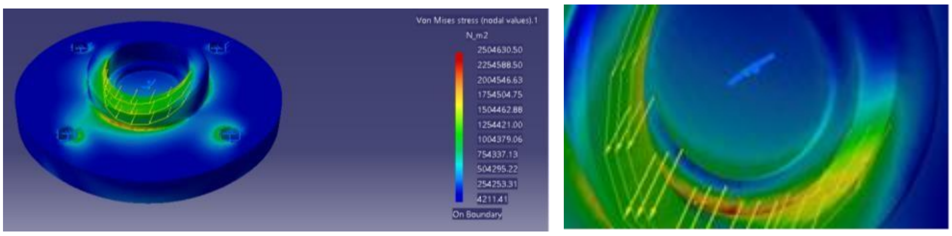

Figure 26. Von Mises P4

Based on the simulation results, it is known that the displacement value on the Close 1 pillowblock, the highest value is found in P2 with a displacement value of 0.000608 mm. while the lowest displacement value is found in P4 with a displacement value of 0.000312. it can be concluded that the lower the von mises stress value, the lower the displacement value. In addition, dimensional variations can also affect the displacement value, the larger the dimension, the smaller the resulting displacement value will be.

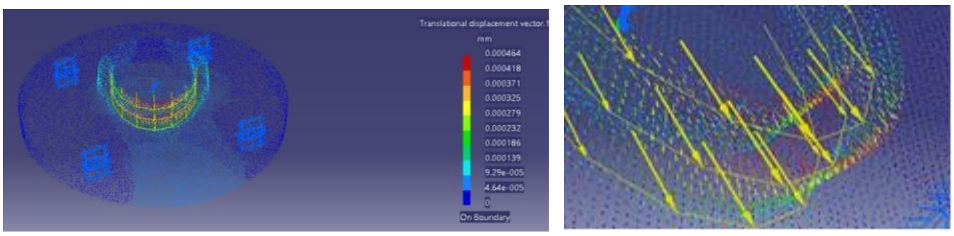

Figure 27. Displacement P1

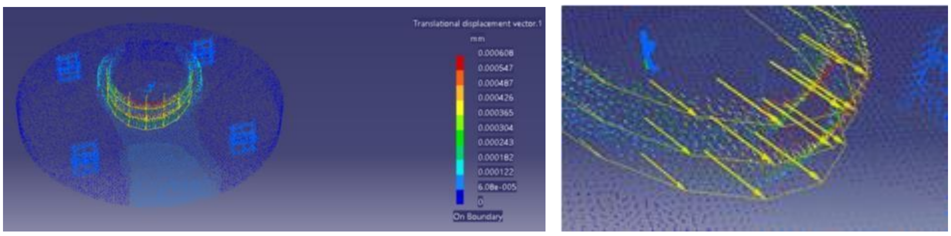

Figure 28. Displacement P2

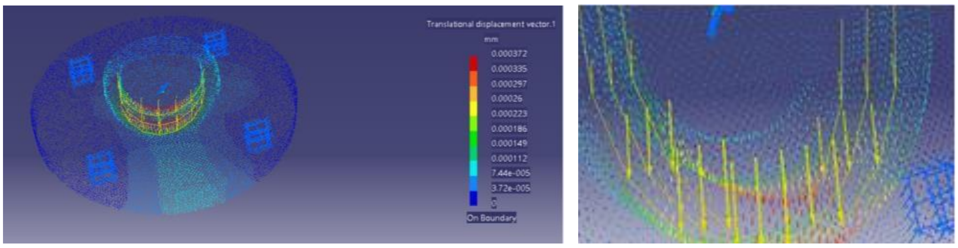

Figure 29. Displacement P3

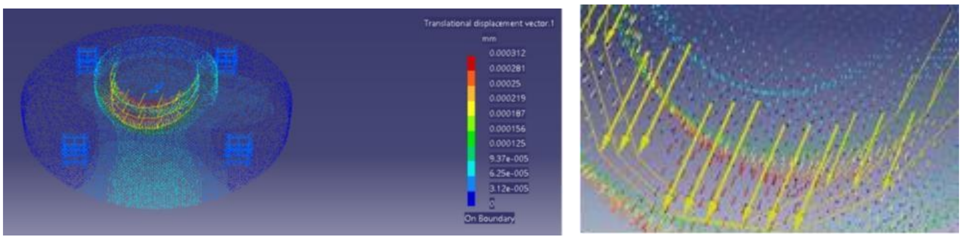

Figure 30. Displacement P4

The safety factor value is obtained based on calculations using equation 6 where the yield strength value of the ST 40 material per von mises stress produced so that the highest value is obtained at P4 with a safety factor value of 109.82. while the lowest safety factor value is at P2 with a value of 61.60. it can be concluded that the higher the von mises stress value, the lower the safety factor value produced.

3.4 Simulation Result Data Analysis

Based on Tables 2, 3 and 4, the von mises stress, displacement, and safety factor values are shown which change with each design variation. this explains that the larger the component structure design, the more it affects the results of the von mises stress, displacement, and safety factor values, where if the von mises stress value decreases, the displacement also decreases but the safety factor value actually increases.

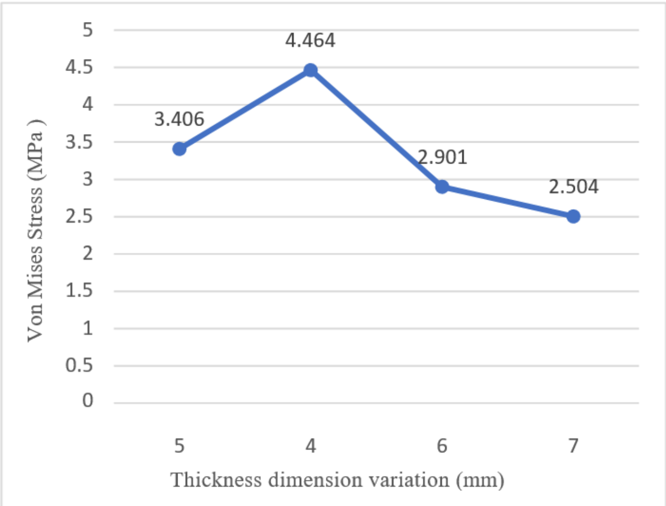

Figure 31. Von Mises Close 1 Analysis

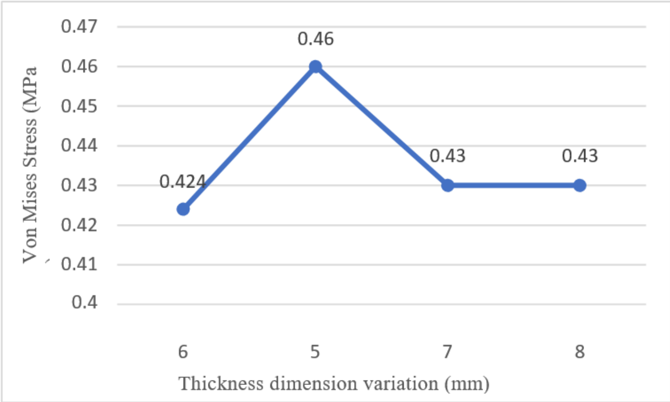

Figure 32. Von Mises Close 2 Analysis

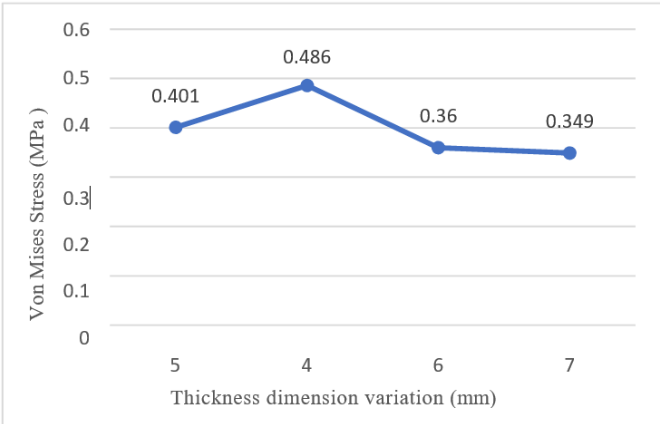

Figure 33. Equipment Von Mises Analysis

Based on the results of the von mises stress test analysis carried out, the difference in the initial design variation with the redesign is that the difference in the size of this dimension affects the von mises stress value, the larger the thickness dimension, the smaller the von mises stress value [9]. The lowest von mises stress value on pillowblock Cap 1 is T4 (7 mm) of 0.349 MPa, pillowblock Cap 2 is R4 (8 mm) of 0.430 MPa, pillowblock Equipment is P4 (7 mm) of 2.504 MPa.

In making a structural part design, the allowable stress has a lower value coMPared to the tensile strength obtained in the static test under certain considerations. The smaller the dimensions used in the design, the greater the von mises stress value. This is influenced by the factors of design dimensions, loading, mesh size, and support [10].

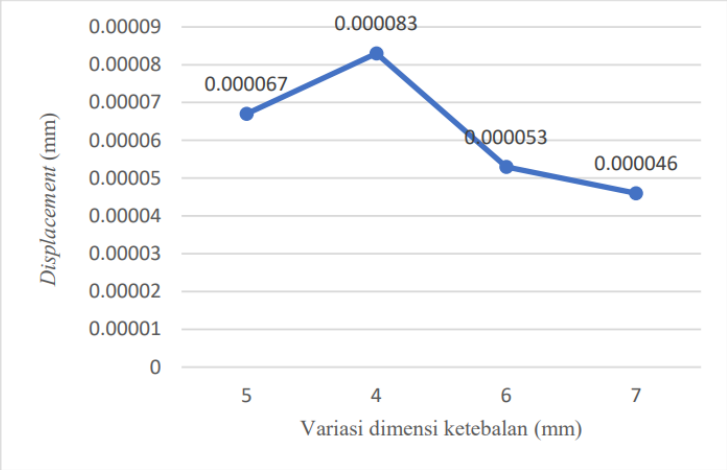

Figure 34. Displacement Close 1 Analysis

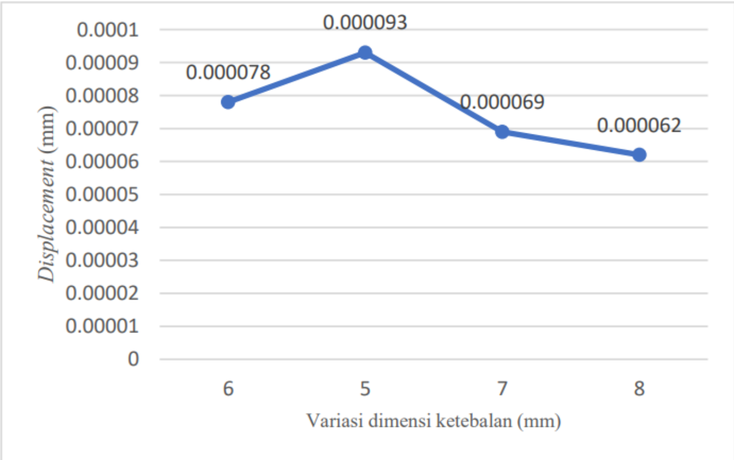

Figure 35. Displacement Close 2 Analysis

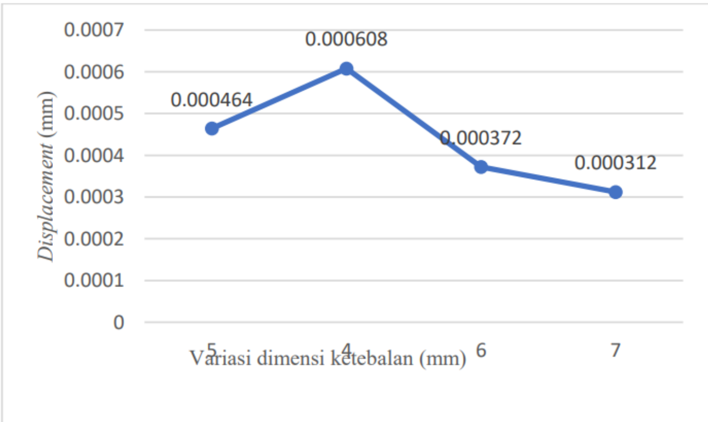

Figure 36. Equipment Displacement Analysis

Based on the results of the test analysis carried out on the thickness of the pillowblock, the displacement value is influenced by the force load in a certain area. The initial design and redesign have differences in the thickness dimension so that it affects the support receiving the load [11]. The pillowblock design that has the lowest displacement value is Cap 1 T4 (7 mm) of 0.000046 mm. Cap 2 R4 (8 mm) of 0.62 mm, Equipment P4 (7 mm) of 0.000312 mm.

Displacement is relatively small if it has a safe category and this is due to the large number of loads that occur in a certain area which results in high displacement. Displacement at the maximum value will show results that will reach the red area. The initial design and redesign of the pillowblock have low displacement values [12].

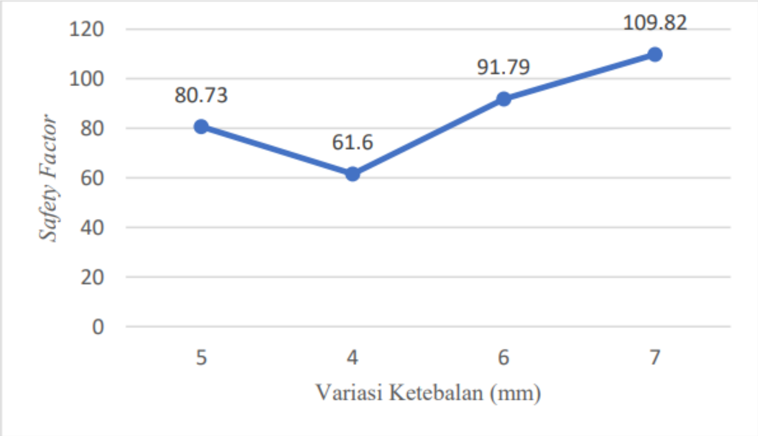

Figure 37. Safety Factor Close 1 Analysis

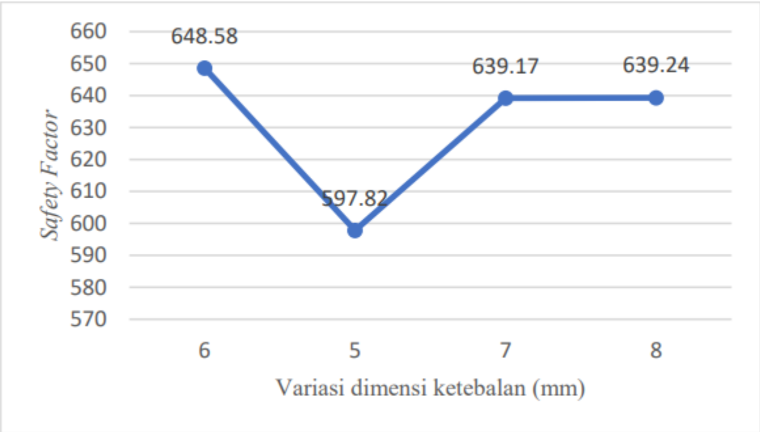

Figure 38. Safety Factor Close 2 Analysis

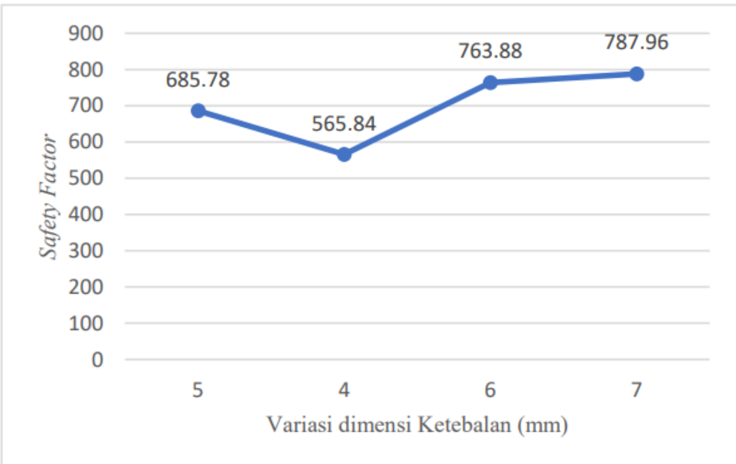

Figure 39. Equipment Safety Factor Analysis

Based on the calculation above, it shows that the smaller the von mises stress value, the greater the safety factor value. The smaller the von mises stress value, the greater the safety factor value will be[]. A specimen can be said to be safe if it has a safety factor value ≥ 2. A specimen can be said to be safe to use and produce if it has a safety factor value ≥ 2 after being loaded

The pillowblock designs that have been tested using CATIA V5 software all have a safety factor value ≥ 2, so it can be concluded that all designs have met the safety standards for use and production that the safety factor value is very important to use as a standard for the suitability of a specimen to be produced. Pillowblock Cover Design 1 T4 (7 mm) of 787.96, Pillowblock Cover 2 R4 (8 mm) of 639.24 and Pillowblock Equipment P4 (7 mm) 109.82 can be used as an alternative for use and production because they have a better safety factor value coMPared to other pillowblock specimens, so that it can increase its effectiveness and efficiency.

4 Conclusion

Based on the results of pillowblock testing with CATIA V5 software, the best results were obtained for Pillowblock Tutup 1, namely T4 (7 mm) with a von mises stress value of 0.349 MPa displacement 0.000046 mm, and a safety factor value of 787.96. While Pillowblock Tutup 2 is R4 (8 mm) with a von mises stress value of 0.430 MPa displacement 0.000062 mm, and a safety factor value of 639.24, and Pillowblock Peralatan P4 (7 mm) with a von mises stress value of 2.504 MPa, displacement 0.000312 mm, and a safety factor value of 109.82.

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