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Analysis of dies material strength in the blade screw conveyor bending process

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Abstract: Screw conveyor is one of material transport equipment in transport bulk materials. When damage will affect the next stage of the production process, a solution in the form of a tool is needed that shortens the fabrication process time of Screw Conveyor, utilizing the pressure from hydraulic cylinder ex excavator against die as the base. To ensure that the tool is able to work optimally with the load received from the hydraulic cylinder pressure 100 tons and upper die 60.28 kg, it is necessary to carry out research using the Finite Element Analysis method of Solidworks Simulation software on material strength of screw conveyor blade bending dies from parameters safety factor and yield strength of Von Misses method with material used is ASTM A36. This research is concluded that strength of die bending blade screw conveyor material which has been made with wall thickness 8 mm meets the requirements with load 981591.347 N, has a maximum stress value using the Von Misses yield strength method of 59 N/mm^2 in Solidworks simulation and 48.959 N/mm^2 in manual calculations, this value is lower than maximum allowable stress 83.333 N/mm^2, maximum displacement value is 0.300 mm, 8 mm wall configuration meets the requirements because it has value 0.108 mm in Solidworks simulation and 0.098 mm in manual calculation. Safety factor value obtained is 4.086, which meets the requirements 3. So that from this research it can be ascertained the ability of the die when given a load of 100 tons during the bending process.

Keywords: Analysis; material strength; dies; bending processes screw conveyor blades

1. INTRODUCTION

A screw conveyor is a type of material moving tool which has a threaded shape and functions to move bulk materials, sometimes used to mix and compress the material being moved by changing the thread type [1][2]. The main part consists of a shaft equipped with a screw that rotates in the casing, the shaft is rotated by a motor located on the outside of the casing [3]. If damage occurs to the tool, it will affect the next stage of the production process, so to ensure that the production process is not disrupted, a short repair time is also needed, one of which is by shortening the fabrication process time of the screw conveyor, especially for the screw blade part which is part the largest number of which is found in one screw conveyor unit [4][5]. In the conventional manufacturing process, this component is formed using a drawing method by first connecting one blade to another by welding which involves 4 workers in the bending process [6]. In working on plates using the bending method or what is also known as the bending method, the forming process uses forming tools using a hydraulic system press, also using anvils or dies as tools to shape the plate as desired, this method can produce bending of the plate neat [7][8]. Utilizing a used excavator hydraulic cylinder with a capacity of 100 tons, helical shaped die components such as the shape of a screw conveyor blade as the basis, so that the results of this process will change the shape of the plate to helical [9]. The dies that have been made have a wall thickness of 8 mm with a rib thickness of 8 mm. As a comparison design, there are several wall thickness configurations, including 6 mm and 10 mm.

The material used in making screw conveyor blade bending dies is ASTM A36 plate with a yield strength of 250 N/mm^2 [10]. In this regard, screw conveyor blade bending dies are made without analysis but only trial and error [11]. To ensure that the design and strength of the dies meet the requirements, research needs to be carried out, based on previous research in 2016 which was carried out to determine the strength of the box-shaped dies material. Accompanied by ribs as reinforcement and given an axial load of 250 tonnes, carried out by carrying out finite element analysis to determine parameter values including the value of maximum stress, yield strength, von misses method, displacement and safety factor values that have met the requirements through software Solidworks Simulation 2019 and also by manual calculations. However, in this study there is a difference in the load of the hydraulic cylinder, namely 100 tons and also has a helical and cylindrical geometry. So that when the bending work is carried out it can be carried out optimally and get results that meet the requirements. The aim of the research is to obtain the analysis results of the maximum von Mises stress, maximum displacement and safety factor that meets the requirements when receiving a load of 100 tonnes during the bending process.

2. METHOD

The analysis process is carried out through the steps of literature study, test preparation, geometric measurements, 3D manufacturing, manual dies analysis, analysis with finite element analysis, manual results and simulations in accordance with the requirements [12]. If there is a discrepancy then material specifications are changed, analysis and discussion and finally is drawing conclusions, a more complete explanation will be explained in the following points:

Literature Study: In this research, it refers to previous research, the data required includes the dimensions of the dies and the material specifications, namely ASTM A36 [13].

Table 1. Material specification.

Property	Value	Units
Elastic Modulus	2×10^{11}	N/m^2
Poisson Ratio	0,26	-
Shear Modulus	$7{,}93 \times 10^{10}$	N/m^2
Density	7850	Kg/m^3
Tensile Strength	4×10^{8}	N/m^2
Yield Strength	$2{,}5 \times 10^{8}$	N/m^2

Based on Table 1, the material specifications for the dies bending blade screw conveyor used are ASTM A36 with a tensile strength of 4×10^8 N/m^2, yield strength of 2.5×10^8 N/m^2 and elastic modulus of 2×10^{11} N/m^2. The loading on the dies is as in Table 2 below:

Table 2. The load received by dies.

Loads	Value	Unit
Hydraulic Cylinder Loads	100,000	kg
Top Dies Mass	60.28	kg

Experiment Preparations: Preparation for testing functions so that the process of data collection and analysis of the data can be carried out well and obtain appropriate results. Things that need to be done include preparing data collection tools such as meters, calipers, calculators, HVS paper and stationery. The tool used as an analysis tool is a laptop that has SolidWorks 2019 software installed.

Geometry Measurements: The geometry measurement process is carried out using a meter which is used to carry out measurements on each geometry of the screw conveyor blade bending die so as to obtain appropriate data results [14]. Then the data is documented on HVS paper in the form of sketches and photos.

3D Model Making: Making a 3D model using SolidWorks 2019 software based on the die dimensions in mm is as shown in Figure 1 below:

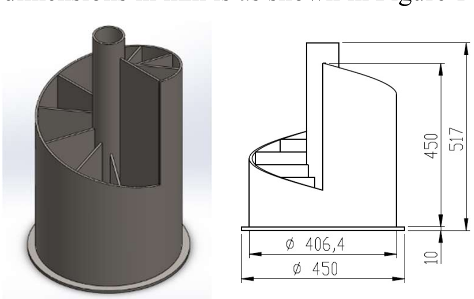

Figure 1. Dies bending blade screw conveyors dimensions.

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Figure 1 is a die bending model of a screw conveyor blade with a baseplate outer diameter of 450 mm with a plate thickness of 10 mm and a cylinder cut helically to suit the shape of the screw conveyor blade with an outer diameter of 406.4 mm with a plate thickness of 8 mm.

Analysis of dies strength manually

Based on the dimensions of the dies, the analysis is carried out through the following steps:

a. Determine allowable stress
The allowable stress is determined based on the A36 material used, using equation 1 below:

$$\sigma_{allow} = \frac{\sigma_{yield}}{\text{Factor of safety}} \tag{1}$$

Where:
σ_{allow} = Allowable stress (N/mm^2)
σ_{yield} = Yield stress in the material (N/mm^2)
Factor of safety = The safety factor is 3

b. Determine the maximum stress using the von mises yield strength method
In the steps to determine the maximum voltage, the sequence includes:

1) Determine the stress due to axial load on the y-axis

$$\sigma_y = \frac{F}{A} \tag{2}$$

Where:
σ_y = Dies axial stress on the y-axis y (N/mm^2)
F = The force acting on the die is in the y-axis direction (N)
A = The cross-sectional area of the die that receives the load (mm^2)
The values of σ_x and σ_z are assumed to be zero because there is no force acting in the direction of these two axes

2) Determine shear strength xy and yz.

$$\tau_{xy} = \tau_{yz} = \frac{F}{A_{shear}} \tag{3}$$

Where:
τ = Shear strength (N/mm^2)
F = The force acting on the die is in the y-axis direction (Nmm)
A_{shear} = The cross-sectional area (mm^2)
The value of τ_{xy} is equal to zero because there is no force acting on the x axis.

3) Determine the maximum stress using von misses method
After carrying out the calculations 1,2 and 3, the next step is to determine the maximum stress using the von Misses method with the following equation 4:

$$\sigma_{vm} = \frac{1}{\sqrt{2}} \sqrt{(\sigma_x - \sigma_y)^2 + (\sigma_y - \sigma_z)^2 + (\sigma_z - \sigma_x)^2 + 6({\tau_{xy}}^2 + {\tau_{yz}}^2 + {\tau_{zx}}^2)} \tag{4}$$

- Determine the maximum elongations. Elongation is determined using the following equation 5:

$$\Delta l = \frac{F\,l}{A\,\varepsilon} \tag{5}$$

Where:
Δl = The difference between initial and final lengths (mm)
F = The load received by the dies (N)
l = Initial length of the dies (mm)
ε = The elastic modulus of the material (N/mm^2)
A = Die surface area (mm^2)

- Determine the factor of safety minimum. The minimum safety factor value is determined by the following equation 6:

$$\text{Safety Factor} = \frac{\sigma_{\text{yield}}}{\sigma_{\text{vm}}} \quad (6)$$

Where:
σ_{yield} = Yield stress in the material (N/mm^2)
σ_{vm} = Yield stress using the von Mises method (N/mm^2)

Analysis with finite element analysis

By using SolidWorks Simulation 2019 software, it will provide comparative data between the results of manual calculations and the results obtained from software simulations [15].

In Figure 2 Analysis in SolidWorks simulation is carried out by placing the bottom of the die as a fixture. A load is applied to the top of the die with a load of 981591.3 N. The direction of the load is in the y-axis downward direction. To set the contact, global contact is used because it is considered that there is no need for a special contact.

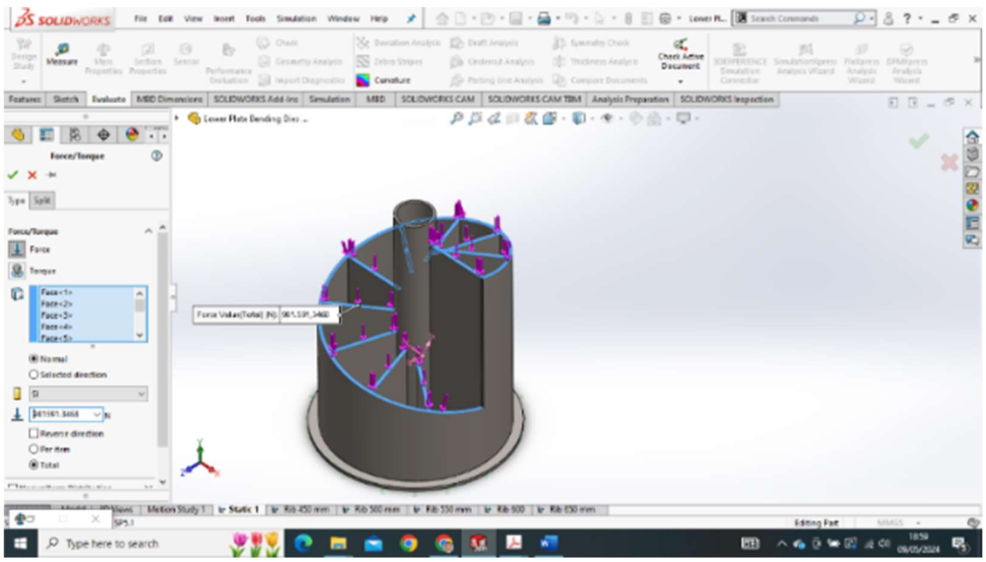

Figure 2. The loading simulation process uses solidworks simulation software.

Compare manual results with simulation: After carrying out analysis using the finite element method from SolidWorks Simulation and also manual analysis, the data will be compared with the conditions specified in this research.

Change the material specifications: Changes to material specifications are made if there are discrepancies in the results after analysis. Carry out analysis using finite element analysis

Analysis and discussion: The analysis result that has been obtained is then discussed with parameters including a comparison of the results between the maximum yield strength of the von misses method in manual calculations, the finite element method from SolidWorks Simulation must be lower than the allowable stress of the material, and also the value of the safety factor must not be less than required values so that conclusions can be drawn.

Conclusion: After all the data has been collected and the analysis has been carried out, conclusions can be drawn from the research results and suggestions can also be obtained so that the results of this research can be developed in the future research.

3. RESULTS AND DISCUSSION

Maximum von misses stress simulation results with solidworks simulation.

The following are the results after the simulation process was carried out using SolidWorks Simulation:

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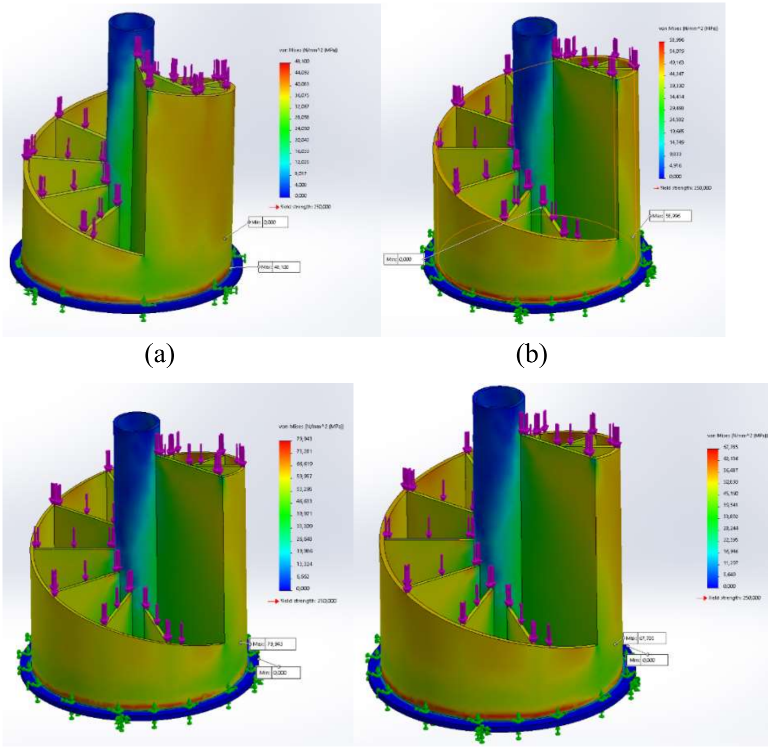


(a) (b)

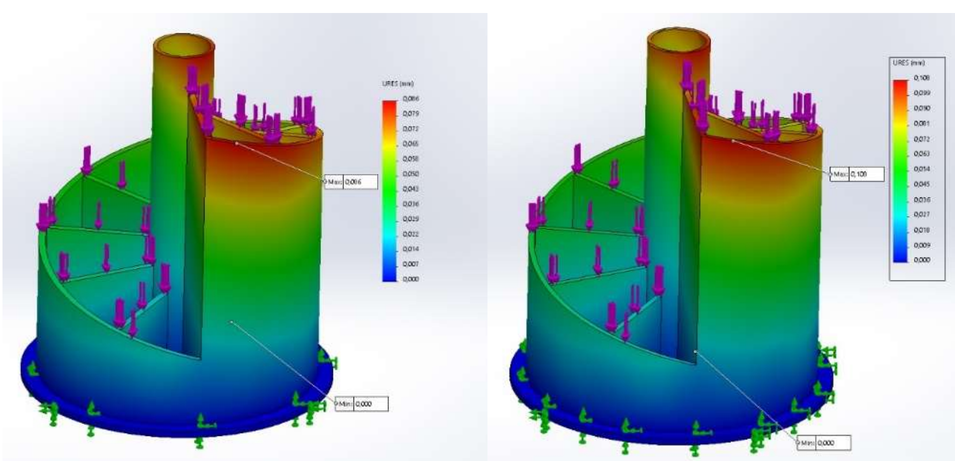
(c) (d)

Figure 3. (a) The maximum von misses stress in the die wall configuration is 10mm. (b) The maximum von misses stress in the die wall configuration is 8mm. (c) The maximum von misses stress in the die wall configuration is 6mm. (d) The maximum von misses stress in the die wall configuration is 8mm.

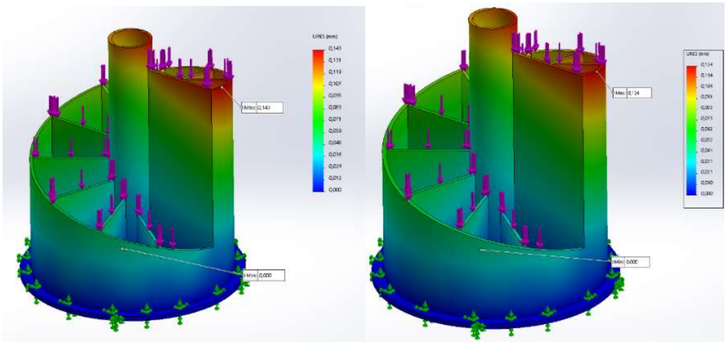
Based on Figure 3, the simulation results using SolidWorks software to compare the stress on dies that have been made with a wall thickness of 8 mm in figure 3.b with several configurations show that the 10 mm thick wall configuration in figure 3.a has a maximum von Mises stress value that is the lowest is 49.060 N/mm^2. Meanwhile, the 6 mm wall configuration in Figure 3.c has a stress value of 79.689 N/mm^2, but this still meets the requirements when compared to 83.333 N/mm^2 as the allowable stress requirement in this study.

Maximum displacement simulation results with solidworks simulation

The following are the results after the simulation process was carried out using SolidWorks Simulation:



(a) (b)



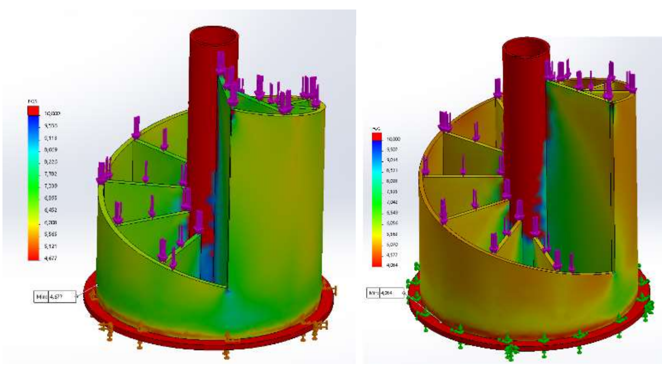
(c) (d)

Figure 4. (a) Maximum displacement in the die wall configuration is 10mm. (b) Maximum displacement in the die wall configuration is 8mm. (c) Maximum displacement in the die wall configuration is 6mm. (d) Maximum displacement in the die wall configuration is 8mm and rib 6mm.

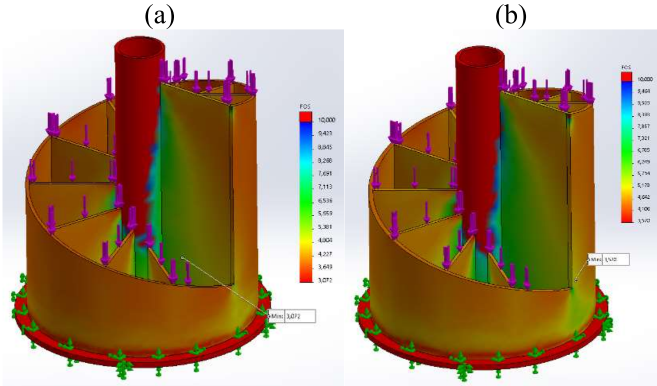
Based on Figure 4, the simulation results with SolidWorks software show the displacement comparison of dies that have been made with a wall thickness of 8 mm in figure 4.b. with several configurations, it was found that the 10 mm thick wall configuration in figure 4.a had the lowest displacement value is 0.086 mm. Meanwhile, the 6 mm wall configuration in Figure 4.c has a displacement value of 0.143 mm but still meets the requirements compared to 0.300 mm [9] as the maximum requirement for displacement in this study.

Simulation results of minimum safety factor values with solidworks simulation

The following are the results after the simulation process was carried out using SolidWorks Simulation:



(a) (b)



(c) (d)

Figure 5. (a) The minimum safety factor value in the die wall configuration is 10mm. (b) The minimum safety value in the die wall configuration is 8mm. (c) The minimum safety factor value in the die wall configuration is 6mm. (d) The minimum safety factor value in the die wall configuration is 8mm and rib is 6mm.

Based on Figure 5, simulation results with SolidWorks software compare the safety factors of dies that have been made with a wall thickness of 8 mm in figure 5b. with several configurations, it was found that the 10 mm thick wall configuration in figure 5.a had the highest minimum safety factor value is 4.713. Meanwhile, for the 6 mm wall configuration in figure 5.a. has a safety factor value of 3.072 but still meets the requirements compared to 3 as the minimum requirement for a safety factor in this study.

3.1. Comparison of Simulation Results with Manual Calculation Results

After carrying out manual calculations and also carrying out simulations with SolidWorks Simulation software, the following results were obtained:

Table 3. Comparison of the results of manual calculations and simulations on the maximum von misses stress value for variations in die wall configuration.

Configuration	Simulation	Manual	Units
Wall thickness 6 mm	79.689	61.816	N/mm^2
Wall thickness 8 mm	59.000	48.959	N/mm^2
Wall thickness 10 mm	49.060	41.615	N/mm^2
Wall thickness 8 mm rib thickness 6 mm	67.788	55.102	N/mm^2

Based on Table 3 comparison of manual calculations and simulations on the comparison of maximum stress values on dies that have been made with a wall thickness of 8 mm with several configurations, it is found that all variations of dies have met the required maximum allowable stress is 83.333 N/mm^2. Meanwhile, the maximum stress value for the Von Misses yield method in the simulation is 79.689 N/mm^2 in the 6 mm thick configuration and 61.816 N/mm^2 in the manual calculation.

Table 4. Comparison of the results of manual calculations and simulations on maximum displacement values for variations in die wall configuration.

Configuration	Simulation	Manual	Units
Wall thickness 6 mm	0.143	0.130	mm
Wall thickness 8 mm	0.108	0.098	mm
Wall thickness 10 mm	0.086	0.079	mm
Wall thickness 8 mm and rib 6 mm	0.124	0.114	mm

Based on Table 4, comparison of manual calculations and simulations on the comparison of maximum displacement values for dies that have been made with a wall thickness of 8 mm with several configurations, it is found that all variations of dies have met the maximum displacement requirements required is 0.300 mm. Meanwhile, the maximum displacement value in the simulation is 0.143 mm in a 6 mm thick configuration and 0.130 mm in manual calculations.

Table 5. Comparison of manual calculation and simulation results on safety factor values for variations in die wall configuration.

Configuration	Simulation	Manual
Wall thickness 6 mm	3.072	4.04
Wall thickness 8 mm	4.086	5.11
Wall thickness 10 mm	4.713	6.01
Wall thickness 8 mm and rib 6 mm	3.570	4.54

Based on Table 5, comparison of manual calculations and simulations on the comparison of safety factor values for dies that have been made with a wall thickness of 8 mm with several configurations, it is found that all variations of dies have met the required minimum safety factor value, namely 3. Meanwhile, for the minimum safety factor value, the highest simulation was 4.713 in the 10 mm thick configuration and 6.01 in manual calculations. In this way, dies that have been made 8 mm thick can still be chosen because they meet these requirements, but it is more recommended to use 6 mm thick because they also meet the requirements. In this way, dies that have been made 8 mm thick will still be chosen because they meet these requirements, but it is more recommended to use 6 mm thick because they also meet the requirements.

4. CONCLUSION

Based on the results of this research, it can be concluded that the material strength of the screw conveyor blade bending dies which has been made with a wall thickness of 8 mm meets the requirements when a load of 981591.347 N is applied from the pressure of the hydraulic press machine and the weight of the upper die, namely it has a maximum stress value using the method. von misses were 59 N/mm^2 in the SolidWorks simulation and 61.816 N/mm^2 in manual calculations, this value is lower when compared to the maximum allowable stress of 83.333 N/mm^2. Then, for the required displacement value of a maximum of 0.300 mm, this 8 mm wall configuration meets the requirements because it has a value of 0.108 mm in the SolidWorks simulation and 0.098 mm in manual calculations. Then it was found that the safety factor value of 4.086 in the SolidWorks software simulation and 5.11 in the manual calculation met the requirements of 3. So, when this tool is used in the bending process, it can work optimally because it meets the requirements.

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