Design of a lift conveyor for the counterweight filling process

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Abstract
The counterweight is one of the excavator components that acts as a counterweight to the weight of the excavator so that it does not roll over when the bucket is carrying the load. The counterweight contains cast material which functions as an additional load, before being filled with cast material the counterweight weighs 3800 Kg and after being filled with cast material the total weight of the counterweight is 16800 Kg. The cast material put into the counterweight is 13000 Kg. The process of filling cast material into the counterweight is still done manually, resulting in delays in the counterweight filling process. The counterweight filling process uses cast materials, namely: iron sand, split stone, and cement. The aim of designing this tool is to simplify and speed up the production process of making counterweights. By designing this lift conveyor tool, it will be possible to increase productivity in the counterweight filling process so that the production of counterweights becomes faster. The design of this tool uses SS400 grade iron plate as a basic material and as a means of transportation, it uses an electric winch hoist with a capacity of 1500 Kg. Design and test the material strength of this tool using Autodesk Inventor 2018 software.

Keywords
Counterweight, Design, Conveyor

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Introduction
The counterweight is one of the excavator components which acts as a counterweight to the weight of the excavator so that it does not roll over when the bucket is carrying the load [1]. Inside the counterweight contains cast material which functions as an additional load. The counterweight filling process is still done manually, resulting in delays in the production process [2]. To speed up the process and meet customer needs, it is necessary to design a tool, namely a lift conveyor [3]. With the development of increasingly sophisticated and modern technology, something manual can become automatic. So, it will simplify or lighten every job [4][5]. In this modern technological world, there is a tool for moving materials which is usually called a conveyor. Maybe

some people, especially the public, don't fully know about this tool, but people who work in the industrial world must be very familiar with this tool [6]. The counterweight filling conveyor lift is a manufacturing tool made from mild steel plate grade SS400 and as a means of transportation it uses an electric winch hoist with a capacity of 1500 kg, this tool functions to transport cast material into counterweights at PT SII. Counterweight requests from customers result in delays in the counterweight filling process.

In recent years, in the design of counterweight projects, much research has been done in this field. Effectively combined justification and static calculation of the adaptive moving counterweight of a single-bucket excavator with the proposed use of one of the methods of counteracting the overturning of a single-bucket universal excavator in the working and transport position [6]. The proposed study on Counterweight Structure with a buffer device and the structure has the advantages of reduced construction time, high safety, and simple structure [7]. Proposes a procedure to mathematically model the counterweight of rotating links based on calculations according to design requirements [8]. The main objective of the research is to introduce an effective method to design the counterweight using CAD drawings.

Through the analysis of the above literature research, it can be found that there are still few related studies on the counterweight filling process. In this study to use a conveyor to speed up the filling process, the reason we use a conveyor is the conveyor does not require a lot of space so it can be applied in narrow places, maintenance is easy, the power required by the conveyor is small so it can save costs, the product flow speed can be regulated, and product transfer can be done automatically [10]. In the manufacturing sector, PT SII is a company that produces excavator counterweights. One of the obstacles faced is the slow filling process on the counterweight.

This research is to minimize delays in the filling process and design a conveyor lift made from mild steel plates and as a means of transportation using an electric winch hoist which previously used a forklift for the counterweight filling process. Therefore, to meet customer needs, it is necessary to provide a conveyor lift to simplify and speed up the counterweight filling process.

Methods

The data collection method in this research uses qualitative methods. Collecting data and information in question is looking for literature, information, and materials as well as data related to conveyor equipment as well as data that supports research. The software, equipment, and materials data used in this research and analysis are as follows:

1. Software Autodesk Inventor 2018
2. Laptop DELL Latitude 5480
3. The materials use carbon steel grade SS400

Analysis procedure

The design and analysis on the design of a lift conveyor for the counterweight carried out at PT. Core Industrial Synergy Jl. Caringin Sumur Batu, Bantar Gebang Bekasi City 1754, Indonesia until the conclusion is made with the following stages:

1. Literature study.
2. Preparation of equipment and software.
3. Design of a lift conveyor for the counterweight.
4. Simulation of a lift conveyor for the counterweight.
5. Stress Analysis of the design of a lift conveyor for the counterweight
6. Analyze and compare results with drawing results
7. The conclusions of the research.

Designing a process that aims to analyze, assess, improve, and develop a system, both physical and non-physical, that is optimal for the future by utilizing existing information.

Stress analysis

Stress analysis is a mathematical numerical technique for calculating the strength and behavior of engineering structures. Stress analysis is carried out by Autodesk Inventor 2018 to allow us to analyze the design that we want, to determine the design we want. Autodesk Inventor simulation is useful for proving the validity of the design. It is much more practical and time-saving when designing a design before making it in the form of a physical prototype and analyzing whether component materials are excessive or insufficient when designed for a certain load.

Result and discussion

Based on previous research, design and simulation of a lift conveyor for the counterweight using Autodesk Inventor 2018 software in this study. Stress analysis is a mathematical numerical technique for calculating the strength and behavior of engineering structures. Stress analysis is carried out by Inventor to allow us to analyze the design that we want, to determine the design we want. Autodesk Inventor simulation is useful for proving the validity of the design. It is much more practical and time-saving when designing a design before making it in the form of a physical prototype and analyzing component materials that are excessive or deficient when designed for several loads.

Strength analysis of the filling counterweight conveyor frame

In Autodesk Inventor software, materials are determined during the modeling process for each part. The material in each part will be re-verified during the testing process. This material verification is in the material properties and will also be displayed when requesting a report on the results of running the simulation. Figure 1 shows the material properties of the filling counterweight conveyor frame which will be simulated strength in Autodesk Inventor 2018.

⊟ Material(s)

Name	Steel, Mild	
General	Mass Density	7,85 g/cm^3
	Yield Strength	207 MPa
	Ultimate Tensile Strength	345 MPa
Stress	Young's Modulus	220 GPa
	Poisson's Ratio	0,275 ul
	Shear Modulus	86,2745 GPa
Part Name(s)	frame stoper belakang stoper belakang Tiang 1 Tiang 2 atas frame bucket Tiang 1_MIR1 Tiang 2_MIR1 frame bucket_MIR1 PLATE STOPER 1 PLATE STOPER 1 plate stoper	

Figure 1. Material properties

Determining Constraints

Determining constraints is done by referring to the position of the supports in the design product that has been modeled. The constraints used in this simulation use fixed constraints. Figure 2 shows a picture of providing constraints on the filling counterweight conveyor frame.

Figure 2. Constraints

Loading

The load or weight is made according to the actual load on the conveyor frame, namely 2000 Kg. Simulation results start at a load of 2000 Kg. Figure 3 shows the load that will be given to the conveyor frame in the Autodesk Inventor software.

⊟ Force:1

Load Type	Force
Magnitude	20000,000 N
Vector X	-34,026 N
Vector Y	48,732 N
Vector Z	-19999,912 N

Figure 3. Loading on the conveyor frame

Determine the direction of gravity

Gravity direction is used to determine the loading direction so that when simulating the loading it matches the actual loading direction. Figure 4 shows the direction of gravity in a conveyor loading simulation using Autodesk Inventor software.

Gravity

Load Type	Gravity
Magnitude	9810,000 mm/s^2
Vector X	-16,690 mm/s^2
Vector Y	23,903 mm/s^2
Vector Z	-9809,957 mm/s^2

Figure 4. Gravity

Mesh and running program

The process of meshing a continuous system of objects to be analyzed is discretized so that the main structure becomes elements that have a smaller size and a certain and finite number. Figure 5 shows that providing mesh on the conveyor functions to produce accurate simulation results. The Running process is carried out after all the pre-analysis and meshing processes have been carried out. The running process runs by reading the calculation process using the Finite Element Analysis (FEM) method.

Mesh settings:

Avg. Element Size (fraction of model diameter)	0,1
Min. Element Size (fraction of avg. size)	0,2
Grading Factor	1,5
Max. Turn Angle	60 deg
Create Curved Mesh Elements	No
Use part based measure for Assembly mesh	Yes

Figure 5. Mesh settings

Von misses stress

Von misses stress is to show the part of an object or object that receives a force marked with the color in that part. The red color will tend to receive a large force, while the blue color will receive a small force. Material strength is the material's ability to withstand the maximum load before breaking. When designing a design, the criterion used is yield strength, not maximum tensile strength. Yield strength is the strength that a material has to withstand a load before experiencing plastic deformation. This means that when the load is still below the yield strength, the material can return to its original shape. The following is an illustration of the results of the equivalent stress analysis. Figure 6 shows the Equivalent stress von misses display with a load of 2000 Kg.

The maximum equivalent stress occurs at the top of the frame at 75.42 MPa, then the minimum equivalent stress is 0 MPa. 1st principal Functions to show the largest principal stress [11]. The principal stress is the stress whose direction is perpendicular to the surface. Figure 7 shows the main stress display with a load of 2000 Kg. The maximum main stress occurs at the top of the frame at 77.97 MPa, then the minimum main stress is -14.84 MPa.

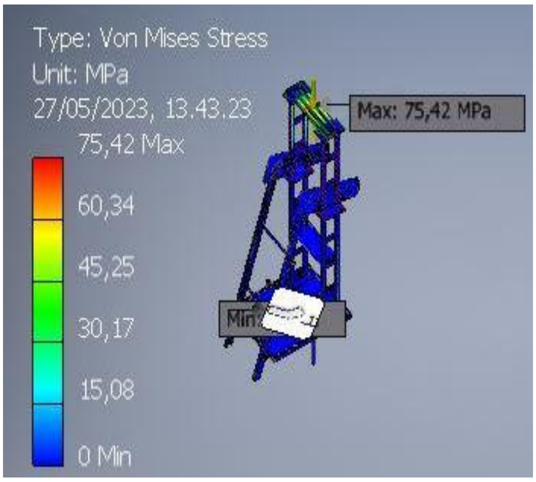

Figure 6. Equivalent von Mises stress display

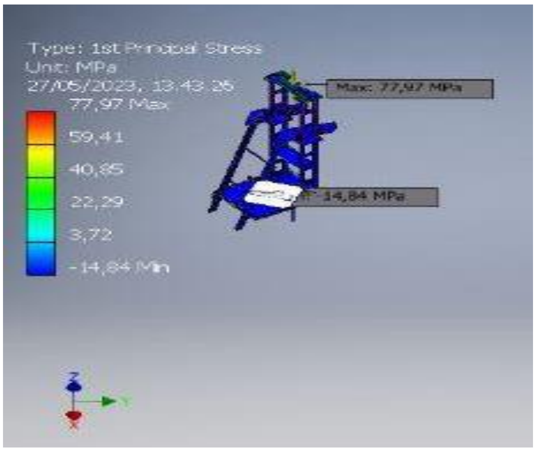

Figure 7. Display of Equivalent stress 1st principal

3rd principal stress

3rd principal stress is the opposite of 1st principal, namely, it shows the smallest main stress. Figure 8 shows the main stress display with a load of 2000 Kg. The minimum main stress occurs at the top of the frame at -75.36 MPa, then the maximum main stress is 12.55 MPa.

Displacement

The main result of static structural analysis using the element method is deformation or displacement. Deformation shows the deformed shape of the model from a scale representation, based on specific load conditions. The use of deformation is to determine the location and extent of the component to be bent and how much force is needed to bend the model a certain distance. The following is an illustration of the results of the total deformation analysis on the conveyor frame. Figure 9 shows the main voltage display with a load of 2000 Kg.

The simulation results show that the largest total deformation is in the upper frame at 1.443 mm, and the smallest total deformation is in the part close to the fixed constraint/support area, namely 0 mm. Because the Von Mises stress value is less than the stress or yield strength of the material, the deformation What happens is elastic.

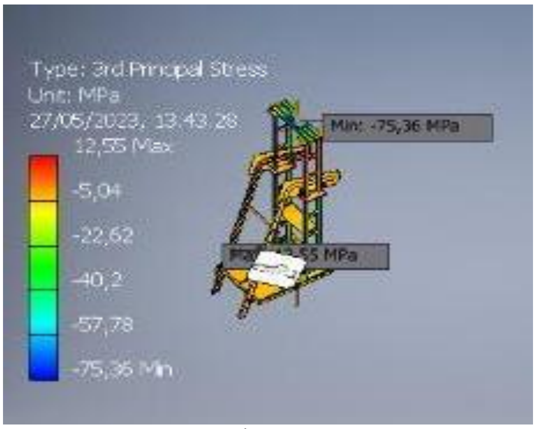

Figure 8. 3rd principal stress

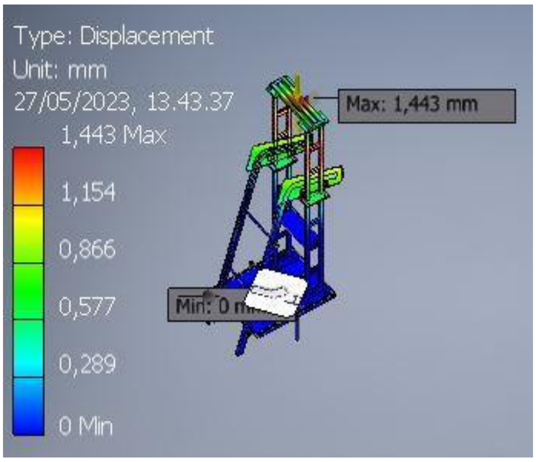

Figure 9. Displacement

Safety Factor

The safety factor or safety figure is an important parameter to determine whether a construction is safe or not. Safety Factor is a comparison between the allowable stress of a material and the stress that occurs. Construction is declared safe if the safety number is above one. According to Joseph P Vidosic (“machine design projects”) safety factor (sf) is based on yield stress: 1) 1.25 -1.5 ul: controlled conditions and the working stress can be determined with certainty. 2) 1.5 – 2.0 ul: known material, constant load, and stress environmental conditions and can be determined easily. 3) 2.0 – 2.5 ul: average operating material with known load limits. 4) 2.5 – 3.0 ul: known material without undergoing tests. Under average load and voltage conditions. 5) sf = 3.0–4.5 ul: known material. Uncertain load, voltage, and environmental conditions. Repetitive loads: Numbers 1 to 5, Shock loads: Numbers 3 to 5, Brittle Materials: Numbers 2 to 5 multiplied by 2. According to Dobrovolsky ("machine element") safety factor (sf) based on yield stress: Static Load: 1.25 – 2 ul, Dynamic Load: 2 – 3 ul, Shock Load: 3 – 5 ul. The following is an illustration of the results of the Autodesk Inventor 2018 analysis. Figure 10 shows the Safety Factor display with a load of 2000 Kg. The simulation results show that the minimum safety factor is 2.74 ul (ultimate material capability) and the maximum is 15 ul (ultimate material capability).

Figure 10. Safety factors

Recapitulation of stress analysis using Autodesk Inventor software

Table 1 shows a recapitulation of the simulation results of the filling counterweight conveyor construction. Based on the simulation results of the strength analysis of the filling counterweight conveyor construction using Autodesk Inventor Professional 2018 software, it can be concluded that the filling counterweight conveyor construction is safe for a load of 2000 kg.

Table 1. Recapitulation of construction simulations.

Simulation Results	**Load Weight**		**Allowable bending stress**
	2000 Kg		**163 Mpa**
Von misses	Maximum	75,42 MPa	
	Minimum	0,78 MPa	ok
	Minimum	0mm N/mm^2	
Safety Factor			Safety Factor 1,5 ul
	Maximum	15 ul	
	Minimum	2,74 ul	ok

The percentage of manual calculations to FEM calculations, for a 30 MPA stress slide for volume geometry is 3.24%. So manual and FEM calculations are close to the same Figure 11.

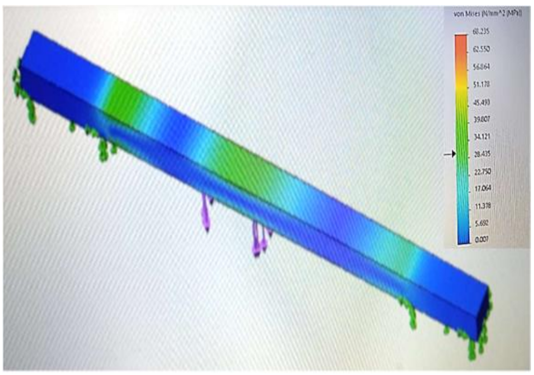

Figure 11. Percentage FEM stress slide

Conclusion

Based on the analysis of the discussion that has been explained, an overall conclusion can be drawn that in the design of the counterweight filling conveyor lift tool, several conclusions can be drawn, namely: 1. Design, material selection with material strength analysis using Autodesk Inventor 2018 software that the conveyor is safe for the load. 2000 Kgs. 2. Proper analysis of material strength greatly influences the final result. So that the tool can function properly, and has good safety standards and is easy to use. 3. To speed up and simplify the counterweight filling production process, a tool is needed, namely a counterweight filling conveyor.

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