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Conceptual Design of Automatic Manipulator for Metal and Non-metal Waste Management Application

Zol Bahri Razali[1], Nuraini Yatim[2]
[1,2] School of Mechatronics Engineering, University Malaysia Perlis, 02400 Arau, PERLIS, MALAYSIA

***Abstract* - This project is focuses on a conceptual design of a conveyor system that can be used to differentiate between metallic and non-metallic materials, as well as to perform transferring of the mentioned materials. The project should be started by means of research on metallic waste sorting machines in the market like magnetic conveyor system. A conveyor system is mechanical handling equipment that moves materials from one location to another and magnetic pulley has been used to separate metal and non-metal waste. Standard design process flow is to be followed e.g. conceptual design and detailed design to be produced prior to the fabrication. Design of the conveyor is using Solidworks Software and analysis is using Ansys Software. Analysis equipment has been done by doing calculation such as calculation of gear and motor torque prior to fabrication. The expected result the fully automated conveyor system that can be used for metallic waste management application is described in detail in this paper.**

***Keywords*—analysis of conveyor frame, AC motor, conveyor system, magnetic pulley, metal and non-metal waste**

I. Introduction

A. Project Background

A conveyor system is a common piece of mechanical handling equipment that moves materials from one location to another. Conveyors are especially useful in applications involving the transportation of heavy or bulky materials. Conveyor systems allow quick and efficient transportation for a wide variety of materials, which make them very popular in the material handling and packaging industries. Many kinds of conveying systems are available, and are used according to the various needs of different industries.

Belt conveyors are the most commonly used powered conveyors because they are the most versatile and the least expensive. A belt conveyor consists of two or more pulleys, with a continuous loop of material, the conveyor belt that rotates about them. One or both of the pulleys are powered, moving the belt and the material on the belt forward.

B. Objective

- Design and fabrication of a conveyor system that can be used to differentiate metal waste and transfer the material in difference place.
- The purpose is to create a proper method for handling hazardous metal waste.
- Analysis the total deformation and equivalent stress of conveyor frame when there is a force act on.
- Analysis equipment by doing calculation prior to fabrication

C. Problem Statement

People used to simply throw the recycle items into a dustbin as they don't even ensure whether it can be recycle or not. As a result, it causes extra work for waste management organization to separate the refuse into each category such as plastics, paper, glass and metal. Some waste materials are normally safe but can be hazardous if not managed properly. For this project, it focuses to separated scrap metal (ferrous) from the other waste.

D. Scope

The scope of the project is to detailed design the conveyor system using SolidWorks software. This project needs a very good understanding in conveyor system application and knowledge in designing product is a must because the main objective is to design a magnetic conveyor which will be functioned automatically to separate metal and other waste.

Next is sourcing and allocation of necessary components. Find the suitable material that can be used within the budget given and manufacturing of the product and other manufacturing considerations will be studied. Relevant analysis and calculation prior to fabrication of conveyor also should be done such as total deformation and max equivalent stress of frame using Ansys Software. Analysis the equipment used also should be done by doing calculation prior to fabrication

II. Literature Review

Waste management is the collection, transport, processing or disposal, managing and monitoring of waste materials. The term usually relates to materials produced by human activity, and the process is generally undertaken to reduce their effect on health, the environment or aesthetics. The management of wastes treats all materials as a single class, whether solid, liquid, gaseous or radioactive substances, and tried to reduce the harmful environmental impacts of each through different methods. [1]

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Different countries have different types of industries in their priority list. All the countries are moving from agro-based labour intensive industries to metal based manufacturing and fully mechanized industries. The waste quality and quantities also varies depending on the types of industries and production processes. In Malaysia, 30% of hazardous waste is generated from electroplating and metal industries, where as in Thailand, the largest hazardous waste is generated from metal smelting (47%) and manufacturing (33%) industries (Cirillo et al, 1994). In the current plan of activities, main emphasis is given for the development of agro-industries, textile, clothing, electronics, petrochemical and base metal related industries. [2]

Non-ferrous metals don't contain iron for example aluminum, brass, copper, gold, silver and titanium. We can also get non-ferrous metals as alloys for example brass is an alloy of copper and zinc. Non-ferrous metals are specified for structural applications requiring reduced weight, higher strength, nonmagnetic properties, higher melting points, or resistance to chemical and atmospheric corrosion. They are also specified for electrical and electronic applications. Some non-ferrous metals are magnetic if it contain nickel and cobalt.[4]

Ferrous metals are metals which contain iron. Ferrous metals may contain small amounts of other elements such as carbon or nickel, in a specific proportion, that are added to achieve the desired properties.All ferrous metals are generally magnetic, have high tensile strength and give little resistance to corrosion such as steel. [4]

According to research conducted by the US Environmental Protection Agency, recycling scrap metals can be quite beneficial to the environment. Using recycled scrap metal in place of virgin iron ore can yield :

- 75% savings in energy
- 90% savings in raw materials used
- 86% reduction in air pollution
- 40% reduction in water use
- 76% reduction in water pollution
- 97% reduction in mining wastes

Every tonne of new steel made from scrap steel saves: 1,115 kg of iron ore, 625kg of coal and 53kg of limestone.[6]

Scrap Metal Heritage agrees with Environment Protection Energy EPA's conclusion that scrap metal is a valuable national resource, the recycling of which should be encouraged. In addition, scrap metal has little potential for release of hazardous constituents to the environment.[7]

E. Existing Method to Separate Metal Waste

Scrap Metal Heritage agrees with Environment Protection Energy EPA's conclusion that scrap metal is a valuable national resource, the recycling of which should be encouraged. In addition, scrap metal has little potential for release of hazardous constituents to the environment.

- *Lifting magnet*

Separating the iron and steel from shredded automobiles takes direct advantage of their magnetic properties to isolate them from nonferrous metals and non-metallics. Advances in materials science have led to the introduction of rare earth alloy permanent magnets with high field strength (e.g., neodymium-boron-iron magnets) that require no power to operate and have sufficiently high fields to allow for the recovery of even weakly magnetic stainless steels.[8]

- *Eddy Current Separator*

The Eddy current separator (ECS), is a conveyor tape made with a particular magnetic field in the head, which is generated by high frequency polar wheel: when the non-ferrous metals are coming near to the magnetic field, they are lifted and "expulsed" to one appropriate collecting canal, while the inert materials freely fall down to another container. All iron till the smallest pieces, which differently from the non-ferrous metals, is kept by the magnetic rotor and downloaded in the proper container under the Eddy Current separator.[9]

- *Magnetic Separator Overbelt*

Magnetic Separator Overbelt is placed crosswise or lengthwise above the conveyor tape at a fixed working distance. From flowing material iron objects are capture by the magnetic power and with the overbelt magnets carried away. When the iron objects leave the area of the magnetic field they automatically drop into appropriate canals or containers. Magnetic Separator with permanent magnets has two categories which are with Ferrite magnets or with Neodymium magnet. Permanent overbelt magnetic separator is free magnet maintenance and no need of electrical current for generation of the magnetic field.

III. METHODOLOGY

The project divided into four phases. The first phase involved comparative study of conveyor system, metallic behavior, magnetic pulley, driving device and other that related with this project. Gather useful information from journal, book and article that are related to this case of study.

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The second phases will involve the design and development phase. Design and development consist of conceptual design, configuration design, parametric design and detailed design. In the third phases, the manufacturing considerations will be introduced. The product will be tested on its performance and checked if there is any changes needed. The final phases involve analysis of the product using Ansys Software such as the tension of belt and the stress of conveyor frame. The equipment that has been used also needed to be analyzed such as motor torque and motor horsepower.

F. Belt - Conveyor System

A conveyor system is a common piece of mechanical handling equipment that moves materials from one location to another. Conveyors are especially useful in applications involving the transportation of heavy or bulky materials. Conveyor systems allow quick and efficient transportation for a wide variety of materials, which make very popular in the material handling and packaging industries. Many kinds of conveyor systems are available, and used according to the various needs of different industries. Usually, it contains:

- Conveyor Bed
- Pulley
- Magnetic Pulley
- Ball Bearing
- AC Motor
- Spur gear

Spur gear properties for conveyor system
Number of teeth = 18
Base circle diameter (BCD) = 15 mm
Spur gear (motor) = Bore 7 mm
Spur gear (pulley) = Bore 10 mm

G. Fabrication of the Conveyor System

The first step is the object will be moving through the belt. When reach at the magnetic pulley, the scrap metal (ferrous) will attracted to the belt. They are then held magnetically and carried to the underside of the pulley to get dislodged from the belt. The other waste is discharged normally over the pulley in vertical drop.

Figure 1: Prototype of the Conveyor System

In order to fabricate this conveyor system, there are several aspects that need to be considering such as material selection for the conveyor frame and find the material that most suitable for the belting. This project should be finish up in a minimum cost. Aluminium has been used for conveyor frame, mild steel for the conveyor leg and canvas for the belting.

H. Design of the Conveyor System

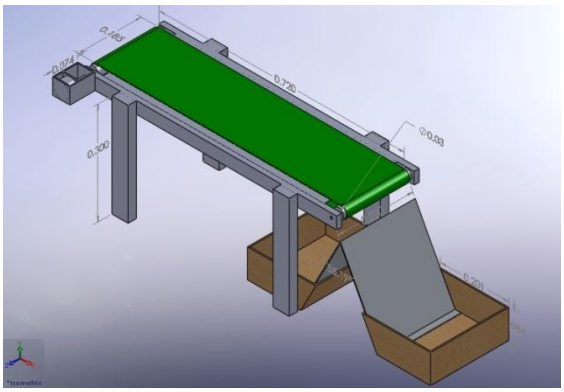

Figure 2: Design and measurement of the conveyor system (isometric view)

IV. Results And Discussions

I. Analysis on Conveyor Frame

By using the Ansys Software, mesh, total deformation and equivalent stress for the conveyor frame has been analyzed. For the material selection, conveyor bed is set as aluminum alloy while the leg is mild steel.

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J. *Mesh Analysis*

For the analysis, mechanical engineering data for the material have been edited, and the frame is mesh with sizing 0.01m.

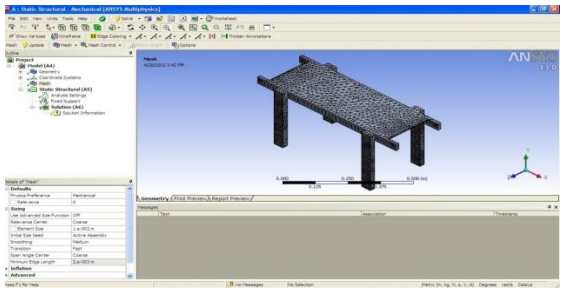

Figure 3: Mesh of the conveyor frame

K. *Total Deformation*

For total deformation, fixed support is selected from the base of each leg. Force is setup at the center of the conveyor bed in vertical direction. This conveyor frame has been analyzed for 11 different values of force which is 0.01N, 1N, 2N, 3N, 4N, 5N, 6N, 7N, 8N, 9N and 10N.The analysis that shown in this section is 2N, 5N and 10N.

- *Force of 200 N*

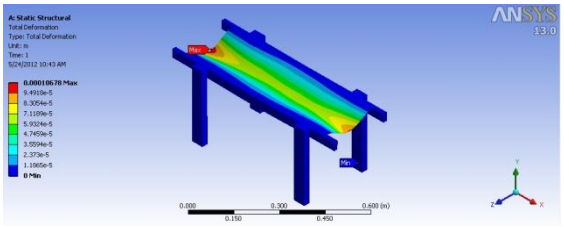

Figure 4: Total Deformation for 200N

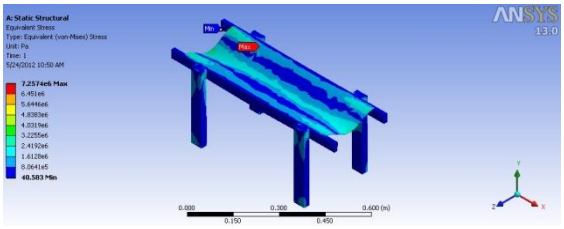

Figure 5: Equivalent (von-Misses) Stress for 200N

TABLE 1
RESULTS OF THE DEFORMATION ANALYSIS

Object Name	*Total Deformation*	*Equivalent Stress*
State	Solved	
Scope		
Scoping Method	Geometry Selection	
Geometry	5 Bodies	All Bodies
Definition		
Type	Total Deformation	Equivalent (von-Mises) Stress
By	Time	
Display Time	Last	
Calculate Time History	Yes	
Identifier		
Results		
Minimum	0. m	40.583 Pa
Maximum	1.0678e-004 m	7.2574e+006 Pa
Minimum Occurs On	leg-5	plate-1
Maximum Occurs On	plate-1	leg-4
Information		
Time	1. s	
Load Step	1	
Substep	1	
Iteration Number	1	
Integration Point Results		
Display Option		Averaged

L. *Motor Calculation*

As shown at the AC motor used that used for this conveyor system, the motor has 3.5/3W and 50 RPM clockwise. From 3.5 watts, it can be converting to horsepower (HP) which is 1 HP equal to 745.7 watts.

Motor Horsepower

1 HP = 745.7 watts

? HP = 3.5 watts

$$\frac{3.5 \text{ watts} \times 1 \text{ HP}}{745.7 \text{ watts}} = 0.0047 \text{ HP}$$

Therefore, this motor has 0.0047 HP.

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Calculating Braking Torque

Full-load motor torque is calculated to determine the required braking torque of a motor. To Determine ***braking torque*** of a motor, apply this formula:

$$T = \frac{5252 \times HP}{rpm}$$

T = full-load motor torque (in lb-ft)
5252 = constant (33,000 divided by 3.14 x 2 = 5252)
HP = motor horsepower
rpm = speed of motor shaft

$$T = \frac{5252 \times 0.0047}{50\ rpm} = 0.4937\ lb\text{-}ft$$

V. CONCLUSIONS

To finish up this project, it gives an excellent understanding of conveyor system, magnetic pulley, detailed design using Solidworks and analysis of total deformation and maximum equivalent (von-Misses) stress using Ansys software. Also developing manufacturing skills and gained an interesting experience to fabricate this conveyor system in prototype size. With the help of the gained knowledge, it was possible to complete this whole project during the time given. Magnetic conveyor system can be the important machine for metal waste management. However, due to the limitation cost this conveyor system can't be set with neodymium magnetic pulley. So it has been replaced with magnet bar which is much cheaper compare to neodymium. Although this prototype is simple, this system able to separated the contaminated material into magnetic material and non-magnetic material without any human intervention. The objective of the project was successfully achieved.

M. Potential of Future Work

In future this project can be improved to sort more categories of waste. Other than this, neodymium magnetic pulley would be recommended as the magnetic head pulley since this pulley is the stronger magnet. If the system needs to be setup as the actual size, the canvas should be replaced with the rubber belt because it is more suitable material as this conveyor used to manage metal waste.

N. Commercialization Potential

This system can be used in all waste management organization to sort all the recyclable items of metal waste (ferrous) with the other waste. This system will very useful for the metal industry whereby the system can easily separated the metal waste from others waste.

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