

Design Improvements and Fabrication of Conveyor Belt Cleaner and Washing System at Westports Malaysia

Tasnim F. Ariff, Muhd. Fahmi B. Jusoh, Malek Parnin and Mohd. Hanif Azenan

Department of Manufacturing and Materials Engineering, Faculty of Engineering,
International Islamic University Malaysia, P.O.Box 10, 50310, Kuala Lumpur, Malaysia.
E-mail (Corresponding): tasnim@iium.edu.my

Abstract

Conveyor belts at ports are used worldwide to carry and transport various materials ranging from fertilizers to foods items such as corn, barley and soy beans from the cargo ship to the packaging site. A serious spillage and carryback problem existed at DB2 terminal, Westports Malaysia where lots of chemical fertilizers (ammonium sulphate) were wasted to some extent and extra manpower was needed to shovel the spillage into the container. The floor was highly corroded due to improper washing and drainage system. The main aim of this research was to eliminate if not reduce spillage and solve the corroded floor issue. The primary and secondary belt cleaners were designed using CATIA software. These newly improved cost effective and simple designs of the primary and secondary belt cleaners together with a spray shaft and proper washing box were fabricated, tested and implemented successfully. The spillage was reduced tremendously and the washing system can prevent corrosion from happening in the future.

Keywords spillage – corrosion – improved design – fabrication – conveyor belt cleaner – washing box

1 Introduction

There are many types of conveyor belts that have been innovated over the years for the sake of improving existing designs and adjusting to the type of materials that needed to be transported and not to forget the surrounding temperature as well. Examples include plastic conveyor belts, vacuum type conveyor belts and warm conveyor belts which have been designed for specific purpose (Boyer, 1975; Palmaer, 1988; Eckhardt et al., 2004). Conveyor belt cleaners on the other hand, have been designed to clean by scraping the hardened materials that are stuck onto the surface of the conveyor belt. Swinderman (1987) successfully designed a conveyor belt cleaner whereby the angle of the blade is able to adjust incrementally with respect to the belt with the ability to go from a negative to a positive angle depending on circumstances and environmental conditions. Meanwhile, Gordon (1993) designed primary and secondary conveyor belt cleaners mainly to solve problems of cleaning and maintenance for industries that need to transport mining materials which are exposed to environments that are wet, dirty and corrosive. However, there are many other types and designs of primary and secondary cleaners which are available in the market and each type and design are used for various types of applications based on various factors such as the type of bulk materials, type of the belt, as well as the speed of the conveyor belt itself.

The previous conveyor belt cleaner at DB2 Terminal, Westports Malaysia was unable to clean the conveyor belt properly which resulted in lots of remaining bulk materials such as corn,

barley, and fertilizer on the conveyor belt. In addition, there was a large amount of spillage of these transported materials accumulated on the floor. Spillage was a serious recurring problem and contributed to extra cost and time in order to clean up the floor. Fig. 1 shows the spillage accumulated on the floor at DB2 Terminal, Westports Malaysia.

Spillage was the main problem resulting from the improper conveyor belt cleaning system. Besides inefficiency and poor maintenance, the position of primary cleaner was not in correct or recommended position and the secondary cleaner not really touching the belt of the conveyor. The blade was not in contact for the secondary cleaner to clean up the belt, thus allowing the excessive amount of spillage accumulated on the floor. Fig. 2 shows the picture of primary cleaner that was used at DB2 Terminal, Westports Malaysia. Fig. 3 shows the condition of the previously used secondary cleaner at the DB2 Terminal. There was a gap between the blade of the secondary cleaner and the belt conveyor which was the main factor that contributed to the spillage problem.

The excessive spillage was then collected and placed back on the conveyor. The process of putting back the spillage on the conveyor was done manually by the workers using a shovel as shown in Fig. 4. It appeared to be a very risky job to be performed because the conveyor was still running and it could have caused unexpected accidents to occur. The running conveyor belt was not to be stopped just for the sake of transferring the spillage onto the conveyor.

Besides, the remaining spillage needed to be cleaned up and the cleaning process was done by spraying the water at the remaining spillage (Fig. 5). The spillage is a chemical fertilizer known as ammonium sulfate which is very corrosive when reacts with the wet steel floor and makes the working environment hazardous to the workers. The floor becomes slippery and may cause workers to be exposed to further accidents and injuries. Besides, it contributes to water contamination due to improper treatment system that can store and treat the contaminated water. Fig. 6 shows one of the corroded floors and there is an area where excess water is trapped (Fig. 7) after the cleaning process is done due to improper drainage.

Therefore, this research project was carried out with the main aim of eliminating or at least reducing spillage and to have a more efficient, uninterrupted and safer material handling process for the fertilizers. This was achieved by improving the existing design of the primary and secondary belt cleaners together with a more effective washing system (tertiary cleaner) using CATIA software. Then, these design improvements were fabricated and tested at Westports Malaysia after approval.

2 Design Methodology

Fig. 8 shows the design procedure used in this research in order to complete the project.

3 Engineering Design Process

Eggert (2010) has mentioned a lot about the product realization process which is vital in transforming the customers' needs into a realized product. This can be achieved through the *House of Quality* which actually functions as a medium to develop the relationships between what the customer wants from a product and which the product's features and overall performance parameters are most critical to fulfilling those wants. This House of Quality is used to determine which engineering characteristics should be treated as constraints for the design process and which

should become decision criteria for selecting the best design concept. Fig. 9 shows the House of Quality used in the improved design process of the conveyor belt cleaners.

The weight factor rating from 1 to 5 was used where 1 is least important and 5 is most important. In this case, the design team decided that easy to maintain, easy to assemble and workplace safety are among the most important customer requirements with the rate of 5. Cleanliness, cost effectiveness, and cleaner strength were picked to be the second most important customer requirements with the rate of 4. This decision was made by the consensus of the design team members supervised by the Westports Malaysia's senior engineer.

There are three strong positive correlations (indicated by “+ +”) among the engineering characteristics pairs. One is the correlation between cleaning efficiency and adjustable holder. It is believed that by designing the adjustable mechanism and adjustable holder for both primary and secondary cleaners, the cleaning efficiency will increase. This is because the adjustable mechanism system used to easily adjust the cleaners to be at the correct contact area with the conveyor belt will efficiently scrap away sticky debris that are attached to the conveyor belt. These two engineering characteristics are strongly positively dependent to one another. There are positive correlations (indicated by “+”) among the engineering pairs. For example when the scraping capabilities of both cleaners are increasing the cleaning efficiency will become higher and it will reduce the amount of spillage accumulated on the floor. Some positive correlations also indicated that some extra features need to be added. For example, to improve the cleaning efficiency the design team decided to design a proper washing tank with extra features to clean up the conveyor belt after the operation. It is also very much related to the workplace safety since the washing tank is able to prevent the water from flooding on the floor that can cause the floor to be slippery.

4 Design, Fabrication and Testing

4.1 Design of Primary Cleaner

Typical specifications in designing primary cleaner include:

1. Primary cleaners perform the initial rough cleaning. They should be designed with flexible (elastomer) blades and radial-adjustment tensioning devices.
2. Primary cleaners should be installed on the face of the head pulley just below the trajectory of the material, utilizing a positive-rake cleaning angle.
3. Primary-cleaner blades should incorporate a constant-cleaning angle and area design. Pre-cleaners should be designed for use on one-directional and reversing belts.
4. Reversing belts should have a primary cleaner installed on each discharge pulley.

Fig. 10 shows the proposed design of primary belt cleaner. Fig. 11 shows the design of the tensioner mechanism that is used to adjust the contact position of the blade. The advantages of this design are:

1. The force of the scrapper towards the pulley can be adjusted. The previous primary belt cleaner had wear at the contact area of the scrapper and the conveyor belt which created the gap between the scrapper and the conveyor belt. By using the spring, it will keep pulling the scrapper towards the conveyor belt to secure its position at the contact area.

2. The removable scrapper was also designed so that it can be removed easily. The scrapper is held by the scrapper holder by using T-slot mechanism. Compared to the previous design, the shaft was only removed during the changing of the scrapper.
3. The shaft also can be moved upward and downward by loosening the screw.

The tensioner mechanism is practically useful in order to adjust the contact position of the blade with the pulley. It is also to ensure that the blade receiving sufficient force exerted by the pulley whenever it is being in contact with the pulley. Sufficient force mean the blade will have longer life and the cleaning efficiency will become higher. When cleaning efficiency become higher, spillage problem will be reduce to almost nothing. The blade will undergo serious wear when it's receiving excessive force exerted by the pulley because of the greater friction of the blade and the belt (Swinderman et al., 2011). The belt also will undergo serious wear problem. Thus, it is necessary for the tensioner mechanism to easily adjust the contact position in order to ensure that the blade receives sufficient force exerted by the pulley. Fig 12a shows the previous shaft of the primary cleaner (without tensioner mechanism) and Fig 12b shows the fabricated tensioner mechanism for the primary cleaner.

4.2 Design of Secondary Cleaner

Secondary cleaner defined as any cleaner located in the secondary position on the return run of the belt. The secondary position is the area from just the past point where the belt leaves contact to the head pulley to just before the belt contact the snub pulley (Swinderman et. al, 2011). Typical specifications of the secondary cleaner are:

1. Secondary cleaners remove the majority of the material that passes by the pre-cleaner's blades. Secondary blades should contact the belt just past the point where the belt has left the head pulley. Alternatively, the cleaners can be located behind the head pulley with a hold-down roll above the blades. The hold-down roll should be a minimum of 100 millimeters (4 in.) in diameter.
2. Secondary-cleaner blades should be designed to contact the belt in a negative-rake position.
3. The blades should be constructed of tungsten carbide or similar abrasion resistant material.
4. On one-directional belts, the cleaners should be adjusted with a radial adjustment tensioning device, and on reversing belts with a vertical-spring tensioner.
5. Reversing belts should have a reversing secondary cleaner installed as close as possible to each terminal (discharge) pulley.

The design of secondary cleaner also needs to follow the requirement for the primary cleaner. The blade length of the secondary cleaner should be approximately 900 mm. The secondary cleaner also need to be equipped with the tensioner mechanism to make sure that it can be easily adjusted. The blade can be either multiple blades or a single type blade. Multiple blades are most commonly used in bulk handling industry. There are many patented design of multiple blades secondary cleaner. Multiple blade mean that, the blade is made smaller into section that it is being combine together based on the width of the belt. There are some specifications that can be used in determining the number of blades required based on the belt width and its application. In this project, the option with the single blade was chosen due to certain constraints.

Figs. 13 and 14 show the proposed design of the secondary cleaner. There is special blade holder to hold the blade (Fig. 15). Easy and quick change of the blade was the main concern. When

it comes to changing the worn blade, the blade is pushed out from the slot. The secondary cleaner is also equipped with a tensioner mechanism that used to mechanically adjust the cleaner and equipped with air spray nozzle to enhance cleaning. This secondary cleaner has two shafts, one used to hold the blade and the other one used to attach the nozzle spray. The material of the shaft is from hot dipped galvanized. There are 6 nozzles available and it sprays air at 8 bars in pressure.

The design of secondary cleaner is equipped with a tensioner mechanism just like the one designed for the primary cleaner. The tensioner pushes the shaft upward with the help of the spring as the adjustable screw is tightened up. There is oval shape at the middle of the shaft holder that allows the vertical movement. There is no horizontal movement since that the secondary cleaner is positioned under the pulley not like the primary cleaner. The shaft is securely locked with the locking screw. Brackets are used to mount the secondary cleaner at the side cover of the head pulley. The bracket is then securely mounted by means of bolt and nuts on the side cover of the head pulley. Table 1 shows the design specifications of the secondary cleaner. The materials used for the blade is tungsten carbide, the holder is made from polyurethane, while the brackets and the connectors are made from steel and the spray shaft is made from stainless steel. The previous shaft of the secondary cleaner without tensioner mechanism and the modified one with adjustable tensioner mechanism with the air spray nozzle are shown in Fig. 16. The close up view of the air spray nozzle fabricated is shown in Fig. 17 where the nozzles are aligned at 45°.

4.3 Design of Washing Tank (Tertiary cleaner)

The washing tank as shown in Fig. 18 was fabricated and placed under the return belt as it was necessary since there was no proper belt washing mechanism provided at DB2 Terminal. Washing tank is equipped with two wipers and a water spray bar (tertiary cleaner) to spray water and clean up the conveyor belt after the operation. The shaft equipped with the wiper holder is shown in Fig. 19. Fig. 20 shows the picture of water spray bar equipped with water inlet. Fig. 21 shows the complete fabricated picture of the washing tank. It is an important system to be installed to prevent the floor from being corroded. It is also used to promote better and safety working condition. The nozzle sprays the water at 45° angle. The specifications are listed out in Table 2. Two wipers were used to improve the cleaning efficiency during the cleaning operation by removing the water that is accumulated on the surface of the conveyor belt. The cleaning process may take some time to make sure that the whole length of the conveyor belt has been cleaned.

The problem of corroded and hollow floor can be solved by implementing a proper washing tank mechanism. There are 6 nozzles that spray the compressed water at a 45° angle and dilute the sticky debris by two cleaners. Two cleaners are necessary to make sure that the belt is completely clean and ready for next operation. The excessive water flow out through the outlet into the proper drainage system. Thus, this washing tank system can be considered as environmental friendly since the contaminated water is properly managed into the drainage system. The tank, shaft and pipe are made from stainless steel SS304, while the wiper blade is from rubber and the outlet pipe is polyvinyl chloride (PVC).

4.3 Selection of Compression Spring for Adjustable Cleaners

Compression springs are used as the adjustable mechanism so that the primary and secondary cleaners can be easily adjusted to the required position. It is important for both cleaners to be at correct contact position to have higher cleaning efficiency. In this project, the design team

decided to use heavy duty helical spring designed for compression. Fig. 22 shows the picture of the compression spring selected and used in this project supplied by the contactor. When a spring is compressed or stretched, the force it exerts is proportional to its change in length. The rate or spring constant of a spring is the change in the force it exerts, divided by the change in deflection of the spring.

Force analysis for the selected compression spring was performed using the guidelines and steps highlighted by Budynas and Nisbett (2011). The pitch (p) was calculated using Eq. 1. Then, the solid length (L_s) of the spring was computed using Eq. 2. The spring stiffness (k) was then found using Eq. 3. Finally, the spring force (F_s) of the spring which is actually the amount of force required to compress the spring to the solid length was found by using Eq. 4. The summary of results is shown in Table 3. The value of spring force obtained is sufficient to withstand the amount of force exerted on it during the cleaning process.

$$p = (L_o - 2d) / N_a \quad (1)$$

where L_o = Free length = 200 mm

d = Diameter spring wire = 5 mm

N_a = No. of active coils = 16

$$L_s = dN_a \quad (2)$$

$$K = (d^4 G) / (8D^3 N_a) \quad (3)$$

Where G = Shear Modulus = 78.6 GPa

D = Mean coil diameter of spring = 35 mm

$$F_s = k (L_o - L_s) \quad (4)$$

4.4 Testing of the Adjustable Cleaners

Fig. 23a shows the spillage accumulated under the return belt before the modification of the primary and secondary cleaners and after modifications, there appeared to be a small amount of spillage, however, not alarming (Fig. 23b). Upon further investigations, a small hole was noticed at the chute which caused this problem. Once the hole was repaired, then the spillage was able to be eliminated as shown in Fig. 24. It is observed that the newly modified primary and secondary cleaners turned to be quite successful. The air spray bar also worked effectively and efficiently by removing the sticky debris materials.

5 Conclusions

The design of the primary and secondary conveyor belt cleaners as well as the belt washing mechanism were fabricated and implemented successfully at DB2 Terminal, Westports Malaysia. Firstly, the overall cleaning efficiency of the conveyor belt system was improved from the test run. Secondly, the spillage was eliminated. Thirdly, the implementation of the new washing tank system considering the safety of the workers and the environmental condition, the problems of corroded and slippery floor can be prevented.

Acknowledgments

Great appreciation goes to Westports Malaysia Sdn. Bhd. for giving the opportunity to pursue this project particularly the site supervisor and Senior Engineer Ir. Mohd. Hafez Iskandar bin Jusoh.

References

1. Boyer, H. E. (1975). Vacuum type conveyor belt with air bearing, United States patent. 3889801.
2. Budynas, R.G., Nisbett, J.K.. (2011). Shigley's Mechanical Engineering Design. (9th ed.) New York: McGraw Hill, (Chapter 3).
3. Eckhardt, S., Stohl, A., Wernli, H., James, P., Forster, C., Spichtinger, N. (2004). A 15-Year Climatology of Warm Conveyor Belts. *Journal of Climate*, 17, 218–237.
4. Eggert, R. J. (2010). Engineering Design. (2nd ed.) New Jersey: Prentice Hall, (Chapter 6).
5. Gordon, J. R. (1993). Conveyor belt cleaners. United States patent. 522589
6. Palmaer, K. V. (1988). Plastic Conveyor Belt. United States patent. 4742907.
7. Swinderman, R. T. (1987). Conveyor belt cleaners. United States patent. 4643293.
8. Swinderman, R. T., Marti, A.D., Golbeck, L.J., Marshall, D., Strebel, M.G. (2009). *Foundations: The Practical Resources for Cleaner, Safer, More Productive Dust & Material Control*. WI, USA: Worzalla Publishing Company, Stevens Point.



Fig. 1
Excessive spillage (fertilizer) accumulated on the floor

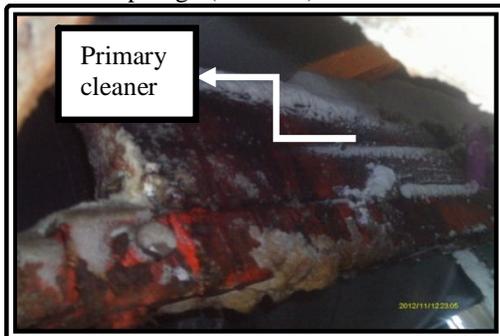


Fig. 2
Primary cleaner used at DB2 Terminal

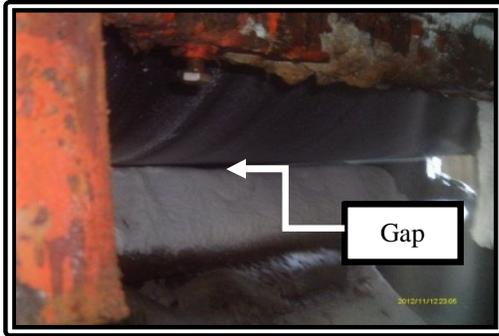


Fig. 3
Gap between secondary cleaner and conveyor belt



Fig. 4
Worker shoveling the spillage manually



Fig. 5
Worker washing the remains of the spillage from the floor



Fig. 6
Corroded floor at DB2 Terminal



Fig. 7
Excess trapped water due to the activity of cleaning up the conveyor belt by spraying water

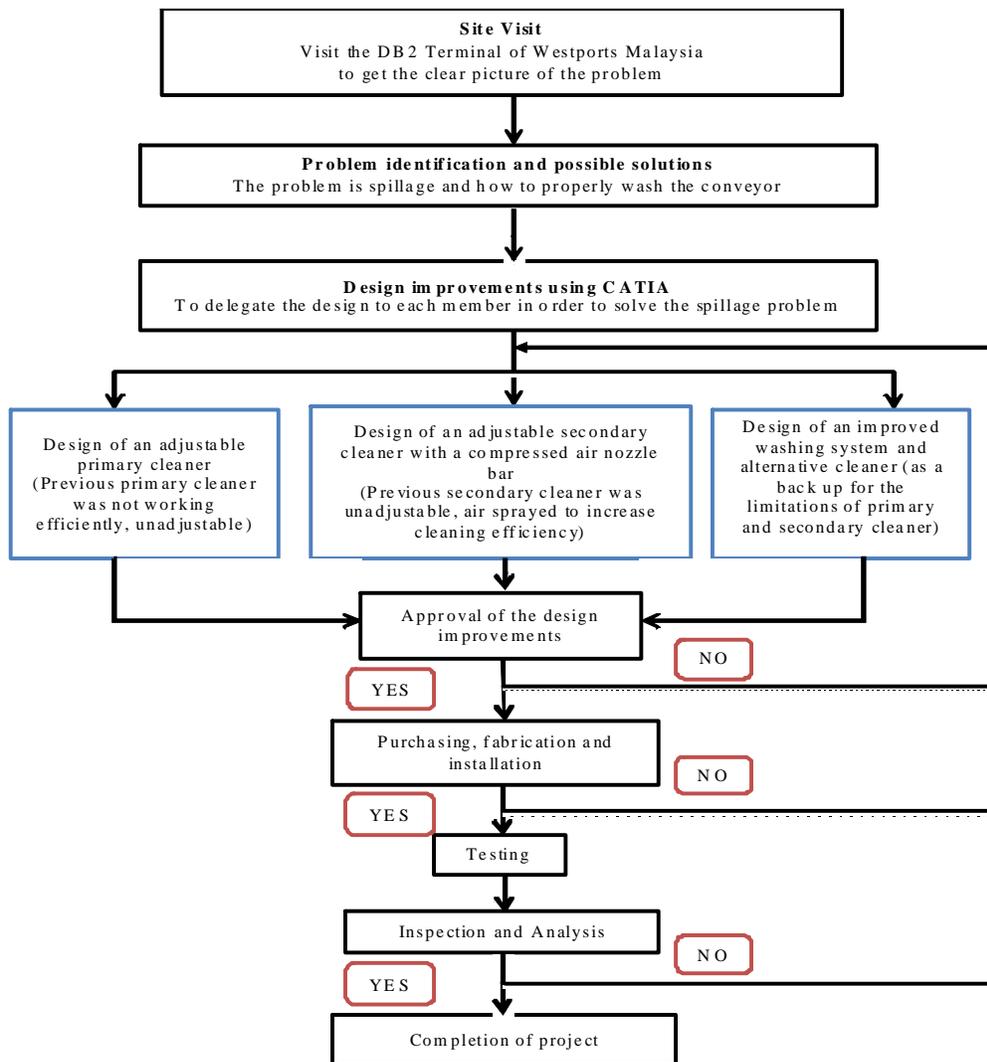


Fig. 8
Flowchart of the design methodology

		Importance weight Factor	Accurate dimension	Anti-corrosion materials	Adjustable holder	Longer product life	Cleaning efficiency	Scraping capability	Customer Requirements	A	B
1.	Cost effectiveness	4	3	4	5		3	3	1. Cost effectiveness	2	3
2.	Cleanliness	4			5		5	5	2. Cleanliness	2	4
3.	Easy to maintain	5		4	5	3	3	3	3. Easy to maintain	1	5
4.	Easy to assemble	5	3		5		2		4. Easy to assemble	2	4
5.	Workplace safety	5					5		5. Workplace safety	2	4
6.	Cleaner's strength	4			5			4	6. Cleaner's strength	2	4
		Total	27	36	110	15	82	63	A= Previous design B= Newly modified design		
		Score (%)	8.11	10.82	33.03	4.50	24.62	18.92			
		Rank	5	4	1	6	2	3			

* Remark: 5- Strong; 3- Medium; 1- Weak
 * Raw Score = 333

Fig. 9
 House of Quality for the conveyor belt cleaners

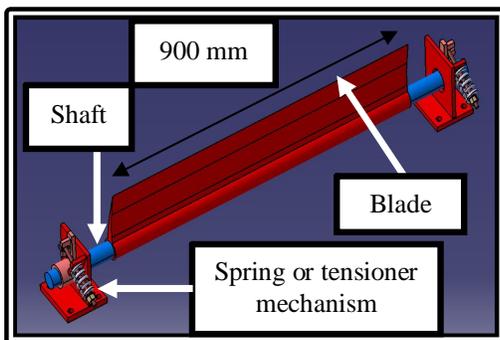


Fig. 10
 The proposed design of primary cleaner

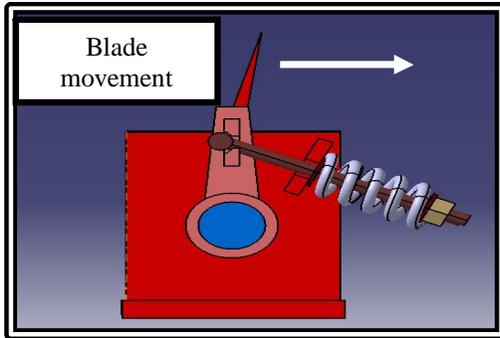


Fig. 11
Close up view of the tensioner mechanism that is used to adjust the contact position of the blade with the pulley



a



b

Fig. 12
Picture of the primary cleaner (a) before and (b) after modification process

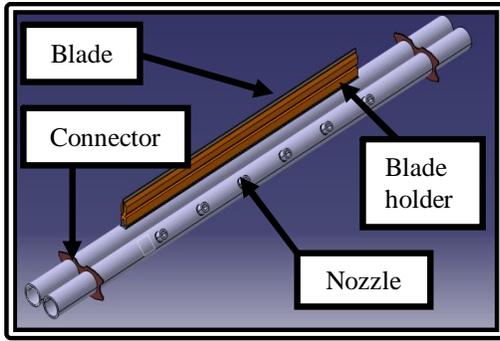


Fig. 13
Proposed design of secondary cleaner

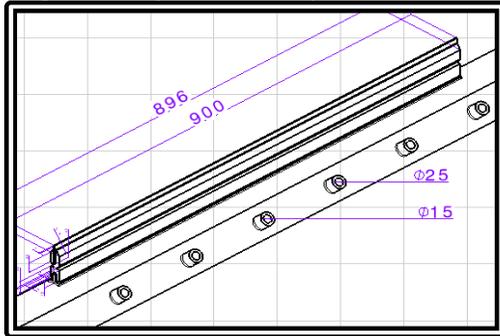


Fig. 14
Design specifications of the blade and blade holder. The inner and outer diameters of the nozzles are also available (dimension in mm)

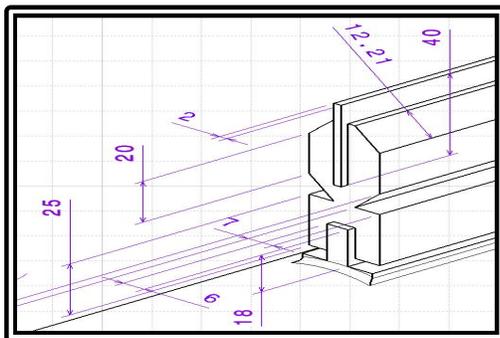


Fig. 15
Design specifications of the side view of the blade and blade holder (dimensions in mm)



a



b

Fig. 16
Picture combination of secondary cleaner (a) before and (b) after modification process



Fig. 17
Air spray nozzles aligned at 45° under the belt



Fig.18
Washing tank fabricated in this project



Fig. 19
Shaft with the wiper holder



Fig 20
Water spray bar



Fig 21
Complete system of washing tank



Fig 22
Compression spring used as adjustable mechanism in this project



a



b

Fig. 23
Spillage accumulated on the floor at the same position (a) before and (b) after the modifications of primary and secondary cleaners

**Fig. 24**

No more spillages after repairing the hole

Table 1

Design specifications of the secondary cleaner

Component	Dimension (mm)
1. Blade length	896
2. Blade holder length	900
3. Shaft length	1600
4. Shaft (outer diameter)	60
5. Spring length	200
6. Spring (outer diameter)	40
7. Distance between nozzle	160
8. Nozzle Outer Diameter	25
9. Nozzle Inner Diameter	15

Table 2

Specifications of the washing tank

Component	Specifications
1. Height	800 mm
2. Length	1800 mm
3. Width	1400 mm
4. Shaft Length	1600 mm
5. Shaft Outer Diameter	60 mm
6. Outlet Diameter	90 mm
7. Water pressure	250 psi
8. Angle of nozzle	45 °
9. Spray Shaft Diameter	50 mm
10. Nozzle Distance	215 mm

Table 3

Summary of results

Pitch (p)	11.875 mm
Solid length (L_s)	80 mm
Spring stiffness (k)	8951 N/m
Spring force (F_s)	1074 N