Design of Dust Collector on Sorting Machine Vibro Mesh Type Using Design for Assembly (DFA) Approach with Boothroyd and Dewhurst Method in PT. Perkebunan Nusantara VIII Ciator

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Abstract. PT. Perkebunan Nusantara VIII is a company that produce orthodox black tea in Indonesia with a land area of less than 400 hectares. In the production section, especially the sorting room in sorting machine, which produces dust contaminants are very disturbing operators who are working. For the maintenance process is scheduled for 2 hours on working hours every 1 month, if maintenance takes more than 2 hours will cause the production process is delayed. To support the maintenance process on dust collector, Design of dust collector using design for assembly (DFA) approach using Boothroyd and Dewhurst method. DFA approach is chosen to simplify the process of maintenance dust collector, which required unloading dust collector every maintenance. There are 2 dust collector designs proposed to get the best assembly design. The design of dust collector with optimal assembly time, with the application of Boothroyd and Dewhurst is design 2 with total component of 82 pieces with assembly time of 552.62 sec with assembling efficiency of 24.43%. It is hoped that by using design 2, the dust collector maintenance process does not interfere with the production process and the shorter time of assembly.

Keywords: material transporters, musculoskeletal disorders, work accident, product design, Ergonomic Function Deployment

1. Introduction

PT. Perkebunan Nusantara VIII Ciator Lembang is a company engaged in the tea plantation, has a land area of approximately 400 hectares. PT Perkebunan Nusantara VIII has several work stations such as timber stations, milling stations, drying stations, sorting stations, and packing stations. Some of these stations produce dust particles when the production process is in progress. But the station that produces the most dust particles is in the sorting station. The sorting station is a station located after the drying station where the tea leaves which have been carried out are dried by burning process. Tea leaves that have been dried will go to the sorting station which will then be sorted based on size and weight. Sorting machines work by turning to push tea powder to filter quickly. This rotation causes the dust from the tea powder to rise into the air. The dust generated by the sorting machine spreads around the station resulting in dirty room and may compromise the respiratory system of the operator. Not only disrupt the respiration of the operator but also disturb the operator's visibility. PT Perkebunan Nusantara VIII will use a tool called a vacuum cleaner as a dust collector to be installed in the sorting machine. The purpose
of installation of this tool is to suck the dust generated by sorting machine but this tool requires regular maintenance to keep the system running properly. The main design of this tool has a working system such as a dust collector.

The design of the dust collector will have a plastic that serves to accommodate the dust that has been inhaled during the sorting process in the machine. The dust accommodated on the bucket can be reused as a dye batik. Cleaning the bucket is done by first turning off the sorting machine and vacuum cleaner then the bucket is removed and the dust that has been accommodated can be accommodated to the dust container. The bucket cleaning process will cause the production process to be suspended temporarily which will have an impact on the loss of production time. Therefore, the design of this vacuum cleaner using DFA to produce design with a fast assembly time so that the production process is not too long inhibited.

2. Methods

2.1. Dust Collector
Dust collector is a system used to improve the air quality generated from industrial and commercial processes by collecting dust and other impurities from air or other gases. The working principle of this tool is by lowering the pressure on the suction side under atmospheric pressure (free air). The air around the suction hole will enter into the suction hole which causes the dust contained in the air around the suction hole will go into the suction hole. The incoming air is then filtered using a filter to filter out the dust so that the air out of the dust collector system is completely clean [1].

2.2. Design for Assembly
The design for assembly approach was chosen with the aim of supporting the maintenance process by minimizing the number of assembly parts, optimizing assembly time when it will be dismantled and reinstalled, as well as the level of assembly efficiency in the design of local exhaust ventilation devices exhaust ventilation is recommended more often in checking LEV systems such as fan motors, air cleaners, hoods, pipes that can experience damage or corrosion [2]. This method depends on the design that will be evaluated and improve continuously [3]. There are 4 primaries expected in design for assembly results:
  1. Reduced material cost.
  2. Reduce labor and automatic assembly.
  3. Reduced assembly cycle time.
  4. Higher product quality and reliability.

2.3. Boothroyd and Dewhurst Method
Quantitative method to calculate efficiency assembly level, there are 2 steps to analyze efficiency assembly level [4].

\[
E = NM \cdot \frac{ta}{TM} \quad (1)
\]

Where,
\[
E = \text{Theoretical minimum item count}
\]
\[
NM = \text{Minimum part count}
\]
\[
ta = \text{Actual assembly process time for the product}
\]
\[
TM = \text{Total assembly process time for all item.}
\]

3. Result and Discussion

3.1. Result
Researchers observe the area on the sorting machine, to decide the proposed design dust collector that will be applied. Researchers proposed 2 design in this research then make different assembly methods,
and parts, then analyze 2 proposed design then evaluate the design after that choose the best proposed design.

A. Design 1
Determination of the various components obtained from the results of benchmarking carried out on the form of similar components through several media and market.

| Part                      | Benchmarking | Description                                                                 | Result                                                                 |
|---------------------------|--------------|-----------------------------------------------------------------------------|------------------------------------------------------------------------|
| Support pillar            |              | The support pillar uses iron plate material and is attached to the ceiling / foundation of the room. | The use of 3 support poles to hold from the main pipe, 2 pieces to hold the hood pipe |
| Ring support pillar       |              | Ring support pillar use rubber material so that it can be stretched when inserting a pipe into the ring | Part of the support pillar ring that is assembled with a support pole using 2 bolts for tightening |
| Dynamo motor enclosure    |              | The enclosure of an electric motor is shaped like a cage with a hole in the front and bottom for the pipe | This cage will be placed on the wall as a barrier |
| Flange                    |              | Circle shape using 8 holes.                                                 | Flange is used as a connection with between pipes and then tightened with screw |

*Figure 1. Proposed Design 1 Dust Collector*

Proposed design 1, determine parts, dimension, and fastener based on benchmarking from literature, and others media.
Table 2. Component of Design 1

| Part                        | Quantity | Description   |
|-----------------------------|----------|---------------|
| Air Cleaner Circle Support  | 1        | Base Part     |
| Fan Cage                    | 1        | Base Part     |
| Pole                        | 5        | Base Part     |
| Hood                        | 2        | Base Part     |
| Flange                      | 2        | Main Part     |
| Hood Pipe                   | 2        | Main Part     |
| T Pipe                      | 1        | Main Part     |
| Main Pipe                   | 1        | Main Part     |
| Outlet Pipe                 | 1        | Main Part     |
| Fan                         | 1        | Main Part     |
| Case Fan-front              | 1        | Main Part     |
| Case Fan-back               | 1        | Main Part     |
| Dinamo                      | 1        | Main Part     |
| Bag Filter                  | 1        | Main Part     |
| Air Cleaner Circle          | 1        | Main Part     |
| Bag Filter Cage             | 1        | Main Part     |
| Bucket                      | 1        | Main Part     |
| Bag Filter Scraper          | 1        | Main Part     |
| Bolt 8                      | 28       | Fastener      |
| Bolt 4                      | 16       | Fastener      |
| Mur 8                       | 24       | Fastener      |

Based on the proposed design 1 there are 21 kind of parts consist of 103 components that needed for design 1. Next step is determine total operation for proposed design 1 that shown in table below.

Table 3. Total Assembly Operation of Design 1

| Sub Assembly | Total Assembly Operation |
|--------------|--------------------------|
| Hood         | 11                       |
| Fan          | 4                        |
| Air Cleaner  | 7                        |
| Hood & Fan   | 1                        |
| Total        | 23                       |

Boothroyd and Dewhurst Method for design 1. Total operation time for assembly 660.48 secs with efficiency assembly level 20.89 %

Table 4. Boothroyd and Dewhurst Method Design 1

| A   | B                  | G                  | H                  |
|-----|--------------------|--------------------|--------------------|
| ID  | Part Name          | Number of times the operation carried out | Operation time (TM), B*(D+F) | Theoritical minimum part (sec) (NM) |
|-----|--------------------|--------------------|--------------------|-----------------------------------|
|     | Sub Assembly Hood  |                    |                    |                                   |
| 1   | Hood               | 2                  | -                  | -                                 |
| 1.1 | Bolt 8             | 16                 | 56.96              | 8                                 |
| 1.2 | Mur 8              | 16                 | 128.96             | 8                                 |
| 1.3 | Hood pipe          | 2                  | 15                 | 2                                 |
| 1.4 | Bending pipe       | 2                  | 14                 | 0                                 |
### Table 4. Boothroyd and Dewhurst Method Design 1 (cont.)

| ID | Part Name                  | Number of times the operation carried out | Operation time (TM), B*(D+F) (sec) | Theorical minimum part (NM) |
|----|----------------------------|-------------------------------------------|------------------------------------|-----------------------------|
| 2  | Sub Assembly Hood & Duct   | 2                                         | 14                                 | 2                           |
| 2.1| Sub Assembly Hood          | 2                                         | 14                                 | 0                           |
| 2.2| T Pipe                     | 1                                         | 7                                  | 0                           |
| 2.3| Bending pipe               | 1                                         | 18                                 | 1                           |
| 2.4| Main Pipe                  | 1                                         | -                                  | -                           |
| 2.5| Support Pole               | 4                                         | 128.96                             | 8                           |
| 2.6| Bolt 4                     | 16                                        | 14                                 | 0                           |
| 3  | Sub Assembly Fan           |                                           |                                     |                             |
| 3.1| Fan Cage                   | 1                                         |                                     | -                           |
| 3.2| Case Fan - front           | 1                                         | 5                                  | 1                           |
| 3.3| Fan                        | 1                                         | 5                                  | 1                           |
| 3.4| Case Fan - back            | 1                                         | 5                                  | 1                           |
| 3.5| Motor                      | 1                                         | 6                                  | 1                           |
| 3.6| Bolt 8                     | 4                                         | 32.24                              | 4                           |
| 4  | Sub Assembly Air Cleaner   |                                           |                                     |                             |
| 4.1| Air Cleaner Circle Support | 1                                         | -                                  | -                           |
| 4.2| Air Cleaner Circle         | 1                                         | 5                                  | 1                           |
| 4.3| Bucket                     | 1                                         | 10.75                              | 1                           |
| 4.4| Bag Filter                 | 1                                         | 7.6                                | 1                           |
| 4.5| Bag Filter Cage            | 1                                         | 7.6                                | 1                           |
| 4.6| Bag Filter Scraper         | 1                                         | 11.35                              | 1                           |
| 4.7| Bending Pipe               | 1                                         | 9.6                                | 0                           |
| 4.8| Outlet Pipe                | 1                                         | 18                                 | 1                           |
| 4.9| Outlet pole                | 1                                         | 5                                  | 1                           |
| 5  | Sub Assembly Hood, Duct & Fan |                                      |                                     |                             |
| 5.1| Sub Assembly Duct          | 1                                         | -                                  | -                           |
| 5.2| Bolt 8                     | 8                                         | 28.48                              | 0                           |
| 5.3| Mur 8                      | 8                                         | 64.48                              | 0                           |
| 5.4| Flange                     | 2                                         | 15                                 | 0                           |
| 5.5| Sub Assembly Fan           | 1                                         | 14.5                               | 1                           |
| 6  | Final Assembly             |                                           |                                     |                             |
| 6.1| Sub Assembly Hood, Duct dan Fan |                          |                                     | -                           |
| 6.2| Sub Assembly Air Cleaner   | 1                                         | 13                                 | 1                           |

| Design 1 | Efficiency Formulation | Efficiency |
|----------|------------------------|------------|
| 103      | (3*NM)/TM              | 20.89%     |

**B. Design 2**

Determination of the various components obtained from the results of benchmarking carried out on the form of similar components through several media and market.
Table 5. Benchmarking Design 2

| Part                    | Benchmarking | Description                                                                 | Result                                                                 |
|-------------------------|--------------|------------------------------------------------------------------------------|------------------------------------------------------------------------|
| Simplifying Design      |              | In the T pipe and hood pipe, pipe turns are no longer used because these two components will be put together | The integration of this design will minimize the time in the pipe hood and pipe T assembly |
| Type of Pipe Connection |              | The pipe is formed with a flange-like tip shape so that it can be directly connected | This connection comes from the vendor so that the assembly process only enters the pipe |

Figure 2. Proposed Design 2 Dust Collector

Proposed design 2, determine parts, dimension, and fastener based on benchmarking from literature, and others media.

Table 6. Component of Design 2

| Part                | Quantity | Description |
|---------------------|----------|-------------|
| Air Cleaner Circle Support | 1        | Base Part   |
| Fan Cage            | 1        | Base Part   |
| Pole                | 5        | Base Part   |
| Hood                | 2        | Main Part   |
| Hood Pipe           | 2        | Main Part   |
| Main Pipe           | 1        | Main Part   |
| Outlet Pipe         | 1        | Main Part   |
| Fan                 | 1        | Main Part   |
| Case Fan - Front    | 1        | Main Part   |
| Case Fan - back     | 1        | Main Part   |
| Dinamo              | 1        | Main Part   |
| Bag Filter          | 1        | Main Part   |
| Air Cleaner Circle  | 1        | Main Part   |
Based on the proposed design 2 there are 19 kind of parts consist of 80 components that needed for design 2. Next step is determine total operation for proposed design 2 that shown in table below.

### Table 6. Component of Design 2 (cont.)

| Part               | Quantity | Description |
|--------------------|----------|-------------|
| Bag Filter Cage    | 1        | Main Part   |
| Bucket             | 1        | Main Part   |
| Bag Filter Scraper | 1        | Main Part   |
| Bolt 8             | 20       | Fastener    |
| Bolt 4             | 16       | Fastener    |
| Mur 8              | 20       | Fastener    |

### Table 7. Total Assembly Operation of Design 2

| No | Sub Assembly | Total Assembly Operation |
|----|--------------|--------------------------|
| 1  | Hood         | 9                        |
| 2  | Fan          | 4                        |
| 3  | Air Cleaner  | 7                        |
| 4  | Hood & Fan   | 1                        |
|    | Total        | 21                       |

Boothroyd and Dewhurst Method for design 2. Total operation time for assembly 515.52 secs with efficiency assembly level 24.44 %

### Table 8. Boothroyd and Dewhurst Method Design 2

| ID  | Part Name                  | Number of times the operation carried out | Operation time (TM), B*(D+F) | Theorical minimum part (NM) |
|-----|----------------------------|------------------------------------------|------------------------------|------------------------------|
| 1   | Sub Assembly Hood & Duct   | 2                                        | -                            | -                            |
| 1.1 | Hood                       | 2                                        | -                            | -                            |
| 1.2 | Bolt 8                     | 16                                       | 56.96                        | 8                            |
| 1.3 | Nuts 8                     | 16                                       | 128.96                       | 8                            |
| 1.4 | T Pipe                     | 1                                        | 14                           | 0                            |
| 1.5 | Bending Pipe               | 1                                        | 7                            | 0                            |
| 1.6 | Main Pipe                  | 1                                        | 18                           | 1                            |
| 1.7 | Support Pole               | 4                                        | -                            | -                            |
| 1.8 | Bolt 4                     | 16                                       | 128.96                       | 8                            |
| 2   | Sub Assembly Fan           |                                          |                              |                              |
| 2.1 | Fan Cage                   | 1                                        | -                            | -                            |
| 2.2 | Case Fan - front           | 1                                        | 5                            | 1                            |
| 2.3 | Fan                        | 1                                        | 5                            | 1                            |
| 2.4 | Case Fan - back            | 1                                        | 5                            | 1                            |
| 2.5 | Motor                      | 1                                        | 6                            | 1                            |
| 2.6 | Bolt 8                     | 4                                        | 32.24                        | 4                            |
| 3   | Sub Assembly Air Cleaner   |                                          |                              |                              |
| 3.1 | Air Cleaner Circle Support | 1                                        | -                            | -                            |
| 3.2 | Air Cleaner Circle         | 1                                        | 5                            | 1                            |
| 3.3 | Bucket                     | 1                                        | 10.75                        | 1                            |
| 3.4 | Bag Filter                 | 1                                        | 7.6                          | 1                            |
| 3.5 | Bag Filter Cage            | 1                                        | 7.6                          | 1                            |
| 3.6 | Bag Filter Scraper         | 1                                        | 9.85                         | 1                            |
| 3.7 | Bending Pipe               | 1                                        | 9.6                          | 0                            |
| 3.8 | Outlet pipe                | 1                                        | 18                           | 1                            |
| 3.9 | Outlet pole                | 1                                        | 5                            | 1                            |
Table 8. Boothroyd and Dewhurst Method Design 2 (cont.)

| A/ID | B Part Name                  | C Number of times the operation carried out | D Operation time (sec) | G Theorical minimum part (NM) |
|------|------------------------------|--------------------------------------------|------------------------|-------------------------------|
| 4    | Sub Assembly Hood, Duct & Fan| 1                                          |                        |                               |
| 4.1  | Sub Assembly Duct            | 1                                          |                        |                               |
| 4.2  | Joint Pipe                   | 1                                          | 7.5                    | 0                             |
| 4.3  | Sub Assembly Fan             | 1                                          | 14.5                   | 1                             |
| 5    | Final Assembly               |                                            |                         |                               |
| 5.1  | Sub Assembly Hood, Duct and Fan| 1                        |                        |                               |
| 5.2  | Sub Assembly Air Cleaner     | 1                                          | 13                     | 1                             |
|      | Design 2                     | 80                                         | 515.52                 | 42                            |
|      | Efficiency Formulation       |                                            | (3*NM)/TM              |                               |
|      | Efficiency                   |                                            | 24.44%                 |                               |

3.2. Discussion

Table 9. Comparison

| No | DFA Goals                        | Design 1 | Design 2 |
|----|----------------------------------|----------|----------|
| 1  | Total Components (piece)         | 103      | 80       |
| 2  | Total Assembly Time (sec)        | 660.48   | 515.52   |
| 3  | Efficiency (%)                   | 20.89%   | 24.44%   |

The comparison proposed design between both design changes with design 1 with 103 components can be reduced until 80 components in design 2 and assembly time 515.52 sec with efficiency level 24.44%. It’s believed that design 2 is the best design to implemented in PT Perkebunan Nusantara with minimum assembly time for maintenance process. With minimize assembly time for dust collector, its hoped that maintenance process for all machine in PT Perkebunan Nusantara VIII will not caused extra time for maintenance process, and production will continue without delay.

4. Conclusion

Based on research that has been done in PT. Perkebunan Nusantara VIII Ciater, the design of dust collector with optimal assembly time, with application method Boothroyd and Dewhurst is design 2 with total of 82 pieces with assembly time 515.52 sec with assembling efficiency 24.44%. It is hoped that by using design 2, the dust collector maintenance process does not interfere with the production process and the shorter time of assembly.

5. References

[1] Nagyszalanczy S 2002 Woodshop Dust Control, A Complete Guide to Setting Up Your Own System Completely Revised and Updated. (Newtown, USA: The Taunton Press, Inc.)
[2] Health and Safety Authority 2014 Local and Exhaust Ventilation Guidance. (Irlandia: Health and Safety Authority)
[3] Yusri 2012 Penerapan Design for Assembly (DFA) Untuk Mereduksi Biaya Produksi Suatu Produk. (Padang: Politeknik Negeri Padang) pp 28-32
[4] Boothroyd G 1994 Product design for manufacture and assembly. Computer-Aided Design 26(7) pp 505–520
[5] Latar M A 2014, Tahapan Perancangan Sistem Ventilasi Lokal. (Jakarta: Universitas Esa Unggul)
[6] Latar M A 2012 Lokal Exhaust Ventilation/Ventilasi Pengeluaran Setempat. (Jakarta: Universitas Esa Unggul)
[7] PT. Perkebunan Nusantara 2008 SOP Pembuatan Teh Hitam Ortodoks. (Bandung: PT. Perkebunan Nusantara)