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Design of Ergonomic Dust Collector Room for Coating Process Using Quality Function Deployment

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Abstract. A coating process is an act of giving layers on a surface, for example, painting process, water-proofing process. The coating process needs more attention from enterprises because the processes could release dangerous particles that can be inhaled by workers. The dangerous particles could make the workers suffer from coughs, sneezing, allergic rhinitis, bronchitis, asthma, silicosis, and other decreased-lung functions. Therefore, the coating process should be done in ergonomic circumstances to avoid them from the bad effects of the un-ergonomic coating process. This research aims to find the dust collector room design meeting the ergonomic requirements for the processes. This research used Quality Function Deployment (QFD) to discover the employee needs and the requirements dust collector room should have. The employee and enterprises needs were obtained using group discussion among them working in sanitary product manufacturing made from sands, marble particles, and cement in Bantul, Yogyakarta, Indonesia. The three most important needs of the room are that the dust collector room should collect dust rapidly, localize dust spreading, and give better air circulation. The needs form the three important functional requirements the room should have, i.e., split-plastic wall, concrete wall, high and wide room. Therefore, the dust collector room should be designed based on the voice of the stakeholders to get healthy-working environment.

1. Introduction

A final product is made through many processes like conventional and non-conventional machining. One of the most frequent-used processes is a coating process. A coating process is an act of giving layers on a surface, for example, painting process, water-proofing process. The coating process needs more attention from enterprises because the processes could release dangerous particles that can be inhaled by workers. The dangerous particles could make the workers suffer from coughs, sneezing, allergic rhinitis, bronchitis, asthma, silicosis, and other decreased-lung functions. Dust could also bring bad effects to students' health in Malaysia [1].

Many studies have been conducted to reduce the dust spreading. The wettability of the surface has a significant effect on the dust removal completion [2]. Careful process control and a correct sampling phase in assessing the explosion hazard of dust are needed to prevent a dust explosion depended by variables that affect the fines content [3,4]. A dust explosion can propagate although there is very few dust, or no dust at all in the connected pipes so right placement of the explosion isolation device is very important to ensure that barrier is in place to stop the fireball, besides that the explosion isolation systems need to be validated and verified through large-scale testing [5]. A moving granular bed filter was developed and tested to get 82.0% - 99.8% filtering efficiencies [6,7]. Furthermore, a dust alarm system should be introduced to warn people about the dust level [8].

QFD has been used in many research area and countries especially in a room and build designs. The voice of the customer and the specifications' priority of the construction industries are met together to get the clients' satisfaction leveling up the chance of successful housing design in Nigeria, Iran, Taiwan, India, and Malaysia [9–13]. The specification variables of vessel engine room design are safety, vessel type, vessel's main dimensions, the arrangement of the engine room, material type, coating, vessel speed, ventilation, temperature, vessel tank capacity, mechanics of materials and pressure which are identified using QFD and DEMATEL techniques [14]. The QFD has been used for improving public transport quality, i.e., the second-class cabins quality of high-speed rails (HSRs) in China through some suggestions such as the cabins should have comfortable seat, sensory comfort, and proper luggage storage [15], comfort or not crowded bus in Belgrade [16], and the improvement of Kansai International Airport based on passengers' needs [17]. The workstation of the school workshop should meet the Malaysian design standard having the comfort standard, safety standard and broad working space [18]. The QFD is also used for designing prospective lodging industry [19]. It helps hospitals to get better patients' satisfaction and makes the hospital having higher competitive advantages [20,21]. Moreover, it also elaborates technology usage into education, for example, smart class, multimedia [22].

However, the ergonomic requirements of the dust collector room have not been identified. The identification of the room's specifications is very important because the coating process should be done in ergonomic circumstances so the workers could be avoided from the bad effects of the un-ergonomic coating process. This research aims to find the dust collector room design meeting the ergonomic requirements for the coating process using QFD.

2. Method

The research is done through several steps. First, the voice user of the room is identified. The need is identified through group discussion with an enterprises' manager and 5 workers working on coating proses, i.e. adding cement-layers and liquid-water proof to workpieces using a spray gun. The processes are done in a small-medium enterprise making sanitary products like a sink made from sands, marble particles, and cement in Bantul, Yogyakarta, Indonesia. The small-medium enterprise has been established since 2008. They are asked about what performances and features the dust collector room should have. Then, the answers are entered to the QFD or House of Quality (HOQ) in the customer-requirement column as shown in Figure 1 or in the demanded-quality column as shown in Figure 2. After that, the importance levels of the voice of the customers are assessed (use a scale of 1 to 10, with 10 indicating very important items [23]. Finally, the relative weights of the customer requirements are obtained to compare the degree of importance level among them.

Second, the functional requirements of the dust collector are established based on the voice of the user (customer). The functional requirements are investigated to fulfill the voice of the customer and place to the technical-requirement rows (see Figure 1) or to the quality-characteristic row (see Figure 2). Then the correlations between the functional requirements of the room are assessed (++ = strong positive correlation; + = positive correlation; − = negative correlation; ▼ = strong negative correlation [23]).

Third, the correlations between the voice of customer and the functional requirements are determined. The corelation clasification are (1) ⊙ = strong relationship = 9; (2) ○ = moderate relationship = 3; (3) △ = weak relationship = 1 [23].

Fourth, the importance weights of the functional requirements of the room are calculated. It is calculated by multiply the value of any relationships shown in the column of the technical requirement by the relative weight of the customer requirement [23]. Finally, the relative weights of the functional requirements can be obtained.

Fifth, the specifications of the room derived from the QFD are implemented. Before the implementation, there was no partition for localizing dust spreading so dust goes elsewhere around the plant.

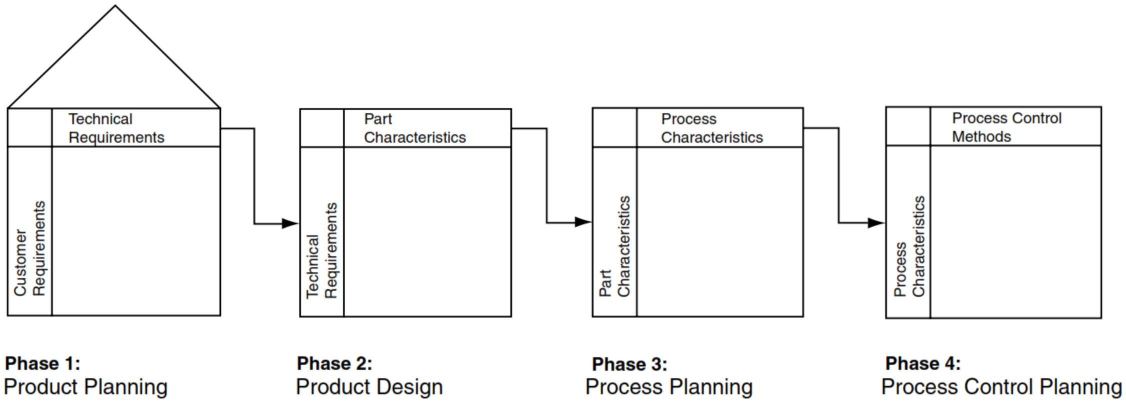

Figure 1. The four phases of the QFD [23].

3. Results and Discussion

The house of quality of the dust collector room identifies 10 needs that should be attached to it. There are demanded requirements having importance level that is more than 8 (see Figure 2). First, the room should absorb dust rapidly so it can reduce the chance of the dust inhalation by workers. It because the dust is dangerous to the humans [1]. Second, the room can prevent dust to spread to other locations, it is very crucial because if dust easily moves to other plant sites the dust could be inhaled by other employees who do not do the coating process. This effort is in line with the dust isolation system that has been introduced [5]. Third, the room can give better air circulation so the worker who does the painting proses could breathe fresh air. Fourth, the workpiece can easily be moved in the room as the workers need to paint other workpieces that have not been painted from the outside. Fifth, the worker can enter to and escape from the room easily without making much dust is going outside since the worker needs allowance for drinking, eating or going to a restroom.

Meanwhile, there are also needs having moderate importance levels. First, the room uses cheap materials because the enterprise could reduce investment cost. Second, the room is easy to be built so that the dust collector room could be made by the existing workers. Third, the room can be used in a long period of time, because it is predicted to be used for the next 4 years. Fourth, the room can decrease the noise level because of the noise resulted by compressors. It shows that the QFD could make a better workstation in an industry like in the lodging industry [19].

Based on the relationship between the demanded requirements and the functional requirements (see Figure 2), the relative weight of the functional requirements of the room can be obtained. There are some functional requirements of the room holding relative weight that is more than 7. First, split-plastic wall (see Figure 4) is very crucial to be attached to the room because it makes the workers and the workpieces go into and outside from the room easily and it prevents dust to scatter outside the room. Second, the concrete floor is also very beneficial for giving easiness movement of the wheeled-table (see Figure 6) and avoiding dust spreading to other sections of the plant. Third, high and wide walls (see Figure 3) makes air circulation goes well, hold a lot of workpieces with many different sizes from small to large. Fourth, fans and blowers (see Figure 3 to Figure 5) are used for pushing and sucking dust from inside the room. While the transparent and thick plastic wall could prevent dust from spreading out and enable the production process to be controlled directly outside the room. Fifth, foam-coated plywood wall is helpful to reduce the noise level.

Sixth, the least importance functional requirement is a mask used by the worker. If the fans and blowers can work properly then the workers do not need to use the mask. Since personal protective equipment is the last effort after controlling dust from the source. This is in line with controlling dust emissions in Beijing through mitigating combustion sources (power, industry, and vehicle exhaust) [24].

The coating process that is done in the ergonomic dust collector room is very beneficial for the enterprise and the workers. The enterprise could reduce a cost for health allowances since the workers can finish the task with minimum health complaints and it can increase the productivity because the workers are able to move the workpieces easily and rapidly. Moreover the workers have higher enthusiasm for doing the job because they are sure that the new dust collector room would bring excellent effect to their health.

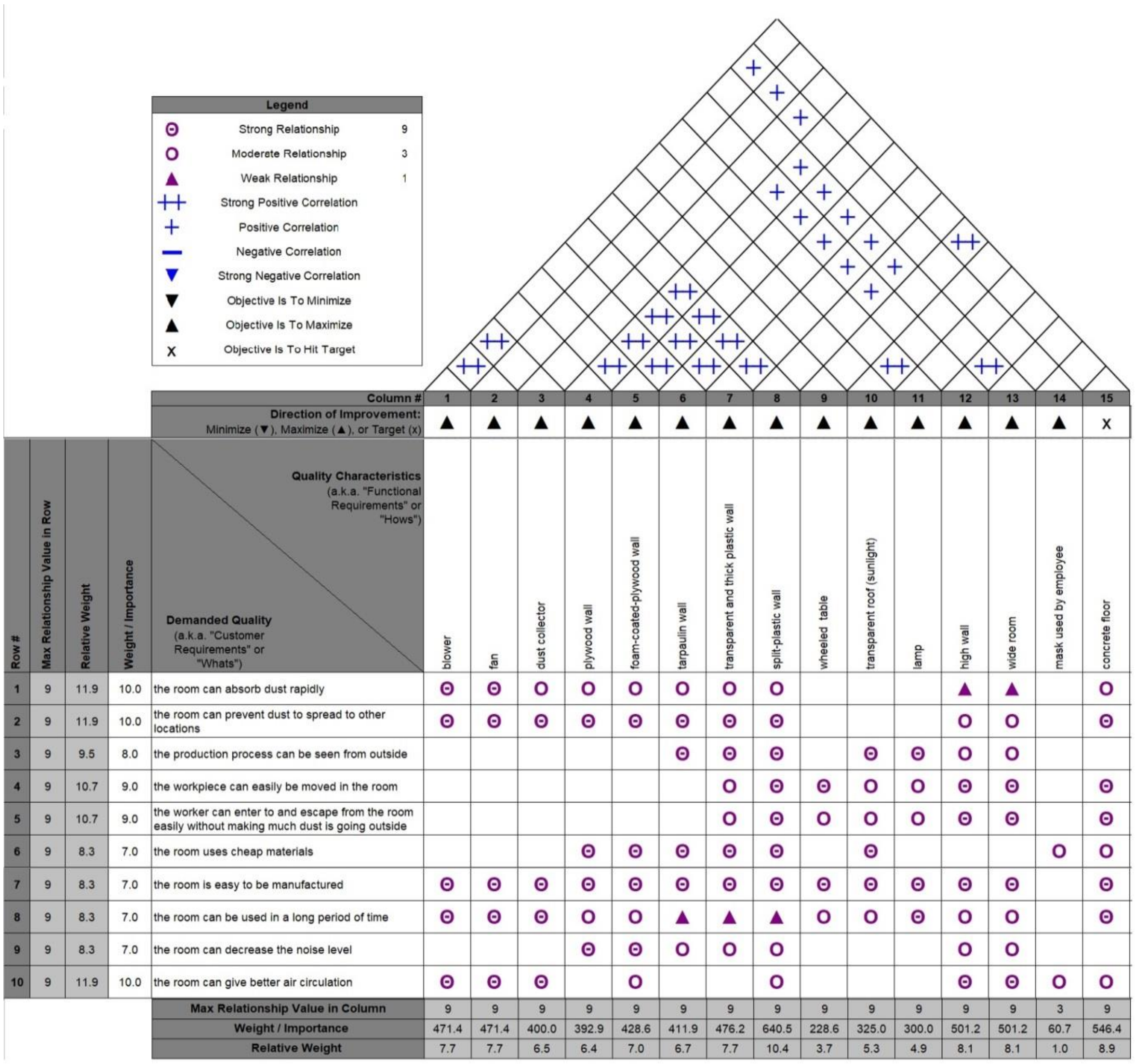

Figure 2. The House of Quality of coating process room.

Figure 3. Plywood wall, tarpaulin wall, and transparent plastic wall are used as a partition for localizing dust.

Figure 4. Split-transparent plastic as a door for easy entering.

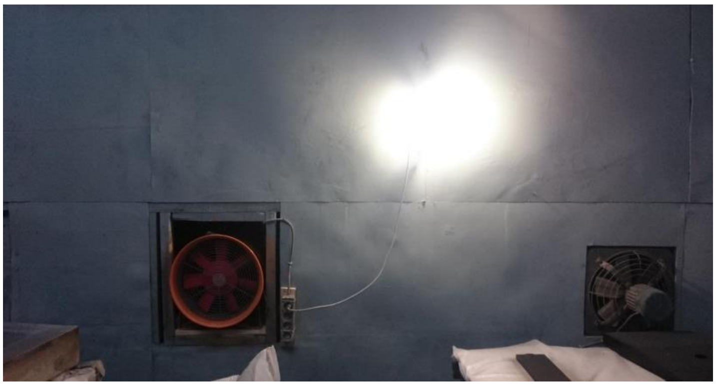

Figure 5. Blowers used for absorbing dust.

Figure 6. Tables equipped by small wheels could make the easy and fast movement of the workpieces.

4. Conclusions

The dust collector room should have abilities to collect dust rapidly, to localize dust spreading, to enable the supervisor to see the production process from the outside, and to transport the workpieces easily. Therefore, the dust collector room should be equipped by blowers, plywood wall, tarpaulin wall, transparent plastic wall, and wheeled tables.

The ergonomic dust collector room gives better insight between the stakeholders of the industry. The top management can level up the productivity and down grade the accident and health cost. The workers have higher time utilization since they can finish the planned job on scheduled by healthier working environment.

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