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Application of Pareto principle and Fishbone diagram for Waste Management in a Powder Filling Process

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Abstract—This paper represents a detailed assessment on raw material waste generation of a semi-automated powder filling and packing process by applying certain quality tools such as Pareto Analysis and Fishbone Diagram. The aim of this study is to identify the sources or categories of raw material waste and analyse its underlying causes. Waste generation is an unavoidable incident in any production process which could even result in products with varied weights. The major waste source; "overfill" occurs when powder is filled more than the actual net weight resulting a loss in waste. Therefore identification of underlying causes for powder waste and a measure to minimize it, using monitoring and controlling is vital to maintain consistency of the product. In this paper, Pareto principle, a major statistical quality control tool is applied to identify the key sources of waste within the production line. In order to detect possible underlying reasons/factors, a fishbone diagram is applied.

Index Terms— Waste, Overfill, Root Cause, Pareto, Fishbone, Quality Tools

1. INTRODUCTION

Raw material waste generation is inevitable in every manufacturing process. The presence of waste is an indication that materials are not being used efficiently hence many companies are taking diverse approaches to minimize wastage to reduce drop in profitability levels and negative impact on the macro and micro environment. When considering the concept of waste management; zero waste is a visionary waste management system that has been presented as an alternative solution for waste problems in recent decades [1]. The organization subjected for the study has already embraced the concept of zero waste; therefore standard quality tools including Pareto analysis and Fishbone diagram are utilized to achieve zero powder waste in order to maximize operational efficiency as well as positive environmental impact. A filling and packing process of powder products is the central point of the study. Major objectives are to determine significant waste categories and analyze root causes as well recommend solutions for reducing the level of powder waste including product overfill. In order to reduce the total costs of quality due to rejects and defects, control must be at the point of manufacture or operation; quality cannot be inspected into an item or service after it has been produced.

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1.1. WASTE GENERATION IN FILLING & PACKING PROCESS

Target Weight	400g
Warning Limits	395-405g
Action Limits	394-406g

Powdered products, as with other food packaging, are subjected to regulations which govern the accuracy of the product package weight. Failure to meet this weight limits or under filling could result in negative consequences from a simple dissatisfied customer to a more serious accusation or penalties [2].Moreover, exceeding the weight limit or overfilling leads to raw material waste, increasing the cost of raw materials hence the company/packer should specify limits of overfilling to control unnecessary waste of raw material [3].

1.2. QUALITY TOOLS & ROOT CAUSE ANALYSIS

Among the many quality tools available for problem solving, the Pareto Diagram and Fishbone Diagram are the most important as they discover root causes and eliminates them, enabling continuous improvement of any process. Dr. Juran suggested the use of Pareto principle also known as the 80/20 rule to quality control for separating the "vital few" problems from the "trivial many" now called the "useful many". [4] The results of a Pareto analysis are typically represented through a histogram which is sorted from the highest frequency to the lowest frequency. It is also considered as one of the seven statistical quality tools in food industry applied frequently to break a problem into several parts and identify which parts directly affects the issue and which parts doesn't. Cause and Effect diagram is a schematic tool that resembles a fishbone that lists causes and sub-causes as they relate to a concern, also known as Fishbone diagram or Ishikawa diagram [5]. "Root Cause Analysis is a structural investigation that aims to identify the true cause of a problem, and the actions necessary to eliminate it". [6] If root cause analysis is used in a reactive mode, it provides objective identification of organizational faults. In the proactive mode, root cause analysis identifies and prevents future mistakes. [7] Various techniques used in a Root Cause Analysis (RCA) are; Why-Why Analysis (WWA), Brainstorming Sessions [8] as well as Corrective And Preventive Action (CAPA) plan. WWA is a methodology to inquire

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the root cause behind surface causes of a problem by asking —Why many times in succession. Corrective action is taken to eliminate the cause of a detected problem, which prevents it from recurring whereas preventive action is defined as an action taken to eliminate the cause of a potential problem from occurring [9]. After the identification of the root causes the CAPA plan is an essential quality tool that could be used to record the actions that are needed to successfully carry out the implementation to avoid repetition of problems.

2. Methodology

The study was conducted in a semi-automated powder filling and packing company. By referring to the "ISO 3951 sampling procedures for inspection by variables for percent nonconforming", sample sizes for data was determined. Inspection by measuring the magnitude of a characteristic of an item is known as inspection by variables. Inspection by variables for percent nonconforming items, as described in the part of ISO 3951, includes several possible modes and Reduced Inspection was carried in this research as directed by the responsible authority. [10] Both primary and secondary data sources were utilized as the basis for determining the current state of the process. By examining production records, secondary data was collected and the primary data was collected by observing and measuring packet weight over a continuous period of time.

In this paper, the major categories of powder waste formed throughout the production line was identified and analyzed by means of a Pareto diagram, and the quantities of waste was arranged in order to identify which source has the greatest impact on increasing overall powder wastage. The application of Pareto principle consisted of several steps.

Step 1: Collection of all data (powder waste) throughout the production line for a specific time period (six months)
Step 2: Determination of the number of columns/waste categories based on their sources.
Step 3: Arranging the categories in descending order of their individual contributions.
Step 4: Tabulating the individual contributions in percent of total and cumulative.
Step 5: Plotting the histogram

Once the Pareto analysis was performed the Fishbone diagram was constructed for to identify the possible factors that can be stated as the potential causes for waste powder generation. The causes were grouped into six categories including Measurement, Material, Methods, Machines, Personnel, And Environment (Fig. 2) [11]. Once the causes are available the root cause affecting the waste generation can be identified, analysis can be made and suggestions can be implemented to improve the performance of the process. The Fishbone diagram is a part of the Root-Cause-Analysis (RCA) which was performed to determine the root causes for powder waste throughout the production line. Several brainstorming sessions were carried out with the Production department as well as Quality Assurance and Engineering department to efficiently extract best possible ideas.

3. Results And Discussion

3.1. Pareto Analysis for Wastage Categories

After the powder waste occurred throughout the powder filling and packing process which was observed closely for a period of six months and a Pareto diagram was drawn highlighting the critical areas of waste generation. Each waste category based on each stage of the powder production process was prioritized by arranging them in descending order of magnitude. Pareto chart is used for preliminary identification of the most significant waste by giving the priority. It is worth noting that this method entirely eliminate the less significant wastes and does not explain the unexpected behavior of them. Therefore it is important to conduct further analysis on various other wastes to improve quality and productivity by reducing rejection of raw materials in this specific processing area.

The data from the table 1was transferred to the Pareto diagram to discover the "vital" problems accounted for 80% of waste problem. Outcome of the analysis is given in Fig. 1 Based on the Pareto principle, list of wastage categories were sorted out to focus where the most impact could likely have resulted in. The data indicated that overfilling waste; 92.0 % occurred most frequently than the other types. While the contribution by sieving wastage which is ranked second is 1.9%, the sweeping wastage contributed to a 0.5 % of total wastage. Metal detector wastage and debagging waste are the minority accounting for 0.2% and 0.1% respectively. It was seen from the above figures, namely 'overfilling' is the type in which most waste occurs and therefore focuses on monitoring and controlling overfilling was identified to be the most effective.

Table 1
Percentage Of Powder Waste Based On Their Categories

Powder Waste Type	Waste (kg)	Waste percentage	Cum: Waste	Cum: Percentage
Overfilling Wastage	1312.94	91.98%	1312.94	91.98%
Sieving Wastage	102.60	7.19%	1415.54	99.17%
Sweeping Wastage	7.80	0.55%	1423.34	99.71%
Metal Detector Wastage	3.30	0.23%	1426.64	99.94%
Debagging Wastage	0.80	0.06%	1427.44	100.00%
Total Waste	1427.44			

4774

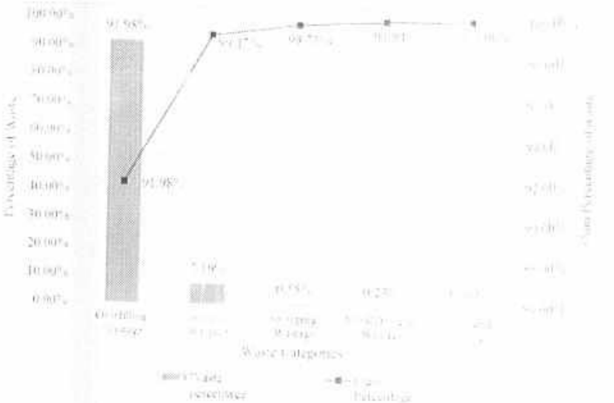

Fig.1. Pareto Chart indicating the percentage of bulk powder waste categories

3.2. Root Cause Analysis for High Powder Waste

The RCA consists of a Fishbone diagram, a Why-Why Analysis and a Key Corrective Action & Preventive Action (CAPA) plan. The potential causes that can have an effect on the waste generation of the powder filling and packing process are identified by the Fishbone diagram given in Fig. 2. These potential causes were identified by brainstorming which is considered to be an effective technique for identifying the categories of causes utilizing an informal approach to problem solving with lateral thinking. The brainstorming sessions contributed nearly around 30 potential causes which were then reduced to 19 unique ideas by eliminating redundancies and formalizing standard definitions. Under categories of causes namely measurement, material, method, maintenance, personnel and environment, factors that may be affecting the cause were listed. A summary of the major categories with their key causes is represented in Table II. With reference to the Fishbone Diagram three key root causes are selected which thought to be affecting the problem statement directly. These factors are used in a Why-Why analysis in order to unearth hidden or deeply buried reasons as shown in Table III. Major reason behind product overfill is manual weight measuring and adjustment and lack of proper training regarding weight control and adjustment. They were identified as the reasons for operator incompetency. These two factors are considered as rank 1 & 2 as they directly impact high powder waste. After a detailed analysis of the actual root causes for high powder waste, the corrective and preventive action plan (CAPA) was suggested as shown in Table IV. As a temporary solution for the product overfilling, a display of daily overfills was arranged. Overfilling waste calculated and displayed in the production floor as a controlling step and data was updated on hourly basis. Process monitoring was made easy with this implementation and corrective actions were easily taken without delay. Another key cause for high powder waste was considered to be the operator incompetency and lack of focus. Therefore instituting ongoing- on the job training programs for all floor level workers and machine operators was the best way to create awareness on waste management as they will then have the knowledge to do their own root cause analysis during day to day activities to solve minor problems.

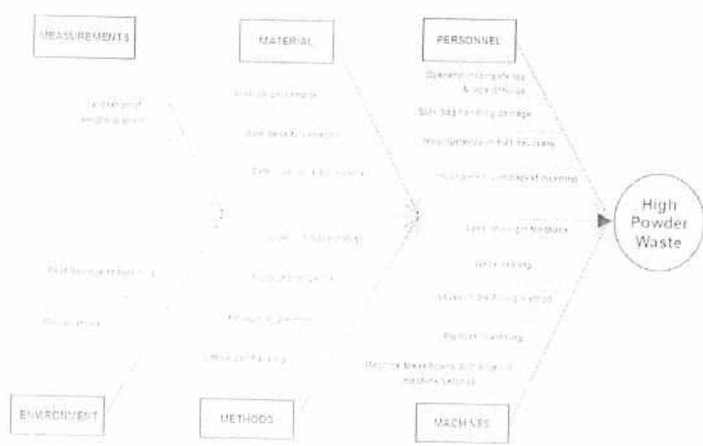

Fig 2. Cause & Effect Diagram for High Bulk Powder Waste

Table 2
Categories and Causes for High Powder Waste

Categories	Key Causes
Measurement	Calibration of weighing scales
Material	Defecting packing material
Personnel	Operator incompetency and lack of focus
Environment	RH Variations
Methods	Production Planning
Machines	Product Overfilling

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TABLE 3
WHY-WHY ANALYSIS FOR KEY ROOT CAUSES

Cause	Why 1	Why 2	Why 3
Product Overfilling	Weight variation	Lack of proper feedback mechanism to control weight	Manual weight measuring and adjustment
High number of dry and wet cleaning	High number of machine changeovers	Sudden changes in the production planning	Demand fluctuation in market
Operator incompetency and lack of focus	Lack of proper mechanism for weight control and adjustment	Lack of training for workers regarding weight control and adjustment	

TABLE 4
RECOMMENDED KEY CORRECTIVE ACTION & PREVENTIVE ACTION (CAPA) PLAN FOR KEY ROOT CAUSES

Rank	Root Cause	Action	Who
1	Product Overfilling	Installation of a check-weigher system	Engineering Manager
		Monitoring & Controlling overfilling quantity through Visual displays	Production Manager
2	Operator incompetency and lack of focus	Additional training on machine setting adjustment and weight variation reduction	HR manager
3	High number of dry and wet cleaning	Streamline production planning	Warehouse Manager

4. CONCLUSION

Pareto analysis is one of the tools that can be used to statistically identify and analyse critical issues that arise in processes. Bulk powder waste and its sources were evaluated at each stages of powder filling and packing process, with special emphasis on overfill waste. Whilst overfilling waste was significantly the major source or the "vital few" of total bulk powder waste; 92.0%, according to the pareto analysis, others are "trivial many" are: sieving waste, sweeping waste, metal detector waste, debagging waste which is 8.0% of the total waste. So more importance should be given to the vital few wastes and its root causes.

To identify underlying causes of overall powder waste a RCA was performed. After several brainstorming activities a Fishbone diagram was formed and the key root causes for powder waste were identified as follows:

- Product overfilling
- High number of dry and wet cleaning
- Operator incompetency and lack of focus

A Why-Why analysis was carried out for each cause to test the underlying reasons and subsequently key CAPA plan was designed with actions recommended for each major cause for waste generation.

5. ACKNOWLEDGMENT

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