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A SEMINAR PAPER ON "OVERALL EQUIPMENT EFFECTIVENESS: A CASE STUDY AT A BOTTLING PLANT"

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Abstract— **Overall Equipment Effectiveness (OEE) is the crucial tool of Total Productive Manufacturing (TPM). OEE evaluates the workability of the equipment in relation to its performance capacity provided that it should be operated in the optimal manufacturing conditions. It considers the whole manufacturing environment not merely the availability of the machine for performing the particular work, but also the efficiency of the product during the equipment availability together with losses in efficiency due to various factors such as yield waste, rework, scraps, etc. Such analysis provides a broad view of machine operation and manufacturing efficiency and assists to formulate efficient strategies to enhance the productivity of the manufacturing line.**

This paper implements the OEE tool to identify the root causes responsible for affecting system line efficiency. For this, a case study on a production line of VBNPL, one of the reputed beverage companies in Nepal working as the franchise of the international brand "PepsiCo. Int", is done. Initially, the OEE of a single production line called "GRB 400" is calculated by recording the total planned breakdown, unplanned breakdown, and filler breakdown. Onwards, becoming specific the OEE of the Filler is computed and all possible reasons for the drop in the efficiency are identified, for instance falling of bottle, bottle burst, bottle jam, loose vent tube, etc. by using various techniques such as Pareto chart and Fishbone diagram. Finally, suitable recommendations are provided to mitigate the issues that hampered the efficiency of the production line.

Keywords— **Overall Equipment Effectiveness (OEE), Net Efficiency, Availability, Performance, Quality**

I. INTRODUCTION

In the face of current global competition and increasing demand, the requirement to improve manufacturing performance is obviously a greater challenge as well as an opportunity for increasing the effectiveness of the manufacturing process. Overall Equipment Effectiveness (OEE) is one of the best practical ways to check and upgrade the manufacturing methodology (i.e., equipment, manufacturing units, assembly units, etc.). It is not sophisticated but rather a more pragmatic approach.

The book called "Introduction to TPM: Total Productive Maintenance." first mentioned the concept of OEE [1]. Prior to the invention of the concept of OEE, downtime or availability was employed for checking the performance of equipment. But after the realization of the fact that there could be the same downtime for the same machinery for different time intervals and can lead to a different output, then it was not much reliable means for scrutinizing the performance of machines. For instance; if the production line has a breakdown time of 10 hours out of the total 100 hours of operation, then it has 90% of availability and 10 % of breakdown. Further, if the same line has 10 times broken down with one hour in each, then at this time also there is the availability of 90% and 10% of downtime [2]. Even though the result shows the same mathematical output but in the practical case the first approach has more output than the second case. It is due to the fact that every time the plants stop then the associated quality loss is also largely due to rework or scrap. And there is the chance of speed loss during each start until it reaches full speed.

Thus to consider the associated factors that can generate the loss and address the parameters that significantly impact the productivity and output of the system, and provide an efficient measurement system for line productivity, the concept of OEE was conceived.

The mathematical relation for the measurement of effectiveness is given below.

- Overall Equipment Effectiveness or "OEE" = Rate of performance* availability*rate of quality

Six losses affecting OEE are:

Affecting availability:

- Losses due to breakdown
- Losses due to adjustment and setup

Affecting rate of performance:
- Losses due to stoppage and losses due to idling
- Losses due to reduced speed

Affecting quality rate:
- Losses due to the defect in quality and losses due to rework.
- Losses due to the start-up (yield)

In recent days including all the above losses, another loss called Planned Downtime loss is included giving overall seven losses. It falls under availability and tries to capture all possible losses such as regular maintenance periods, meal breaks, the start of a new shift, etc. [3].

II. LITERATURE REVIEW

A. What is OEE?

Overall equipment effectiveness or simply OEE is the efficient approach to quantify the performance of the machines or system of the production unit which is utilized as the tool for monitoring and upgrading the productivity of machinery and the quality of the product. In mass production firms or industries, the role of OEE is crucial for checking productivity where the factors like quality, availability, and productivity are considered [4].

There are lots of manufacturing companies where the effectiveness of the plant and the quality output determines the company's performance and help to identify excellent companies. One of the very efficient indicators for measuring plant efficiency is OEE. This tool helps to provide the periodic evaluation of the performance of equipment and machines which is then used to emphasize the factors which cause the lagging of the performance and upgrade the performance by properly interpreting the outcomes of the evaluation. Thus, efficient evaluation of OEE helps to accomplish continuous improvement.

It is crucial to check the safety conditions of the organization in which the conditions of the machinery, equipment, assigned approach, etc. determine safety as well as productivity. OEE can be used as the efficient indicator for checking the safety conditions of the work area and machinery where the proper evaluation of the outcomes of OEE can be used for identifying bottlenecks, identifying the process that is hampering the production, determining the actual performance capabilities of the system and finally for enhancing the productivity with the aim of gaining the world-class performance. Different types of wastes and the downtime that reduces the ability of machines are mentioned in the OEE along with the root causes and the appropriate solutions for them [5].

The OEE not only emphasize the optimum method but also such an approach that is pragmatic and simple while implementing them for bringing improvement in the production [6].

In one of the research projects, it was found that the effectiveness of total productive maintenance, or TPM was highly dependent on the effectiveness of the system, devices, and machinery [7]. It is because the appropriate reasons for failures or breakdown of equipment are properly elaborated by OEE which is very essential for the successful implementation of TPM. OEE helps to identify the different types of losses in production firms and their associated costs.

B. Constituents of OEE

The parameters of OEE are availability, performance, and quality. Further, these factors help to find out the different losses associated with them which are jointly called six big losses [8].

Table-1 OEE elements

Rate of availability	**Performance efficiency**	**Rate of quality**
Losses due to breakdown or losses due to failure.	Losses due to reduced speed.	Losses are due to rework and defects.
Losses due to adjustment or setup	Losses due to small stoppage and idle time.	Losses due to start-up.

C. Six big losses

The six big losses are briefly elaborated on below.

i. Break down losses

Due to the failures of the machine at different time intervals and due to chronic breakdown, the machine has to become idle and eventually increases rework, scraps, etc. Such losses are called breakdown losses. The major causes of the occasional failures are due to working approach, tools conditions, due to jigs, etc., thus the healthy condition of equipment and parts, and efficient methods are essential to minimize occasional failures. Further, chronic failures are caused by hidden defects. Such chronic failure is difficult to address with countermeasures. The root cause analysis is done for finding the causes of breakdown loss.

ii. Setup and adjustment losses

The time of the set up as the name indicates measures the time between the last products manufactured prior to setup and the product manufactured after the setup. At this time different types of activities are conducted to produce a quality product in a smooth way where tasks like changing fixtures, changing jigs, cleaning tasks, etc. are performed.

iii. Small stop

In the small stops, the machine is in the ide conditions due to some short-term issues on the machine which cause the obstruction in smooth production.

iv. Reduced speed

Such types of losses occurred when the machine does not perform its operation at its optimum speed

v. Startup rejects

This is the type of loss that occurs when the machine starts working after the holidays, after repair, after repairs, or afterward suspension. Rejection during the start-up and the rejection of production are different as their root cause are different. Those products which require rework as termed as rejects.

vi. Quality defects rework losses

There are different losses that occur due to rework, and because of poor quality of the product. It also includes losses of time because of corrective maintenance activities. Such losses are called rework losses and rejection losses. They are also called production loss rejects.

The six big losses are described below based on the three crucial factors.

- **Efficiency of availability**

Any activities that halt the production process for short to long time intervals are considered in availability. It includes the time of changeover, shortages of material, failure of equipment, etc. Time of changeover leads to downtime so it is considered to get good operational efficiency. Although the time of changeover can be minimized, it cannot be completely eliminated. The time during which a machine is functional and giving intended deliverables is called operational time.

- **Efficiency of performance**

Any activities that negatively impact the optimum working speed of the machine system are considered in performance. This is usually caused by the selection of poor quality material, wear of the machine, inefficiency of the operator, and misfeeds. The time which is spent on any such events that cause performance losses is when excluded, it is called net operating time.

- **Quality efficiency or rate**

Any product that does not satisfy the quality standard is considered in this section of quality efficiency and it also considers those tasks which require rework. Time other than such rework is called fully productive time. Thus, the goal of any firm or industry is to maximize productive time[9].

D. **Calculating OEE**

OEE can be mathematically computed by equation method or model of unit loss or time loss.

I. **Using Equation**

Availability = (Available time-All recorded downtime)/ (available time)

Where;
All downtime recorded = planned downtime + changeover or setup downtime + unplanned recorded downtime
Available time = total time – planned downtime [8]

Performance rate = (Ideal cycle time *Total Count)/ (Run time)
Where the total count is the total number of products that are produced

Quality = (Good Count)/ (Total Count)

Where Good Count is the total product produced that meets quality standards and the total count is the total amount of products produced

Thus
OEE = % Availability * % Performance rate * % Quality

Table-2 Different types of losses

Total time				
Available time				Planned downtime
Running Time			Unplanned downtime	
Productive time		Performance losses		
Value adding Time	Quality losses			

E. World Class OEE

In a simple way, OEE measured the time which is fully productive to that of the time which is actually planned. Nevertheless, it computed the three major factors described above. Due to such calculation, OEE calculation becomes a bit tough. For instance, if the value of all those major factors is 85% then, the overall value of OEE becomes 61.5%. In a practical scenario, the goals of each factor are different in general [10].

Table-3 OEE of World class

Factors of OEE	World Class
Quality	99.9%
Availability	90.0%
Performance	95.0%
OEE	85%

F. Benefits of OEE

A reactive maintenance approach based on the reports of the breakdowns and the decisions of the product manufacturing based on the schedules of the plant is not considered effective. Rather than this, proactive decisions based on the analysis of the process bottleneck constraints, efficiency, throughput, and effectiveness obtained from the OEE are highly efficient approaches for maintenance. The patterns of equipment failures and their impact on productivity can be evaluated and analyzed from OEE. Further, it helps to identify the root cause and help to give a suitable solution [11].

The causes of the downtime are covered in the OEE which can be due to the conditions of the machine, status of material, workers, or because of quality. Real-time process improvement can be achieved by finding the root cause of the issue and by getting the updates at frequent intervals from the OEE metrics [12].

G. Limitations of OEE

Although the method proves to be very useful there are some limitations of this method. These limitations are stated as follows:

- The application of this method requires some more skilled employers in the plant whose sole duty should be to look after the equipment and the taking all the necessary data.
- A person having experience of practice the OEE method is required initially so that the company gets a better interpretation of the results. Otherwise, people will get misled by the results obtained. The data obtained from the method is to tap down the hidden losses.

III. RESEARCH METHODOLOGY

A. Study area selection

Since it is a case study done on a production plant thus Production line of Varun Beverage Nepal Private Limited is selected to collect the relevant information.

B. Data collection

Primary as well as secondary sources are employed for the data collection in order to complete this seminar work each of which is described below:

- **Primary data**

Since I have done an internship at VBNPL, I got opportunities to understand the engineering practices on production, problem identification, and solution to those problems encountered in the VBNPL. I have used my 90 days of internship program experience to prepare this seminar paper.

Some of the sources of data collection are given below:

- All major breakdowns that occurred during my internship period are collected by direct observation
- Some essential information is collected with the help of the shift engineer.
- Light inspection workers also assist in collecting information such as the number of bottles rejected.

- **Secondary data**

I review different research papers, articles, and journals to develop an idea about OEE methods and their calculation process.

IV. PRODUCTION PROCESS OVERVIEW

The different sections involved in the complete production of the beverage; i.e., from the unloading section where glass bottles are loaded in the conveyor from the casing for washing up to final loading in the pallets, in GRB-400 production line of VBNPL are depicted in the diagram below in sequential order.

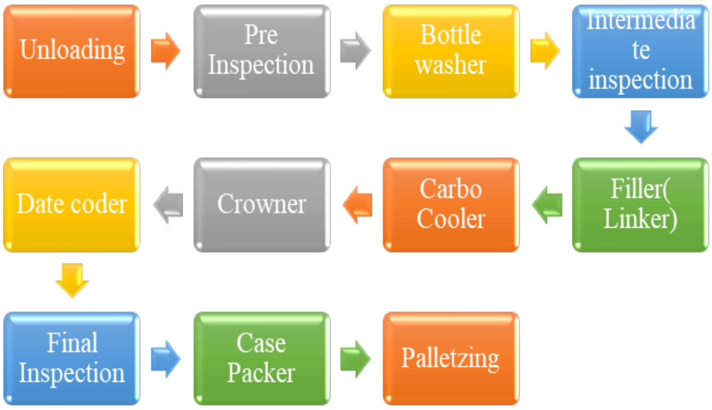

Figure 1: Production stages

- **Principle of filling**

The carbonated beverages are filled into the bottles via Counter Pressure Filling Mechanism. For that, it requires high-speed equipment called counter-pressure fillers. There are different kinds of counter-pressure fillers; however rotary type counter-pressure filler is used in the case of automated high-speed lines. The larger the circumference of the filler bowl, the greater number of bottles that can be filled.

At VBNPL, Linker has 60 whereas Hansa has 40 filling valves. In the process of filling, bottles from the Infeed timing screw let the bottles pass to the fillers. The bottles are lifted up and sealed with the filling valves by lift cylinders. The first and foremost condition for filling is proper sealing. Without proper sealing, the filling cannot commence. Then, CO_2 is injected into the bottles through the vent tubes until the pressure between the bowl and the bottle becomes equal. Once the pressures are balanced the gas valve gets closed and the beverage valve gets opened. However, the gas valve is closed by the actuator which is placed at a calculated distance from the point where sealing is made. The beverage valve gets opened as soon as the pressure gets balanced. The beverage starts flowing inside the bottles by means of gravity flow. Since the beverage is heavier than CO_2, the CO_2 within the bottle is replaced by the beverage. The level of filling is maintained by the size of the vent tube. That means the bottle is filled until the level of the beverage inside the bottle gets to the tip of the vent tube. A short settling period is permitted prior to the closing of the liquid valve and the gas within the bottle headspace is allowed to escape in a controlled way which is also called snifting. This is required to reduce fobbing and loss of beverage.

V. RESULTS AND DISCUSSION

A. Results

A.1 Analysis of OEE

The analysis is done by collecting the data of production for 10 days at the GRB 400 line. Table 4 attached below provides comprehensive information on all major breakdowns of different sections of a production line, along with information on the production and rejection.

Table-4 Data collected to calculate the OEE of a line

Date	Total time	Filler speed	Planned breakdowns (hrs)	Unplanned breakdowns (hrs)	Filler breakdown (hrs)	Operating hours	Production	Rejection
14	15.25	375	2.25	1	0.5	12	7277	205
15	15	375	2.25	0.5	0.5	12.25	6978	132
16	15	375	2.25	1.5	1.5	11.25	6311	121
17	15	370	2.5	3.25	3	9.25	6581	109
18			0	0	0	0		
19	24	370	5.5	0.5	0	18	8023	200
20	24	375	2.75	1.5	1.25	19.75	13600	240
21	24	370	4	1	1	19	11649	198
22	24	370	3	1.25	0	19.75	14157	273
23	24	375	0.5	0.25	0	23.25	16800	241
24	21.5	375	0.5	2	1.25	19	13691	229

After that, the average OEE is computed which is shown in table 5 below:

Table-5 OEE calculation of a line

OEE Parameters	Calculated values
Availability	91.9%
Performance	67.9%
Quality	98.1%
OEE	61.24%

To visualize the losses that occur in different section pie chart is constructed as in **figure 2**.

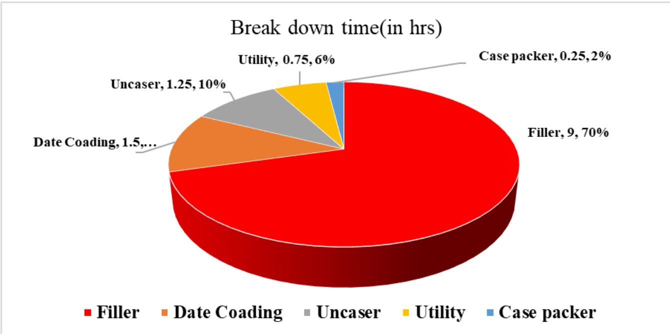

Figure 2: Pie chart to show breakdown hours in a different section of a GRB 400 line

Filler consumes the majority of the time of breakdown. Thus, taking the observation time of eight hours for three days OEE of the filler machine is calculated and factors responsible for losses are identified.

Table-6 Data collection for computing the OEE of filler

Total production (in bottles)	Reject Bottles	Observed hours	Planned downtime(hrs)	Unplanned Downtime(hrs)	Ideal run rate
105334	2134	8	1.5	0.62	385
88883	2483	8	2	0.83	385
93559	2359	8	0.75	0.75	385

After collecting data, the OEE of the filler line is calculated by taking averages of three days of observation which is tabulated in table 7. In addition, the factors responsible for causing losses are categorized and shown below in table 8.

Table-7 Possible causes of filler problems

Sr. No.	Losses Reasons	Frequency	CF	percentage
1	Bottle falling	21	21	34%
2	Looses vent tube	16	37	61%
3	Bottle brust	12	49	80%
4	Bottle shortage	5	54	89%
5	Crown path obstructed	3	57	93%
6	Bottle jam	2	59	97%
7	Bottle obstruted on spiral drive	2	61	100%

Based on the frequency of occurrence, the Pareto chart is constructed as shown in figure 3. This chart illustrates that the majority of obstruction in production is brought by bottles falling on the conveyor. Similarly, the loss vent tube is also a crucial factor for the obstruction in production. Moreover, bottle shortage in the filling section, bottle jam in the conveyor, spiral drive problems, and others issues such as misalignment of vent tubes, the problem with the lever, etc. are also responsible for hampering smooth production.

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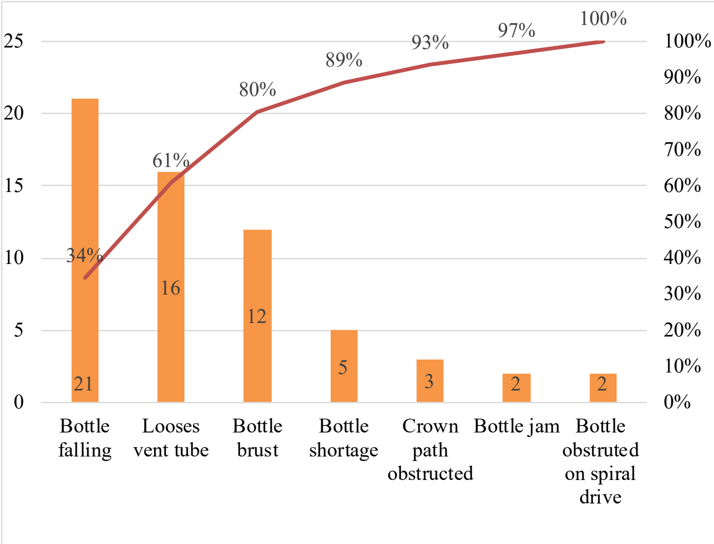

Figure 3: Pareto chart to show events and their frequencies of occurrences

B. **Discussion**

The possible reasons that curtailed the availability of filler machines are listed below:

- Breakdown of the filler valve
- Loses vent tube
- Problem with the lever of filler
- Misalignment of vent tube with a bottle
- Bottles get obstructed in the secondary spiral drive

The potential factors that cause an impact on the performance of filler machines are given below:

- **Unable to meet the capacity of the machine.**

The rated capacity of the machine of that line was 400 Bottles per minute "BPM" but it was operated on 350 to 385 BPM.

- **A minor stoppage such as stopping the filler due to the bottle falling on the conveyor.**

It is clearly illustrated from the Pareto chart in figure 3. that the frequency of bottle falling is significantly high than other factors, where the falling was recorded 21 times in the period of eight hrs.

The main causes of the bottle falling are discussed in the following points:

- ➢ The base of the glass bottle, due to excessive sliding, weaken the grip which led to the slippage of the bottle.
- ➢ Due to the lack of a sufficient SUV in the conveyor.
- ➢ Because of the sudden rise of the speed of a conveyor while meeting another conveyor.

Since only 97.97% of the quality rate is obtained from the calculation. The various possible causes for not being able to reach world-class OEE i.e., 99.9% are discussed below:

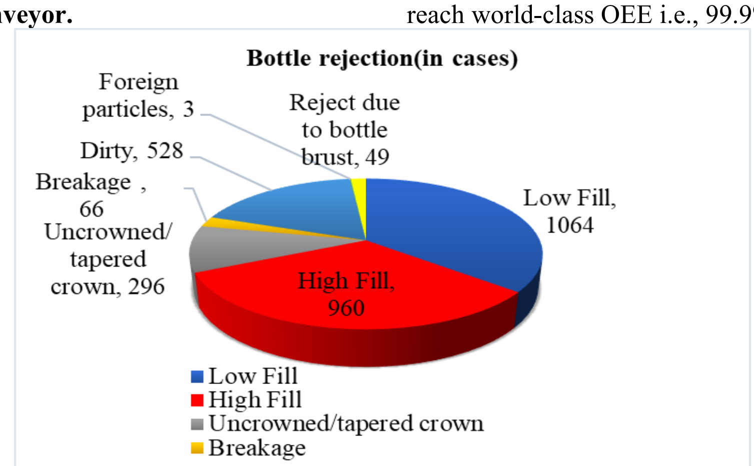

Figure 4: Bottle rejection causes

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The above pie chart in figure 4 illustrates the average number of bottles rejected during the period of eight hours for three days along with the factors which cause rejection.
While analyzing the chart, it is noted that a significant proportion of rejection of the bottle is occupied by the low fill factor, which was followed by high fill, dirty, crowing issue, breakage, bursting of the bottle, and finally foreign particles inside the bottle.
While working on the production line it is essential to check the safety of the operator while meeting the production demand. Bottle bursting is one of the serious issues where a bottle made of glass gets exploded while filling or while putting a crown. Such bursting of the glass bottles could cause safety threats as pieces of the shredded glass coming out from bursting could hurt the worker and lead to injuries that could be minor and sometimes major injuries. Additionally, bursting not only risks the life of the operator but also hampers production.

B.2.1 Fishbone diagram of bottle bursting

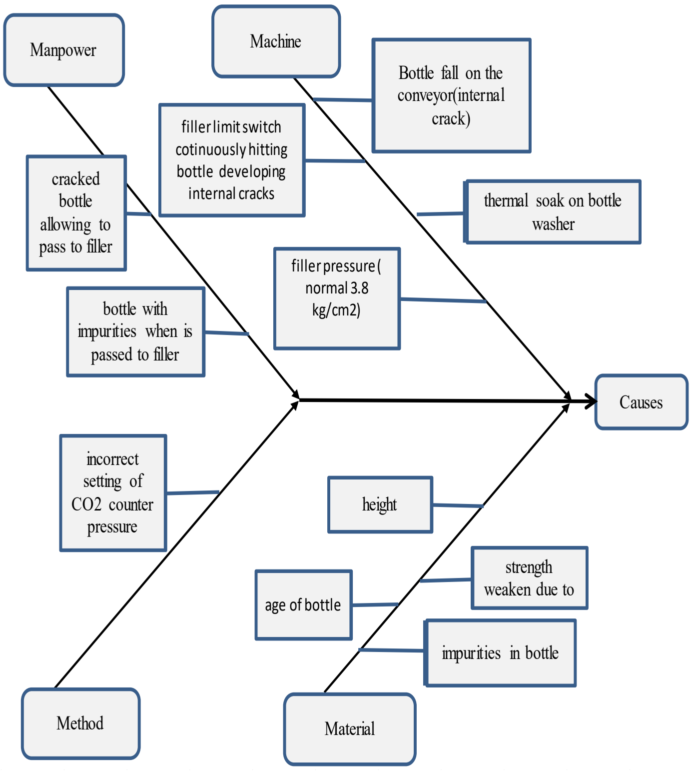

Figure 5: Causes of bottle bursting in the fishbone diagram

Causes of bottle bursting:

a) Manpower

➢ **Passing the cracked bottle to the filler section.**

When the bottles get passed from the washer section, they passed along with the conveyor where there is a light inspection section to observe any dirty and cracked bottles prior to allowing the bottles to pass along with the conveyor to the bottles filling section. However, due to poor inspection, sometimes bottles that had cracks were forwarded to the filler section, and bottles were unable to withstand the filling pressure got burst.

➢ **Passing bottle with impurities to the filler section.**

Due to the negligence of the operators of the light inspection section, when bottles with impurities were passed to the filler section, then the impurities caused the dissolved carbon dioxide to release out which consequently exerted more pressure while filing and ultimately lead to bursting.

b) Machine

➢ **Bottle falling on the conveyor (internal crack)**

Since there is, frequent falling of bottles on the conveyor, this causes the bottle to get weakened and develop internal cracks which lead to the bottle bursting while filling.

➢ **Thermal soak on bottle washer**

The bottle is exposed to temperatures up to 80 degrees Celsius in a bottle washer. The operator, during the initial hours of run, has to manually open the valve to increase temperature. Due to this temperature of each compartment of the bottle washer get increased; meanwhile, the bottle coming out from the bottle washer sometimes have a temperature in the range of thirty to thirty-five degree Celsius. Hence this leads to a temperature difference of more than twenty-five degrees Celsius, which causes a thermal soak. Moreover, the filling is done at a very low temperature, which is two to five degrees Celsius (except "Mirinda beverage" which is done at ambient temperature due to the low gas volume in it). Therefore, the high-temperature difference experienced by the bottle can also be the reason for the bottle bursting while filling.

➢ **The filler limit switch continuously hits the bottle**

The limit switch in the filler continuously hit the bottle. Moreover, the Teflon coating of the limit switch eroded over time and the metal parts get exposed which when hit the bottle, the bottle may develop internal cracks. Thus, it causes a decrease in the strength of the bottle can lead to a burst while applying pressure during filling.

➢ **Filler pressure**

When the filler pressure exceeds normal pressure, which is 3.8kg/cm^2, it causes bursting.

c) Method

➢ **Incorrect setting of CO_2 counter pressure.**

When carbon dioxide pressure is set above normal value then it can lead to bottle bursting.

d) Material

➢ **Strength weakens due to falling**

Since the bottle falls on the conveyor, it develops an internal crack, which leads to bursting while filling.

➢ **Impurities in bottle**

Impurities in the bottle cause the ejection of dissolved carbon dioxide from the beverage and thus causes bursting.

➢ **Age of bottle**

Unlike PET bottle, glass bottle is reused repeatedly by performing cleaning action in it. Since different ages of the bottle are treated at the same time thus some bottles may have got weakened due to frequent use. This causes the bottle to decrease its internal strength and thus may get burst while filling.

➢ **Height**

The bottles of different sizes and volumes may get misplaced. Since, unlike 250 ml bottle there is also 300 ml bottles available in the Indian market, which have nuance difference from the ones which are filled in Nepal. Thus, while collecting empty bottles from the border side, in a hodgepodge such bottles also get misplaced. Therefore, in the filling section due to improper alignment of the bottle height with the filler, bursting may occur.

B.2.2 Fishbone diagram of the low-fill and high fill

Similarly, most bottle rejection occurs due to low fill and high fill in a bottle. The reasons behind low fill and high fill are discussed below:

The various causes behind the low fill are shown in the fishbone diagram in figure 6 below.

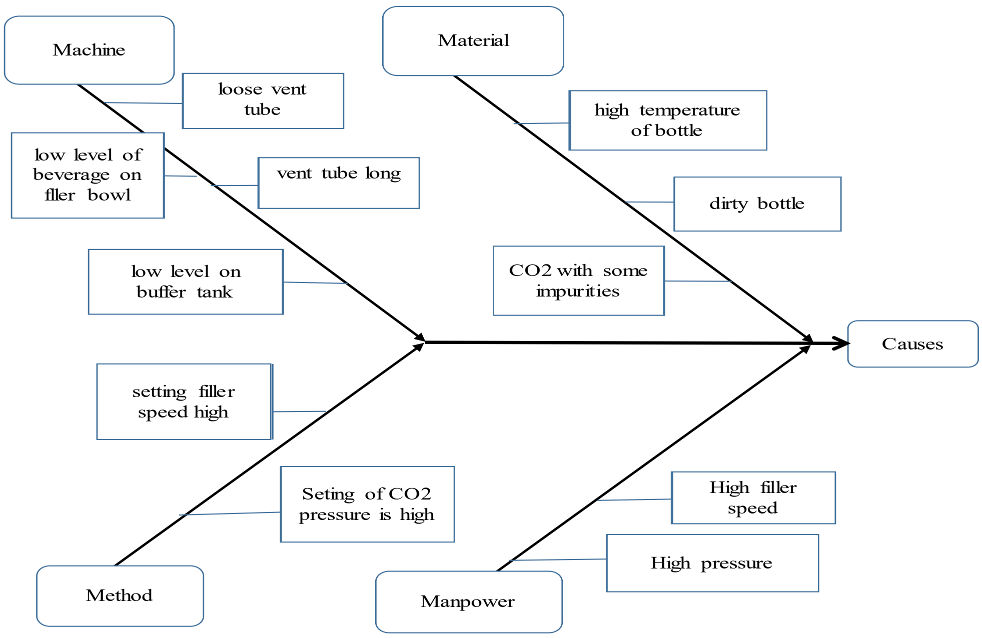

Figure 6: Causes of low fill in the fishbone diagram

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a) Machine

- **Low level of beverage on filler bowl**

When there is a low level of beverage on the filler bowl due to the throttling valve not working, it leads to low fill.

- **Low level of beverage on buffer tank**

- When there is a low level of beverage in the buffer tank, this also causes low fill.

- **Loose vent tube**

A loose vent tube causes the vent tube to get more dipped into the bottle causing low fill.

- **Long vent tube**

When the vent tube becomes long then it causes low fill since it causes the vent tube to dip more into the bottle and thus beverage is filled up to its lowest end.

b) Method

- **The setting of CO_2 pressure**

Normal filler pressure is 3.8 Kg/cm2 to 4.2 Kg/cm2. When pressure exceeds the normal value, the beverage is pressurized to return to the buffer tank thus causing a low level of beverage in the filler bowl which causes low fill.

- **Setting high filler speed**

When the filler speed becomes high (normally operated filler speed is 385 BPM) then it is obvious that the bottle gets less time in contact with the filler valve thus causing the low fill.

c) Material

- **The high temperature of the bottle**

CO_2 always dissolve in the beverage at low temperature. The high temperature of the bottle leads to the bubbling of Carbon dioxide and escaping out of gas along with the beverage.

- **Dirty bottle**

Impurities of dirty bottle cause dissolved Carbon dioxide to release.

- **CO_2 with impurities**

When there are impurities mixed with CO2 then CO2 does not get properly dissolved in the beverage and the beverage is bubbled out with undissolved CO2 prior to crowning.

d) Man Power

- **High filler speed**
- **High pressure of filler**

B.2.3 Causes of high fill

The various reasons behind the high fill are discussed below:

- **Short vent tube**

A short vent tube obviously causes high fill.

- **Damaged seal of the lift cylinder**

When the seal of the lift cylinder gets damaged, the bottle doesn't get adjusted to the appropriate height shifting a little below the required height. This causes the vent tube tip to remain at the top position than the required height which results in high fill.

- **Damaged seal of the filler valve**

Liquid valve seal when get damaged then sealing doesn't work properly causing. This causes the liquid to fall continuously even if the valve is closed thus causing a high fill.

- **Filler getting stopped**

B.2.4 Causes of crowning issues

Uncrown and tapered crown is mainly due to problems in crowning which are discussed below:

- Unable to transport crown from circular cavity to dye area due to obstruction in the path.
- Falling of two crowns simultaneously.
- Due to the lack of crowns.
- Unable to seat the crown in the dye area etc.

B.2.5 Causes of dirty bottles and foreign matter in bottles

The main reasons behind the dirty and foreign matter in bottles are discussed below:

- One of the prime reasons behind the trapping of foreign matter in the bottle is the negligence of workers in the light inspection center where they pass the bottles with foreign matter (such as gutkha covers etc.) along the conveyor.
- Sometimes broken glass pieces are seen inside the bottle which is due to pieces trapped when nearby bottle get burst.

VI. CONCLUSION AND RECOMMENDATION

A.1 Conclusion

By observing and analyzing the production data of the carbonated soft drink production line for the glass bottle filling section it is noted that among different sections (such as filler section, date coding section, un-caser section, case packer section, utility section), major losses are incurred in filler section while calculating the OEE of line. After that, the OEE of the filler section is computed which is obtained as 61.8% which is comparatively less. The various factors that are responsible for the reduction in OEE of the filler section are discussed. Since OEE is affected by these factors: availability, performance, and quality, thus causes behind availability losses, performance losses, and quality losses are tried to figure out. Causes for availability losses are identified which are due to the breakdown of the filler valve, the loose vent tube, the problem with the lever of the filler, misalignment of the vent tube with a bottle, and bottles getting obstructed in the secondary spiral drive. Similarly, causes for performance losses of the filler section are listed such as unable to meet the optimum operating capacity of the filler machine, and frequent minor stoppage of filler (while bottle falling on the conveyor, due to bottle shortage). Finally, causes for quality losses are scrutinized which are low fill, high fill, dirty bottle, uncrowned and tapered crown, bottle burst, and foreign materials in the bottles.

A.2 Recommendation

Recommendations regarding the improvement of the overall equipment efficiency based on the analysis of losses are given below:

- Different causes for availability losses are a breakdown of the filler valve, the loose vent tube, the problem with the lever of the filler, misalignment of the vent tube with a bottle, and bottles getting obstructed in the secondary spiral drive. Strategies regarding preventive maintenance should be designed to check those issues such as while starting a new batch of production all the filler valves should be inspected properly. Further, threading should be checked so that vent tubes do not get frequently loosed.
- Among different causes for performance losses of filler section, two major factors are unable to meet the optimum operating capacity of the filler machine and frequent minor stoppage.
  - For the first case, it depends on the operators who are running the machine. Since the optimum capacity of the machine is 400 BPM but it is noted that it was operating on 350 to 380 BPM. Thus, when it is operators are made aware of the losses associated with the less operating capacity fixation, they will operate the machine at optimum capacity.
  - For the second case, the majority of minor stoppages are recorded due to bottles falling on the conveyor while delivering to the filler section. To check the bottles, the filler operator stopped the filler machine and work on reloading the bottles on the conveyor. To prevent such stoppage, it is necessary to check the SUV on the conveyor periodically. Additionally, if the workers in the light inspecting sector assist to reload fallen bottles, the operator of the filler section doesn’t have to frequently shut down the filler. In the same way, the base of bottles should be inspected. It is because if the grip projection of the base of the bottles is eroded due to continuous sliding, then it causes the bottle to slip.
- Different possible factors for quality losses are discussed which are low fill, high fill, dirty bottle, uncrowned and tapered crown, bottle burst, and foreign materials in the bottles.
  - The various causes for low fill have been discussed in the previous chapter. It is found that continuous use of loose vent tubes has caused a significant impact on low fill. Thus, it is recommended to fix the problems prior to running a new batch of production by properly fastening the vent tube. Similarly, implementation of the 5S strategies (one of the efficient continuous improvement tactics where “S” implies: sort, set in order, shine, standardize, and sustain) while keeping the tools and spare parts nearby of the filler section will be effective. Time and often it was noted that the vent tubes of one product such as Mirinda gets mismatched with others such as Mt. dew. This generates the issue of low fill. Thus, such activities should be checked properly by properly arranging the spare parts.
  - Similarly, for high fill, it is found that most of the time damaged seal of the lift cylinder was responsible for it. Since there is no system to check the seal prior to new batch production, this caused the damaged seal to undergo an operation. Thus, it is quintessential to ensure the seal of the lift cylinder is in good condition before the new batch production operation.
- There are different reasons for bottle bursting which are already discussed. Since it also causes injuries to the operator, thus safety practices should be implemented strictly by wearing personal protective equipment. The major factor for bottle bursting is found due to the age of the bottle and due to developed internal cracks. Therefore, it is recommended to adopt the state of art electronic light inspection system which can easily detect internal cracks which otherwise unable to identify by workers in the light inspection section.
- Dirty bottles and foreign materials in the bottles also have a significant impact on bottle rejection. Since there are two sections prior to the filling section in order to inspect the bottles, and impurities which are done by workers in the light inspection section. Thus, they are directly and indirectly responsible for this rejection. They should be made aware and alert of losses. In addition, job rotation should be done for workers who are continuously involved in the light inspection section so that it becomes effective to filter the dirty bottles.

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