International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-03, Issue 04, May 2017

Reliability Study of Tea Industry

[1]Debapriya Roy, [2]Dr. S. Mukherjee

[1]Post Graduate Scholar, [2]Professor, [1,2]Department of Mechanical Engineering, Jalpaiguri Govt. Engineering College, Jalpaiguri, India.

[1]royz137@gmail.com, [2]sudipmukherjee_63@rediffmail.com

Abstract: The concept of reliability is necessary in the study of 'Maintenance Planning and Control'. Improving the reliability is synonymous to better quality and productivity of an industry. This work identifies the scale of possible improvement in the measure of reliability by addressing each section of a tea industry. In doing so, the processes in a tea industry have been studied. During the analysis of each process, the existing reliability is determined and the scope for reliability improvement has been identified at each section. Reliability analysis of each section has been carried to obtain the present reliability of the system. The achievable reliability has been estimated by applying the necessary relations, considering each section. The scope and calculations follow the concept of Failure Modes, Effects and Criticality Analysis (FMECA). It has been observed that some simple yet effective measures may be enough to improve the overall reliability of the system.

Keywords: FMECA, maintenance planning and control, productivity, quality, reliability, tea industry, etc.

I. INTRODUCTION

Reliability is a measure of the ability of a product to survive and perform its intended function under a given operating environment and prescribed set of conditions. When an industry is considered for such an analysis, the focus is mostly on the ways to improve the productivity without sacrificing the quality of the production. The study and analysis can be both quantitative as well as qualitative. In effect, reliability is a probability [1]. It is one such concept of study, which can help us in reducing the chances of failures of the various components in a system for a smoother functioning of the entire system and thus, an industry. The concept of reliability can be matched with systems concept [3]. The individual component's reliability affects the reliability of the product [4]. Hence, sufficient effort should be given at the design stage so as to maximize the product's reliability.

There are various factors on which the reliability of a system or a product depends [3]. Some basic ways to improve the reliability of a system are mentioned below:

- Improved design of components.
- Usage of better production equipment.
- Maintaining better quality standards.
- Maintaining better testing standards.
- Availability of sufficient number of standby units.
- Scheduling periodic preventive maintenance.

There is scope for reliability improvement in almost every section of an industry. In this work, a CTC (cut, tear & curl) tea industry named, "Evergreen Dooars Tea Private Limited", has been considered for analysis. CTC (Crush, Tear, and Curl or Cut, Tear and Curl) is a method of processing black tea in which tea leaves are passed through a series of cylindrical rollers with serrated blades that crush, tear, and curl the tea into small, even-shaped pellets [2].

CTC tea generally produces a rich red-brown color when they are boiled by the Indian method [5]. The processing of tea aims to produce the final product ready to be consumed from the freshly picked leaves [6]. Selection of the various parameters and the ambient conditions is done on the basis of expertise and experience of the personnel [8].

Higher the reliability of a component, higher is the reliability of the section and higher is the reliability of the entire system involving the sections, which would help to obtain the optimum levels of quality and quantity. The five sections of the tea industry are: withering section, cut, tear and curl (CTC) section, continuous fermentation machine (CFM) section, drying section and sorting section [7]. The processes are briefly described using the following table, i.e. Table 1.

 © 2017, IJREAM All Rights Reserved

Section	Objective	Process(s)	Component(s)	Number of Component(s)
Withering	Removal of moisture from the leaves	Freshly plucked leaves are suspended over troughs and cold air is blown for about 2 hours	Fan with 5 h. p. motor, 48" blades	18
CTC	Cutting, tearing and curling of leaves	Leaves are cut in 4 phases using pairs of rollers rotating at RPM ratio of 1:10 each	Cut, Tear and Curl (CTC machine)	5
CFM	Oxidation (fermentation) of the leaves	Ideal conditions: 20 to 24 ^{0}C with 95% relative humidity	Continuous Fermentation Machine (CFM)	8
Drying	To arrest fermentation	Moisture is removed by exposing the leaves to hot air Temperature: About 120 ^{0}C Time required for drying: 15 to 30 minutes	Dryer	2
Sorting	Separation of tea granules into various grades by their sizes	Number of grades:7; 4th and 5th grades are of ideal qualities	Sorting Machine	1

Table 1: Tea Processing in the Tea Industry

II. LITERATURE REVIEW

Nahid Golafshani (2003) in his research work titled, "Understanding Reliability and Validity in Qualitative Research", stated the following:

"Reliability and validity are conceptualized as trustworthiness, rigor and quality in qualitative paradigm."

Dr. K. G. Karmakar, NABARD, Mumbai and Dr. G.D. Banerjee, NABARD, Nagaland (2005) in their research work titled, "The Tea Industry in India: A Survey", concluded the following:

"The benefits of Tea Board Plantation Subsidy Scheme and Price Stabilization Scheme of Government of India etc. have hardly been gone to the growers due to defect in the prevailing system of land ownership and timely inaction of Government."

Fred Schenkelberg and Carl S. Carlson (2016) in their research work titled, "Introduction to Reliability & Maintainability Management", concluded the following:

"Reliability and Maintainability Engineering are challenging and rewarding endeavors. The tools and resources of R & M engineering provide a means to efficiently achieve the reliability and maintainability goals."

III. EXPERIMENTAL PROCEDURE

A. Objective

The main objective of the study is to calculate the existing reliability of each component of each section concerned for the ultimate evaluation of reliability of the entire system. The possible changes which can be incorporated to improve the reliability of each section are suggested so as to estimate the achievable reliability of the system.

B. Identification of the scope of Reliability Improvement

To identify the scope of reliability improvement of the entire system, each section has been considered separately to study the scope in every component of the sections. The concept of "Failure, Modes, Effects and Criticality Analysis (FMECA)" comes useful in such identification process. FMECA has been implemented to ultimately obtain the scope of reliability improvement in each section of the system.

The Failure Modes, Effects, and Criticality Analysis (FMECA) is an important task under design phase of reliability analysis [3]. In FMECA, the following are considered:

 © 2017, IJREAM All Rights Reserved

- Every possible failure mode.
- Effect of each failure mode on the product.
- The criticality of the effects of each failure mode on the product.
- Measures to be taken to minimize such failure [3].

C. Reliability Calculations

We calculate the reliability of a single component by identifying the failure rate. The number of times a component works satisfactorily out of the total number of trials conducted is the reliability of the component [1, 3].

For a set of similar components, reliability is the number of components survived till the specified time limit by the total number of components operated.

For a system of components, the arrangement can be either of series type or of parallel type. To calculate the reliability of such systems, the reliability of each individual component has to be known first.

IV. OBSERVATIONS

A. Application of the concept of Failure Modes, Effects, and Criticality Analysis (FMECA)

Using the concept of FMECA, the scope of reliability improvement in each section of the system is established in the following table; i.e. Table 2:

Section	Component(s) prone to Failure	Possible Failure Mode(s)	Effect(s) of Failure Mode	Criticality of Failure the Effect(s) of Failure Mode(s)	Suggested Measure(s)
Withering	Fans	Breakdown due to poor operation	Lowered quantity	Significant drop in production rate	Careful operation, preventive maintenance
CTC	Grooved steel rollers	Bluntness of the rollers	Processing in CTC is stopped	Significant drop in production quantity	Providing standby unit(s)
CFM	Oxidation chambers	Poor operation of the oxidation chambers due to the presence of microorganisms	Incomplete oxidation of tea	Lower property of retaining the smell and quality	Daily cleaning of the chambers using hot air to kill the microorganisms
Drying	Grip plates of the dryer	Jamming of the grip plates	Accumulation of tea leaves in the grip plates	Over-heating of the tea leaves which get accumulated, leading to poor quality	Regular cleaning of the grip plates
Sorting	Sorting machine	Breakdown of the machine	Flow system gets stopped completely	Significant drop in production quantity	Scheduling periodic maintenance, providing standby

Table 2: Identification of the Scope of Reliability Improvement

B. Reliability Analysis

1. Withering Section

The reliability of the section lies entirely on the reliability of the fans.

Number of operational fans available: 18
Expected time of operation without any failure: 2 years
Number of failures (on an average) in the period: 3
Thus, the number of fans surviving till the end of the period = (18-3) = 15

Reliability of each fan, R_f = 15/18 = **0.833**

Now, number of fans required to be operating during processing: 16
So, two standby units are available always.
Considering failure of 1 of the 16 units results as a failure of the processing, the 16 operating fans (F_1, F_2, F_3,…., F_{15} and F_{16}) are arranged in series and provided them with 2 standby units (F_{17} and F_{18}), which are linked in parallel.
Here, reliability of 16 fans in series, $(R_f)_{series} = (R_f)$ ^ 16
= (0.833) ^ 16 = **0.054**

 © 2017, IJREAM All Rights Reserved

Thus, reliability of withering section considering the 2 fans (F_{17} and F_{18}) in parallel,

$R_W = 1 – [1 - (R_f)_{series}] * [1 - R_f] * [1 - R_f] = 1 – (1 – 0.054) * (1 – 0.833) * (1 – 0.833) =$ **0.9736**.

By the concept of FMECA, it is observed that the reliability can be further increased by careful operation of the fans by the operators such that the number of failures is reduced to 1 from 3earlier.

Then the reliability of each component (fan): $R_f' = 17/18 =$ **0.944**

Then reliability of 16 fans in series, $(R_f)_{series}' = (R_f) \wedge 16 = (0.944)\wedge16 =$ **0.4**

Thus, $R_W' = 1 – [1 - (R_f)_{series}'] * [1 - R_f'] * [1 - R_f'] = 1 – (1 – 0.4) * (1 – 0.9736) * (1 – 0.9736)$
= **0.9981**.

Hence, an improvement of reliability of **2.52%** can be obtained in this section if the number of failures is reduced. Such improvement is possible by just offering little care to the fans during operation.

2. CTC Section

Number of operational CTC machines: 5

Expected time of operation:

a) During peak season (February to July): 70 hours for 6 months

b) During off season (August to November): 45 hours for 4 months

During peak season, number of CTC machines achieving the mark of 70 hours in 1 run = 4

During off season, number of CTC machines achieving the mark of 45 hours in 1 run = 3

So, reliability of each CTC, $R_C = [(6/10)*(4/5)] + [(4/10)*(3/5)] =$ **0.72**.

Number of set of rollers readily available, i.e., number of standby unit = 1

Here, reliability of 5 CTC machines in series, $(R_C)_{series} = (R_C) \wedge 5 = (0.72) \wedge 5 =$ **0.1935**

Thus, reliability of CTC section considering the standby roller set in parallel,

$R_{CTC} = 1 – [1 - (RC)_{series}] * [1 - R_C] = 1 – (1 – 0.1935) * (1 – 0.72) =$ **0.7742.**

By the concept of FMECA, it can be suggested to keep 1 more set of rollers to be available to be used as standby unit. In such case, the improved reliability can be obtained, such that,

$R_{CTC}' = 1 – [1 - (RC)_{series}] * [1 - R_C] * [1 - R_C] = 1 – (1 – 0.1935) * (1 – 0.72) * (1 – 0.72) =$ **0.9368.**

Hence, an improvement of about **21%** can be obtained in this section if a standby unit is kept ready to be used in case of failures.

3. CFM Section

Number of available oxidation chambers: 8

Minimum number of chambers required to be operating at the same time for optimum quality: 6

So, number of chambers available as standby when 6 chambers are operating: 2

Expected time of operation without the requirement of cleaning: 1 week

Number of chambers required to be cleaned before the weekly cleaning: 2 (on an average)

So, number of chambers surviving: 8 – 2 = 6.

Thus, reliability of each chamber, $R_o = 6/8 =$ **0.75**.

Here, reliability of 6 chambers (O_1 to O_6) in series, $(Ro)_{series} = (R_o) \wedge 6 = (0.75) \wedge 16 =$ **0.178**

Thus, reliability of CFM section considering the 2 chambers as standby (O_7 and O_8) in parallel,

$R_{CFM} = 1 – [1 - (Ro)_{series}] * [1 - R_o] * [1 – R_o] = 1 – (1 – 0.178) * (1 – 0.75) * (1 – 0.75) =$ **0.9486**.

Although the reliability is quite high, for the sake of optimum quality, careful maintenance and proper operation can be suggested to reduce the failure to 1. The concept of FMECA comes helpful in the justification of such suggestion.

Then the reliability of each component (chamber): $R_o' = 7/8 =$ **0.875**

Then reliability of 6 chambers in series, $(Ro)_{series}' = (R_o) \wedge 6 = (0.875) \wedge 6 =$ **0.4488**

Thus, $R_{CFM}' = 1 – [1 - (Ro)_{series}'] * [1 – R_o'] * [1 – R_o'] = 1 – (1 – 0.4488) * (1 – 0.875) * (1 – 0.875)$
= **0.9914**.

Hence, an improvement of reliability of **4.51%** can be obtained in this section if the number of failures is reduced.

4. Drying Section

There are 2 operating dryers in this section. It is practically impossible to identify any considerable failure during the operation of the dryers and hence it is very difficult to statistically compute the reliability of the section. The criticality of any failure is quite low and requires easy maintenance.

Hence, the reliability of the section can be considered as high as 0.9999. There is practically no scope for any feasible suggestion, thus, no improvement required.

 © 2017, IJREAM All Rights Reserved

5. Sorting Section

Number of operating sorting machines: 2

Expected time of operation without any breakdown: 8 years

Work period without failure: 7 years 10 months = 7.833 years

So, reliability of individual machine on the basis of time value, R_s = 7.833/8 = **0.9791**

Considering the machines to be in series, reliability of the section is given by

$R_{Sorting} = R_s * R_s$ = 0.9791 * 0.9791 = **0.9586**

The reliability of this section is quite high as well, but by simply adding a standby unit the reliability shoots up to almost 1. Since, the cost of a sorting machine is not very high, a standby unit can be suggested to exhibit how the reliability can be increased. In such case, the improved reliability can be obtained, such that,

$R_{Sorting}' = 1 - [1 - (R_S)_{series}] * [1 - R_S]$

= 1 – (1 – 0.9586) * (1 – 0.9791) = **0.9991.**

Hence, an improvement of reliability of **4.22%** can be obtained in this section if a standby is made to be available.

V. RESULTS AND DISCUSSION

The obtained values of existing and achievable reliabilities for each section can be compared for better understanding of the concept. The comparisons are illustrated using bar graphs as shown in Figure 1.

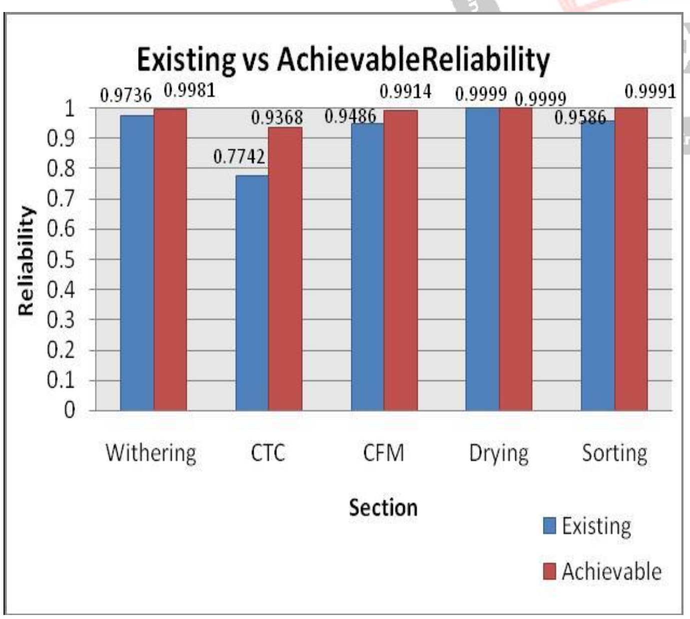

Figure 1: Section-Wise Comparisons between Existing Reliability and Achievable Reliability

Considering each section to be forming a series arrangement, the level of improvement can be effectively measured by comparing the existing and improved reliabilities of the entire system.

Also, it has been observed that **1.8 million kg** of tea was produced in the year 2016 with the existing reliability of **0.6853**. With the achievable reliability of **0.926**, although theoretical, production of **2.43 million kg** of tea may be possible in a year, which is shown in Figure 3. The existing overall reliability is calculated as R = 0.9736 * 0.7742 * 0.9486 * 0.9999 * 0.9586 = **0.6853.**

The achievable overall reliability is calculated as R' = 0.9981 * 0.9368 * 0.9914 * 0.9999 * 0.9991 = **0.926.** The comparison has been shown in Figure 2.

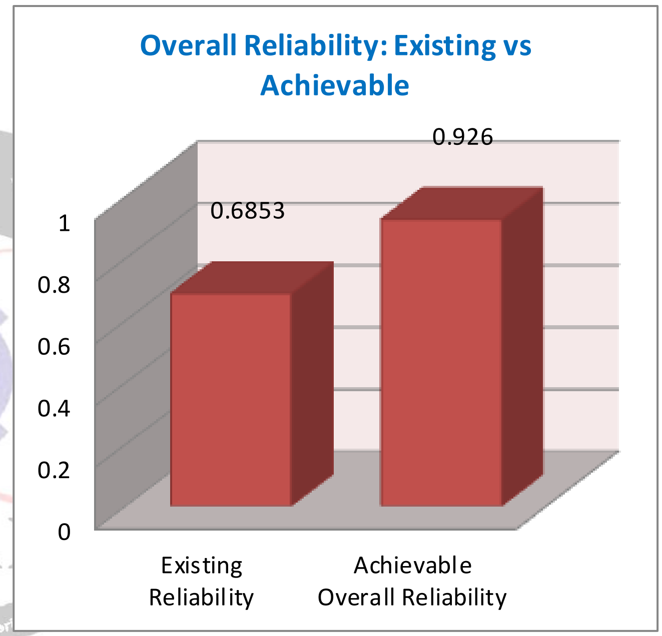

Figure 2: Overall Reliability- Existing vs. Achievable

Level of improvement = [(0.926-0.6853)/0.6853] * 100% = **35.12%**

Hence, an improvement of **35.12%** can be obtained in the reliability of the entire system if certain steps are followed in each section considering each component concerned.

Also, it has been observed that **1.8 million kg** of tea was produced in the year 2016 with the existing reliability of **0.6853**. With the achievable reliability of **0.926**, although theoretical, production of **2.43 million kg** of tea may be possible in a year, which is shown in Figure 3.

 © 2017, IJREAM All Rights Reserved

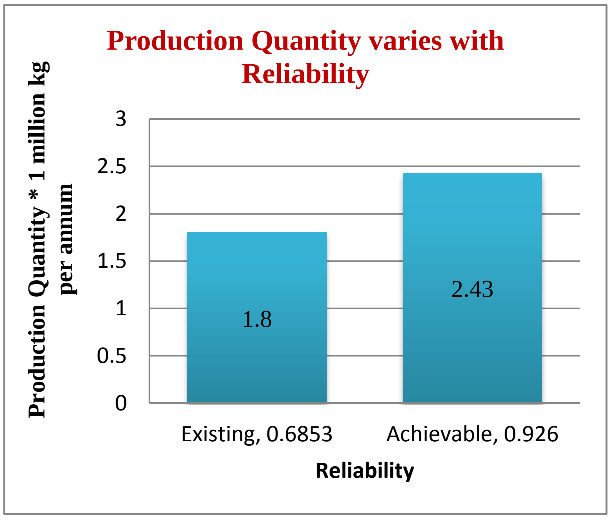

Figure 3: Variation of Production Quantity with Reliability

VI. CONCLUSION

The study has been able to identify the scope of improvement of reliability in a tea industry by analyzing each section and its components.

Some simple yet effective measures, such as careful operations and provision of relevant standby units, may be enough to improve the overall reliability of the system. Improvement of the value of reliability can effectively increase the quantity and improve the overall quality of the product as well.

In this research work, it has been found that the reliability can be improved by 2.52%, 21%, 4.51%, and 4.22% in the withering section, CTC section, CFM section and sorting section, respectively. Also, the overall reliability can be improved by 35.12%.

REFERENCES

[1] R. C. Gupta, Statistical Quality Control and Quality Management, 9th Edition, Khanna Publishers, 2001.

[2] H. N. Das, Assam Tea: Problems and Prospects; in Origin and Development of tea; EBH Publisher; Guwahati, 2008.

[3] Production and Operations Management by R. Panneerselvam, 3rd Edition, PHI Learning Private Limited, 2013

[4] Nahid Golafshani ,"Understanding Reliability and Validity in Qualitative Research", The Qualitative Report, Vol. 8, Number 4, 597-607, December 2003.

[5] V. N. Asopa, " Tea Industry of India- The Cup that Cheers has Tears", Indian Institute of Management, Ahmedabad, W.P. No. 2007-07-02, July 2007.

[6] Kakali Hazarika, "Changing Market Scenario for Indian Tea", International Journal of Trade, Economics and Finance, Vol. 2, No. 4, 285-287, August 2011.

[7] S. Sanyap, S. N. Bora, D. J. Hazarika, R. C. Gogoi, B. D. Barua, B. J. Sarma, P. TamuIi, A. K. Hazarika and L. N. Saikia , "A Study on Micronizer as a Tea Processing Machine", Two and a Bud, 59(2): 78-83, 2012.

[8] Prof. Basudeb Sadhukhan, "Tea Industry in West Bengal- Hopes and Challenges", Volume-3, Issue-7, July-2014, ISSN No 2277-8160.

[9] Sukhin Chawla, "Sustainability in Indian Tea Industry", American Scientific Research Journal for Engineering, Technology and Sciences (ASRJETS), ISSN (Print) 2313-4410, ISSN (Online) 2313-4402, Volume 20, No 1, pp 179-189, 2016.

 © 2017, IJREAM All Rights Reserved