

RELIABILITY ANALYSIS OF CEMENT MANUFACTURING PROCESS USING BOOLEAN FUNCTION TECHNIQUE

A. MERCELINE ANITA¹, S. KALAIARASI², AND G. PADMAVATHY³

ABSTRACT. The device consistency of cement manufacturing process was evaluated throughout this study. The general system in a compact form is obtained by studying the process of cement manufacturing in a systematic manner. The reliability expression has been simplified using Boolean function technique and a mathematical model is developed to measure the reliability of the cement manufacturing system. We determine the system reliability of the cement manufacturing process by considering the time to failure of the process as exponentially distributed. Numerical illustration is provided.

1. INTRODUCTION

The importance of science and technology plays a dominant role in current scenario, and it is increasing tremendously in our society. The involution of business, production of commodities by manufacturing or processing is improving day by day. The appropriate result or product expected is mainly ruled by the System Reliability. The demand of achieving more reliable systems with the improvement of the day to day mechanics has been the need of current situation.

In this paper, the process of cement manufacturing in industries has been analyzed and the reliability is determined as the chance of successful production of cement. Reliability defines four elements namely probability, intended function, time and operating conditions [2]. Reliability of a unit (or product) is the

¹corresponding author

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probability that the unit performs its intended function adequately for a given period of time under the given stated operating conditions or environment [1].

Gupta P. P. and Agarwal S.C have considered a Boolean algebra method for reliability calculations and again Gupta P. P and Kumar A. found reliability and MTTF analysis of Power Plant [3–5] and they have found the system reliability with imperfect fault coverage. The cement manufacturing process involves various stages such as mining, transporting and crushing, stacker and reclaimer, raw material grinding and storage, blending and storage, kiln feed section, clinkerisation, cooler, coal grinding and storage, cement grinding and storage, packing and dispatch. We analyze the above stages of manufacturing and processing of cement and it is viewed as a complex system and the system reliability of this complex system has been determined. Here, we discuss the methodology of Boolean function and other related principles to assess the stability of the method. We discuss the cement manufacturing process with flow diagram and we derive the expressions for obtaining the system reliability and also MTTF by assuming the failure of the system as exponential & Weibull distributions. Finally we study the reliability of the system and MTTF graphically with numerical examples.

System Description

Cement is one of the most essential need in our life and it is obtained by burning and crashing the clay and lime carbonate stones. There are two process namely wet and dry. First the jaw crusher crashes the big stones into the small pieces and it is thus exposed to major failure. The mixture is blended with water up to 30 – 40% in the form of slurry. In dry process, the raw materials are dried. The materials are pumped into the preheater. It is then poured into the rotary kiln and the burning is carried out. In the next section, carbon dioxide is evaporated and the nodules are formed. These nodules are converted into small, hard, dark, greenish ball known as raw cement. This section is clinker section and it is subjected to major failure, the raw cement is grinded and during this process a small quantity of gypsum is added. Finally cement is stored and specially designed for packing. The machine architecture of the cement manufacturing process has been given below.

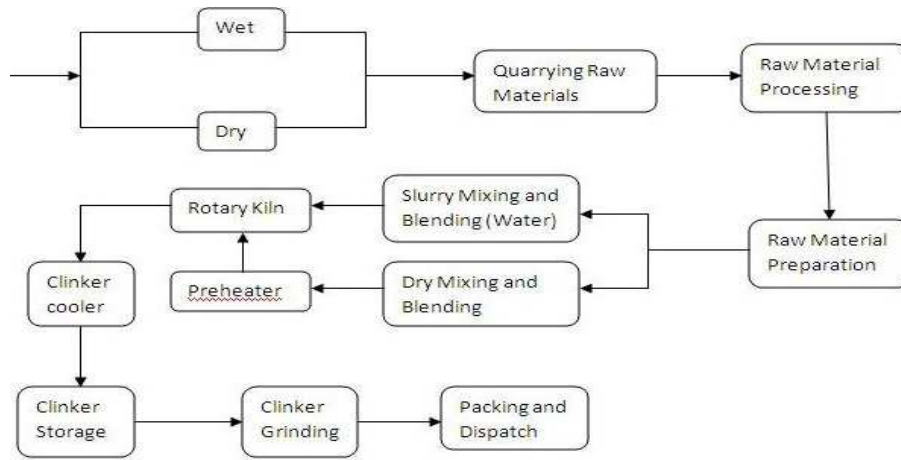


FIGURE 1. Machine Architecture of Cement Manufacturing Process

Assumptions

- (i) At the beginning of the process all the Machine Components are in good condition.
- (ii) At the operating stage every unit is either in good or bad condition.
- (iii) There seems to be no service to restore them.
- (iv) All the states of the components are statistically independent.
- (v) The probability of the functioning of all components should be well known in advance.

Notations

a_1, a_2 = States of both wet and dry process

a_3 = States of quarrying raw materials

a_4, a_5 = States of processing and preparation

a_6, a_7 = States of dry mixing and slurry mixing

a_8, a_9 = States of preheater and rotary kiln

a_{10}, a_{11}, a_{12} = States of clinker cooler, clinker storage and clinker grinding

a_{13} = States of packing and dispatch

$$a_i(i = 1, 2, \dots, 13) = \begin{cases} 1 & \text{for good state} \\ 0 & \text{for bad state} \end{cases}$$

2. MODEL DESCRIPTION

The logical matrix for the successful operation of the system is given as

$$A(a_1, a_2, \dots, a_{13}) = \begin{vmatrix} a_1 & a_3 & a_4 & a_5 & a_6 & a_8 & a_9 & a_{10} & a_{11} & a_{12} & a_{13} \\ a_1 & a_3 & a_4 & a_5 & a_7 & a_9 & a_{10} & a_{11} & a_{12} & a_{13} \\ a_2 & a_3 & a_4 & a_5 & a_6 & a_8 & a_9 & a_{10} & a_{11} & a_{12} & a_{13} \\ a_2 & a_3 & a_4 & a_5 & a_7 & a_9 & a_{10} & a_{11} & a_{12} & a_{13} \end{vmatrix}$$

Solution of the model

Using algebra of logics, we get

$$A(a_1, a_2, \dots, a_{13}) = \begin{vmatrix} a_3 & a_4 & a_5 & a_{13} \wedge B \end{vmatrix}$$

where

$$B = \begin{vmatrix} a_1 & a_6 & a_8 & a_9 & a_{10} & a_{11} & a_{12} \\ a_1 & a_7 & a_9 & a_{10} & a_{11} & a_{12} & a_{13} \\ a_2 & a_6 & a_8 & a_9 & a_{10} & a_{11} & a_{12} \\ a_2 & a_7 & a_9 & a_{10} & a_{11} & a_{12} & a_{13} \end{vmatrix} = \begin{vmatrix} S_1 \\ S_2 \\ S_3 \\ S_4 \end{vmatrix}$$

$$S_1 = \begin{vmatrix} a_1 & a_6 & a_8 & a_9 & a_{10} & a_{11} & a_{12} \end{vmatrix}$$

$$S_2 = \begin{vmatrix} a_1 & a_7 & a_9 & a_{10} & a_{11} & a_{12} & a_{13} \end{vmatrix}$$

$$S_3 = \begin{vmatrix} a_2 & a_6 & a_8 & a_9 & a_{10} & a_{11} & a_{12} \end{vmatrix}$$

$$S_4 = \begin{vmatrix} a_2 & a_7 & a_9 & a_{10} & a_{11} & a_{12} & a_{13} \end{vmatrix}$$

By Orthogonalization algorithm, the above equation may be written as:

$$(2.1) \quad B = \begin{vmatrix} S_1 \\ S'_1 & S_2 \\ S'_1 & S'_2 & S_3 \\ S'_1 & S'_2 & S'_3 & S_4 \end{vmatrix}$$

Now using algebra of logics,

$$S'_1 S_2 = \begin{vmatrix} a_1 & a'_6 & a_7 & a'_8 & a_9 & a_{10} & a_{11} & a_{12} & a_{13} \end{vmatrix}$$

$$S'_1 S'_2 S_3 = \begin{vmatrix} a'_1 & a_2 & a_6 & a'_7 & a_8 & a_9 & a_{10} & a_{11} & a_{12} & a'_{13} \end{vmatrix}$$

$$S'_1 S'_2 S'_3 S_4 = \begin{vmatrix} a'_1 & a_2 & a'_6 & a_7 & a'_8 & a_9 & a_{10} & a_{11} & a_{12} & a_{13} \end{vmatrix}$$

Inserting all these values in the equation (2.1) then we get:

$$B = \begin{vmatrix} a_1 & a_6 & a_8 & a_9 & a_{10} & a_{11} & a_{12} & & & & \\ a_1 & a'_6 & a_7 & a'_8 & a_9 & a_{10} & a_{11} & a_{12} & a_{13} & & \\ a'_1 & a_2 & a_6 & a'_7 & a_8 & a_9 & a_{10} & a_{11} & a_{12} & a'_{13} & \\ a'_1 & a_2 & a'_6 & a_7 & a'_8 & a_9 & a_{10} & a_{11} & a_{12} & a_{13} & \end{vmatrix}$$

Hence, the reliability of the whole system is given by:

$$\begin{aligned} R_s = & R_3 R_4 R_5 R_{13} [R_1 R_6 R_8 R_9 R_{10} R_{11} R_{12} + R_1 R_7 R_9 R_{10} R_{11} R_{12} R_{13} \\ & - R_1 R_7 R_8 R_9 R_{10} R_{11} R_{12} R_{13} - R_1 R_6 R_7 R_9 R_{10} R_{11} R_{12} R_{13} \\ & + R_1 R_6 R_7 R_8 R_9 R_{10} R_{11} R_{12} R_{13} + R_2 R_6 R_8 R_9 R_{10} R_{11} R_{12} \\ & - R_2 R_6 R_7 R_8 R_9 R_{10} R_{11} R_{12} - R_1 R_2 R_7 R_9 R_{10} R_{11} R_{12} R_{13} \\ & + R_1 R_2 R_6 R_7 R_8 R_9 R_{10} R_{11} R_{12} - R_2 R_6 R_8 R_9 R_{10} R_{11} R_{12} R_{13} \\ & + R_2 R_6 R_7 R_8 R_9 R_{10} R_{11} R_{12} R_{13} + R_1 R_2 R_6 R_8 R_9 R_{10} R_{11} R_{12} R_{13} \\ & - R_1 R_2 R_6 R_7 R_8 R_9 R_{10} R_{11} R_{12} R_{13} + R_2 R_7 R_9 R_{10} R_{11} R_{12} R_{13} \\ & - R_2 R_6 R_7 R_9 R_{10} R_{11} R_{12} R_{13} - R_1 R_2 R_7 R_9 R_{10} R_{11} R_{12} R_{13} \\ & + R_1 R_2 R_6 R_7 R_9 R_{10} R_{11} R_{12} R_{13} - R_2 R_7 R_8 R_9 R_{10} R_{11} R_{12} R_{13} \\ & + R_2 R_6 R_7 R_8 R_9 R_{10} R_{11} R_{12} R_{13} + R_1 R_2 R_7 R_8 R_9 R_{10} R_{11} R_{12} R_{13} \\ & - R_1 R_2 R_6 R_7 R_8 R_9 R_{10} R_{11} R_{12} R_{13}] \end{aligned}$$

Special Cases

Case 1: Considering reliability of each of the units as R we arrive:

$$R_s = 4R^{11} - 8R^{12} + 7R^{13} - 2R^{14}$$

Case 2: For Weibull time distribution:

$$(2.2) \quad R_{sw}(t) = \sum_{l=1}^{11} e^{-x_l t^s} - \sum_{l=1}^{10} e^{-y_l t^s}$$

where x_i and y_i denote the failure rates which involves individual failure rates of the components.

Case 3: For Exponential distribution, by putting $s = 1$ in equation (2.2), we get the Exponential distribution. The system reliability and the MTTF of the system is given by:

$$(2.3) \quad R_{se}(t) = \sum_{l=1}^{11} e^{-x_l t} - \sum_{l=1}^{10} e^{-y_l t}$$

$$(2.4) \quad MTTF = \int_0^{\infty} R_{se}(t) dt$$

$$MTTF = \frac{0.0925}{f}$$

where f denotes the combined failure rate of the system.

Numerical computation

Taking the value of the Shape parameter as $s = 2$ and the uniform failure rate of the individual components as 0.001 in (2.2) and (2.3) then we get the system reliabilities as follows:

Time	0	1	2	3	4	5	6	7	8	9	10
$R_{sw}(t)$	1	0.9782	0.9159	0.8207	0.704	0.5784	0.4554	0.3439	0.249	0.1733	0.1158
$R_{se}(t)$	1	0.9782	0.9569	0.9391	0.9157	0.8959	0.8765	0.8574	0.8388	0.8206	0.8029

TABLE 1. Reliability values showing $R_{sw}(t)$, $R_{se}(t)$

For different values of f using (2.4) we arrive the Table 2.

f	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009	0.010
MTTF	92.5	46.25	30.83	23.125	18.5	15.417	13.214	11.5625	10.278	9.25

TABLE 2. MTTF vs failure rate

3. CONCLUSION

The knowledge of system reliability helps us to improve the performance of the system. In this paper, we have made an attempt to analyze the system reliability of cement manufacturing process in industries through Boolean function technique. We have made this study by assuming the time to failure of the

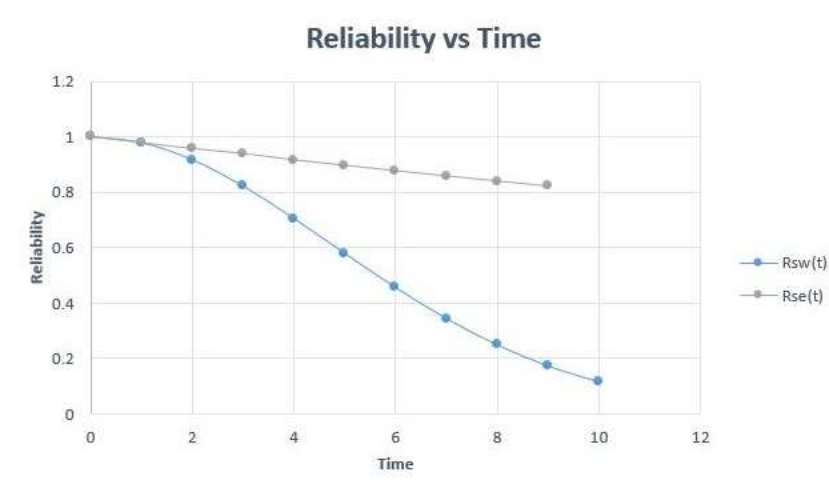


FIGURE 2. Reliability Vs Time graph (Weibull and Exponential distribution)

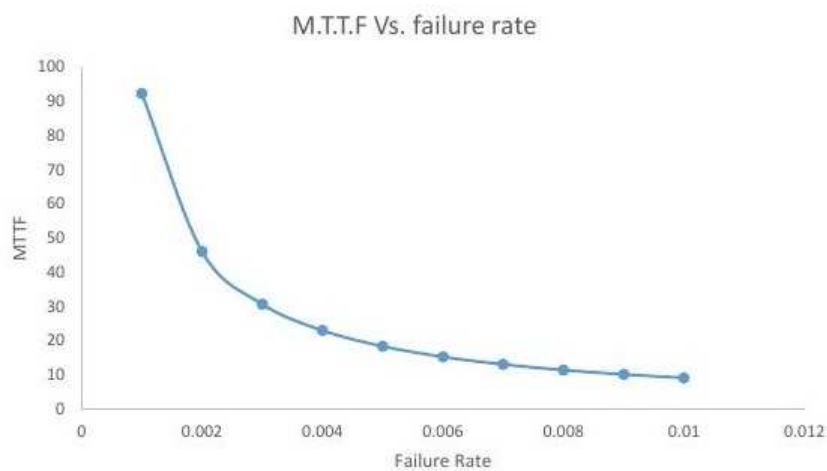


FIGURE 3. Graph showing MTTF Vs Failure Rate

system following Exponential/Weibull distribution. In the case of Exponential distribution, we see that the system reliability decreases approximately at a uniform rate but in the Weibull distribution it decreases fast. Also we observe that for the Exponential distribution, in the beginning the MTTF reduces quite well but later it decreases roughly with the same rate.

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DEPARTMENT OF MATHEMATICS
SACRED HEART COLLEGE
TIRUPATTUR - 635 601.
Email address: mercelineanita@gmail.com

DEPARTMENT OF MATHEMATICS
SACRED HEART COLLEGE
TIRUPATTUR - 635 601.
Email address: skalaiarasi2@gmail.com

DEPARTMENT OF MATHEMATICS
SACRED HEART COLLEGE
TIRUPATTUR - 635 601.
Email address: sumipadma1997@gmail.com