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RELIABILITY ANALYSIS IN CEMENT MILLS OF BERBER CEMENT FACTORY

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Abstract — **Reliability is the probability that a product, system, or service will perform its intended function adequately for a specified period, or will operate in a defined environment without failure.**
In this research, the reliability of Berber cement mill studied. The data collected from the information section of Berber cement factory related to the milling section. It includes the daily production reports, the breakdown and the operating time. The operating time between two failures (TTF) was calculated from the daily report of the mill and then a match was made for the data with the probability distributions to find out what is the probability distribution corresponding to the distribution of these data. The best distribution is the Weibull distribution. the Minitab software was applied and then the distribution parameters for the data (measurement parameters c and the shape parameter d) were obtained and then the reliability of each part of the mill were calculated for each hour and the reliability of the system was calculated as a whole. The study found that the reliability of the system is 75% at the first hour of operation. It decreased during continuous operation to 58% due to the poor reliability of the heating system, which has a reliability of 72% and the reliability of the conveying and feeding belts of the clinker, which have a reliability of 75%.

Keywords— **Reliability Measures; Cement Mills; Berber Cement Factory; Weibull distribution; Mathematical Formulations**

I. INTRODUCTION

High-reliability organizations expect equipment to last a long time and are unhappy when it does not. Not only are they unhappy, but they take effective measures to learn and improve their performance from their past failure history. Production and profit benefits from equipment reliability brings before you, will do what is necessary to get it. If you want plant and equipment to operate trouble-free for a long time, you must do those activities that lead to reliability, and do them well enough to deliver reliability. You get great equipment reliability when you act to control happenstance across the life cycle and replace it with masterly precision. If you want high reliability with low cost you should put into consideration the necessary engineering, purchasing, storage, operating and maintenance regimes and practices that deliver the reliability and life-cycle costs you want. You may have limited opportunity to influence any of these regimes on your plant. In that case, start by looking to get more value from the equipment you have. Improve those plant items with lower than desired reliability i.e. the bad actors. You can do that by using operating practices that reduce equipment risk and by improving machinery health. Use cross-functional teams of operators, trades people, condition monitoring technicians and engineers tasked to understand the causes of a problem and to eliminate or reduce them. Spot the onset of problems and take pre- emptied action. Have contingency plans to mitigate consequences. Operate and maintain plant to precision standards. These risk reduction practices will deliver higher plant reliability [1] – [9].
The main objective of this study for Berber cement mill is to maintain the continuity of machine work, increase the production capacity of the machines and equipment, reduce the failure causes to minimum possible limit and maximize the reliability of production machines [10].

II. RESEARCH METHODOLOGY

This research adopts a descriptive and analytical approach. The methodology used to describe the concept of reliability and a general description of Berber cement factory. The collected data of cement mill from the Berber cement factory and then the operating time and downtime data between the two failures was analyzed using software Minitab and Excel for determining the reliability of the mill [11 - 16].

III. CONCEPT OF RELIABILITY

It is one of the engineering indicators for expressing a tool of any equipment or operating system in terms of probabilities. Reliability is the probability of success or the probability that the system will perform the function prepared for it within a specified period. More specifically, reliability is the probability that a product or part will do the work required over a specified period. Reliability can be a measure of the system's success in performing the function required with high efficiency. Reliability is one of the quality characteristics that consumers demand from the producer. Modern industries characterize by variation and speed of product development. Therefore, the high costs involved in frequent stoppage of machines and equipment due to the occurrence of faults make the study and analysis of their reliability a very important matter.

IV. THE MATHEMATICAL FORMULA FOR RELIABILITY

$$\boldsymbol{R(t) = 1 - \int_0^1 F(t)dt = 1 - f(T)}$$

t = A random variable representing time
R (t) = Indication of the cumulative probability of success
F (t) = Significance of the cumulative distribution
Reliability is a real positive number between zero and one, so if R (t) = zero, then the equipment or system does not work, but if R (t) = one, this is an indication of the absolute assurance that the equipment or machine will continue to work for the time (t), and this is only a theoretical assumption [17] – [41].
The formulation of the reliability function depends on the data related to the time distribution of random failures, as it is the main benefit for it, while failure at different rates during the useful life of the equipment or machine also takes different probability distributions.
Table 1 below shows the most important and common probability distributions for analyzing random failure data and the reliability function for each distribution.

Table -1 the Most Important and Most Common Probability Distributions

Distribution	R(t)
Exponential	$R(t) = e^{-\lambda(t)}$
Weibull	$R(t) = exp\left[\frac{-(t-\gamma)^{\beta}}{\eta}\right]$
Normal	$R(t) = \int_t^{\infty} f(t)dt$
Logistic	$R(t) = \int_t^{\infty} f(t)dt$

V. RELIABILITY MEASURES

A. Function Failure

Failure is a decrease in the performance or complete cessation of production machinery due to use and obsolescence, and it is a change in the performance of the product or system in the case of unsatisfactory work to a state lower than the acceptable standard, which leads to a state of dispersion, inconsistency and regularity of production.

B. Hazard Function

It is the percentage of units that failed during a certain period i.e. that remained until the time A and denoted by the symbol B and its formula also depends on data related to the time distribution of random failures.
Table 2 below shows the most important probability distributions in the analysis of random failure data and the failure function for each distribution.

Table -2 the Most Important Probability Distributions and the Failure Function

Distribution Type	Hazard Failure
Exponential	$r(t) = f(t)R(t) = \frac{\lambda e^{-\lambda t}}{e^{-\lambda t}} = \lambda$
Weibull	$r(t) = \frac{\beta}{\eta}\left[\frac{t-\gamma}{\eta}\right]^{\beta-1}$
Normal	$r(t) = {f(t)}/{d(t)}$
Logistic	$r(t) = {f(t)}/{d(t)}$

There are many reasons for malfunctions, which include designers, selection of engineers, manufacturing, equipment, maintenance workers and users.
Whenever calculating failure rates, there are some factors to consider. These factors are:
1. Failure mode.
2. Time to repair.
3. Time between Failures.

C. Hazard Function State (Failure Rate)

1. If r (t) is incremental then this means that the system is wearing out with time.
2. If r (t) is decreasing then this indicates the reliability of the system is improving with time.
Fig. 1 below shows the general curve of the failure function. The 'bathtub curve' hazard function (blue, upper solid line) is a combination of a decreasing hazard of early failure (red dotted line) and an increasing hazard of wear-out failure (yellow dotted line), plus some constant hazard of random failure (green, lower solid line).

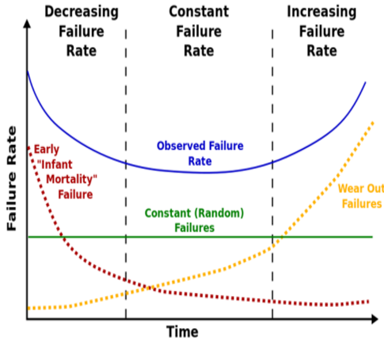

Fig. 1. The General Curve of the Failure Function

VI. SYSTEM COMPONENTS CONNECTION

With the increasing complexity of the products, the chance of failure increases, and the method of arranging the components has a great impact on the reliability of the system as a whole.

The components of the system in general can be arranged in several forms, the components can be arranged in a row, or in parallel.

A. Two Units Series System:

It consists of a group of components connected to each other in series, and the reliability of the system is a product of the components.

A1= Functions of the first unit in time t

P (t) = R (t)

A2= Function of the second unit in time t

P (t) = R (t)

A= Function of the 1 in time t

P (t) = R (t)

P (A) = P (A1) P (A2)

R (t) = R1 (t) R2 (t)

B. Two Units Active Parallel System:

It consists of a group of components connected to each other in parallel, and the system does not fail by the failure of one of its components, but by the failure of all its components.

P (A)= P(A1+A2)= P(A1)+P(A2)- P(A1)P(A2)

R (t) = R1 (t) +R2 (t)-R1 (t) R2 (t)

VII. WEIBULL DISTRIBUTION

The Weibull distribution is the most common distribution in the study of reliability, and it is one of the continuous and important distributions in the field of reliability and life testing.

With the difficulty of describing the behavior of its data with the circulating distributions at that time, it is appropriate to say that the Weibull distribution comprehensively describes all stages of the equipment life cycle, as it describes the phenomena of increase and decrease of the failure rate. This distribution has two parameters:

A. Scale Parameter α

It is the most common parameter. This parameter specifies where the largest portion of the distribution is located, or how far the distribution is.

B. Shape Parameter β

This parameter helps in determining the shape of the distribution and indicates whether the scheduled inspection and repair process is required or not, and checks if this value is less than one or equal to one, then the repair operations are not cost-effective.

The following equation expresses reliability:

$$R(t) = Exp\left[-\left[\frac{t}{\alpha}\right]^{\beta}\right]$$

C. Uses of the Weibull Distribution

Weibull Distribution used in the fields of industrial reliability and failure, survivor analysis, forecasting weather condition, and information system engineering.

VIII. BERBER CEMENT FACTORY

Berber Cement Factory selected for the purpose of reliability analysis, the selection made for the following reasons:

1. Being one of the modern and fertile factories for research studies and the production of a strategic product.
2. The factory contains two cement production lines working in parallel. The comparisons of the general equipment effectiveness for each line are made in order to determine the best line.
3. The use of different type of cement mills that does not found in other cement factories in Sudan.

A. Factory Location

The factory is located in River Nile State, 8 km southeast of the city of Berber.

The quarries of the clay are located on the eastern extension of the factory land, while the marble quarries are located 13 kilometers on the west bank of River Nile.

B. Factory Production Capacity

The production capacity of the factory is 5,000 tons of cement per day, and the cost of its construction was $ 210 million.

C. Factory Departments

1. Raw material mill department.
2. Rotary kiln department.
3. Cement mill department.

D. Vertical Mills

This multi-purpose vertical roller mills is capable of grinding a wide range of products.

Proven to be suitable for grinding ordinary Portland cement and mixed cement in a wide range of additives such as slag, limestone and fly ash. The cement mill consists of the parts shown in Fig. 2 below. These parts are as follows: Main motor, Classifier, gear oil supply, tension hydraulic, roller, clinker feeder, water spray system, cement mill bag house, conveyor chaining, feed cycle system, gas hot, air lock feeder rotary.

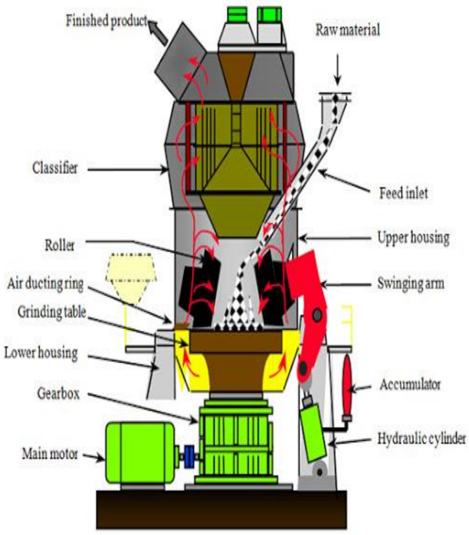

Fig. 2. Vertical Cement Mill

IX. RESULTS AND DISCUSSIONS

A. Data Collection

Data collected from the information section of Berber Cement Factory related to the milling section. The data included daily production reports, downtime and operating time to calculate reliability.

B. Data analysis

Matching made between the (TTF) data shown in Table 4 and the probability distributions to find the best probability distribution closest to the distribution of this data. Using (Minitab) software to calculate the parameters of this distribution ensured that the best distribution is Weibull.

C. Minitab Introduction

Minitab program is one of the statistical packages with wide applications in various scientific fields.

The importance of this program comes from ease of use of data and simplicity of interpretation of the results that obtained, in addition to the accuracy of calculations and its ability to solve many statistical problems.

D. Use the program

D.1 Program input

1. Operating time between faults TBF.
2. Maintenance time TTR.

D.2 Determination of the Types of Data Processing

Choose the type of probability distribution for the data

D.3 Program Output

The values of the parameter of the distribution includes:

1. Reliability function diagram.
2. Hazard function diagram.
3. Probability density function diagram.

D.4 Calculation of the Distribution Parameter for the Data

Using Minitab software, the Weibull distribution parameters computed for the mill data is shown in Table 3 below.

Table -3 Weibull distribution parameters

Shape parameter β	Measurement parameter α	Part name
0.68	149	Main motor
0.78	183	classifier
1.78	655	Gear oil supply
0.83	418	Tension hydraulic
0.80	173	Rollers 3
0.72	70	Clinker feeder
0.82	313	Water spray system
1.66	589	Cement mill bag house
0.62	185	Feed cycle system
0.9	134	Conveyor chaining
1.05	35	Gas hot
0.82	193	Air lock feeder rotary

D.5 Calculation of Reliability of the Mill:

The operating time between two failures computed from the daily report of the data of Berber cement mill as shown in Table 4 below, and by using the program (excel), the reliability of each part of the mill computed as shown in Table 5 below.

Table -4 Operating Time between two failures (TTF)

t	Motor	Classifier	Oil	Hydraulic	roller	Feeder	spray	Bag house	Feed cycle	Conveyor	gas	rotary
1	0.96	0.98	0.99	0.99	0.98	0.95	0.99	0.99	0.96	0.98	0.97	0.98
11	0.84	0.89	0.99	0.95	0.89	0.75	0.93	0.99	0.84	0.89	0.74	0.9
21	0.76	0.83	0.99	0.91	0.83	0.65	0.89	0.99	0.77	0.82	0.56	0.85
31	0.7	0.77	0.99	0.88	0.77	0.57	0.86	0.99	0.71	0.76	0.42	0.79
41	0.65	0.73	0.99	0.86	0.72	0.5	0.82	0.98	0.67	0.7	0.31	0.75
51	0.61	0.69	0.98	0.83	0.68	0.45	0.79	0.98	0.63	0.65	0.23	0.71
61	0.57	0.65	0.98	0.81	0.64	0.4	0.76	0.97	0.6	0.61	0.17	0.67
71	0.54	0.62	0.98	0.79	0.61	0.36	0.74	0.97	0.57	0.56	0.12	0.64
81	0.51	0.58	0.97	0.77	0.57	0.32	0.71	0.96	0.54	0.52	0.09	0.61
91	0.48	0.55	0.97	0.75	0.54	0.29	0.69	0.95	0.52	0.49	0.06	0.58
101	0.46	0.53	0.96	0.73	0.52	0.27	0.67	0.94	0.5	0.46	0.05	0.55
111	0.44	0.5	0.95	0.71	0.49	0.24	0.65	0.93	0.48	0.42	0.03	0.52
121	0.41	0.48	0.95	0.69	0.47	0.22	0.63	0.93	0.46	0.4	0.02	0.5
131	0.4	0.46	0.94	0.67	0.44	0.2	0.61	0.92	0.44	0.37	0.02	0.48
141	0.38	0.44	0.93	0.66	0.42	0.19	0.59	0.91	0.42	0.35	0.01	0.46
151	0.36	0.42	0.95	0.64	0.4	0.17	0.57	0.9	0.41	0.32	0.01	0.44
161	0.34	0.4	0.92	0.63	0.38	0.16	0.56	0.89	0.39	0.3	0.007	0.42
171	0.33	0.38	0.91	0.61	0.37	0.14	0.45	0.87	0.38	0.28	0.005	0.4
181	0.31	0.37	0.91	0.6	0.35	0.13	0.52	0.86	0.37	0.26	0.003	0.38
191	0.3	0.35	0.89	0.59	0.33	0.12	0.51	0.85	0.36	0.25	0.002	0.37

Table -5 below shows the reliability values for each part of the mill and for the whole system at a time (t)

Table -5 the reliability values for each part of the mill

motor	Classifier	oil	hydraulic	roller	feeder	spray	Bag house	Feed cycle	conveyor	gas	rotary	reliability
0.96	0.98	0.99	0.99	0.98	0.95	0.99	0.99	0.96	0.98	0.97	0.98	0.75245908
0.94	0.97	0.99	0.98	0.97	0.92	0.98	0.99	0.94	0.97	0.95	0.97	0.64354159
0.93	0.96	0.99	0.98	0.96	0.9	0.97	0.99	0.92	0.96	0.92	0.96	0.56060149
0.91	0.95	0.99	0.97	0.95	0.88	0.97	0.99	0.91	0.95	0.9	0.95	0.49262477
0.9	0.94	0.99	0.97	0.94	0.86	0.96	0.99	0.89	0.94	0.87	0.95	0.43158937
0.89	0.93	0.99	0.97	0.93	0.48	0.96	0.99	0.88	0.93	0.85	0.94	0.38588771
0.88	0.92	0.99	0.96	0.92	0.82	0.95	0.99	0.87	0.92	0.83	0.93	0.3372916
0.87	0.91	0.99	0.96	0.91	0.81	0.95	0.99	0.86	0.91	0.8	0.92	0.30044843
0.86	0.9	0.99	0.95	0.91	0.79	0.94	0.99	0.85	0.9	0.78	0.92	0.2673469
0.85	0.9	0.99	0.95	0.9	0.78	0.94	0.99	0.84	0.89	0.76	0.91	0.24302149
0.84	0.89	0.99	0.95	0.89	0.76	0.93	0.99	0.84	0.88	0.74	0.9	0.21556886

X. CONCLUSIONS

The study found that: the reliability of the motor at the first hour is 96%, while it decreases with increasing time until it reaches 51% at 81 hours.

The reliability of the classifier at the first hour, which is 98%, decreases with the increase in time to 53% at 101 hours.

The 99% reliability of the gear oil supply at the first hour decreases with increasing time until it reaches 94% at an hour period.

The reliability of the hydraulic unit is 99% at the first hour, while it decreases with increasing time until it reaches 59% at 191 hours.

The reliability of the rollers is 98% at the first hour, while it decreases with increasing time until it reaches 52% at 101 hours.

The reliability of the clinker conveyer and feeding belts is 95% at the first hour while decreases with increasing time until it reaches 50% at 41 hours.

The reliability of the water spray system, which is 99% at the first hour decreases with increasing time until it, reaches 52% at 181 hours.
The reliability of the bag house is 99% at the first hour while it decreases with increasing time until it reaches 83% at 191 hours.
The reliability of feed cycle system 96% at the first hour decreases with increasing time until it reaches 50% at 101 hours.
The reliability of the conveyor chaining which is 98% at the first hour decreases with increasing time to 52% at 81 hours.
The reliability of the gas hot, which is 97% at the first hour, decreases with increasing time to 56% at 21 hours.
The reliability of the feeder rotary that is 98% at the first hour decreases with increasing time to 50% at an hour.
The reliability of the system as a whole that is 75% at the first hour decreases with an increase in time to 56% at 3 hours.
The overall low reliability is due to the poor reliability of the heating system.
By using the analysis parameter β, it is clear that the heating system is in the last stage of its life, while the lubrication system unit is in the first stage of its life.

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