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Availability analysis of a sheet machine: A case study of Eternit Sapele Nigeria limited

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Abstract
The probability that a machine will be available when called upon to perform a function and how the failure rate, time to repair, time before failure have in forming a statistical distribution that is used to determine the machine availability and in order to get the overall view of the equipment function during a given period, therefor; tracking the maintenance data log of the company's equipment becomes imperative. The "Weibull analysis" was used to analyze the data and the equipment being considered is predominantly mechanical machine tear and wears. The Weibull distribution revealed that all the plots formed approximately a straight line which indicates that the Weibull distribution is well distributed. Hence, it can be concluded that the model is valid.

Keywords: availability, maintainability, mean time between failure, mean time to repair, failure rate

Introduction

Availability is a performance criterion used for repairable systems that accounts for both the reliability and maintainability aspects of a component or system [1]. If one considers both reliability (probability that the item will not fail) and maintainability the probability that the item is successfully restored after failure), then an additional metric is needed for the probability that the component/system is operational at a given time, (t) (i.e. has not failed or it has been restored after failure) [2].

Reliability and Availability are not directly related, reasons been that it is possible to have an equipment breaks down frequently, only for short periods; meaning it has a fair level of availability [3]. On the order hand, it is possible to have an equipment that is known to be highly reliable, but low level of availability arising from having long downtime period. Availability is known in literature as stochastic modeling [4, 5] defined availability of a repairable system as "the probability that the system is operating at a specified time (t). The system reliability, availability and maintainability (RAM) have assumed great significance in recent years due to competitive environment and overall operating cost/production cost. Both reliability and availability and maintainability received renewed emphasis in the mid-1980's with the introduction of the Air Force's Reliability and Maintainability (RAM) 2000 program7 [6]. Objectives of the RAM 2000 program were to increase system readiness and availability and to reduce maintenance personal requirement and life-cycle cost through an increased reliability and maintainability by the year 2000 [7]. According to [8] recently, reliability, availability and maintainability have expanded their impact in several business, thus serves as integral quality elements in the organization system and manufacturing process and [9] also studied modeling and availability analysis of the fabric finishing system of a textile industry.

This study evaluates the performance of a sheet machine, which is used in the manufacturing of various roofing material and other sheet related items. It is usually subjected to both wear-out failures and random failures. The term is very important to a company because it determines to a large extent the utilization indices of a product or equipment in ratio to the cost of purchase of the product. In an industrial process, high plant availability plays a key role in helping the direction of industrial growth as the profit is linked directly to the production volume which depends upon plant performance. To achieve high system availability, proper maintenance management system supported by adequate resources such as manpower, spares and machines, etc. are required.

2. Materials and Methods

The process involves in taking the maintenance data log of the company are:

1. Collecting the historical life data for the machine.
2. Computing the necessary information such as the total number of breakdown and failures.
3. Computing the mean time before failure, time to repair and the machine availability

4. Generating plots and graphs by using the Microsoft office Excel program.

The data used was collected from Eternit Sapele Limited which based in Sapele, Nigeria. The data was a secondary data reason been that the company ceased to exist in the present location at the time this research was conducted. The data was gotten from a former employee who worked in the maintenance department of the company. The raw data was taken from the maintenance from the company for two consecutive years in review from 2012 to 2013. The raw data which is a quantitative in form contains the following parameters needed in analyzing the operation of the machine; this includes uptime, downtime which includes the faults that are associated with it. The uptime time of the machine was considered by subtracting the downtime recorded from the available time (24hours/day). The failure rate was obtained by recording the number of times the machine was shut down due to failure or breakdown and the preventive maintenance. Available time is the total time in which a machine is scheduled to in a month as shown in Table 4.1 and 4.2.
Mean time before failure (MTBF) describes the expected time before failure for a non-repairable system. The MTBF is the reciprocal of the failure rate. If these numbers of failures are random samples from a population and the failure times of this population followed a distribution with a probability density function (pdf).

$$\text{MTBF} = \frac{Total\ avaliable\ hours - Total\ breakdown}{Number\ of\ breakdown} \quad (1)$$

Mean time to repair (MTTR) which describes the excepted time a system is going to be fixed after failure must have set in. This is the average time from when downtime occurs to when the preventive maintenance downtime is done

$$MTTR = \frac{Total\ breakdown\ hours}{Number\ of\ breakdown} \quad (2)$$

Machine availability also known as Inherent availability is the steady state availability when considering only the corrective maintenance (CM) downtime of the system. This classification is what is sometimes referred to as the availability as seen by maintenance personnel. The corrective downtime reflects the efficiency and speed of the maintenance personnel, as well as their expertise and training level. Avliability model, A_v as shown below:

$$A_v = \frac{MTBF}{MTBF+MTTR} \quad (3)$$

Deals with reducing the frequency of failures over a period of time interval and is a measure of the probability for failure-free operation during a given interval, i.e., It is a measure of success for a failure free operation. The reliability is often expressed as:

$$R(t) = e^{-\lambda t} \quad (4)$$

3.0 Results and Discussion

Table 1: 2012 Machine Monthly Indicators for Sheet machine

S/N	Month	Available Time (hrs)	Total Breakdown (hrs)	Services (hrs)	Uptime (hrs)	Total no of breakdown (hrs)
1	January	608	137.14	21.61	449.25	31
2	February	672	54.59	46.41	571.00	28
3	March	728	68.67	52.65	606.68	30
4	April	352	25.61	43.86	282.33	16
5	May	360	0.50	35.88	323.62	15
6	June	312	0.33	35.42	276.25	13
7	July	528	0	76.26	451.74	22
8	August	288	0	17.44	270.56	12
9	September	408	0	52.87	355.13	17
10	October	480	0	48.14	431.86	20
11	November	360	0	48	312	15
12	December	96	0	13.6	82.4	4

Table 2: 2013 Machine Monthly Indicators for Sheet machine.

S/N	Month	Available Time (hrs)	Total Breakdown (hrs)	Services (hrs)	Uptime (hrs)	Total no of breakdown
1	January	640	110.58	55.72	473.70	27
2	February	672	135.88	46.12	490	28
3	March	744	94.13	49.50	600.37	31
4	April	624	75.58	44.59	503.83	26
5	May	432	61.14	25.67	345.19	20
6	June	568	57.15	42.64	468.21	26
7	July	560	53.01	8	498.99	24
8	August	568	77.73	41.49	448.78	26
9	September	552	36.34	34.98	474.17	25
10	October	480	81.75	38.42	359.83	20
11	November	400	80.32	17.20	302.48	19
12	December	408	54.91	3.50	346.59	17

Using January 2012 data, we have Total Operating time = 608 hours, Uptime = 449.25 hours, Downtime = 158.75 hours, Number of failures = 21. The failure rate, Repair rate, mean time between failures (MTBF), Number of failures, Reliability function and Availability were all calculated as follows:

$Failure\ rate\ (\lambda) = \frac{Total\ numbers\ of\ failure}{total\ operation\ time}$

$(\lambda) = \frac{21}{608}$ =0.034539

$Repair\ rate\ (\mu) = \frac{Total\ number\ of\ failures}{Total\ repair\ time}$

M = $\frac{21}{158.75}$ = 0.13228

Mean time between failures MTBF = $\frac{1}{\lambda}(\lambda)$ is the failure rate

We have Failure rate = 0.034539

MTBF = $\frac{1}{0.034539}$ = 28.9527 hours

MTTR = $\frac{Total\ repair\ time}{total\ number\ of\ failures}$

MTTR = $\frac{158.75}{21}$ = 7.559 hours MTTR = $\frac{Total\ repair\ time}{total\ number\ of\ failures}$

Reliability function:

R(t) = $e^{-(0.050987*608)}$ = 3.4421466*10^-14

Availability = $\frac{MTBF}{MTBF+MTTR}$

A table for the availability values for Eternit Sapele Limited for the year 2012 is shown in Table 4.3 below

Table 3: Availability values for 2012

S/N	Month	Repair Rate	Failure Rate	MTBF (hr)	MTTR (hr)	Availability
1	January	0.195214	0.050987	19.6129	5.122581	0.792906
2	February	0.277228	0.041667	24	3.607143	0.86934
3	March	0.24728	0.041209	24.26667	4.044	0.857156
4	April	0.229654	0.045455	22	4.354375	0.834776
5	May	0.412314	0.041667	24	2.425333	0.908219
6	June	0.363636	0.041667	24	2.75	0.897196
7	July	0.288487	0.041667	24	3.466364	0.873796
8	August	0.688073	0.041667	24	1.453333	0.942902
9	September	0.321543	0.041667	24	3.11	0.885282
10	October	0.415455	0.041667	24	2.407	0.90885
11	November	0.3125	0.041667	24	3.2	0.882353
12	December	0.294118	0.041667	24	3.4	0.875912

$Failure\ rate\ (\lambda)\ \frac{Total\ numbers\ of\ failure}{total\ operation\ time}$

Using January 2013 data, we have
Total Operating time = 640 hours
Uptime = 473.70 hours
Downtime = 166.3 hours
Number of failures = 27

$(\lambda) = \frac{27}{640}$ =0.04218

The others months were tabulated using the above formula

Repair rate $((\mu) = \frac{Total\ number\ of\ failures}{Total\ repair\ time}$

Downtime = 166.3 hours
Number of failures = 27

M = $\frac{1}{MTTR}$

M = $\frac{27}{166.3}$ = 0.162357

MTBF = $\frac{1}{\lambda}$

Failure rate = 0.04218

MTBF = $\frac{1}{0.04218}$ = 23.7079 hours

The value conveys the average time before failure can occur is (23.70 hours) day before failure will occur.

MTTR = $\frac{Total\ repair\ time}{total\ number\ of\ failures}$

Downtime = 166.3
Number of failures = 27

MTTR = $\frac{166.3}{27}$ = 6.1592 hours
Availability $= \frac{MTBF}{MTBF+MTTR}$

A table for the availability values for Eternit Sapele Limited for the year 2013 as well as a graph of useful life and burn in for the year 2013 are shown below:

Table 4: Availability values for 2013

S/N	Month	Failure Rate	Repair Rate	MTBF (hr)	MTTR (hr)	Availability
1	January	0.0421875	0.162357	23.7037	6.159259	0.740156
2	February	0.0416667	0.153846	24	6.5	0.729167
3	March	0.0416667	0.215832	24	4.633226	0.806949
4	April	0.0416667	0.21636	24	4.621923	0.80742
5	May	0.0462963	0.230388	21.6	4.3405	0.799051
6	June	0.0457746	0.260547	21.84615	3.838077	0.824313
7	July	0.0428571	0.393378	23.33333	2.542083	0.891054

8	August	0.0457746	0.218084	21.84615	4.585385	0.790106
9	September	0.0452899	0.350533	22.08	2.8528	0.869255
10	October	0.0416667	0.166431	24	6.0085	0.749646
11	November	0.0475	0.194832	21.05263	5.132632	0.7562
12	December	0.0416667	0.291046	24	3.435882	0.855778

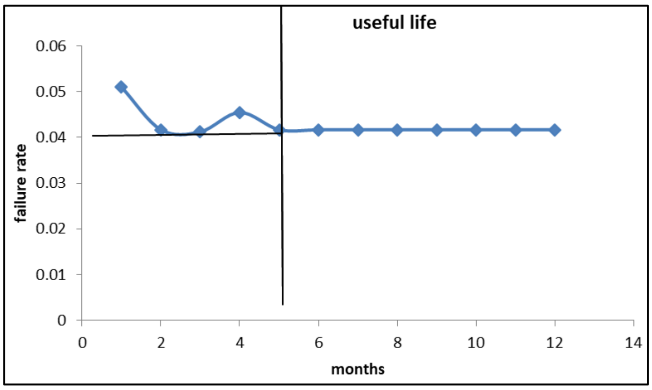

Fig 1: Failure rate plot for 2012

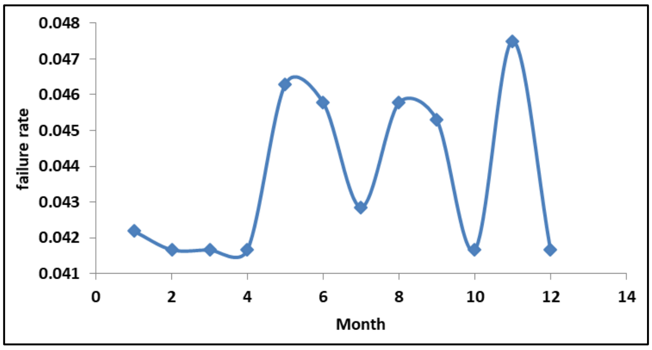

Fig 2: Failure rate plot 2013

From the graph can we can deduce that the 2012 failure rate obeys the bathtub curve where the infant mortality starts from January to may then the useful life begins from may indicating that the machine is on its useful life period. The year 2013 recorded a mixed variety of trend where linearity is not existing meaning that the machine performed poorly.

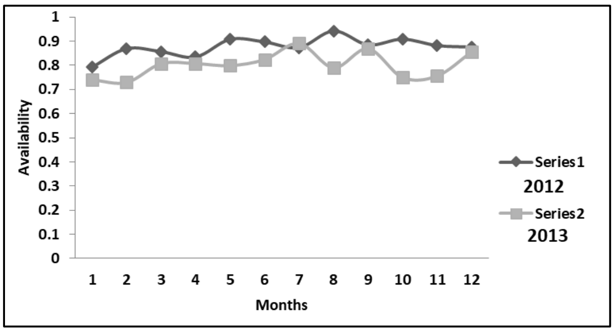

Fig 3: Availability plot for 2012 and 2013

The graph curve shows that the machine was more available in 2012 having its highest peak at the month of august and has the result of the failure rate to be low. Four months have 0.900 availability with the rest below and shows that the failure rate in those remaining months have greater failure rate. The year 2013 represented a low availability in comparison with the year 2012 collaborating the failure rate curve that shows that the useful life was not available.

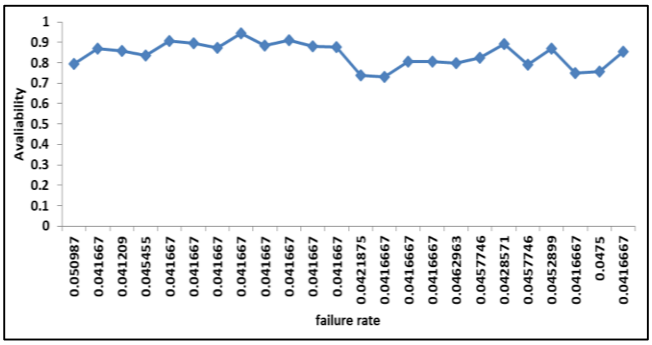

Fig 4: Availability plots from January 2012-December 2013

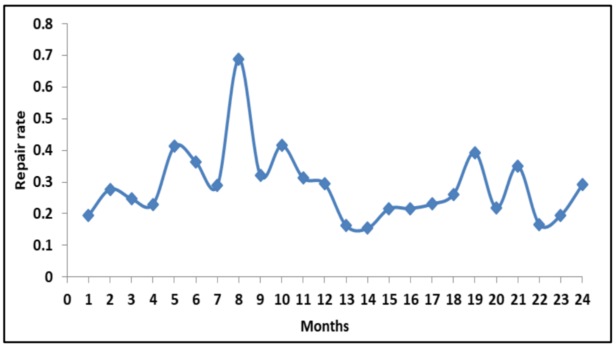

Fig 5: Plot showing 24-month repair rate from January 2012-December 2013

The tables 4 indicated to a large degree the relationship between the reliability function and the unavailability factor from the year 2012 and this shows that the highest unavailability was recorded in the month of March meaning that it was the month the machine experienced the lowest value of availability. The reason being that it has the highest failure rate. The same observation was recorded for the year 2013 in table 4.6.

The cumulative Density function for a two parameter Weibull distribution

The equations for solving the parameter are contained in Equation (1) to (5)

Where F(t) is the cumulative density function

Table 5: CDF Parameters for Weibull Distribution

I	Xi	ln(xi)	F(t)	ln -ln(1-F(t)
1	0.05099	-2.97618	0.041667	-3.15685
2	0.04167	-3.17805	0.125	-2.01342
3	0.04121	-3.1891	0.208333	-1.45408
4	0.04546	-3.09103	0.291667	-1.06467
5	0.04167	-3.17805	0.375	-0.75501
6	0.04167	-3.17805	0.458333	-0.48922
7	0.04167	-3.17805	0.541667	-0.24826
8	0.04167	-3.17805	0.625	-0.01936
9	0.04167	-3.17805	0.708333	0.208755
10	0.04167	-3.17805	0.791667	0.450194
11	0.04167	-3.17805	0.875	0.732099
12	0.04167	-3.17805	0.958333	1.156269

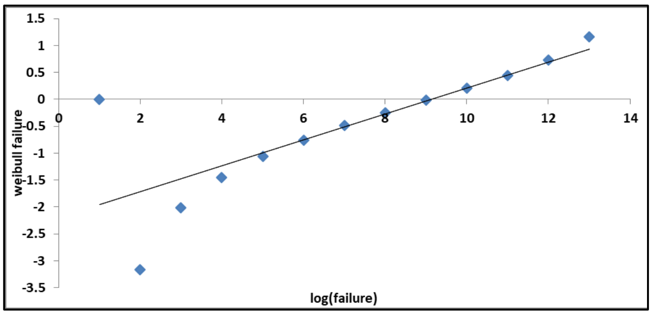

Fig 6: Weibull failure plot for 2012

This is the result of linearization of the Weibull distribution function

The Weibull distribution revealed that all the plots formed approximately a straight line which indicated that the Weibull distribution is well distributed [10]. Hence, it can be concluded that the model is valid. Weibull plot has special scales that are designed so that if the data do follow a Weibull distribution, the least square fits yields an estimate for the shape and scale parameters of the Weibull distribution, the location is assumed to be zero. The estimator of this is the sample correlation coefficient of the two years and is given as 0.567 indicating that the data was moderate [10].

5. Conclusion

The month of August has an availability of 0.942920 with failure rate of 0.0428 and highest repair rate of 0.688073. The month of January has an availability of 0.792906 with failure rate of 0.050987 and lowest repair rate of 0.195274, all these were witnessed in the year 2012. The month of July has an availability of 0.891054 with failure rate of 0.042871 and highest repair rate of 0.393378. The month of February has an availability of 0.729167 with failure rate of 0.0416667 and lowest repair rate of 0.153846, all these were witnessed in the year 2013. The year 2013 represented a low availability when compared with the year 2012 and collaborating that the failure rate curve shows the useful life was not available. This is indicated to a large degree the relationship between the reliability function and the unavailability factor and how failure rate is inversely proportional to the availability of a machine. In order to achieve optimal utilization of the machine the failure rate must be reduced drastically.

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