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Research Article

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Failure of Fan Belt and Electric Motor a Major Effect on Downtime of Asphalt Plant Production Capacity: A Case Study

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Abstract Research was conducted to study the low in production capacity of an Asphalt plant located in Port Harcourt City of Rivers State in Nigeria. In this study two major components was identified and isolated, which was classified as fan belt and electric motor. The failure of these components increases as the asphalt plant service time and utilization increases. From this research, it was observed that the components with frequent failures during production are; the fan belt and electric motor components. This research was carried out by considering the functional parameters such as meantime between failures (MTBF), Failure Rate (FR), Lost Time to repair, Downtime, reliability (R), unreliability (UR), availability (A) and unavailability (UA). Data from the Asphalt plant as a case study over a five years period of January 2014 to December 2018was investigated in terms of failure per year (FPy), operating time per year or uptime (UT) and repair time (RTy). The reliability of fan belt and electric motor of the asphalt plant component was evaluated and the results obtained reveals that fan belt was at 5.2% in the first year and 1.2% after the fifth years as well as the electric motor was at 74.4% in the first year and then 51.2% after the fifth year. Increase in fan belt failure as the year increases as well as the electric motor was fluctuating (decreasing and increasing) as the year increases.

Keywords Failure, fan belt, electric motor, major effect, downtime, asphalt plant, production capacity

Introduction

Failure, risk and reliability analysis of plants are important to the engineers as well as the mode of operation of each plant. The asphalt plant is design to achieve the objective and aim for which it is produced or manufactured. For example, a major unit in road construction and the product to obtain from such plant is required to meet the international standard [1]. Although, plant failure influence the quality of the product, if repair last more than expected and measures are not put in place to correct .the menace. This investigation will highlight the significance of some asphalt component parts for achieving high reliability in the process plant [2]. The asphalt plant was studied for 5 years to enable us ascertain the characteristics of the fail terms of the plant considered for this investigation and the findings will showcase the best approach that will help the company to improve their operation [3].

Failure analysis and internal consistency in plant components was considered in this study. The survey was carried out using oral interview on key personnel as well as questionnaire was used to obtain the data for this investigation. Reliability model was used in this research for the computation of component parameters of asphalt plant components studied (Fan Belt and Electric Motor) [4].

Reliability analysis has been used worldwide for asphalt plant components study [5]. Studies on Asphalt plant components in terms of phased mission system and highlighted the aim of considering asphalt plant components in this study [5]. Research conducted on reliability of Asphalt plant components showcase the effect of inadequate maintenance in plant failure as well as the significant impact on the cost of unreliability [6]. Other research groups considered Asphalt plant components in terms of modeling to account the unreliability resulting from poor maintains and improper utilization of the asphalt plant components for operational objectives [7-8]. Further investigation was conducted by other researchers in the area of bitumen influence on the quality of the Asphalt as well as the contributing factors of operating components to enhance performance and quality [9].

In the Nevada phased mission system performance of the job was attributed to the quality of the bitumen, used in the production of the Asphalt [8]. The effects of reliability analysis of asphalt plant components in quality of product can be attributed mostly on the Asphalt plant maintainability [8].

An appraisal of the reliability analysis of Asphalt plant components was conducted and their studies outline the significance of Asphalt plant components appraisal as a medium to enhance reliability of plants [10]. Investigation on the reliability of cement plant components and the behaviour of each unit plant components was studied [11]. In their investigation, the following effects were identified as a major to low performance of the cement plant bag separator, which include unit plant components failure [11]. Further study revealed the conducted of reliability impact on Asphalt plant components degradation, system that will enhance improvement if practice [12]. Their research outlines the approach of modeling of the dependent variables as well as the independent variables of the Asphalt plant components. Investigation on the contributing impacts of dependent and independent variable in reliability in terms of empirical or theoretical tools were studied [12]. Their research revealed significantly the impact of these variables in examining the performance of Asphalt plant components.

Investigation was conducted on the degradation of Asphalt plant components as factor that contributes to Asphalt part component failure and advices of continuous maintain as the best option to reduce unreliability and increase reliability of an asphalt plant components due to the dusting nature of the operation [5-6]. Other researchers investigated the effect of stress of asphalt plant components failure and discovered that operating asphalt plant above the allowable limit can influence the efficiency as well as increase degradation of the components.

Materials and Methods

Sampled Area

The Construction Company where samples are collected is located in Port Harcourt. The company has asphalt plant that produces a minimum of 400 tons of asphalt weekly in dry season and a minimum of 150 to 200 tons of asphalt, weekly in rain season. The company has 38 staff. The company has both atlas asphalt plant and moon asphalt plant, 11 pieces of Mack double axel truck, 2 pieces of Mack lowbed truck, 4 pieces of caterpillar, pay loader, 2 pieces of pieces of caterpillar swamp-buggy, 2 pieces of caterpillar grader, D7h caterpillar, dozzer, 4 pieces of asphalt paver machine, 1 asphalt combination roller, 2 pieces of steel to steel asphalt roller, 1 piece of 320 cat excavator, 1 piece of caterpillar back-hole, concrete mixer truck, 2 pieces of steel to tyre compactor and asphalt cutting machine.

Reliability Test

Reliability means the consistency of a measure. A measure is said to be reliable if it is consistently reproducible. Reliability, therefore, refers to whether a test that is repeated on or about a study would give the same results or not.

Methods of Data Collection

Data collection is the process of gathering data from either the primary or secondary sources for the purpose of the study analysis. The primary sources consist of first-hand information or raw data obtained by the researcher himself through the records and data collected from the company as regard to as asphalt plant. The secondary sources are existing data obtained from relevant materials such; books, journals, magazines and so on an unpublished work of others as well as valuable documents available to the researcher.

Materials Used in Asphalt Production

The following materials are used such as: Stone dust also called 0-5mm, coarse aggregate 5 – 15mm called ½ inch for wearing, coarse aggregate 15 – 22mm or ¾ inch for binding, sharp sand and bitumen.

Asphalt Plant

Asphalt plant refers to as the machine or equipment which is used in the production of asphalt. There are basically two types of asphalt plant, they include the batch mix asphalt plant and drum mix asphalt plant

The components for this drum mix asphalt plant include: Dryer drum, four bin feeder, conveyor belts both inlet and outlet, electric motors, bearings, fan belt, bitumen tank, control panel, gear box, exhaust and vibrating screen. In course of carrying out this study, it was observed that there are few components that usually fail during production over a period of time and those components are the ones we carried out reliability analysis to ascertain failure rate and other parameters.

The Materials Components to be Analyzed Includes

The following asphalt components are to be analyzed in this study: Fan belt and electric motors

Reliability Tools and Techniques

There are reliability tools and techniques methodologies available for failure of plant components. We have the Monte Carlo reliability model which can realistically assess plant condition when combined with cost, repair times and statistical events. Monte Carlo simulation model is very helpful for considering approximate operating conditions in a plant including cost effectiveness and sizing to provide protection for short duration failures.

Reliability model stimulate correctives ideas for solving costly problems and present, replication of old problems. Reliability model offer a scientific method of studying actions, responses and cost in the virtual laboratory of the computer using actual failure data from existing plants. It is noted that either Monte Carlo model is never better than the data supplied or obtained as a failure that occurs.

Model Formulation and Development

The mathematical model for this research was established by considering five (5) year study interval (S.I) as well as the number of failures (NF) and the repair time per failure (CTPF) for each of the components to be analyzed.

Mean Time between Failures (MTBF)

Mena time between failure (MTBF) for each asphalt plant components was evaluated using the mathematically expression given in equation (1), we have

$$(MTBF) = \frac{SI}{NF} \quad (1)$$

Total Mean Time between Failure (TMTBF)

To determine the total mean time between failures for each of the asphalt plant components for each year for five year period, we must first establish total failure per year.

Thus,

$$(TFPy) = \left[(\frac{1}{MTBF})_{y1} + (\frac{1}{MTBF})_{y2} + (\frac{1}{MTBF})_{y3} + (\frac{1}{MTBF})_{y4} + (\frac{1}{MTBF})_{y5}\right] x\ annual\ hr/\ yr \quad (2)$$

Therefore, the total time between failure (TMTBF) for one component of the asphalt plant for 5 years is expressed as

$$TMTBF = \frac{annual\ \ hours\ per\ year}{Total\ failure\ per\ year} = \frac{AHPY}{TFPY} \quad (3)$$

Failure Rate (FR)

To determine the failure rate for each asphalt plant component, the mathematical expression stated below can be applied,

$$FR = \frac{1}{MTBF} = \frac{1}{SI/_{NF}} = \frac{NF}{SI} \quad (4)$$

$$\text{FR} = \left[\frac{1}{MTBF}\right] = \left[\frac{NF}{SI}\right] \quad (5)$$

Total Failure Rate (TFR)

The total rate (TFR) is determined by the summation of each failure rate of each asphalt plant component investigate and is expressed mathematically as

$$TFR = [(TFR)_1 + (TFR)_2 + (TFR)_3 + (TFR)_4 + (TFR)_5] \quad (6)$$

Failure Per Year (FPY)

To determine the failure per year (FPY) for each asphalt plant to be investigated, the mathematical expression is the:

Fpy = (failure rate for each product) x (annual hour per year)

$$= (\text{FR})\ (\text{AHP}_1) \quad (7)$$

$$= \left(\frac{NF}{SI}\right)(ANPY) \quad (8)$$

$$\text{FPY} \left[\frac{1}{MTBF}\right] (\text{AHPY}) \quad (9)$$

Total Failure Per Year (TFPY)

Therefore the failure per year (TFPY) is the summation of failure per year (FPY) for each of the asphalt plant component for 5 year include

$$TFP_Y = \sum\left[(FP_y)_1 + (FP_y)_2 + (FP_y)_3 + (FP_y)_4 + (FP_y)_5\right] \quad (10)$$

Total Repair TimePer Failure (TRTPF)

The total repair time per failure (TRTPF) is determined using the mathematically expression as shown below:

$$(\text{TRTPF}) = \frac{Repair\ time\ per\ failure\ of\ each\ component\ \ x\ failure\ per\ year\ of\ each\ component}{Total\ failure\ per\ year} \quad (11)$$

$$= \frac{(CTPF)_1\,(FPY)_1 + (CTPF)_2\,(FPY)_2 + (CTPF)_3\,(FPY)_3 + (CTPF)_4\,(FPY)_4 + (CTPF)_5\,(FPY)_5}{TFPY} \quad (12)$$

Reliability Model

To determine the reliability of each asphalt plant component, the mathematically expression is giving as

$$R = e^{-}\left(\frac{1}{MTBF}\right)^t \quad = e^{-\lambda t} \quad (13)$$

Where,

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

When as the reliability for each asphalt component for five year study is give as

$$R = e^{-}\left[\left(\frac{1}{MTBF}\right)_1 + \left(\frac{1}{MTBF}\right)_2 + \left(\frac{1}{MTBF}\right)_3 + \left(\frac{1}{MTBF}\right)_4 + \left(\frac{1}{MTBF}\right)_5\right]^t \quad (14)$$

Unreliability model

To determine unreliability for each asphalt plant component, the mathematical expression is given by,

$$U_R = 1 - R = e^{-}\left(\frac{1}{MTBF}\right)_t = 1 - e^{-\lambda t} \quad (15)$$

Availability Model

To determine availability (A) of each asphalt plant component per year.

$$A = \frac{uptime}{uptime + down\ time} \quad (16)$$

Unavailability

The unavailability (UA) for each component is determined by using the expression below

$$UA = 1 - A = 1 - \left[\frac{uptime}{uptime + down\ time}\right] \quad (17)$$

Fan Belt

The fan belt of the Asphalt plant was one of the components of which investigation was carried out on. The fan belt is located just slightly close to the hot conveyor and it aids in rotating the drum containing the bitumen and other components.

Table 1: Results of Reliability Parameters for the Fan Belt (F)

Parameters	Period(Year)				
	1	**2**	**3**	**4**	**5**
Uptime (UT)	2592	2400	2208	2064	1920
Study Interval (SI)	8760	8760	8760	8760	8760
Mean Time Between Failure (MTBF)	259.2	200	147.2	121.4	96
Failure Rate (FR)	0.00114	0.00137	0.00171	0.00194	0.00228
Downtime (DT)	30	24	30	30	40
Reliability (R)	0.0521	0.00373	0.0229	0.0182	0.0126
Unreliability (UR)	0.9479	0.9627	0.9771	0.9818	0.9874
Availability (A)	0.9886	0.9901	0.9866	0.9838	0.9796
Unavailability (UA)	0.0114	0.0099	0.0134	0.0162	0.0204

From Table 1 it is observed that there is a steady increase in the failure rate while the down time barely had any increase in the 2nd year but there was a decrease. This was because the plant was still anew and the fan belt was very much effective during both the first and second year. From the 3rd year, the failure rate increased significantly from the 3rd year to the 5th year. There is also a decrease in the reliability of the component.

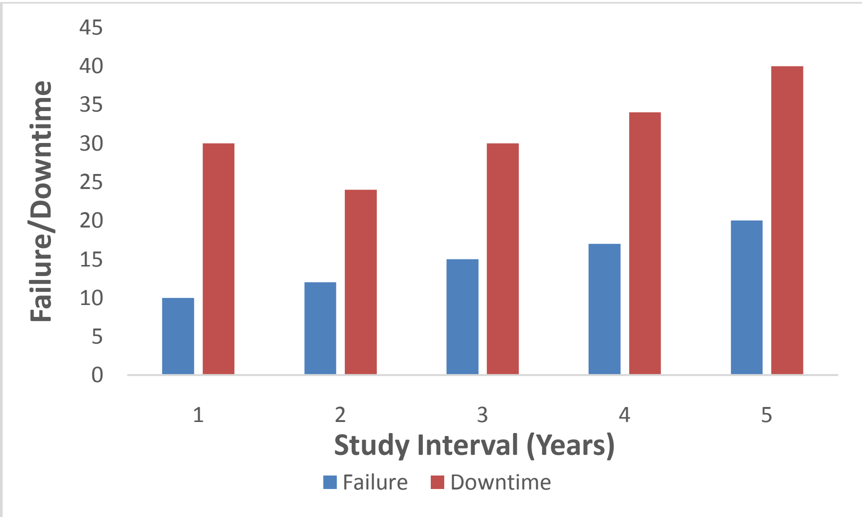

Figure 1: The Chart of Number of Failure Downtime for a 5 Year Period

Figure 1 also shows the slight increase in the downtime time after the decrease in the 2nd year while the number of failure increases as the year increases.

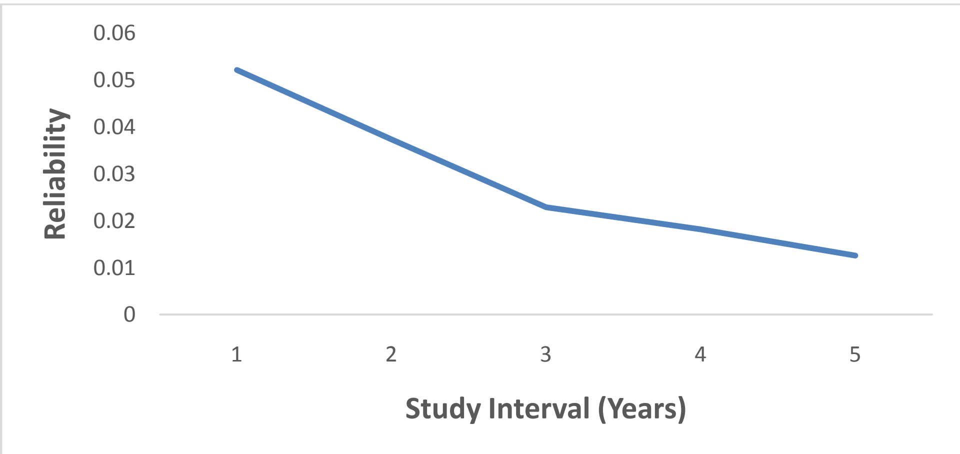

Figure 2: Reliability Analysis of the Fan Belt Component over a Period of 5 Years

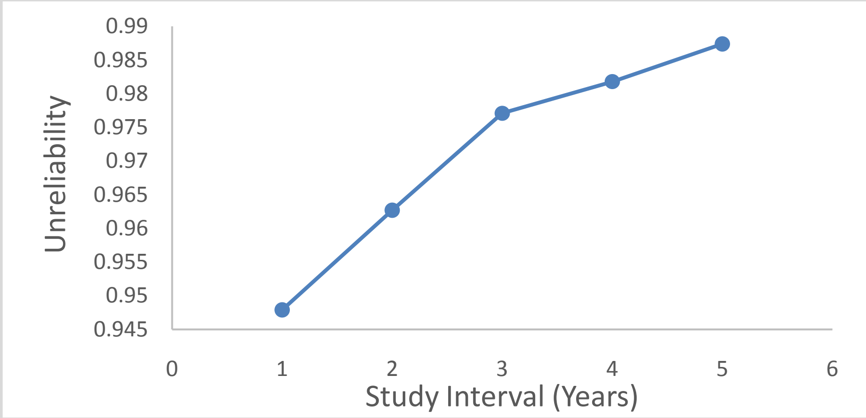

Figure 3: Unreliability Analysis of the Fan Belt Component over a Period of 5 Years

From Figure 2, the reliability of the fan belt was decreasing steadily as the year increases while the unreliability curve showed a linear increase as seen on Figure 3. This steady decrease of reliability is directly proportional to the increase in failure rate per year for the 5 year period.

Electric Motor (EM)

The electric motor used in rotating the drum in the asphalt plant also had regular breakdown and maintenance due to its usage. Table 2 shows the various computational data obtained using the Monte Carlo method of reliability analysis for asphalt plant electric motor.

Table 2: Results of Reliability Parameters for Electric Motor 2014-2018

Parameters	Period (Year)				
	1	**2**	**3**	**4**	**5**
UT	2592	2400	2208	2064	1920
SI(h)	8760	8760	8760	8760	8760
MTBF	2592	2400	1104	1032	640
FR	0.00114	0.000114	0.000228	0.000228	0.000342
DT	3	2.5	5	4	6
R	0.7440	0.7606	0.6045	0.6246	0.5186
UR	0.2560	0.2394	0.3955	0.3754	0.4814
A	0.9988	0.9990	0.9977	0.9977	0.9969
UA	0.0012	0.0010	0.0023	0.0019	0.0031

From Table 2 the failure rate was constant in the year 2014 (1^{st} year) and the year 2015 (2^{nd} year), there was an increase in the failure rate in 2016 but it remained constant in 2017(4^{th} year) before and increasing in 2018(5^{th} year) before an increase in the year 2018. Also the down time decreased in the year 2015 and later increased by 2.5 hours in the year 2016 and later dropped in 2017 before an increasing in the year 2018.

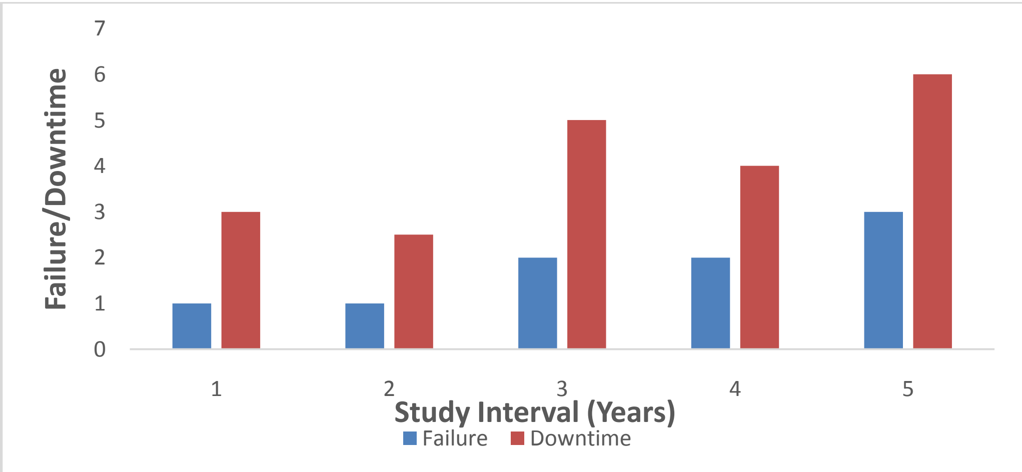

Figure 4: The Number of Failure/Downtimes against Study Interval (Year)

In Figure 4 the failure rate and downtime has the increase and decrease pattern every year. Most of the downtime was observed in the 3rd year and 5th year.

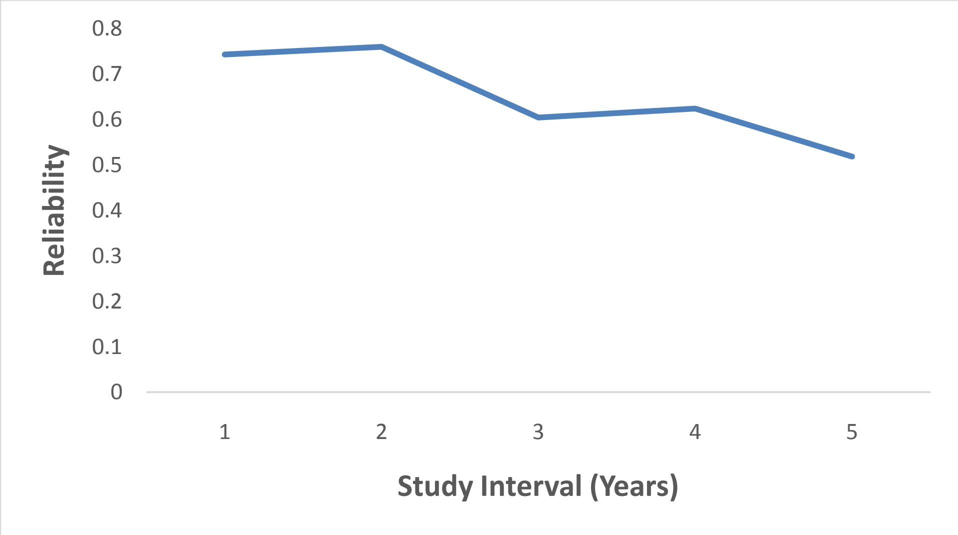

Figure 5: Reliability Analysis of Electric Motor Component in the Asphalt Plant

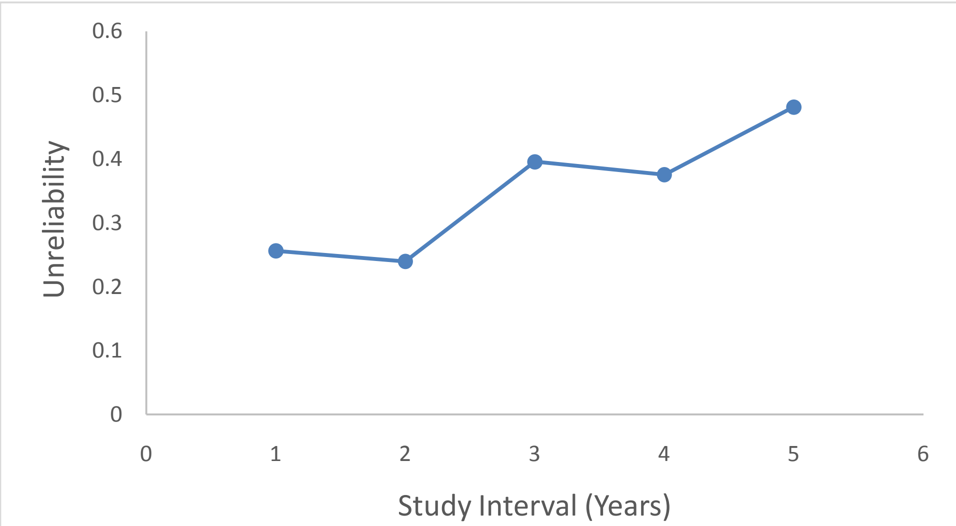

Figure 6: Unreliability Analysis of Electric Motor Component in the Asphalt Plant

From Figure 5 the reliability is stable between the 1st and 2nd year and then a decrease in the 3rd year. For the 4th year it was much more stable until the 5th year when there was another decrease. Figure 6 shows the unreliability was also increasing but it reduced in the 2nd year and 4th year.

Computational Data and Reliability Analysis for Electric Motors (EM) Component

The electric motor component of Asphalt plant was also observed to be one of the equipment with regular breakdown. Table 2 shows the data collected for the electric motor for a period of 5 years (study interval) which included the failure rate per year, operating time per week and repair time to repair each breakdown per year.

Table 3: Data Collected from Asphalt Plant for Electric Motor Component

Years	Failure/year	Repair Time (Hours)	Operating (Hours/ Week)
1	1	3	54
2	1	2.5	50
3	2	2.5	46
4	2	2	43
5	3	2	40

To Evaluate the Operating Time Per Year

Operating Time Per Year = Operating Time per Week x 4 Weeks x 12 Months

For 1st year = 54 x 4 x 12 = 2592, for 2nd year = 50 x 4 x 12 = 2400, for 3rd year = 46 x 4 x 12 = 2208, for 4th year = 43 x 4 x 12 = 2064 and for 5th year = 40 x 4 x 12 = 1920

Meantime between Failure (MTBF) for Electric Motor (EM)

MTBF (EM) = $\frac{operating\ time}{no\ of\ failures}$

For 1st year = $\frac{2592}{1}$ = 2592, for 2nd year = $\frac{2400}{1}$ = 2400, for 3rd year = $\frac{2208}{2}$ = 1104, for 4th year = $\frac{2064}{2}$ = 1032 and for 5th year = $\frac{1920}{3}$ = 640

Total Meantime between Failure for electric motor for 5 year period

TMTBF = $\frac{Total\ annual\ hour\ per\ year}{Total\ failure\ per\ year}$

= $\frac{2592+2400+1104+1032+640}{9}$

TMTBF = $\frac{7768}{9} = 863.11$

Failure Rate for Electric Motor (EM) Per Year

Failure rate = $\frac{Number\ of\ failure}{study\ interval} = \frac{NF}{SI}$

Study interval (hours) = 1 year x 24 hours = 365 x 24 = 8760 hours/year

For 1st year = $\frac{1}{8760}$ = 0.000114, for 2nd year = $\frac{1}{8760}$ = 0.000114, for 3rd year = $\frac{2}{8760}$ = 0.000228, for 4th year = $\frac{2}{8760}$ = 0.000228 and for 5th year = $\frac{2}{8760}$ = 0.000342

Total failure rate for 5 years = $\sum failure\ per\ year$

= 0.000114 + 0.000114 + 0.000228 + 0.000228 + 0.000342

= 0.001026

Lost Time per year (LPy) for Electric Motor

Lost time per year = Failure of each component per year X repair time

For 1st year = 1 x 3 = 3 hours, for 2nd year = 1 x 2.5 = 2.5hours, for 3rd year = 2 x 2.5 = 5 hours, for 4th year = 2 x 2 = 4 hours and for 5th year = 3 x 2 = 3 hours

Reliability (R) for Electric Motor

$R = e^{-\lambda t}$

Where, λ = failure rate/year and t = operating time/year

For 1st year = $e^{-0.000114\ x\ 2592}$ = 0.7440 ≃74.4%, for 2nd year = $e^{-0.000114\ x\ 2400}$ = 0.7606 ≃76.06%, for 3rd year = $e^{-0.000228\ x\ 2208}$ = 0.6045 ≃60.45%, for 4th year = $e^{-0.000228\ x\ 2064}$ = 0.6246 ≃ 62.46% and for 5th year = $e^{-0.000342\ x\ 1920}$ = 0.5186 ≃51.86%

Unreliability (UR) for Electric Motor

Unreliability (UR) = 1 – R

Where, R = Reliability

Therefore, for 1st year = 1- 0.7440 = 0.256 ≃ 25.6%, for 2nd year = 1- 0.7606 = 0.2394 ≃ 23.94%, for 3rd year = 1- 0.6045 = 0.3955 ≃ 39.55%, for 4th year = 1- 0.6246 = 0.3754 ≃ 37.54% and for 5th year = 1- 0.5186 = 0.4814 ≃48.14%

Availability (A) for Electric Motor

Availability (A) = $\frac{Uptime}{Uptime+Downtime}$

For 1st year = $\frac{2592}{2592+3}$ = 0.9988 = 99.88%, for 2nd year = $\frac{2400}{2400+2.5}$ = 0.9990 = 99.9%, for 3rd year = $\frac{2208}{2208+5}$ = 0.9977 = 99.77%, for 4th year = $\frac{2064}{2064+4}$ = 0.9981 = 99.81% and for 5th year = $\frac{1920}{1920+6}$ = 0.9969 = 99.69%

Unavailability (UA) for Electric Motor

Unavailability = 1 – A

When, A = Availability

For 1st year = 1- 0.9988 = 0.0012 ≃ 0.12%, for 2nd year = 1- 0.9990 = 0.001 ≃ 0.1%, for 3rd year = 1- 0.9977 = 0.0023 ≃ 0.23%, for 4th year = 1- 0.9981 = 0.0019 ≃ 0.19% and for 5th year = 1- 0.9969 = 0.0031 ≃0.31%.

Computational Data and Reliability Analysis for Fan Belt (F) from 2014 – 2018

The Fan Belt component of Asphalt plant rotating drum was analyzed from the data obtained from the Asphalt Plant. Table 4 shows the data collected for the fan belt for a period of 5 years (study interval) which included the failure rate per year, operating time per week and repair time to repair each breakdown per year.

Table 4: Data Collected from Asphalt Plant for Fan Belt Component

Years	Failures/y	Repair Time/week	Operating Time /week
1	10	3	54
2	12	2	50
3	15	2	46
4	17	2	43
5	20	2	40

To Evaluate the Operating Time Per Year

Operating Time Per Year = Operating Time per Week x 4 Weeks x 12 Months

For 1st year = 54 x 4 x 12 = 2592hrs/y, for 2nd year = 50 x 4 x 12 = 2400hrs/y, for 3rd year = 46 x 4 x 12 = 2208hrs/y, for 4th year = 43 x 4 x 12 = 2064hrs/y and for 5th year = 40 x 4 x 12 = 1920hrs/y

Mean between Failure for Fan Belt (F)

$$MTBF_{(F)} = \frac{Operating\ time}{no\ of\ failure}$$

For 1st year = $\frac{2592}{10}$ = 259.2hrs, for 2nd year $= \frac{2400}{12}$ = 200hrs, for 3rd year $= \frac{2208}{15}$ =147.2hrs, for 4th year = $\frac{2064}{17}$= 121.4hrs and for 5th year = $\frac{1920}{20}$= 96hrs

TMTBF = $\frac{total\ annual\ \ hour\ per\ year}{Total\ failure\ per\ year}$

= $\frac{259.2+200+147.2+121.4+96}{10+12+15+17+20}$

= $\frac{823.8}{74}$ = 11.13hrs

Failure Rate for the Fan Belt (F) Per Year

Failure rate = $\frac{number\ \ of\ failure}{study\ \ interval} = \frac{NF}{SI}$

Study interval (hours) = 365 x 24 = 8760 hours/year

For 1st year = $\frac{10}{8760}$ = 0.00114, for 2nd year $= \frac{12}{8760}$ = 0.00137, for 3rd year = $\frac{15}{8760}$ = 0.00171, for 4th year = $\frac{17}{8760}$ = 0.00194 and for 5th year = $\frac{20}{8760}$ = 0.00228

Total failure rate for 5 years = $\sum failures/year$

= 0.00114 + 0.00137 + 0.00171 + 0.00194 + 0.00228 = 0.00844

Lost Time Per Year for Fan Belt

Lost time year = failure of each component per year x repair time

For 1st year = 3 x 10 = 30 hours, for 2nd year = 2 x 12 = 24 hours, for 3rd year = 2 x 15 = 30 hours, for 4th year = 2 x 17 = 34 hours and for 5th year = 2 x 20 = 40 hours

Reliability (R) for Fan Belt (F)

$R = e^{-\lambda t}$

When, λ = failure rate/year, t = operating time/year

For 1st year = $e^{-\,0.000114\ x\ 2592}$ = 0.0521 ≃ 5.21%, for 2nd year = $e^{-\,0.000137\ x\ 2400}$ = 0.0373 ≃3.73%, for 3rd year = $e^{-\,0.000171\ x\ 2208}$ = 0.0229 ≃2.29%, for 4th year = $e^{-\,0.000194\ x\ 2064}$ = 0.0182 ≃1.82% and for 5th year = $e^{-\,0.000228\ x\ 1920}$ = 0.0126 ≃1.26%

Unreliability (UR) for Fan belt

Unreliability (UR) = 1 –R

Where, R = Reliability

Therefore, for 1st year = 1- 0.0521 = 0.9479 ≃94.79%, for 2nd year = 1- 0.0373 = 0.9627 ≃96.27%, for 3rd year = 1- 0.0229 = 0.9771 ≃ 97.71%, for 4th year = 1- 0.0182 = 0.9818 ≃98.18% and or 5th year = 1 - 0.0126 = 0.9874 ≃98.74%

Availability (A) for Fan Belt

Availability (A) = $\frac{uptime}{Uptime + downtime}$

For 1st year = $\frac{2592}{2592+30}$ = 0.9886 ≃98.86%, for 2nd year = $\frac{2400}{2400+24}$ = 0.9901 ≃99.01%, for 3rd year = $\frac{2592}{2208+30}$ = 0.9866 ≃ 98.66%, for 4th year = $\frac{2064}{2064+34}$ = 0.9838 ≃98.38% and for 5th year = $\frac{1920}{1920+40}$ = 0.9796 ≃97.96%

Unavailability (UA) for Fan Belt

Unavailability = 1- A

Where, A = Availability, for 1st year =1- 0.9886 = 0.0114 ≃1.14%, for 2nd year = 1- 0.9901 = 0.0099, ≃0.99%, for 3rd year = 1- 0.9866 = 0.0134 ≃1.34%, for 4th year = 1- 0.9838 = 0.0162 ≃1.62% and for 5th year = 1- 0.9796 = 0.0204 ≃2.04%

Conclusion

The research work demonstrates the following outcome

i. This research work will provide relevant information for prospective businessmen (buyers) to know more about the drum mix asphalt plant in terms of knowing some of the major components associated with failure during production and also planning to avert such failure to avoid total breakdown and enhance productivity.
ii. This research has also contributed on the role played by fan belt and electric motor in an asphalt plant
iii. Quality part is recommended for smooth operation, regardless of its cost effectiveness.
iv. Sub-standard component parts should be avoided and the use of quality and right parts should be encouraged during maintenance.
v. Periodic and preventive maintenance should be put in place to avoid breakdown.
vi. Asphalt plant component should be available always to reduce the down time.
vii. The environmental influence in the failure and performance of the asphalt plant should be considered.
viii. Trained personnel should be allowed to operate the equipment so as to know when best to expect failure and prepare towards it rather than changing operators off and on.

Reference

[1]. Coit, D., Feng, Q. (2010). Integrated modeling and optimization of manufacturing variability and product reliability for advanced/evolving technologies. *International Journal of Advanced Manufacturing Technology*. 51, (5), 29-45.

[2]. Daigle, M. J., Goebel, K. (2011). A model-based prognostics approach applied to pneumatic valves. *International Journal of Prognostics and Health Management*, 2, 84.

[3]. Frenzel, P.L. (2013). MEMS oscillators replace quartz crystal oscillators. *Journal* of *Electronic Design*, 9, (1), 12-19.

[4]. Fritzsche,R. J., Gupta, N. D., Lasch. R. (2014). Optimal prognostic distance to minimize total maintenance cost: The case of the airline industry. *International Journal of ProductionEconomics*151, 76-88.

[5]. Huysman, S., Debaveye, S., Schaubroeck, T., De Meester, S., Ardente, F., Mathieux, F., Dewulf, J., (2015). The recyclability benefit rate of closed-loop and open-loop systems: A case study on plastic recycling in Flanders. *Journal of Recycling and Resources Conservation*, 101, 53-60

[6]. Iannacci, J., Repchankova, A., Faes, A., Tazzoli, A., Meneghesso, G. (2010). Enhancement of RF-MEMS switch reliability through an active anti-stiction heat-based mechanism, *Microelectronics Reliability*, 9, 1599-1603.

[7]. Jiang, L, Qianmei F., David, W. C. (2012). Reliability and maintenance modeling for dependent competing failure processes with shifting failure thresholds. Journal of *Reliability Transactions* 4, 932-948.

[8]. Moghaddass, R., Zuo, M. J. (2014). Multistate degradation and supervised estimation methods for a condition-monitored device. Journal of *Reliability Transactions* 6, 31-148.

[9]. Peng, H.., Feng, Q., Coit, D. W. (2010). Reliability and maintenance modeling for systems subject to multiple dependent competing failure processes," *IIE transactions*, 43, 1, 12-22.

[10]. Saxena, A. S.S., Kai, G. (2014). Performance evaluation for fleet-based and unit-based prognostic methods. *Second European conference of the Prognostics and Health Management society*. 7, (1), 22-39

[11]. Song, S., Coit, D.W., Feng, Q. (2014). Reliability for Systems of Degrading Components with Distinct Component Shock Sets," *Reliability Engineering & System Safety*, 132, 115-124.

[12]. Song, D. W., Feng, C.Q. (2013). Reliability Analysis for Parallel Systems with Different Component Shock Sets, *Proceedings of the Industrial & Systems Engineering Research Conference*, 2013.