British Journal of Applied Science & Technology
15(6): 1-13, 2016, Article no.BJAST.20813
ISSN: 2231-0843, NLM ID: 101664541

SCIENCEDOMAIN _international_
www.sciencedomain.org

Validation of Process Performance through Reliability Measurement

Christopher Chukwutoo Ihueze[1] and Ebisike Paschal Soroibe[1*]

[1]Department of Industrial and Production Engineering, Nnamdi Azikiwe University, Awka, Nigeria.

Authors' contributions

This work was carried out in collaboration between authors CCI and EPS. Author EPS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript and managed literature searches. Author CCI managed the analysis of the study and literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/BJAST/2016/20813
Editor(s):
(1) Giovanni Bucci, Department of Industrial Engineering and Information and economy, University of L'Aquila, Italy.
(2) Manjinder Singh, Department of Biological and Agricultural Engineering, University of Georgia, Georgia, USA.
Reviewers:
(1) G. Y. Sheu, Chang-Jung Christian University, Tainan, Taiwan.
(2) Ahmad Hosseini, Umea University, Sweden.
(3) Rajendra Prasad Payasi, Motilal Nehru National Institute of Technology Allahabad, India.
Complete Peer review History: http://sciencedomain.org/review-history/14384

Original Research Article

Received 11th August 2015
Accepted 27th September 2015
Published 28th April 2016

ABSTRACT

This study employed excels graphic tools to model and evaluate the reliability of production system using Eleme Petrochemical in Nigeria as a case study. The mean time between failures (MTBF) is the reliability parameter used. The exponential distribution function model was used to evaluate the consistency of ten production components and five cooling tower fans in series arrangement as an individual component in a production system. The Eleme Petrochemical production probability distribution function has exponential reliability distribution model with a reliability of 0.9999 within five hundred hours of operation while the reliabilities of critical components ranges from 0.63 to 0.89 for five hundred hours of operation. For 1000 hours of operation the reliability of components ranges from 0.40 to 0.63. Most of the system components have reliability of 0.37 at their mean lives. The hazard rate has exponential distribution described as chance failure phase in reliability analysis. This report recommends scheduled maintenance of 500hours and provision of redundancy to ensure maintainability and serviceability.

_*Corresponding author: E-mail: ebisike4real_82@yahoo.com;_

Keywords: Hazard rate; reliability; probability of failure; means life; exponential distribution.

1. INTRODUCTION

The development of science and technology and the needs of modern society are racing against each other. Industries are trying to introduce more and more automation in their industrial processes in order to meet the ever-increasing demand of society. The complexities of industrial/production systems as well as their products are increasing day-by-day. The improvement in effectiveness of such complex systems has therefore acquired special importance in recent years. The ability of countries like America, Japan, Germany, France etc. to produce dependable goods and services is ascribable to the effectiveness and evaluation of reliability of production systems. A critical failure in a deep-water oil and gas production systems, entails long downtime and extremely high cost of lost production and intervention for repair, such failures can have disastrous environmental and health consequences. As a result, evaluation of reliability analysis related to production system characterized by a high cost of failure must necessarily be based on the losses from failures.

Hansen and Ghare [1] opined that probability is that aspect of quality assurance that is concerned with the quality of performance. AGREE Report [2] also defined reliability as the probability of performing without failure of a specified function for a specified period of time.

This study employed the exponential reliability model and excels graphic tools to model and evaluate the reliability of production system of ELEME PETROCHEMICAL.

2. THEORETICAL BACKGROUND

According to Barringer [3] evaluation of reliability of production systems begins with management and how they communicate the need for a failure free environment to mobilize actions to preserve production systems and processes. The need for reliability considers cost of alternatives to prevent or mitigate failures, which require knowledge about times to failure, and failure modes which are found by reliability technology. Justification for reliability improvements requires knowing: (1) when things fail, (2) how things fail, and (3) conversions of failures into time and money.

Barringer and Kotlyar [4] developed a methodology to evaluate and determine the necessary level of reliability for process equipment such as large centrifugal compressors and turbines in a refinery environment using MTBF and Weibull analysis.

Bruce [5] total assessment of reliability requires the quantitative estimate of three distinct and separate classes of failure, early life, event-related and wears out failure phases. The early life, also known as infant mortality, is as result of relatively severe defects introduced during any level of manufacture or assembly, and typically results in decreasing failure rates. Event-related failure mechanisms occur randomly and are as a result of external and internal stresses during service life. Wear out failure mechanisms occur as a result of prolonged exposure to environmental and operating stresses and will occur in the entire population of items if they are in service long enough.

Other researches on reliability studies are also reported by Barringer and David [6], Abernethy [7], Barringer [8], Allen [9], George and Panayiotis [10], Harrison [11], Block and Geitner [12], Kshamta and Shedom [13] and Marina and Tatjanakaraulora [14].

2.1 Reliability Models

The analysis of reliability of a system begins with a plot of failure or hazard rate with time to establish the distribution pattern. Classical studies show three phases of distribution of hazard rate with time as debugging period characterized with the initial decreasing rate of failure with time, the next or second phase is characterized by a relatively constant chance failure rate period, which is the effective life of the system. This is followed with the next last phase, a period of increasing failure rate which indicates the beginning of wear-out failures in the population. The probability models for these three phases are commonly referred to as the DFR (decreasing failure rate), CFR (constant failure rate), and IFR (increasing failure rate) models, respectively.

Scholars have tried to establish some approximate models to analyses some distributions such as Weibull distribution, Gamma distribution, exponential distribution and normal distribution to characterize DFR, CFR and IFR of distribution.

Hansen and Ghare and Dieter [1,15] reported the following models for the analysis of reliabilities of serving systems.

- **Exponential failure density model Hansen and Ghare [1]**

$$f(t) = \lambda e^{-\lambda t}, \text{ when } t \geq 0 \tag{1}$$

$$F(t) = 1 - e^{-\lambda t} \tag{2}$$

$$R(t) = 1 - F(t) = e^{-\lambda t} \quad \text{when } t \geq 0 \tag{3}$$

$$h(t) = \frac{f(t)}{R(t)} = \frac{\lambda e^{-\lambda t}}{e^{-\lambda t}} = \lambda \tag{4}$$

$$\theta = MTTF \text{ or } MTBF = \frac{1}{\lambda} \tag{5}$$

$$f(t) = \frac{1}{\theta} e^{-t/\theta} \tag{6}$$

- **Weibull failure density model**

The Weibull probability density function for failure is stated as:

$$f(t) = \alpha\beta t^{\beta-1} e^{-\alpha t^{\beta}} \quad \text{when } t \geq 0$$

$$f(t) = 0 \text{ when } t < 0 \tag{7}$$

$$F(t) = \int_0^t \alpha\,\beta\theta^{\beta-1} e^{-\alpha\theta^{\beta}} d\theta = 1 - e^{-\alpha t^{\beta}}, t \geq 0 \tag{8}$$

The reliability function is expressed as:

$$R(t) = 1 - F(t) = e^{-\alpha t^{\beta}} \quad \text{when } t \geq 0 \tag{9}$$

Similarly the hazard rate is

$$h(t) = \frac{f(t)}{R(t)} == \alpha\beta t^{\beta-1} \quad , t \geq 0 \tag{10}$$

Although Weibull failure density distribution can represent a wide range of situations, it is very difficult to device acceptance procedures based on Weibull failure density, due to the difficulties involved in obtaining estimates for the parameters.

Other relations associated with reliability estimates are expressed for mean time between failure and failure rate as:

The Mean Time Between Failures (MTBF)

$$MTBF = \frac{study\ interval}{Number\ of\ failure} \tag{11}$$

In some cases, is the ratio of the operating time of the restorable system component to the number of failures during this time.

$$MTBF = \frac{operating\ time}{Number\ of\ failure} \tag{12}$$

Failure Rate (FR)

The failure rate is also the inverse of the MTBF and is expressed as:

$$Failure\ rate = MTBF^{-1} \tag{13}$$

Also

$$\text{Failure rate} = \frac{Number\ of\ failure}{operating\ time} \tag{14}$$

where $R(t)$ = reliability of system, $f(t)$ = probability distribution function, $F(t)$ = probability of failure at a time, θ = mean life, λ = hazard rate, α = scale parameter, β = shape parameter, t = length of life.

For the analysis within the useful life of a system all models phases reduces to exponential distribution of chance failure phase (CFR).

The exponential distribution model provides a good model for a systems that is just likely to fail any time, regardless of whether it is brand new, a year old, or several years old. For this reasons, the exponential model is used to model components that typically do not wear out until long after the expected life of the system in which they are installed.

3. METHODOLOGY

The number of failures recorded for system components are used to evaluate the mean time between failures, mean time to repair to evaluate the hazard rate and used subsequently to evaluate the reliability of the system using classical relations and excel software.

3.1 Recorded Information from Maintenance Record Book

The data obtained from the maintenance record book is presented and analyzed as shown in Tables 1 to 10 using Excel tool package.

Table 1. Frequency analysis of failure for process gas compressor (1-K-1)

Year	Mcode	Number of failure	MTBF(h)	MTTR(h)	Failure rate(1/h)
JAN-JUNE, 2000	1	3	1460	2	0.0006849
JULY-DEC, 2000	2	3	1460	2	0.0006849
JAN-JUNE, 2001	3	2	2190	3	0.0004566
JULY-DEC, 2001	4	2	2190	1	0.0004566
JAN-JUNE, 2002	5	2	2190	1	0.0004566
JULY-DEC, 2002	6	3	1460	2	0.0006849
JAN-JUNE, 2003	7	4	1095	4	0.0009132
JULY-DEC, 2003	8	4	1095	2	0.0009132
JAN-JUNE, 2004	9	5	876	2	0.0011416
JULY-DEC, 2004	10	5	876	2	0.0011416

Table 2. Frequency analysis of failure for process gas compressor (1-K-2)

Year	Mcode	Number of failure	MTBF(h)	MTTR(h)	Failure rate (1/h)
JAN-JUNE, 2000	1	3	1460	2	0.000685
JULY-DEC, 2000	2	2	2190	1	0.000457
JAN-JUNE, 2001	3	2	2190	1	0.000457
JULY-DEC, 2001	4	2	2190	1	0.000457
JAN-JUNE, 2002	5	4	1095	2	0.000913
JULY-DEC, 2002	6	5	876	2	0.001142
JAN-JUNE, 2003	7	6	730	3	0.00137
JULY-DEC, 2003	8	7	625.7143	3	0.001598
JAN-JUNE, 2004	9	8	486.6667	4	0.002055
JULY-DEC, 2004	10	10	438	3	0.002283

Table 3. Frequency analysis of failure for propylene supply pump (31-P-7A)

Year	Mcode	Number of failure	MTBF(h)	MTTR(h)	Failure rate (1/h)
JAN-JUNE, 2000	1	3	1460	2	0.000685
JULY-DEC, 2000	2	2	2190	1	0.000457
JAN-JUNE, 2001	3	2	2190	1	0.000457
JULY-DEC, 2001	4	2	2190	1	0.000457
JAN-JUNE, 2002	5	2	2190	1	0.000457
JULY-DEC, 2002	6	4	1095	2	0.000913
JAN-JUNE, 2003	7	5	876	3	0.001142
JULY-DEC, 2003	8	6	730	3	0.00137
JAN-JUNE, 2004	9	6	730	3	0.00137
JULY-DEC, 2004	10	8	547.5	4	0.001826

Table 4. Frequency analysis of failure for catalyst metering pump (P104 A)

Year	Mcode	Number of failure	MTBF(h)	MTTR(h)	Failure rate (1/h)
JAN-JUNE, 2000	1	2	2190	1	0.000457
JULY-DEC, 2000	2	3	1460	2	0.000685
JAN-JUNE, 2001	3	4	1095	2	0.000913
JULY-DEC, 2001	4	2	2190	1	0.000457
JAN-JUNE, 2002	5	3	1460	1	0.000685
JULY-DEC, 2002	6	3	1460	2	0.000685
JAN-JUNE, 2003	7	4	1095	3	0.000913
JULY-DEC, 2003	8	5	876	3	0.001142
JAN-JUNE, 2004	9	7	625.7143	4	0.001598
JULY-DEC, 2004	10	8	547.5	4	0.001826

Table 5. Frequency analysis of failure for jacket water pump (P205)

Year	Mcode	Number of failure	MTBF(h)	MTTR(h)	Failure rate (1/h)
JAN-JUNE, 2000	1	3	1460	2	0.000685
JULY-DEC, 2000	2	3	1460	1	0.000685
JAN-JUNE, 2001	3	4	1095	2	0.000913
JULY-DEC, 2001	4	4	1095	2	0.000913
JAN-JUNE, 2002	5	4	1095	2	0.000913
JULY-DEC, 2002	6	4	1095	1	0.000913
JAN-JUNE, 2003	7	5	876	3	0.001142
JULY-DEC, 2003	8	5	876	3	0.001142
JAN-JUNE, 2004	9	6	730	4	0.00137
JULY-DEC, 2004	10	7	625.7143	4	0.001598

Table 6. Frequency analysis of failure for water transfer pump (22-P-20A)

Year	Mcode	Number of failure	MTBF(h)	MTTR(h)	Failure rate (1/h)
JAN-JUNE, 2000	1	3	1460	3	0.000685
JULY-DEC, 2000	2	2	2190	4	0.000457
JAN-JUNE, 2001	3	2	2190	1	0.000457
JULY-DEC, 2001	4	2	2190	1	0.000457
JAN-JUNE, 2002	5	2	2190	2	0.000457
JULY-DEC, 2002	6	2	2190	3	0.000457
JAN-JUNE, 2003	7	2	2190	2	0.000457
JULY-DEC, 2003	8	3	1460	3	0.000685
JAN-JUNE, 2004	9	3	1460	2	0.000685
JULY-DEC, 2004	10	3	1460	4	0.000685

Table 7. Frequency analysis of failure for ethylene refrigerant compressor (1-K-3)

Year	Mcode	Number of failure	MTBF(h)	MTTR(h)	Failure rate (1/h)
JAN-JUNE, 2000	1	2	2190	3	0.000457
JULY-DEC, 2000	2	2	2190	4	0.000457
JAN-JUNE, 2001	3	2	2190	1	0.000457
JULY-DEC, 2001	4	1	4380	1	0.000228
JAN-JUNE, 2002	5	1	4380	2	0.000228
JULY-DEC, 2002	6	1	4380	3	0.000228
JAN-JUNE, 2003	7	1	4380	2	0.000228
JULY-DEC, 2003	8	2	2190	3	0.000457
JAN-JUNE, 2004	9	2	2190	2	0.000457
JULY-DEC, 2004	10	2	2190	4	0.000457

Table 8. Frequency analysis of failure for ethylene liquid supply pump (3-P-1A)

Year	Mcode	Number of failure	MTBF(h)	MTTR(h)	Failure rate (1/h)
JAN-JUNE, 2000	1	3	1460	2	0.000685
JULY-DEC, 2000	2	3	1460	1	0.000685
JAN-JUNE, 2001	3	2	2190	1	0.000457
JULY-DEC, 2001	4	2	2190	2	0.000457
JAN-JUNE, 2002	5	2	2190	2	0.000457
JULY-DEC, 2002	6	2	2190	3	0.000457
JAN-JUNE, 2003	7	1	4380	2	0.000228
JULY-DEC, 2003	8	1	4380	4	0.000228
JAN-JUNE, 2004	9	1	4380	3	0.000228
JULY-DEC, 2004	10	2	2190	3	0.000457

Table 9. Frequency analysis of failure for corrosion inhibitor pump (23-P-4)

Year	Mcode	Number of failure	MTBF(h)	MTTR(h)	Failure rate (1/h)
JAN-JUNE, 2000	1	2	2190	2	0.000457
JULY-DEC, 2000	2	2	2190	2	0.000457
JAN-JUNE, 2001	3	1	4380	4	0.000228
JULY-DEC, 2001	4	1	4380	2	0.000228
JAN-JUNE, 2002	5	1	4380	3	0.000228
JULY-DEC, 2002	6	1	4380	2	0.000228
JAN-JUNE, 2003	7	1	4380	3	0.000228
JULY-DEC, 2003	8	1	4380	4	0.000228
JAN-JUNE, 2004	9	2	2190	2	0.000457
JULY-DEC, 2004	10	2	2190	3	0.000457

Table 10. Frequency analysis of failure for sanity pump (22-P-21)

Year	Mcode	Number of failure	MTBF(h)	MTTR(h)	Failure rate (1/h)
JAN-JUNE, 2000	1	2	2190	2	0.000457
JULY-DEC, 2000	2	2	2190	2	0.000457
JAN-JUNE, 2001	3	2	2190	2	0.000457
JULY-DEC, 2001	4	2	2190	3	0.000457
JAN-JUNE, 2002	5	2	2190	2	0.000457
JULY-DEC, 2002	6	2	2190	3	0.000457
JAN-JUNE, 2003	7	1	4380	3	0.000228
JULY-DEC, 2003	8	1	4380	4	0.000228
JAN-JUNE, 2004	9	1	4380	4	0.000228
JULY-DEC, 2004	10	4	1095	4	0.000228

3.2 Curve Fitting and Establishment of Reliability Function

Mean time between failure (MTBF) and hazard or failure rate λ are evaluated from the maintenance record book of ELEME PETROCHEMICAL and used to evaluate the distribution and reliabilities of system components as presented in the following tables 1 to 10 and Figs. 1 to 4 using equations (1,2,3,5,8,9,10 and 11).

3.2.1 Hazard rate with time response of system components

The first best practice in the analysis of the system is to understand the response of the

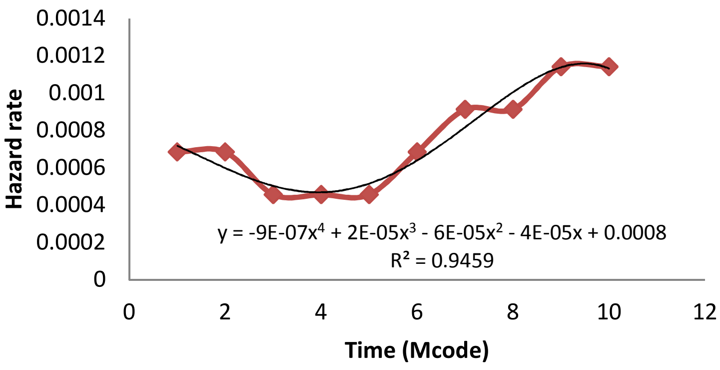

Fig. 1. Depiction for hazard rate for process gas compressor (1-k-1) and other components with same constant hazard rate

hazard rate with time. In this study hazard rate of system components are plotted against the operation period as depicted in Figs. 1 to 4. The important stages, the initial falling rate, the constant rate and the increasing rate period at old age are captured to decide on the reliability model to apply. Classical studies concentrate on the constant rate period which identifies the useful life of the component or system.

3.3 Evaluation of Reliability of System at 500 hrs of Operation

Since the scheduled maintenance is 500 hours, it is good to evaluate the reliability of the system for 500 hours.

Equation (2) and equation (3) are applied for the completion of Table 11.

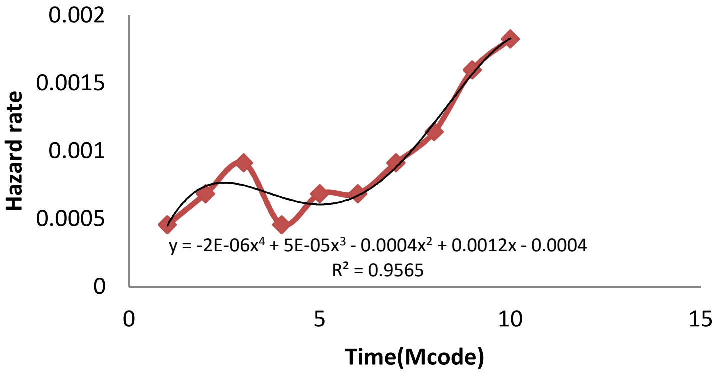

Fig. 2. Depiction for hazard rate for catalyst metering pump (P104A)

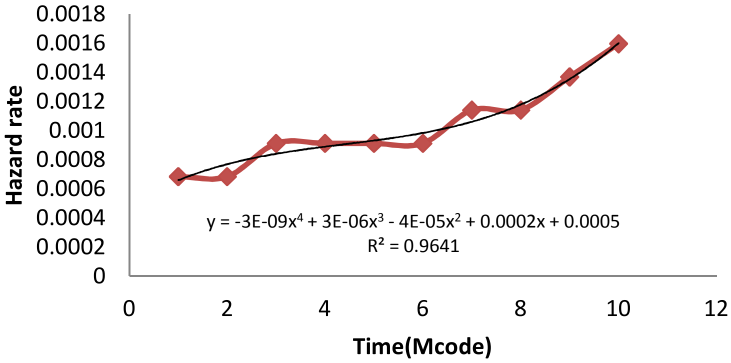

Fig. 3. Depiction for hazard rate for jacket water pump (P205)

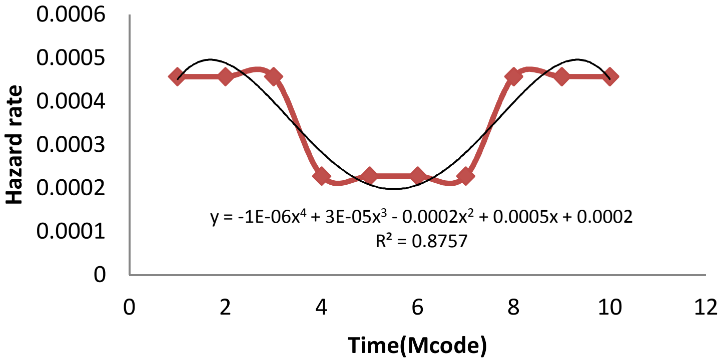

Fig. 4. Depiction for hazard rate for ethylene refrigerant compressor (1-k-3)

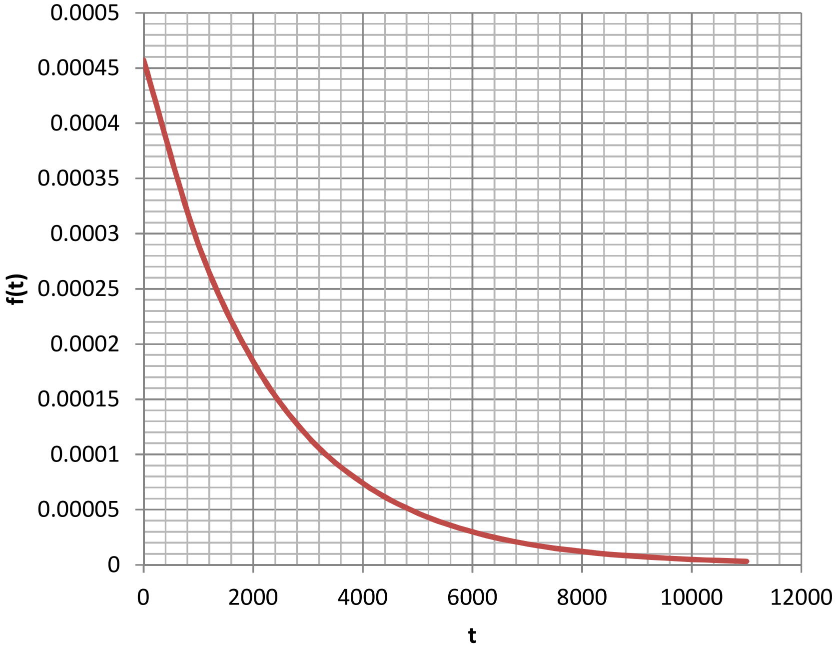

Fig. 5. Depiction of exponential density function for, process gas compressor, propylene supply pump, water transfer pump, sanity pump and process gas compressor (I-K-1): Mean life (MTBF= ϴ)= 2190 hours

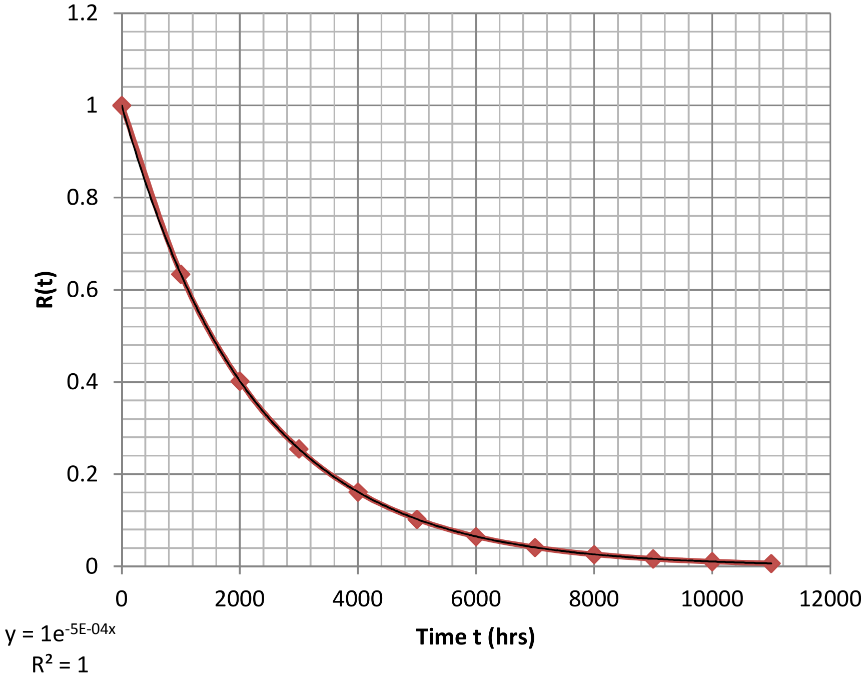

Fig. 6. Depiction reliabilities at time t for, process gas compressor, propylene supply pump, water transfer pump, sanity pump and process gas compressor: Mean life (MTBF= ϴ)= 2190 hours

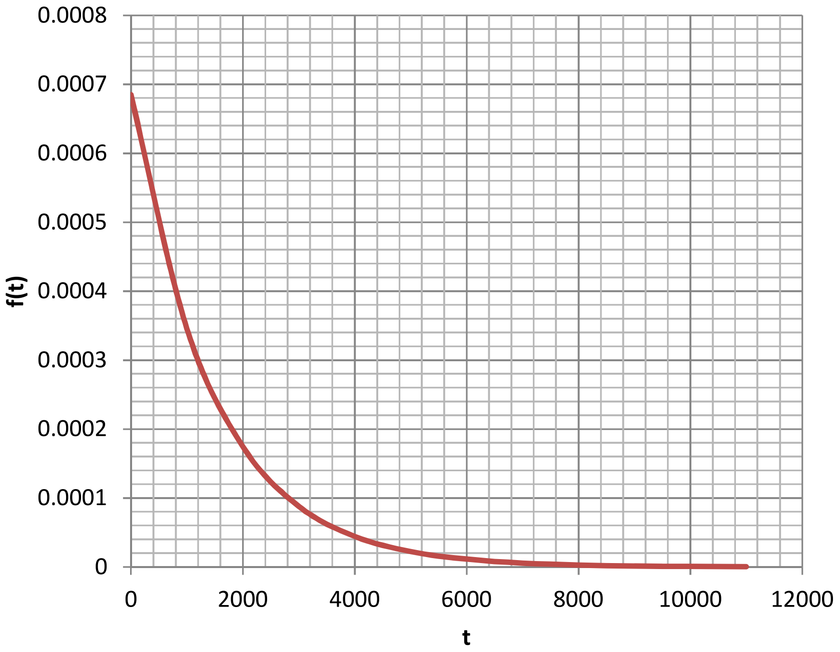

Fig. 7. Depiction of exponential density function for catalyst metering Pump 4, mean life (MTBF= ϴ) = 1460 hours

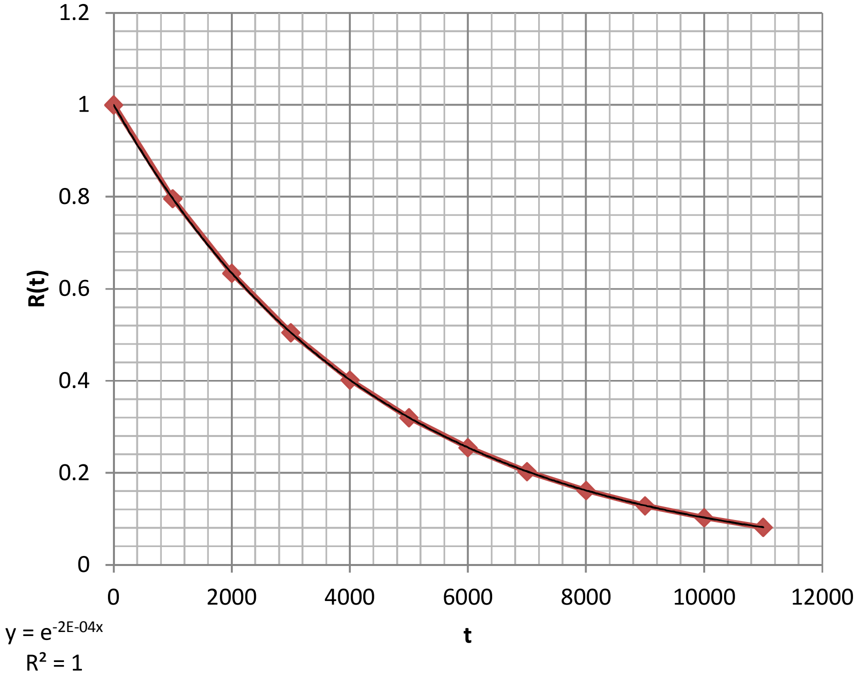

Fig. 8. Depiction of reliabilities at time t for catalyst metering Pump 4, Mean life (MTBF= ϴ) = 1460 hours

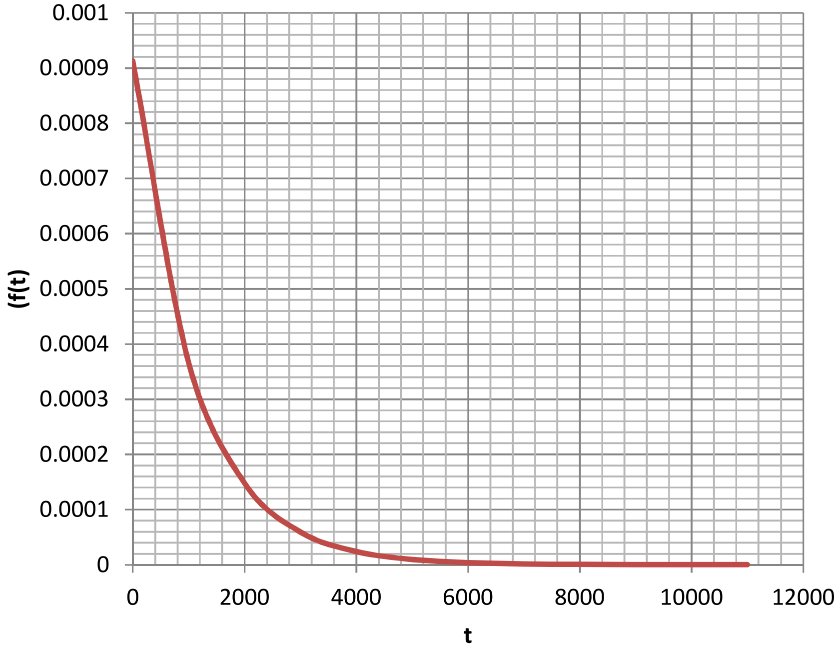

Fig. 9. Depiction of exponential density function for jacket water pump 5, mean life (MTBF= ϴ) = 1095 hours

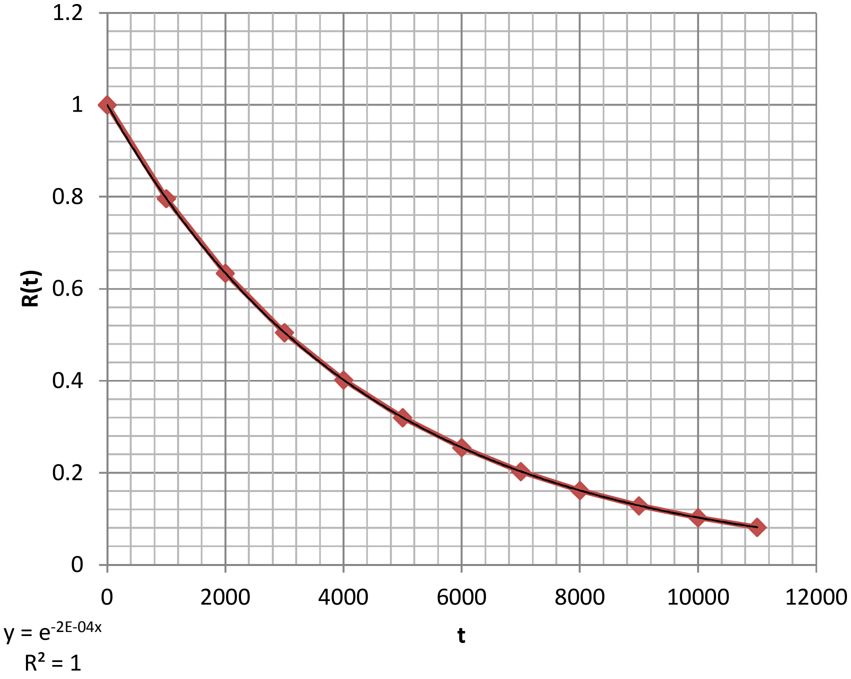

Fig. 10. Depiction of reliabilities at time t for jacket water pump 5, mean life (MTBF= ϴ) = 1095 hours

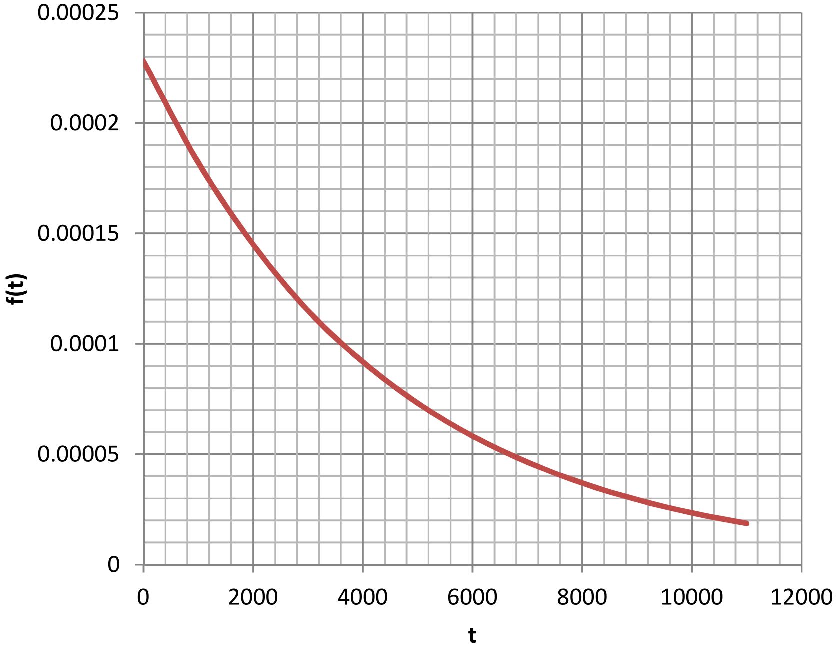

Fig. 11. Depiction of exponential density function for ethylene refrigerant compressor, ethylene liquid supply pump, corrosion inhibitor pump: Mean life (MTBF= Θ) = 4380 hours

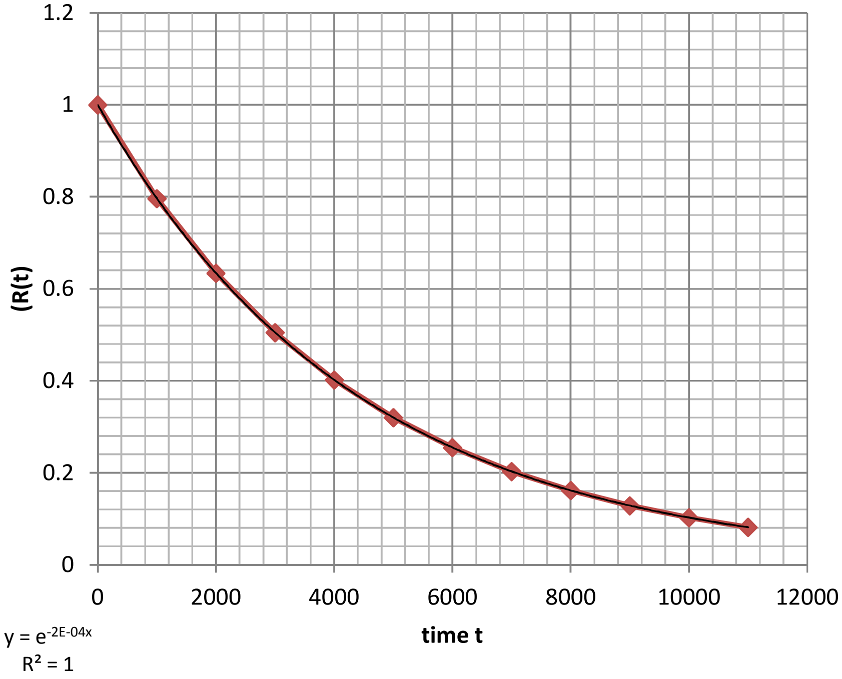

Fig. 12. Depiction of reliabilities at time t for ethylene refrigerant compressor, ethylene liquid supply pump, and corrosion inhibitor pump: Mean life (MTBF= Θ) = 4380 hours

Table 11. Depiction of equipment reliability in 500 hours

Equipment	Hazard rate (h^{-1})	R (t)	F (t)
Process gas compressor(1-k-1)	0.000457	0.80	0.20
Process gas compressor(1-k-2)	0.000457	0.80	0.20
Propylene supply pump	0.000457	0.80	0.20
Catalyst metering pump	0.000685	0.71	0.29
Jacket water pump	0.000913	0.63	0.37
Water transfer pump	0.000457	0.80	0.20
Ethylene refrigerant compressor	0.000228	0.89	0.11
Ethylene liquid supply pump	0.000228	0.89	0.11
Corrosion inhibition pump	0.000228	0.89	0.11
Sanity pump	0.000457	0.80	0.20

The reliability of ten components in parallel (component 1 to component 10) is evaluated with the equation expressed in Dieter (2000) as:

$$R_p = 1 - (1 - R_1)(1 - R_2) \dots (1 - R_n) \qquad (15)$$

So that the reliability of ten components in parallel is obtained as:

$$R_p = 1 - (1 - R_1)(1 - R_2) \dots (1 - R_n) = 0.9999 \qquad (16)$$

There are also five fans that are connected in series and are assumed to operate within their mean lives so that their mean life reliability becomes 0.37 (Dieter, 2000). The reliability of the ELEME PETROCHEMICAL can then be evaluated using

$$R_{System} = 1 - (1 - R_P)(1 - R_S) = 1 - (1 - 0.9999)(1 - 0.37) = 0.9999 \qquad (17)$$

where R_S is the mean life joint reliability of five fans in series which are in parallel with other system components.

4. DISCUSSION OF RESULTS

The mean time between failure MTBF and failure rates of different system components are shown in Tables 1 to 10 for ELEME production system. Figs. 1 to 4 are plots of hazard rates of components with time. These graphics of Figs. 1 to 4 clearly show the DFR, CFR and IFR failure phases of system components. The graphics of Figs. 1 to 4 also represents the system components responses of fourth order polynomial of the form:

$$a_0 + a_1x + a_2x^2 + a_3x^3 + a_4x^4 \qquad (18)$$

The first thing to do in analysis of system reliability is to obtain a plot of hazard rate and time to establish the reliability model to apply. Figs. 1 to 4 clearly support the exponential model. Table 11 clearly expresses the reliabilities of 10 production units in parallel within the system for 500 hours of operation. The data was used to evaluate the reliability of the ELEME production system which has other five cooling tower fans in series on assumption that the fans has common reliability of 0.37 (assumptions is that the fans are operating at mean life).

Table 11 clearly describes the dependency of reliability on the hazard rate, the reliability decreasing with increasing hazard rate. The jacket water pump was found to have the lowest reliability of 0.63 and the highest constant hazard rate of 0.000913. The system reliability is evaluated as 0.9999. However the components reliabilities decrease with time as shown in Figs. 10, 11 and 12 at 1000 hours operation as 0.63, 0.50 and 0.40. This report recommends scheduled maintenance of 500hours for ELEME system.

5. CONCLUSIONS

The ELEME PETROCHEMICAL production probability distribution function has exponential reliability distribution model with a reliability of 0.9999 within five hundred hours of operation while the reliabilities of critical components ranges from 0.63 to 0.89 for five hundred hours of operation. For 1000 hours of operation the reliability of components ranges from 0.40 to 0.63. Most of the system components have reliability of 0.37 at their mean lives. The hazard rate has exponential distribution described as chance failure phase in reliability analysis. The implementation of Weibull and Exponential models made it possible to discover the stages of system failures. Accordingly, it has become possible to plan detailed and effective counter measure for each failure, from which distinctive equipment reliability can be anticipated. (i) Forecasting how failure will occur in the future, (By making it possible to plan a system and arrangement in terms of equipment). (ii) Analyzing current equipment capabilities on a quantitative basis. (iii) Consideration of appropriate counter measure approaches in terms of current systems failure.

This report recommends scheduled maintenance of 500hours and provision of redundancy to ensure maintainability and serviceability.

5.1 Contribution to Knowledge

The key issue in realization of this work is not only the basic research but the transfer of this knowledge to the user community, designers of production systems. The research is meant to guide systems manufacturers and operators, as well as process engineers to improve the design and operation of their production lines. And also be valuable to reliability analysts who wish to model and analyze real production systems.

In addition, finding and recommendations that emanate from this research, will guide engineers and managers to make economically viable decisions as regards best practices in systems selection and maintenance of production systems.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Hansen BL, Ghare PM. Quality control and application. Prentice Hall of India, New Delhi; 1987.
2. AGREE Report. Reliability of military electronic equipment (Washinton, D. C. National Technical Information Service); 1957.
3. Barringer H. Paul. Predict failure: Crow-AMSAA 101 and Weibull 101: International Mechanical Engineering Conference Kuwait; 2004.
4. Barringer H. Paul, Kotlyar Michael. Reliability of critical turbo/compressor equipment*.* Fifth International Conference on Process Plant Reliability, Marriot Houston Westside, Houston, Texas; 1996.
5. Bruce Dudely. Reliability prediction: A publication of the DoD Reliability Analysis Center, P.O. Box 4700, Rome, NY 13442-4; 2004.
6. Barringer H. Paul, Weber David P. Where is my data for making reliability improvements. Hydrocarbons processing Magazine 4th International Reliability Conference, Houston Texas; 1995.
7. Abernethy RB. The new weibull analysis handbook, 2nd edition. Self-published, North Palm Beach, Florida; 1996.
8. Barringer H. Paul. An overview of reliability engineering principle: Pennwell Conference and Exhibitions Houston Texas; 1996.
9. Allen T. US Navy analysis of submarine maintenance data and the development of age and reliability profiles. Department of Navy SUBMEPP, Portsmouth, NH, USA; 2001.
10. George Liberopoulos, Panaiotis Toarouhas. Reliability analysis of an automated pizza production line: http//www.google.com; (Reliability Analysis) 2003.
11. Harrison M. Wadsworth. Handbook on statistical methods for engineers and scientist. Second Edition, McGraw-Hill. 1997;6.1-6.33.
12. Heinz P. Block, Fred K. Geitner. Machinery failure analysis and trouble shooting. Third Edition, Gulf Publishing Company, Huston Texas. 1993;2.
13. Kshamta, Shedom. Reliability analysis of an anti-lock braking system using stochastic petri nets. School of electrical engineering and computer science Washington state University, Pullman USA; 2005.
14. Marina kostina, Tatjana Karaulora. Reliability evaluation in manufacturing industry. A Journal on Elaboration of Tool for Production Process; 2007.
15. Dieter GE. Engineering design: A material and processing approach. 3rd Edition McGraw-Hill International Edition, Singapore; 2000.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/14384