A Method of Reliability Estimation of Individual Section Machine (IS) of Glass Manufacturing Facility; a Systematic Approach with Exponential Model, Availability and Mean Time between Failures

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Abstract – This project is on the evaluation of reliability of individual section machine of glass manufacturing facilities. The evaluation was carried out for five years using exponential model, availability and mean time between failures (MTBF) as the reliability tool for the analysis. The data used in the analysis were obtained from the corrective maintenance record book in the production department of West African Glass industry Oginigba Trans Amadi Port Harcourt. The failure rate, failures per year of the machine were obtained from the parameters. The individual section machine showed poor reliability of $15.757x10^{-26}$, suggesting that the frequency of failures of the machines was high and good availability of 0.8428, suggesting that the user of the machine has effectively utilized the length of time. The graphs of failure rate against time were plotted, to determine the goodness of fit of the data. Regression analysis was carried out to ascertain the relationship between the response variable *y* and the regressor variable *x* using SPSS. The results from the regression analysis showed an acceptable level of significance of chance failures of *0.035* and *0.019* respectively and good correlation of $R^2 = 0.818$ and 0.878 respectively, between the two variables for the sets of machines.

Index Terms – Mean time between failures, mean time to repair, exponential model, availability, regression analysis, Individual section machine (IS) machine 2 and (IS) machine 3, failure rate, reliability analysis, spss.

1. INTRODUCTION

The glass manufacturing industry is one of the industrial/domestic manufacturing sectors of the Nigerian economy of which West African Glass Industry; Oginigba Port Harcourt is one of them. Most glass products in the world are manufactured industrially on specialized, automated high speed production lines. Such lines consist of several stages in series integrated into one system by a common transfer mechanism by the use of conveyor belt and in common speed reduction system by the use of gear box. Materials move between stages automatically by mechanical means and no storage exist between the stages. Glass product machinery manufacturers worry more about the processing and engineering aspects of the lines that they manufacture than about their operations management aspects. An important managered concern about glass manufacturers is to keep production line running, with minimum interruptions. Unfortunately because of motion on industrial section machine of production lines, various pieces of equipment can breakdown in the line, forcing the line upstream the failure to short down thereby causing a bridge in the production downstream of the failure to shut. The negative effect in the effective production rate of the automated production lines puts pressure on glass manufacturers to evaluate and improve on the reliability of their lines. It forces production managers to collect and analyze field data from production lines they manage as they can take measures to reduce the frequency.

As systems grew larger and more complex, the need for rigorous analysis became increasingly evident and in recent years the formal concept and methods of reliability theory, have been applied, to almost every aspect of system, where a high degree of reliability is expected, as a result reliability is and should always, be one of the major factors in planning, design, operation and maintenance of manufacturing or production outfit. Unfortunately the failure rates of facilities in productive system potentially depend on several factors and the correct identification and quantification of independent variables leading to facility failure, present a difficult problem. The endpoint being that the West African Glass Industry will produce lower output which in turn affects the country's food, pharmaceutical industry and brewery industry. Available data from the corrective maintenance record book in the production department revealed that the IS machine is posed with a reliability problem of high cost of manufacturing, which is associated with maintenance cost of industrial equipment and can be reduced with reliability analysis. Sheu and Krajewski (1994) said that maintenance is the largest controllable expense in business. Evaluating reliability gives, an indication of failure rate, when should preventive maintenance take place and help in reducing short down, due to breakdown. It must be stated however that this industry, places maintenance of equipment as an integral inevitable reoccurring decimal that requires adequate attention in the life history of the industry.

The primary objective of this research is to access the benefits of probalistic methods for reliability estimation of individual section machine of glass manufacturing facility. The outcome will enable reliability engineers in the glass industry make decisions in the allocation of funds for maintenance and operation of their facility.

2. RELATED WORK

Barringer (2004a), used the analytical model of reliability indices in evaluating the reliability of industrial machine (Pump). The author studied the number of failures per machine for a given period of time from the time it take to affect the repairs, the study obtained the MTBF, the failure rate, the equipment reliability and lost time. The method applied by Barringer was used in evaluating the reliability of the industrial pump. The essence of this method is based on their ability to predict the rate at which failure can be expected and the percentage of time the system can be expected to perform its intended purpose with its inherent MTBF.

3. PORPOSED MODELLING

The data obtained from maintenance record book is presented as showed in Table 3.1. and 3.2. The Table contains the number of failures per machine. The mean time to repair (MTTR) is in the maintenance record which the personnel had in their record book. The mean time between failures (MTBF) is based on the number of failures for the period under review.

Table 3.1: Frequency of Failure for I.S. 3 Machine

YEAR	J	F	M	A	M	J	J	A	S	O	N	D	MTTR (h)	NO. OF FAILURES
JAN 03-DEC 03	3	4	4	3	2	1	2	3	2	3	3	3	4	33
JAN 04-DEC 04	3	2	3	4	3	2	3	2	3	3	3	3	6	34
JAN 05-DEC 05	4	3	2	2	2	3	3	2	2	4	3	2	5	32
JAN 06-DEC 06	4	2	3	2	4	1	2	3	2	3	2	2	6	30
JAN 07-DEC 07	4	2	2	3	2	1	4	2	2	3	3	1	5	28
TOTAL													**26**	**157**

Data collected from production department of West Africa Glass Industry, Oginigba, Trans-Amadi, Port-Harcourt.

Table 3.2: Frequency of Failure for I.S. 2 Machines

YEAR	J	F	M	A	M	J	J	A	S	O	N	D	MTTR(h)	NO. OF FAILURES
JAN 03-DEC03	2	1	1	2	1	2	2	1	2	1	1	1	5	17
JAN 04-DEC 04	1	1	2	1	1	2	2	1	2	2	2	2	8	19
JAN 05-DEC 05	2	2	2	2	2	3	3	2	2	3	2	2	4	28
JAN 06-DEC 06	3	2	2	3	3	2	2	4	3	3	1	1	7	30
JAN 07-DEC 07	2	2	3	3	3	3	3	3	4	3	3	3	5	35
TOTAL													**29**	**129**

Data collected from production department of West Africa Glass Industry, Oginigba, Trans-Amadi, Port-Harcourt.

3.2 NUMBER OF FAILURES

The number of failures for these machines was determined by going through the corrective maintenance log book in the efficiency unit of the production department. These failures were based on the corrective maintenance record for a period of five years.

3.3 THE MEAN TIME BETWEEN FAILURES (MTBF)

The MTBF was computed from the available data. It is the study of interval hour divided by the number of failures for the 1S machine.

The study interval for this division is

365 days x 24hours x ***5*** years = 43800 3.1

And the MTBF was based on this number of hours.

$$\text{That is MTBF} = \frac{Study\ \text{int}\, erval}{Number\, of\ \ failures} \quad 3.2$$

3.4 DETERMINING THE FAILURE RATE (λ)

There are two methods of determining failure rate, namely the method of using data for a comparable system already in use and then applying the principle of transferability; which states that the failure data from one system can be used to predict the reliability of comparable system. The second method ***is*** through testing. The first method was used since there will be not testing equipment for this work. The failure rate is as the reciprocal of MTBF that is mathematically.

$$\text{Failure rate } \lambda = \frac{1}{MTBF} \quad 3.3$$

$$\lambda = (MTBF)^{-1} \quad 3.4$$

3.5 THE MEAN TIME TO REPAIR (MTTR*)*

The mean time to repair for the IS machine is the summation of the time it took to effect the repairs for every breakdown for the entire five years under consideration. It was obtained from the corrective maintenance log book.

3.6 EQUIPMENT RELIABILITY

Reliability has already been defined as the probability that a system will perform its prescribed function without failure for a given time when operated correctly in a specified environment.

Reliability R (t) = $e^{(-\lambda t)}$ 3.5

Where λ = failure rate

t = mission time = 8760hrs

Reliability can also be a product of many different reliability terms such as

$$^{R}{}_{T} = R_1 \ x \ R_2$$

3.7 EQUIPMENT UNRELIABILITY

From the definition of IEC 600 50-191, (1996), reliability is a measure of the ability of a machine to perform a required function for a given interval of time. While availability is the measure of the ability of the machine to perform a required function at a given time instant. These parameters have quantitative relationship. US department of Defense, (1982) and IEC 60050 - 199, (1996) defined measured availability as mathematically as

$$A = \frac{Uptime}{Uptime + Downtime} \qquad 3.7$$

Where:

Uptime = Mission time
Down time = Number of failure per year x mean time to repair

3.9 SPSS SOFT WARE FOR REGRESSION ANALYSIS

The SPSS was used to run the analysis for this project because of the comprehensive nature and standard at which the software exhibits.

The SPSS is multinational software that provides statistical product and service solutions for survey research, marketing and sales analysis, quality improvement, scientific research. SPSS software products run on most models of all major computers. SPSS is intended as a complete tool kit of statistics, graphs and report.

4. RESULTS AND DISCUSSIONS

A methodology has been presented for reliability analysis of Individual section machine of glass manufacturing facility with tables 4.1 and 4.2 showing the analytical results obtained from the corrective record of the production department of the West African Glass Industry Oginigba Port Harcourt.

Time (year)	MTBF (hr)	Failure Rate (λ)
2003	1327.3	0.00075
2004	1288.2	0.00078
2005	1368.8	0.00073
2006	1460.0	0.00068
2007	1564.3	0.00064
TOTAL	**7,008.6**	**0.00359**

Table 4.1: mtbf and failure rate for 1s3 machine

Time (year)	MTBF (hr)	Failure Rate (λ)
2003	2576.5	0.00039
2004	2305.3	0.00043
2005	1564.3	0.00064
2006	1460.0	0.00059
2007	1251.4	0.00070
TOTAL	**9,157.5**	**0.00294**

Table 4.2: mtbf and failure rate for 1s2 machine

4.1.1 Reliability and availability analyses for individual section machine 3

The reliability are computed using the failure rate and the mission time.

Reliability ® = $e^{(-\lambda t)}$

Where λ = 0.00359

t = 8760

Therefore R_{IS3} = $e^{-31.36}$

= $2.402 \ x \ 10^{-14}$

$$\text{Availability} = \frac{Uptime}{Uptime + Downtime}$$

$$a_{is3} = \frac{8760}{8760 + 816.4}$$

$$a_{is3} = \frac{8760}{9.576.4}$$

a_{is3} = 0.9148

4.1.2 Reliability and availability analysis for individual section machine 2

The reliability is computed using the failure rate and the mission time 1.

reliability ® $= e^{(-\lambda t)}$

$$= e^{-(0.00294\, x\, 8760)}$$

$$= e^{-25.75}$$

$$= 6.560\ x\ 10^{-12}$$

$$\text{availability} = \frac{Uptime}{Uptime + Downtime}$$

$$a_{is2} = \frac{8760}{8760 + 748.3}$$

$$a_{is2} = \frac{8760}{9508.3}$$

a_{is2} = 0.9213

The overall reliability for the individual section machine

$r_t = r_{is3}\ x\ r_{is2}$

$r_t = 2.402\ x\ 10^{-14}\ x\ 6.560\ x\ 10^{-12}$

$r_t = 15.757\ x\ 10^{-26}$

The overall availability for the individual section machine

$a_t = a_{is3}\ x\ a_{is2}$

= 0.9148 x 0.9213

= 0.8428

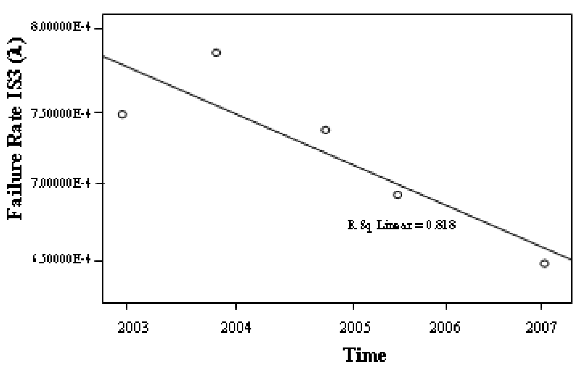

Fig. 4.1: Failure rate vs time for IS machine 3

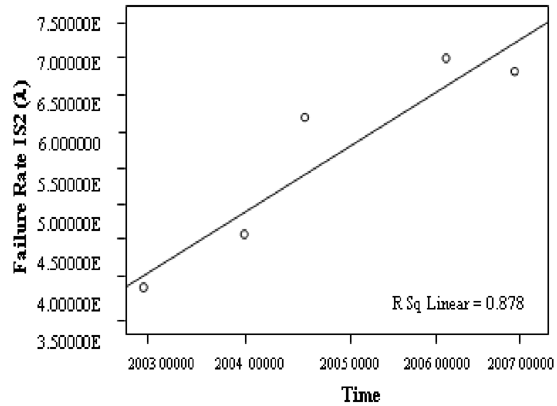

Fig. 4.2: Failure rate vs time for IS machine 2

Regression analysis and the graphical analysis from fig.4. 1 and fig. 4.2 of shows that there is a strong negative correlations and strong positive correlation respectively for the two sets of machines helps to access the level of significance of change failure and help to see if there is a correlation in the set of data. Nwaogaazie (2000) stated that the predictions puts a check on effective field data, and are put in use in decision making and this study helps the company to know when to undergo total overhauling at a particular time.

Appendix I shows the regression analysis of the set of two IS machines; 1S3 machine and 1S2 machine. The results from the regression for IS machine 3. The following interpretations are deduced;

(i) Statistically significant at 0.035 (probability that results are due to chance i.e. there is high significance).

(ii) For 1% increase in x, y decreases 25.55%

(iii) R^2 of 0.818 indicates that 81.8% of the variance in the dependent variable y can be explained by variations in x.

(iv) Statistically significant at 0.0 19 (probability that results are due to chance i.e. there is high significance.

(v) For 1% increase in x, y increases 99.7%

(vi) R-Square of 0.878 indicates that 87.8% of the variance in the dependent variable y can be explained by variations in x.

The results from the regression for IS machine 2.

5. CONCLUSION

Using the above approach the reliability was computed to be 15.757 x 10^{-26} and availability to be 0.8428. In line with the findings the machines had a very poor reliability and good availability numbers. Regression analysis using SPSS software refers to Appendix I indicates that R^2 = 0.818 and 0.878. For IS

3 machines and 1S2 machines. This sets of data showed an acceptable level of significance of 0.035 and 0.019 respectively. A graph of failure rate against time revealed that there is a correlation between the sets of data for both machine.

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APPENDICES

REGRESSION ANALYSIS OF FAILURE RATES IS MACHINE 3 AGAINST TIME

Descriptive Statistics

	Mean	Std. Deviation	N
Time (year)	2005 0000	1,58113883	5
Failure Rate IS3	0007160	00005595	5

Correlations

		Time (Year)	Failure Rate IS3
Pearson Correlation	Time (Year)	1.000	-904
	Failure Rate IS3	-904	1.000
Sig.(1-tailed)	Time (Year)	-	017
	Failure Rate IS3	017	-
N	Time (Year)	5	5
	Failure Rate IS3	5	5

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Failure Rate IS3[a]		Enter

a. All requested variables entered

b. Dependent Variable: Time (Year)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	904[a]	818	757	77912050

a. Predictors (Constant6) Failure Rule IS3

ANOVA[B]

Model		Sum of Squares	df	Mean Square	F	Sig
1	Regression	8.170	1	8.170	13.474	0.35[a]
	Residual	1.821	3	607		

Total	10.000	4			

a. Predictors (Constant) Failure Rate IS3

b. Dependent Variable Time (Year)

Coefficients [a]

Model	Unstandardized Coefficients		Standardized Coefficients	1	Sig
	B	Std. Error	Rate		
1 (Constant)	2023.300	4.998		404.843	.000
Failure Rate IS3	-25559.11	6963.097	-904	-3.671	.035

a. Dependent Variable: Time (Year)

REGRESSION ANALYSIS OF FAILURE RATES IS MACHINE 2 AGAINST TIME

Descriptive Statistics

	Mean	Std. Deviation	N
Time (year)	2005 0000	1,58113883	5
Failure Rate IS2	0005700	00014840	5

Correlations

		Time (Year)	Failure Rate IS3
Pearson Correlation	Time (Year)	1.000	-037
	Failure Rate IS2	-037	1.000
Sig.(1-tailed)	Time (Year)	-	000
	Failure Rate IS2	000	-
N	Time (Year)	5	5
	Failure Rate IS2	5	5

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Failure Rate IS2[a]		Enter

c. All requested variables entered

d. Dependent Variable: Time (Year)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	937[a]	878	837	63760236

b. Predictors (Constant6) Failure Rule IS2

ANOVA[B]

Model		Sum of Squares	df	Mean Square	F	Sig
1	Regression	8.780	1	8.780	21.591	0.19[a]
	Residual	1.220	3	407		
	Total	10.000	4			

c. Predictors (Constant) Failure Rate IS2

d. Dependent Variable Time (Year)

Coefficients [a]

Model	Unstandardized Coefficients		Standardized Coefficients	1	Sig
	B	Std. Error	Rate		
1 (Constant)	1999.313	1.256		1500.019	.000
Failure Rate IS2	0077.524	2.147222	037	-4.042	.019

a. Dependent Variable: Time (Year)

Author

Engr. Choice Nwika was born in Nigeria. He holds a B.Tech and an M.Tech degree in mechanical engineering from University of Science and Technology, Port Harcourt, Nigeria. and a potential PhD scholar. He has a diverse engineering background with valuable experience in Pipeline engineering, asset risk analysis /management, piping engineering, operation research, supply chain management, reliability , corrosion, production and maintenance engineering. His professional work experience as reliability, pipeline and piping engineer in the oil and gas industry and his years of experience in academics has given him not only a strong, technical foundation but also a domain knowledge and exposure to work environment. His key strength include effective communication, quick problem solving ability, strong trouble shooting skills and passion to learn and adopt new technologies and skills. He is a member of Nigerian society of engineers, American society of mechanical engineers and a chattered engineer in Nigeria.