Using the Quality control to determine the Factors of Failure Operation in cement Sector

A THESIS

Submitted to the Council of College Administration & Economics - University of Sulaimani, As Partial Fulfillment for the Requirements of the Master Degree of Sciences in Statistics

By

Sherzad Arif Hama

Supervised by:

Assistant Professor

Dr. Kawa M. Jamal Rashid

2016(AD) 2716(Kurdish)

﴿ بسم الله الرحمن الرحيم ﴾

﴿ فَتَعَالَى اللَّهُ الْمَلِكُ الْحَقُّ وَلَا تَعْجَلْ بِالْقُرْآنِ مِنْ قَبْلِ أَنْ يُقْضَى إِلَيْكَ وَحْيُهُ وَقُلْ رَبِّ زِدْنِي عِلْمًا ﴾

سورة طه : 114

بەکارهێنانی کوالێتی کۆنترۆڵ بۆ دەرخستنی هۆکارەکانی شکستی کار لەکەرتی چیمەنتۆ

نامەیەکی ماجستێره

پێشکەش کراوە بە ئە نجومەنی کۆلێجی کارگێڕی و ئابووری- زانکۆی سلێمانی وەك بەشێك لە پێداویستیەکانی وەدەستهێنانی پلەی ماجستێر لە زانستی ئامار

لەلایەن

شێرزاد عارف حمه

بەسەرپەرشتی

پرۆفیسۆری یاریدەدەر

د.کاوە محمد جەمال رشید

2016(AD) 2716(Kurdish)

استخدام السيطرة النوعية لأيجاد عوامل عملية الفشل في قطاع الأسمنت

رسالة مقدمة

إلى مجلس كلية الإدارة والإقتصاد – جامعة السليمانية

وهي جزء من متطلبات نيل درجة ماجستير علوم في الإحصاء

من قبل

شيرزاد عارف حمة

باشراف

الأستاذ المساعد

د.كاوة محمد جمال رشيد

2016(AD) 2716(Kurdish)

Dedication

Every challenging work needs self-efforts as well as guidance of elders especially those who were very close to our heart.

My humble effort I dedicate to my sweet and loving

Mother, Sisters and Brother

Whose affection, love, encouragement and prays of day and night make me able to get such success and honor.

Along with all hard working and respected

Teachers

Acknowledgements

Foremost, I am highly grateful to God for His blessing that continue to flow into my life, and because of You, I made this through against all odds. With a great pleasure I would like to acknowledge the support, assistances and contribution made by individuals from the beginning of the fieldwork, providing me access, data and information, to the writing process until the completion of this thesis.

First of all. I would like to thank my supervisor Assist. Professor Dr. Kawa Muhammad Jamal Rashid for his support, guidance, encouragement and patience.

I would like to express my thanks to the Head of Department of Statistics, Dr. Mohammad Faqe.

I would also like to give my appreciation to my teachers who inspired me through my MS.c study, especially Professor Dr. Monem Aziz. Assist. Professor Dr. Nawzad M. Ahmed, Dr. Shawnim Abdulkader, Dr. Sozan sabir and Dr.Samira M. Salh.

Thanks to the department of statistics staff higher education unit staff as well as and staff the college librarian of administration and economics at the sulaimani University for their Cooperation during the study, and I thank my friends for all their useful assistant.

I express great gratitude to Mr. Omer Ismaeel and Mass cement factory staffs for their information and help in data collection.

I would like to express my gratitude toward my family for the encourgement which helped me in completion of this thesis.

Abstract

The present thesis work demonstrate application of reliability analysis for five cement mills from Mass Cement Factory, based on failure time data of those mills for three years. According to (Weibull++) program three goodness of fit tests has been under taken to find the fit distribution, As a result the best distribution which is Generalized Gamma Distribution (G-Gamma) is selected for the data analysis. Through using function of (Reliability, Failure Rate and Probability Density Function), the best and worst reliability for each month of years (2012, 2013 and 2014) for all the five mills has been found. In this thesis physical test (comp.st. test) data was used for the three types of cement (OPC, SBC and SRC) in (2014), the data was analyzed by Statgraphics Centurion (v16.1) program. The quality of the products manufactured in this factory has been estimated according to quality control process through the use of specific control chart named Exponentially Weighted Moving Average (EWMA) chart. As the result of this study factors that affecting function of mills which produces cement has been illustrated, also it has been found out that these factors will increase failure rate of mills and lower their life span, through which quality of products will be affected.

TABLE OF CONTENTS

List of Abbreviations

Abbreviation	Details
R (t)	Reliability
CDF	Cumulative Distribution Function
Pdf	Probability density function
λ (t)	Failure rate
AVGOF	Average value Kolmogorov-Smirnov test
AVPLOT	Average value correlation coefficient test
LKV	likelihood value test
DESV	Weighted decision variable
UCL	Upper Control limit
LCL	Lower Control limit
EWMA	Exponentially Weighted moving average
USL	Upper specification Limit
LSL	Lower Specification Limit
OPC	Ordinary Portland Cement
SBC	High Blaine Portland Cement
SRC	High Sulfur Resistant Cement
CM	Cement Mill
Cp	Process Capability
Cpk	Process Capability Index
Cpl	Capability process lower specification limit
Cpu	Capability process upper specification limit
TQM	Total Quality Management
PCI	Process Capability Index
SQC	Statistical Quality Control

Chapter one

Introduction, Literature Review

and

Aim of thesis, layout of thesis

1.1 Introduction [2] [4] [21] [37]

The degree to which measures are free from error and therefore yield consistent results is defined as reliability. This can be applied to a human being; it usually refers to that person's capability to do certain tasks according to a specified standard. The word of reliability is also applied to a piece of equipment, or a component of a larger system, to mean the ability of that equipment or component to bring about what is required of it. The history of the reliability field goes back to early (1930) s, when probability principles were applied to electric power generation-related problems in the United States. The basic reliability concepts were applied by Germany during World (War II), to improve reliability of their (V1 and V2) rockets. Also during World (War II), the United States Department of Defense recognized the need for reliability improvement of its equipment. It performed numerous studies which dealt with the failure of electronic equipment, equipment maintenance and repair cost between(1945–1950), as the result of those studies, in (1950) the US Department of Defense set up an ad hoc committee on reliability. In (1952), this committee turned out to became a very well-known group named Advisory Group on the Reliability of Electronic Equipment (AGREE). In (1954), a symposium on Reliability and Quality Control was held for the first time in the United States under the name of National Symposium. Two years later, in (1956), the first commercially available book on reliability was released. The first master's degree program in system reliability engineering came into being at the Air Force Institute of Technology of the United States Air Force (USAF) in (1962). The original use of the term was purely qualitative. For example, aerospace engineers documented the necessity of having more than one engine on an aero plane without any accurate measurements of failure rate. As used today, almost always a quantitative concept is used for reliability,

There are factors that show why reliability should to be quantitative. Economics is the most important factor for making it qualitative since to improve reliability costs money, and this can be acceptable only if the costs of unreliable equipment are measured. For a critical component whose successful operation is integral to a system, reliability may be measured as the probability that the component is working successfully, and the cost of an unreliable component is expected and measured as the output of the probability of failure and the cost of failure. In either case, the requirement for a probabilistic definition of reliability is obvious. The need of expertise for handling the complex and multidisciplinary issues of reliability and risk analysis has slowly permeated into all engineering applications, with risk analysis and management gaining a relevant role both as an instrument in support of plant design and operation, and as a vital means for emergency planning in accidental situations. Failure is something that cannot be avoided; it is a phenomenon in all technological products and systems. Proper control and management will become essential is in order to reduce failure. This is done through process quality control which is a management function by controlling of raw materials' and manufactured items' quality, the production of defective items is stopped. Among competing products and services, quality has become one of the most important consumer decision factors. Regardless of whether the consumer is an individual, an industrial organization, a retail store, a bank or financial institution, or a military defense program, this phenomenon is applied to all of them. Eventually, considering and developing quality are the leading factors to bring about business success, growth, and enhanced competitiveness. There is a large return on investment from improved quality and from successfully employing quality as a vital part of the whole business strategy.

The history of the quality field goes back to the early times to the construction of pyramids by the ancient Egyptians (1315–1090 BC). However, in the modern times (i. e., by 1907) the Western Electric Company was the first to use basic quality control principles in design, manufacturing, and installation. And in (1917, G.S). Radford coined the term "quality control". The modern quality control has six stages which are Statistical Quality Control, Total quality control, Statistical process control, companywide quality control, total quality management, and six sigma.

Statistical Quality Control; in the early 1920's the use of statistical methods to improve a manufacturing process came to existence. Dr. Walter Shewhart at the Bell Telephone Company made this happen. The use of these techniques has largely been used by large manufacturing companies and many of the small ones. by carrying out quality control effectively necessitates the cooperation of all people in the company, involving top management, managers, supervisors, and workers in all areas of corporate activities such as market research, research and development, product planning, design, preparation for production, purchasing, vendor management, manufacturing, inspection, sales and after-service, as well as financial control, personnel administration, and training and education. Statistical process control; Feedback and feed-forward techniques is used in Algorithmic Statistical Process Control (ASPC) which is an approach to quality improvement that reduces predictable quality variations. (ASPC) is a logical step in the drive for continuous quality improvement. Companywide quality control; (SKF) restructured its manufacturing world-wide in response to competition from Japan in the early (1970) s. The necessity of a company-wide quality procedure soon became evident. Total quality management; The (TQM) model is a systematic method to make the quality better based on: team-based work groups, control of the work process owned by the individual, motivation, personal responsibility for group success, quality desired over quantity, and facilitated communication between groups and functional areas. Six Sigma; At Motorola in the mid-(1980) s Six Sigma has been introduced significantly and continues to improve the performance of its processes. Six sigma is defined as an organized and systematic technique for strategic process improvement and new product and service development that depends on statistical tools and the scientific method to lower customer defined defect rate.

1.2 Literature Review:

In (1987), William Q. Meeker, Jr., has done a research on Limited Failure Population Life Tests: Application to Integrated Circuit Reliability is a research studied failures of solid-state electronic components which are often caused by manufacturing defects. Typically, a small proportion of the manufactured components has one or more defects that cannot be detected in a simple inspection but that will eventually cause the component to fail. By assuming a time-to-failure distribution for the units that are susceptible to failure from manufacturing defects, laboratory life tests of limited duration can be used to estimate the proportion of units that have such defects and the parameters of the assumed time-to-failure distribution of the defective subpopulation [30].

Accelerated Degradation Tests: Modeling and Analysis research done on (1998), the study gives an important information on a relationship between component failure and amount of degradation which makes it possible to use degradation models and data to make inferences and predictions about a failure-time distribution. This article describes degradation reliability models that correspond to physical-failure mechanisms. The researchers (Luis A. ESCOBAR, C. Joseph Lu) explained the connection between degradation reliability models and failure-time reliability models. Acceleration is modeled by having an acceleration model that describes the effect that temperature has on the rate of a failure-causing chemical reaction [23].

In (1999), Jason Allen Denton, has done a research on, a large number of software reliability growth models are now available. It is widely known that none of these models performs well in all situations, and that choosing the appropriate model a priori is difficult. For this reason recent work has focused on how these models can be made more accurate, rather than trying to find a model which works in all cases.

This includes various efforts at data filtering and recalibration, and an examination of the physical interpretation of model parameters. Here we examine the impact of the parameter estimation technique on model accuracy, and show that the maximum likelihood method provides for estimates which are more reliable than the least squares method. We present an interpretation of the parameters for the popular logarithmic model, and show that it may be possible to use this interpretation to overcome some of the difficulties found in working with early failure test data. We present a new software reliability model, based on the objective measure of program coverage, and show how it can be used to predict the number of defects in a program. We discuss the meaning of the parameters of this model, and suggest what needs to be done in order to gain a greater understanding of it. Finally, we present a tool we have developed which supports and integrates many of the techniques and methods presented here, making them easily accessible to practitioners [22].

IN (2003), EWMA Charts for Monitoring the Mean and the Autocovariances of Stationary Gaussian Processes was an important study done by, M. Rosol, owski and W. Schmid, in this article simultaneous individual control charts for the mean and the autocovariances of a stationary process are introduced. All control schemes are EWMA (exponentially weighted moving average) charts. A multivariate quality characteristic is considered. This quantity is transformed to a one-dimensional variable by using the Mahalanobis distance. The control statistic is these variables. Another control procedure is based on a multivariate obtained by exponentially smoothing EWMA recursion applied directly to their multivariate quality characteristic. After that the resulting statistic is transformed to a univariate random variable. Besides modified control charts they considered residual charts. In an extensive simulation study all control schemes are compared with each other [28].

IN (2005), Levaggi, Rosella, International Journal of Health Care Finance and Economics, Levaggi, Rosella has done a research on The cost of hospital care depends on the quality of the service where hospitals can observe patient severity and compete according to the rules of Hoteling's spatial competition. The scheme is designed from the standpoint of a purchaser that sets up a contract with several providers for services of a given quality at the least possible cost [27].

In (2006), Mendez, Michelle A., Vioque Jesús, Porta Miquel, Morales Eva, López Tomàs, Malats Núria, Crous Marta, and Gómez Luis, European Journal of Epidemiology, have done a research on clinical settings for the use of the reliability of a brief food frequency questionnaire was used in a study of patients with pancreatic and biliary diseases in eastern Spain. The structured interview included a section probing the frequency of intakes of 14 food groups, using 4 response categories. Data from a 93-item semi-quantitative food frequency questionnaire (SFFQ) with 9 response categories was used to develop estimates of nutrient intakes for each food group, and to simulate how intakes would have been estimated using the bFFQ. They found out Intake estimates from the bFFQ may be useful in exploratory analyses of the role of diet in bilio-pancreatic diseases and related etiopathogenic events [31].

IN (2007), Jean Nakamura, has done a research on predicting Time-to-Failure of Industrial Machines with Temporal Data Mining, the project performs temporal data mining, which is a method of choice to predict future events based on known past events. The difficulty in determining time-to-failure (TTF) of industrial machines is that the failure mode is not a linear progression. The progression of a severity of a fault increases at a higher rate as the machine approaches failure. Through experience, it is known that discrete frequencies in the vibration spectra are associated with machine faults and will reach expected amplitudes at the point of machine failure. This project determined that it is possible to analyze a machine's temporal vibration data results to produce an estimated time to a failure based on the progression of identified faults [26].

IN (2010), McCulloch, Peter, Kreckler Simon, New Steve, Sheena Yezen, Handa Ashok, and Catchpole Ken. " 2010, British Medical Journal. Have done a research on service reliability and efficiency in healthcare for the British Medical Journal to determine the risk in Emergency surgical patients because there are errors in care. Therefore, a new redesign has been introduced such as "Lean," to improve service reliability and efficiency in healthcare at a university hospital in the United Kingdom. Strategy for change A Lean intervention targeting five of the seven care processes relevant to patient safety. The proportion of patients requiring transfer to other wards fell from (27% to 20%). Lessons learnt Lean can substantially and simultaneously improve compliance with a bundle of safety related processes [29].

In (2011), Zhiguo Li, a, Shiyu Zhou, Crispian Sievenpiper and Suresh Choubey, have done a research about Statistical Monitoring of Time-to-Failure Data Using Rank Tests, In this article, they developed a control chart to monitor the time-to-failure data in the presence of right censoring using weighted rank tests. On the basis of the asymptotic properties of the rank statistics, they derived the generic formulae for the operating characteristic functions of the control chart to show the relationship between type I error probability, type II error probability, sample size, and hazard rate change. They presented case studies to illustrate the design procedure and the effectiveness of the proposed control chart system [36].

In (2011), Rekha Rani, has done a research on Reliability Analysis of n-policy, K-out-of-n: g Machining System with Warm and Cold Spares, the paper deals with a Markov model for analyzing the reliability of N- policy, K- out –of – N: G Machining system with warm and cold spares, which are provided to replace the failed machines. The machines are assumed to fail in M-modes. They have considered two cases for reliability analysis, with repair and without repair. An inverse Laplace transform is used to solve the simultaneous differential equations for non-repairable case and used Runge- Kutta Method to analyze the reliability of repairable system. Mean time to failure and mean time between failures are also derived. It concluded that the reliability system can be improved up to a desired level in particular when there is constraint of limited spare part support [34].

In (2012), Rafiei, Kamran, Amir Kavussi, and Shahaboddin Yasrobi Journal of Civil Engineering & Management, have done a research on construction quality control. In this research, a laboratory testing unit box was prepared in which unbound materials were compacted at different compaction levels. The stiffness modulus of the compacted layers was then determined under PFWD Testing. The tests were repeated several days after construction when the materials moisture content was decreased to lower values. In this paper it was concluded that PFWD is an appropriate testing device for quality control and compaction monitoring of pavement layers during construction phases [33].

In (2013), Pilar Espinet-González, had done a research on Evaluation of the Reliability of Commercial Concentrator Triple-Junction Solar Cells by Means of Accelerated Life Tests (ALT), A temperature accelerated life test on commercial concentrator lattice-matched GaInP/GaInAs/Ge triple junction solar cells have been carried out. The solar cells have been tested at three different temperatures (119, 126 and164 C) and the nominal photo-current condition (820 X) has been emulated by injecting current in darkness. All the solar cells have presented catastrophic failures. The failure distributions at the three tested temperatures have been fitted to an Arrhenius-Weibull model. The main reliability functions and parameters of these solar cells at the nominal working temperature (80 C) have been obtained. The warranty time obtained for a failure population of 5 % has been 69 years [24].

IN (2014), Mihalcin, Matthew J., et al, Systems Engineering, had done a research on manufacturing industry to determine quality control by using statistical process control which presents an approach concerning the statistical process control technique of control charting, demonstrating its applicability to control and monitor operational systems involving human processes with multiple quality characteristics. In his paper, the researcher utilizes the applicability of the proposed approach on a corporate information technology help desk. This would be beneficial to multiple industries and organizations for evaluation of systems consisting of human-involved processes [32].

In (2014), Heba Nagaty Mohamed, M.Y. Haggag, had worked on research Reliability Estimation and Analysis of DDL MYSQL Server by using Generalized Gamma and Weibull Distribution, in this paper the time between failures for different Operating Systems (Windows and Linux) of DDL MYSQL open source data base server is analyzed and compared. The purpose of this study is to estimate and compare the reliability of two Operating Systems (Windows and Linux) of DDL MYSQL server by using Generalized Gamma and Weibull Distribution which are the best distributions in their rankings. In the result the Reliability Estimation of two Operating Systems are evaluated and compared theoretically and graphically [25].

In (2015), J. Appl. Environ. Biol. Sci, has done a research on Power Law Model for Reliability Analysis of Crusher System in Khoy Cement Factory, concluded that The first step of the cement making process is crushed limestone by crusher system. The performance of this system is affected by maintenance, the operating environment, efficiency, the operation process, the technical expertise, transporting material, distance, failures and etc. On the other hand, according to high costs of keeping these systems in operational mode and existence of complex connections between different subsystems, carrying out proper maintenance become more and more important. The purpose of this paper is to discuss operational and maintenance challenges by assessing system reliability. The required data (time between failures (TBF)) for statistical analysis were collected and sorted in chronological order from two main data sources that consisted of daily operation and production reports and maintenance reports for 18-month periods. Then, reliability-based maintenance was considered to achieve the 90% level of reliability performance. Based on this critical level, 47.25 hours are suggested as PM intervals. Analysis of the effect of this strategy indicated 1.6 times improving efficiency of the fixed capital [35].

1.3 Aim of this thesis:

- To estimate the reliability and hazard function as well as the (MTTF) for some generated distributions (Gamma, exponential and Weibull).
- Illustrates the real data in application of cement manufacture.
- Determining the reliability of each cement mill in Mass Cement Factory through using data of failure time.
- Identification of issues that affect the quality of the product (cement) by using quality control process through which many methods can be recommended for the manufacture to repair any modifiable defect and improve the quality of the product.
- Determine the best and most appropriate cement mill by using Life Comparison tool.
- Identifying the most capable cement types among (OPC, SBC and SRC) through using the process capability index.
- Demonstrating the variability and area of process improvement by process capability, and preceding this improvement.

1.4 Layout of thesis:

The thesis organized in four chapters: chapter one consists of introduction of reliability and quality control, Literature review, aim of thesis and layout of thesis. Chapter two which is theoretical part gives detail information about reliability function, failure rate and quality control process. Chapter three presents application of reliability and quality control. Finally, chapter four shows conclusion and recommendation.

Chapter two

Reliability and Quality Control

2.1 Introduction [13] [11] [15]:

The capability of an item or a system to perform a designed function under given conditions for a given time interval is called reliability. Probability, intended functions, time period and the working conditions are the vital factors associate with the reliability. Since, the reliability is denoted as probability; its value changes from zero to unity thereby giving quantitative measure. In our daily life we make an analogy between one product over the other for its superiority by dependability or reliability. The degree of superiority can only be expressed in quantitative terms. The pre-mature failure of a product/system will aid to set up the creditability of producer for the superiority/quality when compared with other producer for the same product. The time period for which the reliability valuation has to be done is a complex issue until and unless it is specified properly based on the past experience it may lead to further problems. For mechanical tools, it is easy to digest the time limit since their failures are slow in nature whereas, but electronic tool is really hard since their failures are irregular and reasons for failures are much more. Reliability depends on operating conditions. In other words, a device is reliable under given conditions but can be unreliable under more severe conditions.

2.2 Types of Reliability [9] [12]:

2.2.1 Test-Re-test Reliability

One of the most often used and obvious ways of establishing reliability is to repeat the same test on a second occasion— test/re-test reliability. The obtained correlation coefficient is between the two scores of each individual on the same test administered on two different occasions. If the test is reliable, we expect the two scores for each individual to be similar, and thus the resulting correlation coefficient will be high (close to _1.00). This measure of reliability assesses the stability of a test over time.

2.2.2 Parallel Forms Reliability:

One means of controlling for test/retest problems is to use alternate-forms reliability—using alternate forms of the testing instrument and correlating the performance of individuals on the two different forms. In this case, the tests taken at times (1 and 2) are different but equivalent or parallel (hence, the terms equivalent-forms reliability and parallel-forms reliability are also used). As with test/retest reliability, alternate forms reliability establishes the stability of the test over time and also the equivalency of the items from one test to another. One problem with alternate-forms reliability is making sure that the tests are truly parallel. To help ensure equivalency, the tests should have the same number of items, the items should be of the same difficulty level, and instructions, time limits, examples, and format should all be equal—often difficult if not impossible to accomplish. Second, if the tests are truly equivalent, there is the potential for practice effects, although not to the same extent as when exactly the same test is administered twice.

. 2.2.3 Split-half method:

This method treats the two halves of a measure as alternate forms. It provides a simple solution to the problem that the parallel-forms method faces: the difficulty in developing alternate forms. This method involves administering a test to a group of individuals, splitting the test in half correlating scores on one half of the test with scores on the other half of the test the correlation between these two split halves is used in estimating the reliability of the test. However, the responses from the first half may be systematically different from responses in the second half due to an increase in item difficulty and fatigue. In splitting a test, the two halves would need to be as similar as possible, both in terms of their content and in terms of the probable state of the respondent.

2.2.4 Internal consistency:

Internal consistency is a method of reliability in which we judge how well the items on a test that are proposed to measure the same construct produce similar result.

2.2.5 Inter-rater Reliability

Measure the reliability of observers rather than tests, you can use inter-rater reliability. Inter-rater reliability is a measure of dependability or consistency that assesses the agreement of observations made by two or more raters or judges.

2.3 The Reliability Function [10]:

A reliability function is same probability expressed as a function of the time period, in that every reliability value has an associated time value. This function gives the probability of an item operating for a certain amount of time without failure.

$$\mathbf{R(t) = P(T > t) = 1 - F(t) = \int_0^{\infty} f(u)du} \qquad \ldots\ldots\ldots\ldots\ldots\ (1)$$

R (t) is the probability that the item will not fail in the interval [0, t].

$$F(t) = pr(T \leq t) = \int_{u=0}^{t} f(u)du$$

$$f(t) = \lim_{\Delta t \to 0} \frac{pr(t \leq T < t + \Delta t) - F(t)}{\Delta t} = \frac{dF(t)}{dt} = -\frac{dR(t)}{dt} \qquad \ldots\ldots\ldots\ldots (2)$$

Usually $(f(t) \geq 0)$, $[F(0)=0]$, $[F(\infty)=1]$, $[R(0)=1]$, $[R(\infty)=0]$

(T) Be continuous random variable representing the life length of product (or Component).

Let (f *(t))* be the (pdf) of the time to failure of the gives component, then the probability that component will fail in the interval (0, t) is given:

$$F(t) = \int_{u=0}^{t} f(u)du$$

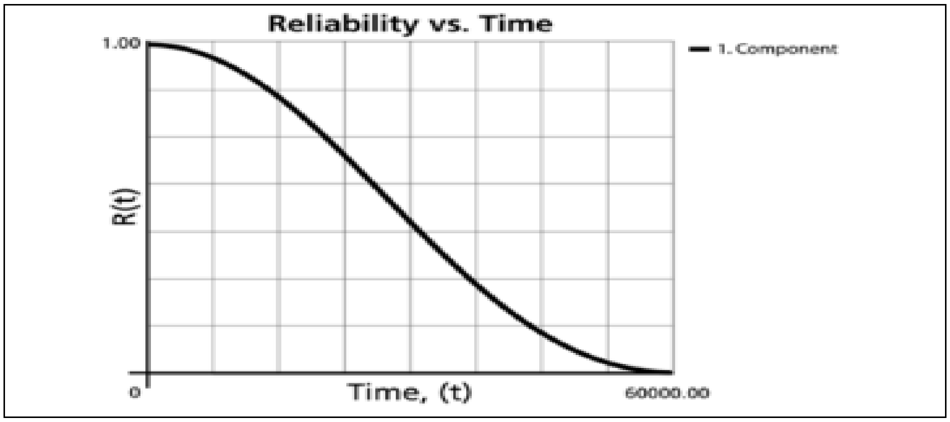


Figure (2-1): Represents the Reliability function

2.4 Failure [11]:

A fault is the state of the product characterized by its inability to fulfill its required function. Namely, a fault is a state resulting from a failure.

Failure will happen when an item or system fails from performing its intended function safely, reliably and cost-effectively via any circumstances. Some failures take only a short time and they are recognized as intermittent failures, while other failures keep going until some corrective action repairs the failures. Such failures are named as extended failures. Complete and partial failures are the component of extended failures. A complete failure results in total loss of function, while a partial failure results in partial loss of function. According to whether a failure takes place with warning or not, the extended failures can be divided into sudden and gradual failures. A complete and sudden failure is known as a catastrophic failure and a gradual and partial failure is known as a degraded failure.

2.5 Failure rate [5]:

The frequency of an engineered system or component that fails is called Failure rate, and it's expressed in failures per unit of time. It is often denoted by the Greek letter (λ) (lambda) and is highly used in reliability engineering. The failure rate of a system usually is determined by time, with the rate changing over the life cycle of the system.

Now we can define the concept of failure rate, which is vital for reliability analysis and other disciplines. Consider an interval of time (t, t +Δt). There are interests in the probability of failure in this interval given that it didn't take place before in [0, t]. This probability can be expressed as the risk of failure (or of some other harmful event) in (t, t +Δt) given the stated condition.

Consider the conditional probability:

$$\mathbf{Pr}\,[\,\mathbf{t} < \mathbf{T} \leq \mathbf{t} + \Delta\mathbf{t}/\mathbf{T} > \mathbf{t}] = \frac{\mathbf{P}\,(\mathbf{t} < \mathbf{T} \leq \mathbf{t} + \Delta\mathbf{t})}{\mathbf{P\,r}(\mathbf{T} > \mathbf{t})}$$

$$= \frac{\mathbf{F}(\mathbf{t} + \Delta\mathbf{t}) - \mathbf{F}(\mathbf{t})}{\mathbf{R}(\mathbf{t})}$$

And define the failure rate λ (t) as its limit when Δt → 0. As the pdf f(t) exist,

$$\boldsymbol{\lambda}\,(\mathbf{t}) = \lim_{\Delta\mathbf{t}\to\mathbf{0}} \frac{\mathbf{Pr}[\,\mathbf{t} < \mathbf{T} \leq \mathbf{t} + \Delta\mathbf{t}/\mathbf{T} > \mathbf{t}]}{\Delta\mathbf{t}} * \frac{\mathbf{1}}{\boldsymbol{p}(\boldsymbol{T} > \boldsymbol{t})}$$

$$= \lim_{\Delta\mathbf{t}\to\mathbf{0}} \frac{\mathbf{F}(\mathbf{t} + \Delta\mathbf{t}) - \mathbf{F}(\mathbf{t})}{\mathbf{R}(\mathbf{t})} * \frac{\mathbf{1}}{\boldsymbol{R}(\boldsymbol{t})}$$

$$= \frac{dF(t)}{dt} * \frac{1}{R(t)}$$

$$\lambda(t) = \frac{f(t)}{R(t)} = \frac{f(t)}{1-F(t)} \quad , R(t) > 0 \qquad \text{..............} (3)$$

Which provides a very common and significant interpretation of $\lambda(t)\,\Delta t$ a fairly accurate conditional probability of a failure in (t, t +Δt]. Note that f (t) Δt defines the corresponding approximate unconditional probability of a failure in (t, t +Δt]. It is very likely that, owing to this interpretation, failure rate has an integral role in reliability analysis, and other fields.

2.5.1 Bathtub Curve [18]:

Failure, for most parts of an operation, is a function of time' (Slack, 2001). In many instances, plotting the failure rate against a continuous time scale, the outcomes will compose the so-called 'bath-tub' curve (Figure 2-2). From its shape, the curve can be divided into three distinct zones or periods quite readily.

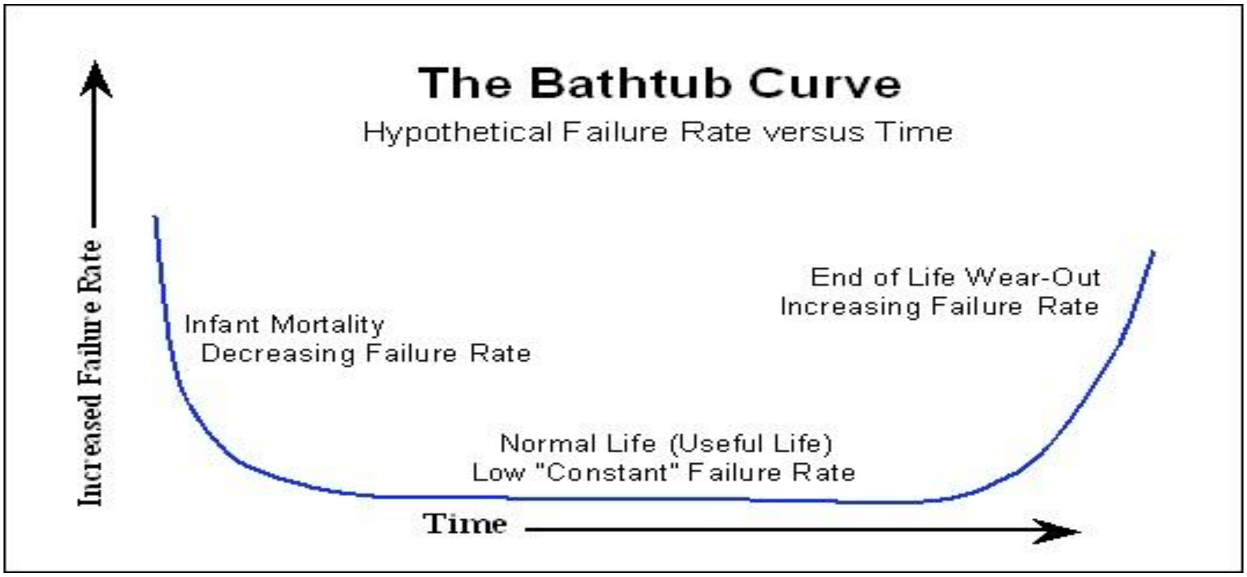


Figure (2-2): Represents the Bathtub Curve

These zones differ from each other in failure rate and in causation pattern, as follows:

- Early Life Period:

In Fig (2-2), if we follow the slope from the start to where it begins to flatten out this can be measured by the first period. The first period is featured by a decreasing failure rate. It is what occurs during the early life of a population of units. The weaker units die off leaving a population that is more rigorous. This first period is also known as infant mortality period.

- Useful Life Period:

This is the flat portion of the graph shown in Fig (2-2). As the product matures, the weaker units die off, the failure rate will become nearly constant, and modules have entered what is considered the normal life period. This period is featured by a relatively ongoing failure rate. The length of this period is referred to as the system life of a product or component. It is during this period of time that the lowest failure rate takes place. Notice how the amplitude on the bathtub curve is at its lowest during this time. The useful life period is the most common time frame for making reliability predictions.

- Wear-out Period:

It starts at the point where the slope begins to escalate and extends to the end of the graph Fig (2-2). As components start to fatigue or wear-out, failures take place at increasing rates. Wear-out in power supplies is usually triggered by the breakdown of electrical components that are subject to physical wear and electrical and thermal stress. It is this area of the graph that the MTBFs or FIT rates calculated in the useful life period no longer apply. No parts count method can predict the time to wear-out of components.

2.6 Statistical distribution [6]:

A probability distribution is a statistical function that describes all the possible values and likelihoods that a random variable can take within a given range. This range will be between the minimum and maximum statistically possible values, but where the possible value is likely to be plotted on the probability distribution.

2.6.1 Types of Distribution [6]:

Probability distributions are either continuous probability distributions or discrete probability distributions, depending on whether they define probabilities for continuous or discrete variables.

- **Discrete distribution**:

A discrete distribution describes the probability of occurrence of each value of a discrete random variable. A discrete random variable is a random variable that has countable values. Discrete distributions such as (Binomial, Discrete Uniform, Geometric, Hyper-geometric, Poisson …..…etc.)

- **Continuous distribution:**

A continuous distribution describes the probabilities of the possible values of a continuous random variable. A continuous random variable is a random variable with a set of possible values (known as the range) that is infinite and uncountable. Continuous distributions such as (Beta, Cauchy, Chi-square, Exponential, Gamma, Lognormal, Normal, Generalized Gamma ……….. etc.)

2.7 Gamma Distribution [6]:

The gamma distribution includes the chi-squared, Erlang, and exponential distributions as special cases, but the shape parameter of the gamma is not confined to integer values.

The gamma distribution starts at the origin and has a flexible shape. The parameters are easy to estimate by matching moments.

The pdf of the gamma distribution is given by:

$$f(t) = \frac{e^{kz-e^z}}{t\Gamma(k)}$$ ………………. **(4)**

Where:

$$z = \ln(t) - \mu$$

And:

$$e^\mu = \text{scale parameter}$$
$$k = \text{shape parameter}$$

Where, 0< t < ∞, -∞ < μ < ∞ and. K > 0

The reliability for a mission of time t for the gamma distribution is:

$$R = 1 - \Gamma_I(k; e^z)$$ ………………. **(5)**

The instantaneous gamma failure rate is given by:

$$\lambda = \frac{e^{kz-e^z}}{t\Gamma(k)(1-\Gamma_I(k; e^z))}$$ ………………. **(6)**

The standard deviation for the gamma distribution is:

$$\sigma_T = \sqrt{k}e^\mu$$

2.8 Weibull Distribution [6]:

The Weibull Variate is commonly used as a lifetime distribution in reliability applications. The two-parameter Weibull distribution can represent decreasing, constant, or increasing failure rates. These correspond to the three sections of the "bathtub curve" of reliability, referred to also as "burn-in," "random," and "wear-out" phases of life. The bi-Weibull distribution can represent combinations of two such phases of life.

Variate W: η, β.
Range $0 \leq x < \infty$
Scale parameter $\eta > 0$ is the characteristic life.
Shape parameter $\beta > 0$.

Probability density function:

$$f(t) = \frac{\beta x^{\beta-1}}{n^{\beta}} * exp^{[-\left(\frac{x}{n}\right)^{\beta}]} \text{ .... } \mathbf{(7)}$$

Hazard function:

$$\lambda(t) = \frac{\beta x^{\beta-1}}{n^{\beta}} \text{ …………….. } \mathbf{(8)}$$

2.9 Lognormal Distribution:

The lognormal distribution is applicable to random variables that are constrained by zero but have a few very large values. The resulting distribution is asymmetrical and positively skewed.

Variate L : m, σ or L : μ, σ.

Range $0 \leq x < \infty$.

Scale parameter $m > 0$, the median.

Alternative parameter μ, the mean of log L.

m and μ are related by $m = \exp \mu$, $\mu = \log m$.

Shape parameter σ > 0, the standard deviation of log L.

Probability density function:

$$f(t) = \frac{1}{t * \sigma(2\pi)^{\frac{1}{2}}} * e^{-\frac{1}{2}\left(\frac{\ln(t)-\mu}{\sigma}\right)^2} \quad \text{................. (9)}$$

Where:

$f(t) \geq 0,\ t > 0,\ -\infty < \mu < \infty,\ \sigma > 0$

The Lognormal Reliability Function:

$$R(t) = \int_{\ln(t)}^{\infty} \frac{1}{\sigma\sqrt{2\pi}}\ e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} dx$$

2.10 Generalized Gamma Distribution [14] [49] [44]:

The generalized gamma distribution is a younger distribution (1962) than the normal distribution (1774). It was presented by Stacy and Mihran in order to associate the power of two distributions, the Gamma distribution and the Weibull distribution. The generalized gamma distribution is a common distribution because it is extremely flexible. This distribution is also convenient because it has as special cases several distributions: the exponential distribution, the log-normal distribution, the Weibull distribution. These interests are nevertheless in contradiction with the difficulties in evaluating the parameters.

The generalized gamma distribution three types (β > 0) is Location parameter, with (θ > 0) is scale parameter, and (λ > 0) is shape parameter.

2.10.1 Characteristics of the Generalized Gamma Distribution [14]:

As mentioned previously, the generalized gamma distribution includes other distributions as special cases based on the values of the parameters.

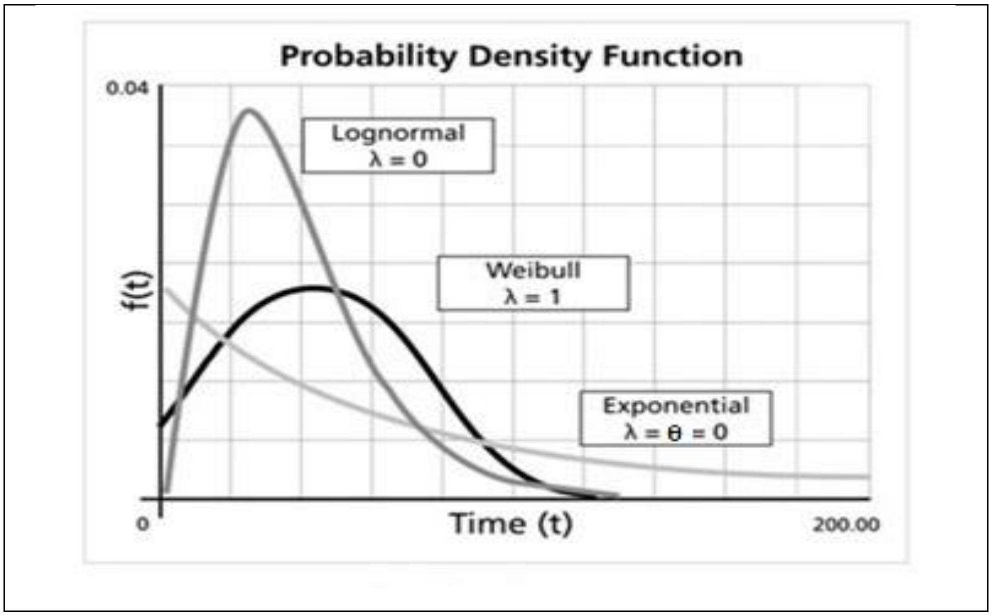


Fig (2-3): Represents the generalized gamma distribution special cases based on the values of the parameters

- The Weibull distribution is a special case when $\lambda=1$:
- The exponential distribution is a special case when $\lambda=1$ and $\theta = 1$.
- The lognormal distribution is a special case when $\lambda=0$
- The gamma distribution is a special case when $\lambda= \theta$

By allowing taking negative values, the generalized gamma distribution can be further extended to include additional distributions as special cases.

2.10.2 Generalized Gamma Probability Density Function (pdf) [14]:

The generalized gamma function is a 3-parameter distribution. One version of the generalized gamma distribution uses the parameters (β, θ and λ). The (pdf) for this form of the generalized gamma distribution is given by:

Where:

β: Location parameter.
θ: scale parameter.
λ: shape parameter.

$$f(t) = \left[\frac{\lambda}{\theta * t} * \frac{1}{\Gamma\left(\frac{1}{\lambda^2}\right)} * e^{\left[\frac{\lambda * \frac{\ln(t)-\beta}{\theta} + ln\left(\frac{1}{\lambda^2}\right) - e^{\lambda * \frac{\ln(t)-\beta}{\theta}}}{\lambda^2}\right]} \quad if\ \lambda \neq 0 \right] \quad \ldots\ldots\ldots\ldots\ldots (10)$$

$$f(t) = \left[\frac{1}{t * \theta\sqrt{2\pi}}\ e^{-\frac{1}{2}\left(\frac{\ln(t)-\beta}{\theta}\right)^2} \quad if\ \lambda = 0 \right] \quad \ldots\ldots\ldots\ldots\ldots (11)$$

2.10.3 Cumulative Distribution Function (CDF) [13] [5]:

It is apparent that this function would have a direct application to life data analysis. This function returns the probability of a failure occurring in a certain time given. Note that the cdf measures the area under the pdf curve up to a given time, and that the area under the pdf curve is always equal to (1). Given these concepts, subtracting the (cdf) from (1) would result in the probability of a failure occurring after a given time. This is the widely-used reliability function. Accordingly, the (cdf) is also known as the unreliability function, and is represented by the function Q (T).

$$\mathbf{F\ (t) = Q\ (t) = 1 - \Gamma_I\left(\frac{e^{\lambda\left(\frac{\ln(t)-\beta}{\theta}\right)}}{\lambda^2}; \frac{1}{\lambda^2}\right)} \quad \text{............ (12)}$$

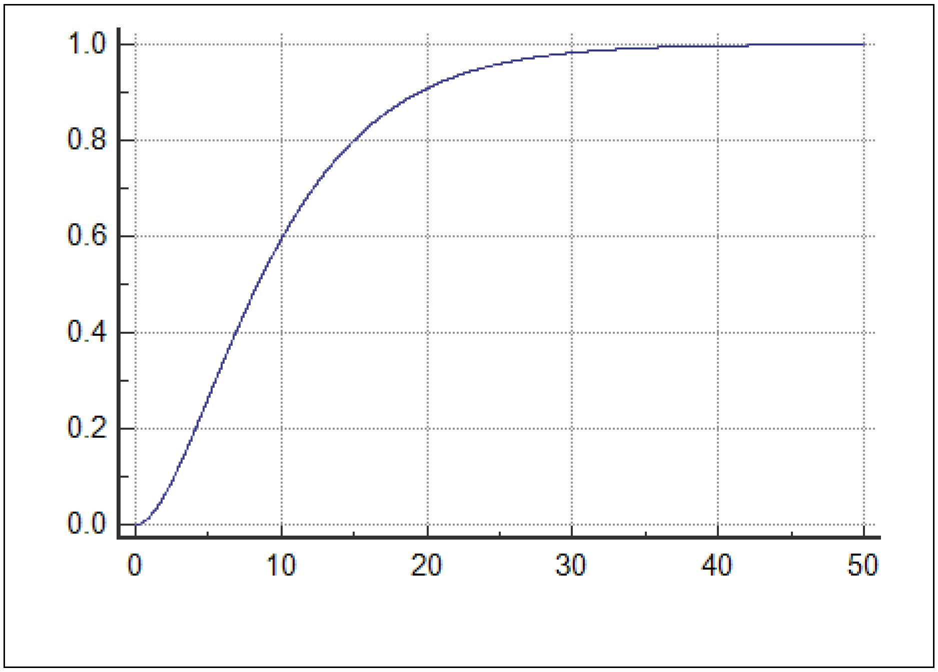


Figure (2-4): Represent cumulative distribution function (cdf)

2.10.4 Generalized Gamma Reliability Function [14]:

The reliability function for the generalized gamma distribution is given by:

$$\boldsymbol{R(t) = 1 - \Gamma_I\left(\frac{e^{\lambda\left(\frac{\ln(t)-\beta}{\theta}\right)}}{\lambda^2}; \frac{1}{\lambda^2}\right)\ \ If\ \lambda > 0} \quad \text{.............. (13)}$$

$$\boldsymbol{R(t) = 1 - \phi\left(\frac{ln(t)-\beta}{\theta}\right)\ if\ \lambda = 0} \quad \text{......................... (14)}$$

$$\boldsymbol{R(t)} = \Gamma_{\boldsymbol{I}}\left(\frac{e^{\lambda\left(\frac{\ln(t)-\beta}{\theta}\right)}}{\lambda^2}; \frac{1}{\lambda^2}\right) \boldsymbol{if\ \lambda < 0} \quad \text{.......................} \ \textbf{(15)}$$

$$\boldsymbol{\phi(z)} = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{z} e^{-\frac{x^2}{2}}\, dx$$

And $(\Gamma_I(k; x))$ is the incomplete gamma function of (k)

And(x), which is given by:

$$\Gamma_{\mathbf{I}}(\mathbf{k}; \mathbf{x}) = \frac{1}{\Gamma(\mathbf{k})} \int_{0}^{x} s^{k-1} e^{-s}\, ds$$

Where $\Gamma(x)$ is the gamma function. Note that in Weibull++ the probability plot of the generalized gamma is created on lognormal probability paper. This means that the fitted line will not be straight unless$(\lambda = 0)$.

2.10.5 Generalized Gamma Failure Rate Function [14]:

As defined in Basic Statistical Background, the failure rate function is given by:

$$\boldsymbol{\lambda(t)} = \frac{\left[\frac{\lambda}{\theta * t} * \frac{1}{\Gamma\left(\frac{1}{\lambda^2}\right)} * e^{\left[\frac{\lambda * \frac{\ln(t)-\beta}{\theta} + \ln\left(\frac{1}{\lambda^2}\right) - e^{\lambda * \frac{\ln(t)-\beta}{\theta}}}{\lambda^2}\right]} \quad \boldsymbol{if\ \lambda \neq 0}\right]}{\Gamma_{I}\left(\frac{e^{\lambda\left(\frac{\ln(t)-\beta}{\theta}\right)}}{\lambda^2}; \frac{1}{\lambda^2}\right)} \quad \text{.............}$$

(16)

Due to the complexity of the equations involved, the function will not be shown here, but the failure rate function for the generalized gamma distribution can be achieved merely by dividing the pdf function by the reliability function.

2.11 Estimation Methods [14]:

Several parameter estimation methods are accessible. Starting with the relatively simple method of Probability Plotting and continue with the more sophisticated methods of Rank Regression (or Least Squares), Maximum Likelihood Estimation and Bayesian Estimation Methods…..etc.

2.11.1 Definition of Estimation [8]:

The process of utilizing sample data (in reliability engineering, usually times-to-failure or success data) to evaluate the parameters of the selected distribution is known as parameter estimation. The sample statistic is calculated from the sample data and the population parameter is inferred (or estimated) from this sample statistic. So statistics are calculated, parameters are estimated.

2.11.2 Types of Estimation [7]:

There are two types of estimation: Point Estimates and Interval Estimates.

- Point Estimates: A single numerical quantity obtained from the sample data and used to estimate population parameter.
- Interval Estimate: The point estimate is going to be different from the population parameter because due to the sampling error, and there is no way to know how close it is to the actual parameter. For this reason, statisticians like to give an interval estimate which is a range of values used to estimate the parameter. A confidence interval is an interval estimate with a specific level of confidence. A

level of confidence is the probability that the interval estimate will contain the parameter.

A good estimator must satisfy three conditions:

- Unbiased: The expected value of the estimator must be equal to the mean of the parameter.
- Consistent: The value of the estimator approaches the value of the parameter as the sample size increases.
- Relatively Efficient: The estimator has the smallest variance of all estimators which could be used.
- Sufficiency: an estimator is said to be sufficient if it uses all the information in the sample estimating the required population parameter.

2.12 GOODNESS-OF-FIT [2] [14]:

It is always important to test the adequacy of the model as part of a statistical analysis which involves fitting a parametric model. One may utilize either a formal goodness-of-fit test or appropriate data analytic methods. Graphical procedures are particularly valuable in this context.

The sum of the three weights for each parameter estimation method must equal 100%.

Table (2-1): Weights for maximum likelihood according to Reliasoft program

Test	Weight
Goodness of Fit	40%
Plot Fit	10%
likelihood Ratio	50%
Total	100%

- The AVGOF is the average values from the GOF test (Kolmogorov-Smirnov test, which tests for statistical difference, which means the difference between the expected and obtained results).

$$\mathrm{AVGOF} = \mathrm{probability}(\mathrm{D} > \mathrm{d}) \quad \ldots\ldots\ldots\ldots \textbf{(17)}$$

Where d is a random variable. Note that AVGOF = 1 - p-value.

- The AVPLOT is the average values from the PLOT test (correlation coefficient test, which measures how well the plotted points fit a straight line).

$$AVPLOT = 100\,\frac{1}{N}\sum_{i=1}^{N}|\hat{Q}_i - Q_i| \ldots\ldots\ldots.(\mathbf{18})$$

Where:

- Q_i = observed probability
- $\hat{Q}_i$ = predicted probability based on the distribution
- N = number of observations

- The LKV is the average values from the LKV test (Likelihood Value test), which computes the value of the log-likelihood function given the parameters of the distribution according to (eqn. 22).

In conjunction with weights assigned to each test. The distribution with the lowest weighted decision variable (DESV) value is seen to be the best fit for the data. The weights appointed to each test are based on the parameter estimation method.

DESV= (AVGOF Rank * AVGOF Weight) + (AVPLOT Rank * AVPLOT Weight) + (LKVRank * LKV Weight) **……………………. (19)**

2.13 The Likelihood Function [14]:

Maximum probability estimation is utilized to evaluate distribution parameters for a set of data by maximizing the value of Likelihood function. This Likelihood function is largely based on the probability density function (pdf) for a given distribution. As an example, consider a generic pdf:

$$\boldsymbol{f(x_i, \theta_1, \theta_2, \theta_3, \ldots\ldots\ldots, \theta_k)} \ldots\ldots\ldots\ldots \mathbf{(20)}$$

If $(x_i;\ \theta_1; \theta_2; \theta_3; \ldots\ldots\ldots.; \theta_k)$ where (x_i) refers to the Failure time data and$(\theta_1; \theta_2;\ldots\ldots;\ \theta_k)$ are the parameters to be estimated. For complete data, the likelihood function is an outcome of the (pdf) functions, with one element for each data point in the data set:

$$\boldsymbol{L = \prod_{i=1}^{n} f(x_i, \theta_1, \theta_2, \theta_3, \ldots\ldots\ldots, \theta_k)} \ldots\ldots\ldots.(\mathbf{21})$$

Where (n) is the number of failure data points in the complete data set, and is the failure time. It is often mathematically easier to control this function by first taking the logarithm of it. This log-likelihood function then has the form:

$$\ln \mathrm{L} = \sum_{i=1}^{n} \boldsymbol{f(x_i, \theta_1, \theta_2, \theta_3, \ldots\ldots\ldots, \theta_k)} \ldots\ldots\ldots.(\mathbf{22})$$

Parameters are estimated by using following partial derivatives

$$\frac{\partial \mathbf{lnL}}{\partial \grave{\mathrm{e}}\mathbf{j}} = \mathbf{0}\ ,\ \ \boldsymbol{J = 1, 2, \ldots.k} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(23)}$$

These parameters can be obtained by solving above equations. The distribution with the largest (L) value is the best fit statistically. The log-likelihood function is used for goodness of fit because it is much easier to calculate log likelihood function than likelihood function.

2.14 Maximum Likelihood Estimation [1]:

Method of maximum likelihood is the most widespread statistical method of parameter evaluation. This method is based on the method of calculating values of parameters that maximize the probability of achieving the particular sample. The total probability of drawing each item of the sample is the probability of the sample. The total likelihood is the outcome of all the individual item probabilities. This item is distinguished with respect to the parameters, and the resulting derivatives are set to zero to obtain the maximum.

Maximum-likelihood solutions for model parameters are statistically efficient solutions, meaning that parameter values have minimum variance. This definition of a best method, however, is theoretical. Maximum-likelihood solutions do not always result in solvable equations for the parameters. For some distributions, including notably the normal distribution, the method of moments and maximum-likelihood estimation result in identical solutions for the parameters.

2.15 Test of Life Comparison [14]:

The life comparison test uses the following equation to evaluate the probability of failure based on the probability that the life of one data set is greater or equal than the other data set

$$\mathbf{P[t_2 \geq t_1] = \int_0^\infty f_1(t) * R_2(t)\,dt} \quad \text{.........................} \mathbf{(24)}$$

Where $[f_1(t)]$ is the (pdf) of the first data set and $[R_2(t)]$is the reliability function of the second data set. The evaluation is based on whether this probability is less than or greater than (0.5). The result is interpreted as follows:

- If $P = 0.5$ then lives of both data sets are equal.
- If $P < 0.5$, then the life of data (set 1) exceeds the life of data (set 2). For example, if P=0.10, then data (set 1) is better than data (set 2) with a (90%) probability.
- If $P > 0.5$, then the life of data (set 2) exceeds the life of data (set 1). For example, if P=0.8, then data (set 2) is better than data (set 1) with an (80%) probability.

2.16 Process Quality Control [4] [16] [17]:

It is a process by which entities review the quality of all factors involved in production. Quality control via the use of statistical methods is a very large area of study in its own right and is central to success in modern industry with its emphasis on reducing costs while at the same time improving quality.

2.16.1 Process:

A process is the transformation of a set of inputs, which can include raw materials, actions, methods and operations into desired outputs, in the form of products, information. In each area or function of an organization that included many processes. There are many processes and each process may be examined by an examination of the inputs and outputs. This will control the action necessary to develop quality.

2.16.2 Quality:

It is all the features and characteristics of a product or service that has ability to satisfy stated needs. This is the extent to which an item, function, or process can satisfy or please the needs and wants of users and customers. The phenomenon is prevalent; it doesn't matter if the consumer is an individual, an industrial organization, a retail store, a bank or financial institution, or a military defense program. As a result, considering and developing quality are key factors leading to business triumph, growth, and enhanced competitiveness. There is a vital return on investment from improved quality and from successfully employing quality as an integral part of overall business strategy. Quality is simply as meeting the requirements of the customer and final users.

2.16.3 Control:

All processes can be checked and taken 'under control' by gathering and using data. This refers to measurements of the performance of the process and the response required for corrective action, where necessary.

2.17 Statistical Quality Control (SQC) [7]:

By (SQC) we mean the different statistical techniques used for the maintenance of quality. Data is basically collected, organized and analysis interpretation is done this is all called statistics, and is based on large number of mathematical theory of probability. Statistical quality control includes the following:

(a) Systematic collection and graphic recording of precise data.
(b) Analyzing the data.
(c) Management action, if the information obtained shows significant deviations from the limits.

Modern method of (SQC) and acceptance sampling has an important role to play in the development of quality, and productivity, creation of consumer confidence and development of national economy.

2.18 Quality Control Charts [4]:

A graphical method utilized for shaping whether a process is in a “state of statistical control” or out of control is known as control chart. The history of control goes back to a memorandum written by Walter Shewhart on (May 16, 1924), in which he gives the concept of a control chart. Nonetheless, the building of control charts is based on statistical principles and distributions and a chart is basically composed of three elements: average or standard value of the characteristic under consideration, upper control limit (UCL), and lower control limit (LCL). Two error types can happen in control chart including type's I and II.

(The type I error) takes place when the process is in-control and the control chart signals the presence of an assignable cause. On the other hand, if the process is not in control and the control chart cannot notice this status, **(The type II error)** takes place usually; the performance of the control charts is estimated by using the probability of these errors.

2.19 Types of Control Chart [19]:

We can use different sorts of control charts to notice assignable causes in a process under different situations. There are two types of control charts:

- **Attributes control charts:**

Attribute data are counted and cannot have fractions or decimals. Attribute data arise when you are determining only the presence or absence of something: success or failure, accept or reject, correct or not correct. For example, a report can have four errors or five errors, but it cannot have four and a half errors. Applied to data following discrete distribution. Many sub-types of Attributes control charts are present like the following:

  - (p) chart (proportion chart)
  - ($n_{p)}$ chart
  - (c) chart (count chart)
  - (U) chart

- **Variables control charts:**

Variable data are measured on a continuous scale. For example: time, weight, distance or temperature can be measured in fractions or decimals. Applied to data with continuous distribution. There are many sub-types of Variables control charts such as:

- X-bar and ® chart (also called averages and range chart)
- X-bar and (S) chart
- moving average–moving range chart (also called MA–MR chart)
- target charts (also called difference charts, deviation charts and nominal charts)
- (CUSUM) (cumulative sum chart)
- multivariate chart
- (EWMA) (exponentially weighted moving average chart)

2.20 Cumulative Sum (CUSUM) [20]:

A (CUSUM) chart is a time-weighted control chart that displays the cumulative sums (CUSUMs) of the deviations of each sample value from the target value. The (CUSUM) chart is based on the charting of cumulative sum of previous observations which allows us to use all the information about the process to make more accurate decisions. Similar to the (CUSUM), the (EWMA) is also an effective method for quick shift identifications for small process shifts.

$$\boldsymbol{S_1 = X_1 - r}$$

$$\boldsymbol{S_2 = (X_2 - r) + (X_1 - r) = (X_2 - r) + S_2}$$

.

.

$$\boldsymbol{S_k = \sum_{i=1}^{k}(X_i - r) = (X_k - r) + S_{k-1}} \quad \ldots\ldots\ldots.. \textbf{(25)}$$

Where:

$X_i =$ the ith observation.

$S_i =$ the ith cumulative sum.

2.21 The classical Exponentially Weighted Moving Average (EWMA) control charts [45] [46] [49]:

Exponentially weighted moving average (EWMA) control chart is more influential than the Shewhart control charts in noticing small shifts actually less than (1.5σ) in the process mean (Roberts). The (EWMA) control chart was presented by Roberts (1959). The exponentially weighted moving average (EWMA) rule for internal quality control is a well-known type of control rule in industry. The concept of the rule is to associate control measurements from previous runs with control measurements in the current run to evaluate systematic errors more efficiently. Thus, a small, fixed shift or a gradually developing trend in one direction is detected sooner than when only the control measurements from the current run are considered.

The plotting statistic of the (EWMA) control chart is a weighted combination of the current and past information and is defined as:

$$\mathbf{Zi} = \boldsymbol{\lambda}\mathbf{Xi} + (\mathbf{1} - \boldsymbol{\lambda})\boldsymbol{Z_{i-1}} \;, \boldsymbol{i} = \mathbf{1}, \mathbf{2}, \ldots\ldots, \boldsymbol{n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (26)$$

Where:

Zi = i^{th} EWMA

Xi = i^{th} Sample result

λ = the weight factor ($0 < \lambda \leq 1$) or λ is smoothing parameter.

Z_{i-1} = $(i\text{-}1)^{th}$ EWMA is the past information.

$$\boldsymbol{Mean(Z_i) = \mu_0}, \quad \boldsymbol{Variance(Z_i) = \sigma^2 \left\{\frac{\lambda}{2-\lambda}\left(1 - (1-\lambda)^{2i}\right)\right\}} \ldots\ldots\ldots (27)$$

Where (σ^2) is the process variance which may have a known value (σ_0^2) or has to be valued from initial in-control process samples. We continue with the case of a known parameter. Based on the above results, the control structure of a (EWMA) control chart is given as:

$$\mathbf{LCL = \mu_0 - L\sigma\sqrt{\frac{\lambda}{2-\lambda}\left(1-(1-\lambda)^{2i}\right)},} \quad \text{.......................} \ \mathbf{(28)}$$

$$\mathbf{UC\,L = \ \mu_0 + L\sigma\sqrt{\frac{\lambda}{2-\lambda}\left(1-(1-\lambda)^{2i}\right)}} \quad \text{.......................} \ \mathbf{(29)}$$

$$\mathbf{CL = \ \mu_0}$$

All the terms used in (20, 21) are defined as earlier. (L) Determines the width of the control limits and its value is chosen according to the choice of the smoothing constant (λ). The above-mentioned limits given in (20, 21) are called time-varying limits of the (EWMA) charts. For large values of (i), these limits converge to the constant limits which are given as:

$$\mathbf{LCL = \mu_0 - 3\sigma\sqrt{\frac{\lambda}{2-\lambda}}} \quad \text{........................} \ \mathbf{(30)}$$

$$\mathbf{UCL = \mu_0 + 3\sigma\sqrt{\frac{\lambda}{2-\lambda}}} \quad \text{.....................} \ \mathbf{(31)}$$

$$\boldsymbol{CL = \mu_0}$$

Hence, the factor$(1-(1-\lambda)^{2i}$ in (20, 21) tends to (1) as the sample number becomes large and ultimately the time variant limits will become constant. In this article, we will use the time variant limits so that the exact width of the control limits at each sample point is utilized and we will refer it as the classical (EWMA) control chart in the sequel.

2.22 Process Capability Indices [7] [47]:

With the help of globalization, there is strong national and international competition amongst business groups. This competition leads to manufacturing defect-free products. In order to obtain this goal, companies have started adopting different strategies like Total Quality Management (TQM) and Six Sigma throughout their organizations. This requires the monitoring of the performance of the individual processes. These results are then compared with those of industry leaders through competitive benchmarking like comparing similar products with each other. One metric popularly used is the Process Capability Index (PCI) (Spiring, 1995). Essentially a (PCI) measures the variability of a process relative to its specification limits. Comparisons amongst hundreds of processes emanating from a whole range of production processes, industries, and even countries are done. Many (large) companies have made the use of these indices to promote and drive quality improvement program throughout their organizations (Barnett, 1990; Gill, 1990; McCoy, 1991). Moreover, the incorporation of capability analysis into a company's (Six Sigma) program makes it a particularly important topic for management reporting. Briefly, Six Sigma is a quality and business improvement methodology that makes heavy use of statistical methods.

The behavior of a process is often defined by a probability distribution. In order to measure its adequacy, the hypothesized distribution has to be linked with the corresponding specifications. A (PCI) tries to summarize the procedure performance and hence is a function of the process distribution and the corresponding specification. Important objectives of a (PCI) have already been discussed by Tsui (1997). Suffice it to say that a (PCI) should be revealing enough to lead the users in their decision problems adequately and unambiguously. Another desirable feature of a (PCI) is that its numerical value should increase when the variability decreases.

The indices aid in the prevention of (NC) products by creating a benchmark capability.

- Being dimensionless, they ease communication between engineering and manufacturing departments and between manufacturers and suppliers.
- They help in setting up the priority areas for process improvement and continuous improvement.
- The indices also give information on the location and variability of a process and hence recommend the road map for process improvement.
- Finally, the indices can be utilized in audits to aid establishing the problem areas.

2.22.1 Monitoring Capability Indices using a EWMA Approach [48]:

When executing a capability analysis, it is suggested to first monitor that the process is stable, for example, by using control charts. However, there are occasions when a process cannot be stabilized, but it is nevertheless capable. Then the classical control charts fail to efficiently display the process position and variability. The proposed procedure uses the [Cp (u, v)] family of capability indices proposed by V¨annman combined with a logarithmic transformation and a (EWMA) approach. One important property of the procedure presented here is that the control limits used for the monitoring of capability indices only depend on the capability level assumed for the process.

2.22.2 Definition and method of Process Capability Indices [7] [11] [48]:

Process capability indices were introduced to give a quick indication of the capability of a manufacturing process. They are designed to quantify the relation between the desired engineering specifications and the actual performance of the process.

According to specification limits there are two types of process capability which are:

(a) Unilateral (one-sided, with target not specified)

(i) Only Upper Specification Limit (USL).

$$C_{(pu)} = \frac{USL - M}{3\sigma} \quad \text{..................} \ (32)$$

Where:

C_{pu} : Capability process upper specification limit.

USL : Upper Specification Limit.

M : Mean.

σ : Standard deviation.

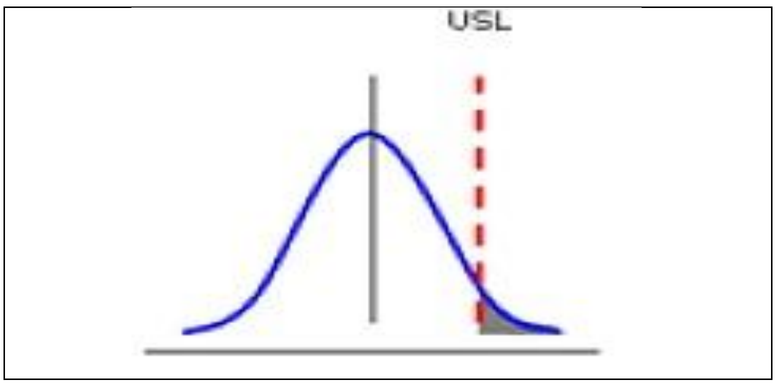


Figure (2-5): Represents capability upper one side

Estimates process capability for specifications that consist of an upper limit only (for example, concentration). Assumes process output is approximately normally distributed.

(ii) Only Lower Specification (LSL).

$$C_{(pl)} = \frac{M - LSL}{3\sigma} \quad \text{..................} \ (33)$$

Where:

C_{pl} : Capability process lower specification limit.

M : Mean.

LSL : Lower Specification Limit.

σ : Standard deviation.

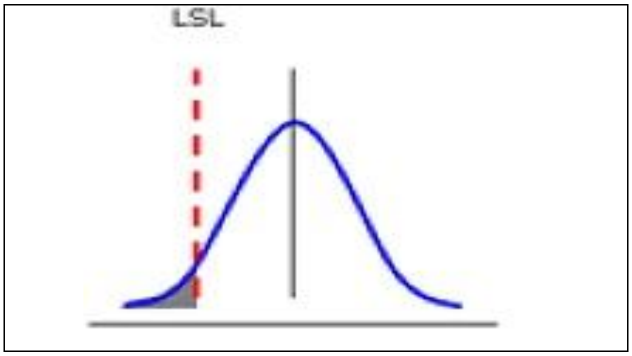


Figure (2-6): Represents capability lowers one side

Estimates process capability for specifications that consist of a lower limit only (for example, strength). Assumes process output is approximately normally distributed.

(b) Bilateral (two-sided, with target specified) and this subdivi ded into:

(i) Centered target, that is, = M

$$C_P = \frac{USL-LSL}{6\sigma} \quad \dots\dots\dots\dots\dots (34)$$

Where:

C_P **:** Process Capability.

LSL : Lower Specification Limit.

USL : Upper Specification Limit.

σ : Standard deviation.

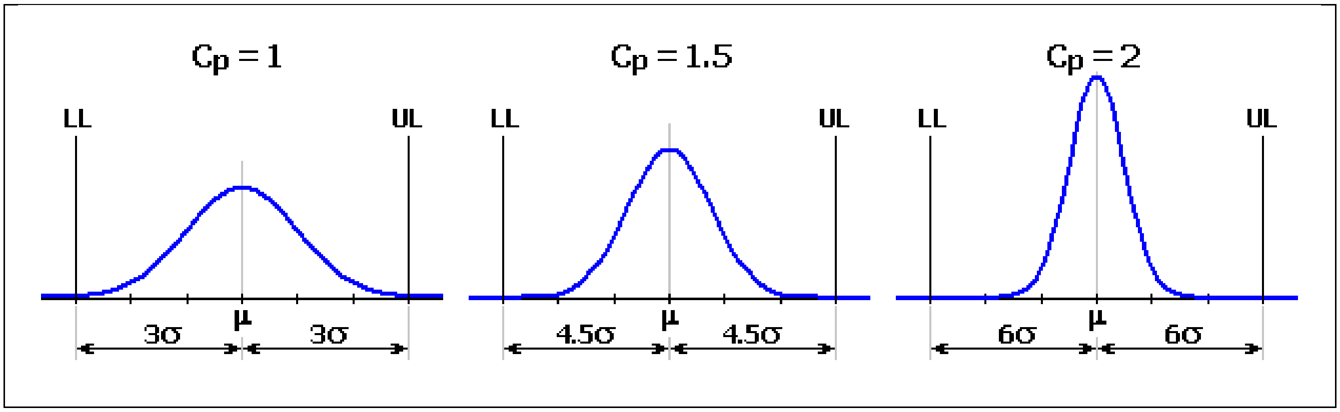


Figure (2- 7): Represents capability index two sides target value = mean

Estimates what the process would be capable of producing if the process could be centered. Assumes process output is approximately normally distributed.

(ii) Off-centered target that is ≠ M

$$C_{pk} = Min\left[\frac{USL-M}{3\sigma} , \frac{M-LSL}{3\sigma}\right] \quad \text{................ (35)}$$

$C_{(pk)}$ **:** Process Capability Index.

LSL : Lower Specification Limit.

USL : Upper Specification Limit.

σ : Standard deviation.

The following values of the (Cpk) index represent the given level of confidence in the process capability:

- (Cpk < 1) A situation in which the producer is not capable and there will inevitably be non-conforming output from the process.
- (Cpk = 1) A situation in which the producer is not really capable, since any change within the process will result in some undetected non-conforming output.

■ (Cpk = 1.33) A still far from acceptable situation since nonconformance is not likely to be detected by the process control charts.

■ (Cpk = 1.5) not yet satisfactory since non-conforming output will occur and the chances of detecting it are still not good enough.

■ (Cpk = 1.67) Promising, non-conforming output will occur but there is a very good chance that it will be detected.

■ (Cpk = 2) High level of confidence in the producer, provided that control charts are in regular use.

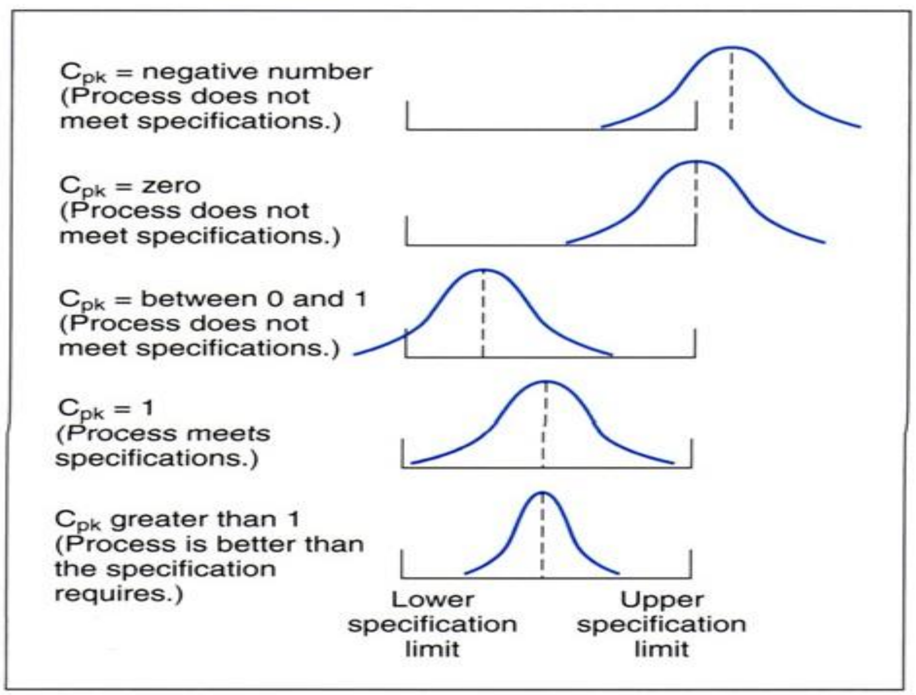


Figure (2- 8): Represents capability index two sides target value ≠ mean

Estimates what the process is capable of producing, if the process target is of-centered between the specification limits. If the process mean is not centered, (C_p) overestimates process capability. ($C_{pk} < 0$) If the process mean falls outside of the specification limits. Assumes process output is approximately normally distributed.

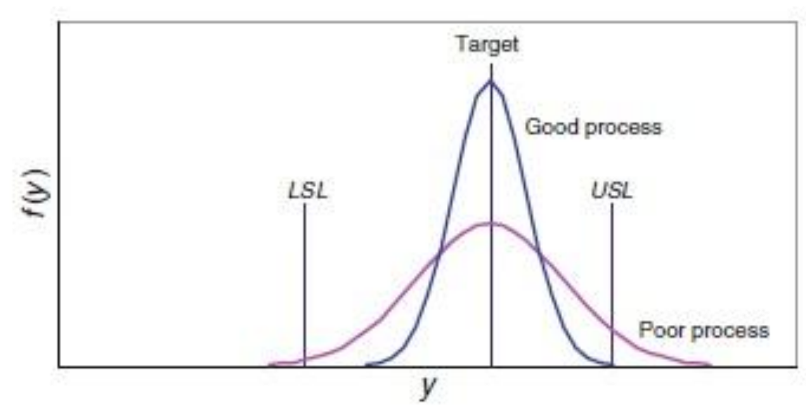


Figure (2-9): Represents good and bad process

In the figure above the blue curve indicates a good process since all observations are included between specification limits, and the purple curve determine poor process because there are observations out of limits.

2.22.3 Process Capability Metrics (Cp and Cpk) [7]:

- (Cp) measures how well the data would fit within the spec limits (USL, LSL).
- (Cpk) measures how centered the data is between the spec limits.
- Use (Cp, Cpk) when you have a sample, not the population, and are testing the potential capability of a process to meet customer needs.
- (Cp) and (Cpk) use Sigma estimator.

Chapter three

Data Description

and

Application

3.1 Introduction:

Mass Cement Plant is one of Mass – Iraq for industrial investments Company's strategic located in Bazian district. the plant stared production in (2010), The plant produces three types of cement, [(OPC), (SBC) and (SRC)] and the manufacture composed of three lines, each line product (2 million tonnes) of cement each year. In This chapter of the study reliability of (5) cement mills selected from Mass Cement Factory has been estimated through using of failure time data, the researcher also has tried to determine the quality of product produced in this factory and factors that affect that quality have been highlighted, also in this chapter the best distribution of the study has been demonstrated.

3.2 Data Description:

The data set used in this study consist of monthly failure time of five cement mills from Mass Cement Factory. (36) Observations of each cement mill have been taken for three years (2012, 2013 and 2014). Since proper data of physical tests (compressive strength test) of year (2012 and 2013) was not available so the researcher could only use data of physical tests of year (2014) which are (294) observation for Ordinary Portland Cement (OPC), (299) observation for High Blaine Portland Cement (SBC) and (299) observation for High Sulfur Resistant Cement (SRC) to determine that how far the failure time of cement mills affected the quality control of the products in that year.

For the analysis of failure time data software application which is Reliasoft program (Weibull++) has been used. For analysis of physical test data Software application Statgraphics Centurion (v16.1) has been used.

3.3 Variable of study:

In this study two variable are exist, the first variable (X_1) is the failure time data of all five cement mills, which consists of (36) observations for each mill. Second variable (X_2) is the data of physical test which is compressive strength test for all the (3 types) of cement produced in Mass Cement Factory which are [Ordinary Portland cement (OPC), High Blaine Portland Cement (SBC) and High Sulfur Resistant Cement (SRC)], a sample of each variable shown in the table below (More detail of variable (X_1) and (X_2) has been shown in appendix section (Table A and B) respectively).

Table (3-1): Failure time data of cement mills (1, 2, 3, 4, and 5)

Year	Month	Failure time				
		Mill (1)	Mill (2)	Mill (3)	Mill (4)	Mill (5)
2012	January	157.5	101.5	504.5	295.5	336
	February	96.5	86	412.5	299	398
	March	128	71.75	424.5	206.5	322.2
	April	52.5	121	63.8	76.3	94.3
	May	298.72	306.52	65.18	33.7	127.23
	June	31.82	67.31	85.36	50.96	97.66
	July	77.34	113.88	116.81	91.72	135.97
	August	234.21	365.54	293.23	360.11	316.79
	September	39.13	26.17	79.06	78.72	91.45
	October	129.8	126.91	103.52	152.94	165.42
	November	172.69	200.45	156.25	137.81	102.11
	December	219.67	258.58	234.94	202.33	161.41

Table (3-2): Compressive strength test data of each product (OPC, SBC and SRC)

Date	*comp.strength:Kg/*cm^2, 7 day		
	OPC	**SBC**	**SRC**
1/2/2014	381.48	522.24	369.24
1/4/2014	379.44	539.58	368.22
1/5/2014	381.48	537.54	374.34
1/6/2014	381.48	534.48	384.54
1/7/2014	387.6	538.56	389.64
1/8/2014	379.44	523.26	384.54
1/9/2014	375.36	538.56	353.94
1/11/2014	382.5	531.42	366.18
1/12/2014	370.26	525.3	358.02
1/13/2014	375.36	541.62	348.84
1/14/2014	382.5	529.38	346.8
1/15/2014	381.48	531.42	344.76

3.4. Application:

The data that has been collected as described in appendix are used to perform reliability and quality (table (A) and (B)).

3.4.1 Failure time of cement mill (1):

The monthly failure time data of cement mill (1) for three years as shown in (Appendix, table A) in different times tested to choose a suitable distribution for cement mill (1). For these three goodness of fit tests performed and final result has been found by weighted decision variable (DESV) as in (eq. 19) test through which rank of distributions determined. This analysis done by Reliasoft Program (Weibull++) as shown in the table below:

Table (3-3): Rank of Distributions for cement mill (1).

	Distribution	(DESV)	Ranking
Mill 1	G-Gamma	140	1
	Loglogistic	220	2
	Gamma	240	3
	Logistic	450	4
	1P-Exponential	540	5
	Normal	550	6
	Gumbel	660	7
	Parameters Calculated for G-Gamma Distribution:		
	Start G-Gamma		
	(β)	5.431 Location	
	(θ)	0.7072 Scale	
	(λ)	1.0144 Shape	

The (pdf) of Generalized Gamma Distribution explained as follows:

$$f(t) = \left[\frac{1.0144}{0.7072 * t} * \frac{1}{\Gamma\left(\frac{1}{(1.0144)^2}\right)} * e^{\left[\frac{1.0144 * \frac{\ln(t) - 5.431}{0.7072} + ln\left(\frac{1}{(1.0144)^2}\right) - e^{1.0144 * \frac{\ln(t) - 5.431}{0.7072}}}{(1.0144)^2}\right]} \quad if\ \lambda \neq 0 \right]$$

Distribution having minimum weighted decision variable (DESV) as in (eqn.19) is considered as best distribution to be fitted for given data. Thus from (Table 3-3) it is clear that G-Gamma Distribution is best suited and estimated it in parameters then (Reliability, Failure Rate, Probability density function, Cumulative distribution function) are calculated for cement mill (1), as shown in the table below:

Table (3-4): Represent Reliability, Failure Rate, Probability density function, Cumulative distribution function for cement mill (1)

Year	Month	Failure time (T)	Reliability (R(t))	Failure rate (λ(t))	Probability density function (pdf)	cumulative distribution function (CDF)
2012	January	157.5	0.55138	0.00532/Hr	0.002933	0.44862
	February	96.5	0.74151	0.004349/Hr	0.003225	0.25849
	March	128	0.64101	0.004883/Hr	0.00313	0.35899
	April	52.5	0.88035	0.003397/Hr	0.002991	0.11965
⋮	⋮	⋮	⋮	⋮	⋮	⋮
2013	May	126.55	0.64556	0.004861/Hr	0.003138	0.35444
	June	4.12	0.99636	0.001235/Hr	0.001231	0.00364
	July	309.43	0.21366	0.007053/Hr	0.001507	0.78634
	August	366.23	0.14101	0.007573/Hr	0.001068	0.859
	September	96.85	0.74038	0.004356/Hr	0.003225	0.25962
	October	127.63	0.64217	0.004878/Hr	0.003133	0.35783
	November	159.41	0.5458	0.005346/Hr	0.002918	0.45421
	December	192.94	0.4528	0.005787/Hr	0.00262	0.5472
2014	January	132.67	0.62645	0.004956/Hr	0.003105	0.37355
	February	97.72	0.73757	0.004372/Hr	0.003225	0.26243
	March	36.39	0.92652	0.002932/Hr	0.002717	0.07348
	April	268.35	0.2831	0.006643/Hr	0.001881	0.7169
	May	161.19	0.54061	0.005371/Hr	0.002904	0.45939
	June	447.95	0.07384	0.008248/Hr	0.000609	0.92616
	July	712.74	0.00648	0.010056/Hr	0.000065	0.99352
	August	523.31	0.03881	0.008812/Hr	0.000342	0.96119
	September	301.73	0.22552	0.006978/Hr	0.001574	0.77448
	October	301.81	0.2254	0.006979/Hr	0.001573	0.77461
	November	325.83	0.19008	0.007208/Hr	0.00137	0.80992
	December	415.35	0.09621	0.007987/Hr	0.000768	0.90379

From **Table (3-4)**, it’s clear that the minimum value of failure time is (4.12hr.) in (June 2013) which means at that time the reliability for that specific month is at the highest point, this was equal to (0.99636), it shows that the mill is performing its intended function very well, and the production for that month is the highest as well. Since it has high reliability, as we know that (R (t)) has an opposite relationship with failure time. This means that the worst (R (t)) of the first mill occurs when the failure time goes to (712.74 hr.) in (July 2014) Then reliability is equal to (0.00648). This is a good point and a bad point about it.

- **Graphical representation of (probability of failure, Reliability, Probability density function, Cumulative distribution function):**

Each of above has been more explained through their plot according to failure time data of cement mill (1) as shown in figures below:

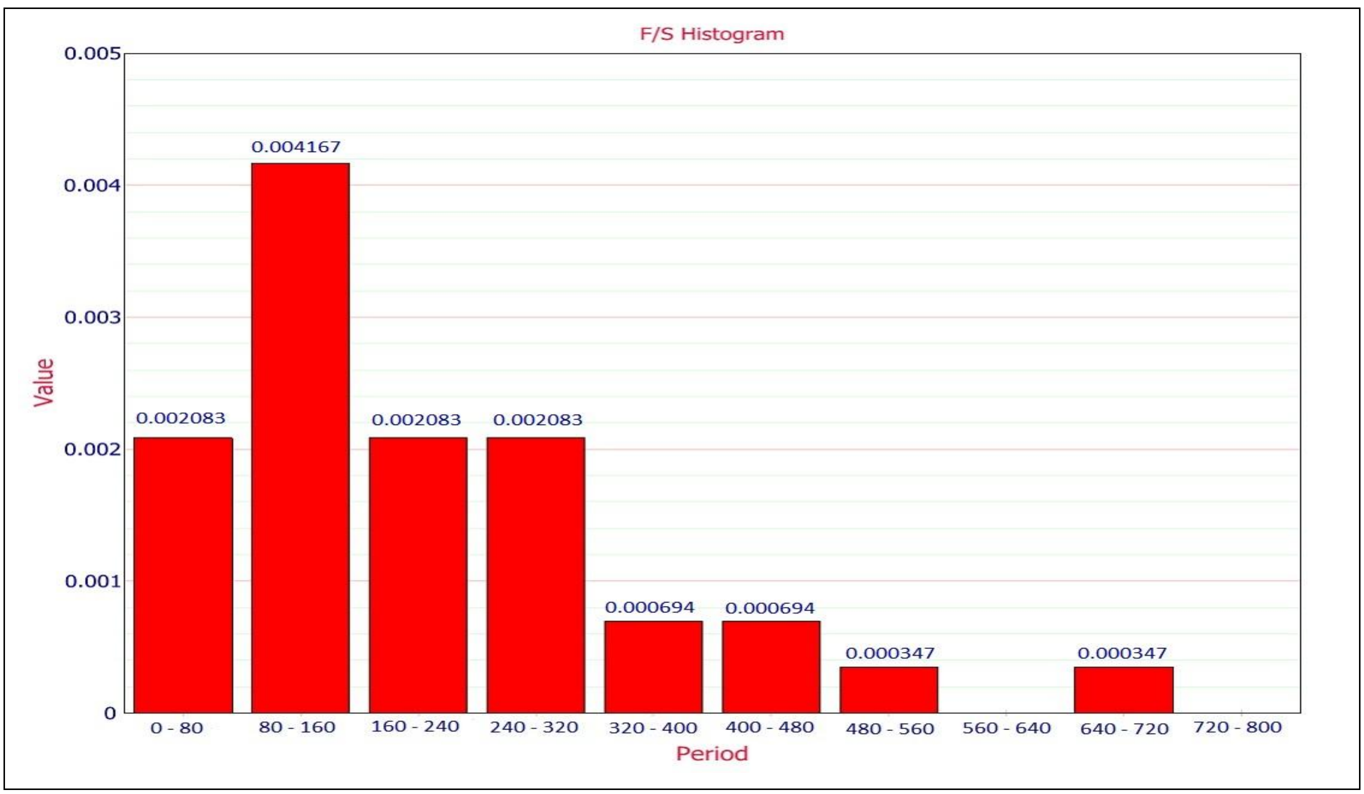


Figure (3-1): Represents Plot the Histogram of cement mill (1)

The above histogram represent the probability of hours of failure for cement mill (1) it shows that most failure of cement mill (1) has happened in a range time between (80 –

160 hr.) and the probability of failure at that time is equal to (0.004167). The minimum probability of failure has taken place between [(480 – 560) and (640 – 720) hr.].

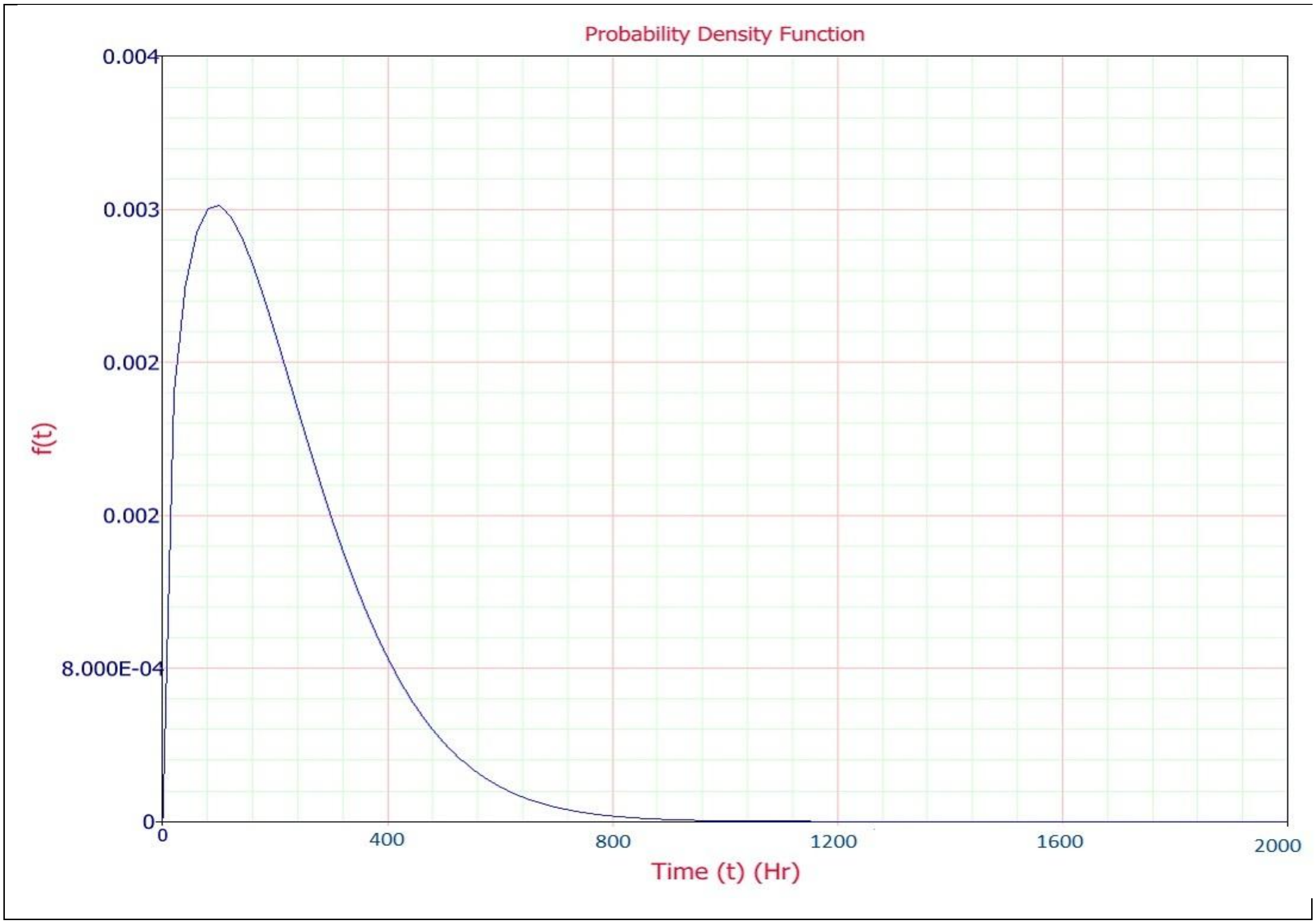


Figure (3-2): Represents the probability density function of the failure time of cement mill (1)

This plot illustrates (pdf) of cement mill (1) which is increasing until the failure time reach to (100 hr.) approximately at this time of failure; the probability is equal to (0.00305), after reaching (100 hr.) of failure, the probability density function is decreasing.

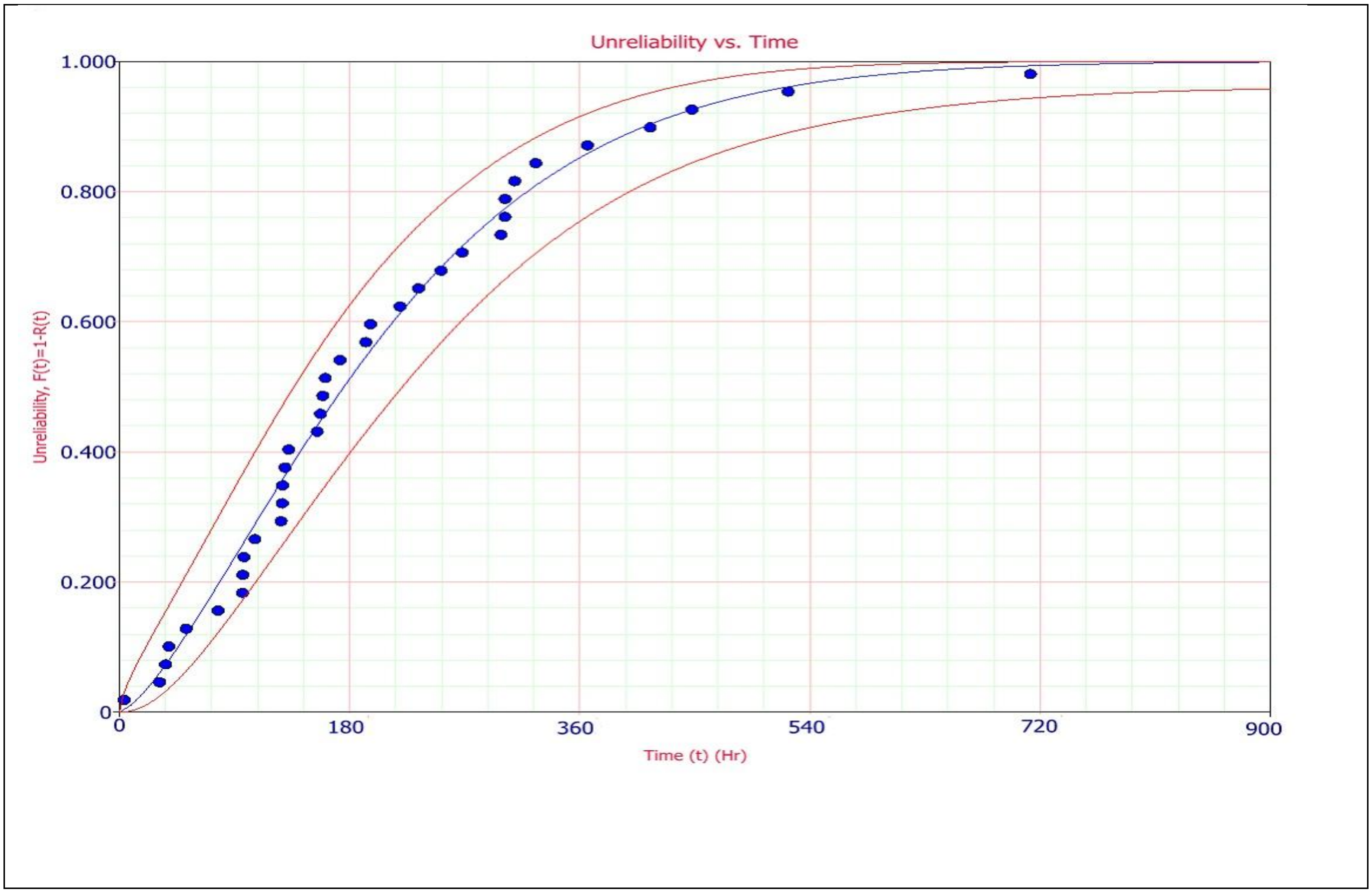


Figure (3-3): Represents the cumulative distribution function of failure time for cement mill (1).

It's obvious from the above graph that the cumulative distribution function is increasing as vertical shape with failure time, since it has direct relationship with time, so cumulative distribution function value reaches to the highest points when the failure time is equal to (712.74 hr.) in (July 2014).

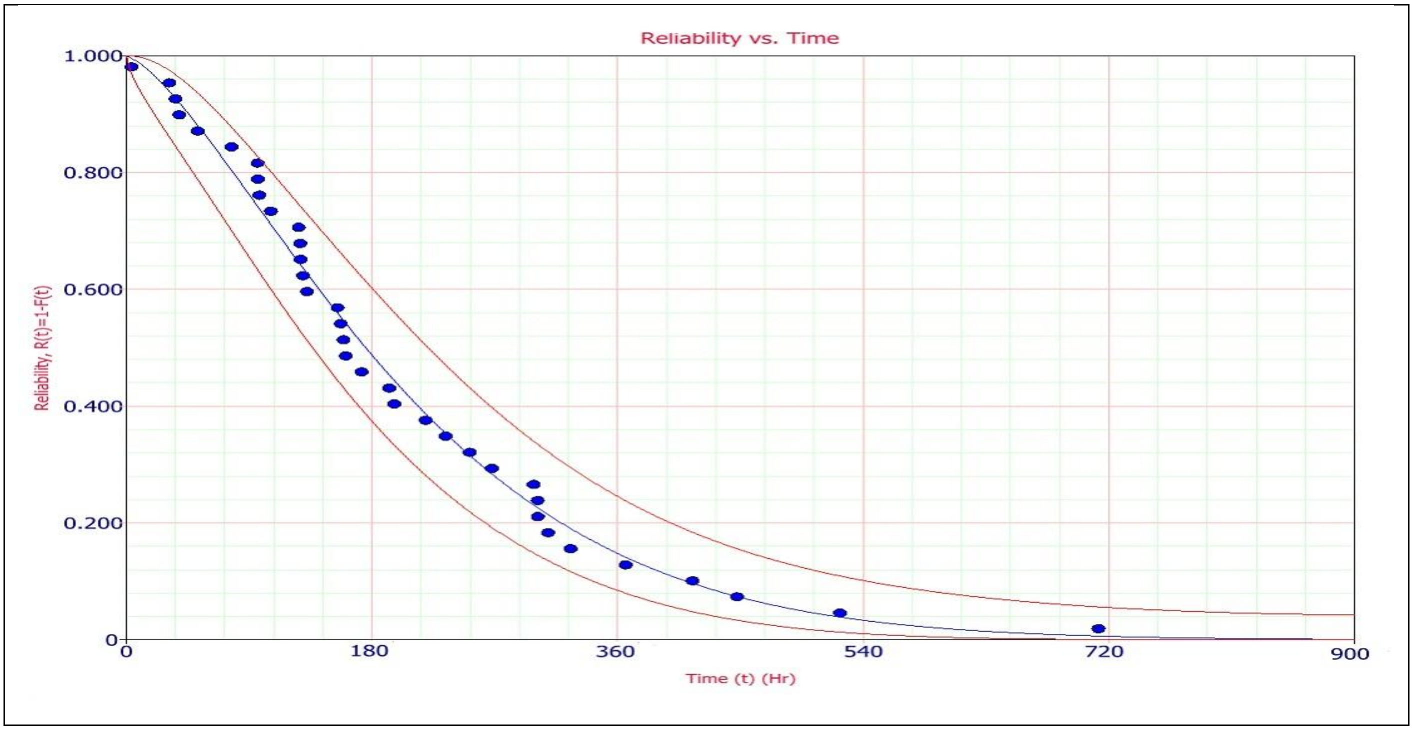


Figure (3-4): Represents the reliability of cement mill (1).

The above graph represents the reliability of cement mill (1) which is decreasing as failure time increases because reliability has an indirect relationship with time. When the failure time is equal to (4.12 hr.) in (June 2013) the reliability is equal to (0.99636) which is the best reliability of the mill and the worst reliability occurs when the failure time reaches over (712.74 hr.) in (July 2014) where the reliability is equal to (0.00648).

3.4.2 Failure time of cement mill (2):

The monthly failure time data of cement mill (2) for three years as shown in (Appendix, table A) in different times tested to choose a suitable distribution for cement mill (2). For these three goodness of fit tests performed and final result has been found by weighted decision variable (DESV) as in (eq. 19) test through which rank of distributions determined. This analysis done by Reliasoft Program (Weibull++) as shown in the table below:

Table (3-5): Rank of Distributions for cement mill (2).

	Distribution	(DESV)	Ranking
Mill 2	G-Gamma	230	1
	Gamma	270	2
	Normal	360	3
	Gumbel	380	4
	Loglogistic	390	5
	Logistic	470	6
	1P-Exponential	700	7
	Parameters Calculated for G-Gamma Distribution:		
	Start G-Gamma		
	(β)	5.594 Location	
	(θ)	0.4589 Scale	
	(λ)	1.3751 Shape	

The (pdf) of Generalized Gamma Distribution explained as follows:

$$f(t) = \left[\frac{1.3751}{0.4589 * t} * \frac{1}{\Gamma\left(\frac{1}{(1.3751)^2}\right)} * e^{\left[\frac{1.3751 * \frac{\ln(t) - 5.594}{0.7072} + ln\left(\frac{1}{(1.3751)^2}\right) - e^{1.3751 * \frac{\ln(t) - 5.594}{04589}}}{(1.3751)^2}\right]} \quad if\ \lambda \neq 0 \right]$$

Distribution having minimum weighted decision variable (DESV) as in (eqn. 19) is considered as best distribution to be fitted for given data. Thus from (Table 3-4) it is clear that G-Gamma Distribution is best suited and estimated it in parameters then (Reliability, Failure Rate, Probability density function, Cumulative distribution function) are calculated for cement mill (2), as shown in the table below:

Table (3-6): (Reliability, Failure Rate, Probability density function, Cumulative distribution function) of cement mill (2).

Year	Month	Failure time(T)	Reliability (R(t))	Failure rate (λ(t))	Probability density function (pdf)	cumulative distribution function (CDF)
2012	January	101.5	0.829772	0.003143/Hr	0.002607973	0.170228
	February	86	0.868578	0.002756/Hr	0.002393801	0.131422
	March	71.75	0.901124	0.002407/Hr	0.002169005	0.098876
	April	121	0.776634	0.003649/Hr	0.002833937	0.223366
	May	306.52	0.224678	0.010408/Hr	0.002338449	0.775322
	June	67.31	0.910588	0.002299/Hr	0.002093442	0.089412
	July	113.88	0.796541	0.003461/Hr	0.002756828	0.203459
	August	365.54	0.111158	0.013526/Hr	0.001503523	0.888842
	September	26.17	0.979933	0.001239/Hr	0.001214137	0.020067
	October	126.91	0.759712	0.003807/Hr	0.002892224	0.240288
⋮	⋮	⋮	⋮	⋮	⋮	⋮
2013	August	329.23	0.175129	0.011546/Hr	0.002022039	0.824871
	September	60.98	0.923484	0.002144/Hr	0.00197995	0.076516
	October	123.52	0.769461	0.003716/Hr	0.002859317	0.230539
	November	178.46	0.601142	0.005318/Hr	0.003196873	0.398858
	December	205.98	0.512881	0.006237/Hr	0.003198839	0.487119
2014	January	180.66	0.594105	0.005388/Hr	0.003201038	0.405895
	February	123.82	0.768603	0.003724/Hr	0.002862278	0.231397
	March	45.27	0.952214	0.001754/Hr	0.001670183	0.047786
	April	300.8	0.238272	0.010134/Hr	0.002414648	0.761728
	May	222.53	0.460331	0.006832/Hr	0.003144981	0.539669
	June	314.06	0.207432	0.010778/Hr	0.002235702	0.792568
	July	530.66	0.004847	0.025146/Hr	0.000121883	0.995153
	August	351.66	0.133385	0.012745/Hr	0.001699992	0.866615
	September	239.96	0.406315	0.007496/Hr	0.003045737	0.593685
	October	266.85	0.327321	0.008599/Hr	0.002814633	0.672679
	November	292.36	0.259112	0.009737/Hr	0.002522974	0.740888
	December	403.3	0.063943	0.015800/Hr	0.001010299	0.936057

Table (3-6), determines that minimum value of failure time is (26.17 hr.) in (September 2012), so at that time the reliability of cement mill (2) for that specific month was at the highest point, which was equal to (0.979933), this clarifies that the second mill is performing its intended performance very well, and the production for that month was the highest as well. The worst (R (t)) of the cement mill (2) occurs when the failure time goes to (530.66 hr.) in (July 2014), the reliability is equal to (0.004847). This highlighting that (R (t)) has an opposite relationship with failure time.

- **Graphical representation of (probability of failure, Reliability, Probability density function, Cumulative distribution function):**

Each of above has been demonstrated through their plot according to failure time data of cement mill (2) as shown in figures below:

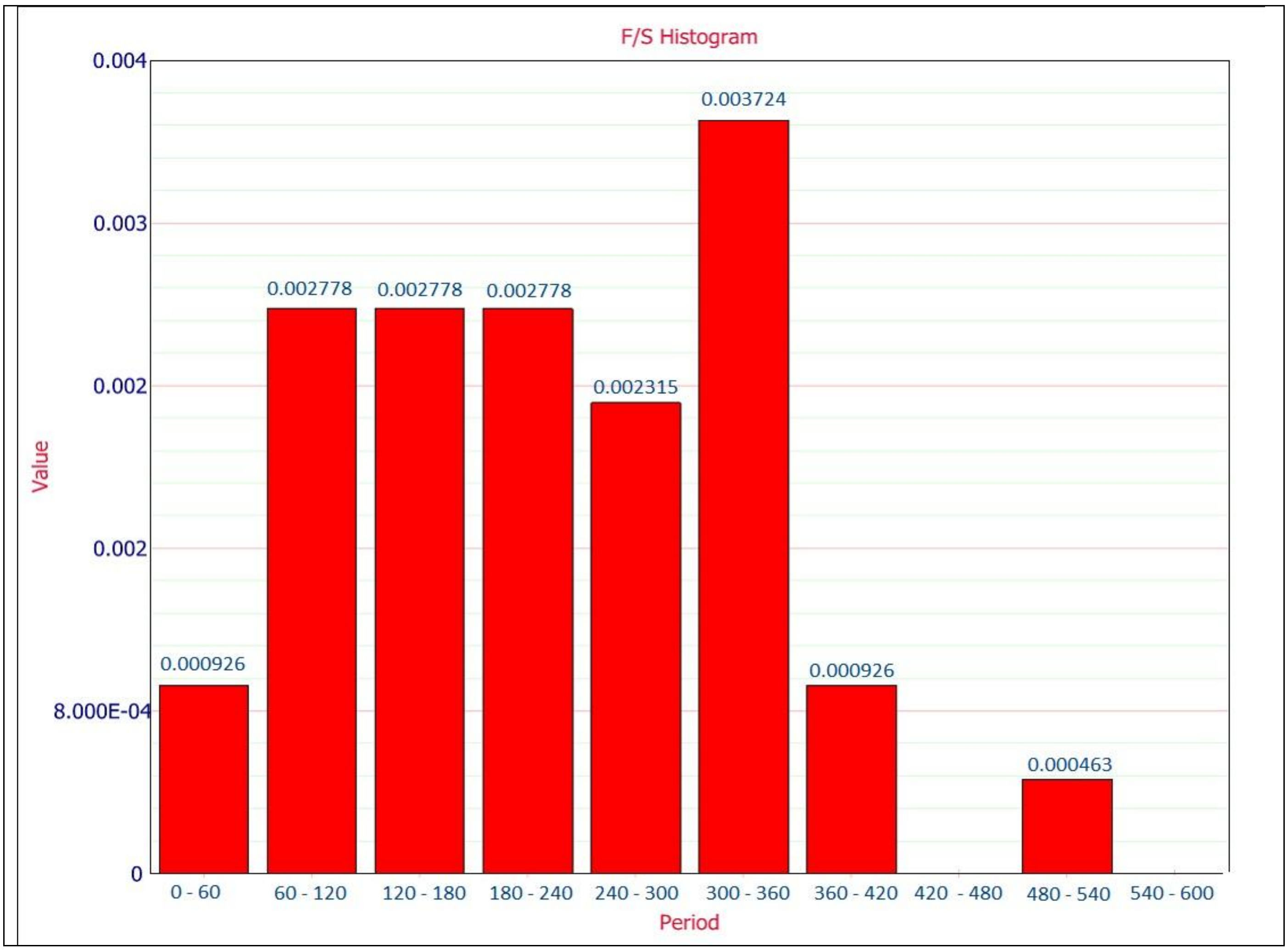


Figure (3-5): Represents Plot the Histogram of cement mill (2).

The histogram is determining that at a range time between (300 - 360 hr.) most of the failure of cement mill (2) has happened, the probability of that failure time was equal to (0.003704), and minimum probability of failure time has taken place between [(480 – 540)

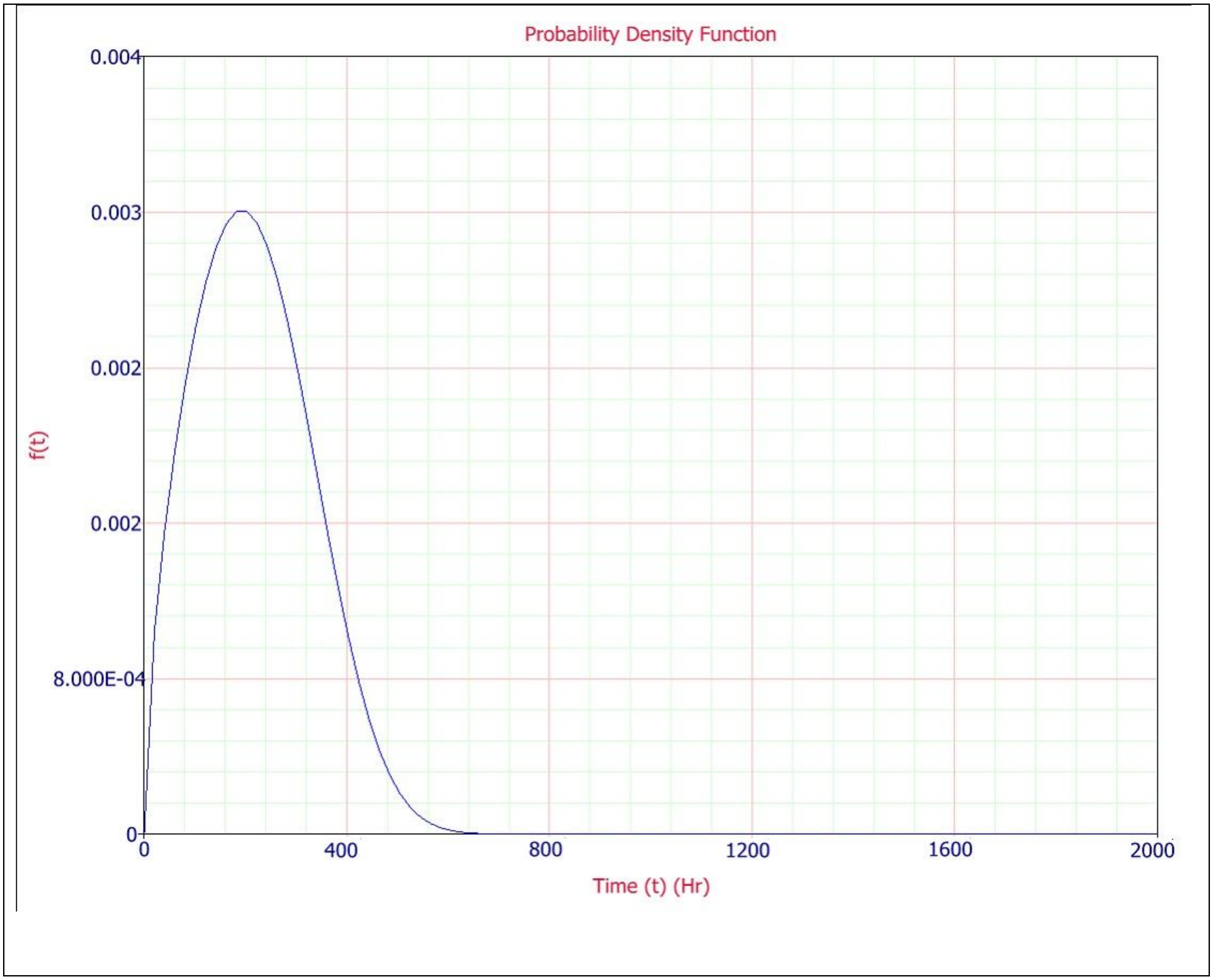


Figure (3-6): Represents the probability density function of the failure time of cement mill (2).

The above graph represents the probability density function value of cement mill (2) which increases until the failure time reaches (200 hr.) at this time of failure; the probability is approximately equal to (0.0029),but after (200 hr.) of failure, the probability density function is decreasing.

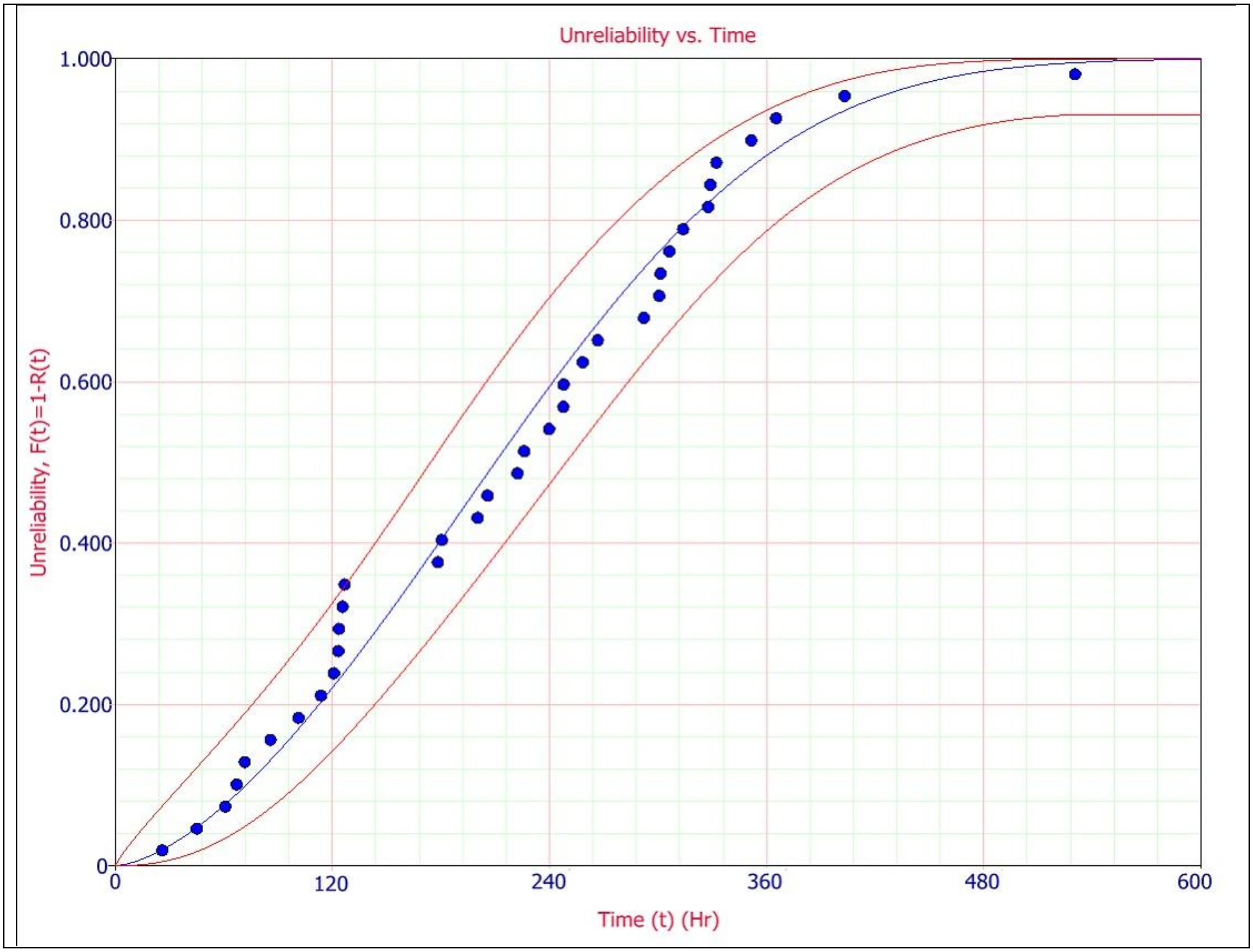


Figure (3-7): Represents the cumulative distribution function of cement mill (2)

The above figure determines the cumulative distribution function of cement mill (2) which is increasing with increasing failure time and reaching its highest value at failure of (530.66 hr.) in (July 2014).

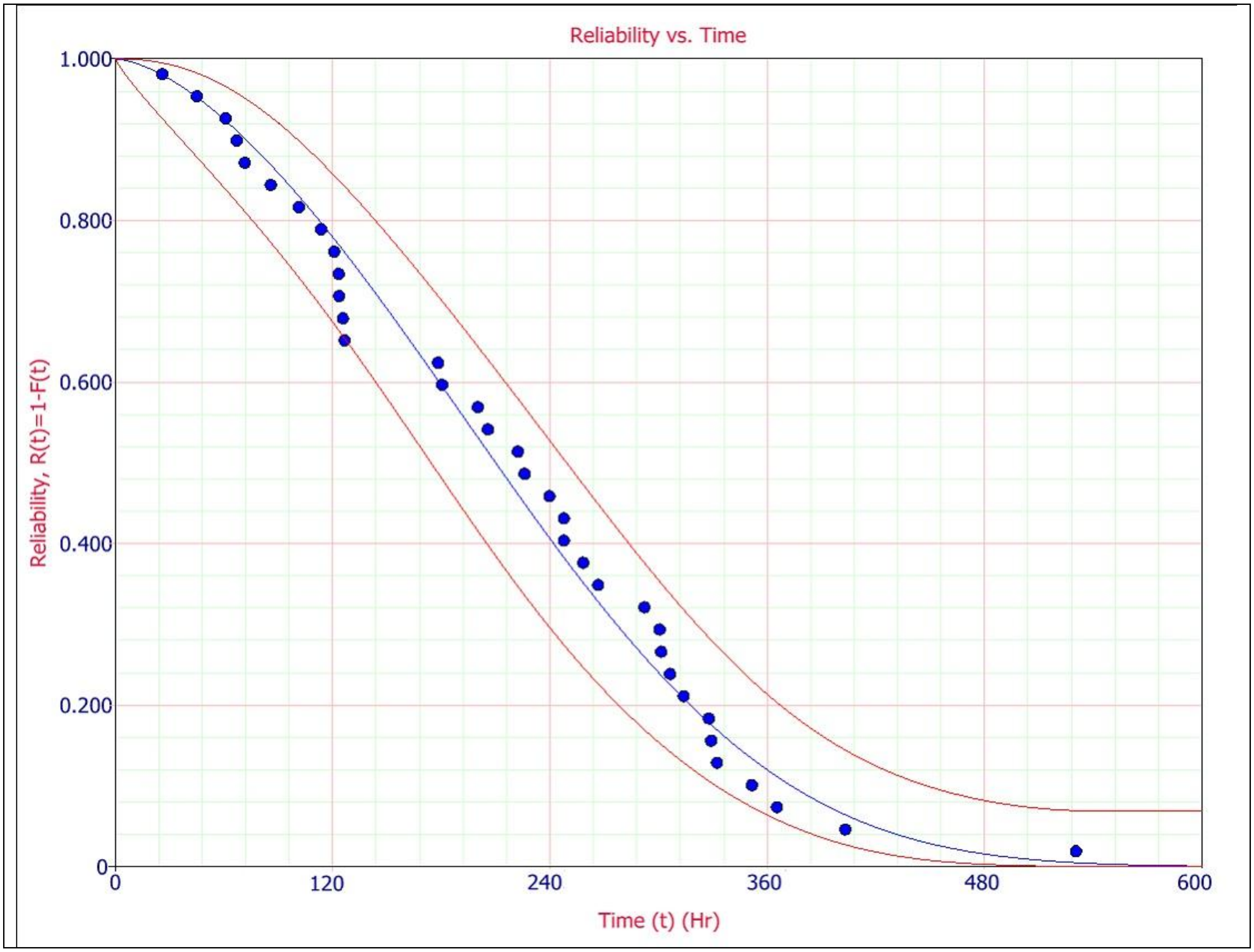


Figure (3-8): Represents the reliability of cement mill (2)

The graph above represents the reliability of the cement mill (2) which is equal to (0.979933) at a failure time equaling (26.17hr.) in (September 2012), it is best reliability of the mill and the worst reliability occurs when the failure time reaches over (530.66 hr.) in (July 2014) where the reliability is equal to (0.004847), since reliability is in indirect relationship with failure time.

3.4.3 Failure time of cement mill (3):

The monthly failure time data of cement mill (3) for three years as shown in (Appendix, table A) in different times tested to choose a suitable distribution for cement mill (3). For these three goodness of fit tests performed and final result has been found by weighted decision variable (DESV) is as (eqn. 19) test through which rank of distributions determined. This analysis done by Reliasoft Program (Weibull++) as shown in the table below:

Table (3-7): Rank of Distributions for cement mill (3).

	Distribution	(DESV)	Ranking
Mill 3	G-Gamma	100	1
	Gamma	200	2
	Loglogistic	300	3
	Normal	450	4
	Logistic	450	4
	1P-Exponential	650	5
	Gumbel	650	5
	Parameters Calculated for G-Gamma Distribution:		
	Start G-Gamma		
	(β)	5.3754 Location	
	(θ)	0.604 Scale	
	(λ)	0.352 Shape	

The (pdf) of Generalized Gamma Distribution explained as follows:

$$\boldsymbol{f(t)} = \left[\frac{\mathbf{0.352}}{\mathbf{0.604} * \boldsymbol{t}} * \frac{\mathbf{1}}{\Gamma\left(\frac{\mathbf{1}}{(\mathbf{0.352})^{2}}\right)} * \boldsymbol{e}^{\left[\frac{0.352 * \frac{\ln(t) - 5.431}{0.604} + ln\left(\frac{1}{(0.352)^{2}}\right) - e^{0.352 * \frac{\ln(t) - 5.431}{0.604}}}{(0.352)^{2}}\right]} \quad \boldsymbol{if\ \lambda \neq 0} \right]$$

Distribution with minimum weighted decision variable (DESV) value as in (eqn.19) is considered as best distribution fitted for given data. So from (Table 3-4) it is clear that G-Gamma Distribution is best suited and estimated it in parameters then (Reliability, Failure Rate, Probability density function, Cumulative distribution function) are calculated for cement mill (3), as shown in the table below:

Table (3-8): Represent Reliability, Failure Rate, Probability density function, and Cumulative distribution function for cement mill (3).

Year	Month	Failure time	Reliability (R(t))	Failure rate (λ(t))	Probability density function (pdf)	cumulative distribution function (CDF)
2012	January	504.5	0.050242	0.008000/Hr	0.008	0.000401936
	February	412.5	0.104491	0.007896/Hr	0.007896	0.000825061
	March	424.5	0.095033	0.007918/Hr	0.007918	0.000752471
	April	63.8	0.953747	0.002104/Hr	0.002104	0.002006684
	May	65.18	0.950937	0.002173/Hr	0.002173	0.002066386
	June	85.36	0.901119	0.003144/Hr	0.003144	0.002833118
	July	116.81	0.799478	0.004413/Hr	0.004413	0.003528096
	August	293.23	0.261993	0.007428/Hr	0.0078	0.001946084
	September	79.06	0.918305	0.002852/Hr	0.002852	0.002619006
⋮	⋮	⋮	⋮	⋮	⋮	⋮
2013	September	70.69	0.938907	0.002447/Hr	0.002447	0.002297505
	October	111.82	0.816914	0.004233/Hr	0.004233	0.003457997
	November	69.9	0.94071	0.002408/Hr	0.002408	0.00226523
	December	327.57	0.202295	0.007622/Hr	0.007622	0.001541892
2014	January	469.67	0.066362	0.007976/Hr	0.007976	0.000529303
	February	191.22	0.532382	0.006295/Hr	0.006295	0.003351345
	March	264.59	0.323137	0.007210/Hr	0.00721	0.002329818
	April	221.19	0.437738	0.006746/Hr	0.006746	0.002952981
	May	269.85	0.311074	0.007255/Hr	0.007255	0.002256842
	June	372.11	0.143469	0.007795/Hr	0.007795	0.001118341
	July	489.21	0.056775	0.007992/Hr	0.007992	0.000453746
	August	544.78	0.036392	0.008010/Hr	0.00801	0.0002915
	September	146.5	0.691425	0.005326/Hr	0.005326	0.00368253
	October	175.42	0.586715	0.005999/Hr	0.005999	0.003519703
	November	156.07	0.656287	0.005570/Hr	0.00557	0.003655519

The above table explains that cement mill (3) had carried out its intended function very well at April 2012, since at that time it had shortest failure time which was (63.8 hr.) in (April 2012), at that time highest reliability recorded which was equal to (0.953747), and worst (R (t)) of the mill (3) was on August 2014, when the failure time became (544.78 hr.) in (August 2014), The reliability was equal to (0.036392). Because as we know that (R (t)) has an opposite relationship with failure time.

- **Graphical representation of (probability of failure, Reliability, Probability density function, Cumulative distribution function):**

According to failure time data of cement mill (3) each of above have been more explained through their plots as in figures below:

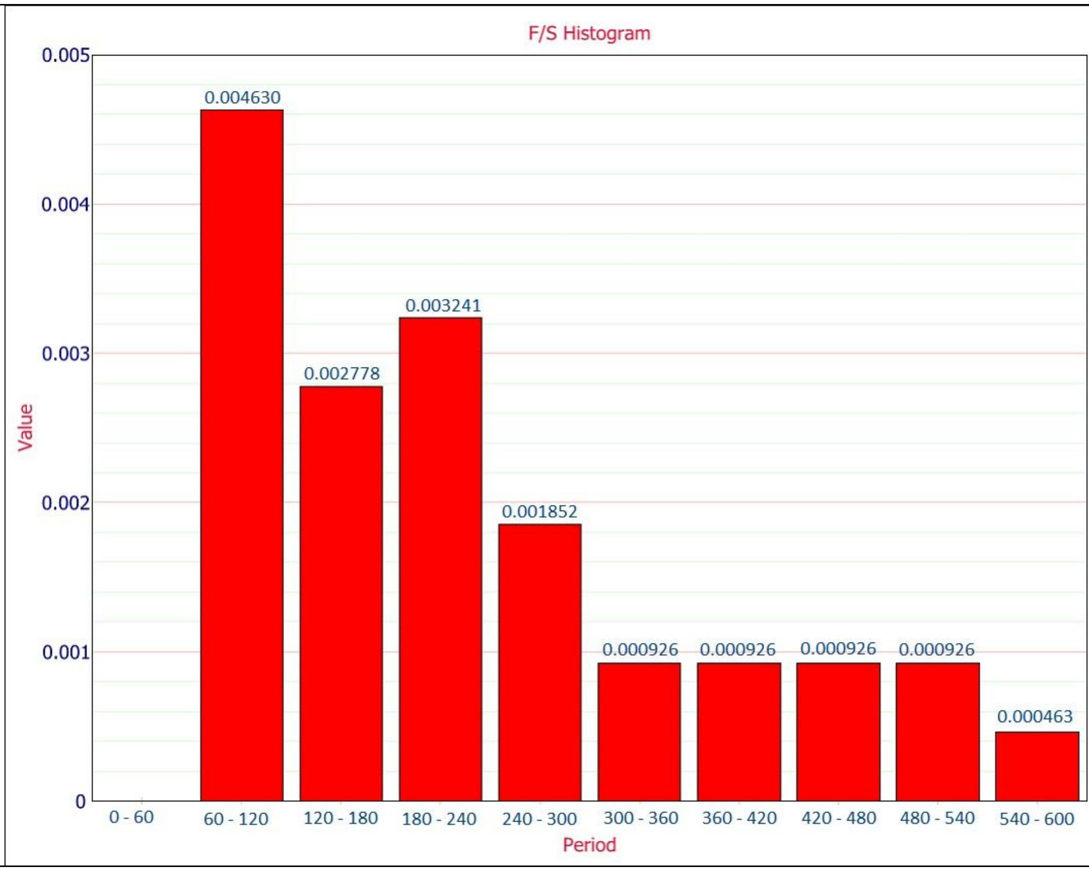


Figure (3-9): Represents Plot the Histogram of cement mill (3).

The above histogram represents the probability of hours of failure of cement mill (3). It highlighted that in cement mill (3) most of failure has happened between (60 –120 hr.) Where probability of hours of failure is equal to (0.00463), and the minimum probability of failure is equal to (0.000463) it has taken place between (540-600 hr.)

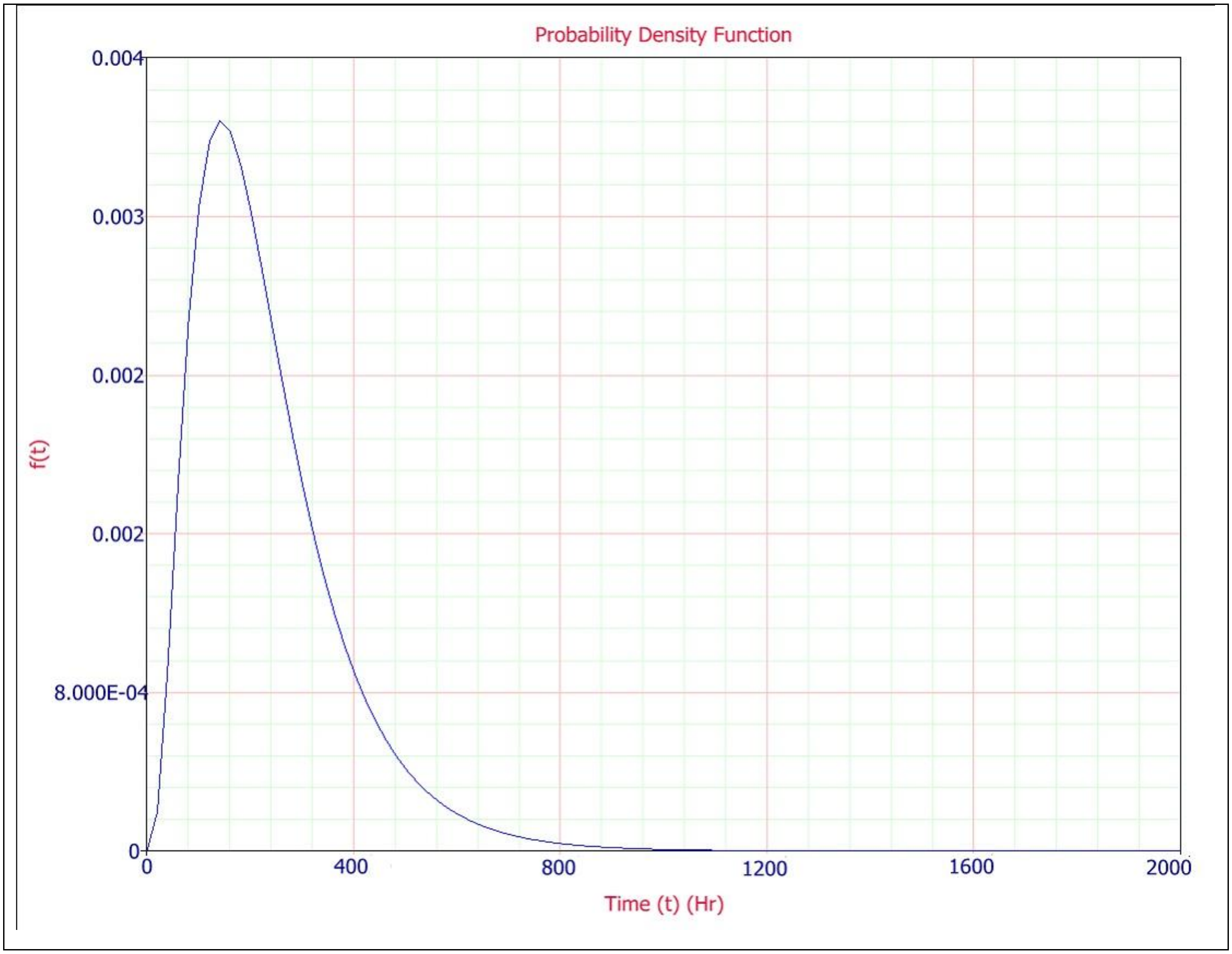


Figure (3-10): Represents the probability density function of cement mill (3).

The graph shows that probability density function value of cement mill (3) is equal to (0.0035) and increasing until the failure time reaches to (150 hr.), then lowering down after reaching (150 hr.) of failure.

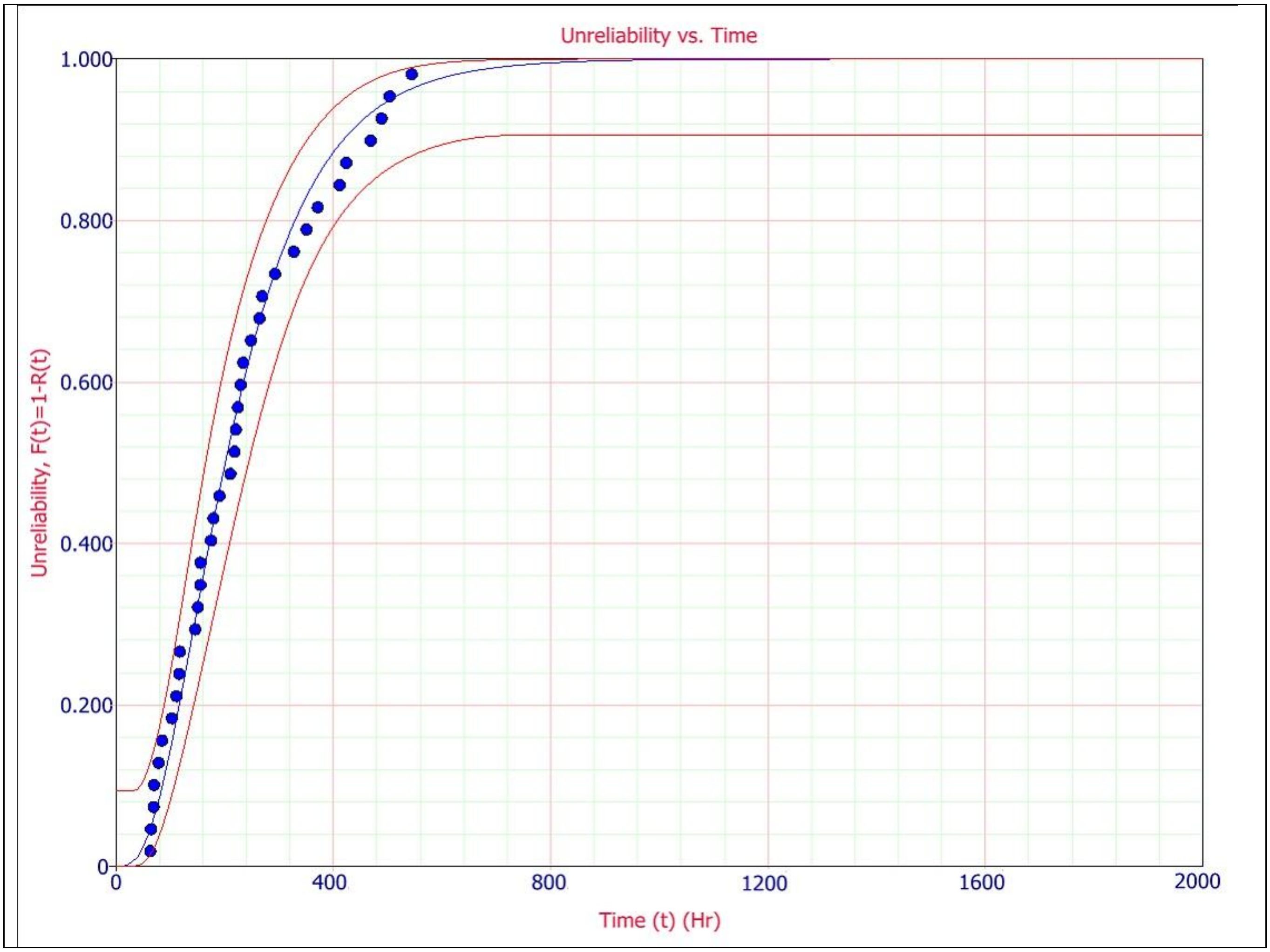


Figure (3.11): Represents the cumulative distribution function of cement mill (3).

The figure above illustrates cumulative distribution function of cement mill (3). Its value reaches the highest points when the failure time is equal to (544.78 hr.) in (August 2014), because cumulative distribution function is increasing with increasing time, so it's clear from the above graph that (cdf) is increasing as vertical shape with failure time.

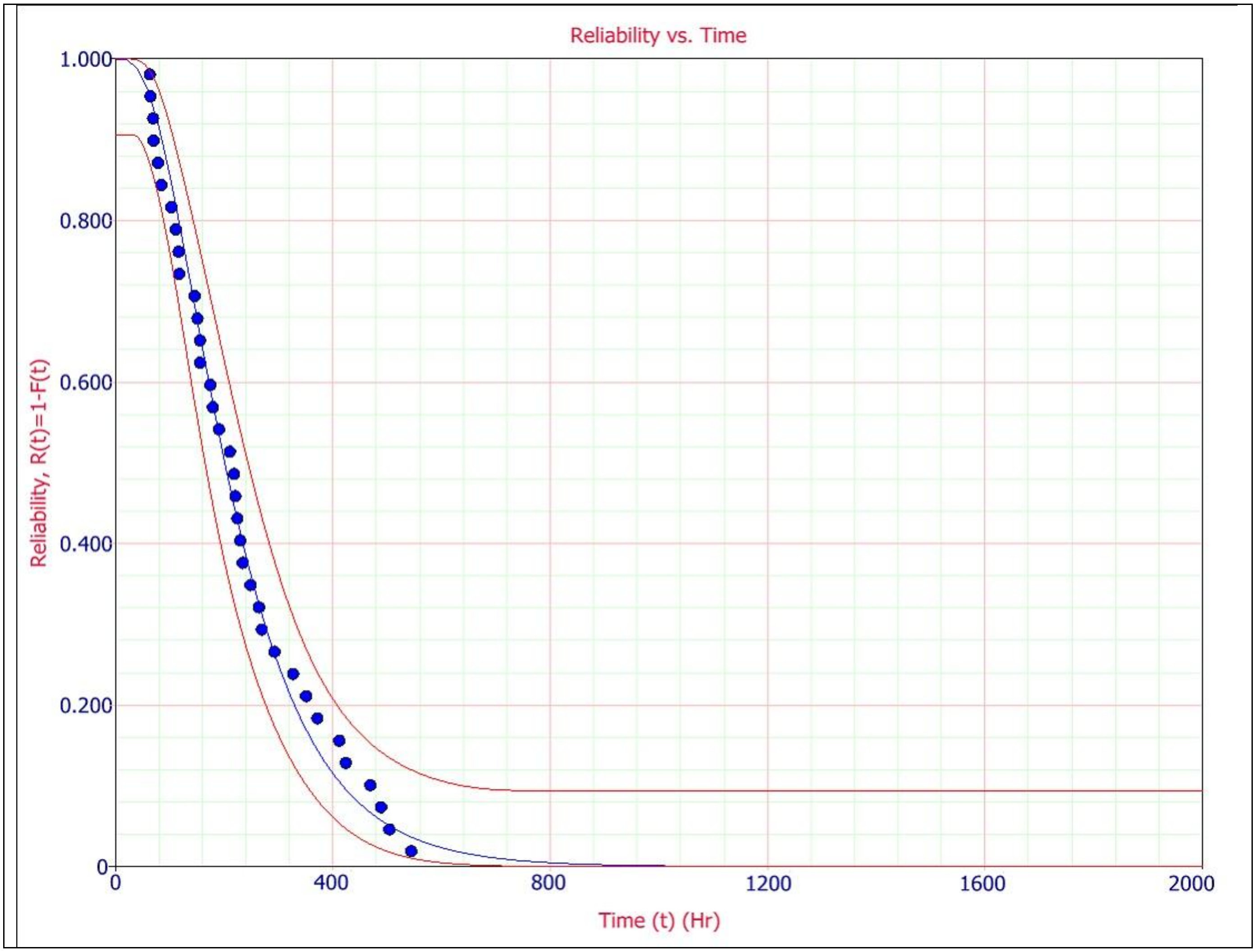


Figure (3-12): Represents the reliability of cement mill (3)

The figure explaining the reliability of cement mill (3). Since reliability has indirect relationship with failure time, so best reliability of the mill is equal to (0.953747) when the failure time is equal to (63.8 hr.) in (April 2012), and the worst reliability is equal to (0.036392), where the failure time reaches over (544.78hr.) in (August 2014).

3.4.4 Failure time of cement mill (4):

The monthly failure time data of cement mill (4) for three years as shown in (Appendix, table A) in different times tested to choose a suitable distribution for cement mill (4). For these three goodness of fit tests performed and final result has been found by weighted decision variable (DESV) as in (eqn.19) test through which rank of distributions determined. This analysis done by Reliasoft Program (Weibull++) as shown in the table below:

Table (3-9): Rank of Distributions for cement mill (4).

	Distribution	(DESV)	Ranking
Mill 4	G-Gamma	100	1
	Gamma	250	2
	Loglogistic	250	2
	Logistic	400	3
	Normal	550	4
	1P-Exponential	590	5
	Gumbel	660	6
	Parameters Calculated for G-Gamma Distribution:		
	Start G-Gamma		
	(β)	5.2355 Location	
	(θ)	0.6776 Scale	
	(λ)	0.2376 Shape	

The (pdf) of Generalized Gamma Distribution explained as follows:

$$f(t) = \left[\frac{0.2376}{0.6776 * t} * \frac{1}{\Gamma\left(\frac{1}{(0.2376)^2}\right)} * e^{\left[\frac{0.2376 * \frac{\ln(t) - 5.2355}{0.6776} + ln\left(\frac{1}{(0.2376)^2}\right) - e^{0.2376 * \frac{\ln(t) - 5.2355}{0.6776}}}{(0.2376)^2}\right]} \quad if\ \lambda \neq 0 \right]$$

As its clear the best distribution for a given data is the one having minimum weighted decision variable (DESV) value (eqn. 19). Here from (Table 3-4) it is clear that G-Gamma Distribution is best suited and estimated it in parameters then (Reliability, Failure Rate, Probability density function, Cumulative distribution function) are calculated for cement mill (4), as shown in the table below:

Table (3-10): Represent Reliability, Failure Rate, Probability density function, Cumulative distribution function of cement mill (4)

Year	Month	Failure time (T)	Reliability (R(t))	Failure rate (λ(t))	Probability density function (pdf)	cumulative distribution function (CDF)
2012	January	295.5	0.222045	0.007054/Hr	0.001566305	0.777955
	February	299	0.21663	0.007055/Hr	0.001528325	0.78337
	March	206.5	0.412998	0.006804/Hr	0.002810038	0.587002
	April	76.3	0.881339	0.003925/Hr	0.003459256	0.118661
	May	33.7	0.986847	0.001238/Hr	0.001221717	0.013153
	June	50.96	0.956073	0.002428/Hr	0.002321345	0.043927
	July	91.72	0.824944	0.004626/Hr	0.003816191	0.175056
	August	360.11	0.140864	0.007016/Hr	0.000988302	0.859136
	September	78.72	0.872879	0.004046/Hr	0.003531668	0.127121
⋮	⋮	⋮	⋮	⋮	⋮	⋮
2013	August	229.79	0.351944	0.006925/Hr	0.002437212	0.648056
	September	68.51	0.907263	0.003511/Hr	0.0031854	0.092737
	October	108.44	0.759562	0.005226/Hr	0.003969471	0.240438
	November	86.77	0.843622	0.004418/Hr	0.003727122	0.156378
	December	337.3	0.165362	0.007041/Hr	0.001164314	0.834638
2014	January	479.49	0.06173	0.006786/Hr	0.0004189	0.93827
	February	182.98	0.483675	0.006617/Hr	0.003200477	0.516325
	March	280.33	0.247107	0.007044/Hr	0.001740622	0.752893
	April	194.61	0.447578	0.006719/Hr	0.003007277	0.552422
	May	275.96	0.254829	0.007039/Hr	0.001793741	0.745171
	June	376.02	0.126008	0.006994/Hr	0.0008813	0.873992
	July	572.5	0.033178	0.006563/Hr	0.000217747	0.966822
	August	628.72	0.02303	0.006425/Hr	0.000147968	0.97697
	September	70.28	0.901565	0.003609/Hr	0.003253748	0.098435
	October	176.38	0.505155	0.006549/Hr	0.00330826	0.494845
	November	178.29	0.498866	0.006569/Hr	0.003277051	0.501134
	December	468.41	0.06656	0.006811/Hr	0.00045334	0.93344

Table (3-10), shows that shortest failure time for cement mill (4) is (33.7 hr.) in (May 2012), and the reliability for that specific month was at the highest point, which was equal to (0.986847), so cement mill (4) was performing its intended performance very well and production for that month was the highest as well. But the worst reliability of cement mill (4) recorded was equal to (0.02303), this happened when failure time reached (628.72 hr.) in (August 2014). This emphasize that reliability has an opposite relationship with failure time.

- **Graphical representation of (probability of failure, Reliability, Probability density function, Cumulative distribution function):**

Each of above for cement mill (4) has been explained through their plot according to failure time data of mill (4), as shown in figures below:

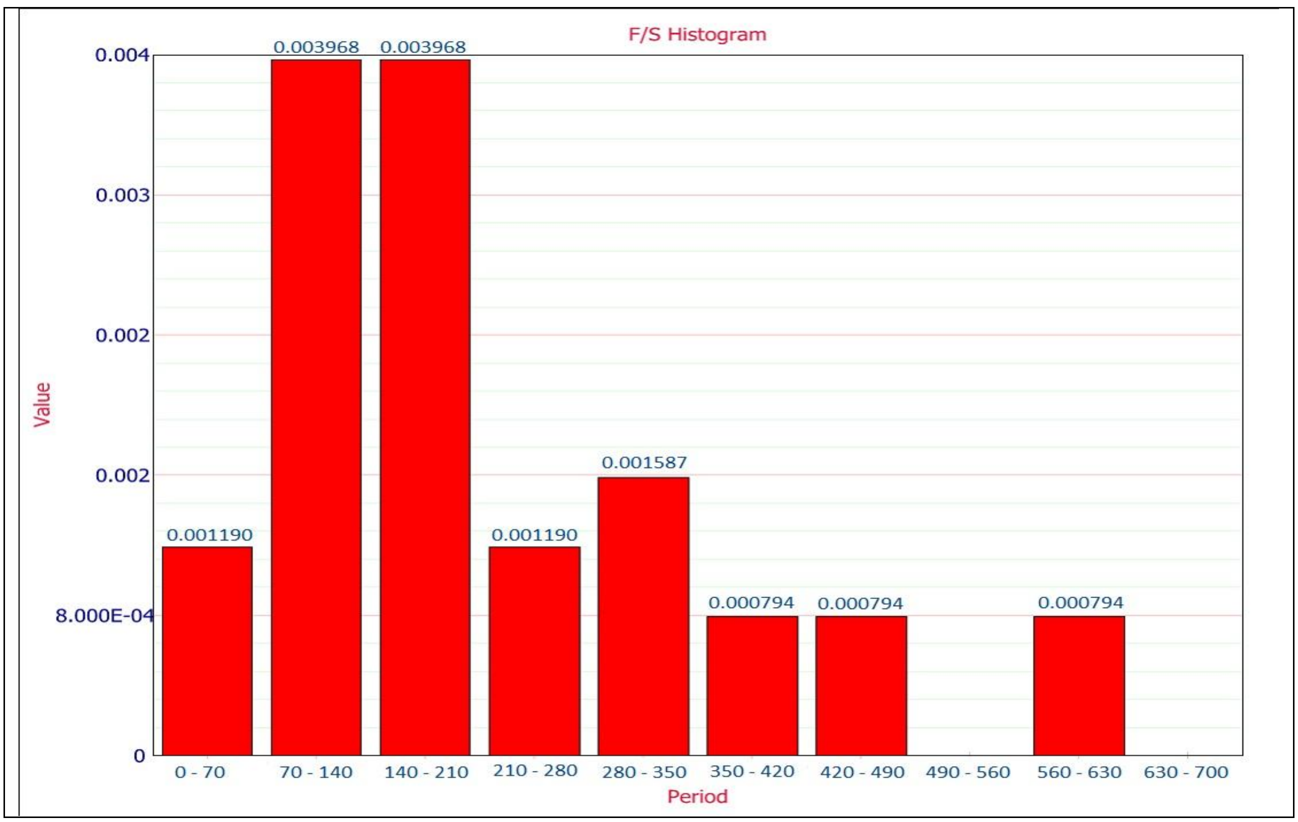
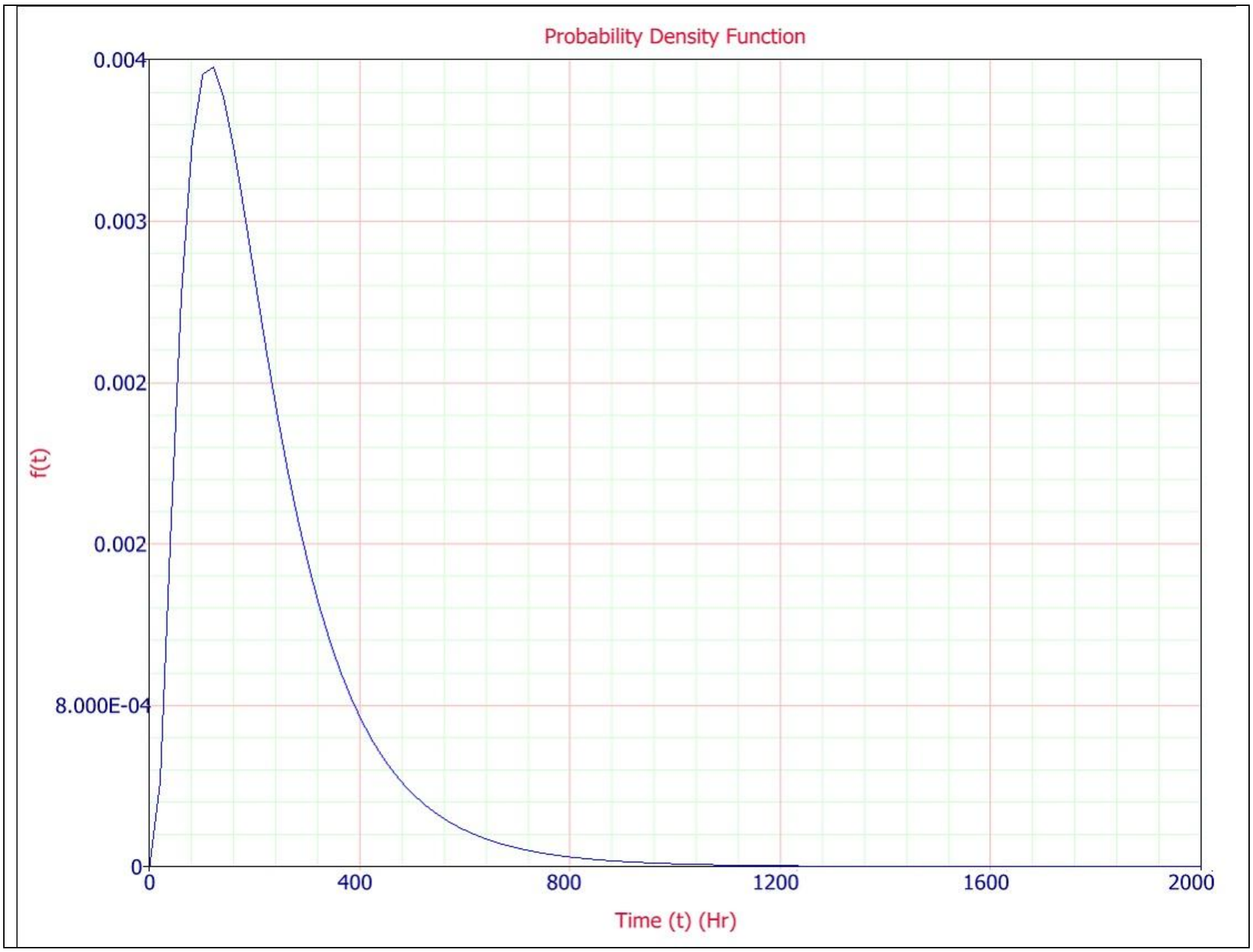


Figure (3-13): Represents Plot the Histogram of cement mill (4).

The above histogram clarifies the probability of hours of failure for the cement mill (4). It is at its highest at a time range between (70 – 210hr.) which is equal to (0.003968). And the least probability of failure time has taken place between [(350 – 420), (420 – 490) and (560 – 630)hr.] .



Figure(3-14): Shows the probability density function of cement mill (4).

The graph is demonstrating that the probability density function value is increasing until the failure time reaches to (140 hr.) approximately at this time of failure; the probability density function value is equal to (0.039), but it starts to decrease after reaching (140 hr.) of failure.

.

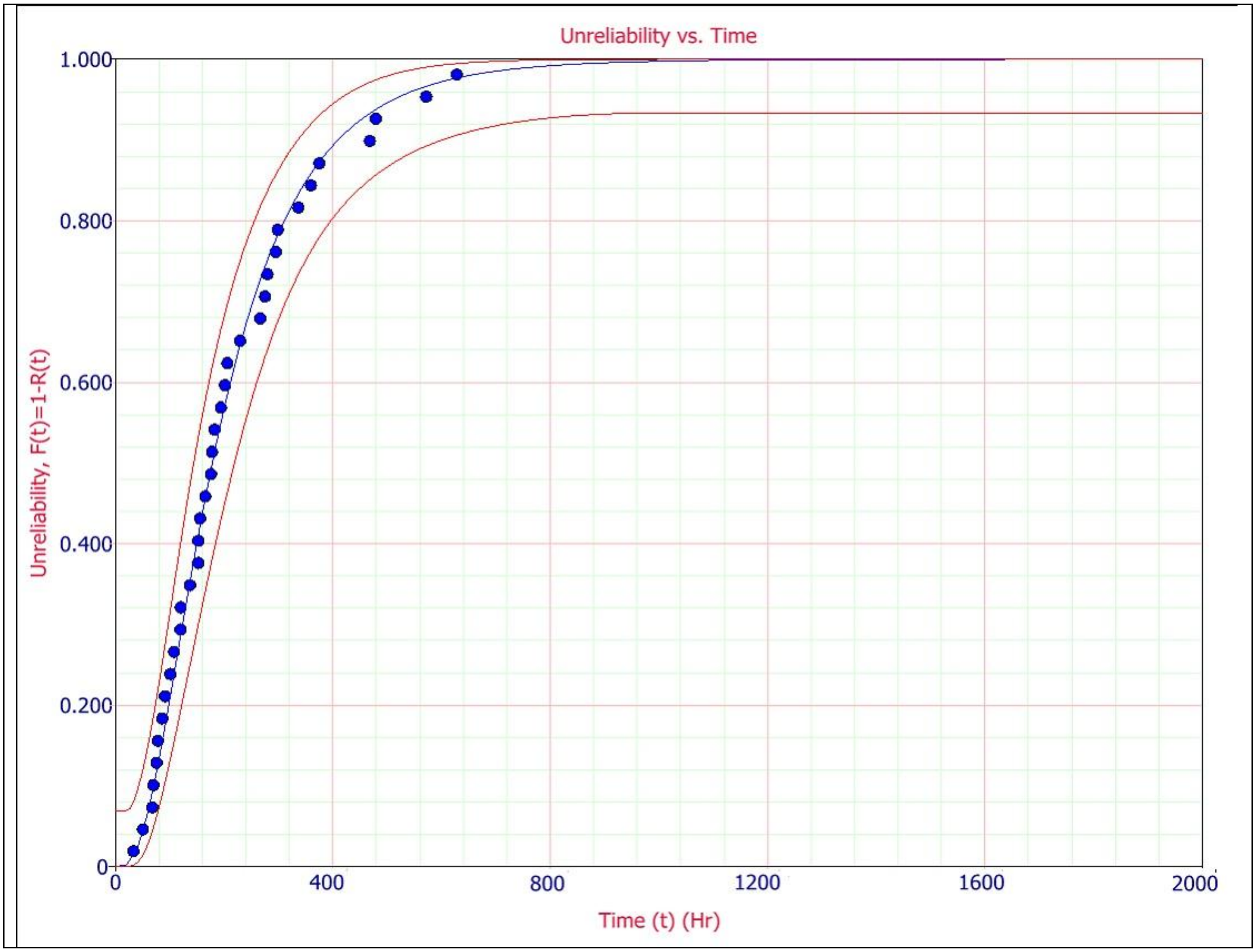


Figure (3-15): Represents the cumulative distribution function of cement mill (4)

The above graph explains that the cumulative distribution function of cement mill (4) is increasing as vertical shape with increasing failure time, reaching the highest points when the failure time is equal to (628.72 hr.) in (August 2014) , since cumulative distribution function has a direct relationship with time.

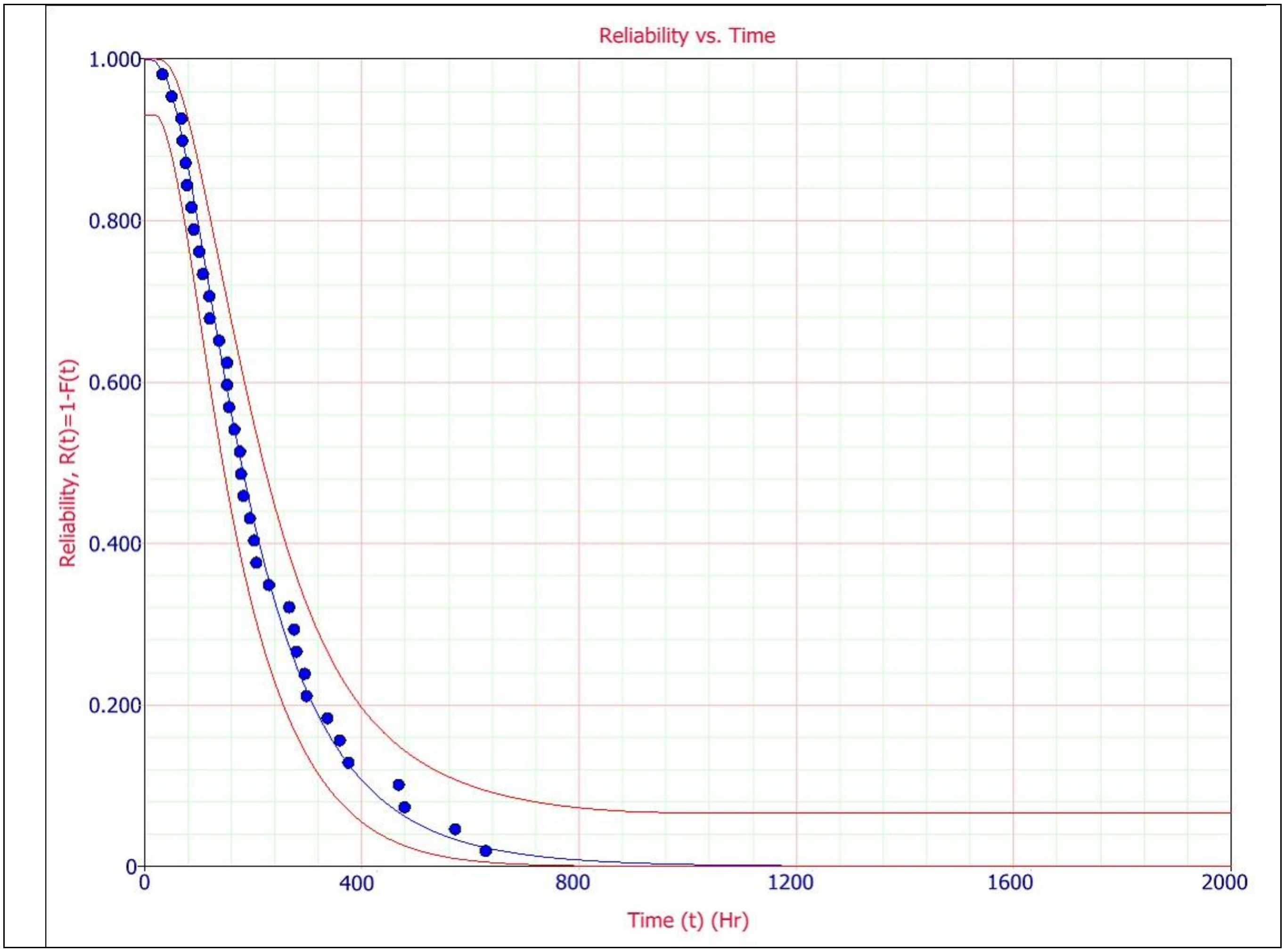


Figure 3-16: Represents the reliability of cement mill (4).

The plot shows reliability of cement mill (4) which is decreasing with increasing failure time of mill. So when the failure time is equal to (33.7 hr.) in (May 2012), the reliability is equal to (0.986847) which is the best reliability of cement mill (4), and the worst reliability occurs when the failure time reaches over (628.72 hr.) in (August 2014), at that time reliability is equal to (0.02303).

3.4.5 Failure time of cement mill (5):

The monthly failure time data of cement mill (5) for three years as shown in (Appendix, table A) in different times tested to choose a suitable distribution for cement mill (5). For these three goodness of fit tests performed and final result has been found by weighted decision variable (DESV) as in (eqn.19) test through which rank of distributions determined. This analysis done by Reliasoft Program (Weibull++) as shown in the table below:

Table (3-11): Rank of Distributions for cement mill (5).

	Distribution	(DESV)	Ranking
Mill 5	G-Gamma	150	1
	Loglogistic	200	2
	2P-Weibull	250	3
	Normal	450	4
	Logistic	470	5
	Gumbel	580	6
	1P-Exponential	700	7
	Parameters Calculated for Each Distribution:		
	Start G-Gamma		
	(β)	5.2729 Location	
	(θ)	0.5535 Scale	
	(λ)	0.0272 Shape	

The (pdf) of Generalized Gamma Distribution explained as follows:

$$f(t) = \left[\frac{0.0272}{0.5535 * t} * \frac{1}{\Gamma\left(\frac{1}{(0.0272)^2}\right)} * e^{\left[\frac{0.0272 * \frac{\ln(t) - 5.2729}{0.5535} + \ln\left(\frac{1}{(0.0272)^2}\right) - e^{0.0272 * \frac{\ln(t) - 5.2729}{0.5535}}}{(0.0272)^2}\right]} \quad if\ \lambda \neq 0 \right]$$

From above table it can be seen that a distribution with minimum weighted decision variable (DESV) value (eqn. 19) is considered as best distribution to be fitted for given data. here it is clear that G-Gamma Distribution is best suited among other distributions, then estimated it in parameters and (Reliability, Failure Rate, Probability density function, Cumulative distribution function) are calculated for cement mill (5), as shown in the table below:

Table (3-12): Represent Reliability, Failure Rate, Probability density function, Cumulative distribution function of cement mill (5).

Year	Month	Failure time (T)	Reliability	Failure rate	Probability density function	cumulative distribution function
2012	January	336	0.159461	0.008260/Hr	0.00826	0.001317148
	February	398	0.095809	0.008154/Hr	0.008154	0.000781227
	⋮	⋮	⋮	⋮	⋮	⋮
	October	165.42	0.613186	0.006800/Hr	0.0068	0.004169665
	November	102.11	0.875648	0.004101/Hr	0.004101	0.003591032
	December	161.41	0.629996	0.006688/Hr	0.006688	0.004213413
2013	January	275.61	0.26236	0.008189/Hr	0.008189	0.002148466
	February	149.98	0.678694	0.006331/Hr	0.006331	0.004296812
	⋮	⋮	⋮	⋮	⋮	⋮
	November	73.46	0.959127	0.002213/Hr	0.002213	0.002122548
	December	428.64	0.074726	0.008066/Hr	0.008066	0.00060274
2014	January	457.22	0.059418	0.007973/Hr	0.007973	0.00047374
	February	402.63	0.092262	0.008141/Hr	0.008141	0.000751105
	⋮	⋮	⋮	⋮	⋮	⋮
	November	129.6	0.766227	0.005538/Hr	0.005538	0.004243365
	December	211.41	0.4383	0.007696/Hr	0.007696	0.003373157

Table (3-12), shows that shortest failure time of cement mill (5) recorded is (73.46hr.) in (November 2013), at that time reliability was equal to (0.959127) which is highest reliability of mill (5), and this means that the mill was performing its intended performance very well, and the production for that month was the highest. The worst reliability of fifth mill was when the failure time reached to (457.22 hr.) in (January 2014) which was equal to (0.059418).

- **Graphical representation of (probability of failure, Reliability, Probability density function, Cumulative distribution function):**

Each of above for cement mill (5) is more explained through their plot according to failure time data. As shown in figures below:

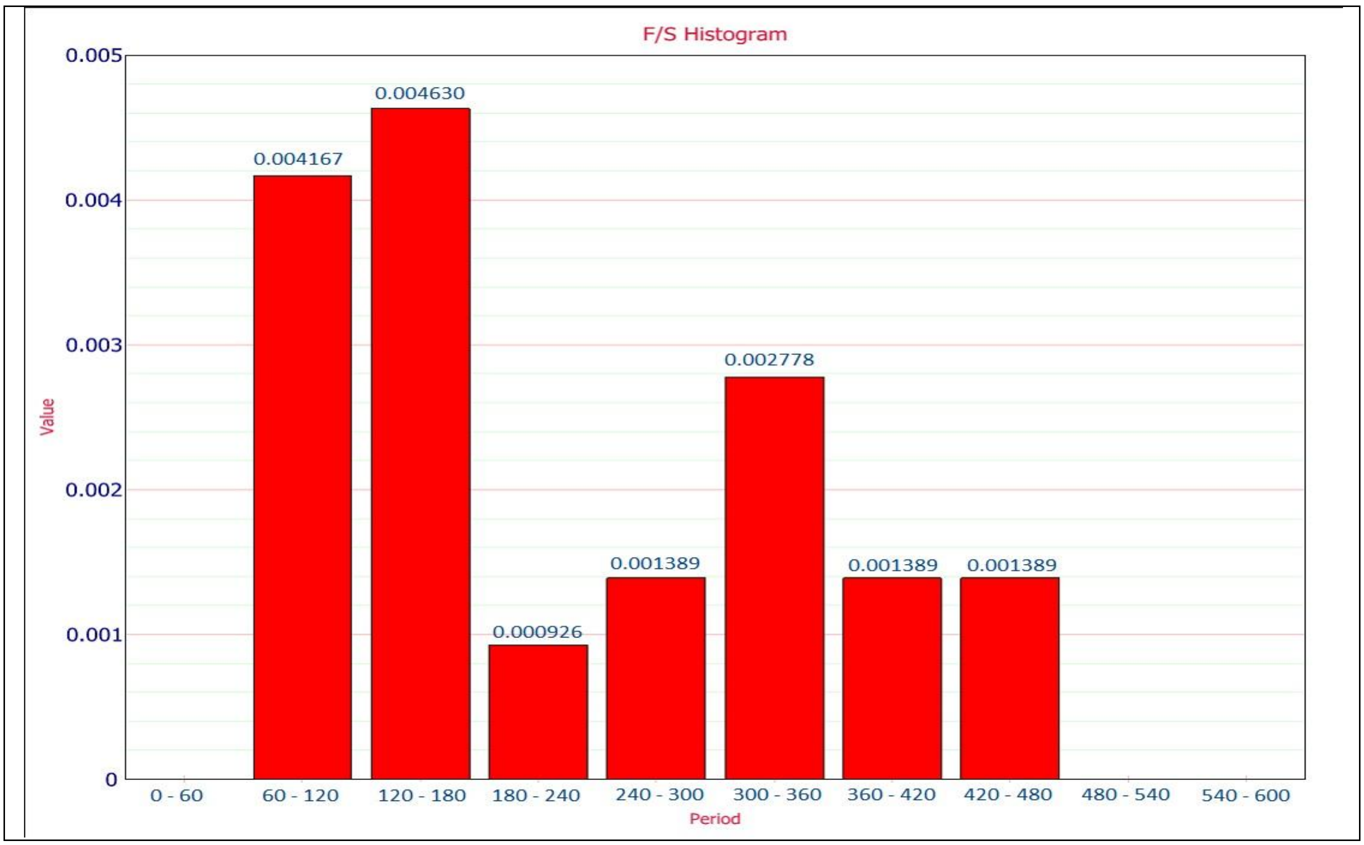


Figure (3-17): Represents Plot the Histogram of cement mill (5).

The above histogram depicts the probability of hours of failure of cement mill (5), it's clear that the highest probability of hours of failure for this mill is between (120 – 180 hr.) which is equal to (0.00463) this means that the most failure has happened in this range of time, and the least probability of failure has taken place between [(180 – 240) hr.)].

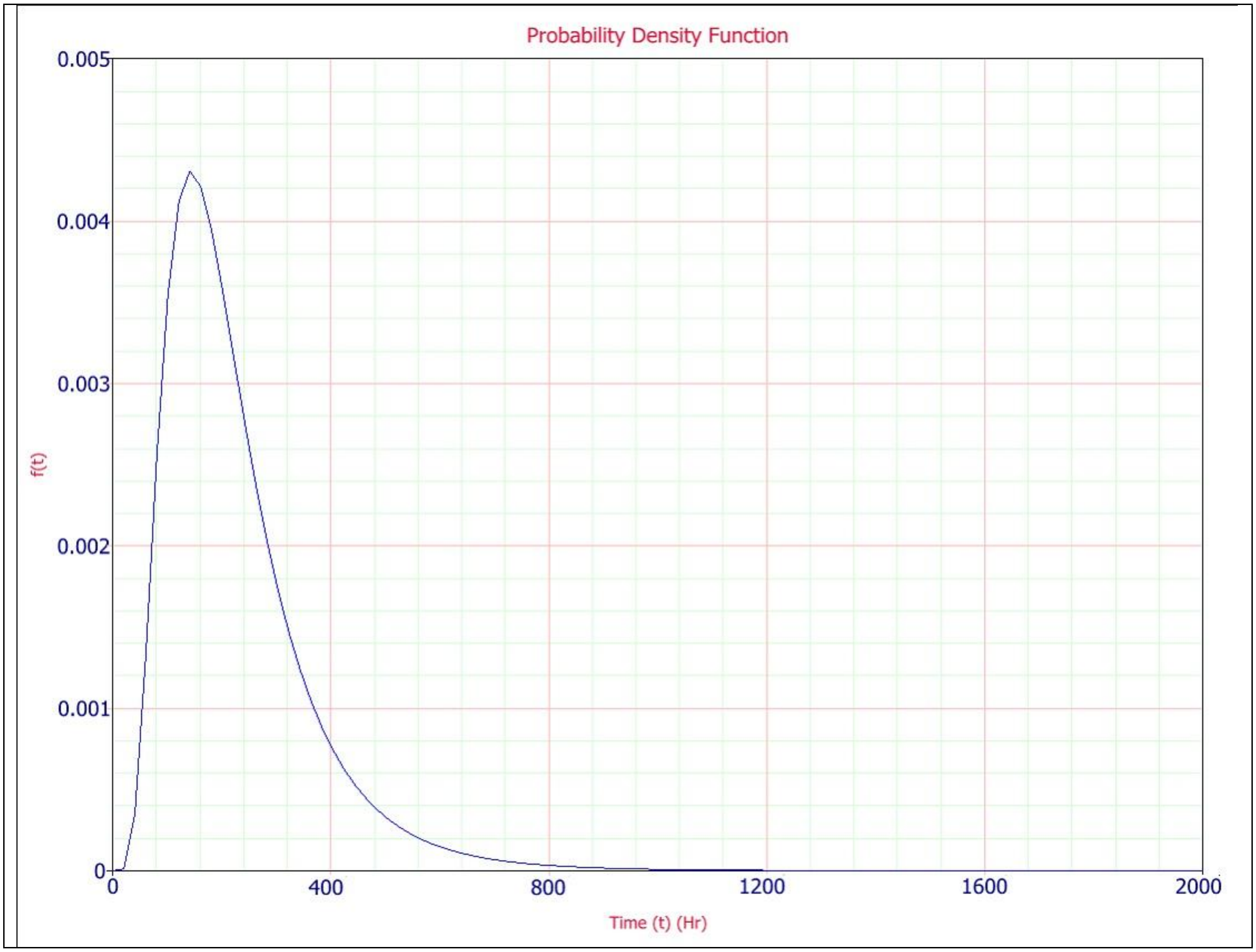


Figure (3-18): Represents the probability density function of cement mill (5).

It explains that the probability density function value of cement mill (5) is increasing until failure time reaches to (150 hr.) approximately at this time of failure; the probability is equal to (0.043) while it decreases after reaching (150 hr.) of failure.

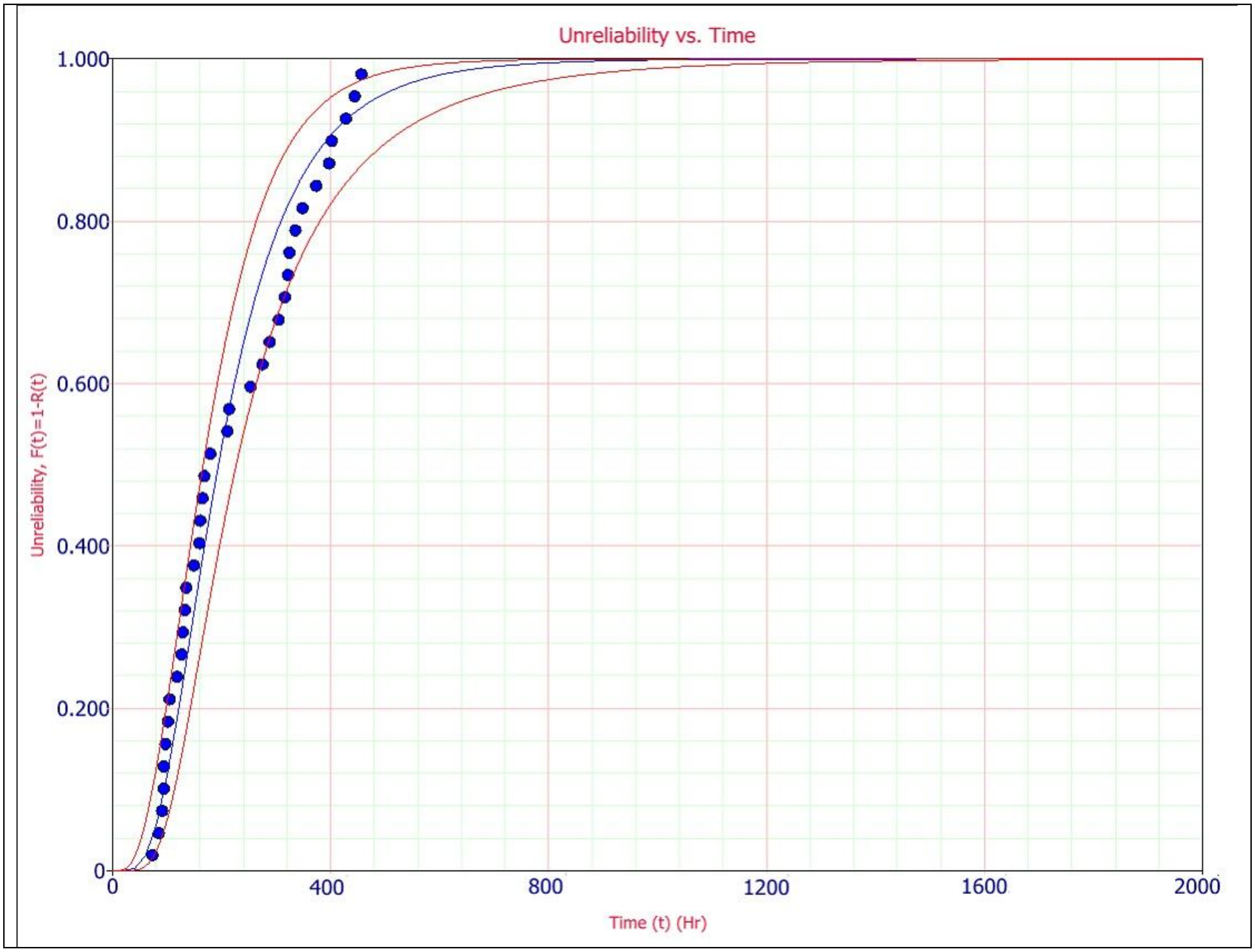


Figure (3-19): Shows the cumulative distribution function of cement mill (5).

The above graph demonstrates that the cumulative distribution function value of cement mill (5) is reaching the highest point when the failure time is equal to (457.22 hr.) in (January 2014). As cumulative distribution function has a direct relationship with time.

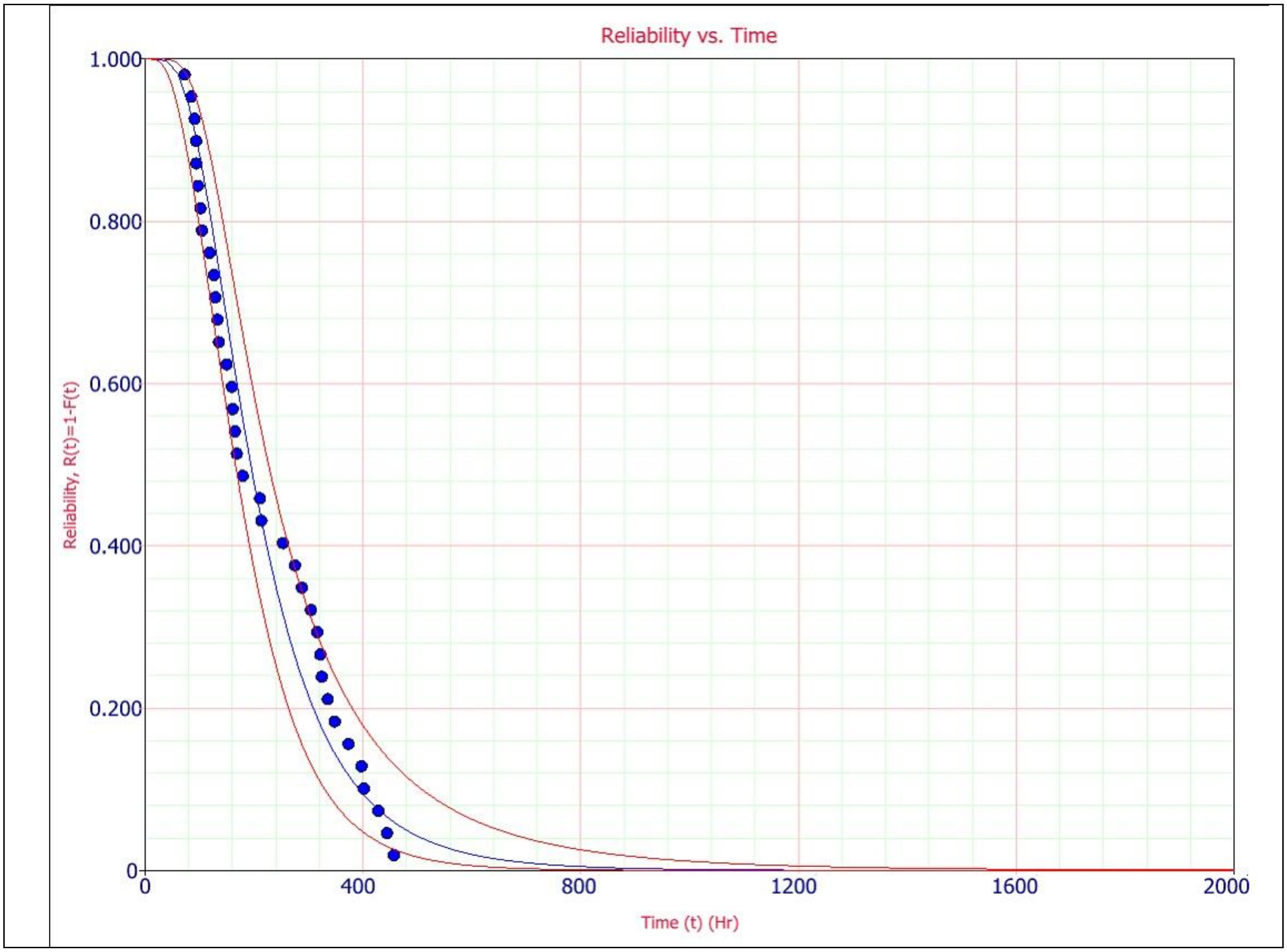


Figure (3-20): Represents the reliability of cement mill (5).

As it's shown in the graph the reliability of mill (5) is decreasing with increasing failure time, since it has indirect relationship with time. Here the reliability of the cement mill (5), here the reliability is equal to (0.959127) which is the best reliability of the mill, when the failure time is equal to (73.46 hr.) in (November 2013), and the worst reliability occurs when the failure time reaches over (457.22 hr.) in (January 2014) at that time the reliability is equal to (0.059418).

3.5 Life comparison test between cement mills:

This comparison is used to determine which mill has more chance to last longer than others through which we can decide which mill is the best and which is the worst, the result of comparison between each mill shown in the table below:

Table (3-13): Life comparison between cement mills

Life Comparison Between Mills	Result of Comparison
*CM(2) vs CM(1)	55.60%
CM(3) vs CM(1)	56.53%
CM(4) vs CM(1)	52.15%
CM(5) vs CM(1)	55.88%
CM(3) vs CM(2)	50.53%
CM(2) vs CM(4)	54.26%
CM(2) vs CM(5)	50.75%
CM(3) vs CM(4)	54.95%
CM(3) vs CM(5)	51.00%
CM(5) vs CM(4)	54.34%

*CM = Cement Mill

According to the results shown in the table (3-13) it can be demonstrating that the cement mill (2) have more chance to last longer than each of cement mill (1, 4 and 5), cement mill (3) will last longer than (1, 2, 4, and 5), cement mill (4) will live more than cement mill (1), and cement mill (5) will last longer than cement mill (1 and 4) according to this the best cement mill is mill (3) and worst one is cement mill (1). Which has shortest life span in comparing to other mills.

3.6 Quality control of Ordinary Portland Cement (OPC):

By using data of a type of physical test which is (compressive strength test) on (OPC) each of center limit, upper and lower limit has been found, to determine whether the observations taken are in-control or out of control. This has been done by using (EWMA) control chart in Statgraphics Centurion (v16.1).

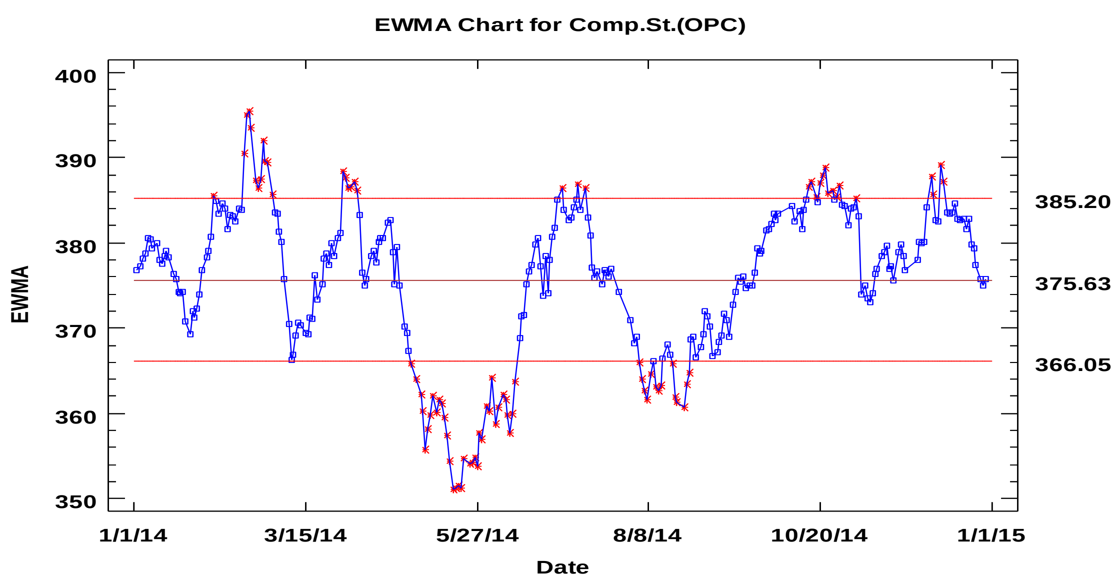


Figure (3-21): EWMA control chart of Comp.st. (OPC)

Procedure created a chart for Compressive Strength of (OPC). The chart constructed under the assumption that the data come from a normal distribution with a mean equal to (375.627), upper control limit equal to (385.204) and lower control limit equal to (366.051). This parameter was estimated from the data. From (294) observations shown on the chart each observation represents a data of a day of year (2014). As shown in the above chart 86 observations are out of control limits, factors causing this described in Table (3-5).

3.6.1 Factors influencing product's quality:

From observations of year (2014), (86) observations were out of control limits (Figure 3-5). (53) Observations were out of control because of technical problems in the mill. The topmost cause of this was fullness of cement silo, making failure time to prolong to (305.67 hr.), while the least cause was blockage of mill's entrance, in which failure time decrease to (2.15 hr.). Since the longer the failure time is more lowering of mill's reliability through which the quality of the product will be affected resulting in more data to be out of control limits.

Table 3-14: Factors that have an impact on quality control of cement.

No.	Causes of failure of the mill (OPC)	NO. of failures	Failure time
1	Fullness of cement silo	22	305.67
2	Stoppage according to plan.	7	114.11
3	Maintenance.	6	102.13
4	Contractor's inability to provide clinker.	3	5.95
5	Tighten the screws in the body of the mill.	2	17.94
6	Reducing electrical loads.	2	15.37
7	Programmed interruption of power supply.	1	16.17
8	Elevation of the vibration of the Kerr Box main Motor.	1	15.78
9	Government electrical power outage	1	7.73
10	Problem in the translation (6610).	1	5.22
11	An electrical problem in the (8419) air slide fan.	1	4.7
12	Stop one of the (Rotary) down the (bag filter).	1	4.48
13	Unnecessary	1	4.3
14	SuddeFn electrical power outage.	1	2.58
15	Translation interruption (6617).	1	2.28
16	Electrical problem in the Alsbritor.	1	2.2
17	Mill entrance blockage	1	2.15

3.7 Quality control of High Blaine Portland Cement (SBC):

By using data a type of physical test which is (compressive strength test) on (SBC) each of center limit, upper and lower limit has been found, to determine the observations taken are in-control and out of control observation. This has been done by using (EWMA) control chart in Statgraphics Centurion (v16.1).

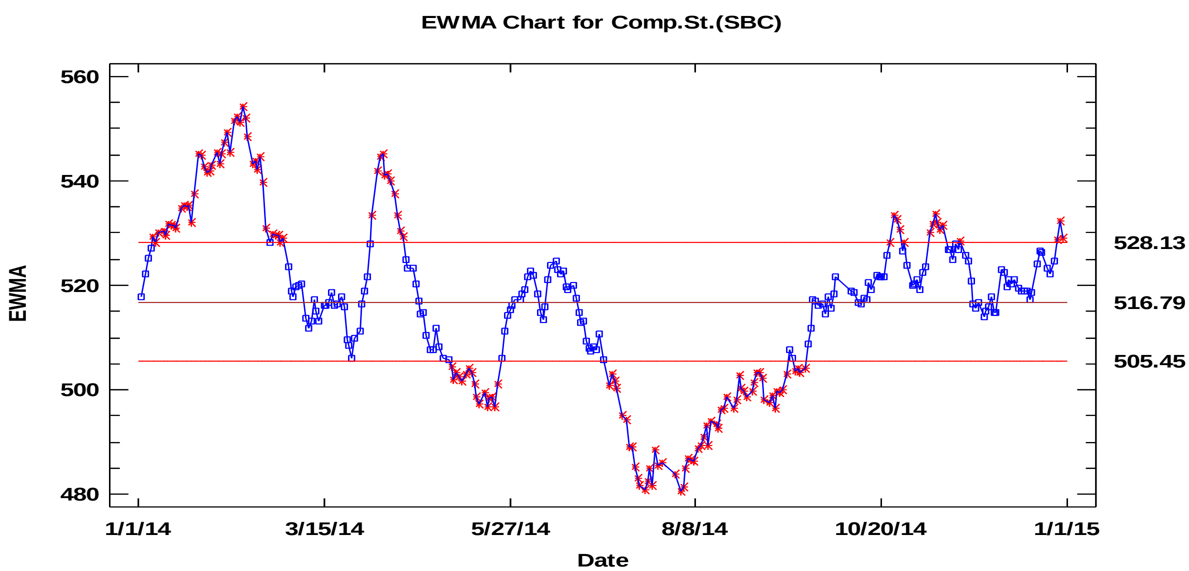


Figure (3-22): (EWMA) control chart of Comp.st. (SBC)

The procedure created a chart for Compressive Strength of (SBC). The chart constructed under the assumption that the data come from a normal distribution with a mean equal to (516.787), upper control limit equal to (528.128) and lower control limit equal to (505.447). The parameter was estimated from the data. From (299) observations shown on the charts each observation represents a data of a day of year (2014). Here (146) observations are out of control limits, the influencing factors lead to this is described in Table (3-6).

3.7.1 Factors influencing product's quality:

As shown in (**Figure 3-22**) from all observations of the year (2014), just (146) observations were out of control limits (90) of them was because of technical problem in the mill. The biggest cause was a fullness of cement silo which made highest failure time equal to (718.04 hr.) and least cause was problem in translation (8310), resulting failure time to be (0.75 hr.). So the longer failure time is more decreasing in reliability of cement mill through which the quality control of the product will be affected and making more data to be out of control limits.

Table (3-15): Factors that have an impact on quality control of cement.

No.	Causes of failure of the mill (SBC)	NO. of failures	Failure time
1	Fullness of cement silo	48	718.04
2	Reducing electrical loads	25	522.45
3	Increased temperature of (outlet slide shoe)	7	63.94
4	Stoppage according to plan	4	37.34
5	Electrical problem in the fan (8413)	1	19.95
6	Tighten the screws in the body of the mill	1	11.22
7	Problem in the lubrication system	1	9.78
8	Electrical jerk	1	2.95
9	Contractor's inability to provide clinker	1	2.73
10	Problem in the translation (8310)	1	0.75

3.8 Quality control of High Sulfur Resistant Cement (SRC):

By using data of a type of physical test which is (compressive strength test) on (SRC) each of center limit, upper and lower limit has been found, to indicate the observations that are in-control and those are out of control. This has been performed by using (EWMA) control chart in Statgraphics Centurion (v16.1).

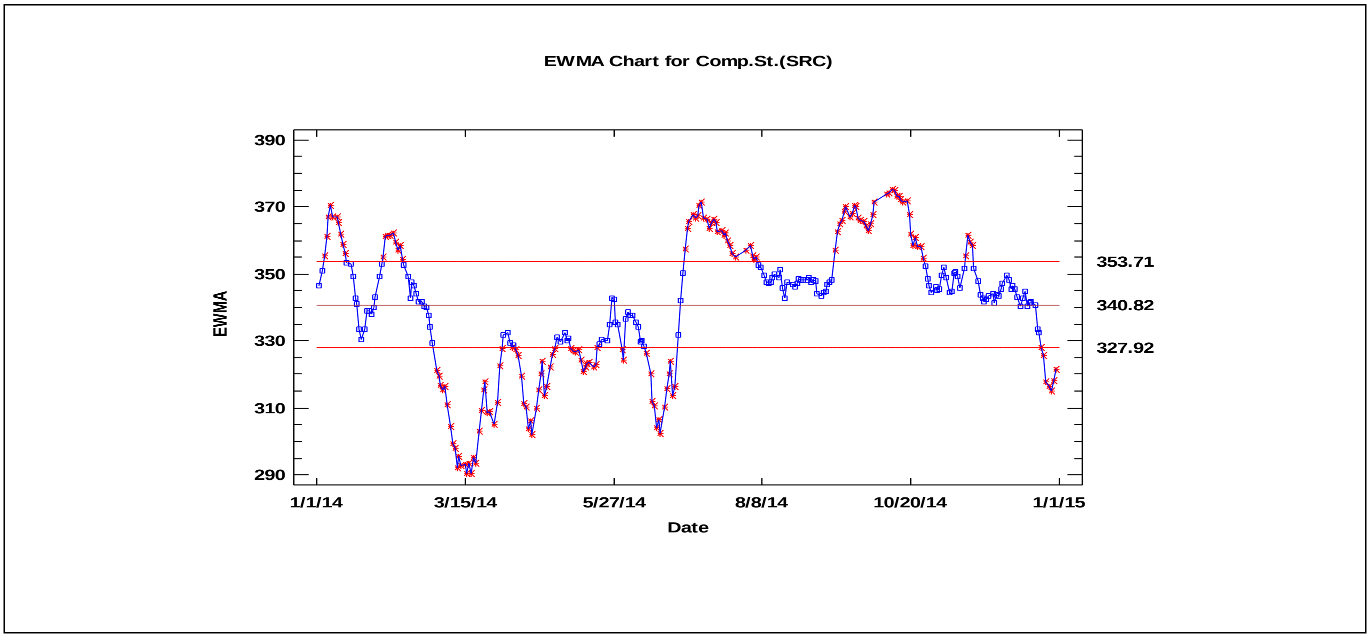


Figure 3-23: EWMA control chart of Comp.st. (SRC)

The procedure created a chart for Comp. St .of (SRC).The chart constructed under the assumption that the data come from a normal distribution with a mean equal to (340.816), upper control limit equal to (353.713), and lower control limit equal to (327.92). This parameter was estimated from the data. From (299) observations shown on the charts each observation represents a data of a day of year (2014). As we can see in the chart (164) observations are out of control limits, factors leading to this described in Table (3-7).

3.8.1 Factors influencing product's quality:

In the year (2014), (164) observations were out of control limits, as clarified in (figure 3-23). (115) observations were out of control limits as a result of technical problems in the mill. Largest factor leading to this was stoppage of mill according to plan and it made longest failure time equaling to (467.6 hr), smallest factor was blockage of mill entrance with failure time equaling to (1 hr). So the longer the failure time the more decrease in reliability of cement mill through which the quality control of the product will be affected leading to more data to be out of control limits.

Table (3-16): Factors that have an impact on quality control of cement.

No.	Causes of failure of the mill (SRC)	NO. of failures	Failure time
1	Stoppage according to plan	34	467.6
2	Fullness of cement silo	23	385.8
3	Maintenance	15	338
4	Examination of the mill by the CMD company	4	96
5	Reducing electrical loads	7	88.15
6	Contractor's inability to provide clinker	12	55.87
7	Increased temperature of (outlet slide shoe)	6	53.07
8	Abnormal sound in the main Kerbox motor	2	24.23
9	Problem in the translation (6617)	1	16.38
10	Elevation of the vibration of the Kerr Box main Motor	1	15.17
11	Sudden power outage	2	14.1
12	Blockage in the (hopper)	1	7.25
13	Cable damage in one of the main station for the plant towers.	1	6.62
14	Electrical jerk	1	5.5
15	Mechanical maintenance in the water valves (compressor Room).	1	4.03
16	Translation interruption (6617)	1	2.33
17	An electrical problem in the Alsbritor	1	1.6
18	Repair rubber transporter (6611)	1	1.47
19	An electrical problem in the main Motor	1	1

From tables (3-14, 3-15 and 3-16) it can be demonstrated that through using (EWMA) chart the out of control observations has been found and factors that affecting quality of each product (OPC, SBC and SRC) has been determined. Fullness of cement silo had major impact on quality of each (OPC and SBC), and for SRC major impact is Stoppage according to plan.

Table (3-17): represent in and out of control observations

Type	Observation	in-control	out-control
OPC	294	208	86
SBC	299	153	146
SRC	299	135	164

The table (3-17) above explain the physical test (compressive strength test) observations which are out of control and those are in- control which has been found by using (EWMA) for each cement mill.

3.9 Process capability:

Through this procedure we compare the output of in-control process to specification limits [Upper Specification Limit (USL) and Lower Specification Limit (LSL)] which had been put by the factory to meet costumer's requirement. This comparison made by forming ratio between specification widths to the process width. Measures used in this process called capability indices which are (C_p, C_{pk}).

According to data provided by Mass cement factory process capability indices for each product **(OPC, SBC and SRC**) has been estimated as shown in the table below:

Table (3-18): Represent Process Capability indices of product (OPC, SBC and SRC)

Cement Type		Capability
OPC	Cp	1.78
	Cpk	1.51
SBC	Cp	1.65
	Cpk	0.71
SRC	Cp	1.19
	Cpk	0.96

Through histograms below process capability of each product can be more explained (Fig 3-24). Histogram of each data along with normal curve overlaid it can be used to check and see whether the process data are normally distributed or not through which capability process of the data can be determined

Also through finding of K value for each process we can determine how far the process mean is away from center of specifications.

Since (K value =mean value- target value/ one-half the distance between the specifications)

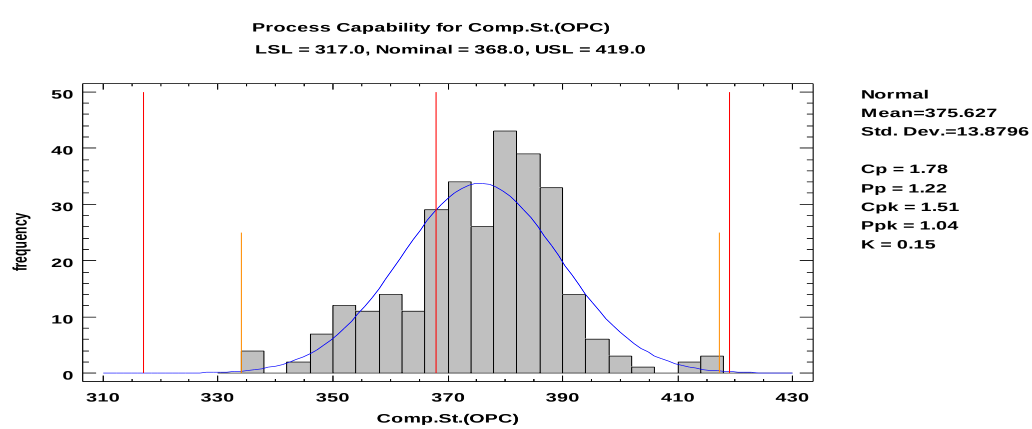


Fig: 3-24 (a) OPC

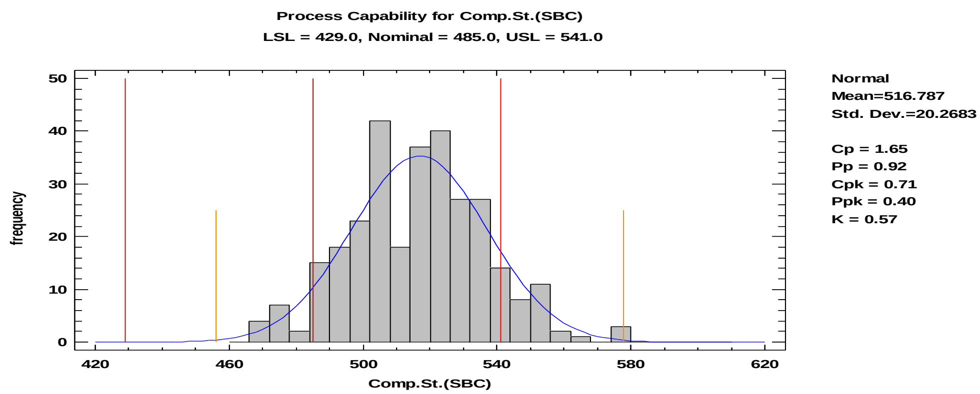


Fig: 3-24 (b) SBC

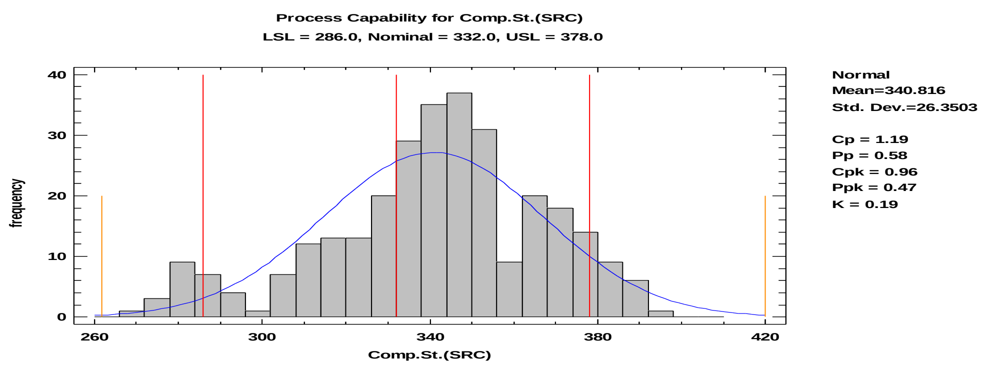


Fig: 3-24 (c) SRC

Figure (3-24): Process capability for Comp.st. (OPC, SBC and SRC)

Fig (3-24): Fig (3-24 (a)) shows capability process of (OPC) here as reported in the histogram all measures are fell between the specification limits so the process is capable and there is deviation of the process mean (375.627) from the target (368).

Since here (K = 0.149552), the mean is located (14.9552%) of the way from the center of the specifications and toward the upper specification limit, Fig (3-24 (b)) demonstrate process capability of (SBC), here it can be seen that there is a significant numbers of data are outside the upper specification limit so the process is incapable and there is deviation of the process mean which is equal to (516.787) from the target which is (485).Here (K = 0.567633), which means that the mean is located (56.7633%)of the way from the center of the specifications and toward the upper specification limit. The last Fig (3-24 (c)) represents the process capability of (SRC) it shows that the data failed to meet specification limits and it’s out of specification on both sides so we can decide that the process is incapable, and there is deviation of the process mean which equals to (340.816) from the target which is (332), and (K) value here is equal to (0.191662), so the mean is located (19.1662%) of the way from the center of the specifications and toward the upper specification limit.

Chapter four

Conclusion

and

Recommendation

4 conclusion and Recommendation

4.1 Conclusion:

The Mythology in this study provided a technique to determine the best and worst cement mill in Mass cement factory. This has been analyzed by studying data of failure time of five mills in three years' duration, through which reliability of all five mills has been estimated. The study shows the reliability of each mill month by month. It concludes that the first mill has the highest failure time has been recorded on (July 2014) which was (712.74 hrs.) Reliability in this month was in the lowest condition which was (0.00648). The lowest failure time has taken place on (June 2013) which was (4.12 hrs.) At that time reliability was (0.99636).

For the second mill the highest failure time was (530.66hrs.) On (July 2014) and reliability was (0.004847). The lowest failure time took place on (September 2012) which was (26.17hrs.) And reliability was (0.979933). For the third mill the highest failure time happened on (August 2014) was (544.78hrs.) And reliability was (0.036392). The lowest failure time has taken place on (April 2012) which was (63.8hrs.) and reliability was (0.953747). The highest failure time of the fourth mill has taken place on (August 2014) which was (628.72hrs). And reliability was (0.02303). The lowest failure time has taken place on (May 2012) which was (33.7 hrs.) at that time reliability was (0.986847). For the fifth mill the highest failure time happened on January which was (457.22hrs). And reliability was (0.059418). The lowest failure time has taken place on (November 2013) which was (73.46 hrs.) at that time reliability was (0.959127).

Those above mentioned data show that the lowest failure time has occurred in beginning of the establishment of the factory since the machines were fresh and pressure on them was relatively low, and reliability was very high. Once time passes the reliability goes down and failure rate goes up due to increasing pressure on the machines.

In this study life comparison has been used to determine which Mill has longer life span. And the result was that the first mill has the lowest life span comparing to the second, third, fourth and the fifth mill (44.40%, 43.47%, 47.85%, and 44.12 %.) And the third mill has the highest life span comparing to the other mills (56.53%, 50.53%, 54.95%, and 51.00 %.).

The study determined the quality control by using a specific chart which is Exponentially Weighted Moving Average (EWMA) chart; it also shows the correlation between failure time, quality control and capability process for (OPC), (SBC), and (SRC) only in (2014). For (OPC), there has been (628.76) hours of failure time which caused the cement not to pass the quality control for (53) times. For (SBC), there has been (1389.15) hours of failure time which again made the cement not to pass the quality control for (90) times, and finally for (SRC), there has been (1584.17) hours of failure time which caused the cement not to pass the quality control for (115) times. According to capability indices of (OPC), (SBC) and (SRC) it has been determined that in case of (OPC) because (Cp >1) which is equal to (1.78), and (Cpk) value is also greater than one which is equal to (1.51) this means the process is capable although it is off-centered because value of (Cp) is greater than (Cpk) value, thus higher value of (Cpk) indicates that the process is meeting the target with Minimum process variation. While the process of (SBC) and (SRC) both are incapable because the (Cpk) value in both cases are less than one in which (Cpk) value of (SBC) is equal to (0.71), and (Cpk) value for (SRC) is equal to (0.96) although (Cp) value for (SBC) and (SRC) is more than one, thus the process to be capable the value of (Cp) and (Cpk) at least should be one, so in case like that improvement in variation needed. Through this it has been found out that the less the failure time the more increase the reliability of the mill which enhances the chance of the product to pass quality control and the process to be more capable.

4.2 Recommendation:

According to the results and their analysis in this thesis the researcher suggests some opinions, explained in the following points:

1. By using function (Gamma distribution, Lognormal distribution and Weibull distribution …), instead of Generalized Gamma distribution.
2. By using statistical function in continuous in reliability.
3. The maintenance staff must have an excellent experience in repairing the non-functioning devices in the factory in shortest time duration to decrease failure time to its minimum level.
4. Staff working on cement mills should be well trained.
5. There should be strict follow-up and inspection of the quality of products through using quality control chart to meet customer satisfaction.
6. Producing a capable product through comparing variables to specifications and trying to maintain those variables in between specifications as much as possible to meet target value.

References

Books

[1] Ayyub, Bilal M., and Richard H. McCuen. Probability, Statistics and Reliability for Engineers and Scientists. Boca Raton, Fla.: CRC, (2011).

[2] Crowder, M. J. A.C.kimber, R.L.Smith and T.J.Sweeding Statistical Analysis of Reliability Data. London: Chapman & Hall, (1991).

[3] Chandra, M. Jeya. Statistical Quality Control. Boca Raton, FL: CRC, (2001).

[4] Dillon, B. S. Applied Reliability and Quality: Fundamentals, Methods and Procedures. London: Springer, (2007).

[5] Finkelstein, Maxim. Failure Rate Modeling for Reliability and Risk. London: Springer, (2008).

[6] Forbes, C. S. Statistical Distributions. Hoboken, NJ: Wiley, (2011).

[7] Furterer, Sandra L. Lean Six Sigma in Service: Applications and Case Studies. Boca Raton: CRC, (2009).

[8] Hilbe, Joseph M., and Andrew Robinson. Methods of Statistical Model Estimation. (2013).

[9] Jackson, Sherri L. Research Methods and Statistics: A Critical Thinking Approach. Australia: Heinle Cengage Learning, (2008).

[10] Jardine, A. K. S., and Albert H. C. Tsang. Maintenance, Replacement, and Reliability: Theory and Applications (2010).

[11] Jiang, Renyan. Introduction to Quality and Reliability Engineering. Place of Publication Not Identified Nielsen Bookdata, (2015).

[12] Kenneth_J._Meier, _Jeffrey_L._Brudney,_John_Bohte. Applied Statistics: For Public and Nonprofit Administration, (2011).

[13] Lazzaroni, Massimo. Reliability Engineering Basic Concepts and Application in ICT. Berlin: Springer, (2011).

[14] Life Data Analysis Reference Weibull. Tucson: ReliaSoft, (2015).

[15] Mishra, R. C., and Ankit Sandilya. Reliability and Quality Management. New Delhi: New Age International (P), (2009).

[16] Montgomery, Douglas C. Introduction to Statistical Quality Control. Hoboken, NJ: Wily, (2013).

[17] Oakland, John S. Statistical Process Control Sixth Edition. New York: Wiley, (2008).

[18] R. B. Abernethy, The New Weibull Handbook 4th edition, Abernethy (2000).

[19] Wallace, Michael. Quality Control for Dummies. Johan Wiley & Sons, (2007).

[120] Xie, M., T. N. Goh, and V. Kuralmani. Statistical Models and Control Charts for High-quality Processes. Boston: Kluwer Academic, (2002).

[21] Zio, Enrico. An Introduction to the Basics of Reliability and Risk Analysis. Singapore: World Scientific, (2007).

Thesis

[22] Jason Allen Denton. “ACCURATE SOFTWARE RELIABILITY ESTIMATION"(1999), Fort Collins, Colorado 80523.

[23] Escobar Luis A., and Lu C. Joseph. "Accelerated Degradation Tests: Modeling and Analysis." Technometrics 40.2 (1998): 89-99.

[24] Espinet-González, Pilar, et al. "Evaluation Of The Reliability Of Commercial Concentrator Triple-Junction Solar Cells By Means Of Accelerated Life Tests (ALT)." AIP Conference Proceedings 1556.1 (2013): 222-225. Academic Search Complete.

[25] Heba Nagaty Mohamed, M.Y. Haggag, “Reliability Estimation and Analysis of DDL MYSQL Server by using Generalized Gamma and Weibull Distribution” International Journal of Engineering (2014).

[26] Jean Nakamura, “predicting Time-to-Failure of Industrial Machines with Temporal Data Mining” Technometrics (2007).

[27] Levaggi, Rosella. "Hospital Health Care: Pricing and Quality Control in a Spatial Model with Asymmetry of Information." International Journal of Health Care Finance and Economics 5.4 (2005).

[28] M. Rosol, owski and W. Schmid, “EWMA Charts for Monitoring the Mean and the Autocovariances of Stationary Gaussian Processes” Technometrics (2003).

[29] McCulloch, Peter, Kreckler Simon, New Steve, Sheena Yezen, Handa Ashok, and Catchpole Ken. "Effect of a "Lean" Intervention to Improve Safety Processes and

Outcomes on a Surgical Emergency Unit." BMJ: British Medical Journal 341.7781 (2010).

[30] Meeker, William Q. "Limited Failure Population Life Tests: Application to Integrated Circuit Reliability." Technometrics 29.1 (1987).

[31] Mendez, Michelle A., Vioque Jesús, Porta Miquel, Morales Eva, López Tomàs, Malats Núria, Crous Marta, and Gómez Luis I. "Estimating Dietary Intakes from a Brief Questionnaire: A Simulation Study of Reliability in a Molecular Epidemiologic Study of Pancreatic and Biliary Diseases." European Journal of Epidemiology 21.6 (2006).

[32] Mihalcin, Matthew J., et al. "Quality Control-An Approach Applying Multivariate Control Charts During The Operation Of Systems Involving Human Processes." Systems Engineering 17.2 (2014): 204-212. Academic Search Complete.

[33] Rafiei, Kamran, Amir Kavussi, and Shahaboddin Yasrobi. "Construction Quality Control Of Unbound Layers Based On Stiffness Modulus Criteria." Journal of Civil Engineering & Management 18.1 (2012): 5-13. Academic Search Complete.

[34] Rani, Rekha. "Reliability Analysis of N-Policy, K-Out-Of-N: G Machining System with Warm and Cold Spares." International Transactions in Applied Sciences 3.2 (2011): 251-260. Academic Search Complete.

[35] J. Appl. Environ. Biol. Sci, has done a research on Power Law Model for Reliability Analysis of Crusher System in Khoy Cement Factory, 5(7S) 340-348, (2015)

.

[36] Zhiguo Li, a, Shiyu Zhou, Crispian Sievenpiper and Suresh Choubey, Statistical Monitoring of Time-to-Failure Data on 2011.

Jstor

[37] Adams, Arthur J. "A Cautionary Note on the Reliability of Advertising Test-Retest Scores." Journal of Advertising 13.1 (1984).

[38] Antony, J., Kumar M., and Labib A. "Gearing Six Sigma into UK Manufacturing SMEs: Results from a Pilot Study." The Journal of the Operational Research Society 59.4 (2008)

[39] Barclay, C. (1993). Quality Strategy and TQM Policies: Empirical Evidence. MIR: Management International Review, 33, 87-98. Retrieved from (Jstor). Stable/40228180.

[40] Faltin, Frederick W., Hahn Gerald J., Tucker William T., and Scott A. Vander Wiel. "Algorithmic Statistical Process Control: Some Practical Observations." International Statistical Review / Revue Internationale De Statistique 61.1 (1993).

[41] Gitlow, H. (1994). A Comparison of Japanese Total Quality Control and Deming's Theory of Management. The American Statistician, 48(3), 197-203. doi:1. Retrieved from jstor. stable/2684716 doi:1

[42] Hellstrand, C., Oosterhoorn A. D., Sherwin D. J., and Gerson M. "The Necessity of Modern Quality Improvement and Some Experience with Its Implementation in the Manufacture of Rolling Bearings [and Discussion]." Philosophical Transactions of the Royal Society of London. Series A, Mathematical and Physical Sciences 327.1596 (1989)

[43] Howell, J. (1952). Statistical Quality Control. Mathematics Magazine, 25(3), 155-157. doi:1. Retrieved from jstor. stable/3029448 doi:1

[44] Stacy, E. W., and Mihram G. A. "Parameter Estimation for a Generalized Gamma Distribution."Technometrics 7.3 (1965): 349-58. Web.

EBSCOhost

[45] Abbas, Nasir, Muhammad Riaz, and Ronald J. M. M. Does. "Enhancing the Performance of EWMA Charts." Quality & Reliability Engineering International 27.6 (2011): 821-833. Academic Search Complete.

[46] Amiri, Amirhossein, Amir Moslemi, and Mohammad Doroudyan. "Robust Economic And Economic-Statistical Design Of EWMA Control Chart." International Journal Of Advanced Manufacturing Technology 78.1-4 (2015): 511-523. Academic Search Complete.

[47] Anis, Mohammed Z. "Basic Process Capability Indices: An Expository Review." International Statistical Review / Revue Internationale De Statistique 76.3 (2008): 347-67. Academic Search Complete.

[48] Castagliola, Philippe, and Kerstin Vännman. "Monitoring Capability Indices Using An EWMA Approach." Quality & Reliability Engineering International 23.7 (2007): 769-790. Academic Search Complete..

[49] Linnet, Kristian. "The Exponentially Weighted Moving Average (EWMA) Rule Compared With Traditionally Used Quality Control Rules." Clinical Chemistry & Laboratory Medicine 44.4 (2006): 396-399. Academic Search Complete.

Appendix

Table A: Failure time data of years (2012, 2013 and 2014).

Month	Failure time				
	Mill (1)	Mill (2)	Mill (3)	Mill (4)	Mill (5)
January	157.5	101.5	504.5	295.5	336
February	96.5	86	412.5	299	398
March	128	71.75	424.5	206.5	322.2
April	52.5	121	63.8	76.3	94.3
May	298.72	306.52	65.18	33.7	127.23
June	31.82	67.31	85.36	50.96	97.66
July	77.34	113.88	116.81	91.72	135.97
August	234.21	365.54	293.23	360.11	316.79
September	39.13	26.17	79.06	78.72	91.45
October	129.8	126.91	103.52	152.94	165.42
November	172.69	200.45	156.25	137.81	102.11
December	219.67	258.58	234.94	202.33	161.41
January	196.67	327.93	218.74	266.88	275.61
February	154.96	226.22	211.11	166.11	149.98
March	106.23	247.86	151.47	120.81	159.81
April	251.85	301.59	224.92	101.58	94.48
⋮	⋮	⋮	⋮	⋮	⋮
May	161.19	222.53	269.85	275.96	253.61
June	447.95	314.06	372.11	376.02	444.53
July	712.74	530.66	489.21	572.5	348.89
August	523.31	351.66	544.78	628.72	374.07
September	301.73	239.96	146.5	70.28	118.94
October	301.81	266.85	175.42	176.38	305.34
November	325.83	292.36	156.07	178.29	129.6
December	415.35	403.3	351.37	468.41	211.41

Table B: EWMA for comp. strength: Kg / cm^2 , 7 day.

Date	comp.st. (OPC)	EWMA (OPC)	comp.st. (SBC)	EWMA (SBC)	comp.st. (SRC)	EWMA (SRC)
2/1/2014	381.48	376.798	522.24	517.878	369.24	346.501
4/1/2014	379.44	377.326	539.58	522.218	368.22	350.845
5/1/2014	381.48	378.157	537.54	525.283	374.34	* 355.544
6/1/2014	381.48	378.822	534.48	527.122	384.54	* 361.343
7/1/2014	387.6	380.577	538.56	* 529.41	389.64	* 367.003
8/1/2014	379.44	380.35	523.26	* 528.18	384.54	* 370.51
9/1/2014	375.36	379.352	538.56	* 530.256	353.94	* 367.196
11/1/2014	382.5	379.981	531.42	* 530.489	366.18	* 366.993
12/1/2014	370.26	378.037	525.3	* 529.451	358.02	* 365.198
13/01/2014	375.36	377.502	541.62	* 531.885	348.84	* 361.927
14/01/2014	382.5	378.501	529.38	* 531.384	346.8	* 358.901
15/01/2014	381.48	379.097	531.42	* 531.391	344.76	* 356.073
16/01/2014	375.36	378.35	529.38	* 530.989	342.72	353.402
18/01/2014	368.22	376.324	549.78	* 534.747	350.88	352.898
19/01/2014	373.32	375.723	537.54	* 535.306	334.56	349.23
20/01/2014	368.22	374.222	533.46	* 534.937	317.22	342.828
21/01/2014	373.32	374.042	537.54	* 535.457	333.54	340.971
22/01/2014	375.36	374.306	518.16	* 531.998	302.94	333.364
23/01/2014	357	370.844	558.96	* 537.39	319.26	330.544
25/01/2014	363.12	369.3	576.3	* 545.172	345.78	333.591
26/01/2014	382.5	371.94	543.66	* 544.87	361.08	339.089
27/01/2014	368.22	371.196	533.46	* 542.588	338.64	338.999
28/01/2014	376.38	372.233	537.54	* 541.578	334.56	338.111
29/01/2014	380.46	373.878	542.64	* 541.791	346.8	339.849
30/01/2014	388.62	376.826	547.74	* 542.98	355.98	343.075
1/2/2014	384.54	378.369	555.9	* 545.564	373.32	349.124
2/2/2014	381.48	378.991	533.46	* 543.144	369.24	353.147
3/2/2014	387.6	380.713	552.84	* 545.083	363.12	* 355.142
4/2/2014	404.94	* 385.558	555.9	* 547.246	385.56	* 361.225
5/2/2014	382.5	384.947	557.94	* 549.385	363.12	* 361.604
6/2/2014	377.4	383.437	530.4	* 545.588	361.08	* 361.5

Date	comp.st. (OPC)	EWMA (OPC)	comp.st. (SBC)	EWMA (SBC)	comp.st. (SRC)	EWMA (SRC)
8/2/2014	389.64	384.678	575.28	* 551.526	365.16	* 362.232
9/2/2014	381.48	384.038	555.9	* 552.401	348.84	* 359.553
10/2/2014	372.3	381.691	546.72	* 551.265	347.82	* 357.207
11/2/2014	389.64	383.281	566.1	* 554.232	363.12	* 358.389
12/2/2014	382.5	383.124	543.66	* 552.118	338.64	* 354.439
13/02/2014	380.46	382.592	533.46	* 548.386	345.78	352.708
15/02/2014	389.64	384.001	522.24	* 543.157	334.56	349.078
16/02/2014	383.52	383.905	546.72	* 543.869	317.22	342.706
17/02/2014	417.18	* 390.56	535.5	* 542.196	366.18	347.401
18/02/2014	413.1	* 395.068	553.86	* 544.528	342.72	346.465
19/02/2014	396.78	* 395.41	520.2	* 539.663	334.56	344.084
20/02/2014	385.56	* 393.44	495.72	* 530.874	332.52	341.771
22/02/2014	363.12	* 387.376	517.14	528.127	341.7	341.757
23/02/2014	382.5	* 386.401	536.52	* 529.806	334.56	340.318
24/02/2014	391.68	* 387.457	528.36	* 529.517	338.64	339.982
25/02/2014	410.04	* 391.973	530.4	* 529.693	327.42	337.47
26/02/2014	380.46	* 389.671	522.24	* 528.203	320.28	334.032
27/02/2014	388.62	* 389.461	532.44	* 529.05	310.08	329.241
1/3/2014	370.26	* 385.62	501.84	523.608	288.66	* 321.125
2/3/2014	375.36	383.568	499.8	518.847	312.12	* 319.324
3/3/2014	382.5	383.355	513.06	517.689	307.02	* 316.863
4/3/2014	373.32	381.348	528.36	519.823	310.08	* 315.507
5/3/2014	375.36	380.15	521.22	520.103	319.26	* 316.257
6/3/2014	358.02	375.724	521.22	520.326	289.68	* 310.942
8/3/2014	349.86	370.551	487.56	513.773	278.46	* 304.445
9/3/2014	348.84	366.209	503.88	511.794	278.46	* 299.248
10/3/2014	369.24	366.815	518.16	513.067	291.72	* 297.743
11/3/2014	378.42	369.136	533.46	517.146	269.28	* 292.05
12/3/2014	376.38	370.585	506.94	515.105	309.06	* 295.452
13/03/2014	369.24	370.316	505.92	513.268	281.52	* 292.666
15/03/2014	366.18	369.489	528.36	516.286	294.78	* 293.089
16/03/2014	368.22	369.235	516.12	516.253	279.48	* 290.367
17/03/2014	379.44	371.276	519.18	516.838	304.98	* 293.289
18/03/2014	370.26	371.073	525.3	518.531	278.46	* 290.324
19/03/2014	396.78	376.214	506.94	516.213	315.18	* 295.295
20/03/2014	362.1	373.391	517.14	516.398	285.6	* 293.356

Date	comp.st. (OPC)	EWMA (OPC)	comp.st. (SBC)	EWMA (SBC)	comp.st. (SRC)	EWMA (SRC)
22/03/2014	382.5	375.213	523.26	517.77	341.7	* 303.025
23/03/2014	389.64	378.098	507.96	515.808	334.56	* 309.332
24/03/2014	381.48	378.775	484.5	509.547	338.64	* 315.193
⋮	⋮	⋮	⋮	⋮	⋮	⋮
1/12/2014	388.62	380.103	518.16	515.761	352.92	343.768
2/12/2014	379.44	379.97	526.32	517.873	342.72	343.558
3/12/2014	380.46	380.068	502.86	514.87	352.92	345.43
4/12/2014	400.86	384.227	515.1	514.916	353.94	347.132
6/12/2014	401.88	* 387.757	555.9	523.113	360.06	349.718
7/12/2014	377.4	* 385.686	520.2	522.53	342.72	348.318
8/12/2014	370.26	382.601	507.96	519.616	334.56	345.567
9/12/2014	382.5	382.581	527.34	521.161	350.88	346.629
10/12/2014	415.14	* 389.092	517.14	520.357	341.7	345.643
11/12/2014	379.44	* 387.162	524.28	521.141	333.54	343.223
13/12/2014	369.24	383.578	513.06	519.525	329.46	340.47
14/12/2014	382.5	383.362	516.12	518.844	351.9	342.756
15/12/2014	384.54	383.598	519.18	518.911	352.92	344.789
16/12/2014	388.62	384.602	519.18	518.965	323.34	340.499
17/12/2014	375.36	382.754	510	517.172	344.76	341.351
18/12/2014	382.5	382.703	524.28	518.594	343.74	341.829
20/12/2014	383.52	382.866	546.72	524.219	335.58	340.579
21/12/2014	376.38	381.569	535.5	526.475	306	333.663
22/12/2014	387.6	382.775	525.3	526.24	328.44	332.619
23/12/2014	368.22	379.864			309.06	* 327.907
24/12/2014	377.4	379.371	511.02	523.196	316.2	* 325.566
25/12/2014	369.24	377.345	518.16	522.189	286.62	* 317.776
27/12/2014	369.24	375.724	534.48	524.647	311.1	* 316.441
28/12/2014	372.3	375.039	545.7	* 528.858	309.06	* 314.965
29/12/2014	378.42	375.715	545.7	* 532.226	330.48	* 318.068
30/12/2014			516.787	* 529.138	334.56	* 321.366

Table C: Represent Reliability, Failure Rate, Probability density function, Cumulative distribution function for cement mill (1)

Year	Month	Failure time	Reliability	Failure rate	Probability density function	cumulative distribution function
2012	January	157.5	0.55138	0.00532/Hr	0.002933	0.44862
	February	96.5	0.74151	0.004349/Hr	0.003225	0.25849
	March	128	0.64101	0.004883/Hr	0.00313	0.35899
	April	52.5	0.88035	0.003397/Hr	0.002991	0.11965
	May	298.72	0.2303	0.006949/Hr	0.0016	0.7697
	June	31.82	0.93869	0.002779/Hr	0.002609	0.06131
	July	77.34	0.80312	0.003974/Hr	0.003192	0.19689
	August	234.21	0.35297	0.006275/Hr	0.002215	0.64703
	September	39.13	0.91899	0.003019/Hr	0.002774	0.08101
	October	129.8	0.63539	0.004911/Hr	0.00312	0.36461
	November	172.69	0.50778	0.005527/Hr	0.002806	0.49223
	December	219.67	0.38623	0.006109/Hr	0.002359	0.61378
2013	January	196.67	0.4431	0.005833/Hr	0.002585	0.5569
	February	154.96	0.55886	0.005284/Hr	0.002953	0.44114
	March	106.23	0.71018	0.004524/Hr	0.003213	0.28983
	April	251.85	0.31545	0.006468/Hr	0.00204	0.68456
	May	126.55	0.64556	0.004861/Hr	0.003138	0.35444
	June	4.12	0.99636	0.001235/Hr	0.001231	0.00364
	July	309.43	0.21366	0.007053/Hr	0.001507	0.78634
	August	366.23	0.14101	0.007573/Hr	0.001068	0.859
	September	96.85	0.74038	0.004356/Hr	0.003225	0.25962
	October	127.63	0.64217	0.004878/Hr	0.003133	0.35783
	November	159.41	0.5458	0.005346/Hr	0.002918	0.45421
	December	192.94	0.4528	0.005787/Hr	0.00262	0.5472
2014	January	132.67	0.62645	0.004956/Hr	0.003105	0.37355
	February	97.72	0.73757	0.004372/Hr	0.003225	0.26243
	March	36.39	0.92652	0.002932/Hr	0.002717	0.07348
	April	268.35	0.2831	0.006643/Hr	0.001881	0.7169
	May	161.19	0.54061	0.005371/Hr	0.002904	0.45939
	June	447.95	0.07384	0.008248/Hr	0.000609	0.92616
	July	712.74	0.00648	0.010056/Hr	0.000065	0.99352
	August	523.31	0.03881	0.008812/Hr	0.000342	0.96119
	September	301.73	0.22552	0.006978/Hr	0.001574	0.77448
	October	301.81	0.2254	0.006979/Hr	0.001573	0.77461
	November	325.83	0.19008	0.007208/Hr	0.00137	0.80992
	December	415.35	0.09621	0.007987/Hr	0.000768	0.90379

پوختە

ئـەم توێژینەوەیـە بـەکارهێنانی شـیکاری ریلابیلیتـی روون دەکاتـەوە بـۆ پێـنج ئاشـی چـیمەنتۆ لـە کارگـەی چـیمەنتۆی مـــاس. بە پشت بەستن بـە داتـای شکسـتی (فەشـەل) ئـەو ئاشـانە لەهـەر مانگێکـدا بـۆ مـاوەی سـێ سـاڵ ،بـە پێی ی پرۆگرامـی (++Weibull) سـێ تـاقیکردنـەوەی (Goodness of fit) ئە نجامــداوە بــۆ دۆزینــەوەی گونجــاوترین توزیــع. لــە ئە نجامــدا باشــترین توزیــع کــە (G.Gamma) یــە هەڵبــژێردراوە بــۆ شــیکارکردنی داتاکــەز . لــە رێگــەی بــەکارهێنانی دالــەی (Reliability, Failure rate and Probability Density function) ە باشـترین وە خـرا پترین ریلابیلیتـی بـۆ هـەر مـانگیکی سـالەکانی (2012, 2013 and 2014) ی هەریـەك لـە پێنج ئاشەکە دۆزراوەتەوە .

لەم توێژینەوەیەدا داتای تاقیکردنەوەی فیزیایی کە (Comp.St. test)ە بەکارهاتوە بۆ هەر سێ جۆرەکەی چیمەنتۆ کە بریتین لە (OPC, SBC and SRC)لە سالی (2014) دا. شیکاری داتاکە ئە نجامدراوە لە رێگەی پرۆگرامی (Statgraphics Centurion (v16.1). هەروەها لەم لێکۆلینەوەیەدا جۆری ئەو بەرهەمەی لەم کارگەیەدا بەرهەم دەهێنرێت خەملێندراوە بە پێی پرۆسەی چاودێری جۆری لە رێگای بەکارهێنانی کۆنترۆڵ چارتێکی تایبەتمەندەوە کە پێی دەوترێت (exponentially weighted moving average). بە پێی دەرهاویشتەکانی ئەم لێکۆلینەوەیە ئەو هۆکارانە دەستنیشانکراون کە کاریگەریان لەسەر کاری ئەو ئاشانە هەیە کە چیمەنتۆ دروست دەکەن بۆمان ڕوون بۆتەوە کە ئەو هۆکارانە رێژەی شکستی ئاشەکان زیاد دەکات و لە تەمەنی کارکردنیان کەم دەکاتەوە، کە دەبێتە هۆکارێك بۆ زیان گەیاندن بەجۆرێتی چیمەنتۆی بەرهەمهێنراو.

ملخص

هذه الأطروحة توضح تطبيق تحليل الموثوقية لخمسة من مطاحن الأسمنت في معمل اسمنت ماس اعتمادا على بيانات زمن الفشل لتلك المطاحن لمدة ثلاثة سنوات .

تم اجراء ثلاثة اختبارات جودة لمعرفة انسب توزيع وذلك عن طريق برنامج (Weibull++) **، و قد اختير** (**توزيع كاما العام**) (Generalized Gamma Distribution) **كأحسن توزيع لتحليل البيانات .**

من خلال استخدام وظائف ال(الموثوقية ، معدل الفشل ، وظيفة الكثافة الأحتمالية) تم ايجاد احسن و اسوأ موثوقية لكل شهر لأعوام (2012 ، 2013 و 2014) **في المطاحن الخمسة . في هذه الأطروحة تم استخدام بيانات الأختبارات الفيزياوية لثلاثة انواع من الأسمنت** (OPC, SBC and SRC) **لسنة** 2014 **، و قد تم تحليل البيانات عن طريق برنامج** (Statgraphics Centurion (v16.1) **. ان نوعية المنتجات المصنوعة في هذا المعمل قد تم تخمينها حسب عملية السيطرة النوعية من خلال استخدام مخطط سيطرة خاص يسمى مخطط** (Exponentially Weighted Moving Average (EWMA)) **نتيجة لهذه الدراسة تم الكشف عن العوامل المؤثرة على وظيفة المطاحن المنتجة للأسمنت وكيف ان تلك العوامل ستزيد من نسبة الخطأ في تلك المطاحن و تقلل من عمرها الأفتراضي و الذي بدوره يؤثر على نوعية المنتجات .**