



Using the Quality Control to Determine the Factors of Failure Operation in Cement Sector

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Article info	Abstract
Original: 10 July 2020 Revised: 10 February 2021 Accepted: 2 March 2021 Published online: 20 June 2021	Quality control technic is an important method of designing a strategic plan for many productive industries. The Shewhart control chart is that it uses only the information observation. Cumulative sum (CUSUM) and Exponentially weighted moving average (EWMA) two very effective alternatives to the Shewhart control chart may be used when small process shifts are of interest. This paper discusses data on failure time of five cement mills in Sulaimani Mass cement factories, used, the reliability methods for analysis the failure time., The quality of the products manufactured in this factory has been estimated according to a quality control process through the use of specific control chart one of the chart Exponentially Weighted Moving Average (EWMA) chart. Whereas reliability concerns functioning under specified time. So, it can be said that the reliability is a relation between production with expected period time in quality. This study investigates the implementation of reliability and quality control. The findings indicate that factors that affecting the function of mills which will increase the failure rate of mills and lower their life span, through which quality of products will be affected.
Key Words: Quality Control; Exponentially Weighted Moving Average (EWMA); Process Capability Indices	

Introduction

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 associated with the reliability. Since, reliability is denoted as probability; its value changes from zero to unity thereby giving quantitative measure. 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, for electronic tool, it's really hard for 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 [5, 7]. 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, 10]. It can be said that reliability is a standard of quality by the expected period time [1].

Generalized Gamma Distribution:

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 [8, 9].

Generalized Gamma Probability Density Function (pdf):

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 Tucson [8]:

Where:

β : Location parameter. θ : Scale Parameter.

λ : Shape parameter.

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

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

Cumulative Distribution Function (CDF):

It is apparent that this function would have a direct application to life data analysis. This function returns the probability of a failure occurring at 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 (QT) [3, 7].

$$F(t) = Q(t) = 1 - \Gamma_I \left(\frac{e^{\lambda \left(\frac{\ln(t) - \beta}{\theta} \right)}}{\lambda^2}; \frac{1}{\lambda^2} \right) \quad \dots (3)$$

Generalized Gamma Reliability Function:

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

$$R(t) = 1 - \Gamma_I \left(\frac{e^{\lambda \left(\frac{\ln(t) - \beta}{\theta} \right)}}{\lambda^2}; \frac{1}{\lambda^2} \right) \text{ If } \lambda > 0 \quad \dots (4)$$

$$R(t) = 1 - \phi \left(\frac{\ln(t) - \beta}{\theta} \right) \text{ if } \lambda = 0 \quad \dots (5)$$

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 [8].

$$DESV = (AVGOF \text{ Rank} * AVGOF \text{ Weight}) + (AVPLOT \text{ Rank} * AVPLOT \text{ Weight}) + (LKVR \text{ Rank} * LKV \text{ Weight}) \quad \dots (6)$$

Test of Life Comparison:

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

$$P[t_2 \geq t_1] = \int_0^\infty f_1(t) * R_2(t) dt \quad \dots (7)$$

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 [8]:

- 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 the data (set 1) are 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 the data (set 2) are better than data (set 1) with an (80%) probability.

The classical Exponentially Weighted Moving Average (EWMA) control charts:

The Exponentially Weighted Moving Average (EWMA) control charts and other sequential approaches, like Cumulative Sum (CUSUM) charts, are an alternative to Shewhart (EWMA) chart is more influential than the Shewhart control charts in noticing small shifts actually less than (1.5σ) in the process mean (Roberts). And are especially effective in detecting small process shifts EWMA control chart was introduced by Roberts (1959) [6]. The exponentially weighted moving average (EWMA) rule for internal quality control is a well-known type of control rule in the 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 [9, 11]:

$$Z_i = \lambda X_i + (1 - \lambda)Z_{i-1}, i = 1, 2, \dots, n \quad \dots (8)$$

Where:

Z_i = ith EWMA

X_i = ith Sample result

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

Z_{i-1} = (i-1)th EWMA is the best information.

Mean(Z_i) = μ_0 ,

$$\text{Var}(Z_i) = \sigma^2 \left\{ \frac{\lambda}{2-\lambda} (1 - (1 - \lambda)^{2i}) \right\} \quad \dots (9)$$

Not that the value $(1 - (1 - \lambda)^{2i})$ approaches unity as i gets larger.

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:

$$LCL = \mu_0 - 3\sigma \sqrt{\frac{\lambda}{2-\lambda}} \quad \dots (10)$$

$$UCL = \mu_0 + 3\sigma \sqrt{\frac{\lambda}{2-\lambda}} \quad \dots (11)$$

$$CL = \mu_0$$

Definition and method of Process Capability Indices:

Process capability is a good statistical techniques to for product 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 [4, 5].

Where the Process capability is:

$$C_{(pu)} = \frac{USL - \mu}{3\sigma} \quad \dots \quad (12)$$

Where:

C_{pu} : Capability process upper specification limit.

USL : Upper Specification Limit.

μ : Mean.

σ : Standard deviation.

$$C_{(pl)} = \frac{\mu - LSL}{3\sigma} \quad \dots \quad (13)$$

Where:

C_{pl} : Capability process lowers specification limit.

μ : Mean.

LSL : Lower Specification Limit.

$$C_p = \frac{USL - LSL}{6\sigma} \quad \dots \quad (14)$$

Where:

C_p : Process Capability.

LSL : Lower Specification Limit.

USL: Upper Specification Limit.

σ : Standard deviation.

Application:

The Mass Cement factory is one of Mass – Iraq for industrial investments Company’s strategic located in Bazian district-kurdistan Region of Iraq. The plant started production in (2010), The plant produces three types of cement, Ordinary Portland Cement (OPC), High Blaine Portland Cement (SBC) and High Sulfur Resistant Cement (SRC), the manufacture composed of three lines, each line produces (2 million tons) of cement each year. In The paper study the 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, the best distribution of the study has been demonstrated.

The data set used in this study consist of monthly failure time of five cement mills three mills produce OPC, one mill produces SRC and one mill produce SBC. (36)Observations of each cement mill have been taken for three different years (Year 1, Year 2 and Year 3). Since proper data of physical tests (compressive strength test) of the year (Year 1 and Year 2) was not available so the researcher could only use data of physical tests of the year 3 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.

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 three types of cement produced in the factory which are OPC, SBC and SRC. 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.

Failure time of cement mill SRC:

The monthly failure time data of cement mill SRC for three years at different times tested to choose a suitable distribution for cement mill SRC. For these three goodness of fit tests performed and the final result has been

found by weighted decision variable DESV as in (eq.6) test through which rank of distributions determined. This analysis done by Reliasoft Program (Weibull++) as shown in the table below:

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

	Distribution	(DESV)	Ranking
Mill (SRC)	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

Distribution having minimum weighted decision variable (DESV) use in Eq.6) is considered as best distribution to be fitted for giving data. Thus, from (Table 1-1) 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 the SRC cement mill, as shown in the table below.

Table (1-2): Represent Reliability, Failure Rate , Probability density function , Cumulative distribution function for cement mill (SRC)

Year	Month	Failure time (T)	Reliability (R(t))	Failure rate ($\lambda(t)$)	Probability density function (pdf)	Cumulative distribution function (CDF)
Year 1	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
⋮	⋮	⋮	⋮	⋮	⋮	⋮
Year 3	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 (1-2), it's clear that the minimum value of failure time is (4.12hr.) in (June Year 2) 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 SRC mill occurs when the failure time goes to (712.74 hr.) in (July Year 3) 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 the above has been more explained through their plot according to failure time data of cement mill SRC as shown in the figures below:

Plot the Histogram of cement mill SRC:

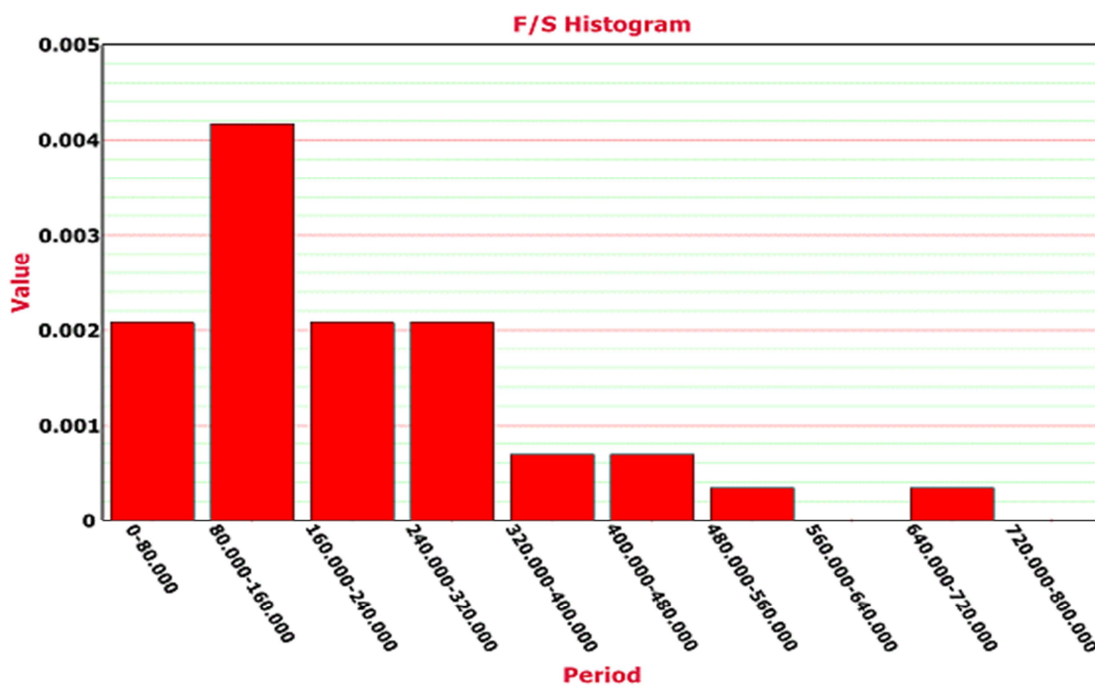


Figure (1): Represents Plot the Histogram of cement mill (1)

The above histogram represent the probability of hours of failure for SRC cement mill it shows that most failures of the SRC cement mill has happened in a range time between(80 –160hr.) and the probability of failure at that time was equal to (0.00417).The minimum probability of failure has taken place between [(480 – 560) and (640– 720)] hr.

Plot the probability density function:

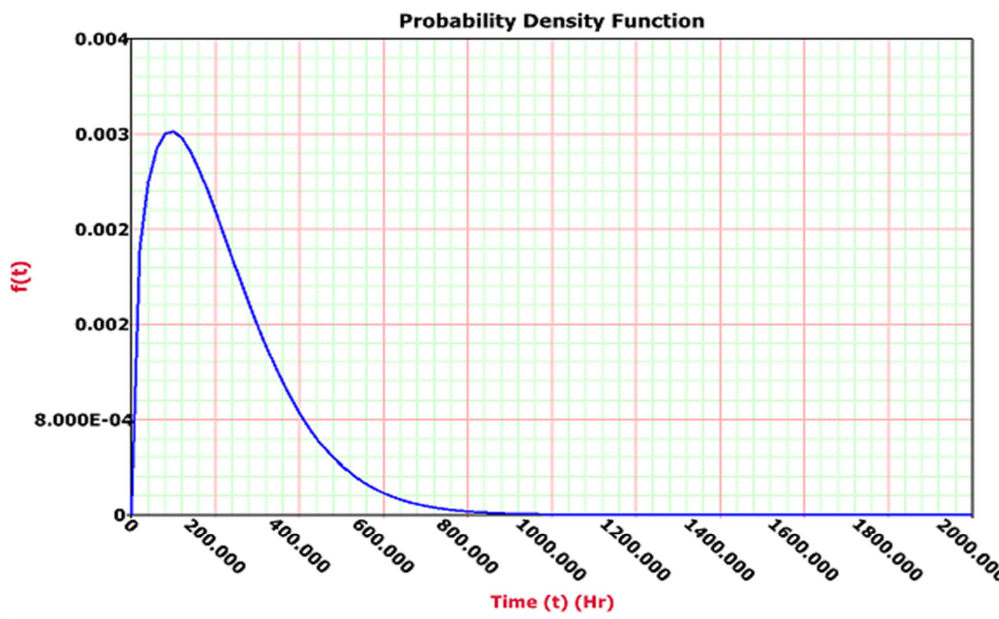


Figure (2): Represents the probability density function of the failure time of cement mill (SRC)

This plot illustrates (pdf) of SRC cement mill 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.

Plot the cumulative distribution function:

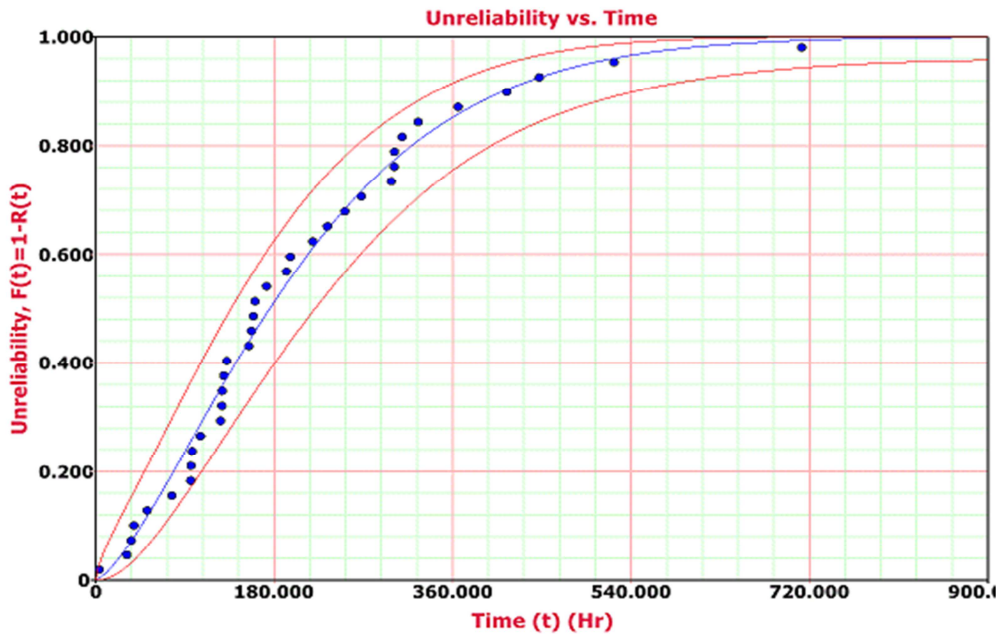


Figure (3): Represents the cumulative distribution function

It's obvious from the above graph that the cumulative distribution function is increasing as a vertical shape with failure time, since it has a 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 Year 3).

Plot the reliability:

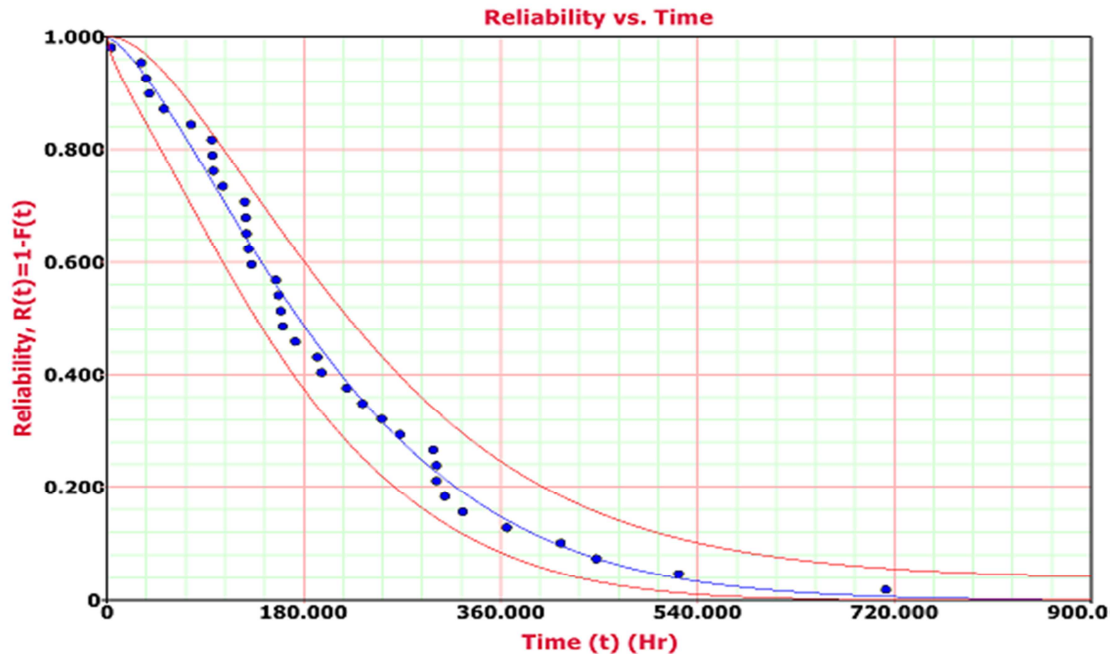


Figure (4): Represents the reliability

The above graph represents the reliability of SRC cement mill 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 Year 2) the reliability is equal to (0.996) 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).

Note (Same methods used in finding the result, mill SRC for SBC and OPC.)

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 (1-3): Life comparison between cement mills

Life Comparison Between Mills	Result of Comparison
CM(OPC) vs CM(SRC)	56.53%
CM(OPC) vs CM(SBC)	51.00%
CM(SBC) vs CM(SRC)	54.34%

*CM = Cement Mill

According to the results shown in the table(1-3) it can be demonstrated that the OPC cement mill have more chance to last longer than each of cement mill SRC and SBC. And SBC cement mill will last longer than cement mill SRC, according to this the best cement mill is OPC mill and the worst one is cement mill SRC mill, which has shortest life span in comparison to other mills.

Quality control for types of cement:

By using data of a type of physical test which is (compressive strength test) on each type cement 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).

The 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 (385.20) and lower control limit equal to (366.07). This parameter was estimated from (294) observations, each observation represents a data of a daily of the year (Year 3) .As shown in Fig(5). it is seen that there are (86) observations are out of control limits.

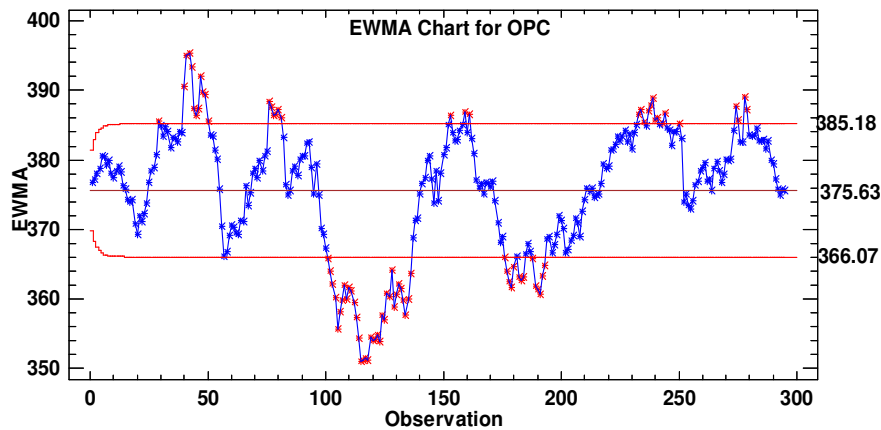


Figure (5): EWMA control chart of Copm.st. OPC

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 (515.94), upper control limit equal to (528.2) and lower control limit equal to (503.67). The parameter was estimated from the data. From (299) observations shown on the charts each observation represents a data of (Year 3). Here (146) observations are out of control limits, As shown in Fig(6).

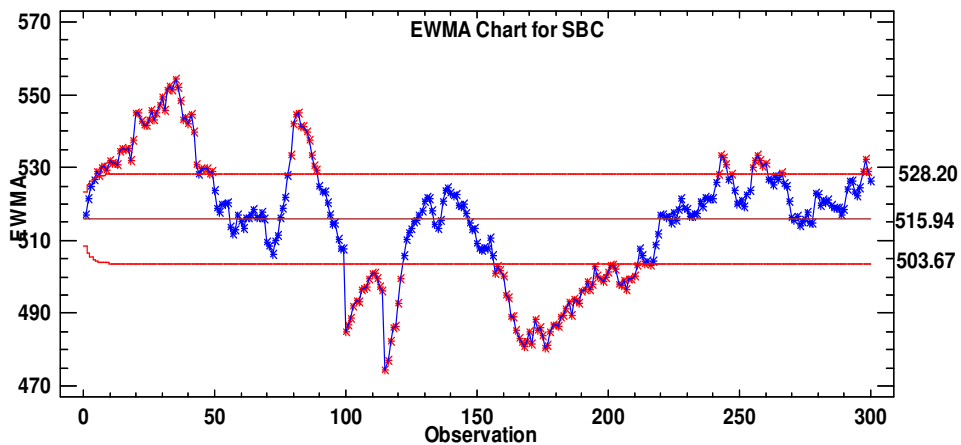


Figure (6): EWMA control chart of Copm.st. SBC

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 year 3. From Fig(7) it is seen that there are (164) observations are out of control limits.

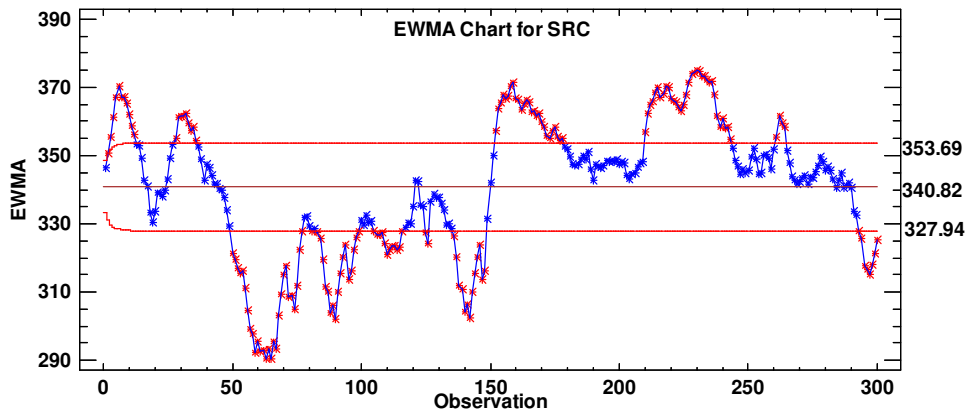


Fig (7) EWMA Control Chart of Comp.st. SRC

Factors influencing product’s quality:

During the control charts of daily observations of the year 3 for type OPC, it is seen that 53 out of control points from 86 points ,type SBC, 90 points from 146, and for type SRC 115 points from 164, it comes from technical problems in the cement mill, it means that the reason of most points of out of control limit it comes from technical problems, it means that the reason of most of out of control limit is technical problems. Since the length 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 1-4: Factors failure time that has an impact on quality control of cement

Causes of failure of the mill	OPC	SBC	SRC
Fullness of cement silo	305.67	718.04	385.8
Stoppage according to plan.	114.11	37.34	467.6
Maintenance.	102.13	-----	338
Contractor's inability to provide clinker.	5.95	2.73	55.87
Tighten the screws in the body of the mill.	17.94	11.22	-----
Reducing electrical loads.	15.37	522.45	88.15
Programmed interruption of power supply.	16.17	-----	-----
Elevation of the vibration of the Kerr Box main Motor.	15.78	-----	15.17
Government electrical power outage	7.73	-----	-----
Problem in the translation (6610).	5.22	-----	-----
An electrical problem with the (8419) air slide fan.	4.7	-----	-----
⋮			
Total	628.76	1389.15	1584.17

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 the ratio between specifying 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 1-5: 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
SR C	Cp	1.19
	Cpk	0.96

Through histograms below process capability of each product can be more explained (Fig 8). 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.

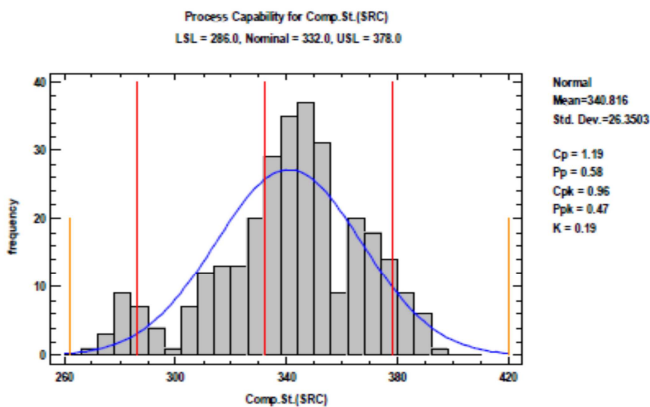
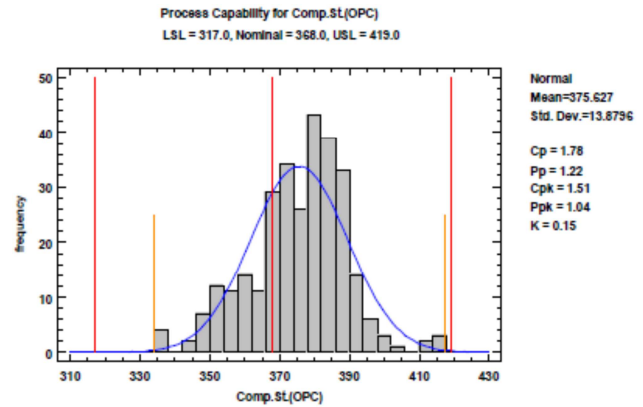


Fig (8-a) Process Capability Of OPC



Fig(8-B) Process Capability Of SRC

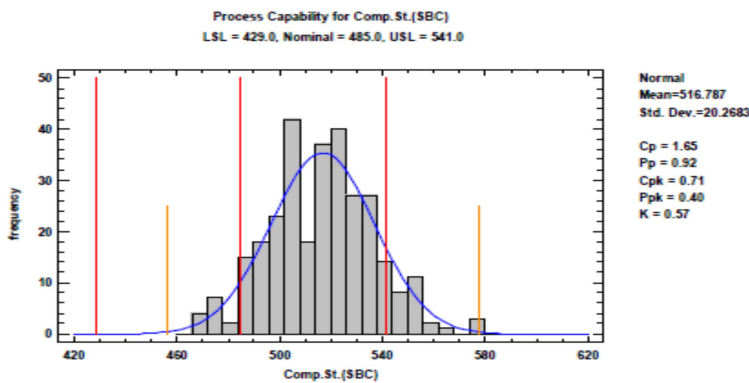


Fig (8-C) Process Capability Of SBC

Result and Conclusion:

Methodology in this study provided a technique to determine the best and worst cement mill in a Mass cement factory. This has been analyzed by studying data of failure time of mills producing cements OPC, SRC and SBC) in three years’ duration, through which reliability of each mill has been estimated. The study shows the reliability of each mill month by month. It concludes that the SRC, OPC and SBC mills have the highest failure time have been recorded on July Year 3, August Year 3 and January Year 2, which were (712.74,544.78 and 457.22) hours respectively. Reliability in those months was in the lowest condition which was (0.0065,0.0364 and 0.05942). The lowest failure time has taken place on (June Year 2, April Year 1 and November Year 2) which were (4.12,63.8,and 73.46) hours at that time reliability was (0.996, 0.954 and

0.959) respectively. In this study life comparison has been used to determine which Mill has a long life span. And the result was that the SRC mill has the lowest life span compared to OPC and SBC (43.47% and 45.66 %.) And the OPC mill has the highest life span comparing to the other mills (56.53% and 51.%.). The study determined the quality control by using a specific chart which is EWMA chart; it also shows the correlation between failure time, quality control and capability process for OPC, SBC, and SRC only in (Year 3). For SRC, OPC and SBC, there have been (1584.17, 628.76 and 1389.15) hours of failure time which caused the cement not to pass the quality control for (115, 53 and 90) times. According The to capability indices of OPC, SBC and SRC it has been determined that in case of OPC because ($C_p > 1$) which is equal to (1.78), and (C_{pk}) 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 (C_p) is greater than (C_{pk}) value, While the process of SBC and SRC both are incapable because the (C_{pk}) value in both cases are less than one in which (C_{pk}) value of SBC and SRC are equal to (0.71 and 0.96).

Through this study 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. There for it mean that there is a good relationship between failure time and quality

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