Reliability Of Electrical Oven by Using Weibull -Three Parameters

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دراسة معولية الفرن الكهربائي باستخدام توزيع ويبل ذو الثلاث معالم

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تاريخ استلام البحث 2018/9/17

تاريخ قبول النشر 2018/10/9

Abstract:

One of the most statistical techniques that used to study and analyze the failure time of a system or a machine is reliability analysis, in this paper we studded and analyzed a series of failures times that occurs respectively in electrical oven performance of (Alfa steel) manufactory for steel industry that is located in Sulaimani city (Iraq), the data under study were (105) observations that has been recorded during three months.

using weibull++ software we got that the minimum failure time is (0.01) minute and the maximum reaches to (24) minutes it makes the reliability of the electrical oven decrease to (0.58) which is approximately fifty percentage of performance; It implies that the electrical oven is losing its efficiency.

Keywords: reliability analysis and Weibull three parameters distribution.

الخلاصة:

ان احدى اكثر التقنيات الاحصائية التي تستخدم في عصر الحديث هي تحليل المعولية في كثير من المجالات كالطبية و الهندسية و ... الخ ، في هذه الدراسة قمنا بدراسة و تحليل سلسلة من الفشل التي سجلت بشكل متتالي لفرن الكهربائي في مصنع (الفاستيل) لصناعة شيش وبليت الحديدية في محافظة السليمانية (العراق)، والبيانات الخاضعة للدراسة كانت (105) مشاهدة للعطل خلال ثلاث اشهر، و ظهر ان عينة الدراسة اتبعت توزيع ويبل ذو ثلاث معالم (القياس، الشكل، الموقع)، و ذلك تمت باستخدام برنامج احصائي الجاهز، ++ College of Commerce Weibull، فتوصلنا الى ان ادنى وقت للفشل تساوي (0.01) دقيقة واعلى وقت للفشل تصل الى (24) دقيقة، حيث احتمال المعولية عندما وقت الفشل تصل الى اعلى حد (24) دقيقة تساوي (0.58) و هذا تعني ان الفرن الكهربائي تفقد نصف كفاءته بشكى تقريبي.

الكلمات المفتاحية: الاحتمالات، المعولية، توزيع ويبل.

1-1 Introduction

Coreless induction furnace is the most widely used type of furnaces in the melt shops, and steel plants throughout the world, it’s known for its reputable heat efficiency and low emissions, as well as high production rate. Its main function is to transfer energy from the induction coil to the material inside and melting the material down by means of electromagnetic field; which in turn induces electric current inside (eddy currents) ultimately melting the material through a phenomena called joule heating. (Mann, Nancy R, 1974).

They feature simple design and construction, and have fewer parts in comparison to other types of furnaces, they’re mostly comprised of a crucible, inductor coil, and shell, cooling system, and tilting mechanism. The lining around the coil forms the crucible which contains the material to be melted, and the copper coils are hollow to allow water circulation to remove the heat generated during the process (IEEE, 1998).

Copper is known for its excellent electrical conductivity which possesses less resistance to the current flow on the other hand steel offer much more resistance to the flow of the current which leads to dissipating some of the electrical energy in the form of thermal energy and thus increasing the temperature of the steel and eventually melting it down (Jiang, R., Murthy, 2011).

Although coreless induction furnaces offer a variety of attractive features, there are some inherited drawbacks, for example the coils are getting clogged after a period of operation, which leads to a rise in temperature and bursting the coil in that spot due to pressure build up, this in addition to the wear of the interior walls of the coil due to the flow of the water inside which holds some certain amounts of salts which erodes the coils from the inside and creating a weak spot in the coil, making it vulnerable to failures.

The wear of the coil's refractory lining is another issue of these types of the furnaces, and they should be kept under careful monitoring as catastrophic consequences may arise in case of lining failure, such as bursting of the furnace while fully loaded in which molten metals are spewed to high altitudes, which may lead to fatal injuries in case of contacting a human flesh. Additionally there are other production/process related concerns such as inability to control the rates of Carbon, Sulphur, and Phosphorous, and relying heavily on the charge selection process to refine the materials and choosing less impurity (Rosin, P.; Rammler, 1993).

Despite of having all these drawbacks these types of furnaces are widely used across the world for their higher production capacities due to the absence of combustion source which leads to reduces the oxidation losses, flexibility in changing the end product as it's not dependent on the alloy type. The energy conservation is the most appealing part of it, as it's more efficient than the combustion type of furnaces requiring less time for heating up during the starting up phase, and less time to reach the required temperature between taps. Furthermore there are some more advantages for selecting these type of furnaces such as (faster startups, natural stirring, cleaner environment, less noise, compact installation) all of these features are reasons to favor the selection of coreless induction furnaces for steel plants across the globe (Jiang, R., Murthy, 2011).

Reliability is the probability of a contrivance or system performing its function adequately, for the period of time intended, under the operating conditions intended. Or it is the probability that a product or accommodation will operate opportunely for a designated period of time (design life) under the design operating conditions (such as temperature or voltage) without failure (Mendez, Michelle A, 2006).

The Weibull distribution is by far the world's most popular statistical model for life data. It is additionally utilized in many other applications, such as weather forecasting and fitting data of all kinds. Among all statistical techniques, it may be employed for engineering analysis with more minuscule sample sizes than any other method. And its distribution was first published in 1939, over 80 years ago and has proven to be invaluable for life data analysis in aerospace, automotive, electric potency, nuclear puissance, medical, dental, electronics, , (MIL-HDBK , 1996).

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 have one or more defects that cannot be detected in a simple inspection but that will eventually cause the component to fail (Meeker, William Q., 1987).

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.(Jason Allen Denton, 1999).

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 (Jean Nakamura, 2007).

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 (Rani, Rekha, 2011).

In (2013), PilarEspinet-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/Getriplejunction 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 (Espinet-González, Pilar, 2013).

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 (J. Appl. Environ 2015).

2-1 Reliability theory

In statistics tools of reliability is so important where the study relative to life time data, that provides measuring of probability for (*h(x)*) failure rate and reliability (life time), these mention can be calculated as follows (Muraleedharan, G.; Rao,2007).

1: *F(t)* this function can called cumulative distribution function that can be derived from the integral of the probability density function as follow: (NASA GSFC, 1996)

$$F(t) = \int_0^t f(\tau)d\tau \qquad (1)$$

2: *R(t)* It is a probability function gives the probability of an item or a system running for a certain interval of time without occurring any failure in the system. It can be calculated from interval of f(t) or from (1-F(t)) (Rosin, P, 1933).

$$R(t) = \int_t^\infty f(\tau)d\tau \qquad (2)$$

$$R(t) = 1 - F(t) \qquad (3)$$

3: *h(t)* failure ratio :It is also called hazard function this function is important for any probability studies, which is depended on the ratio of probability density function to reliability function in another word it has an inverse relationship with reliability function and positive relationship with probability density function, the hazard function is increased with increasing time of operating a system . It can be calculated as follow (Aerospace Report Number ,2007):

$$h(t) = \frac{f(t)}{R(t)} = \frac{f(t)}{1-F(t)} \qquad (4)$$

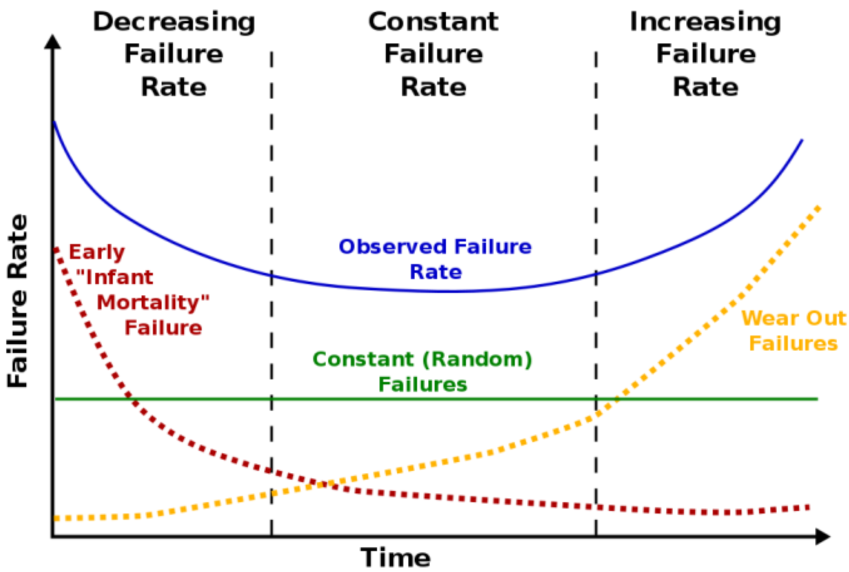


Figure (2-1)
Represents the bathtub curve of reliability

From the above figure that called that called "bathtub curve "the failure rate behavior can be shown in three parts where the first part if for "infant mortality" failure, second part is for random failure and the third part is for wear out failure (NSWC, 2006).

It is obvious from the first part the failure rate is decreasing; it means that the risk apart will fail decreases with increasing time, and the second part shows constant failure rate, but the third part show an increasing of failure rate with increasing time.

2-2 Weibull three parameter distributions

It is one of the continuous distributions that have the wildly using in life time studies such as reliability analysis. The most uses of this distribution is because of the sensitivity of its shape parameter which is gives adequate results (DoD, 1982).

In this study Weibull three parameters distribution have been used and the probability density function (f(x)), cumulative distribution function F(x), reliability function R(t) and hazard function h(t) are shown below (J. Appl. Environ, 2 015):

$$f(t)=\frac{\alpha}{\beta}\left(\frac{t-\gamma}{\beta}\right)^{\alpha-1}e^{-\left(\frac{t-\gamma}{\beta}\right)^{\alpha}} \qquad (5)$$

Where:

α : Is shape parameter, β Is scale parameter.

γ : Is location parameter.

$\alpha,\beta > 0$

$$F(t) = 1 - e^{-(\frac{t-\gamma}{\beta})^{\alpha}} \qquad (6)$$

$$R(t) = e^{-(\frac{t-\gamma}{\beta})^{\alpha}} \qquad (7)$$

$$h(t) = \frac{\alpha}{\beta}(\frac{t-\gamma}{\beta})^{\alpha-1} \qquad (8)$$

$$MTTF = \gamma+\beta\, \Gamma(\frac{1}{\alpha}+1) \qquad (9)$$

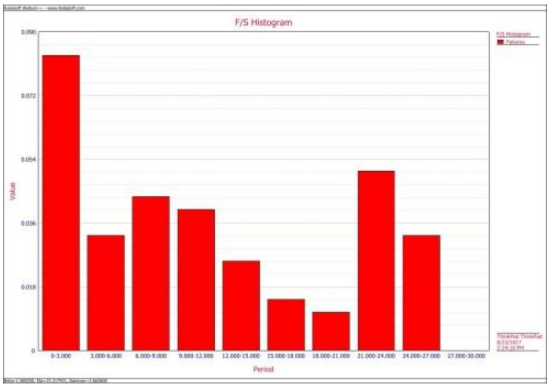
3.1 Applications

The daily failure time data of electrical oven for three month in different times tested to choose a suitable distribution, the analysis have been done by using Reliasoft Program (Weibull++) as shown in the table below:

Table number (1)
Rank of Distributions for electrical oven

<table>
<tr><th>Distribution</th><th>(DESV)(deviance)</th><th>Ranking</th></tr>
<tr><td>3P-Weibull</td><td>348</td><td>1</td></tr>
<tr><td>1P-Exponential</td><td>485</td><td>2</td></tr>
<tr><td>2P-Exponential</td><td>485</td><td>3</td></tr>
<tr><td>G-Gamma</td><td>510</td><td>4</td></tr>
<tr><td>Gamma</td><td>513</td><td>5</td></tr>
<tr><td>2P-Weibull</td><td>513</td><td>6</td></tr>
<tr><td>Normal</td><td>554</td><td>7</td></tr>
<tr><td>Parameters Calculated for 3P-Weibull Distribution:</td><td colspan="2" rowspan="2"></td></tr>
<tr><td>Start 3P-Weibull</td></tr>
<tr><td>(α)</td><td colspan="2">1.58025 Shape</td></tr>
<tr><td>(γ)</td><td colspan="2">-2.6626 location</td></tr>
<tr><td>(β)</td><td colspan="2">15.317931 scale</td></tr>
</table>

From the above table 1 it is obvious that the weibull 3-P has minimum DESV with the rank of number one then one can say that the failure time has a weibull 3-P distribution.



Histogram (1)
represents the probability of minutes of failure when the oven failed

The histogram (1) shows that the max failure time is occurred between time periods (0-3sec) and the minimum failure time is occurred between. time periods (18-21sec).

Figure number (1)
Represents the probability density function of the failure time.

From the above figure, it is clear that the probability failure is higher from the starting time period.

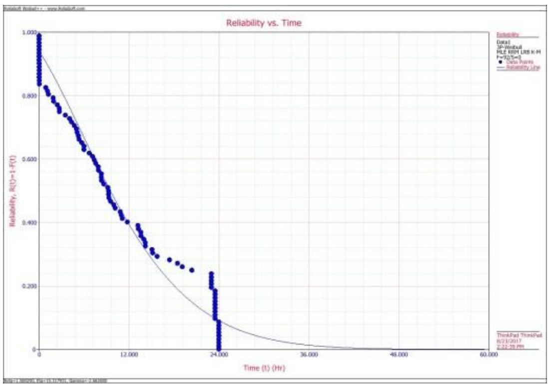


Figure number (2)
Represents the reliability of the oven.

It is obvious from figure (2) that the reliability is decrease with passing the time of starting the electrical oven.

Figure number (3)
Represents the cumulative distribution function of failure time

The above figure shows that the cumulative distribution function is increase with working the electric oven.

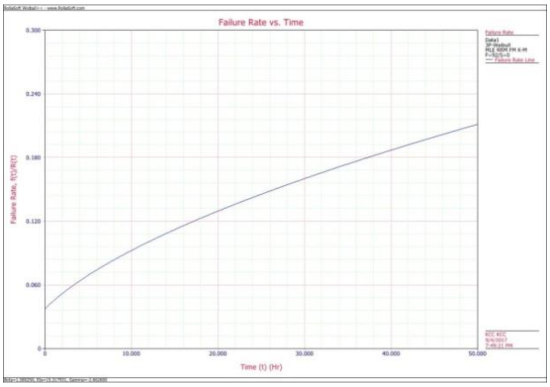


Figure number (4)
Represents the failure rate of the oven

It is clear from the above figure the hazard function is increase with working the electrical oven.

Table number (2)
Represented the calculation of R (t), h (t), f (t) and F (t) values.

Dare	Failure time	Reliability	Failure rate	Probability density function	cumulative distribution function
4/1/2017	8.3	0.5547	0.085	0.0471	0.4453
4/2/2017	8.63	0.5392	0.0864	0.0466	0.4608
4/3/2017	6	0.6661	0.0741	0.0494	0.3339
4/4/2017	7.57	0.5894	0.0816	0.0481	0.4106
4/5/2017	1.25	0.8907	0.0467	0.0416	0.1093
4/6/2017	0.01	0.9386	0.0375	0.0352	0.0614
4/7/2017	5.08	0.7116	0.0694	0.0494	0.2884
4/8/2017	8.35	0.5523	0.0852	0.0471	0.4477
4/9/2017	5	0.7156	0.069	0.0494	0.2844
4/10/2017	0.01	0.9386	0.0375	0.0352	0.0614

Dare	Failure time	Reliability	Failure rate	Probability density function	cumulative distribution function
4/11/2017	20.4	0.1482	0.1308	0.0194	0.8518
4/12/2017	0.01	0.9386	0.0375	0.0352	0.0614
4/13/2017	13.6	0.3331	0.1068	0.0356	0.6669
4/14/2017	9.55	0.4971	0.0905	0.045	0.503
4/15/2017	1.95	0.8607	0.0514	0.0443	0.1394
4/16/2017	0.01	0.9386	0.0375	0.0352	0.0614
4/17/2017	15.07	0.2836	0.1123	0.0319	0.7164
4/18/2017	23	0.1043	0.1392	0.0145	0.8957
4/19/2017	2.43	0.8391	0.0545	0.0457	0.161
4/20/2017	13.27	0.345	0.1056	0.0364	0.655
4/21/2017	14.17	0.3133	0.109	0.0341	0.6867
4/22/2017	0.9	0.905	0.0443	0.0401	0.095
4/23/2017	0.02	0.9383	0.0375	0.0352	0.0617
4/24/2017	11.78	0.402	0.0997	0.0401	0.598
4/25/2017	13.58	0.3339	0.1067	0.0356	0.6662
4/26/2017	9.28	0.5093	0.0893	0.0455	0.4907
4/27/2017	19.12	0.1748	0.1266	0.0221	0.8252
4/28/2017	4.07	0.7613	0.064	0.0487	0.2388
4/29/2017	23	0.1043	0.1392	0.0145	0.8957
4/30/2017	23	0.1043	0.1392	0.0145	0.8957
5/1/2017	0.01	0.9386	0.0375	0.0352	0.0614
5/2/2017	0.01	0.9386	0.0375	0.0352	0.0614
5/3/2017	0.01	0.9386	0.0375	0.0352	0.0614
5/4/2017	0.01	0.9386	0.0375	0.0352	0.0614
5/5/2017	4.32	0.749	0.0654	0.049	0.251
5/6/2017	0.02	0.9383	0.0375	0.0352	0.0617
5/7/2017	0.02	0.9383	0.0375	0.0352	0.0617
5/8/2017	0.02	0.9383	0.0375	0.0352	0.0617
5/9/2017	10.97	0.4353	0.0964	0.042	0.5647
5/10/2017	1.88	0.8637	0.051	0.044	0.1363
5/11/2017	8.3	0.5547	0.085	0.0471	0.4453
5/12/2017	17.42	0.2156	0.1207	0.026	0.7844
5/13/2017	24	0.0906	0.1423	0.0129	0.9094
5/14/2017	10.83	0.4412	0.0958	0.0423	0.5588
5/15/2017	24	0.0906	0.1423	0.0129	0.9094
5/16/2017	23	0.1043	0.1392	0.0145	0.8957
5/17/2017	23	0.1043	0.1392	0.0145	0.8957
5/18/2017	24	0.0906	0.1423	0.0129	0.9094
5/19/2017	18.48	0.1894	0.1244	0.0236	0.8106
5/20/2017	24	0.0906	0.1423	0.0129	0.9094
5/21/2017	24	0.0906	0.1423	0.0129	0.9094
5/22/2017	24	0.0906	0.1423	0.0129	0.9094

Dare	Failure time	Reliability	Failure rate	Probability density function	cumulative distribution function
5/23/2017	24	0.0906	0.1423	0.0129	0.9094
5/24/2017	23.5	0.0973	0.1407	0.0137	0.9027
5/25/2017	23.5	0.0973	0.1407	0.0137	0.9027
5/26/2017	23.5	0.0973	0.1407	0.0137	0.9027
5/27/2017	15.75	0.2625	0.1148	0.0301	0.7375
5/28/2017	23.5	0.0973	0.1407	0.0137	0.9027
5/29/2017	23.5	0.0973	0.1407	0.0137	0.9027
5/30/2017	23.5	0.0973	0.1407	0.0137	0.9027
5/31/2017	23.5	0.0973	0.1407	0.0137	0.9027
6/1/2017	23.5	0.0973	0.1407	0.0137	0.9027
6/2/2017	23.5	0.0973	0.1407	0.0137	0.9027
6/3/2017	9.97	0.4783	0.0923	0.0441	0.5217
6/4/2017	7.15	0.6098	0.0797	0.0486	0.3903
6/5/2017	24	0.0906	0.1423	0.0129	0.9094
6/6/2017	5.7	0.681	0.0726	0.0495	0.319
6/7/2017	13.98	0.3198	0.1083	0.0346	0.6802
6/8/2017	14.2	0.3123	0.1091	0.0341	0.6878
6/9/2017	5.33	0.6993	0.0707	0.0495	0.3007
6/10/2017	0.02	0.9383	0.0375	0.0352	0.0617
6/11/2017	0.02	0.9383	0.0375	0.0352	0.0617
6/12/2017	0.02	0.9383	0.0375	0.0352	0.0617
6/13/2017	10.97	0.4353	0.0964	0.042	0.5647
6/14/2017	1.88	0.8637	0.051	0.044	0.1363
6/15/2017	8.3	0.5547	0.085	0.0471	0.4453
6/16/2017	17.42	0.2156	0.1207	0.026	0.7844
6/17/2017	24	0.0906	0.1423	0.0129	0.9094
6/18/2017	10.83	0.4412	0.0958	0.0423	0.5588
6/19/2017	24	0.0906	0.1423	0.0129	0.9094
6/20/2017	23	0.1043	0.1392	0.0145	0.8957
6/21/2017	23	0.1043	0.1392	0.0145	0.8957
6/22/2017	24	0.0906	0.1423	0.0129	0.9094
6/23/2017	18.48	0.1894	0.1244	0.0236	0.8106
6/24/2017	24	0.0906	0.1423	0.0129	0.9094
6/25/2017	24	0.0906	0.1423	0.0129	0.9094
6/26/2017	24	0.0906	0.1423	0.0129	0.9094
6/27/2017	24	0.0906	0.1423	0.0129	0.9094
6/28/2017	23.5	0.0973	0.1407	0.0137	0.9027
6/29/2017	23.5	0.0973	0.1407	0.0137	0.9027
6/30/2017	23.5	0.0973	0.1407	0.0137	0.9027
7/1/2017	15.75	0.2625	0.1148	0.0301	0.7375
7/2/2017	23.5	0.0973	0.1407	0.0137	0.9027
7/3/2017	23.5	0.0973	0.1407	0.0137	0.9027

Dare	Failure time	Reliability	Failure rate	Probability density function	cumulative distribution function
7/4/2017	23.5	0.0973	0.1407	0.0137	0.9027
7/5/2017	23.5	0.0973	0.1407	0.0137	0.9027
7/6/2017	23.5	0.0973	0.1407	0.0137	0.9027
7/7/2017	23.5	0.0973	0.1407	0.0137	0.9027
7/8/2017	9.97	0.4783	0.0923	0.0441	0.5217
7/9/2017	7.15	0.6098	0.0797	0.0486	0.3903
7/10/2017	24	0.0906	0.1423	0.0129	0.9094
7/11/2017	5.7	0.681	0.0726	0.0495	0.319
7/12/2017	13.98	0.3198	0.1083	0.0346	0.6802
7/13/2017	14.2	0.3123	0.1091	0.0341	0.6878

4- Result and dictation

Depending on the results in table (2) we conclude that when the failure time is minimum (0.01) the reliability of the electrical oven decreased to (0.998), and when it reaches to (24) minutes the reliability of performance decreasing to (0.58) where it is close to fifty percentage of performance, that is because of the electrical oven is depending on pipers of water to cooling its self, also the failure rate is reaches to (0.1423)when the failure time is maximum (24) minutes that means the production will be less than expected because of decreasing performance of the electrical oven.

5- Recommendations

Through the results of this study, the researchers recommended the manufactory engineer staff to control the failure through cleaning the tubes of water around the oven and trying to start training courses for the staff that has the responsibility of controlling the oven.

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