4.1: Introduction

This chapter includes the applied aspect to what explained in the theoretical chapter and we will describe the data , test the distribution of the data , estimate renewal process model and lifetime test in this chapter.

4.2: Description of study's data

We applied this study on bahri thermal station which was established in 1981 with two machines developed to six machines such:

Machine no(1) productive power 30 mw/D

Machine no(2) productive power 30 mw/D

Machine no(3) productive power 60 mw/D

Machine no(4) productive power 60 mw/D

Machine no(5) productive power 100 mw/D

Machine no(6) productive power 100 mw/D

The data of this study have been collocated for five machines with exceptional to the machine no(2) because it had never got fault in duration of the study. The sample size has been determined according to the method that not tided to the number of time of failure occurs condition for each machine. The technical fault data collected from the efficiency department in the station and it was (type of machine, time of stopping, time of return, failure time , times between failures and power loss) during the period (2011-2015).

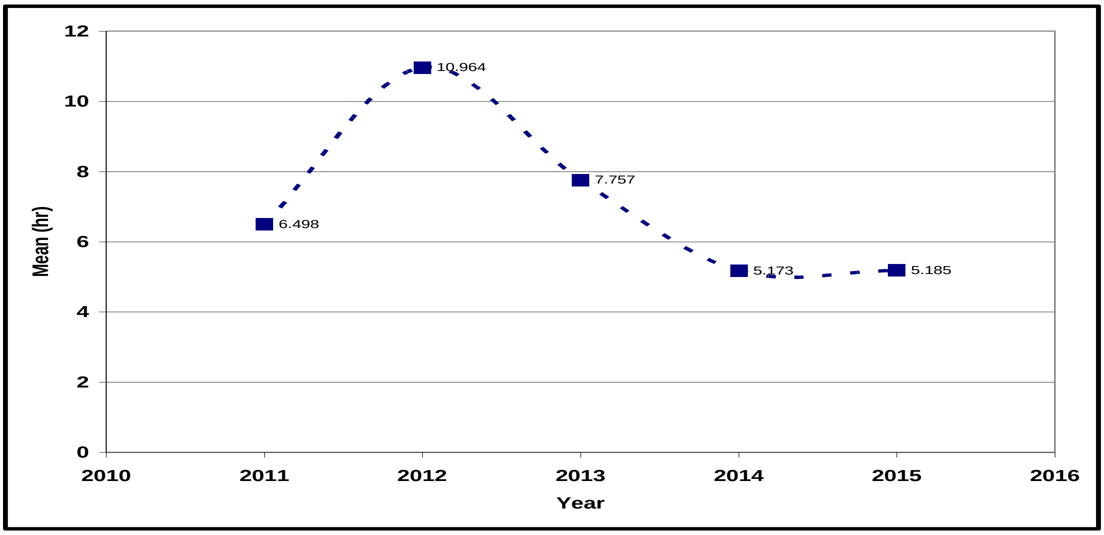
There are two types of faults there are mechanical faults and the faults due to preventive maintenance in this study we applied the data of mechanical faults.

4.2.1: Failure time:

Table (4.1): Annual rates for the failure times of the machines (hr) for the period (2011-2015)

Year	*Mean(hr)*	*Std. Deviation(hr)*	*95% Confidence Interval for Mean*	
			Lower Bound	*Upper Bound*
2011	6.498	11.217	3.466	9.531
2012	10.964	13.314	7.140	14.788
2013	7.757	12.322	4.601	10.912
2014	5.173	5.174	2.988	7.358
2015	5.185	3.376	3.145	7.226
Mean	7.720	11.374	6.142	9.298

Source: The researcher from applied study, SPSS Package, 2015



Source: The researcher from applied study, Excel Package, 2015

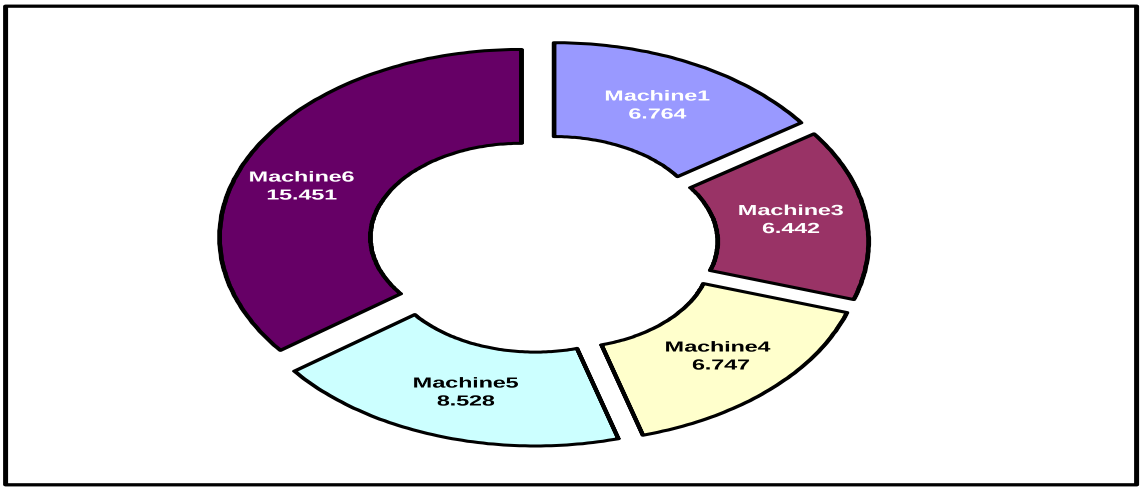
Fig (4.1): Annual rates for the failure times of the machines (hr) for the period (2011-2015)

From above table and figuer, it has been shown that the mean time of failure for Bahri Thermal Station, decreased gradually until the year (2014), and then increases exponentially during the period (2011-2015), the reason refers to the quality of spare parts.

Table (4.2): Rates of failure times for each machines

Machine	***Mean(hr)***	***Std. Deviation(hr)***	***95% Confidence Interval for Mean***	
			Lower Bound	***Upper Bound***
Machine1	6.764	9.249	9.249	10.217
Machine3	6.442	9.023	9.023	9.153
Machine4	6.747	11.808	11.808	9.263
Machine5	8.528	10.719	10.719	13.545
Machine6	15.451	15.174	15.174	22.552
Mean	7.720	11.374	11.374	9.298

Source: The researcher from applied study, SPSS Package, 2015



Source: The researcher from applied study, Excel Package, 2015

Figure (4.2): Rates of failure times for each machine

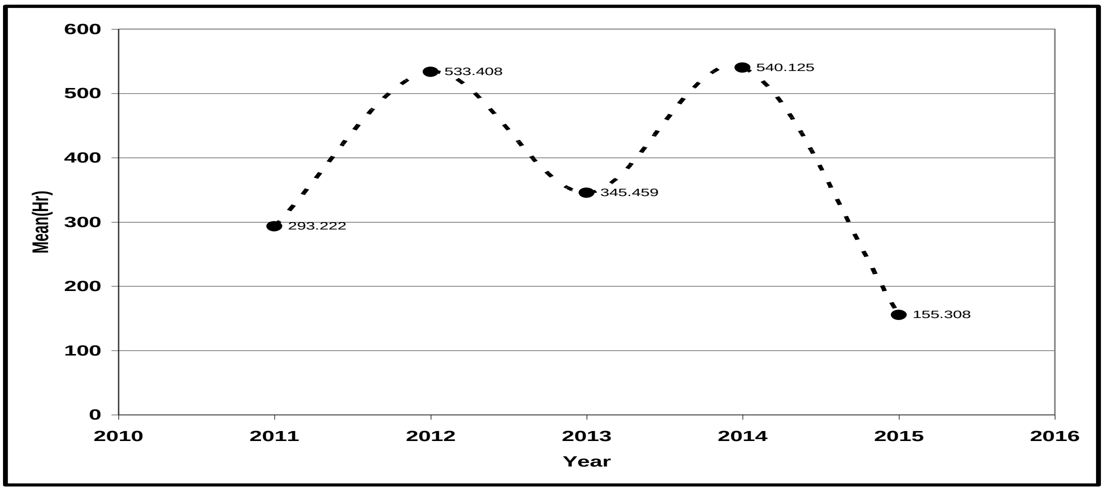
From above table and figuer, it has been shown that according to the mean values for the five machines ,the machine(6) have the highest mean failure time depending on the value of the largest mean (15.45) hours, followed by machine(5) depending on the value of the second largest mean (8.53) hours, followed by machine(1) depending on the value of the third largest mean (6.76) hours, lastly machine(1) and machine(4) (6.76) and (6.75) respectively.

4.2.2: Between failure time:

Table (4.3): ***Annual rates for the time between failures machines (hr) for the period (2011-2015)***

Year	*Mean(hr)*	*Std. Deviation(hr)*	*95% Confidence Interval for Mean*	
			Lower Bound	*Upper Bound*
2011	293.222	463.350	167.961	418.483
2012	533.408	600.911	360.806	706.010
2013	345.459	549.323	204.771	486.147
2014	540.125	800.033	202.301	877.949
2015	155.308	245.500	6.954	303.662
Mean	387.719	570.308	308.595	466.842

Source: The researcher from applied study, SPSS Package, 2015



Source: The researcher from applied study, Excel Package, 2015

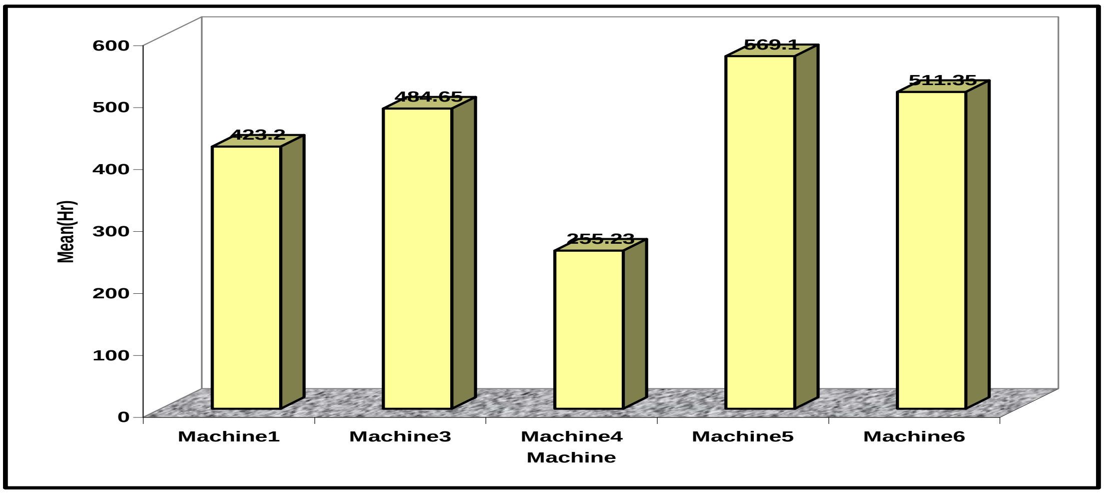
Figure (4.3): Annual rates for the time between failures machines (hr) for the period (2011-2015)

The table and figure, shows the work time for each machine for period (2011-2015).in (2011) the work time of the machine reached (293.22) hours, in (2012) the work time of the machine increased to (533.408) hours, in (2013) decreased to (345.459), then increased in (2014) to (540.125) hours, however in (2015) decreased sharply to (155.304) hours. This indicated to fualts of the machine increased with period long.

Table No(4-4): Rates for the time between failures of machines (hr)

Machine	***Mean(hr)***	***Std. Deviation(hr)***	***95% Confidence Interval for Mean***	
			Lower Bound	***Upper Bound***
Machine1	423.20	660.447	176.59	669.81
Machine3	484.65	653.594	288.29	681.02
Machine4	255.23	327.709	185.38	325.07
Machine5	569.10	599.228	288.65	849.55
Machine6	511.35	886.153	96.62	926.08
Mean	387.72	570.308	308.60	466.84

Source: The researcher from applied study, SPSS Package, 2015



Source: The researcher from applied study, Excel Package, 2015

Figure (4.4): Rates for the time between failures of the machines (hr)

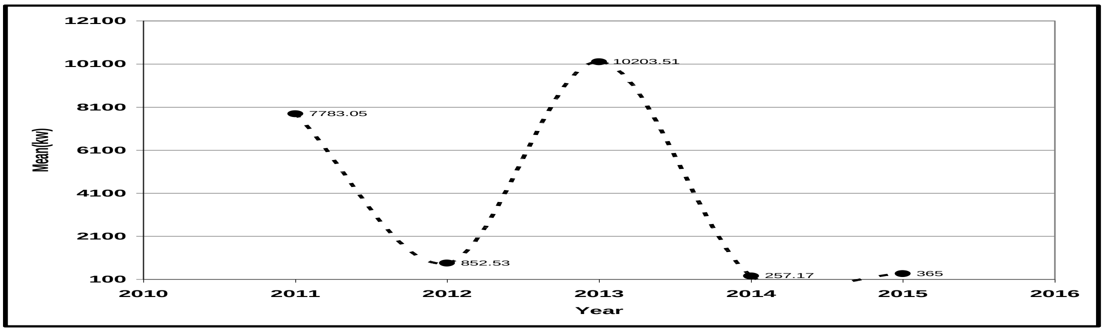
From table and figuer, it has been shows that according to the mean values for the five machines ,the machine(5) have the highest mean for working time depending on the value of the largest mean (569.10) hours, followed by machine(6) depending on the value of the second largest mean (511.35) hours, followed by machine(3) depending on the value of the third largest mean (484.65) hours, followed by machine(1) depending on the value of the third largest mean (423.20) hours and lastly the machine(4) has alow mean (255.23) hours.

4.2.3: Power loss

Table (4.5): Annual rates for the power loss of the machines for the period (2011-2015)

Year	***Mean(kw)***	***Std. Deviation(kw)***	***95% Confidence Interval for Mean***	
			Lower Bound	***Upper Bound***
2011	7783.05	11170.936	4763.13	10802.98
2012	852.53	1346.781	465.69	1239.37
2013	10203.51	17392.126	5749.18	14657.84
2014	257.17	259.879	147.43	366.90
2015	365.00	342.468	158.05	571.95
Mean	5461.25	11944.012	3804.16	7118.34

Source: The researcher from applied study, SPSS Package, 2015



Source: The researcher from applied study, Excel Package, 2015

Figure* (4.5): *Annual rates for the power loss of the machines for the period (2011-2015)

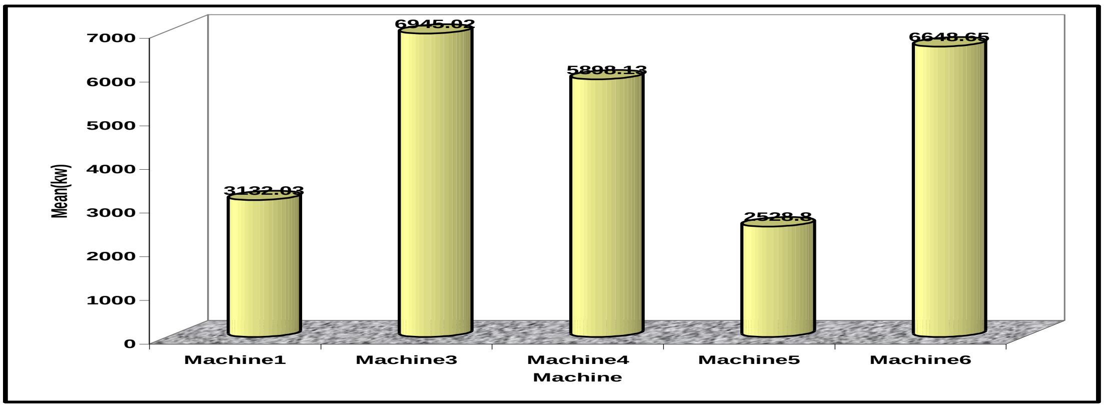
The table and figure, shows the power loss caused by fault of the machines for period (2011-2015).in (2011) the power loss of the machines reached (7783.05) kw, in (2012) the power loss of the machines decreased to (852.53) kw, in (2013) increased to (10203.51), then decreased deramatically in (2014) to (257.17) kw, in (2015) increased slightly to to

(365.00) kw. This indicated to the fualts are unconstant there is no main trend exist.

Table (4.6): Rates for the power loss of the machines (kw)

Machine	***Mean(kw)***	***Standard. deviation(kw)***	***95% Confidence Interval for Mean***	
			Lower Bound	***Upper Bound***
Machine1	3132.03	6553.157	685.04	5579.02
Machine3	6945.02	14996.316	2439.63	11450.41
Machine4	5898.13	12767.361	3177.03	8619.22
Machine5	2528.80	2369.602	1419.79	3637.81
Machine6	6648.65	12418.708	836.52	12460.78
Mean	5461.25	11944.012	3804.16	7118.34

Source: The researcher from applied study, SPSS Package, 2015



Source: The researcher from applied study, Excel Package, 2015

Figure (4.6): Rates for the power loss of the machines (kw)

From table and figure, it has been shows that according to the mean values for the five machines ,the machine(3) have the highest mean for power loss depending on the value of the largest mean (6945.02) kw, followed by machine(6) depending on the value of the second largest mean (6648.65) kw, followed by machine(4) depending on the value of the third largest mean (5898.13) kw, followed by machine(1) depending on the value of the third largest mean (3132.03) kw and lastly the machine(5) has low mean (252880.) kw.

4.3: Model for machine no(1)

Here we test the following hypothesis:

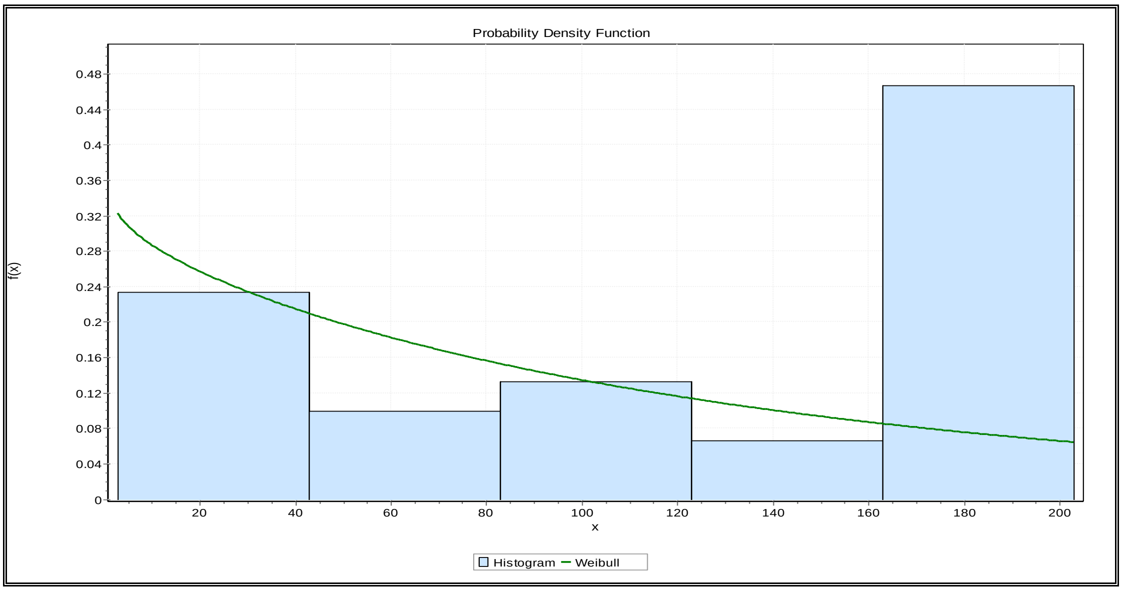
H_o: The failure data follow Weibull distribution

H_1: The failure data not follow Weibull distribution

Table (4.7): Kolmogorov-Smirnov test for machine no(1)

Test	*Statistic*	*Sample Size*	*P-value*
Kolmogorov-Smirnov	0.23796	30	0.05595

Source: The researcher from applied study, Easyfit Package, 2015



Source: The researcher from applied study, Easyfit Package, 2015

Figure (4.7): density funcation of Weibull Vs time for machine no(1)

From above table, it shows the p-value of Kolmogorov-Smirnov test (0.05595) is greater than significant level (0.05) that mean the failure time data of machine no(1) follow Weibull distribution with 2-parameters.

4.3.1:Renewal Process Model:

For estimating Renewal Process model, we must test the time trend whether exists or not , and determine if the Process represent homogeneous Poisson process (HPP) or non-homogeneous Poisson Process (NHPP). used laplace test as:

H_o: No time trend exist (HPP)

H_1: Time trend exist (NHPP)

Table (4.8): Laplace Test for machine no (1)

Test	***Statistic***	***P-value***
Laplace	1.39377	0.163387

Source: The researcher from applied study, STATGRAPHIC Package, 2015

From above table, it shows the p-value of Laplace test (0.163387) is greater than significant level (0.05), that mean no time trend exist and the Process is homogeneous Poisson process (HPP).that means rate of renewals (repair) of machine no(1) is constant ,The following table shows estimate of renewal process model:

Table (4.9): Result of Renewal Process model for machine no(1)

Parameter (Weibull)	***Value***	***Repair rate (ROCOF)***
$\hat{\alpha}$	0.916457	0.149246
$\hat{\beta}$	6.43011	

Source: The researcher from applied study, STATGRAPHIC Package, 2015

Mean cumulative renewals model: 0.149246*t

Table (4.10): Mean cumulative events Renewal Process model for machine no(1)

t	***Rate***	***Mean cum events***	***Mean interevent time***
0	0.149246	0.0000	6.70036
48	0.149246	7.16379	6.70036
96	0.149246	14.3276	6.70036
144	0.149246	21.4914	6.70036
192	0.149246	28.6552	6.70036
240	0.149246	35.8189	6.70036

Source: The researcher from applied study, STATGRAPHIC Package, 2015

From the table (4.10), it has been shown that:

- The repair rate or rate of occurrence of failure (ROCOF) for machine no(1) equal (0.149246) is constant and mean time between failure equals (6.70036) renewals (repair).
- The number of renewals occurred at (t=48 hr) equals approximately (7) renewals during (2011-2015).
- The number of renewals occurred at (t=96 hr) equals approximately (14) renewals during (2011-2015).
- The number of renewals occurred at (t=144 hr) equals approximately (21) renewals during (2011-2015).
- The number of renewals occurred at (t=192 hr) equals approximately (27) renewals.
- The number of renewals occurred at (t=240 hr) equals approximately (36) renewals.

Form above result we notice that renewals increased by fixed rate that means there are more faults.

4.3.2: Goodness-of-Fit Test model :

H_o: The underlying distribution of the renewal process is Weibull

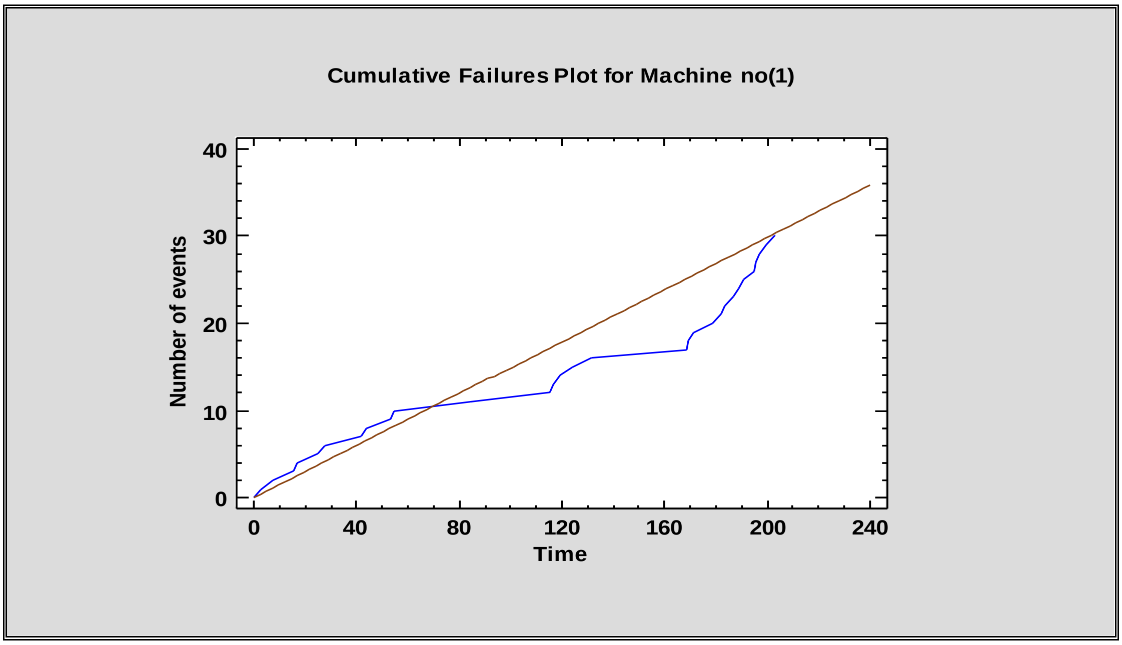
H_1: The underlying distribution of the renewal process is not Weibull

Table no(4.11): Goodness-of-Fit Test for machine no(1)

Test	*Statistic*	*P-value*
Kolmogorov-Smirnov	0.186259	0.249717

Source: The researcher from applied study, STATGRAPHIC Package, 2015

From above table, it shows the p-value of Kolmogorov-Smirnov test (0.249717) is greater than significant level (0.05), that mean the underlying distribution of the renewal process is Weibull. This indicates that the time of replacing parts is stationary Poisson regenerative process.



Source: The researcher from applied study, STATGRAPHIC Package, 2015

Figure (4.8): Cumulative number of failure Vs time for machine no (1)

From figure no (4.8), shows the cumulative number of failure for renewal process model it provides best fit for this data and number of renewals is increased by time.

From above the rate of repair is constant with $\lambda = 0.119365$ the homogeneous Poisson process model as:

$$P\left[N(t) = k\right] = \frac{(0.149246\ \mathrm{t})^{k} e^{0.149246\ t}}{k\,!}$$

***4.3.3: Lifetime Model*:**

The lifetime test has been conducted for machine no(1) for a period of time (100 hours) and the following measure has been calculated:

Table (4.12): Result of Life time test for machine no(1)

Measure	*Value*
Distribution of fault $f\ (t)$	0.51858
Reliability $R(t)$	0.48142
Hazard rate $h(t)$	1.07719
Availability	0.98

Source: The researcher from applied study, STATGRAPHIC Package, 2015

From the table (4.12), it has been shown that:

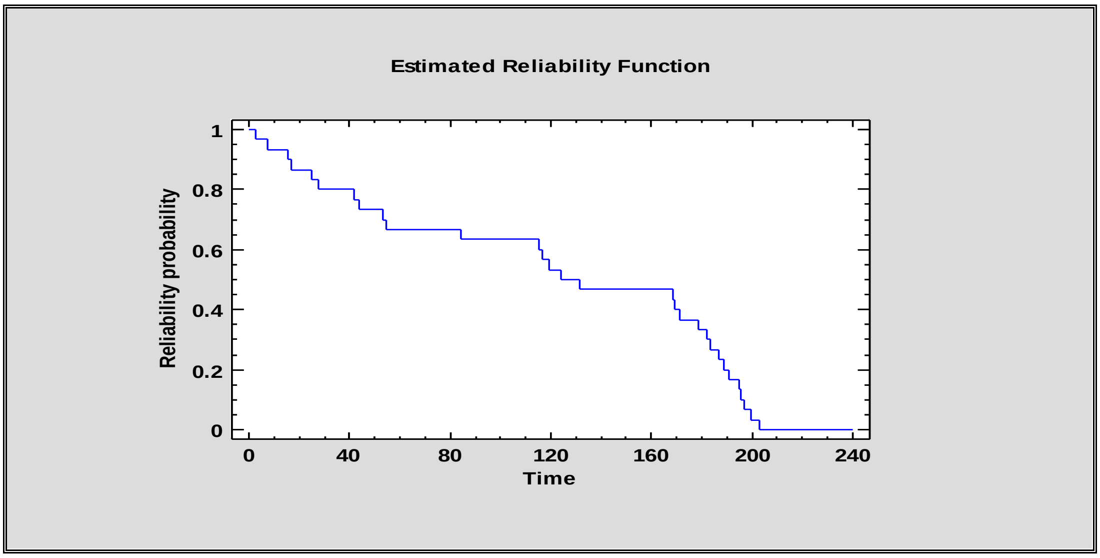
- The probability fault of the machine no(1) is $f(t = 100) = 0.51858$ during (100) hours, this indicate the probability fault of machine no(1) is very high during this period.
- The reliability, for machine no(1) is $R(t = 100) = 0.48142$ it is weak reliability. this mean that the probability for machine to work for (100) hours without fault is (0.48) .
- The rate of randomly fault occurred for machine no(1) $h(t = 100) = 1.07719$, that indicated the rate that occurred fault randomly during (100) hours is very high .
- The probability of available time to repair machine no(1) when it fault is (0.98),that indicates this machine has high availability.

Table (4.13): Life Tables (Times) for machine no(1)

Time	***Reliability*** $R(t)$	***Cum.Hazard*** $h(t)$
0	1	0.000
100	0.48142	0.73103
200	0.24286	1.4153
300	0.12457	2.0829
400	0.06457	2.7400
500	0.03373	3.3893
600	0.01773	4.0326

Source: The researcher from applied study, STATGRAPHIC Package, 2015

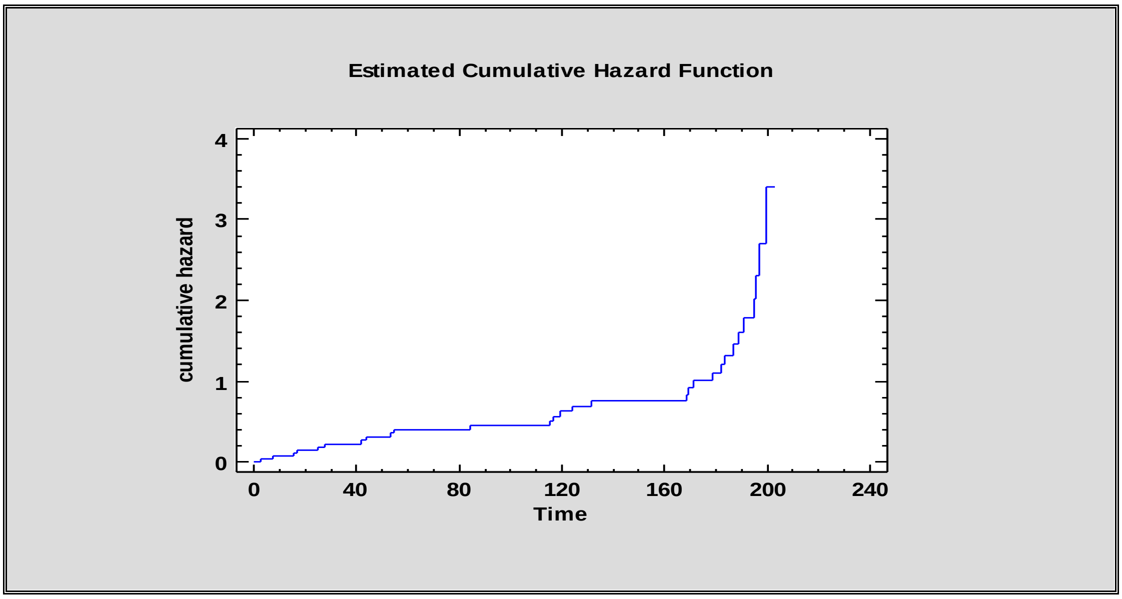
From the table (4.13), it has been shown that The reliability decreases whenever the working time of the machine increase. When the time (t=100) hours the reliability is about (48%), at time (t=200) hours the reliability is about (24%), at time (t=300) hours the reliability (12%), at time (t=400) hours the reliability is about (6%), at time (t=500) hours the reliability is about (3%), at time (t=600) hours the reliability is about (2%).The hazard rate increases whenever the working time increases too.



Source: The researcher from applied study, Easyfit Package, 2015

Figure (4.9): Reliability funcation Vs time for machine no(1)

From the Figure (4.9), it has shown that The reliability decreases whenever the working time of the machine increase in till equal zero.



Source: The researcher from applied study, Easyfit Package, 2015

Figure (4.10): Cumulative hazard funcation Vs time for machine no(1)

From the Figure (4.10),the hazard funcation increases whenever the working time increases too.

4.4: Model for machine no(3)

To test whether this data follow Weibull distribution or not we used Kolmogorov-Smirnov test as the following:

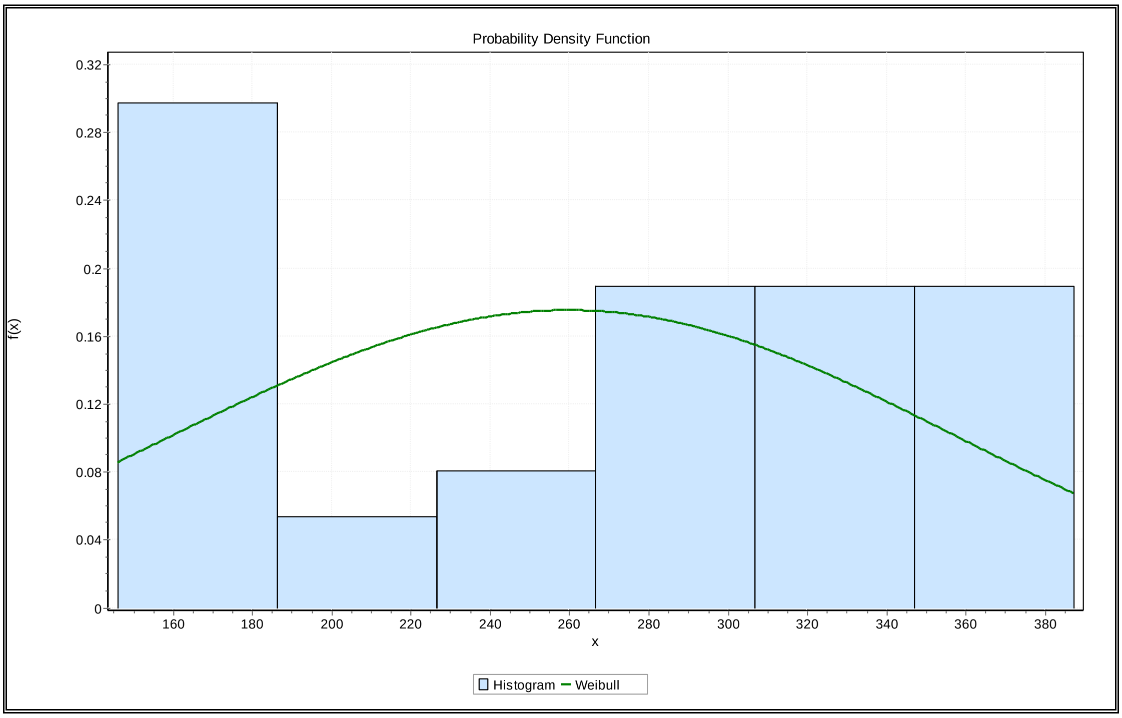
H_o: The failure time data follow Weibull distribution

H_1: The failure time data not follow Weibull distribution

Table (4.14): Kolmogorov-Smirnov test for machine no(3)

Test	***Statistic***	***Sample Size***	***P-value***
Kolmogorov-Smirnov	0.13482	44	0.47132

Source: The researcher from applied study, Easyfit Package, 2015



Source: The researcher from applied study, Easyfit Package, 2015

Figure (4.11): density funcation of Weibull Vs time for machine no(3)

From above table, it shows the p-value of Kolmogorov-Smirnov test (0.47132) is greater than significant level (0.05) that mean the failure time data of machine no(3) follow Weibull distribution with 2-parameters and its shape look like a bend bell in case ($B > 1$).

4.4.1:Renewal Process Model:

For estimating Renewal Process model, we must test the time trend whether exists or not , and determine if the Process represent homogeneous Poisson process (HPP) or non-homogeneous Poisson Process (NHPP). used laplace test as:

H_o: No time trend exists (HPP)

H_1: Time trend exists (NHPP)

Table no(4.15): Laplace Test for machine no(3)

Test	***Statistic***	***P-value***
Laplace	1.90625	0.056617

Source: The researcher from applied study, STATGRAPHIC Package, 2015

From above table, it shows the p-value of Laplace test (0.056617) is greater than significant level (0.05), that means no time trend exist and the Process is homogeneous Poisson process (HPP).that means rate of renewals (repair) is constant .The following table shows estimate of renewal process model:

Table (4.16): Result of Renewal Process model for machine no(3)

Parameter (Weibull)	***value***	***Repair rate (ROCOF)***
$\hat{\alpha}$	0.771699	0.119365
$\hat{\beta}$	7.19846	

Source: The researcher from applied study, STATGRAPHIC Package, 2015

Mean cumulative renewals model: 0.119365 *t

Table (4.17): Mean cumulative renewals Process model for machine no(3)

Cum.time(t)	***Rate***	***Mean cum renewal***	***Mean time between failure (MTBF)***
0	0.119365	0.000	8.37763
80	0.119365	9.54924	8.37763
160	0.119365	19.0985	8.37763
240	0.119365	28.6477	8.37763
320	0.119365	38.1969	8.37763
400	0.119365	47.7462	8.37763

Source: The researcher from applied study, STATGRAPHIC Package, 2015

From the table (4.17), it has been shown that:

- The repair rate or rate of occurrence of failure (ROCOF) for machine no(3) equal (0.11936) is constant and mean time between failure equals (8.37763) renewals (repair).
- The number of renewals occurred at (t=80 hr) equals approximately (10) renewals during (2011-2015).

- The number of renewals occurred at (t=160 hr) equals approximately (19) renewals during (2011-2015).
- The number of renewals occurred at approximately (t=240 hr) equals (29) renewals during (2011-2015).
- The number of renewals occurred at (t=400 hr) equals approximately (48) renewals.

For above result we notice that renewals increased by fixed rate that mean there are more faults.

4.4.2: Goodness-of-Fit Test model:

H_o: The underlying distribution of the renewal process is Weibull

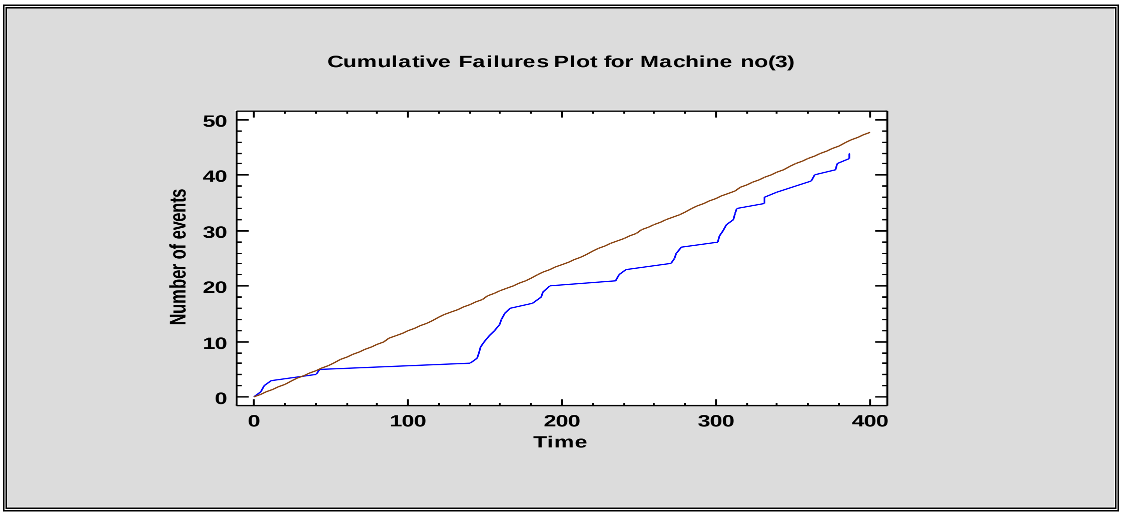
H_1: The underlying distribution of the renewal process is not Weibull

Table (4.18): Goodness-of-Fit Test for machine no(3)

Test	*Statistic*	*P-value*
Kolmogorov-Smirnov	0.200644	0.0578703

Source: The researcher from applied study, STATGRAPHIC Package, 2015

From above table, it shows the p-value of Kolmogorov-Smirnov test (0.0578703) is greater than significant level (0.05). that mean the underlying distribution of the renewal process is Weibull. This indicates that the time of replacing parts is stationary Poisson regenerative process.



Source: The researcher from applied study, STATGRAPHIC Package, 2015

Figure (4.12): Cumulative number of failure Vs time for machine no(3)

From figure (4.12), shows the cumulative number of failure for renewal process model it provides best fit for this data.

From above the rate of repair is constant with $\lambda = 0.119365$ the homogeneous Poisson process model as:

$$P\left[N(t)=k\right]=\frac{(0.119365\ \mathrm{t})^{k} e^{0.119365\ \mathrm{t}}}{k\,!}$$

4.4.3: Lifetime Model:

The lifetime test has been conducted for machine no (3) for a period of time (100 hours) and the following measure has been calculated:

Table (4.19): Result of Life time test for machine no(3)

Measure	***Value***
Distribution of fault $f(t)$	0.28492
Reliability $R(t)$	0.71508
Hazard rate $h(t)$	0.39844
Availability	0.97

Source: The researcher from applied study, STATGRAPHIC Package, 2015

From the table (4.19), it has been shown that:

- The probability fault of the machine no(3) is $f(t=100)=0.28492$ during (100) hours .this indicate the probability fault of machine no(1) is low during this period.
- The reliability for machine no(3) is $R(t=100)=0.71508$ it is weak reliability. This means that the probability for machine to work for (100) hours without fault is (0.72), the reliability is very high.
- The rate of randomly fault occurred for machine no(1) $h(t=100)=0.39844$. That indicates the rate that occurred fault randomly during (100) hours is low .

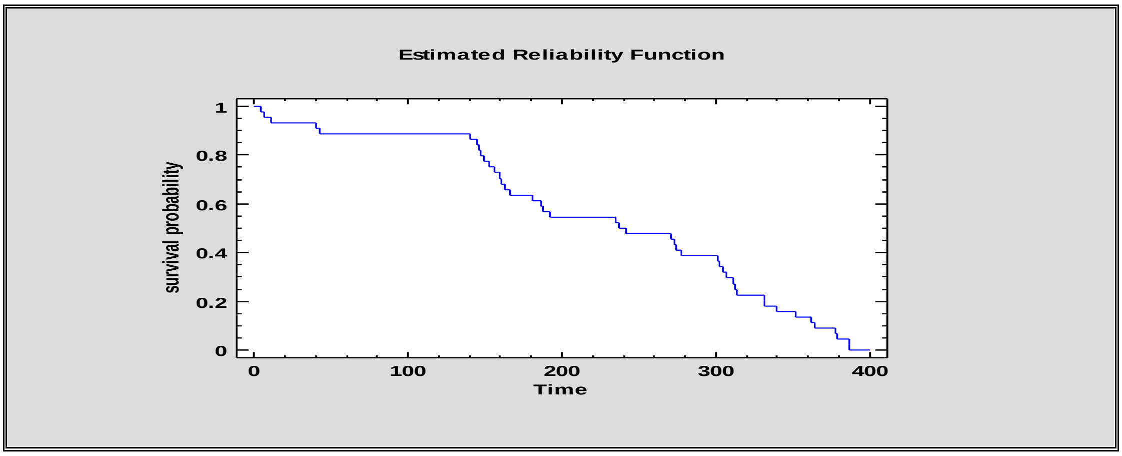
- The probability of available time to repair machine no(3) when it fault is (0.97),that indicates this machine has high availability.

Table (4.20): Life Tables (Times) for machine no(3)

Time	***Reliability*** $R(t)$	***Cum.Hazard*** $h(t)$
0	1	0.000
100	0.71508	0.33536
200	0.50892	0.67547
300	0.36153	1.0174
400	0.25653	1.3605
500	0.18186	1.7045
600	0.12883	2.0492

Source: The researcher from applied study, STATGRAPHIC Package, 2015

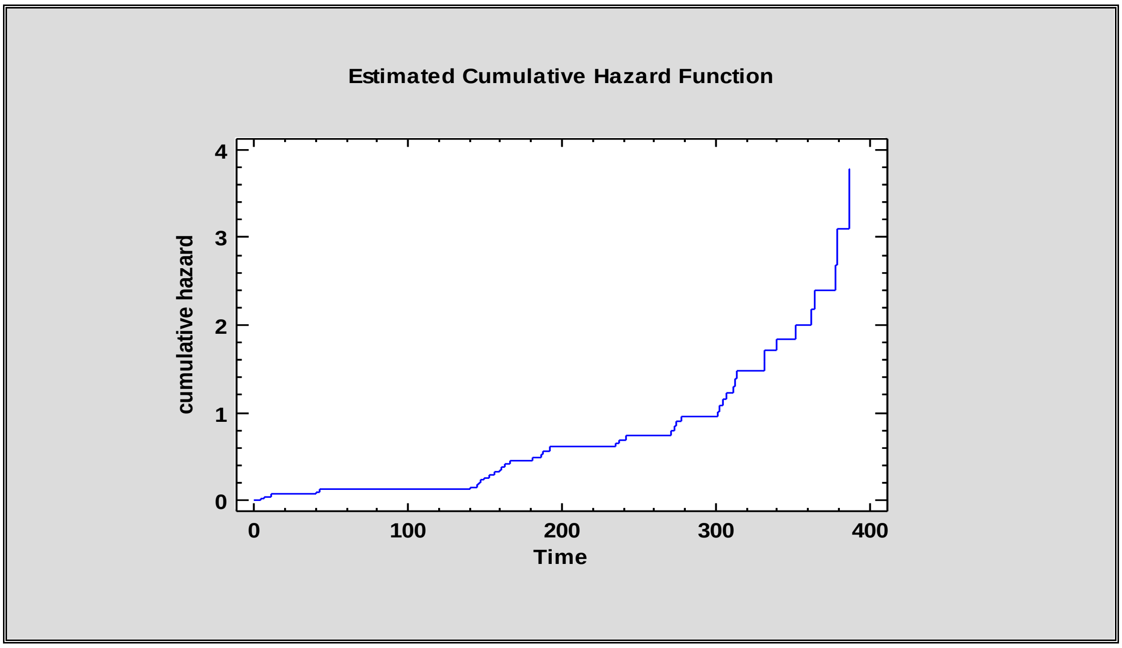
From the table (4.20), it has been shown that The reliability decreases whenever the working time of the machine increase. When the time (t=100) hours the reliability is about (72%), at time (t=200) hours the reliability is about (51%), at time (t=300) hours the reliability (36%), at time (t=400) hours the reliability is about (25%), at time (t=500) hours the reliability is about (18%), at time (t=600) hours the reliability is about (13%).The hazard funcation increases whenever the working time increases too.



Source: The researcher from applied study, STATGRAPHIC Package, 2015

Figure (4.13): Reliability funcation Vs time for machine no(3)

From the Figure (4.13), it has been shown that the reliability decreases whenever the working time of the machine increase in till equal zero.



Source: The researcher from applied study, STATGRAPHIC Package, 2015

Figure no(4.14): Cumulative hazard funcation Vs time for machine no(3)

From the Figure no (4.11),the hazard funcation increases whenever the working time increases too.

4.5: Model for machine no(4)

Here we test the following hypothesis**:**

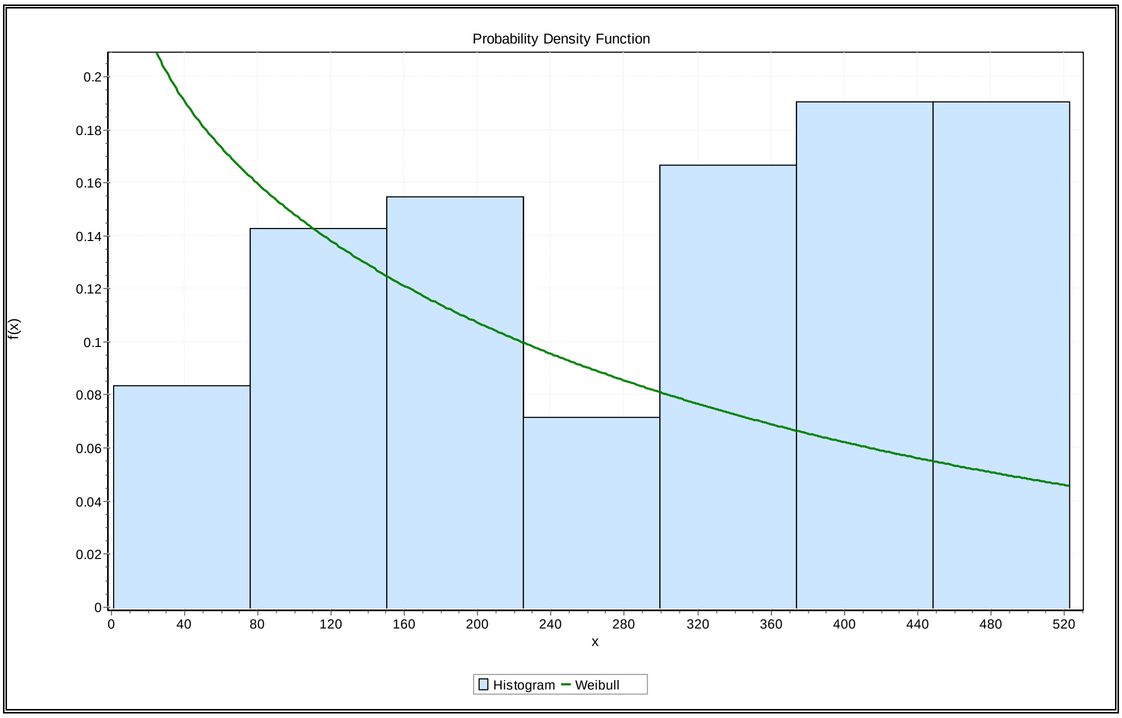
H_o: The failure time data follow Weibull distribution

H_1: The failure time data not follow Weibull distribution

Table (4.21): Kolmogorov-Smirnov test for machine no(4)

Test	***Statistic***	***Sample Size***	***P-value***
Kolmogorov-Smirnov	0.13482	84	0.41859

Source: The researcher from applied study, Easyfit Package, 2015



Source: The researcher from applied study, Easyfit Package, 2015

Figure (4.15): density funcation of Weibull Vs time for machine no(4)

From above table, it shows the p-value of Kolmogorov-Smirnov test (0.41859) is greater than significant level (0.05) that mean the failure time data of machine no(4) follow Weibull distribution with 2-parameters.

4.5.1:Renewal Process Model:

For estimating Renewal Process model, we must test the time trend whether exist or not , and determine if the Process represent homogeneous Poisson process (HPP) or non-homogeneous Poisson Process (NHPP). used laplace test as:

H_o: *No time trend exist (HPP)*

H_1: *Time trend exist (NHPP)*

Table no(4.22): Laplace Test for machine no(4)

Test	*Statistic*	*P-value*
Laplace	1.84127	0.0655822

Source: The researcher from applied study, STATGRAPHIC Package, 2015

From above table, it shows the p-value of Laplace test (0.0655822) is greater than significant level (0.05), that mean no time trend exist and the Process is homogeneous Poisson process (HPP).that means rate of renewals (repair) is constant .The following table shows estimate of renewal process model:

Table no(4.23): Result of Renewal Process model for machine no(4)

Parameter (Weibull)	***value***	***Repair rate (ROCOF)***
$\hat{\alpha}$	0.947382	0.161706
$\hat{\beta}$	6.0346	

Source: The researcher from applied study, STATGRAPHIC Package, 2015

Mean cumulative renewals model: 0.161706*t

Table (4.24): Mean cumulative renewals Renewal Process model for machine no(4)

t	***Rate***	***Mean cum renewal***	***Mean time between failure (MTBF)***
0	0.161706	0.000	6.18406
120	0.161706	19.4047	6.18406
240	0.161706	38.8094	6.18406
360	0.161706	58.2142	6.18406
480	0.161706	77.6189	6.18406
600	0.161706	97.0236	6.18406

Source: The researcher from applied study, STATGRAPHIC Package, 2015

From the table (4.24), it has been shown that:

- The repair rate or rate of occurrence of failure (ROCOF) for machine no(4) equal (0.161706) and mean time between failure equals (6.18406) renewal (repair).

- The number of renewal at (t=120 hr) to have occurred equals (19.4047) renewals.
- The number of renewal at (t=240 hr) to have occurred equals (38.2142) renewals.
- The number of renewal at (t=480 (hr)) to have occurred equals (77.6189) renewals.
- The number of renewal at (t=600 hr) to have occurred equals (97.0236) renewals.

From above result we notice that renewals increased by fixed rate that means there are more faults.

4.9.3: Goodness-of-Fit Test model for machine no(4) **:**

H_o: The underlying distribution of the renewal process is Weibull

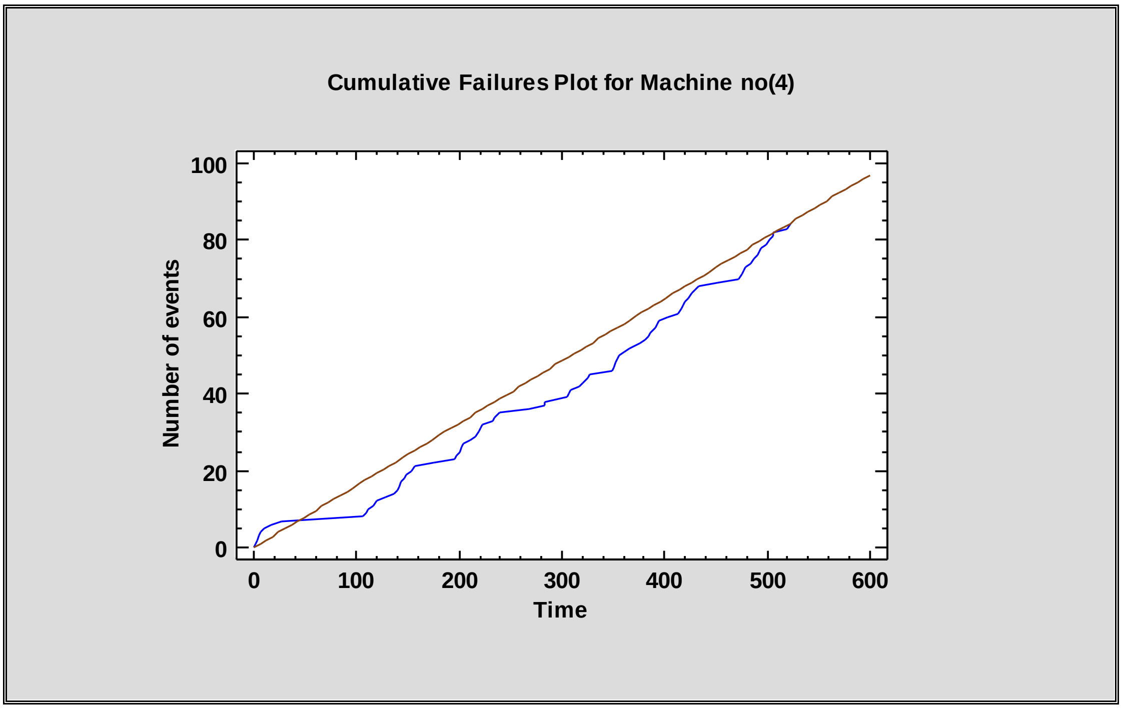
H_1: The underlying distribution of the renewal process is not Weibull

Table (4.25): Goodness-of-Fit Test for machine no(4)

Test	***Statistic***	***P-value***
Kolmogorov-Smirnov	0.151492	0.052323

Source: The researcher from applied study, STATGRAPHIC Package, 2015

From above table, it shows the p-value of Kolmogorov-Smirnov test (0.052323) is greater than significant level (0.05), that mean the underlying distribution of the renewal process is Weibull. This indicates that the time of replacing parts is stationary Poisson regenerative process.



Source: The researcher from applied study, STATGRAPHIC Package, 2015

Figure (4.16): Cumulative number of failure Vs time

From figure (4.16), shows the cumulative number of failure for renewal process model is provide best fit for this data.

From above the rate of repair is constant with $\lambda = 0.161706$ the homogeneous Poisson process model as:

$$P\left[N(t) = k\right] = \frac{(0.161706\ \mathrm{t})^{k} e^{0.161706\ \mathrm{t}}}{k\,!}$$

4.9.4: Lifetime Model :

The lifetime model has been conducted for machine no(4) for a period of time (100 hours) and the following measure has been calculated:

Table (4.26): Result of Life time test for machine no(4)

Measure	***Value***
Distribution of fault $f(t)$	0.37294
Reliability $R(t)$	0.62706
Hazard rate $h(t)$	0.59474
Availability	0.99

Source: The researcher from applied study, STATGRAPHIC Package, 2015

From the table (4.26), it has been shown that:

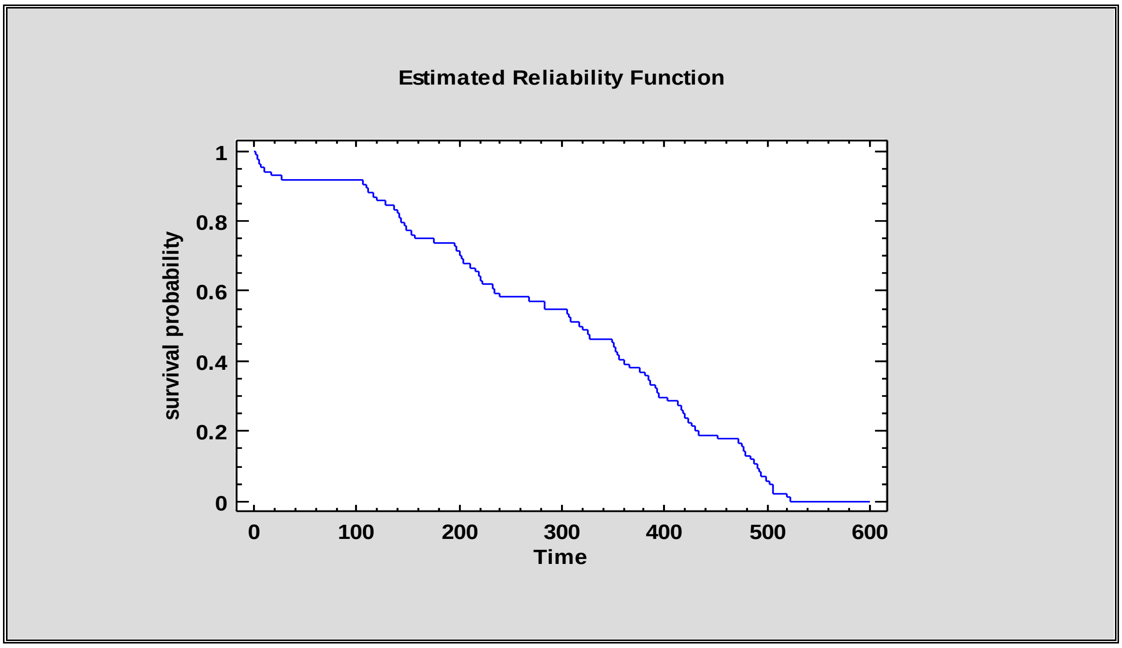
- The probability fault of the machine no(4) is $f(t=100)=0.37294$ during (100) hours, this indicate the probability fault of machine no(4) is low during this period.
- The reliability for machine no(4) is $R(t=100)=0.62706$ it is high reliability. this mean that the probability for machine to work for (100) hours without fault is (0.63), the reliability is very high.
- The rate of randomly fault occurred for machine no(4) $h(t=100)=0.59474$. That indicates the rate that occurred fault randomly during (100) hours is middle .
- The probability of available time to repair machine no(1) when it fault is (0.99).that indicates this machine has high availability.

Table no(4.27): Life Tables (Times) for machine no(4)

Time	***Reliability*** $R(t)$	***Cum.Hazard*** $h(t)$
0	1	0.000
100	0.62706	0.59474
200	0.44404	0.81185
300	0.32552	1.1223
400	0.2436	1.4122
500	0.18494	1.6877
600	0.14195	1.9523

Source: The researcher from applied study, STATGRAPHIC Package, 2015

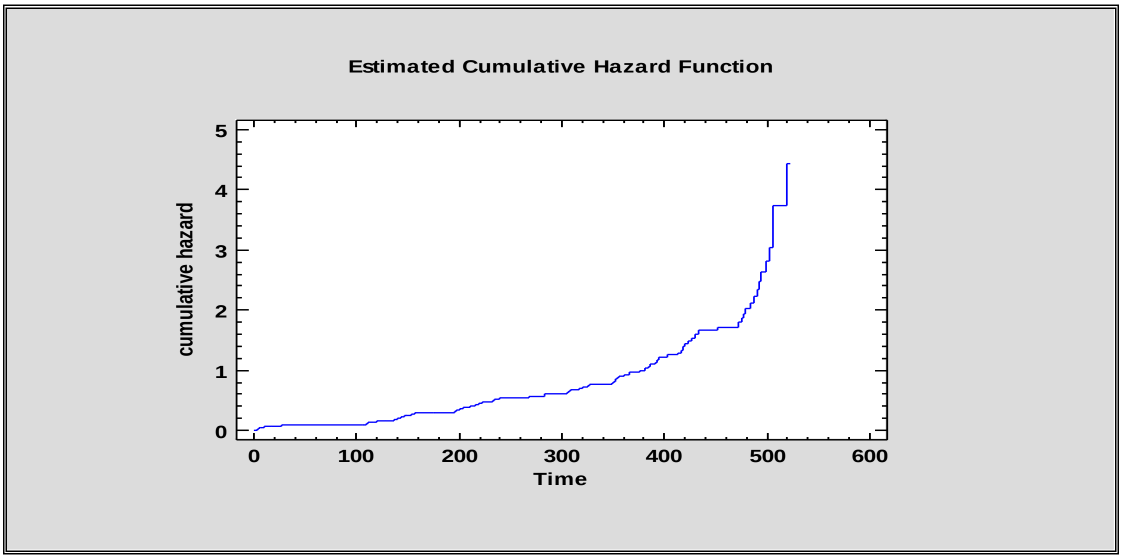
From the table (4.27), it has been shown that The reliability decreases whenever the working time of the machine increase. When the time (t=100) hours the reliability is about (63%), at time (t=200) hours the reliability is about (44%), at time (t=300) hours the reliability (13%), at time (t=400) hours the reliability is about (33%), at time (t=500) hours the reliability is about (24%), at time (t=600) hours the reliability is about (14%).The hazard funcation increases whenever the working time increases too.



Source: The researcher from applied study, STATGRAPHIC Package, 2015

Figure (4.17): Reliability funcation Vs time for machine no(4)

From the Figure (4.17), it has been shown that The reliability decreases whenever the working time of the machine increase



Source: The researcher from applied study, STATGRAPHIC Package, 2015

Figure (4.18): hazard funcation Vs time for machine no(4)

From the Figure (4.18), The hazard funcation increases whenever the working time increases too

4.6: Model for machine no(5)

Here we test the following hypothesis**:**

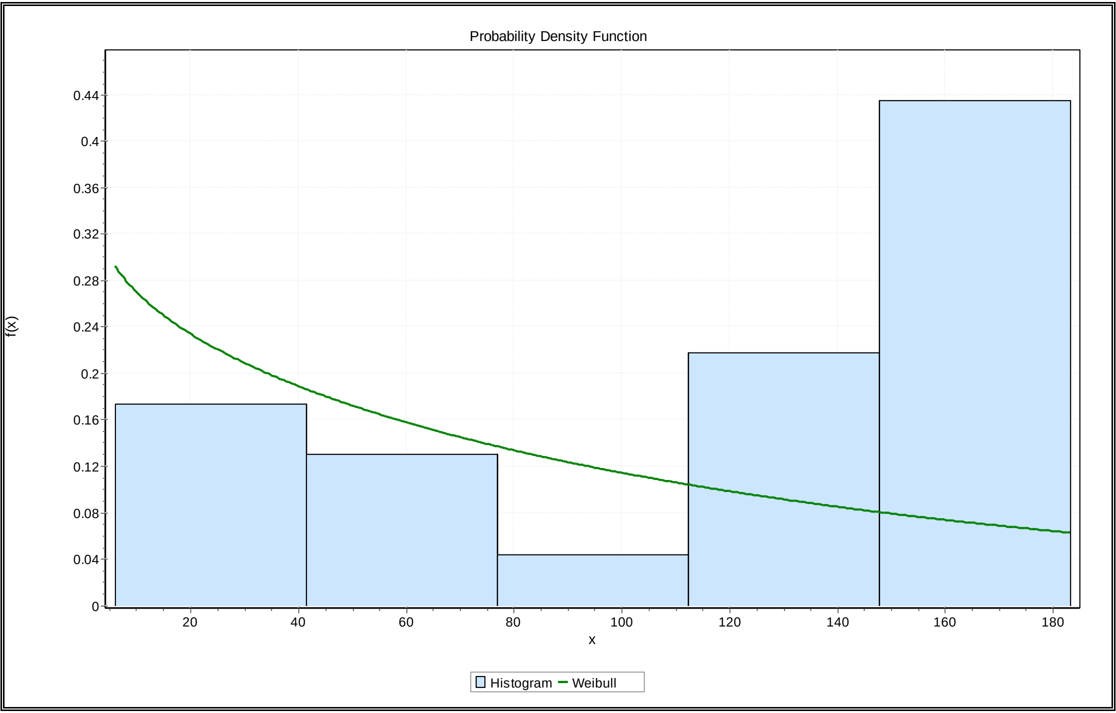
H_o: The failure time data follow Weibull distribution

H_1: The failure time data not follow Weibull distribution

Table (4.28): Kolmogorov-Smirnov test for machine no(5)

Test	***Statistic***	***Sample Size***	***P-value***
Kolmogorov-Smirnov	0.27464	23	0.05035

Source: The researcher from applied study, Easyfit Package, 2015



Source: The researcher from applied study, Easyfit Package, 2015

Figure no(4.19): density funcation of Weibull Vs time for machine no(5)

From above table, it has been shown the p-value of Kolmogorov-Smirnov (0.05035) is greater than significant level (0.05), that mean the failure time data of machine no(5) follow Weibull distribution with 2-parameters.

4.6.1:Renewal Process Model:

For estimating Renewal Process model, we must test the time trend whether exists or not , and determine if the Process represent homogeneous Poisson process (HPP) or non-homogeneous Poisson Process (NHPP). used laplace test as:

H_o: No time trend exists (HPP)

H_1: Time trend exists (NHPP)

Table no(4.29): Laplace Test for machine no(5)

Test	*Statistic*	*P-value*
Laplace	1.741	0.0816836

Source: The researcher from applied study, STATGRAPHIC Package, 2015

From above table, it has been shown the p-value of Laplace test 0.0816836) is greater than significant level (0.05), that mean there is no time trend exist and Process is Homogeneous Poisson Process (HPP). Indicated that the rate of renewal (repair) is constant by time, the following show estimate of renewal process model:

Table (4.30): Result of Renewal Process model for machine no(5)

Parameter (Weibull)	*value*	*Repair rate (ROCOF)*
$\hat{\alpha}$	0.979765	0.12573
$\hat{\beta}$	7.88332	

Source: The researcher from applied study, STATGRAPHIC Package, 2015

Mean cumulative renewals model: 0.12573*t

Table no(4.31): Mean cumulative renewals Renewal Process model for machine no(5)

t	*Rate*	*Mean cum renewal*	*Mean time between failure (MTBF)*
0	0.12573	0.000	7.95355
40	0.12573	5.0292	7.95355
80	0.12573	10.0584	7.95355
120	0.12573	15.0876	7.95355
160	0.12573	20.1168	7.95355
200	0.12573	25.146	7.95355

Source: The researcher from applied study, STATGRAPHIC Package, 2015

From the table (4.3), it has been shown that:

- The repair rate or rate of occurrence of failure (ROCOF) for machine no(4) equal (0.12573) and mean time between failure equals (7.95355) renewal (repair).
- The number of renewal at (t=40 (hr)) to have occurred equals (5.0292) renewals.
- The number of renewal at (t=80 (hr)) to have occurred equals (10.0584) renewals.
- The number of renewal at (t=120 (hr)) to have occurred equals (15.0876) renewals.
- The number of renewal at (t=160 (hr)) to have occurred equals (20.1168) renewals.
- The number of renewal at (t=200 (hr)) to have occurred equals (25.146) renewals.

From above result we notice that renewals increased by fixed rate that means there are more faults.

4.6.2: Goodness-of-Fit Test model :

Ho: The underlying distribution of the renewal process is Weibull

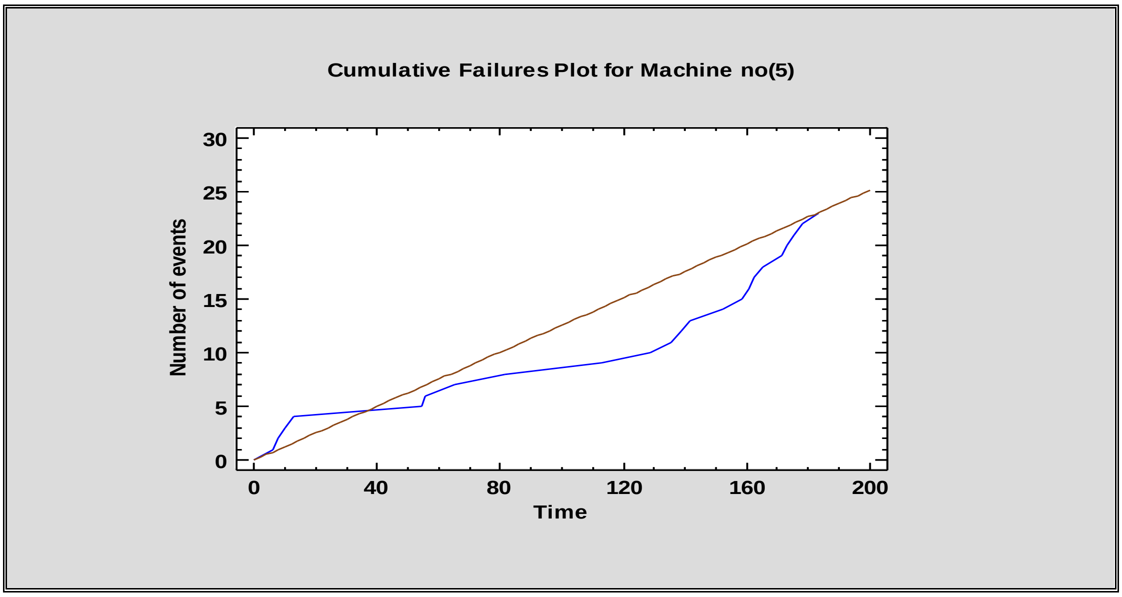
H1: The underlying distribution of the renewal process is not Weibull

Table (4.32): Goodness-of-Fit Test for machine no(5)

Test	***Statistic***	***P-value***
Kolmogorov-Smirnov	0.188084	0.394419

Source: The researcher from applied study, STATGRAPHIC Package, 2015

From above table, it shows the p-value of Kolmogorov-Smirnov test (0.394419) is greater than significant level (0.05). that mean the underlying distribution of the renewal process is Weibull. This indicates that the time of replacing parts is stationary Poisson regenerative process.



Source: The researcher from applied study, STATGRAPHIC Package, 2015

Figure (4.20): Cumulative number of failure Vs time

From figure no (4.20), shows the cumulative number of failure for renewal process model is provide best fit for this data.

From above the rate of repair is constant with $\lambda = 0.12573$,the homogeneous Poisson process model as:

$$P\left[N(t)=k\right]=\frac{(0.12573t)^{k}e^{0.12573t}}{k!}$$

4.6.3: Lifetime Model:

The life time model has been conducted for machine(5) for a period of time (100 hours) and the following measure has been calculated:

Table no(4.33): Result of lifetime model for machine no(5)

Measure	*Value*
Distribution of fault $f(t)$	0.52511
Reliability $R(t)$	0.47489
Hazard rate $h(t)$	1.10575
Availability	0.99

Source: The researcher from applied study, STATGRAPHIC Package, 2015

From the table (4.33), it has been shown that:

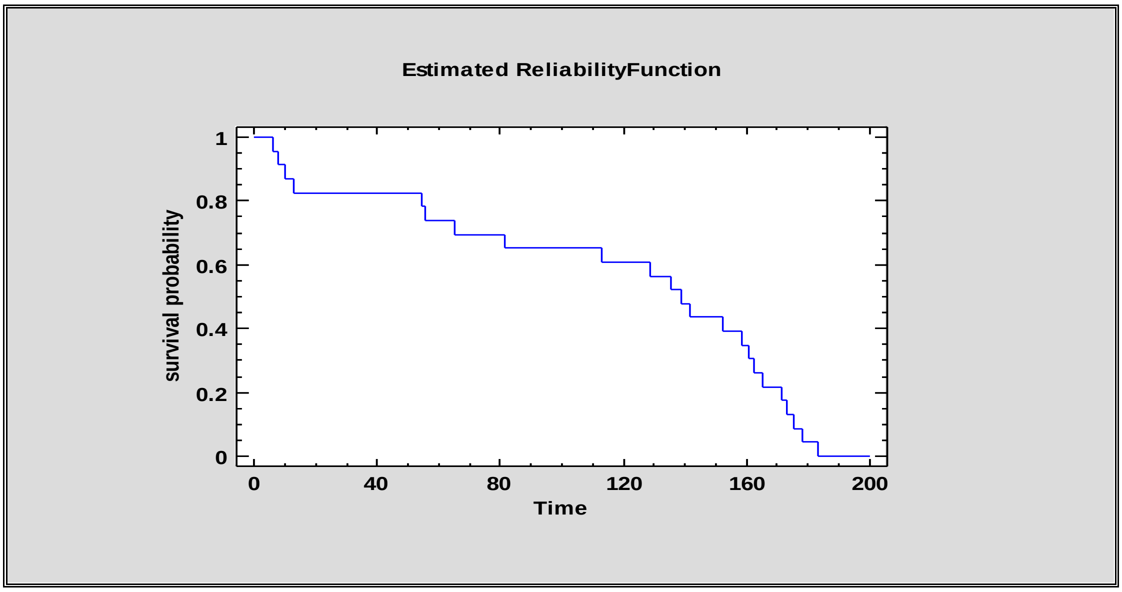
- The probability fault of the machine no(5) is $f(t=100)=0.52511$ during (100) hours ,this indicate the probability fault of machine no(5) is low during this period.
- The reliability for machine no(5) is $R(t=100)=0.47489$ it is high reliability, this mean that the probability for machine to work for (100) hours without fault is (0.47), the reliability is weak.
- The rate of randomly fault occurred for machine no(5) $h(t=100)=1.10575$, that indicates the rate that occurred fault randomly during (100) hours is very high .
- The probability of available time to repair machine no(5) when it fault is (0.99),that indicated this machine has high availability.

Table no(4.34): Life Tables (Times) for machine no(5)

Time	***Reliability*** $R(t)$	***Cum.Hazard*** $h(t)$
0	1	0.000
100	0.47489	1.1058
200	0.24683	1.3991
300	0.13223	2.0232
400	0.07219	2.6285
500	0.03995	3.2202
600	0.02235	3.8011

Source: The researcher from applied study, STATGRAPHIC Package, 2015

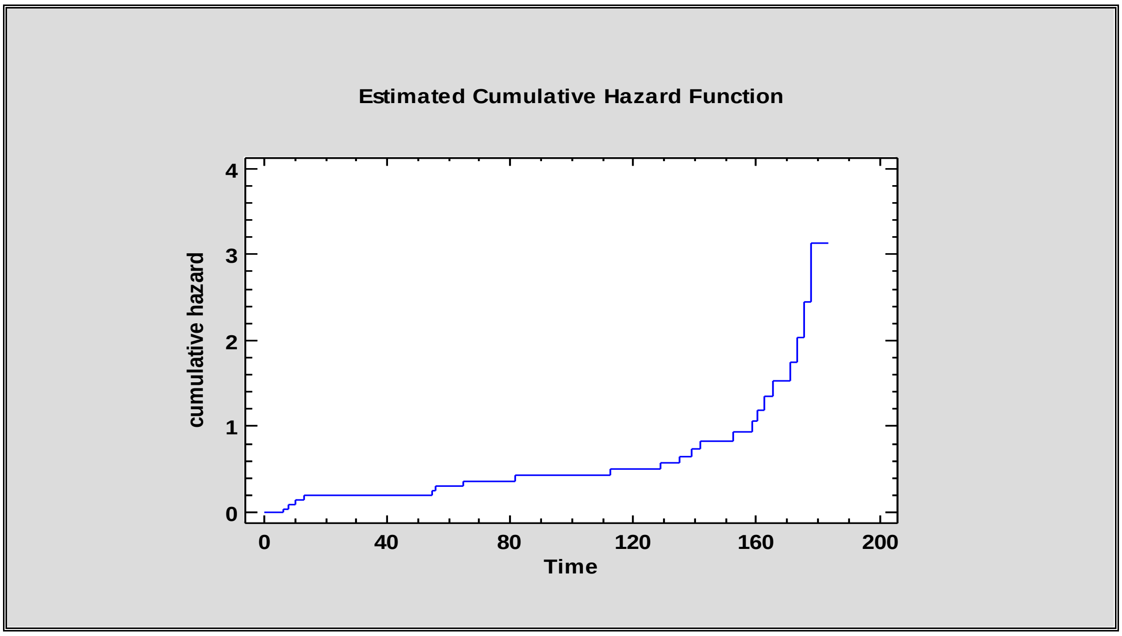
From the table (4.34), it has been shown that The reliability decreases whenever the working time of the machine increase. When the time (t=100) hours the reliability is about (47%), at time (t=200) hours the reliability is about (25%), at time (t=300) hours the reliability (13%), at time (t=400) hours the reliability is about (7%), at time (t=500) hours the reliability is about (4%), at time (t=600) hours the reliability is about (2%).The hazard funcation increases whenever the working time increases too.



Source: The researcher from applied study, STATGRAPHIC Package, 2015

Figure (4.21): Reliability funcation Vs time for machine no(5)

From the Figure (4.21), it has been shown that The reliability decreases whenever the working time of the machine increase.



Source: The researcher from applied study, STATGRAPHIC Package, 2015

Figure (4.22): Hazard funcation Vs time for machine no(5)

From the Figure (4.22),the hazard funcation increases whenever the working time increases too.

4.7: Model for machine no(6)

Here we test the following hypothesis**:**

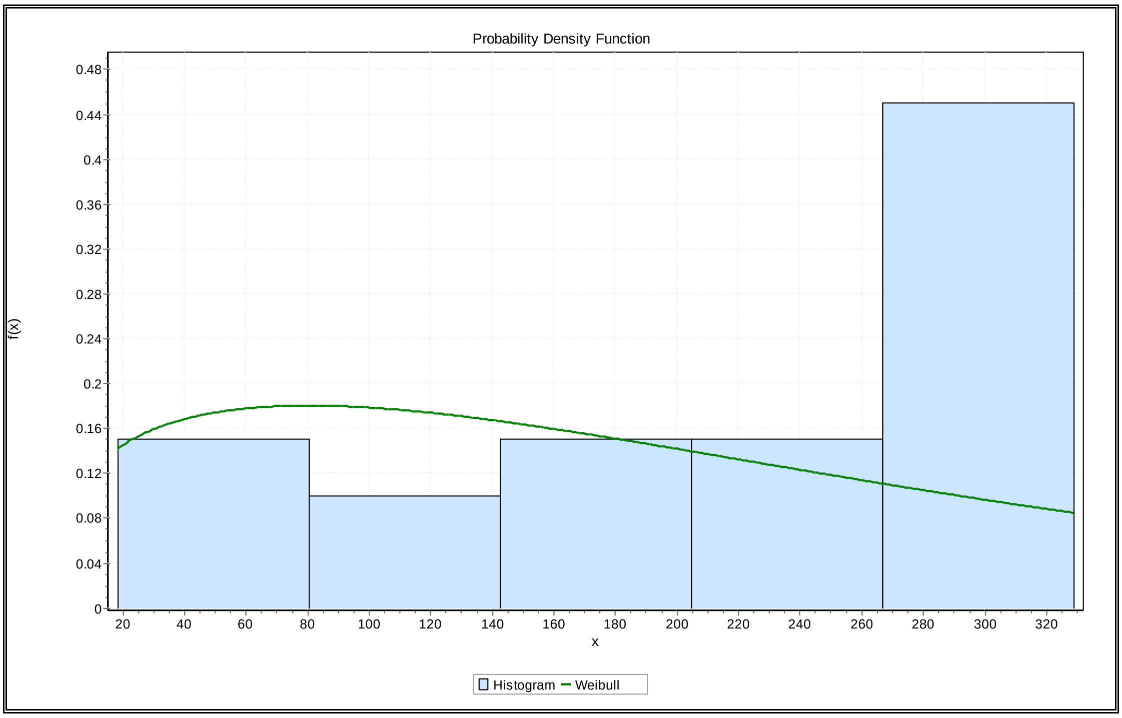
H_o: The failure time data follow Weibull distribution

H_1: The failure time data not follow Weibull distribution

Table (4.35): Kolmogorov-Smirnov test for machine no(6)

Test	***Statistic***	***Sample Size***	***P-value***
Kolmogorov-Smirnov	0.2479	20	0.1438

Source: The researcher from applied study, Easyfit Package, 2015



Source: The researcher from applied study, Easyfit Package, 2015

Figure (4.23): density funcation of Weibull Vs time

From above table, it has been shown the p-value of Kolmogorov-Smirnov (0.1438) is greater than significant level (0.05) that mean the failure time data of machine no(6) follow Weibull distribution with 2-parameters.

4.7.1:Renewal Process Model:

For estimating Renewal Process model, we must test the time trend exists or not exists, and determine the Process is Homogeneous Poisson Process (HPP) or Non-Homogeneous Poisson Process (NHPP).used laplace test as:

H_o: *No time trend exists (HPP)*

H_1: *Time trend exists (NHPP)*

Table no(4.36): Laplace Test for machine no(6)

Test	*Statistic*	*P-value*
Laplace	1.97223	0.058582

Source: The researcher from applied study, STATGRAPHIC Package, 2015

From above table, it has been shown the p-value of Laplace test (0.058582) is greater than significant level (0.05), that mean there is no time trend exist and Process is Homogeneous Poisson Process (HPP). Indicated that the rate of renewal (repair) is constant by time .the following show estimate of renewal process model:

Table (4.37): Result of Renewal Process model for machine no(6)

Parameter (Weibull)	***Value***	***Repair rate (ROCOF)***
$\hat{\alpha}$	1.10631	0.0605552
$\hat{\beta}$	17.1464	

Source: The researcher from applied study, STATGRAPHIC Package, 2015

Mean cumulative renewals model: 0.0605552*t

Table no(4.38): Mean cumulative renewals Renewal Process model for machine no(6)

t	***Rate***	***Mean cum renewal***	***Mean time between failure (MTBF)***
0	0.0605552	0.0000	16.5139
80	0.0605552	4.84442	16.5139
160	0.0605552	9.68883	16.5139
240	0.0605552	14.5332	16.5139
320	0.0605552	19.3777	16.5139
400	0.0605552	24.2221	16.5139

Source: The researcher from applied study, STATGRAPHIC Package, 2015

From the table (4.37), it has been shown that:

- The repair rate or rate of occurrence of failure (ROCOF) for machine no(6) equal (0.0605552) and mean time between failure equals (16.5139) renewal (repair).

- The number of renewal at (t=80 hr) to have occurred equals (4.84442) renewals.
- The number of renewal at (t=160 hr) to have occurred equals (9.68883) renewals.
- The number of renewal at (t=240 hr) to have occurred equals (14.5332) renewals.
- The number of renewal at (t=320 hr) to have occurred equals (19.3777) renewals.
- The number of renewal at (t=400 hr) to have occurred equals (24.2221) renewals.

From above result we notice that renewals increased by fixed rate that mean there are more fault.

4.7.2: Goodness-of-Fit test model :

H_o: The underlying distribution of the renewal process is Weibull

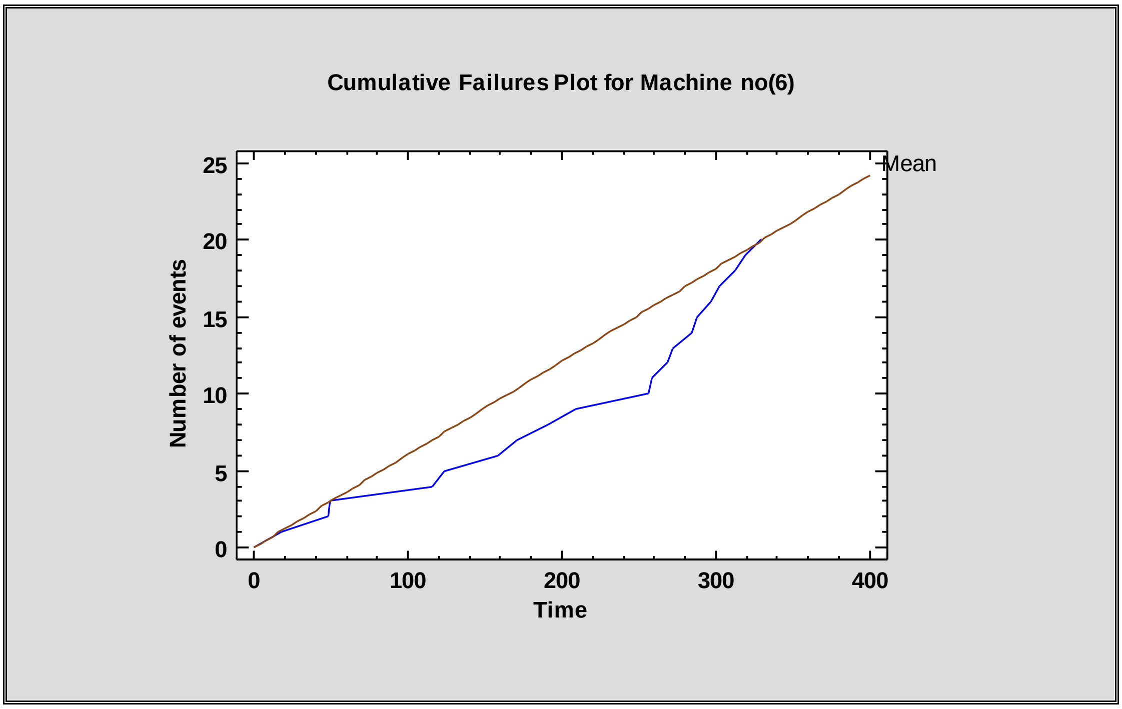
H_1: The underlying distribution of the renewal process is not Weibull

Table (4.39): Goodness-of-Fit Test for machine no(6)

Test	*Statistic*	*P-value*
Kolmogorov-Smirnov	0.161352	0.675058

Source: The researcher from applied study, STATGRAPHIC Package, 2015

From above table, it has been shown the p-value of Kolmogorov-Smirnov (0.675058) is greater than significant level (0.05) that mean the underlying distribution of the renewal process is Weibull. indicates that the time of replacing parts is stationary Poisson regenerative process.



Source: The researcher from applied study, STATGRAPHIC Package, 2015

Figure (4.24): Cumulative number of failure Vs time

From figure (4.24), shows the cumulative number of failure for renewal process model is provide best fit for this data

From above the rate of repair is constant with $\lambda = 0.06056$ the homogeneous Poisson process model as:

$$P[N(t) = k] = \frac{(0.06056t)^k e^{0.06056t}}{k!}$$

4.7.3: Lifetime Model :

The life time model has been conducted for machine(6) for a period of time (100 hours) and the following measure has been calculated:

Table (4.40): Result of Lifetime model for machine no(6)

Measure	***Value***
Distribution of fault $f(t)$	0.25874
Reliability $R(t)$	0.74126
Hazard rate $h(t)$	0.349054
Availability	0.97

Source: The researcher from applied study, STATGRAPHIC Package, 2015

From the table (4.40), it has been shown that:

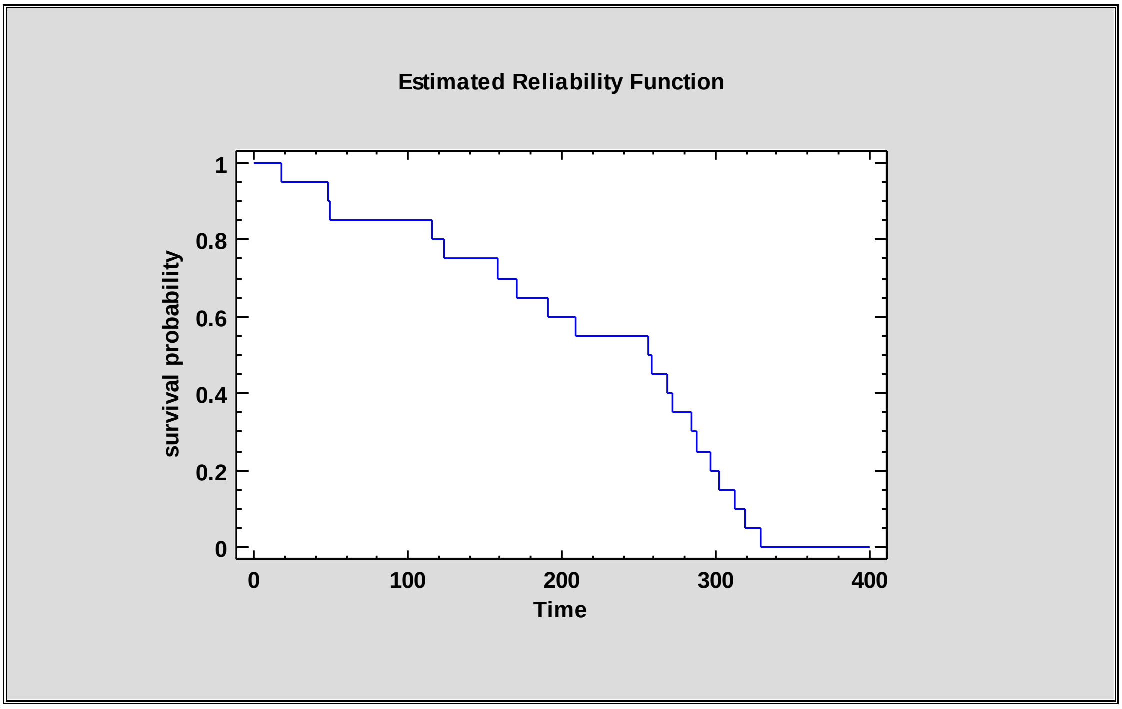
- The probability fault of the machine no(6) is $f(t=100)=0.25874$ during (100), hours .this indicate the probability fault of machine no(6) is high during this period.
- The reliability for machine no(4) is $R(t=100)=0.74126$ it is weak reliability, this mean that the probability for machine to work for (100) hours without fault is (0.74), the reliability is very high.
- The rate of randomly fault occurred for machine no(6) $h(t=100)=0.349054$, that indicates the rate that occurred fault randomly during (100) hours is very weak.
- The probability of available time to repair machine no(6) when it fault is (0.97).that indicates this machine has high availability.

Table no(4.41): Life Tables (Times) for machine no(6)

Time	***Reliability*** $R(t)$	***Cum.Hazard*** $h(t)$
0	1	0.000
100	0.74126	1.1058
200	0.4804	0.73313
300	0.28999	1.2379
400	0.1661	1.7952
500	0.09117	2.3951
600	0.04826	3.0312

Source: The researcher from applied study, STATGRAPHIC Package, 2015

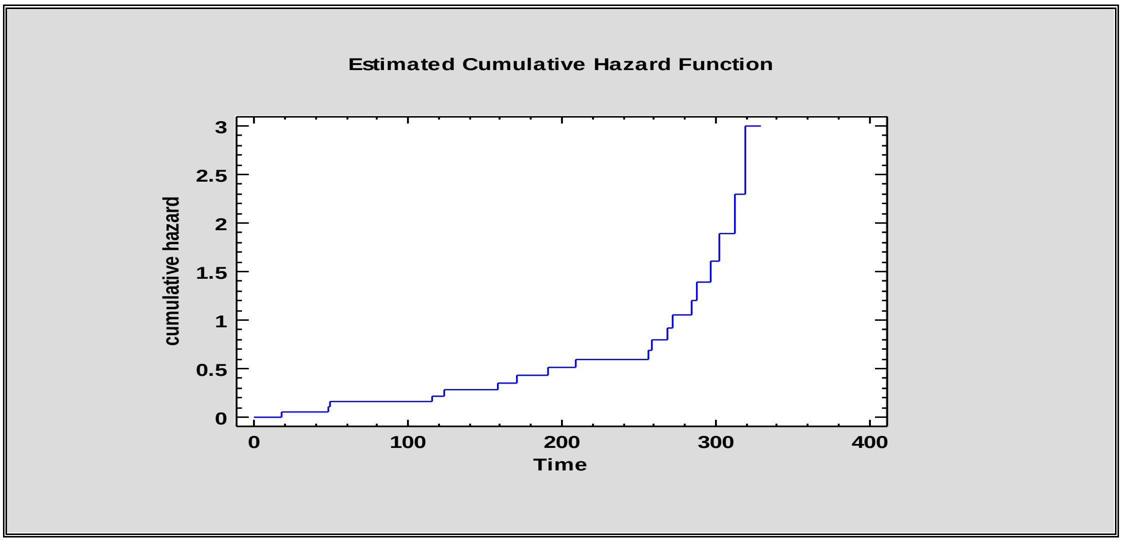
From the table (4.41), it has been shown that. The reliability decreases whenever the working time of the machine increase. When the time (t=100) hours the reliability is about (74%), at time (t=200) hours the reliability is about (48%), at time (t=300) hours the reliability (29%), at time (t=400) hours the reliability is about (17%), at time (t=500) hours the reliability is about (9%), at time (t=600) hours the reliability is about (5%).The hazard funcation increases whenever the working time increases too.



Source: The researcher from applied study, STATGRAPHIC Package, 2015

Figure (4.24): Reliability function Vs time for machine no(6)

From the figure (4.25), it has shown that The reliability decreases whenever the working time of the machine increase.



Source: The researcher from applied study, STATGRAPHIC Package, 2015

Figure no(4.26): Hazard funcation Vs time for machine no(6)

From the figure (4.26),the hazard funcation increases whenever the working time increases too.

4.8: Comparison between Machines:

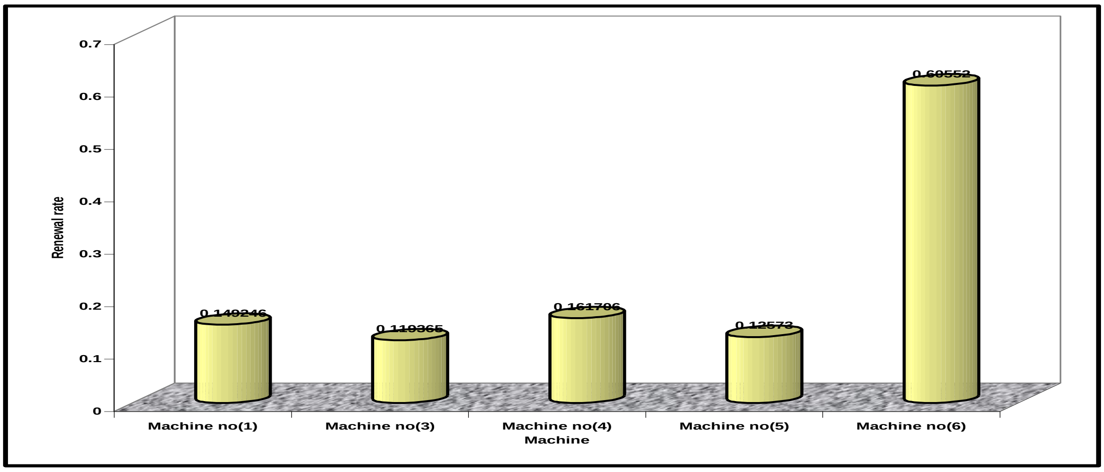
We compare the four machines according to renewal process model and lifetime model,and Reliability. In renewal process model we compare between parameters model, renewal rate(repair), mean time between renewals (MTBF) in lifetime model the comparison was among the following measures probability of fault, reliability, hazard rate and availiability:

4.8.1: Renewal Process Models

Table (4.42): Comparison between machines for renewal process model

Machine	***Renewal process parameter***		***Renewal rate (Repair)***	***MTBF***
	$\hat{\alpha}$	$\hat{\beta}$		
Machine no(1)	0.916457	6.43011	0.149246	6.70036
Machine no(3)	0.771699	7.19846	0.119365	8.37763
Machine no(4)	0.947382	6.0346	0.161706	6.18406
Machine no(5)	0.978765	7.88332	0.12573	7.95355
Machine no(6)	1.10631	17.1464	0.60552	16.5139

Source: The researcher from applied study, 2015



Source: The researcher from applied study, Excel Package, 2015

Figure no(4.27): Renewal rate Vs machines

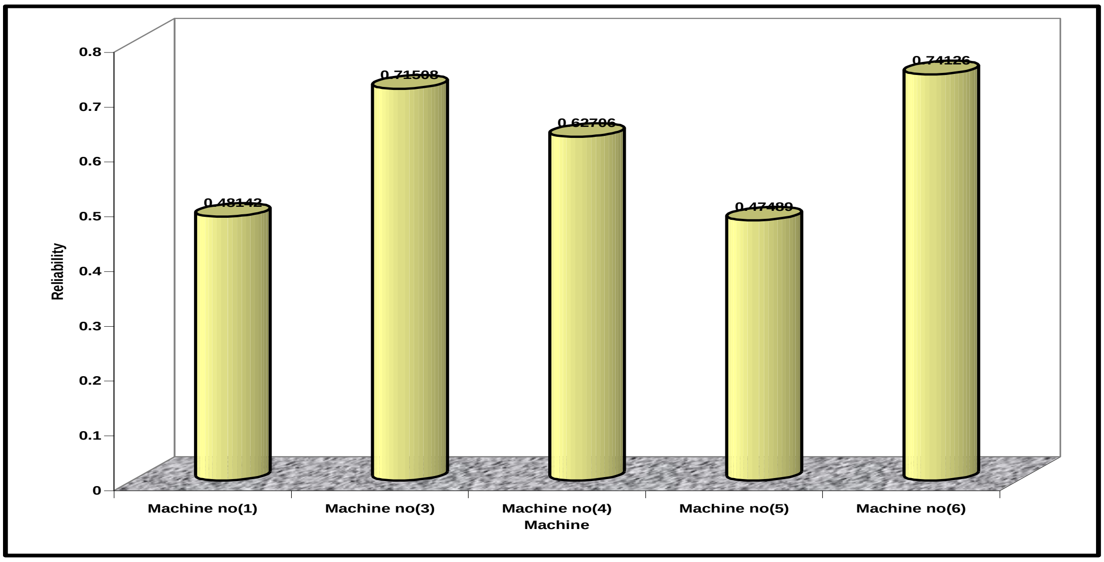
From above table and figure, and according to the renewal rate (repair) and the mean time between renewals (MTBF), the machine no(6) achieved high renewal rate it was about (0.61) with mean time between renewals it was about (17 hours), it followed by the machine no(3) which has the second high renewal rate it was (0.16) with mean time between renewal it was about (6 hours),then the machine no (1) in third class acording to high value for the renewal rate which was about (0.14) with mean time between renwals about (8 hours). The machine no(5) was in the fourth class according to fourth high value for the renwal rate it was about (0.13) with mean time between renewals which was about (8 hours). At last the machine no(3) according to the low value for the renewal rate which was about (0.12) for mean time between the renwals which was (8 hours).

4.8.2: Lifetime models Comparison:

Table (4.43): Comparison between machines for lifetime model

Machine	$f(t)$	$R(t)$	$h(t)$	$A(t)$
Machine no(1)	0.51858	0.48142	1.07719	0.98
Machine no(3)	0.28492	0.71508	0.39844	0.97
Machine no(4)	0.37294	0.62706	0.59474	0.99
Machine no(5)	0.52511	0.47489	1.10575	0.99
Machine no(6)	0.25874	0.74126	0.349054	0.97

Source: The researcher from applied study,2015



Source: The researcher from applied study, Excel Package, 2015

Figure (4.28): Reliability Vs machines

From above table and figure we note that ,the machines no (3,4 and 6) have high reliability and the machines no (1 and 5) have low reliability, The machines with high reliability have a low faults probability and hazard rate but the machines with low reliability have high faults probability and hazard rate.

4.8.3: MTBF and Reliability Comparison:

Table no(4.44): Comparison between machines in MTBF and Reliability

Type	*MTBF*	*Reliability*
Machine no(1)	6.70036	0.48142
Machine no(3)	8.37763	0.71508
Machine no(4)	6.18406	0.62706
Machine no(5)	7.95355	0.47489
Machine no(6)	16.5139	0.74126

Source: The researcher from applied study,2015

From above table , we note that whenever mean time between renewals (repairable) increseases the reliability increased too and that appear clearly in the machinen no(6) result which its mean between renewals is approximately (17 hours) and the reliability (0.74).