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Reliability Investigation and Hazard Rate Diagnosis of Shaliwahana MSW 12MW Green Power Plant Components

A. Suresh[1], V. Karthik[2], K. Lalitha Manjusha[3], R. Karthik[4]
[1]*Assistant Professor, Department of Mechanical Engineering, CVR College of Engineering, Hyderabad, India*
[2,3,4]*B.Tech. Student, Department of Mechanical Engineering, CVR College of Engineering, Hyderabad, India*

***Abstract*: Investigation of reliability is by default a must needed process to access the status of the machine. The machine condition of performance and ability to perform its intended tasks are understood by the investigation of the reliability. Basically reliability is the ability of the machine to perform its intended task with zero or minimum number of failures. The more is the reliability of the machine the better is the performance. Hence this research is very much needed and useful one for the understanding of the machine. Here the term machine describes the boiler and turbine in the power plant. Although there are many numbers of components available in the plant only boiler and turbine are considered here in this research for the analysis. The power plant considered here in this research is a municipal solid waste power plant MSW named Shaliwahana MSW 12MW green power plant. While performing the analysis the boiler and turbine performance and failure data for the previous 4 years is considered that is from the 2015 to 2019. The data pertaining to these components is refined and trend analysis is done to know the machine trend to find the position of the machine in bath tub curve. Then the hazard rate diagnosis is done by two parameter weibull analysis is made to ascertain the nature of machine performance with respect to reliability. From the results of the weibull analysis the functioning of the machine is formulated and further an arena is made towards its performance and maintenance formulation.**

***Keywords*: Hazard rate diagnosis, Reliability investigation, Weibull analysis.**

1. Introduction

Electricity is a major requirement to the mankind for every need; one cannot imagine the present world without electricity. In this scenario the performance of the electric power plant is very much needed to make the productivity as maximum as possible. In the other terms making the machines to work with zero or minimum number of failures. In this context the present research presented in this paper focuses on the behavior of machines such as boiler and turbine used in the plant. If the past and present performance of the machine is analyzed means the future performance can be controlled with ease. With this as motto of the present research is made to analyze the boiler and turbine of the Shaliwahana 12 MSW green power plant since 2015 to 2019. In each year around two months of time is spent on the annual maintenance hence the net effective working days of the power plant becomes 300days in a year. Within the 300 working days of operation in each year, how much time the boiler and turbine suffered with failures and their repairing times along with their networking time is recorded, collected and refined [1]-[3]. The data obtained from the plant log books and systems along with the manpower are collected, refined, analyzed and summarized in such a way that the time of operation is formulated as time between failures (TBF) and the time consumed for the machines repair is formulated as time to repair (TTR).Further the data formulated as TBF and TTR are converted in to ordered time between failures (OTBF) and ordered time to repair (OTTR) as well as cumulative time between failures (CTBF) and cumulative time to repair (CTTR) [4], [5]. And also the refined data is used to calculate the mean time between failures (MTBF) and mean time to repair (MTTR).

2. Literature survey

There is a lot of need and necessity behind the investigation of reliability of the power plant. By investigating the ability and capability of the machines employed in the power plant a better maintenance policy can be formulated. And also the present status of the machine and its position in its life cycle can be found [6]-[8]. Be far this is very important consideration for the decision making about the replacement analysis of the power plant components. In general, one may experience a doubt like why to make all this analysis as the product or machine manufacturer used to detail the life span of the machine. But in reality the machines performance alters from the numbers given while manufacturing to the numbers obtained while functioning. It is because of many uncertainties, out of these uncertainties some are of system generated and some are of manmade. Hence in order to understand the machine's performance in terms its ability to discharge the duties well one has to undergo the reliability investigation as well as hazard rate diagnosis [9], [10].

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3. Methodology

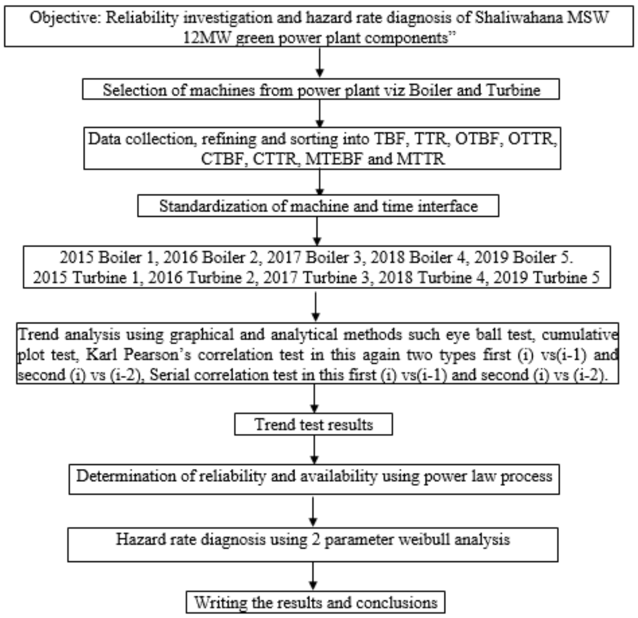

Fig. 1. Methodology of reliability investigation and hazard rate diagnosis of Shaliwahana MSW 12MW green power plant components

4. Analysis

The analysis of the work starts with the refined data at first, then the trend analysis is carried out using six tests then the majority of them are considered as actual trend. Out of the six tests two are of graphical type and the remaining four are of analytical type. Graphical tests are Eye ball test, Cumulative plot test and analysis tests are Karl Pearson's correlation test in this again two types first (i) vs(i-1) and second (i) vs (i-2), Serial correlation test in this first (i) vs(i-1) and second (i) vs (i-2). While performing the analysis in each year boiler and turbine are considered as two separate machines and they are given below in table 1.

Table 1
List of machines considered for the analysis

S. no.	Machine number	Machine name	Machine number	Machine name
1	1	2015 Boiler	6	2015 Turbine
2	2	2016 Boiler	7	2016 Turbine
3	3	2017 Boiler	8	2017 Turbine
4	4	2018 Boiler	9	2018 Turbine
5	5	2019 Boiler	10	2019 Turbine

The results of the eye ball tests and cumulative plot tests based on the TBF and TTR are illustrated below. In the graphs the x ordinate represents cumulative number of failures (CNF) and y axis represents cumulative time between failures (CTBF) for the reliability trend analysis and in the same way for the availability calculation x axis is same as CNF and Y axis changed as cumulative time to repair (CTTR).

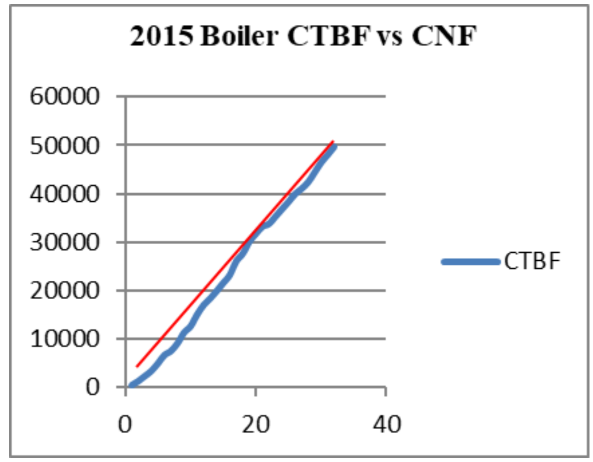

Fig. 2. Cumulative plot test result for the machine 2015 boiler

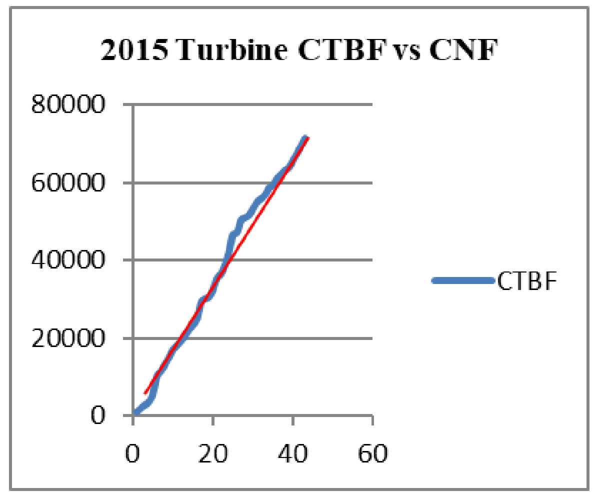

Fig. 3. Cumulative plot test result for the machine 2015 Turbine

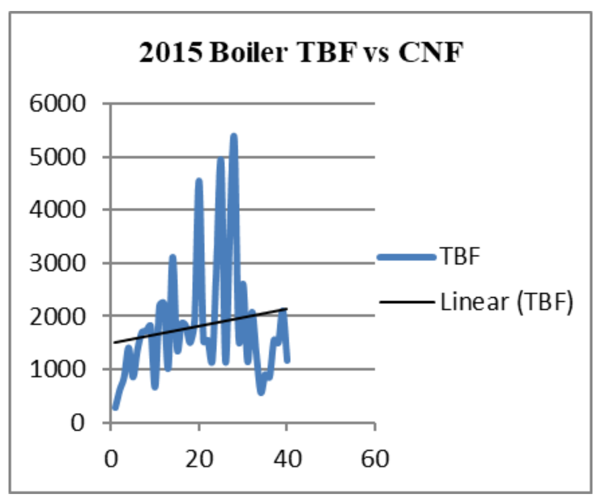

Fig. 4. Eye ball test result for the machine 2015 Turbine

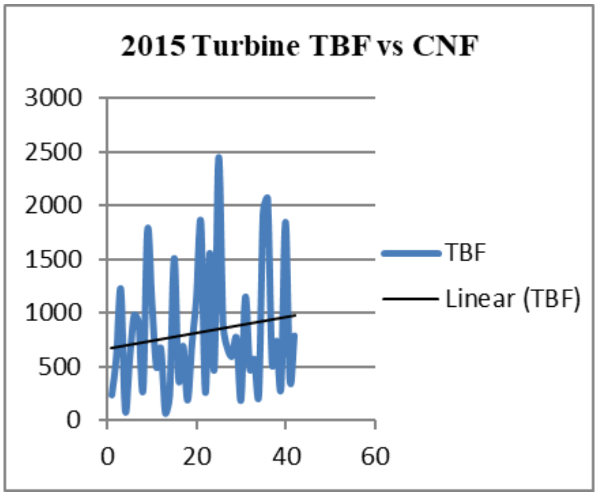

Fig. 5. Eye ball test result for the machine 2015 Boiler

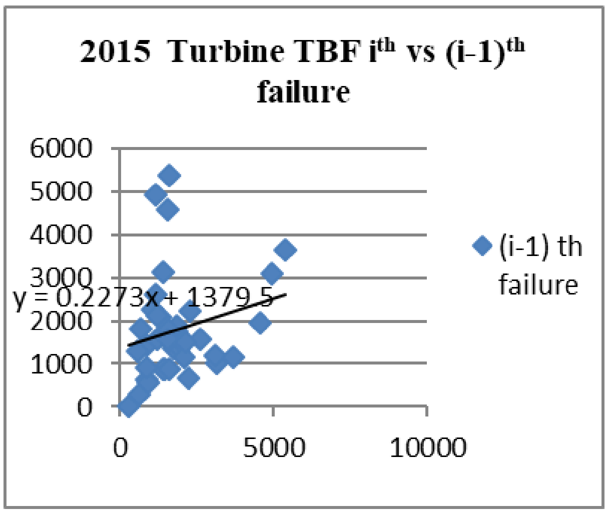

Fig. 6. Serial correlation test (i vs i-1) result for the machine 2015 Turbine

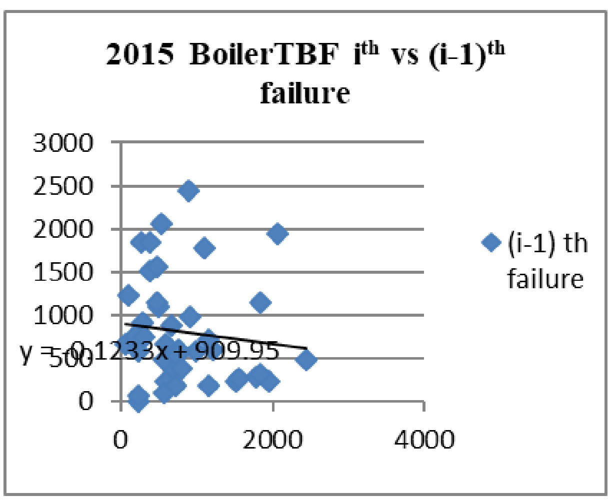

Fig. 7. Serial correlation test (i vs i-1) result for the machine 2015 Boiler

In the above graphs the figure 2 and 3 represents the trend test results using the cumulative plot test for the machines 2015 boiler and turbine respectively and in the figure 4 and figure 5 they belongs to the trend tests results (for reliability) of the eye ball test. In the same way using the TTR for the availability calculations eye ball tests are drawn for the trend analysis of all the 10 machines. And similarly using the CTTR for the availability calculations cumulative plot tests are drawn for the trend analysis of all the 10 machines.

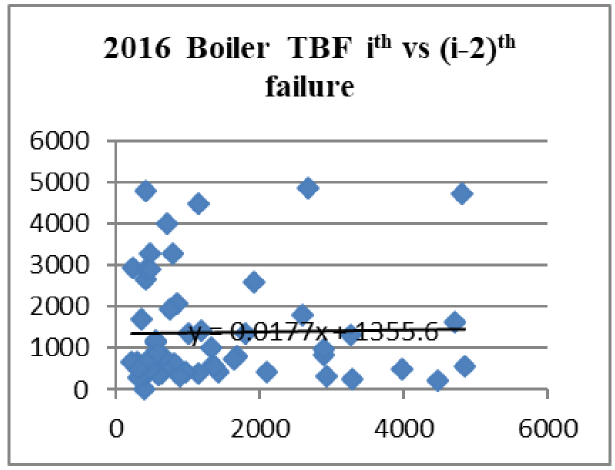

Fig. 8. Serial correlation test (i vs i-2) result for the machine 2016 Boiler

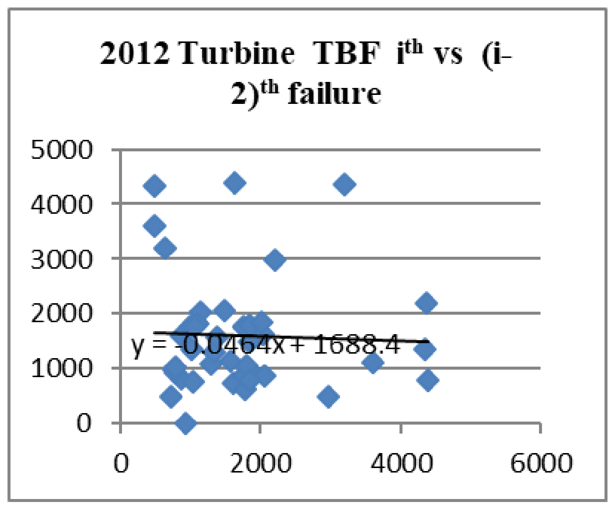

Fig. 9. Serial correlation test (i vs i-2) result for the machine 2016 Turbine

The above figures 6,7,8 and 9 shows the serial correlation test of i^{th} vs $(i-1)^{th}$ and i^{th} vs $(i-2)^{th}$ test results for10 machines each for TBF and TTR. 4 graphs are shown above similarly the graphs can be plotted for all the machines.

And after these graphical tests the analytical test is carried out to know the trend of 10 machines. As mentioned above in the analytical test used here is Karl Pearson's coefficient of correlation test first (i) vs(i-1) and second (i) vs (i-2). The formula to calculate the trend is given below.

Coefficient of Correlation {r}=

sum x*y/sqrt{(sum x**2)*(sum y**2)} = 0.9976

Table 2
Karl Pearson's coefficient of correlation test (i) vs(i-1) of 2016 Boiler

	2016 Boiler						
S. No.	TBF(i)	x=i-1298	i-2	y=(i-1)-1307	x**2	y**2	x*y
0	0						
1	240	-1058					
2	264	-1034	0	-1307	1069156	1708249	1351438
3	312	-986	240	-1067	972196	1138489	1052062
4	432	-866	264	-1043	749956	1087849	903238
5	216	-1082	312	-995	1170724	990025	1076590
6	672	-626	432	-875	391876	765625	547750
7	936	-362	216	-1091	131044	1190281	394942
8	480	-818	672	-635	669124	403225	519430
9	504	-794	936	-371	630436	137641	294574
10	384	-914	480	-827	835396	683929	755878
11	672	-626	504	-803	391876	644809	502678
12	1920	622	384	-923	386884	851929	-574106
13	240	-1058	672	-635	1119364	403225	671830
14	2040	742	1920	613	550564	375769	454846
15	432	-866	240	-1067	749956	1138489	924022
16	552	-746	2040	733	556516	537289	-546818
17	552	-746	432	-875	556516	765625	652750
18	432	-866	552	-755	749956	570025	653830
19	648	-650	552	-755	422500	570025	490750
20	648	-650	432	-875	422500	765625	568750
21	912	-386	648	-659	148996	434281	254374
22	648	-650	648	-659	422500	434281	428350
23	264	-1034	912	-395	1069156	156025	408430
24	3192	1894	648	-659	3587236	434281	-1248146
25	3936	2638	264	-1043	6959044	1087849	-2751434
26	360	-938	3192	1885	879844	3553225	-1768130
27	4080	2782	3936	2629	7739524	6911641	7313878
28	744	-554	360	-947	306916	896809	524638
29	3456	2158	4080	2773	4656964	7689529	5984134
30	600	-698	744	-563	487204	316969	392974
31	4392	3094	3456	2149	9572836	4618201	6649006
32	5412	4114	600	-707	16924996	499849	-2908598
33	2640	1342	4392	3085	1800964	9517225	4140070
34	5652	4354	5412	4105	18957316	16851025	17873170
35	768	-530	2640	1333	280900	1776889	-706490
36	576	-722	5652	4345	521284	18879025	-3137090
37	672	-626	768	-539	391876	290521	337414
38	2904	1606	576	-731	2579236	534361	-1173986
39	4968	3670	672	-635	13468900	403225	-2330450
40	384	-914	2904	1597	835396	2550409	-1459658
41	1032	-266	4968	3661	70756	13402921	-973826
42	216	-1082	384	-923	1170724	851929	998686
43	816	-482	1032	-275	232324	75625	132550
44	672	-626	216	-1091	391876	1190281	682966
45	1896	598	816	-491	357604	241081	-293618
46	288	-1010	672	-635	1020100	403225	641350
47	1776	478	1896	589	228484	346921	281542
48	192	-1106	288	-1019	1223236	1038361	1127014
49	504	-794	1776	469	630436	219961	-372386
50	2352	1054	192	-1115	1110916	1243225	-1175210
51	2280	982	504	-803	964324	644809	-788546
52	480	-818	2352	1045	669124	1092025	-854810
53	816	-482	2280	973	232324	946729	-468986
54	408	-890	480	-827	792100	683929	736030
55	1824	526	816	-491	276676	241081	-258266
56	2208	910	408	-899	828100	808201	-818090
57	288	-1010	1824	517	1020100	267289	-522170
58	720	-578	2208	901	334084	811801	-520778
59	528	-770	288	-1019	592900	1038361	784630
60	576	-722	720	-587	521284	344569	423814
61	176	-1122	528	-779	1258884	606841	874038
	1298		1307		118043984	119062908	37152824
			r=	0.31338749			

The above table 2 shows Karl Pearson's coefficient of correlation test (i) vs(i-1) of 2016 Boiler based on reliability (TBF) and likewise for all the machines computations are calculated.

5. Hazard rate diagnosis

To make the hazard rate diagnosis the 2 parameter weibull analysis is done. In this the two parameters are α and β. α is known as scale parameter of weibull distribution and β is known as shape parameter of weibull distribution. The analysis is done using the following governing equation.

$$F_{(t)} = 1 - \exp(-(t/\alpha)^{\beta})$$

It can be further modified into

$$\ln \ln [1/\{1- F_{(t)}\}] = \beta \ln t - \beta \ln \alpha$$

In the above equation $F_{(t)}$ can be calculated using the

Table 3
Trend tests results based on reliability

Item	TBF based Cumulative Plot Test	Eye Ball Test	Karl Pearson (i-1)	Karl Pearson (i-2)	Serial Correlation (i) vs (i-1)	Serial Correlation (i-1) vs (i-2)	Result
2015 T	Week - ve Trend	Week + ve Trend	- ve Trend	+ ve Trend	- ve Trend	- ve Trend	- ve Trend
2016 T	Week - ve Trend	Week + ve Trend	Week - ve Trend	Week + ve Trend	Week - ve Trend	Week - ve Trend	- ve Trend
2017 T	No Trend	Week + ve Trend	Week + ve Trend	Week + ve Trend	+ ve Trend	+ ve Trend	+ ve Trend
2018 T	Week + ve Trend	Week - ve Trend	Week + ve Trend	Week + ve Trend	Week + ve Trend	Week + ve Trend	+ ve Trend
2019 T	Week - ve Trend	Week + ve Trend	Week + ve Trend	Week + ve Trend	+ ve Trend	+ ve Trend	+ ve Trend
2015 B	Week + ve Trend	- ve Trend	- ve Trend	Week - ve Trend	+ ve Trend	- ve Trend	- ve Trend
2016 B	Week - ve Trend	Week + ve Trend	Week - ve Trend	Week + ve Trend	Week - ve Trend	Week - ve Trend	- ve Trend
2017 B	Week - ve Trend	Week + ve Trend	Week + ve Trend	Week + ve Trend	+ ve Trend	+ ve Trend	+ ve Trend
2018 B	Week - ve Trend	Week + ve Trend	Week + ve Trend	Week + ve Trend	+ ve Trend	+ ve Trend	+ ve Trend
2019 B	Week - ve Trend	Week + ve Trend	Week - ve Trend	Week + ve Trend	Week - ve Trend	Week - ve Trend	- ve Trend

Table 4
Trend tests results based on availability

Item	TTR based Cumulative Plot Test	Eye Ball Test	Karl Pearson (i-1)	Karl Pearson (i-2)	Serial Correlation (i) vs (i-1)	Serial Correlation (i-1) vs (i-2)	Result
2015 T	Week + ve Trend	Week + ve Trend	Week - ve Trend	Week - ve Trend	Week - ve Trend	Week - ve Trend	- ve Trend
2016 T	No Trend	Week - ve Trend	Week - ve Trend	Week - ve Trend	- ve Trend	- ve Trend	- ve Trend
2017 T	Week - ve Trend	+ ve Trend	Week + ve Trend	Week - ve Trend	- ve Trend	- ve Trend	- ve Trend
2018 T	Week - ve Trend	Week + ve Trend	Week - ve Trend	Week - ve Trend	- ve Trend	- ve Trend	- ve Trend
2019 T	Week - ve Trend	Week + ve Trend	Week - ve Trend	Week - ve Trend	- ve Trend	- ve Trend	- ve Trend
2015 B	Week + ve Trend	Week - ve Trend	Week - ve Trend	Week + ve Trend	- ve Trend	- ve Trend	- ve Trend
2016 B	No Trend	Week + ve Trend	Week - ve Trend	Week - ve Trend	- ve Trend	- ve Trend	- ve Trend
2017 B	No Trend	No Trend	Week - ve Trend	Week + ve Trend	- ve Trend	- ve Trend	- ve Trend
2018 B	Week + ve Trend	Week - ve Trend	Week - ve Trend	Week - ve Trend	- ve Trend	- ve Trend	- ve Trend
2017 B	No Trend	No Trend	Week - ve Trend	Week + ve Trend	- ve Trend	- ve Trend	- ve Trend

Table 5
Summary of results

S. no.	Trend analysis			Hazard rate diagnosis using 2 parameter weibull analysis		
	Parameter	Machine	Trend	α	β	Nature of machine behavior
1	TBF	2015 Boiler	-ve	18.7	0.8	Decreasing failure rate
2	TBF	2016 Boiler	-ve	19.6	0.7	Decreasing failure rate
3	TBF	2017 Boiler	+ve	18.8	1.4	Increasing failure rate
4	TBF	2018 Boiler	+ve	21.2	1.3	Increasing failure rate
5	TBF	2019 Boiler	+ve	19.8	1.5	Increasing failure rate
6	TBF	2015 Turbine	-ve	22.7	0.9	Decreasing failure rate
7	TBF	2016 Turbine	-ve	18.9	0.8	Decreasing failure rate
8	TBF	2017 Turbine	+ve	24.7	1.6	Increasing failure rate
9	TBF	2018 Turbine	+ve	31.39	1.8	Increasing failure rate
10	TBF	2019 Turbine	-ve	30.8	0.8	Decreasing failure rate
11	TTR	2015 Boiler	-ve	28.7	0.7	Decreasing failure rate
12	TTR	2016 Boiler	-ve	29.8	0.7	Decreasing failure rate
13	TTR	2017 Boiler	-ve	26.7	0.8	Decreasing failure rate
14	TTR	2018 Boiler	-ve	27.9	0.9	Decreasing failure rate
15	TTR	2019 Boiler	-ve	30.8	0.9	Decreasing failure rate
16	TTR	2015 Turbine	-ve	31.7	0.8	Decreasing failure rate
17	TTR	2016 Turbine	-ve	30.3	0.7	Decreasing failure rate
18	TTR	2017 Turbine	-ve	29.7	0.8	Decreasing failure rate
19	TTR	2018 Turbine	-ve	31.6	0.7	Decreasing failure rate
20	TTR	2019 Turbine	-ve	29.7	0.7	Decreasing failure rate

relationship $F_{(t)} = \frac{j-0.3}{n+0.4}$ and α, β values are computed from the graph.

6. Results

The results of trend tests are as follows shown in table 3 and 4.

From the figure 10 the shape parameter β value is 1.8, scale parameter α value is 31.39, intercept value is -5.963. These values indicate that the machine 2018 turbine has the concave distribution and its property is it has the increasing failure rate. This implies that the machine is in old age from the bath tub curve.

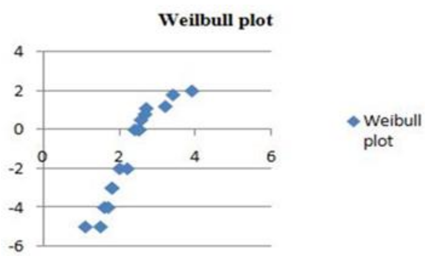

Fig. 10. Weibull plot for 2018 Turbine (TBF)

7. Conclusion

It is concluded from the above analysis the trend based on reliability and availability of all the machines are calculated and listed in table 5. And also the hazard rate diagnosis based on reliability and availability of all the machines are calculated and listed in table 5.

Based on the above research the machine exact status is found in its life cycle it gives the arena to understand about the machine and from that a decision can be made towards the betterment of the machine.

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