IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

INVESTIGATION AND RELIABILITY ANALYSIS OF AUTOMOBILE ENGINE COMPONENTS USING DISTRIBUTION METHODS

M. Prathyusha[*1], Dr. K. Hemachandra reddy[2] & Rajendra N Dhage[3]
[*1]PG Student, Mechanical Engineering, JNTUA, College of engineering, Anatapur, A.P, India
[2]Professor Mechanical Engineering, JNTUA, College of engineering, Anatapur, A.P, India
[3]Global Reliability Specialist , Cummins Global Analytics Center (GAC) Cummins Indian Office, Pune, Maharashtra

ABSTRACT

In the past two decades the necessity for improved data collection methods in the automotive industry has become increasingly important. With a growing number of new vehicle models and their specifications becoming available to the customer, it is essential that OEM's (Original Equipment Manufacturer) have a detailed knowledge of how their products are performing in relation to the rest of the market. The ability to well present this knowledge generates customer confidence and provides the right platform for both parties to work with the common goal of project profitability in a sustainable green environment.

Reliability analysis for complete engine is generally done by using constant failure rate distribution and for component it's done by using Weibull Distribution.

The main objective of this project is to use warranty claims data to determine the failure characteristics of a product and there by analyzing the risk associated with warranty cost. Typically, the failure distribution and its parameters are determined using product manufacturing data for each month of production and the corresponding monthly failure counts derived from the warranty

Claims. If the data is collected systematically, the product ages at the times of failure can be derived. Classical methods are then used to determine the failure time distribution and parameters. However, in many cases, it may not be possible to know the failure ages of Components. The information available each month might be limited to the volume of shipments and total claims or product returns. In such cases, the data hides the component age at the time of failure.

The reliability analysis method used 20 years back cannot be applied today, that too to all components as they have different material specification, manufacturing process, functions, operating condition and role in the entire engine.

Scope of this paper is to study current process used in industry to carry out reliability analysis of engine and using actual data study different method and propose new method for all engine components to evaluate the reliability of entire engine.

An attempt is made to analyse current process and to adopt different analysis methods for engine components. The data is validated with available data and best method to evaluate engine reliability is proposed, Bottom to top approach will be used to estimate system reliability

KEYWORDS: warranty analysis, hazard function, utilisation and time lag distribution, Mathematical model, Minitab tool.

INTRODUCTION

Reliability Engineering ensures that a product will be reliable when operated in specify manner. In other word the function of reliability is to avoid failures. Reliability Engineering is implemented by taking structural and feasible actions and minimise the effects of failure. In general, three steps are necessary to accomplish this objective; the first step is to build the maximum reliability in to the product during design and development stage. This step is more critical in that it determines the inherent reliability. The second step is to minimise production process does not appreciably degrade the inherent reliability. The third step employs large variety of reliability techniques.

To run the engine following systems are associated and they are

a) Air intake system consist of fresh air handling and exhaust gas handling system
b) Fuel system
c) Fuel Combustion system
d) Powertrain
e) Governing mechanism
f) Cooling system
g) Starting system
h) Lubrication system
i) Exhaust has treatment system.
j) Engine control unit

With following components

- Engine block(Crank case) , Crankshaft, Camshaft, Main bearing, Bushings, Connecting rods, turbo assembly, fuel pump assembly, sensor body, piston crown
- Cylinder liner, Cylinder head, Turbocharger, Fuel pump and Injectors Starter motor ,Alternator
- Flywheel, Timing gears, Water pump, ECM, wiring harness, sensors, actuators.

For example reliability planning and specifications, allocation, prediction, robust reliability design, failure mode and effective analysis(FMEA), fault tree analysis, accelerated life testing, Degradation testing, Reliability verification testing, stress screening and warranty analysis.

WARRANTY ANALYSIS

Warranty analysis is performed in the field deployment. In earlier phases, including product planning, design and development, verification and validation, production, a production team should have accomplished various well-orchestrated reliability tasks. The role of warranty in marketing a product is described in, for example in the market place, lengthy warranty coverage has become a bright sales point for many commercial products.
When products fail under warranty coverage, customer returns their products for repair or replacement. The failure data, such as fail time, fail mode and use condition, are made known to manufactures. Often, manufactures maintain warranty databases to record and track these data. Such data contain precious and credible information about how well products perform in the field, and thus should be fully analysed to serve different purposes.

HAZARD FUNCTION

In field reliability studies, the hazard function plays an important role. Hazard functions are useful towards providing estimates the distribution parameters, the proportion estimates, the proportions of units falling in a given age, percentiles of the distribution, the behaviour of the failure rate as the function of age and conditional failures probability. To perform hazard rate we required ESN, build year, build month, fail date, in-service date, MIS (months in service), Miles.

UTILISATION AND TIME LAG DISTRIBUTION

Utilisation and time lag database is divided in to 3 sections:

- Product details: which contains the customer name, product name, product rate and application?
- Utilisation distribution: which contains the units of distribution like miles/month, Km/month, hrs/month etc., number of data points create a distribution, life characteristic(Eta value), slope of the curve(Beta value), correlation coefficient(Rho value- defines the fit of the data on the line)

- Time lag distribution: which contains the units of distribution like days , months etc., number of data points used to create a distribution, characteristic life(Eta value), slope of the curve(Beta value), correlation coefficient(Rho value- defines the fit of the data on the line).
-

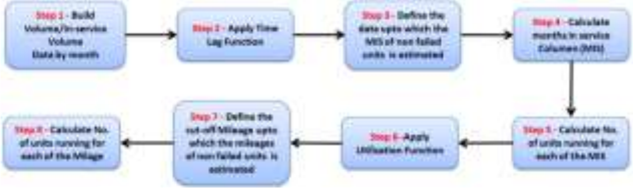
“*Engine* ***Components considered for this analysis are”***

- ECM calibration
- Control module
- Injector assembly
- Turbo charger
- SCR Dosing unit
- Sensor

MATHEMATICAL MODEL

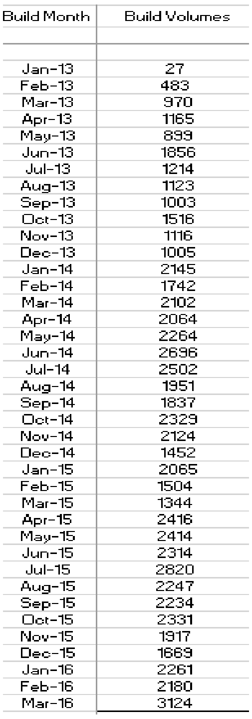
As for time lag and utilisation distribution we are using Weibull distribution.

$$F(t) = 1 - (e^{-\left(\frac{t}{eta}\right)^{Beta}})$$



Step 1 to distribute the data by build month/in-service month as shown in the above figure.

TABLE-1(data about Build month and build volume)



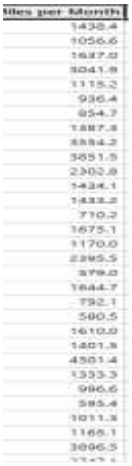
Build Month	Build Volumes
Jan-13	27
Feb-13	483
Mar-13	970
Apr-13	1165
May-13	899
Jun-13	1856
Jul-13	1214
Aug-13	1123
Sep-13	1003
Oct-13	1516
Nov-13	1116
Dec-13	1005
Jan-14	2145
Feb-14	1742
Mar-14	2102
Apr-14	2064
May-14	2264
Jun-14	2696
Jul-14	2502
Aug-14	1951
Sep-14	1837
Oct-14	2329
Nov-14	2124
Dec-14	1452
Jan-15	2065
Feb-15	1504
Mar-15	1344
Apr-15	2416
May-15	2414
Jun-15	2314
Jul-15	2820
Aug-15	2247
Sep-15	2234
Oct-15	2331
Nov-15	1917
Dec-15	1669
Jan-16	2261
Feb-16	2180
Mar-16	3124

MINITAB

Minitab is statistical analysis software. It can be used for learning about statistics as well as statistical research. It has the advantage of being accurate, reliable and generally faster than computing statistics and drawing graphs by hand. Minitab is relatively easy to use once we know the few fundamentals.

In this analysis for finding Eta and Beta values Minitab is required. Once we have the data for Miles per month we need to give the input data in Minitab for finding probability density
function, survival function. Weibull,Hazard function.

TABLE-2(data explains about MILES PER MONTH)



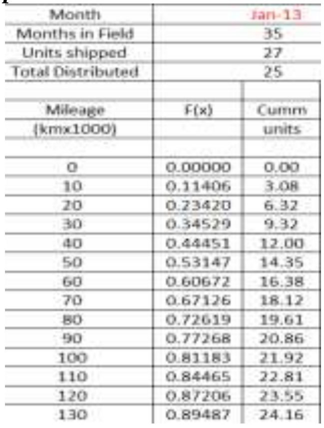
iles per Month
1438.4
1056.6
1637.0
3041.8
1115.2
936.4
854.7
1387.3
3554.2
3651.5
2302.8
1434.1
1433.2
710.2
1675.1
1170.0
2395.5
379.0
1644.7
792.1
580.5
1610.0
1401.3
4501.4
1333.3
996.6
585.4
1011.3
1166.1
3096.5

FIGURE-1(distribution plot about MILES PER MONTH)

Where slope=1.13966
Characteristic life=1821.43 Miles per month.
Step 2 is apply the time lag function; in this step the model calculates the probability; in this step the model calculates the probability for a unit to have 0 month in- service this will create an F(x)

For each build month we then multiply F(x) by the volume which calculates the cumulative number of units having 0 MIS. Repeat the task for up to 39 month in-service

TABLE-3(Data explains about MILEAGE and UNITS OF MONTH)



Month	Jan-13	
Months in Field	35	
Units shipped	27	
Total Distributed	25	
Mileage (kmx1000)	F(x)	Cumm units
0	0.00000	0.00
10	0.11406	3.08
20	0.23420	6.32
30	0.34529	9.32
40	0.44451	12.00
50	0.53147	14.35
60	0.60672	16.38
70	0.67126	18.12
80	0.72619	19.61
90	0.77268	20.86
100	0.81183	21.92
110	0.84465	22.81
120	0.87206	23.55
130	0.89487	24.16

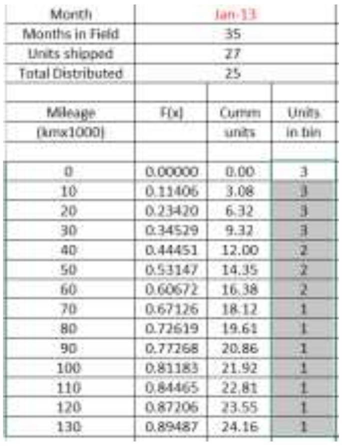
Here

$$F(x) = \frac{1 - Exp(-(1000 * First\ Mileage))}{(Months\ in\ field * \beta)^{slope}}$$

Once the cumulative number of units column is created for entire “Months to go into service” column, Next step is to subtract the “cummunits” value for a particular month from with the “cumm units” value of next one to get the estimated no of units that particular MIS

Step 3 is to determine the date up to which the user wanted to estimate the mileage.
Step 4 is to subtract the “Months to go into service” from “month in service (MIS) column for each of the build volume then copy the units in bin column

TABLE-4(Data explains about CUMM UNITS and UNITS based on MILEAGE)



Month	Jan-13		
Months in Field	35		
Units shipped	27		
Total Distributed	25		
Mileage (kmx1000)	F(x)	Cumm units	Units in bin
0	0.00000	0.00	3
10	0.11406	3.08	3
20	0.23420	6.32	3
30	0.34529	9.32	3
40	0.44451	12.00	2
50	0.53147	14.35	2
60	0.60672	16.38	2
70	0.67126	18.12	1
80	0.72619	19.61	1
90	0.77268	20.86	1
100	0.81183	21.92	1
110	0.84465	22.81	1
120	0.87206	23.55	1
130	0.89487	24.16	1

Step5 is adding all the no of units column which have a same MIS
The total no of units=3+3+3+3+2+2+2+1
+1+1+1+1+1+1=25

Step 6 explains a utilisation distribution to calculate the probability for a unit to have 0 miles this will create an F(x), now for each of the build month multiply the F(x) with the estimated in-service volume (units running)which will calculate the cumulative no of units having 0 miles. Repeat the task for up to 455,000 miles with a bin of 105,000 miles differences.

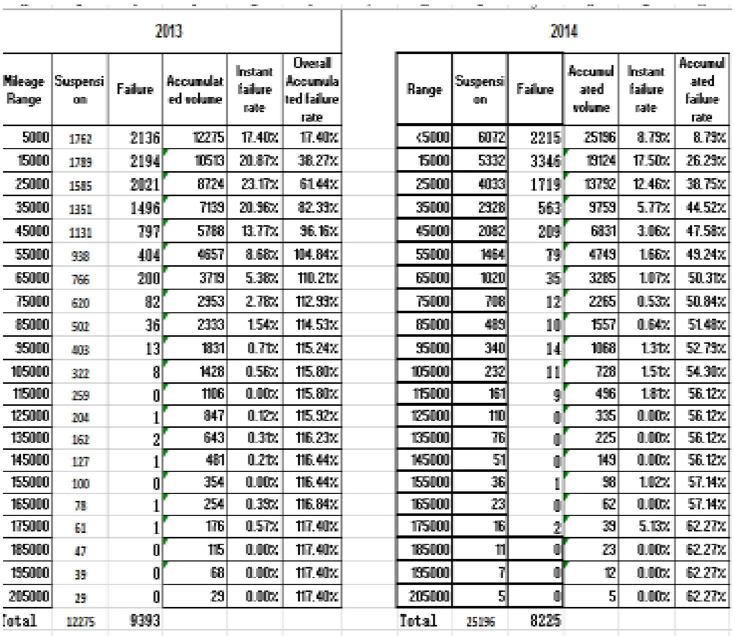
Step 7 is to define the cut-off mileage (defined under critical parameter flow) as in step 6 the interval used to bin the mileages is 105,000 units; therefore the cut-off mileage needs to be selected from that interval only.

If we use the units in bin column to up to 105,000 miles for all the build period the summary tab le would be;

TABLE-5(Data explains about MILEAGE and MONTHS IN FIELDS)

	Jan	Feb	Mar	Apr	may	jun
Months in Field	35	34	33	32	31	30
Total Distributed	25	483	969	1163	898	1854
Median Bin (kmx1000)	No of Units in Bin	No of Units in Bin	No of Units in Bin	No of Units in Bin	No of Units in Bin	No of Units in Bin
5	3	57	118	146	117	249
15	3	60	123	152	121	256
25	3	55	113	138	109	230
35	3	49	99	121	95	199
45	2	42	86	104	81	169
55	2	37	74	89	69	142
65	2	31	62	75	57	117
75	1	26	52	62	47	97
85	1	22	44	52	39	79
95	1	19	36	43	32	64
105	1	15	30	35	26	52
115	1	13	25	29	21	42
125	1	11	20	23	17	33
135	1	9	17	19	14	27

Step 8 is to add all the no of units in bin column from all build period.
For finding Hazard rates we required Mileage, suspension, failure, accumulated volume, instant failure rate.

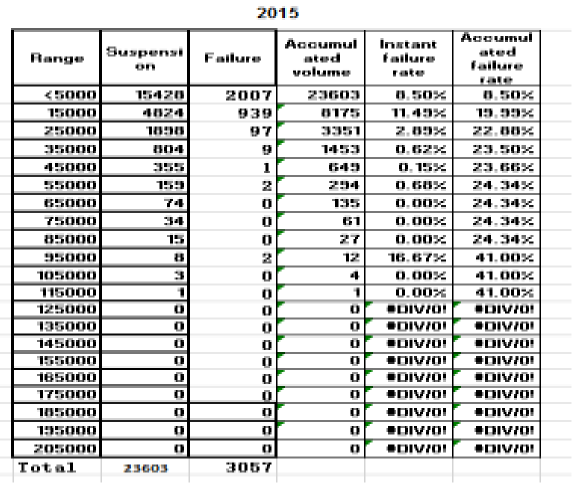


2013

Mileage Range	Suspension	Failure	Accumulated volume	Instant failure rate	Overall Accumulated failure rate
5000	1762	2136	12275	17.40%	17.40%
15000	1789	2194	10513	20.87%	38.27%
25000	1585	2021	8724	23.17%	61.44%
35000	1351	1496	7139	20.96%	82.33%
45000	1131	797	5788	13.77%	96.16%
55000	938	404	4657	8.68%	104.84%
65000	766	200	3719	5.38%	110.21%
75000	620	82	2953	2.78%	112.99%
85000	502	36	2333	1.54%	114.53%
95000	403	13	1831	0.71%	115.24%
105000	322	8	1428	0.56%	115.80%
115000	259	0	1106	0.00%	115.80%
125000	204	1	847	0.12%	115.92%
135000	162	2	643	0.31%	116.23%
145000	127	1	481	0.21%	116.44%
155000	100	0	354	0.00%	116.44%
165000	78	1	254	0.39%	116.84%
175000	61	1	176	0.57%	117.40%
185000	47	0	115	0.00%	117.40%
195000	39	0	68	0.00%	117.40%
205000	29	0	29	0.00%	117.40%
Total	12275	9393			

2014

Range	Suspension	Failure	Accumulated volume	Instant failure rate	Accumulated failure rate
<5000	6072	2215	25196	8.79%	8.79%
15000	5332	3346	19124	17.50%	26.29%
25000	4033	1719	13792	12.46%	38.75%
35000	2928	563	9759	5.77%	44.52%
45000	2082	209	6831	3.06%	47.58%
55000	1464	79	4749	1.66%	49.24%
65000	1020	35	3285	1.07%	50.31%
75000	708	12	2265	0.53%	50.84%
85000	489	10	1557	0.64%	51.48%
95000	340	14	1068	1.31%	52.79%
105000	232	11	728	1.51%	54.30%
115000	161	9	496	1.81%	56.12%
125000	110	0	335	0.00%	56.12%
135000	76	0	225	0.00%	56.12%
145000	51	0	149	0.00%	56.12%
155000	36	1	98	1.02%	57.14%
165000	23	0	62	0.00%	57.14%
175000	16	2	39	5.13%	62.27%
185000	11	0	23	0.00%	62.27%
195000	7	0	12	0.00%	62.27%
205000	5	0	5	0.00%	62.27%
Total	25196	8225			



2015

Range	Suspension	Failure	Accumulated volume	Instant failure rate	Accumulated failure rate
<5000	15428	2007	23603	8.50%	8.50%
15000	4824	939	8175	11.49%	19.99%
25000	1898	97	3351	2.89%	22.88%
35000	804	9	1453	0.62%	23.50%
45000	355	1	649	0.15%	23.66%
55000	159	2	294	0.68%	24.34%
65000	74	0	135	0.00%	24.34%
75000	34	0	61	0.00%	24.34%
85000	15	0	27	0.00%	24.34%
95000	8	2	12	16.67%	41.00%
105000	3	0	4	0.00%	41.00%
115000	1	0	1	0.00%	41.00%
125000	0	0	0	#DIV/0!	#DIV/0!
135000	0	0	0	#DIV/0!	#DIV/0!
145000	0	0	0	#DIV/0!	#DIV/0!
155000	0	0	0	#DIV/0!	#DIV/0!
165000	0	0	0	#DIV/0!	#DIV/0!
175000	0	0	0	#DIV/0!	#DIV/0!
185000	0	0	0	#DIV/0!	#DIV/0!
195000	0	0	0	#DIV/0!	#DIV/0!
205000	0	0	0	#DIV/0!	#DIV/0!
Total	23603	3057			

Here

$$Accumulated\ volume = sum\ (suspension\ of\ first\ value: suspension\ of\ last\ value)$$

$$Instant\ failure\ rate = \frac{Accumulated\ volume}{failure}$$

After finding all these values the hazard rate will be as follows:

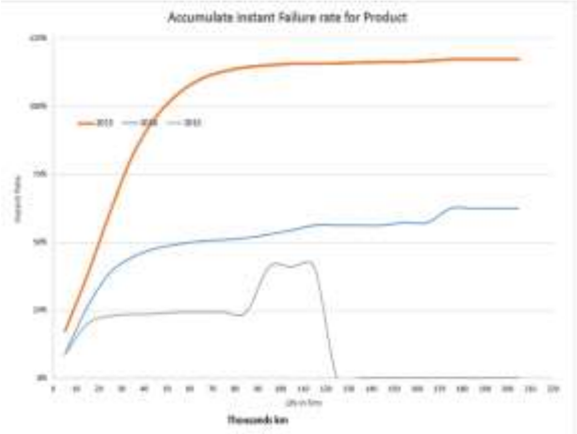


FIGURE-2(Accumulative instant failure rate for the product)

For different components we can see how the hazard rates will be in different behaviours

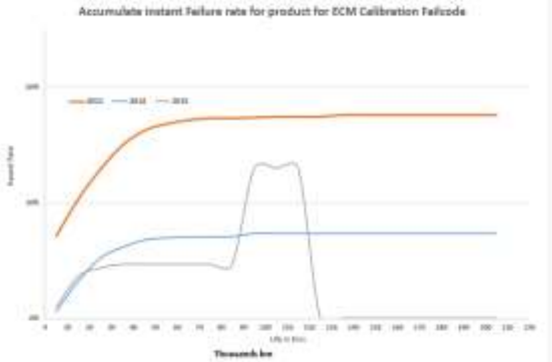


FIGURE-3(Accumulative failure rate for ECM Calibration component)

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

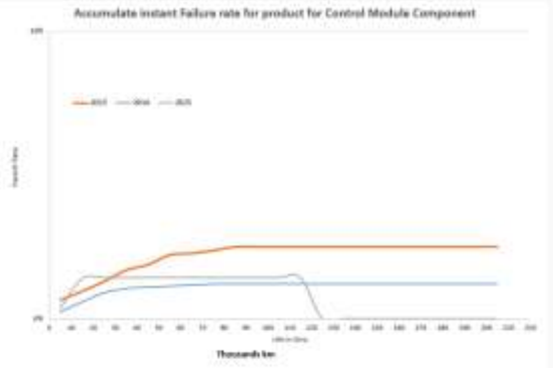


FIGURE-4(Accumulative failure rate for control module component)

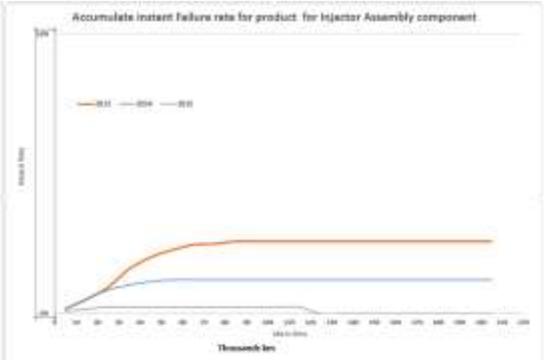


FIGURE-5(Accumulative failure rate for injector assembly component)

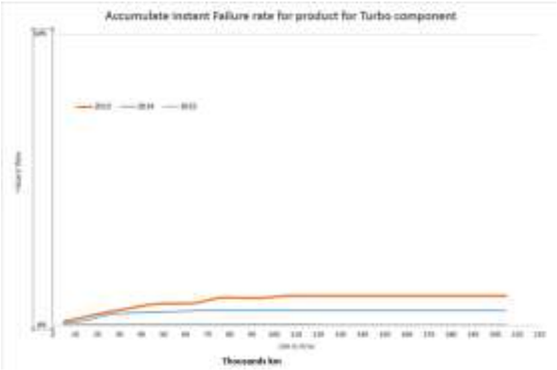


FIGURE-6(Accumulative instant failure rate for Turbo charger component)

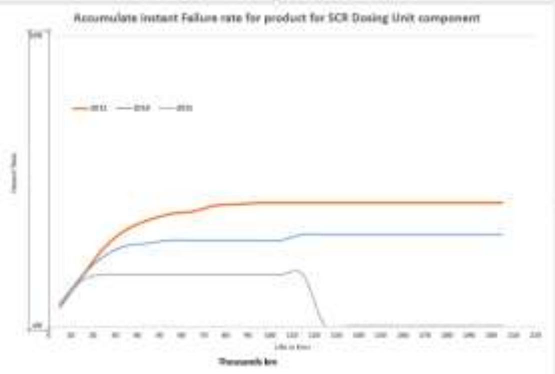
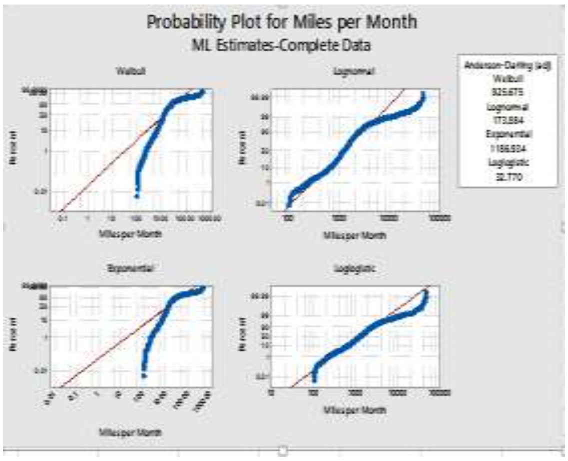


FIGURE-7(Accumulative failure rate for SCR Dosing unit component)

FIGURE-8(Accumulative failure rate for Sensor component)

After finding the hazards plots in the analysis with this Miles per months we can show the behaviours of the 4 way distributions. In Minitab we can find this distributions. We need to give the input data in to Minitab and if we fit the distributions the behaviours will be as follows:



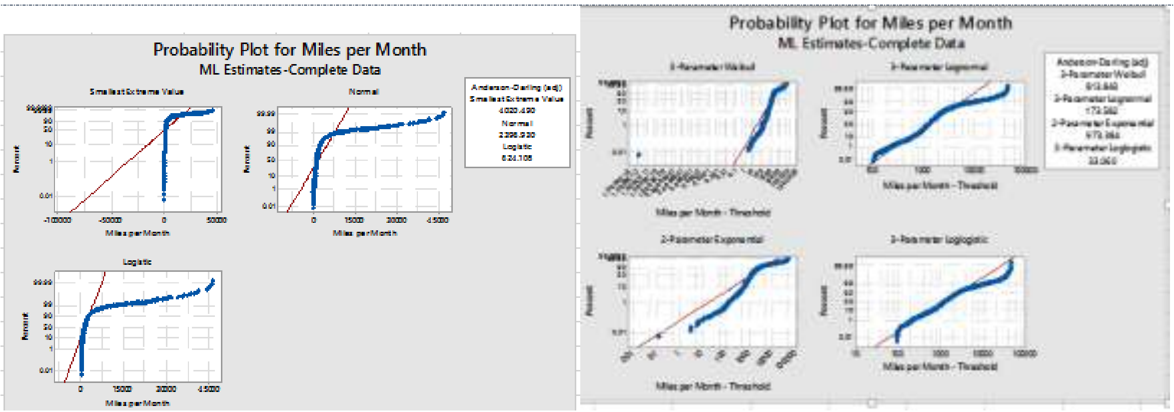


FIGURE-9(Distribution Methods)

From the above reliability analysis it can be observed that among the above four distributions, log logistic is showing minimum deviation. Log logistic is showing good fit for this product. From Anderson darling test it is found that statistic log logistic is the best fitted distribution.

CONCLUSION

Product that has been developed and redesigned must undergo patent registration, hence the manufacturer can verify the durability and reliability for domestic international market. The verification process includes mechanical properties test and field usage test. Since the export market has more volume compared to domestic, this new design drive shaft will have benefited from the reduction of the manufacturing cost.
The outcome of this work is as follows:

- The manufacturing time will be more than 50%, thus the productivity will improved especially in mass production
- Forging process is expected to be decreased about 30%, this manufacturing cost will be reduced.

This analysis is aimed to show the entire engine reliability in best possible way so that the problems in engine can be detected.
The results obtained can be used to

- Improve design
- Improve productivity
- Use alternate manufacturing material and method to make a component
- Decrease production cost
- Most importantly to help increasing the product competitiveness power.

By this the hazards rates behaviour of the product and product components can be obtained

REFERENCES

[1] *K. Suzuki, "Estimation of lifetime parameters from incomplete field data, "Techno metrics, vol 27, pp.263-271, 1985*

[2] *J.D. Kalbfleisch, J.F. Lawless, and J. A. Robinson, "Methods for the estimations of the failure distributions and rates from automobile warranty data," Lifetime Data Analysis, vol. 14, pp.103-108, 1988.*

[3] *B. K.Rai and N.Singh, "Hazard rate estimation from incomplete and unclean warranty Data," Reliability Engineering & System safety, vol.81 pp.79-92, 2003*

[4] *W. Q. Meekar and L.A. Escobar, Statistical Methods for Reliability Data. New York: John Wiley& sons, 1988*

[5] *W. Nelson, "Hazard plotting of left truncated life data. "Journal of Quality Technology, vol. 22,pp.230-238,1990*

[6] C. A. Cohen, Truncated and censored samples: Theory and Applications. New York: Marcel Dekker, 1991.

[7] K.D. Majeske, A mixture model for automobile warranty data, "Reliability Engineering and System Safety, vol.81, pp.71-77, 2003.

[8] D.Kececiouglu, Reliability and Life Testing Handbook vol. 1. NJ, PTR prentice Hall, 1993

[9] B. K. Rai, "Modelling, Analysis and Prediction From Automobile Warranty Datasets, "Ph.D. dissertation, Dept. Industrial Engineering, wanye State University, Detroit,MI,2004

[10]X. J.Hu,J.F.Lawless, and K. Suzuki. "Nonparametric estimation of a lifetime distribution when censoring times are missing, "techno metrics, vol,pp.3-13,1998

[11]D. Stephen and M .Crowder, "Bayesian analysis of discrete time warranty data, "Applied statistics, vol 53, pp.195-217, 2004

[12] "Nonparametric estimation of lifetime distributions from a record of failures and follow-ups," Journal of American statistical Association, vol.80, pp.68-72, 1985.