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MANAGEMENT MEASURES FOR FOUR CYLINDER DIESEL ENGINES BY EMPLOYING ALGEBRA OF LOGICS

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ABSTRACT: Reliability assessment as such is not new; engineers have always striven to operate systems that are relatively free from failures. In the past, generally reliability has been achieved from the subjective and qualitative experience of design and operation. The skeptics of modern reliability evaluation techniques often reject to this method of assessing the reliability of a system as engineering judgment. It is fallacy; however, to suggest that engineering judgment is displaced by quantitative reliability evaluation since as much engineering judgment is required in its use. In addition to provide a set of numerical indices, reliability evaluation can be used to indicate how a system may fail, the consequences of failures and also to provide information to enable engineers and managers to relate the quality of their system to economics and capital investment. In doing so, it can lead to better and more economics designs and a much improved knowledge of the operation and behavior of a system.

KEYWORDS: striven, information, economics.

INTRODUCTION

An unreliable system has higher probability of failure as and when any item of the associated equipment is damaged or destroyed due to some causes. Consequently, the unreliability of the system may result into wastage of cost, time of personal as well as national security. Thus, in conclusion, a high degree of reliability is prime requirement in various practical fields e.g., nuclear power plant, space systems and defense systems etc. So, it is necessary to evaluate reliability and other performance measures in advance to avoid above mentioned losses. The previous methods of obtaining reliability have tedious calculations and are so typical. So, in this paper, the author has evaluated reliability of four cylinder diesel engine by employing the Boolean function technique which is easier in comparison of old techniques.

Fuel system, discussed here, helps to transfer the fuel from the fuel tank to the engine and regulate its flow into the cylinders depending on speed and local requirements. Here, a multi-component fuel system in diesel engine, comprising of four subsystems in series, has considered. In this system the fuel is injected into the cylinders using an injection pump and injectors. The diesel fuel from the tank is pumped to the fuel injection device. This device consists of small plunger pump operating to push the fuel through the injectors (nozzles) into the cylinders and one can operates one pump from the fuel injection pumps at the appropriate time i.e., towards the end of the compression stroke the fuel is pushed through the small hole in the injector and is atomized as it enters into the cylinder. The author, in this model, has considered a parallel redundant fuel injective device to improve the system's performance. The whole system can fail due to failure of atleast one component of all the routes of flow.

Boolean function technique has used to formulate and solve the mathematical model. Reliability and M.T.T.F. of the considered diesel engine have been obtained to connect the model with physical situations. A numerical example and its graphical representation have been appended at last to highlight important results.

ASSUMPTIONS

Following assumptions have been considered in this paper:

(i) Initially, all components of the system are good.
(ii) Each component of the system remains either in good or in bad state.
(iii) There is no repair facility available.
(iv) Failure times of all the components of the system are arbitrary.
(v) All the states of different components are statistically independent.
(vi) Reliability of each component of the system is known in advance.
(vii) The diesel engine as a whole can fail, if atleast one component in all the routes of flow fails.

(viii) Transition from one component to other is hundred percent reliable.

NOMANCLATURE

Used nomenclature in this study is as follows:

x_1 : State of diesel tank.
x_2 : State of transfer pump.
x_3, x_4 : States of fuel injective devices.
: States of cylinders.
$x_i'(i = 1,2 - -8)$: Negation of x_i .
$x_i(i = 1,2 - -8)$: 1 in good state; 0 in bad state.

FORMULATION OF MATHEMATICAL MODEL:

Using Boolean function technique, the conditions of capability of the successful operation of the diesel engine in terms of logical matrix are expressed as:

$$D(x_1, x_2 --, x_8) = \begin{vmatrix} x_1 & x_2 & x_3 & x_5 \\ x_1 & x_2 & x_3 & x_6 \\ x_1 & x_2 & x_3 & x_7 \\ x_1 & x_2 & x_3 & x_8 \\ x_1 & x_2 & x_4 & x_5 \\ x_1 & x_2 & x_4 & x_6 \\ x_1 & x_2 & x_4 & x_7 \\ x_1 & x_2 & x_4 & x_8 \end{vmatrix} \quad \ldots(1)$$

SOLUTION OF THE MODEL

By making use of algebra of logic, we may rewrite equation (1) as:

$$D(x_1, x_2 --, x_8) = \left| x_1 \quad x_2 \wedge \; d(x_1, x_2 ----x_8) \right| \quad \ldots(2)$$

where,

$$d(x_1, x_2 ----x_8) = \begin{vmatrix} x_3 & x_5 \\ x_3 & x_6 \\ x_3 & x_7 \\ x_3 & x_8 \\ x_4 & x_5 \\ x_4 & x_6 \\ x_4 & x_7 \\ x_4 & x_8 \end{vmatrix} \quad \ldots(3)$$

Substituting

$$A_1 = |x_3 \quad x_5| \qquad \ldots(4)$$

$$A_2 = |x_3 \quad x_6| \qquad \ldots(5)$$

$$A_3 = |x_3 \quad x_7| \qquad \ldots(6)$$

$$A_4 = |x_3 \quad x_8| \qquad \ldots(7)$$

$$A_5 = |x_4 \quad x_5| \qquad \ldots(8)$$

$$A_6 = |x_4 \quad x_6| \qquad \ldots(9)$$

$$A_7 = |x_4 \quad x_7| \qquad \ldots(10)$$

and $A_8 = |x_4 \quad x_8|$ $\qquad \ldots(11)$

these values in equation (3), one obtains:

$$d(x_1, x_2, -----x_8) = \begin{vmatrix} A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \\ A_6 \\ A_7 \\ A_8 \end{vmatrix} \qquad \ldots(12)$$

Using orthogonalisation algorithm, equation (12) may be written as:

$$d(x_1, x_2, ------x_8) = \begin{vmatrix} A_1 & & & & & & & \\ A_1' & A_2 & & & & & & \\ A_1' & A_2' & A_3 & & & & & \\ A_1' & A_2' & A_3' & A_4 & & & & \\ A_1' & A_2' & A_3' & A_4' & A_5 & & & \\ A_1' & A_2' & A_3' & A_4' & A_5' & A_6 & & \\ A_1' & A_2' & A_3' & A_4' & A_5' & A_6' & A_7 & \\ A_1' & A_2' & A_3' & A_4' & A_5' & A_6' & A_7' & A_8 \end{vmatrix} \qquad \ldots(13)$$

Now, we have

$$A_i' = \begin{vmatrix} x_3' & \\ x_3 & x_{i+4}' \end{vmatrix} \quad ;\ i=1,2,3 \text{ and } 4 \qquad \ldots(14)$$

$$A_j' = \begin{vmatrix} x_4' & \\ x_4 & x_j' \end{vmatrix} \quad ;\ j=5,6,7 \text{ and } 8 \qquad \ldots(15)$$

Using algebra of logic, one can obtain the following results:

$$A_1' \ A_2 = \begin{vmatrix} x_3' & \\ x_3 & x_5 \end{vmatrix} \wedge |x_3 \quad x_6| = |x_3 \quad x_5' \quad x_6| \qquad \ldots(16)$$

Similarly, we get

$$A_1' A_2' A_3 = |x_3 \quad x_5' \quad x_6' \quad x_7| \quad \ldots(17)$$

$$A_1' A_2' A_3' A_4 = |x_3 \quad x_5' \quad x_6' \quad x_7' \quad x_8| \quad \ldots(18)$$

$$A_1' A_2' A_3' A_4' A_5 = |x_3' \quad x_4 \quad x_5| \quad \ldots(19)$$

$$A_1' A_2' A_3' A_4' A_5' A_6 = |x_3' \quad x_4 \quad x_5' \quad x_6| \quad \ldots(20)$$

$$A_1' A_2' A_3' A_4' A_5' A_6' A_7 = |x_3' \quad x_4 \quad x_5' \quad x_6' \quad x_7| \quad \ldots(21)$$

$$A_1' A_2' A_3' A_4' A_5' A_6' A_7' A_8 = |x_3' \quad x_4 \quad x_5' \quad x_6' \quad x_7' \quad x_8| \quad \ldots(22)$$

Using the equations (16) through (22), equation (13) becomes

$$d(x_1, x_2, ---, x_8) = \begin{vmatrix} x_3 & x_5 & & & & \\ x_3 & x_5' & x_6 & & & \\ x_3 & x_5' & x_6' & x_7 & & \\ x_3 & x_5' & x_6' & x_7' & x_8 & \\ x_3' & x_4 & x_5 & & & \\ x_3' & x_4 & x_5' & x_6 & & \\ x_3' & x_4 & x_5' & x_6' & x_7 & \\ x_3' & x_4 & x_5' & x_6' & x_7' & x_8 \end{vmatrix} \quad \ldots(23)$$

By making use of equation (23) equation (2) gives:

$$D(x_1, x_2, ---, x_8) = \begin{vmatrix} x_1 & x_2 & x_3 & x_5 & & & & \\ x_1 & x_2 & x_3 & x_5' & x_6 & & & \\ x_1 & x_2 & x_3 & x_5' & x_6' & x_7 & & \\ x_1 & x_2 & x_3 & x_5' & x_6' & x_7' & x_8 & \\ x_1 & x_2 & x_3' & x_4 & x_5 & & & \\ x_1 & x_2 & x_3' & x_4 & x_5' & x_6 & & \\ x_1 & x_2 & x_3' & x_4 & x_5' & x_6' & x_7 & \\ x_1 & x_2 & x_3' & x_4 & x_5' & x_6' & x_7' & x_8 \end{vmatrix} \quad \ldots(24)$$

Since, R.H.S. of equation (24) is disjunction of pair-wise disjoint conjunctions, therefore, reliability of considered diesel engine will be:

$$R_s = P_r \ \{D(x_1, x_2, ---x_8) = 1\}$$

$$= R_1 R_2 [R_3 R_5 + Q_5 R_3 R_6 + Q_5 Q_6 R_3 R_7 + Q_5 Q_6 Q_7 R_3 R_8 + Q_3 R_4 R_5 + Q_3 Q_5 R_4 R_6 + Q_3 Q_5 Q_6 R_4 R_7 + Q_3 Q_5 Q_6 Q_7 R_4 R_8$$

$$= R_1 R_2 [R_3 R_5 + R_3 R_6 + R_3 R_7 + R_3 R_5 R_6 R_7 + R_3 R_8 + R_3 R_5 R_6 R_8 + R_3 R_6 R_7 R_8 + R_3 R_5 R_7 R_8 + R_4 R_5 + R_4 R_6 + R_3 R_4 R_5 R_6 + R_4 R_7 + R_3 R_4 R_5 R_7 + R_4 R_5 R_6 R_7 + R_3 R_4 R_6 R_7 + R_4 R_8 + R_3 R_4 R_5 R_6 R_7 R_8 + R_3 R_4 R_5 R_8 + R_3 R_4 R_6 R_8 + R_3 R_4 R_7 R_8 + R_4 R_5 R_6 R_8 + R_4 R_5 R_7 R_8 + R_4 R_6 R_7 R_8 - R_3 R_5 R_6 - R_3 R_5 R_7 - R_3 R_6 R_7 - R_3 R_5 R_8 - R_3 R_6 R_8 - R_3 R_7 R_8 - R_3 R_5 R_6 R_7 R_8 - R_3 R_4 R_5 - R_3 R_4 R_6 - R_3 R_5 R_6 - R_3 R_4 R_7 - R_4 R_5 R_7 - R_4 R_6 R_7 - R_3 R_4 R_5 R_6 R_7 - R_3 R_4 R_8 - R_4 R_5 R_8 - R_4 R_6 R_8 - R_4 R_7 R_8 - R_3 R_4 R_5 R_6 R_8 - R_3 R_4 R_6 R_7 R_8 - R_3 R_4 R_5 R_7 R_8 - R_4 R_5 R_6 R_7 R_8] \quad \ldots(25)$$

where, $R_i (i = 1,2 - - 8)$ and $Q_i (i = 1,2 - - 8)$ are reliability and unreliability of the components of diesel engine corresponding to the states $x_i (i = 1,2 - - 8)$,respectively.

SOME PARTICULAR CASES

Case I: If the reliability of every component of diesel engine is R:

In this case, equation (25) yields:

$$R_S = 8R^4 - 16R^5 + 14R^6 - 6R^7 + R^8 \qquad \ldots(26)$$

Case II : When failure rates follow Weibull distribution

Let a_i be the failure rate corresponding to component state $x_i, \forall i = 1,2 - - 8,$ then reliability of diesel engine at instant't', is given by:

$$R_{sw}(t) = \sum_{i=1}^{23} \exp.\{-\alpha_i t^b\} - \sum_{j=1}^{22} \exp.\{-\beta_j t^b\} \qquad \ldots(27)$$

where b is a positive parameter ; and :

$\alpha_1 = c + a_3 + a_5$

$\alpha_2 = c + a_3 + a_6$

$\alpha_3 = c + a_3 + a_7$

$\alpha_4 = c + a_3 + a_5 + a_6 + a_7$

$\alpha_5 = c + a_3 + a_8$

$\alpha_6 = c + a_3 + a_5 + a_6 + a_8$

$\alpha_7 = c + a_3 + a_6 + a_7 + a_8$

$\alpha_8 = c + a_3 + a_5 + a_7 + a_8$

$\alpha_9 = c + a_4 + a_5$

$\alpha_{10} = c + a_4 + a_6$

$\alpha_{11} = c + a_3 + a_4 + a_5 + a_6$

$\alpha_{12} = c + a_4 + a_7$

$\alpha_{13} = c + a_3 + a_4 + a_5 + a_7$

$\alpha_{14} = c + a_4 + a_5 + a_6 + a_7$

$\alpha_{15} = c + a_3 + a_4 + a_6 + a_7$

$\alpha_{16} = c + a_4 + a_8$

$\alpha_{17} = c + a_3 + a_4 + a_5 + a_6 + a_7 + a_8$

$\alpha_{18} = c + a_3 + a_4 + a_5 + a_8$

$\alpha_{19} = c + a_3 + a_4 + a_6 + a_8$

$\alpha_{20} = c + a_3 + a_4 + a_7 + a_8$

$\alpha_{21} = c + a_4 + a_5 + a_6 + a_8$

$\alpha_{22} = c + a_4 + a_5 + a_7 + a_8$

$\alpha_{23} = c + a_4 + a_6 + a_7 + a_8$

Also,

$\beta_1 = c + a_3 + a_5 + a_6$

$\beta_2 = c + a_3 + a_5 + a_7$

$\beta_3 = c + a_3 + a_6 + a_7$
$\beta_4 = c + a_3 + a_5 + a_8$
$\beta_5 = c + a_3 + a_6 + a_8$
$\beta_6 = c + a_3 + a_7 + a_8$
$\beta_7 = c + a_3 + a_5 + a_6 + a_7 + a_8$
$\beta_8 = c + a_3 + a_4 + a_5$
$\beta_9 = c + a_3 + a_4 + a_6$
$\beta_{10} = c + a_3 + a_5 + a_6$
$\beta_{11} = c + a_3 + a_4 + a_7$
$\beta_{12} = c + a_4 + a_5 + a_7$
$\beta_{13} = c + a_4 + a_6 + a_7$
$\beta_{14} = c + a_3 + a_4 + a_5 + a_6 + a_7$
$\beta_{15} = c + a_3 + a_4 + a_8$
$\beta_{16} = c + a_4 + a_5 + a_8$
$\beta_{17} = c + a_4 + a_6 + a_8$
$\beta_{18} = c + a_4 + a_7 + a_8$
$\beta_{19} = c + a_3 + a_4 + a_5 + a_6 + a_8$
$\beta_{20} = c + a_3 + a_4 + a_6 + a_7 + a_8$
$\beta_{21} = c + a_3 + a_4 + a_5 + a_7 + a_8$
$\beta_{22} = c + a_4 + a_5 + a_6 + a_7 + a_8$
and $c = a_1 + a_2$

Case III: When failures follow exponential time distribution:

Exponential distribution is nothing but a particular case of Weibull distribution for $b = 1$ and is very useful for the practical problem purpose. Therefore, the reliability of considered diesel engine as a whole at an instant‘t’, is expressed as:

$$R_{SE}(t) = \sum_{i=1}^{23} \exp.\{-\alpha_i t\} - \sum_{j=1}^{22} \exp.\{-\beta_j t\} \quad \ldots(28)$$

The expression for M.T.T.F., in this case, is given by

$$\text{M.T.T.F.} = \int_0^\infty R_{SE}(t)\,dt$$

$$= \sum_{i=1}^{23}\left\{\frac{1}{\alpha_i}\right\} - \sum_{j=1}^{22}\left\{\frac{1}{\beta_j}\right\} \quad \ldots(29)$$

NUMERICAL COMPUTATION

For a numerical computation, let us set the values:

(a) $a_i (i = 1,2,\text{---},8) = a = 0.04, b = 2$ and $t = 0,1,2$-- in equation (27);

(b) $a_i (i = 1,2,\text{---},8) = a = 0.04$ and $t = 0,1,2$--- in equation (28);

(c) $a_i (i = 1,2,\text{---},8) = a = 0, 0.1, 0.2$ ---------- in equation (29).

By using (a) and (b), one may compute the table-1 and by using (c) the table-2. Corresponding graphs.

TABLE-1

t	**$R_{SW}(t)$**	**$R_{SE}(t)$**
0	1	1
1	0.921695	0.921695
2	0.709935	0.847077
3	0.438569	0.776442
4	0.205129	0.709935
5	0.068285	0.647594
6	0.015498	0.589387
7	0.002365	0.535231
8	0.000244	0.485005
9	1.74×10^{-5}	0.438569
10	1.68×10^{-7}	0.395761

Fig-1

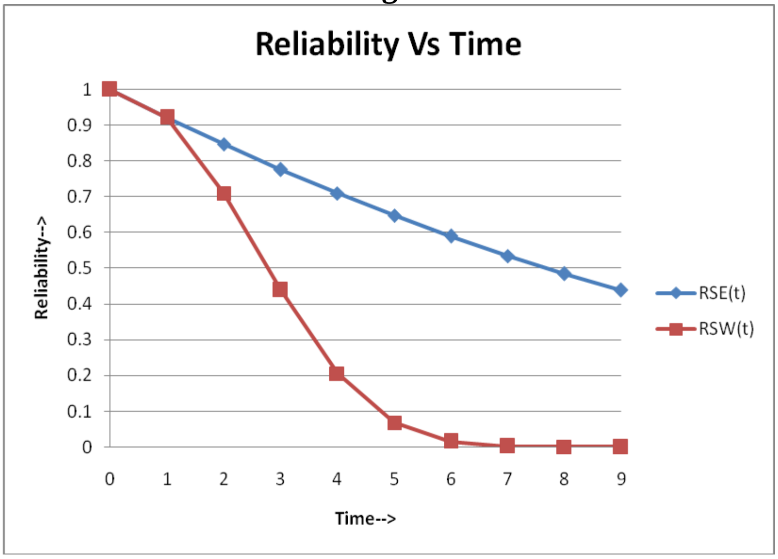
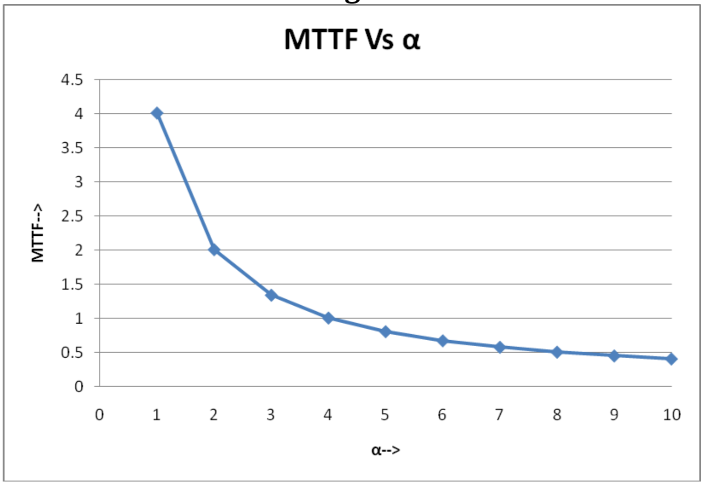


Table-2

□	**MTTF**
0	∞
1	4.0119
2	2.00595
3	1.3373
4	1.002975
5	0.80238
6	0.66865
7	0.573129
8	0.501488
9	0.445767
10	0.40119

Fig-2



CONCLUSION

In this model, the author has considered a four cylinder diesel engine for its reliability and M.T.T.F. evaluation by using Boolean function technique. This technique is easier than the other known techniques for reliability evaluation and used only for non-repairable systems. The author's idea is to taking one parallel redundant fuel injective device to improve system's performance. Reliability of the whole system has been computed in three different cases. M.T.T.F. for the system has been obtained in case failures follow exponential time distribution. A numerical example together with its graphical illustration has also been appended at the last to highlight important results of the study.

Fig-2 is the graph showing the reliability of the system at any time't', when failures follow Weibull and Exponential time distributions. A deep study of this graph yields that the reliability of the complex system decreases approximately at a uniform rate in case of exponential time distribution whereas it decreases very rapidly in case failures follow Weibull time distribution.

REFERENCES

1. Billinton, R.; Allan, R.: "Reliability evaluation of power systems", Springer publication, (2009).
2. Aminto, R.; Allan, R.: "Reliability evaluation of engineering systems: Concepts and techniques", Springer publication, (2011).
3. Capasso, V.; Bakstein, D.: "An introduction to continuous-time stochastic processes: Theory, models and applications", Birkhauser publication, (2013).
4. Wing, B.S.: "Quality control, reliability and engineering design", Marcel Dekker, (2007).
5. Yang, S.D.: "Reliability in computer system design", Intellect Books, (2011).
6. Dhillon, B.S.: "Reliability, Quality and safety engineers", Taylor & Francis, (2012).
7. Degarmo, E.; Black, J.T; Ronald, A.: "Materials and Processes in manufacturing", Prentice Hall of India (2010).