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Reliability analysis of defence vehicles gear box assembly under preventive maintenance

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Abstract

In the era of advancement in technology and global competitiveness the traditional maintenance practices have become obsolete. Also in recent years sophisticated and more advanced equipments have been augmented in the armed forces hence, the role of maintenance workshops/ engineers has become very challenging. Therefore, analyzing various maintenance issues and the associated risk has become very important in the armed forces. Preventive maintenance practices assist in improving the reliability of assemblies and how it will be effective for the equipments of armed forces is illustrated in this article. Gear box assembly used in the medium size vehicles are considered for the analysis and the failure data in various operating conditions is taken from the logbooks of the vehicles. For modeling purposes the Weibull distribution has been chosen (since it has practical utility-ability to model products/systems consisting of large number of components and may have increasing/decreasing or a constant failure rate). The result will be useful to the maintenance engineer to find the unreliability of the gear box assemblies and also for future strategic decision making.

Keywords: Weibull distribution; reliability; preventive maintenance; strategic decision making.

Introduction

For complex systems increased reliability can often be achieved through a preventive maintenance program. Such a program can reduce the effect of aging or wear-out and have a significant impact on the life of the system. Technological advancement in the recent years has resulted in a major change in the equipment profile of the army. This has resulted in change of tactics, organization, doctrines and method of command and control. The large variety of modern and sophisticated equipments introduced into the defence forces has increased the reliability awareness at all levels. Any equipment is susceptible to failure at some time or the other therefore there is a need for evaluating the effect of preventive maintenance on reliability (Ebeling, 2004).

Reliability

The term reliability can mean differently to different people. A generally agreed upon definition is “Reliability is the probability of successful operation of a component/system/equipment for a specified period or usage in given environment” (Singh, 1998-99). Successful operation could mean failure free operation or it could mean not more than a specified number of failures during that period. Reliability therefore could be defined differently in different contexts. For a missile no repair enroute is possible, hence there is no alternative to failure free operation. Thus in this context, reliability would mean failure free operation for a specified period, i.e. duration of flight. Most equipment in the military is repairable, therefore it may be more practical to specify the maximum number of failures acceptable within a given period. Reliability is a probability related to the usage period. As the period increases, the chance of survival decreases. When the operation of new equipment starts, the zero hour reliability is obviously 100%. The reliability reduces as the equipment is used. In some cases it may diminish first slowly and then rapidly. In others it degrades rapidly in the beginning and having reached a certain level, it degrades slowly thereafter. A pattern would thus be formed. To make any worthwhile assessment of the utility of any equipment one must study this pattern (Singh, 1998-99).

Maintenance

Maintenance approach can be broadly classified as being technology oriented, human factors/management oriented or monitoring and inspection oriented. reliability centered maintenance (RCM)–stresses machines reliability, total productive Maintenance (TPM)-a technique based on human aspects and stresses on maintainability, condition based maintenance (CBM)-based on inspection and stresses on availability, skill level upgrade (SLU)-operators skills are upgraded so that they can take up minor repairs and preventive maintenance(PM) is defined as a schedule of planned maintenance measures aimed at the prevention of breakdowns and failures (Smith & Mobley, 2008) . The main goal of preventive maintenance is to prevent the failure of equipment before it really occurs. Worn-out components are replaced in preventive maintenance program to retain and enhance equipment reliability before they actually fail.

Preventive maintenance

Preventive maintenance activities include equipment checks, partial or complete overhauls at specified periods, oil changes, lubrication and so on. In addition, operators can record equipment deterioration so that they are aware when to replace or repair worn-out parts before they cause system failure. In current era of technological advances in monitoring and inspection diagnosis tools have enabled even more accurate and effective equipment maintenance. The perfect preventive maintenance plan would prevent all equipment breakdowns before it occurs. Long-lasting benefits of preventive maintenance include:

- Improved system reliability.
- Decreased cost of replacement.
- Decreased system downtime.
- Better spares inventory management.

There are various misconceptions about preventive maintenance like it is unduly costly i.e. regular scheduled downtime and maintenance costs more than it would normally cost until repair is absolutely essential. However one should look at the continuing benefits and savings associated with preventive maintenance (Fig.1). Without preventive maintenance costs for lost production time from unscheduled equipment breakdown will be incurred. Preventive maintenance will also result in savings due to an increase in systems service life. (enotes from Weibull.com & Reliasoft.com).

Weibull distribution

The Weibull distribution most frequently provides the best fit of life data. Beta (β) & Scale (η) are the two crucial parameters of Weibull line. The slope of the line, β is principally significant and may provide a trace to the physics of failure. The characteristic life η is the typical time to failure in Weibull analysis (Abernethy Robert, 2002). The slope β also indicates which class of failures is present.

- $\beta < 1.0$ indicates infant mortality
- $\beta = 1.0$ means random failures(independent of age)
- $\beta > 1.0$ indicates wear out failures

The Weibull plot shows the beginning of failures. The characteristic life η is defined as the age at which 63.2% (Abernethy Robert, 2002) of the units will have failed. For $\beta = 1$ the mean time to failure and η are equal. The parameter β is a pure number, *i.e.* it is dimensionless. The figure 2 shows the effect of different values of the shape parameter, β, on the shape of the pdf (while keeping η constant). The shape of the pdf can take on a variety of forms based on the value of β. Weibull probability plot (Fig. 2) specifies why the Weibull shape parameter is also known as the slope (Hot Wire, 2002: eMagzine reliability).

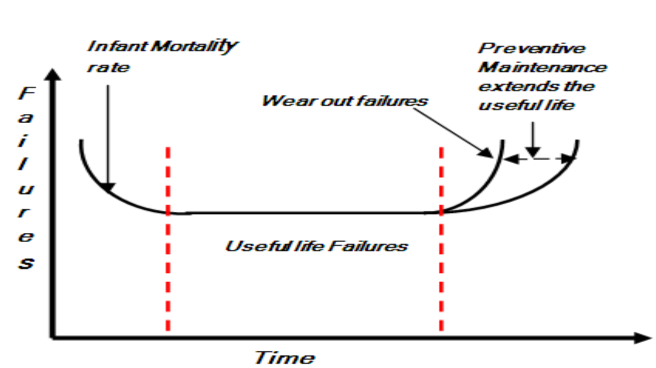
Methodology

The complete Gear Box assembly is divided into six sub assemblies as shown in Fig. 3. In our methodology first by using Least Square Method the parameters of Weibull distribution are calculated and then these parameters are used for calculating the reliability with and without preventive maintenance.

Case study

The failure data is collected from the log books of twenty four vehicles. The data is sorted and subdivided under various subheads (Table 1). The failure data is plotted with the help of graph as shown in Fig. 4. Under a constant failure rate preventive maintenance has no effect. Therefore Weibull distribution has been chosen for the analysis purpose. Weibull parameters β & η are first calculated for individual sub assembly using least square method and subsequently for whole Gear box assembly.

Fig. 1: Life cycle of mechanical equipment



Once we obtain the parameters, reliability with and without preventive maintenance are calculated using the formula given below:

$$R(t) = e^{[-(\frac{t}{\eta})^{\beta}]}$$

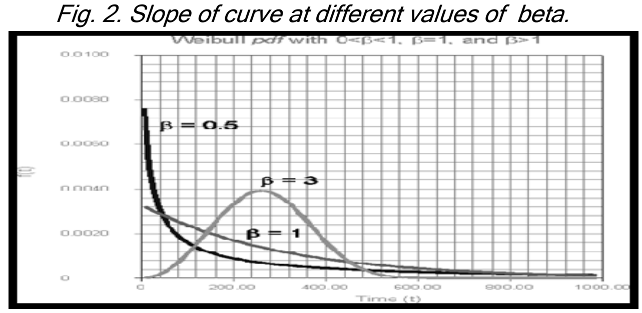
(Without preventive maintenance)

$$R_{pm}(t) = \exp\,[-n(\frac{T}{\eta})^{\beta}]\,\exp\,[-(\frac{t-nT}{\eta})^{\beta}]$$

(With preventive maintenance)

Where T be the interval between preventive maintenance, n is the number of maintenance interval and t is the number of hours/Kilometers for which reliability is to be evaluated. To show the effect of preventive maintenance policy, reliabilities of gear box units are calculated for a mission of 35000 & 47000 Kms (these values are selected randomly) as shown in Table 2.

Fig. 2. Slope of curve at different values of beta.



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Results

For a mission of 35000 and 47000 Kms the computed reliabilities of complete assembly without preventive maintenance are 33.51% & 13.70% respectively which is too less and not acceptable. When preventive maintenance policy is used these values are 84.03% & 72.92% which are 1.5 & 4.3 times higher.The result for the complete gear box assembly is shown in Table 3.

Conclusion

With the available failure data for various units of the gear box assembly parameter β & η are computed subsequently reliabilities with and the without preventive maintenance are calculated as shown in Table 2. Substantial increase in reliability has been observed with PM policy as shown in Fig. 5 & 6 for 35000 and 47000 kilometers run of the vehicle respectively. The analysis will be helpful to the maintenance engineer to develop sound maintenance/replacements frequencies, appropriate provision for spare parts and provision of standby units. The study shows that three units namely primary shaft, release bearing & main shaft are more prone to wear and needs repair/replacement in due time. Therefore Maintenance Order of Priority is to be followed as in Fig. 7.

Table 1. Failure data of subassemblies

Clutch plate		Pressure plate		Release Bearing	Primary shaft	Gears		Main Shaft
14696	87825	24557	91302	24574	24574	24557	91187	24557
24554	89299	24574	92935	37200	24890	24574	92935	26165
24574	89440	26165	93432	61652	26363	24658	93432	82064
26363	91187	26363	95298	71884	79709	26363	95298	89299
33861	92935	33861	96294	87825	82064	33861	98616	92935
37259	93432	37259	98616		93432	37257	98835	93432
50849	95294	50849	98936		96294	50849	99629	99629
61652	95298	61652	146967		146967	71884	146967	146967
71884	98616	71884				73492		
73492	98835	73492				79709		
74176		79704				82064		
79704		87325				87325		
82064		87825				87852		
87325		89294				89299		
		89440				89440		
		91187						

Table 2. Reliability with and without PM at 35000 & 47000 Kms

Sub Assemblies	Slope β	Characteristic Life η	Reliability without PM $R(t) = e^{[-(t/\eta)\beta]}$		Reliability with PM $R_{pm}(t) = \exp[-n(^{T}/_{\eta})^{\beta}]\exp[-(^{t-nT}/_{\eta})^{\beta}]$ (Assuming T = 6000 & 8000 kms , n= 5and t = 35000 & 47000 Kms) { Tn ≤ t ≤ T(n + 1)}	
			35000 Kms	47000 Kms	35000 Kms	47000 Kms
Clutch Plate	2.637	81154	89.68 %	78.91 %	99.41%	98.74 %
Pressure Plate	2.355	82826	87.67 %	76.84 %	98.83%	97.69 %
Release Bearing	2.019	65435	75.37 %	59.88 %	95.52%	92.05 %
Primary Shaft	1.655	79974	77.51 %	66.04 %	92.40%	87.94 %
Gears	2.065	83380	84.65 %	73.62 %	97.54%	95.54 %
Main Shaft	1.826	93314	84.63 %	75.13 %	96.26%	93.68 %

PM: Preventive Maintenance

Fig. 3. Components of gear box assembly

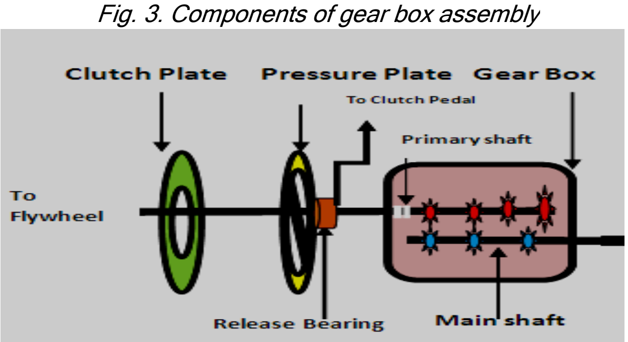

Fig. 4. Failure data plot.

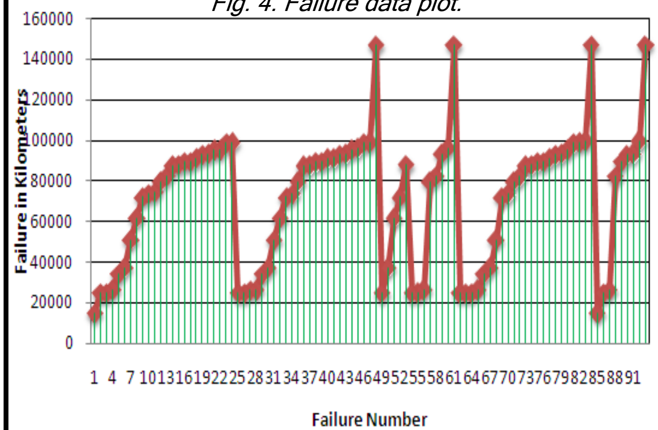

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Fig.5. Reliability with and without PM

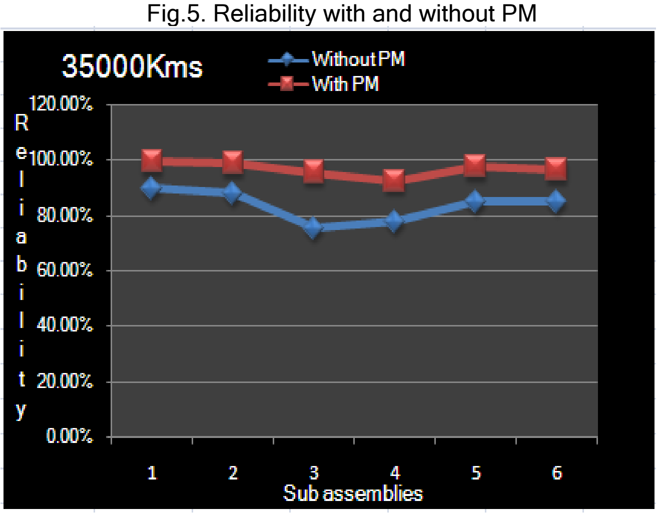

Fig.6. Reliability with and without PM

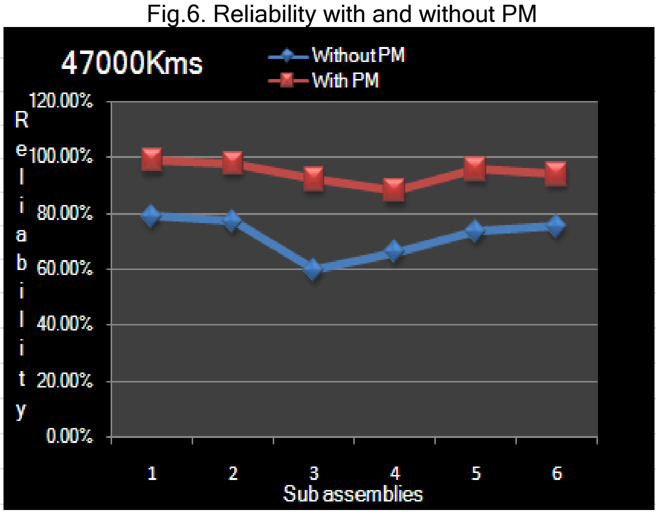

Table 3. Parameters of gear box assembly

Units	Kms
Weibull Shape Factor	2.028
Characteristic Life	33498
Reliability Without PM (35000 Kms)	33.51 %
Reliability Without PM (47000 Kms)	13.70 %
Reliability With PM (35000 Kms)	84.03 %
Reliability With PM (47000 Kms)	72.92 %

Fig. 7. Maintenance order of priority