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RELIABILITY OF A COMPLEX MECHANICAL SYSTEM WITH UNKNOWN CONFIGURATION

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ABSTRACT

In performing the reliability of a mechanical system, models are formulated to fit the logical structure of its decomposition to subsystems and components. But in many cases the system is of a more complicated nature that it seems difficult to relate its configuration to a known model.

In the presented paper a new technique is introduced to determine the reliability of a complex mechanical system with unknown configuration to its subsystems. The solution is based on the experimental data of testing the system as a whole without a need to any information about how the subsystems are interconnected. Even when the tested sample is only one system it is possible to get an information about the reliability of any one of its subsystems.

1. INTRODUCTION:

Many trials had been made to determine the reliability of systems if their subsystem's configuration are known.

In a complex mechanical system the arrangements of its subsystems are unknown and can't be related to the known types (series, parallel, standby and partially parallel).

When a complex mechanical system is tested under simulated environmental conditions, some parts of it will show sensitivity to failures. The other parts (non failed) of the system are insensitive to such stress conditions and their reliability can be con-

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sidered as very high approaching unity.

By this fact, the total number of failures in the system can be viewed as resembling a system of stochastic character. Such a stochastic system can be considered as partially parallel system (K-out-of-N system) with respect to its configuration. This is due to similarity in definition of partially parallel system and to that of the location of main failures (those ones which cause complete stopping of the system normal operation) with respect to the other failures.

2. MATHEMATICAL REPRESENTATION OF FAILURE BEHAVIOUR OF A MECHANICAL SYSTEM

When a complex mechanical system such as heavy tracked vehicle is tested, the failure distribution function is shown in Fig. 1.[1]

Distribution function given in Fig. (1) is possible to be written in the following form:

$$F_{(x)} = \begin{cases} 1-\exp\left[-\left(\frac{x-A}{\tau_1}\right)^{\beta_1}\right] & A \leqslant x \leqslant \infty \\ 1-\exp\left[-\left(\frac{B-x}{\tau_2}\right)^{-\beta_2}\right] & x_{inf} \leqslant x < B \end{cases} \qquad (1)$$

A is the location parameter.

B is the extreme value of the variable (x) at which and beyond it the system distribution function equals one.

The first part of equation (1) is given by the Weibull distribution. The second part is given by a new distribution [3]

Equation (1) can be demonstrated by two straight lines on Weibull probability paper. On this paper the six parameters A, B, τ_1, τ_2, β_1 and β_2 can be determined , Fig. (1)

In the test, the location of individual failures of the system is randon in nature. Each registration of a failure can be taken as representing individual system states. The total system's state assessed by this way can be counted by the total number of failures up to the general overhaul.

The total number of elements constituting the whole system is equal to the total number of failures. The reliability function of j th subsystem is possible to be determined by following equation [2]

$$R_j(x) = 1- \frac{n!}{(n-m)!(m-1)!}\int_0^x h(x)\, R_s^{\,m}(x)\left[1-R_s(x)\right]^{n-m} dx \qquad (2)$$

n number of elements in the system (total number of failures till the overhaul).

m minimum number of survival elements in the system

$R_s(x)$ Reliability function of the whole system

$R_j(x)$ Reliability function of individual failures

Equation (2) is nonparametric equation, which d'nt depend on the complete knowledge of distribution function of the system.

Reliability of j th subsystem can be also determined graphically from the distribution function to failure of the system. This can be obtained from equation (2) and mean rank method, See Fig. (2)

Reliability for jth subsystem among N systems each containing n_i total failures, this can be treated as the average reliability of the whole jth subsystems.

Reliability of jth subsystem by this way can be written as [4] .

$$R_j = \frac{1}{N} \sum_{i=1}^{N} 1 - \frac{n_i\,!}{(n_i - m_i)!\,(m_i - 1)!} \cdot \int_0^x h_{s_i}(x)\, R_{s_i}^{m_i}(x) \left[1 - R_{s_i}(x)\right]^{n_i - m_i} dx \qquad (3)$$

Where

n_i is the total number of failures in the jth system

m_i is the total number of failures in the jth system minus the permissible number of failures till the jth main failure.

$h_{s_i}(x)$ is the hazard function of the jth system

$R_{s_i}(x)$ is the reliability function of the jth system

Graphical solution of equation (3) for the main clutch of nine tracked vehicles is solved in the work [1] and is shown in Fig. (3)

The result is given in comparison with the hazard plot [5] for 99% confidence limit .

CONCLUSION

The reliability of subsystem is possible to be obtained when the system is treated as a black-box scheme.

The solution ignores the inter relations between subsystems which form the system. It is possible to have an idea about the reliability of the subsystem even the tested system is only one.

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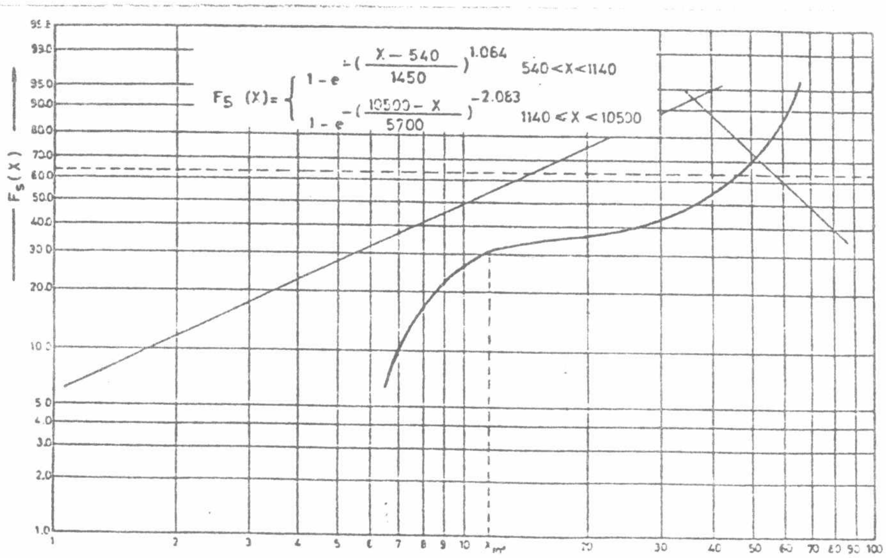

Fig. 1

Distribution Function $F_s(X)$ of Kilometers to Failure of Vehicle

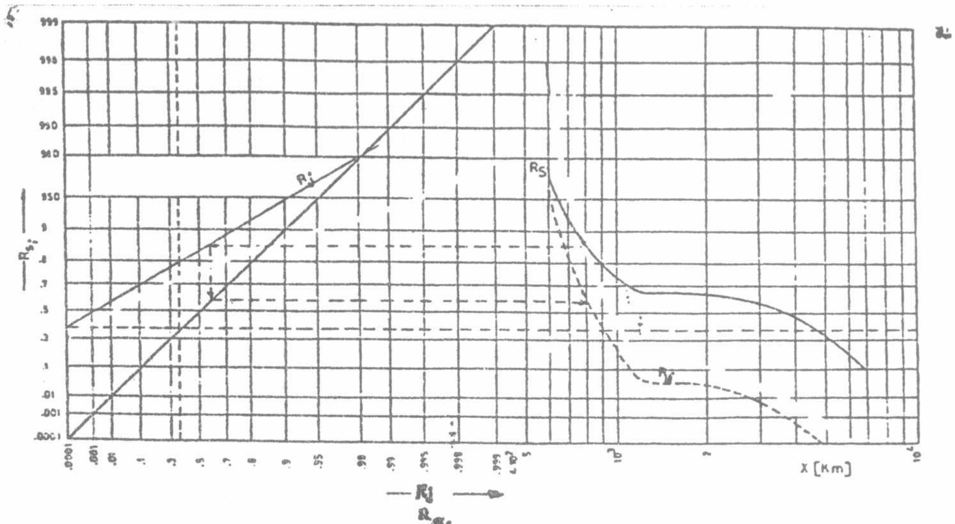

Fig. 2

Reliability of jth subsystem R_j from jth system R_{s_j}

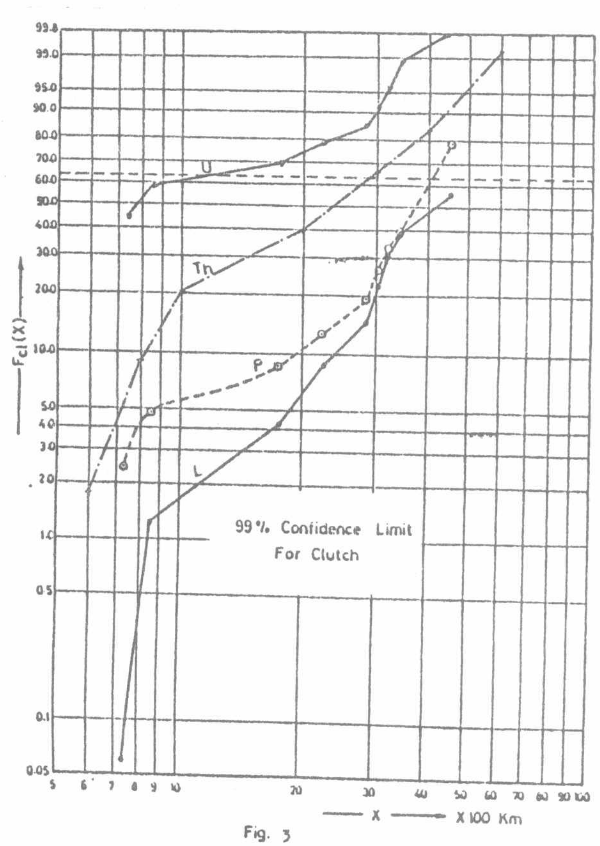

Fig. 3

Reliability of clutch, according to equation 3 (Th.) and hazard plot (P)