FEDERATION EUROPEENNE DE LA MANUTENTION
SECTION IX
SERIES LIFTING EQUIPMENT

FEM 9.221

Performance Data of S/R-Machines
Reliability Availability

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1. Foreword

The present FEM Rule contains a standard method for determining the reliability and availability of S/R-machines. This method makes it possible to draw conclusions about the throughput which the user of a high-bay warehouse requires from the manufacturer, throughput being defined as the number of storage and retrieval operations per unit of time.

Throughput depends both on the availability of system units and on the cycle time, which is dealt with in FEM 9.851 [1]).

On the basis of theoretical principles, a method for determining performance in practice will be described, in which periods of downtime and malfunctions will be differentiated according to areas of responsibility.

2. Definitions and theoretical principles

2.1 Reliability η_n

The reliability of a discontinuously loaded system unit is equal to the probability of this unit carrying out a particular operation correctly and without malfunctions. In tests, reliability is determined by the quotient

$$\eta_n = \frac{n_r}{n_r + n_f} \quad (1)$$

where:

n_r = number of correctly carried out operations

n_f = number of operations carried out incorrectly or with faults

The particular operation should be tested with an adequate statistical frequency.

2.2 Availability η_T

The availability of a system unit for a particular operation is equal to the probability of finding that unit, at any given time during the period of operation, in a state which will allow the operation concerned to be carried out correctly and without malfunctions [2]).

In order to determine the availability of individual system units in tests, the unit concerned is considered under clearly defined operating conditions with the planned average loading for a statistically adequate period of time T.

Availability is determined by the quotient

$$\eta_T = \frac{T - T_{aus}}{T} \quad (2)$$

where:

T = total operating time

T_{aus} = sum of individual periods of downtime

This gives the net operational time

$$T_{net} = T - T_{aus} \quad (3)$$

The mean downtime is the total downtime T_{aus} divided by the number of failures, n_{aus}:

$$\frac{T_{aus}}{n_{aus}} = \text{MTTR} \ [3]) \quad (4)$$

Similarly, the mean time without failures is

$$\frac{T - T_{aus}}{n_{aus}} = \text{MTBF} \ [4]) \quad (5)$$

and, therefore, availability can also be expressed by the quotient

$$\eta_T = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}} \quad (6)$$

2.3 Periods of downtime

Each individual period of downtime may be divided into th following sub-periods:

t_1 = period between stoppage of machine and start of search for fault by appropriate personnel

t_2 = time needed to identify cause of failure

t_3 = time needed to correct fault and restore serviceability

1) FEM 9.851 Performance data of S/R-machines; cycle times

2) In an installation comprising a number of S/R-maschines, the failure of o n e machine will affect the availability of the installation only in part. The availability of the complete installation will be calculated, on the basis of the basic rules of this document, according to the mathematical principles of probability (cf. Appendix A.2).

3) MTTR = mean time to restore

4) MTBF = mean time between failures

Available in English (E), French (F), German (D)

Sources of supply see back page.

3. Practical application

3.1 Performance test

The throughput of a system unit may be checked by performance tests. Cycle times are determined as described in FEM 9.851.

Tests for determining reliability and availability are spread over a certain reference period, which should not be too short. A test of this type may also be carried out for checking agreed performance figures. In this case, the beginning and end of the test period should be agreed between the user and supplier. The duration should be between 1 day and 1 working week, according to the size of the installation.

During the tests, it should be ensured that the machines are subjected to working stresses within the designated limits, as regards both the frequency and spectrum of the loads to be stored, which should be within the limits of the load spectrum for which the machine was designed (cf. FEM 9.512 [5]), as well as an even distribution of storage points over the whole warehouse such as used as the basis for calculating cycle times (cf. FEM 9.851). Stress programmes, such as are found in the filling of a store or during peak periods, are not suitable for this purpose.

3.2 Test certificate

When a test is carried out, the user must complete a fault record as in Form 1 [6], on which should be recorded:

- the times of start and end of operation, with breaks
- the number of correctly completed cycles (n_r)
- the number of incorrectly completed cycles or cycles with failures (n_f)

In addition, the following (time and description) must be entered for each failure:

1. Failure
Time A and nature of failure

2. Fault finding
Time B, arrival of appropriate personnel, and cause of failure established

3. Fault clearance
Time C, start of fault clearance and measures taken

4. Restoration of serviceability (time D)

When the record is evaluated, the periods of downtime mentioned in Section 2.3 may be determined as follows:

$$t_1 = B - A$$
$$t_2 = C - B$$
$$t_3 = D - C$$

3.3 Allocation to areas of responsibility

When tests have been carried out for checking an agreed performance figure, it is necessary to ascribe the causes and sub-periods of downtime to individual areas of responsibility, so that, on the one hand, the user can clearly see if the S/R-machine's performance is as agreed, and, on the other, that the supplier is not attributed with downtime and periods of malfunctioning for which he cannot be held responsible. This assessment should be carried out by the user and supplier together.

When an S/R-machine is assessed, downtime should not be taken into account when the causes are, for instance:

- errors in operation,
- errors in entering data,
- faulty pallets or load units,
- manual storage of goods in automatic installtaions,
- maintenance,

etc.

For the remaining technical faults, a distinction must be made between the sub-periods: t_1, t_2 and t_3

The period t_1 is determined by the user exclusively and cannot be ascribed to the supplier.

The period t_2 is dependent upon causes which may be attributed both to the user and to the supplier. The user's area of responsibility includes, for instance, the training and suitability of maintenance personnel, the availability of the correct tools, etc. The supplier can design the system from the outset so that faults can be identified more easily.

If, in certain cases, time is taken to ascertain the causes of failures in detail, this should not be included as downtime.

The period t_3 may be ascribed to the supplier on the precondition that

- any replacement and wearing parts needed for repairs are kept in stock by the user in accordance with the contractual agreements,
- the maintenance team has the training and the equipment to complete the work within an acceptable period.

3.4 Evaluation

An evaluation sheet such as that in From 2 [7] may be used for this purpose.

3.4.1 Reliability

The number of cycles recorded in the test certificate gives the reliability by the application of formula (1). If a distinction is to be made on the basis of areas of responsibility, for instance that of the supplier, only the number of the incorrect operations for which he must accept responsibility is to be entered (n_{fL}):

$$\eta_{nL} = \frac{n_r}{n_r + n_{fL}} \qquad (7)$$

3.4.2 Availability

The total downtime is arrived at by using the data from the test certificate in the formula

$$T_{aus} = \sum_{i=1}^{n} (t_1 + t_2 + t_3)_i \qquad (8)$$

Downtime is calculated separately for each area and marked by a subsript, e. g. for the supplier's area of responsibility.

$$T_{ausL} = \sum_{i=1}^{n} (t_{2L} + t_{3L})_i \qquad (9)$$

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5) FEM 9.512 Rules for the design of storage and retrieval machines; mechanisms

6) See page 6

7) See page 7