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ABOUT AVAILABILITY OF INDUSTRIAL ENTITIES

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ABSTRACT
Availability is the probability that a system is not failed or undergoing a repair action when needs to be used and it is always associated with time. As wee will see in the later sections, are different availability classifications and for some of which, the definition depends on the time under consideration. For example of this classifications is considered an entity called rolling mill.

KEYWORDS:
availability, classification, entities

1. INTRODUCTION

In practice of quality appraisal for exploitation of industrial entities is generally operated with two notions i.e.: reliability (which represents probability of that entity to work) and maintainability (i.e. probability of restoration after failure). Because the two notions are in close connection one with another is necessary a parameter that should include both of them. This is availability. Availability is a performance criteria for recoverable entities which shows in what measure the entity works when this thing is required, i.e. this is the probability that entity not to fail in case of need. In table 1 is shown in a synthetic manner the connection between reliability, maintainability and availability.

Table 1. Connection between reliability, maintainability and availability

Reliability	Maintainability	Availability
— Steady	↓ Decrease	↓ Decrease
— Steady	↑ Increase	↑ Increase
↑ Increase	— Steady	↑ Increase
↓ Decrease	— Steady	↓ Decrease

2. INFLUENCE OF DOWNTIMES ON AVAILABILITY

For recoverable entities the operation times are not continuous. In other words the lifetime can be described as consisting in sequences of operation and downtime statuses. The entity works until arise a failure, then it is repaired and put into operation again. This will fail after some time, it is repaired again and the operation / downtime process is repeated. This is the process of restoration and depends on aleatory, positive and independent variables. Aleatory variables are times of continuous operation and times of restoration/repair.

The restoration process for each component determines restoration of the entire entity. For example is taken into consideration an entity with two components A and B serially connected. Each of them has a certain distribution law of proper operation and repairs. Because components are serially connected, failure of one of them will cause failure of the entire entity. The entity is shutdown until is repaired the failed component. Figure 1 shows this fact.

The most used hypothesis in Theory of Restoration is the one, which assumes that after failure, the failed component is replaced by a new one, which means that after restoration the entity is as good as new. This hypothesis is valid only if the entity in charge is known in detail. When analysis is performed at subassembly level or if a replacement is performed by a component already used, then study should also include a so-called restoration factor, which shows the performance degree of repairs [3].

3. CLASSIFICATION OF AVAILABILITY

Definition of availability is very comprehensive and depends on reasons of failures, which are taken into account. As result, there are a few types of availability [1] i.e:

- Instantaneous availability (pointwise);
- Average availability;
- Steady state availability;
- Inherent availability;
- Achieved availability;
- Operational availability.

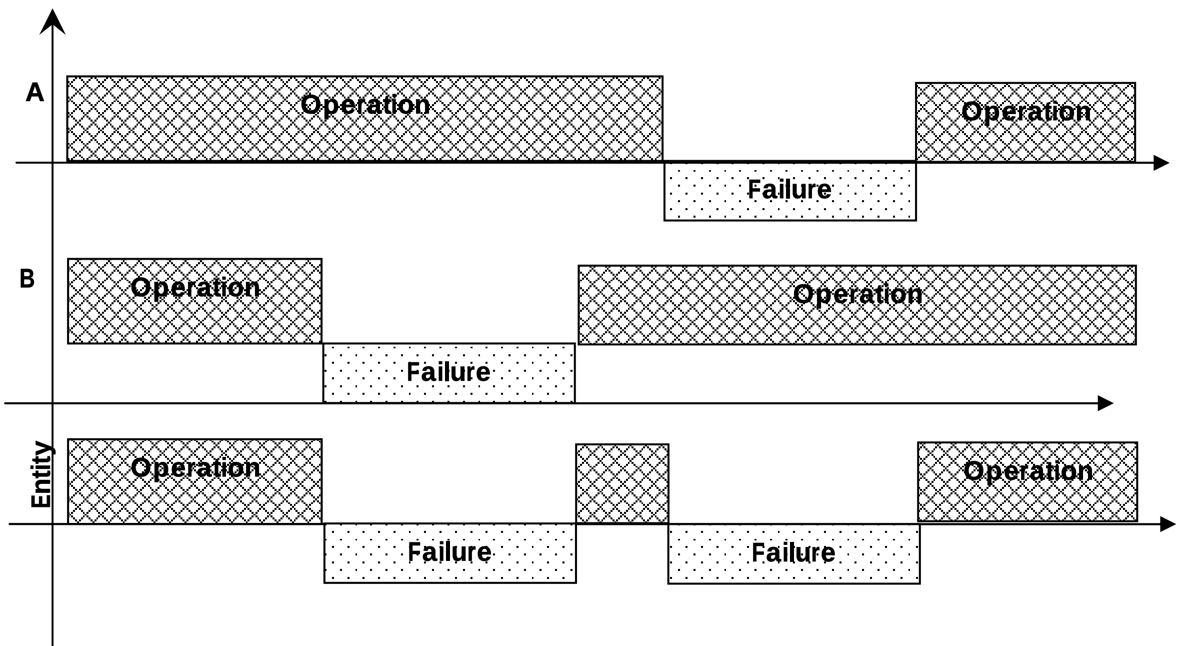

Figure 1. Downtime of an entity with two components A and B serially connected

3.1. Instantaneous availability (pointwise), *A(t)*

Instantaneous availability is the probability that entity to be in operational status at any moment *t*. This definition is similar with the reliability one, but in contrast availability include information about maintainability too.

At any moment *t*, the entity will accomplish its mission if are met the following conditions:
- proper operation in the range (0,*t*] with probability *R(t)*, or
- correct operation from the last repair up to the moment τ, $0 < \tau < t$, with probability:

$$\int_0^t R(t-\tau)m(\tau)d\tau \tag{1}$$

where $m(\tau)$ represents the probability density of entity restoration function.

By these observations the instantaneous availability is:

$$A(t) = R(t) + \int_0^t R(t-\tau)m(\tau)d\tau \tag{2}$$

3.2. Average availability, $\overline{A}(t)$

Represents the average value of instantaneous availability for range (0, *t*) and can be calculated as follows:

$$\overline{A}(t) = \frac{1}{t}\int_0^t A(\tau)d\tau \tag{3}$$

3.3. Steady state availability, *A(∞)*

This is the limit of instantaneous availability, when $t \to \infty$, i.e :

$$A(\infty) = \lim_{t\to\infty} A(t) \tag{4}$$

From practical reasons, instantaneous availability approximates steady state availability after about four operation-downtime cycles. In other words the steady state availability is a value at which the entity availability is stabilized.

3.4. Inherent availability, A_I

The inherent availability is steady state availability one when are taken into consideration only the corrective maintenance times of that entity.
For one component this can be written as follows:

$$A_I = \frac{MTTF}{MTTF + MTTR} \tag{5}$$

where *MTTF* represents the mean time to failure, and *MTTR* is the mean time to repair.

At the entity level things are a little more complicated. Here should be taken into account the mean time between failure, or *MTBF*. In this situation the inherent availability can be written as follows:

$$A_I = \frac{MTBF}{MTBF + MTTR} \tag{6}$$

Although things seem to be simple should be taken into account that when the steady state is richen; *MTBF* is a time function; so that equation (6) should be used cautiously. On the other hand is important to mention that *MTBF* is different from *MTTF* (or more accurately, for repairable entities, *MTTFF*, mean time to first failure).

3.5. Achieved availability, A_A

Achieved availability is similar with the inherent availability one but with the specification according with here are also included the preventive maintenance times together with the corrective ones. This could be defined as depending on the mean time between maintenance actions, *MTBM* and mean maintenance downtime, $\overline{M}$, i.e.:

$$A_A = \frac{MTBM}{MTBM + \overline{M}} \tag{7}$$

3.6. Operational availability, A_O

Operational availability has the meaning of an average availability, which includes all reasons of downtimes, i.e. also, the ones caused by administrative, logistical delays etc.

Mathematically this can be expressed as follows:

$$A_O = \frac{Uptime}{Operating\ \ Cycle} \tag{8}$$

The operation cycle represents the entire period of entity observation, which for is recorded the proper operation total time. It is remarkable that operational availability depends on time.

If times of logistical and preventive maintenance are not specified then the equation (8) will be the average availability $\overline{A}(t)$.

Operational availability reflects the experience in entity utilization and is relatively hard to control it because in exploitation appear a series of aleatory factors that are difficult to be controlled.

4. EXAMPLE OF CALCULATION

For example is considered an entity called rolling mill. There has been observed the operation/downtime of the entity on duration of three months. Data have been recorded on special forms where have been clearly underlined the moments of time when occur changes in status or behavior of the equipment: moment of putting into operation after last capital repair, moment of operational shut-down, moment of reputing into operation, moment of failure, moment of reputing into operation after causes of failure have been removed, causes of failures.

Processing of experimental data has been performed using the Weibull++6 Program [5], thus obtaining the diagrams shown bellow.

Thus both reliability and maintainability have the Weibull distribution laws with parameters:

- reliability : β_f = 3,0243; η_f = 12,7658; γ_f = 0;
- maintainability : β_m = 5,1055; η_m = 17,574; γ_m = -7,1861 hours;

In order to determine the instantaneous availability *A(t)* will be used the following equations:

$$R(t) = e^{-\left(\frac{t}{12,7658}\right)^{3,0243}}$$
$$m(\tau) = \frac{5,1055}{17,574}\left(\frac{\tau + 7,1861}{17,574}\right)^{4,1055} e^{-\left(\frac{\tau+7,1861}{17,574}\right)^{5,1055}} \tag{9}$$

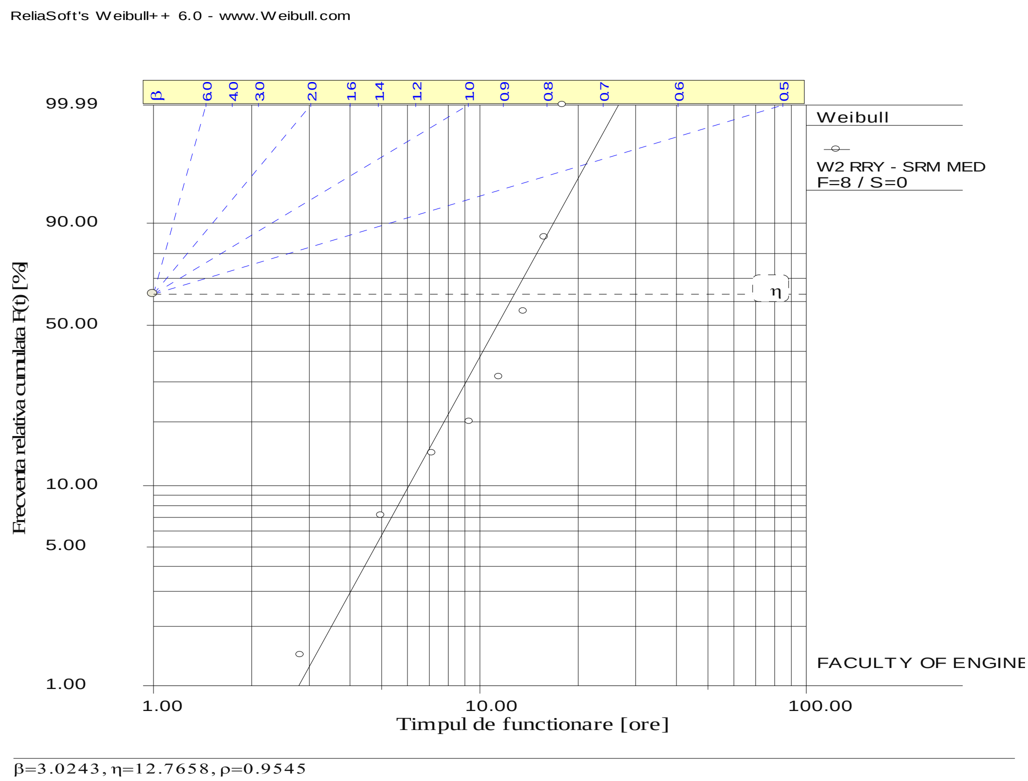

Figure 2. Reliability parameters

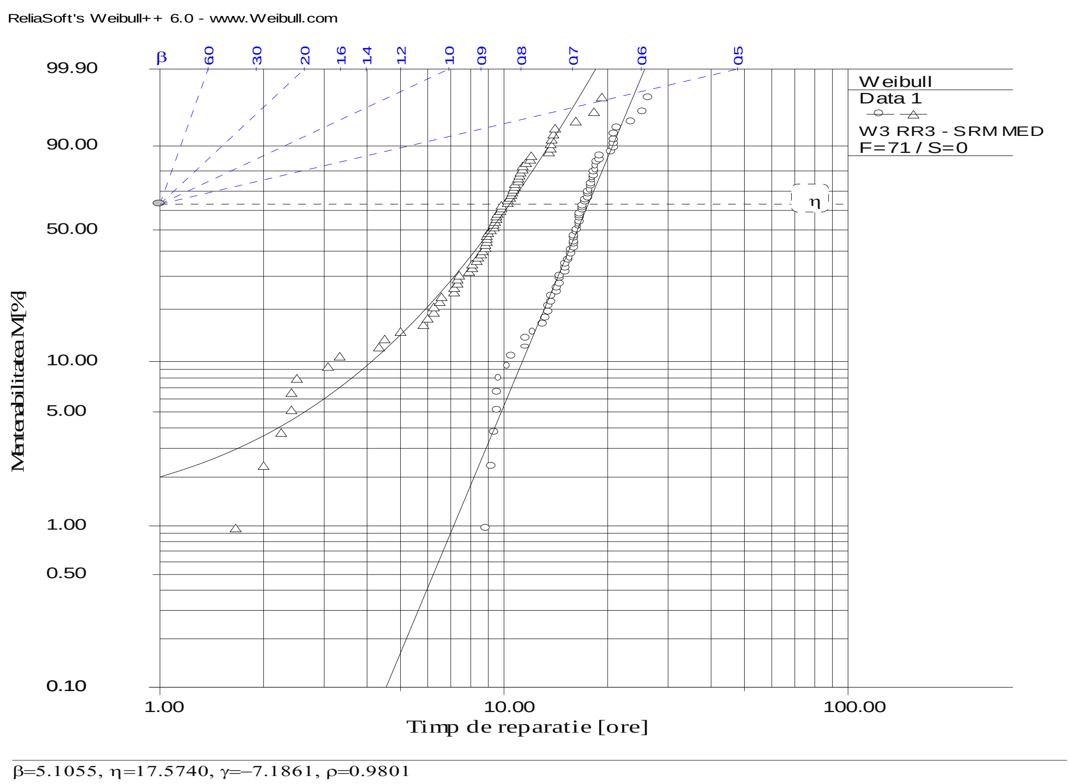

Figure 3. Maintainability parameters

Equation (9) replaced in (2) lead to the real mathematical expression of instantaneous availability. Solving the corresponding integral, for increasing values of *t*, will be obtained the punctual values of availability that will be shown in figure 4.

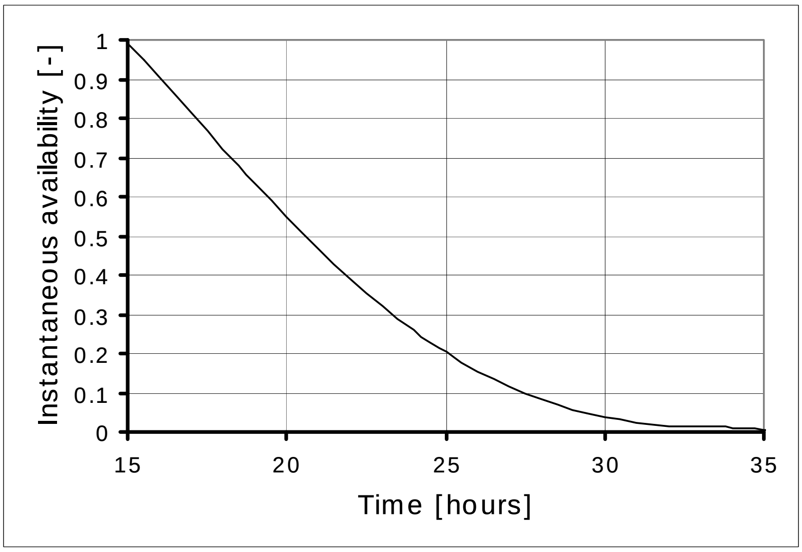

Figure 4. Instantaneous availability depending on time

5. CONCLUSIONS

Has been ascertained that after about 35 hours the instantaneous availability becomes zero. For *t* = 35 hours, the average availability will be (equation (3)): $\overline{A}(35)=\frac{1}{35}\int_0^{35} A(\tau)d\tau$ = 0,648. In the same time the steady state availability $A(\infty)$ = 0, i.e. availability is stabilized at value zero.

The relative low value of average availability, as well as value zero for steady state availability have been expected even when the value of β_f has been determined, which is included in the range [1, 4], more close to 4. For such values, the specialty literature shows that failures that generate breakdowns have hidden causes, difficult to detect. Them, the value β_m >5 for maintainability shows that maintenance management has many lacks, which then are reflected on entity availability.

Processing of experimental data offers important information regarding to the entity operation mode. That information can be decision elements for technical personnel, which is responsible with proper operation of the system.

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