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SURVEY ON REDUCTION GEAR FORECASTING AVAILABILITY

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ABSTRACT
The most important purpose of an operation to determine availabilities is that of establishing, respectively predicting the functionality of an entity as minutely as possible. Thus, the weak aspects can be known in time and therefore processed adequately. To renounce to a multitude of attempts which require long periods of time, calculations methods have been established based on the theory of probability.
It was chosen as example a single stage cylindrical reducing gear. The phases described and performed in this paper are absolutely necessary for a new entity which is quite unfamiliar regarding the functioning-failure succession.

KEY WORDS:
availability, maintainability, reduction gear, functioning-failure

1. INTRODUCTION

Availability of an entity generally represents the probability for that entity to be able to accomplish the required function at a given moment. This requirement is accomplished practically by two very important actions: increasing the reliability (i.e. time of continuous operation) and/or improving the maintainability actions' quality (i.e. reduction of breaking –down times as a consequence of failures).

The most important purpose of the availability determination operation is to set up respectively to forecast the operation/failure behavior of an entity as accurately as possible. In this manner can be ascertained vulnerable points in due time and intervened on them accordingly.

In order to give up on multiple tests that take long time have been established computation methods based on probability theory. A somehow reliable appraisal of an entity surviving process is possible only if are used methods and means of technical diagnosis.

Accidental and early failures from the first stage of life of an entity are difficult to appraise. These are not according to computation methods of forecasting availability. Thus, this appraisal survey will treat limitedely the failures caused by wear, that represent the main reason of operational breaking-downs.

As example has been chosen the one-stage reduction gear shown in Figure 1.

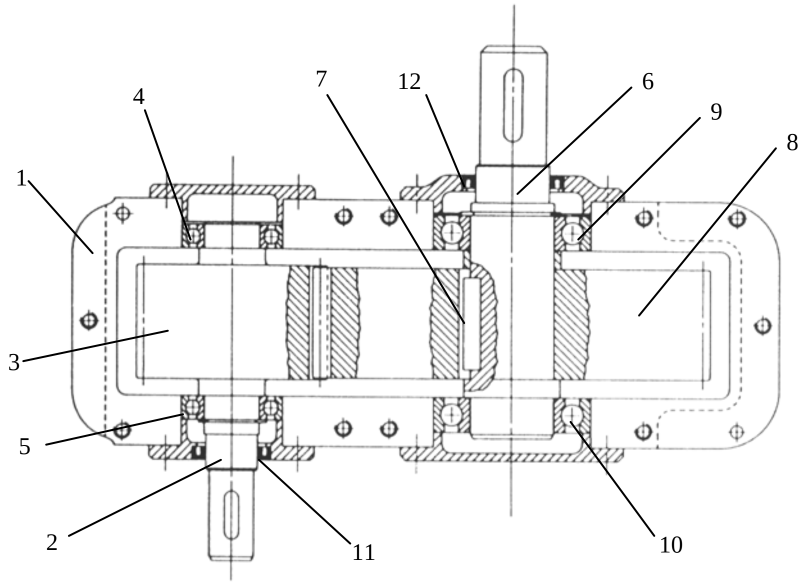


Figure 1. Cylindrical one-stage reduction gear

In order to appraise availability for chosen system we'll proceed according to the plan shown in Figure 2. To analyze the system will be appraised mainly the relevant components related to reliability and security structure of the system.

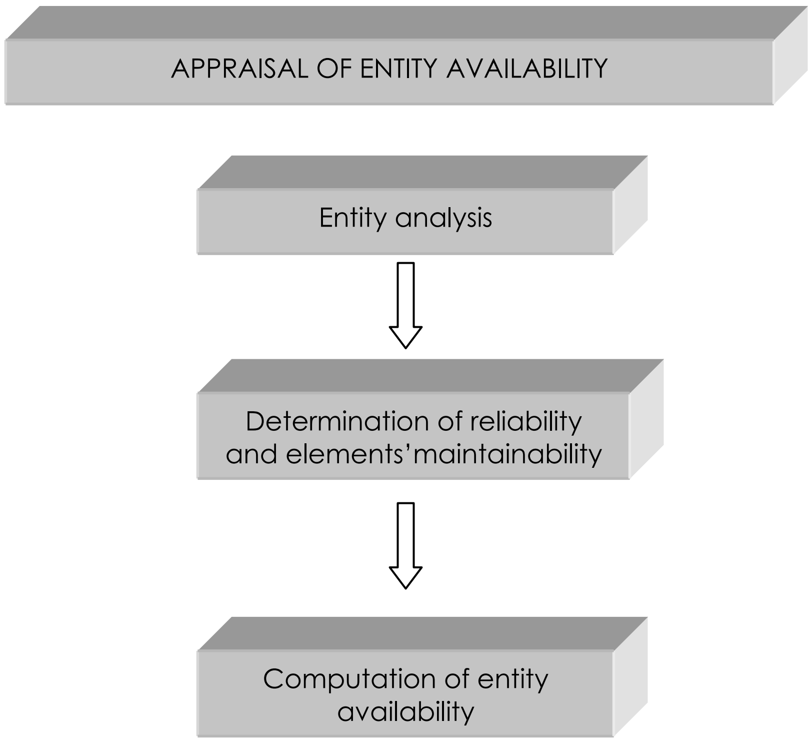


Figure 2. Action plan to appraise the reduction gear availability

2. ENTITY ANALYSIS

At the beginning of analysis should be determined all components of the system in order to have a complete image of the entity (Figure 3).

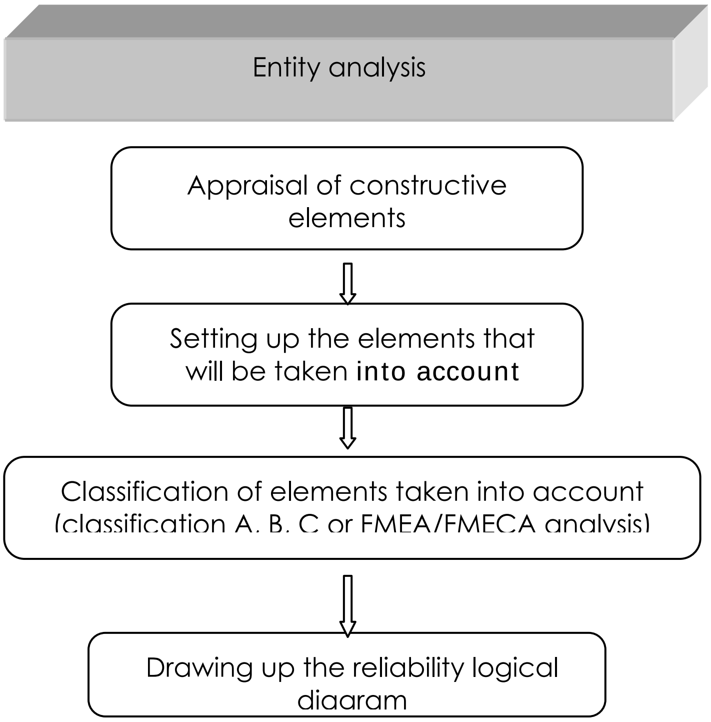


Figure 3. Diagram of entity analysis

2.1. APPRAISAL OF CONSTRUCTIVE ELEMENTS

As components they are considered constructive elements, respectively the places where are located. For example these could be dead or flexible joints, which are critical points related to their operational reliability. With an operational block diagram (Figure 4) can be determined entirely the reduction gear components.

In Table 1 are shown all components of the " cylindrical one-stage reduction gear" entity with examples.

Table 1. Components of the " cylindrical one-stage reduction gear" entity

Lower housing Upper housing Dog screws Upper housing sealing Inlet shaft Outlet shaft Parallel key	Gear 1 Gear 2 Rolling contact bearing 1 Rolling contact bearing 2 Rolling contact bearing 3 Rolling contact bearing 4 Safety ring 1	Safety ring 2 Spacing ring Bearing cover 1 Bearing cover 2 Bearing cover 3 Bearing cover 4 Bearing cover sealing 1	Bearing cover sealing 2 Bearing cover sealing 3 Bearing cover sealing 4 Shaft sealing ring 1 Shaft sealing ring 2 Hexagon cap screws 1-12

2.2 SETTING UP THE ELEMENTS THAT WILL BE TAKEN INTO ACCOUNT

Some determined components can be damaged from many causes. For example, a gear can loose its functionality as a consequence of teeth breaking, sticking or pitting. For a further computation it is better that these types of failure to be considered separately. Thus are established the so-called entity elements depending on failure type.

In Table 2 are shown the elements of "cylindrical one-stage reduction gear" system, where "gear1" and "gear 2" are classified depending on type of possible failure: breaking or pitting.

Table 2. Elements of the "reduction gear" entity

Lower housing	Safety ring 1
Upper housing	Safety ring 2
Dog screws	Spacing ring
Upper housing sealing	Bearing cover 1
Inlet shaft	Bearing cover 2
Outlet shaft	Bearing cover 3
Parallel key	Bearing cover 4
Breaking gear 1	Bearing cover sealing 1
Breaking gear 2	Bearing cover sealing 2
Pitting gear ½	Bearing cover sealing 3
Rolling contact bearing 1	Bearing cover sealing 4
Rolling contact bearing 2	Shaft sealing ring 1
Rolling contact bearing 3	Shaft sealing ring 2
Rolling contact bearing 4	Hexagon cap screws 1-12

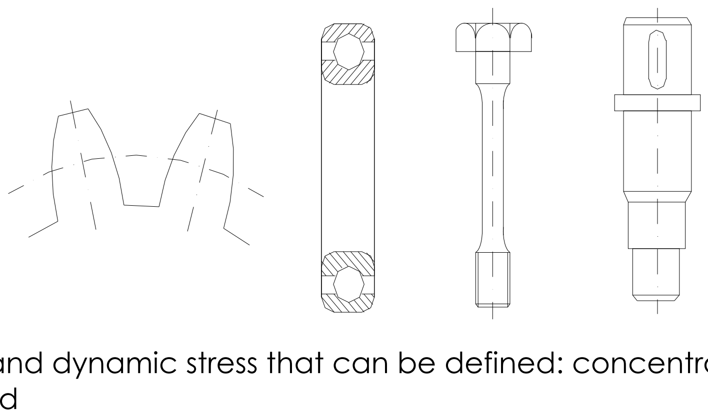
2.3. CLASSIFICATION OF ENTITY ELEMENTS

Elements of the entity accomplish different functions and bring a suitable contribution to operational reliability. In this respect it is not recommended i.e. it is not admitted to view all system elements as identically from importance point of view. Thus it is imperious necessary to realize a classification of entity elements depending on relevant components related to reliability.

Then should be established if elements are subjected to stress that can be defined or if they allow somehow determining the stress of these elements. In Figure 5 is presented a classification A, B, and C of the "cylindrical one-stage reduction gear" entity elements from these points of view.

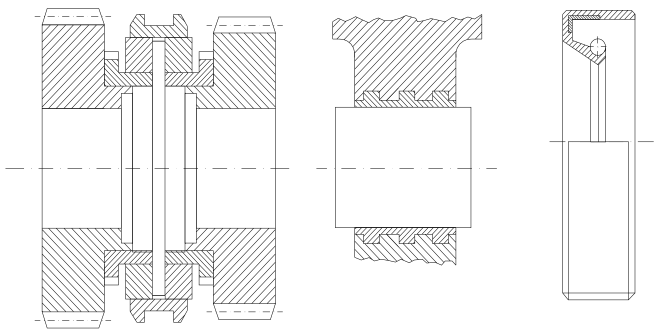
Classification A, B and C of the "cylindrical one-stage reduction gear" entity elements:

Part of type A (with a significant influence on entity operation):



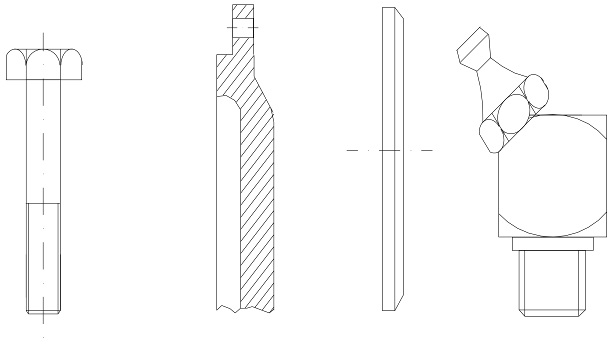
- Static and dynamic stress that can be defined: concentrator of load, transmits the load
- Life-time can be calculated and provided
- It is known the behavior in situation of break-down: distribution shape parameter Weibull $ß > 1$

Part of type B (with a medium influence on entity operation):



- Mechanical stress by corrosion, high temperatures, soil
- Life-time can not be calculated and provided

Part of type C (without influence on entity operation)



- Stress by shocks, friction, wear, etc.
- Numerical appraisals, distribution shape parameter Weibull 0< ß ≤ 1 are not justified

While failure of elements type A can be featured numerically for each entity case, for elements type B we'll be necessary to use the values existent in special literature or will be done experimental determinations. Elements of type C that are neutral from operational reliability point of view will not be taken into consideration anymore. Classification A,B,C represents the simplified form of a FMEA analysis (1) and it is justified to be used for small size systems that can be viewed. In situation of large size and high volume systems the critical elements related to reliability should be determined by a complete FMEA analysis.

For "cylindrical one-stage reduction gear" entity the classification of type A, B, C is showed in Table 3.

Table 3. Classification A,B,C, of "cylindrical one-stage reduction gear" entity elements

Lower housing	C	Safety ring 1	C
Upper housing	C	Safety ring 2	C
Dog screws	C	Spacing ring	C
Upper housing sealing	C	Bearing cover 1	C
Inlet shaft	A	Bearing cover 2	C
Outlet shaft	A	Bearing cover 3	C
Parallel key	A	Bearing cover 4	C
Breaking gear 1	A	Bearing cover sealing 1	C
Breaking gear 2	A	Bearing cover sealing 2	C
Pitting gear ½	A	Bearing cover sealing 3	C
Rolling contact bearing 1	A	Bearing cover sealing 4	C
Rolling contact bearing 2	A	Shaft sealing ring 1	B
Rolling contact bearing 3	A	Shaft sealing ring 2	B
Rolling contact bearing 4	A	Hexagon cap screws 1-12	C

2.4. DRAWING UP THE RELIABILITY LOGICAL DIAGRAM

After classification, in the next phase, will be drawn up the reliability logical diagram starting either block diagram or energy flow scheme. Both types of diagram show what elements are stressed and how these act on the system in situation of failure. Some writers (1), (3) consider that any reduction gear has a serial structure.

However, analysing the energy flow transmission the option was for diagram of Figure 6 that has been performed in "RAPTOR + TITANIUM" program in order to use it for further calculations. It is remarkable the fact that in the diagram are placed first the elements of type A and B and besides these were introduced "lower housing" + "upper housing" by reasons of force flow.

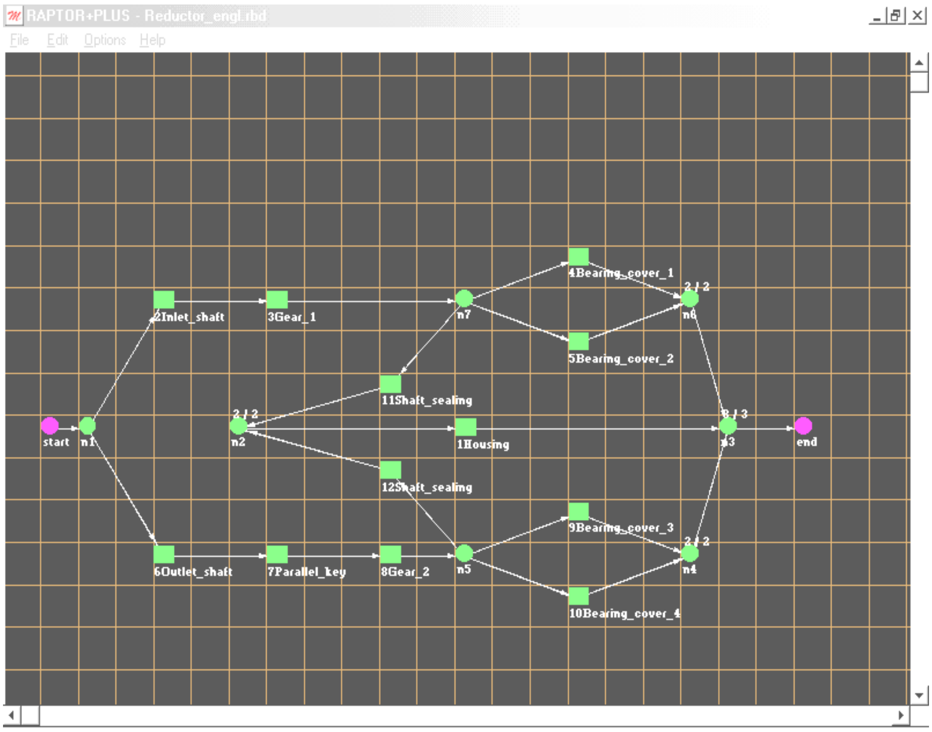


Figure 6. Reliability logical diagram
of cylindrical one-stage reduction gear

3. DETERMINATION OF RELIABILITY AND MAINTAINABILITY OF COMPONENT ELEMENTS

After system analysis should be determined the operational/breaking-down behaviour for those elements with high degree of risk at breaking-down.

For elements of type A, in a certain situation, following of specific strength computation can be determined the life-time (1). However for general situation approached in this survey have been taken into account recommendations of special literature (2), (4), (8), regarding distribution law for each element separately and afferent values of characteristic parameters.

For elements of type B to determine the failure behavior we'll start from experimental values (2), (4), (8). If these values are not available then either will be done tests or we'll be appraised depending on experience of each specialist.

Regarding maintainability, the special literature is lacking in recommendations both elements of type A and B. Sole references (5) are about a distribution law applicable more frequently i.e. the log-normal one.

From this reason the values of log-normal law parameters have been appraised by author that has experience in practical field of corrective and preventive maintainability.

4. DETERMINATION OF ENTITY AVAILABILITY FOR CYLINDRICAL ONE-STAGE REDUCTION GEAR

The Theory of Probabilities (5) shows that connection between moment values of availability A0, Reliability R and maintainability M is the following:

$$A_0 = R + (1 - R)M \quad (1)$$

In this situation, formula (1) is not useful because necessary values aren't known.

This survey being in forecasting phase we'll use probability simulation methods.

The "RAPTOR + TITANIUM" program is based on Monte Carlo method of entity surviving events' simulation. For logical diagram of Figure 6 the values discussed at point 2 have been introduced in the program.

Simulation has done for 40500 hours of continuous operation. Chosen time for simulation corresponds to standard period of continuous operation between two capital repairs of almost cylindrical one-stage reduction gears in the rolling mills(7). Results of simulation process are shown in Figure 7. Besides the value of A0 appear:

MTBDE – average of times between breaking-downs

MDT – average of breaking-times,

MTBM – average of times between repairs and

MRT - average of repair times.

The low value (1 is maximum) of availability is explainable by the fact that during simulation time the breaking-down (% Red Time) represent a higher percentage in comparison with operation (% Green Time).

Final Results

Results from 1 run(s):

Parameter	Minimum	Mean	Maximum	Standard Dev
Total Costs				
Ao	0.345976346	0.345976346	0.345976346	n/a
MTBDE	0.014012	0.014012	0.014012	n/a
MDT	0.026488	0.026488	0.026488	n/a
MTBM	0.007006	0.007006	0.007006	n/a
MRT (0 runs)	n/a	n/a	n/a	n/a
%Green Time	34.597635	34.597635	34.597635	n/a
%Yellow Time	0.000000	0.000000	0.000000	n/a
% Red Time	65.402365	65.402365	65.402365	n/a
System Failures	1	1.000000	1	n/a

R(t=0.040500) =0.000000

Figure 7. Results of simulation process for "cylindrical one-stage reduction gear" entity

5. CONCLUSIONS

Phases described and covered in this survey are absolutely necessary for a new entity about which very few things are known related succession, operation, breaking-down. Some data, known ones, represent the experience made public in entity field, others, unknown ones, result from laboratory experiments or are forecast.

Forecasting solves problems by moment and this should be just an intermediary phase and as shorter as possible.

The simulation process of operation/breaking-down offers values that should be analysed and interpreted with high degree of responsibility. For example, values of Figure 7 show a low availability. What should be done in order to increase the reliability of components and / or to reduce the breaking - down times, where should be acted is the task of maintainability teams.

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