MODERNISATION OF CONSTRUCTIONAL SOLUTIONS OF PROTOTYPE OBJECTS IN THE ASPECT OF EXPLOITATION REQUIREMENTS

Key words
Modernisation, exploitation, prototype objects.

Abstract
The problem of the verification of constructional solutions of prototype objects considered in the aspect of exploitation requirements is discussed in the study. The object’s reliability was assumed as the assessment criterion. The proposed assessment-decision model allows reliable assessments of each realised enterprise, if the prototype reliability in real conditions is lower than the project requirements.

Introduction
Complex prototype objects in which construction-exploitation solutions are verified in real operational conditions, including both internal and external forcing factors, is a subject of the present study.
Laboratory tests of such devices like technological lines, special devices used in the mining industry [3] or metallurgy are conducted with respect to assemblages and elements constituting “weak points” in relation to labour cost and work safety are considered. Real test for this group of objects comprises real operational conditions. The object reliability, i.e. its ability to realisation of
precisely determined tasks executed in defined conditions and time, was taken
as the basic assessment criterion.

In the case of excessive failure frequency, particularly in the preliminary
exploitation phase, examinations combined with the modernisation of objects in
the aspect of operational requirements should be conducted. The conducted
modernisation should be aimed at the construction of solutions, the
manufacturing mode and the exploitation of tested devices. Most of the
implemented modernisations comprise constructional changes related to
tribology.

1. Reliability assessment in individual modernisation phases

In the case of prototype objects, the reliability change process is related to
conducted examinations during which the reasons of the failures can be
detected. The results of each test give us information concerning the advisability
of making changes in the object, which allows the elimination of the probable
cause of the suspected failure.

Since only one specimen is at our disposal during the examination, the
application of reliability methods and models referring to sets of objects is
impossible, because there is insufficient statistical data.

The following groups of models needed for the forecasting, particularly in
preliminary exploitation [2] phase, can be applied:

• statistical models of reliability changes,
• logic-probabilistic models of the expected value of the reliability increment,
• models based on factor analysis, and
• similarity and measure theory-based models.

In case of prototype objects, while realising precisely determined tasks,
reliability changes may be connected with single tests (tasks) in which the
identified causes of failures have been removed as a result of modernisation.
The presented models [2] are theoretical models requiring suitable procedures
allowing their practical adaptation. The proposition of the object reliability
assessment after each modernisation, according to [1], is shown below.

Prototype objects belonging to the class of repairable objects of
a determined operation cycle were the subject of conducted examination.

In forming the testing procedure, it was assumed that, during a single task
realisation the following two events may take place:

• the object can perform its task without break down,
• the object can be damaged.

If a failure causing a break down appears during the realisation of the task,
n, the following activities should be undertaken:

• the localisation of the damaged element, \( e_n \), should be done,
the cause of damage should be found,
the manner of modernisation should be determined,
the modernisation should be realised,
the reliability of the device should be assessed.

If the modernisation is not necessary, the repairs should be made (replacing
or regeneration of the damaged element \( e_n \)).

The examinations should be continued until the moment when the object
satisfies project requirements, via the assessment of the reliability after each
introduced modernisation change. The cycle of \( n \) single tasks realised by a given
object in which \( m \) damages occurred is called \textit{chase}.

In the proposed assessment model, the following relation determines the
reliability function:

\[
R_{j(T_j)} = R_\infty - \frac{a_{j(T_j)}}{j}
\]

where:
\( j \) – chase number,
\( R_\infty \) – final reliability (if \( j \to \infty \)),
\( a_{j(T_j)} \) – parameter of reliability change rate,
\( T_j \) – total time of the object exploitation until completion of \( j \) – phase.

Parameters \( R_\infty \) and \( a_{j(T_j)} \) are determined using statistical methods. First
approximation \( R_\infty \) and \( a_{j(T_j)} \) are obtained with use of the least squares method
which allows a shortened calculation procedure. Next, approximations \( R_\infty \) and
\( a_{j(T_j)} \) are obtained with use of the Maximal reliability method.

Information about each phase should be registered via giving general
number of tasks \( n_j \) and number of tasks \( m_j \), in which the damage occurred. In
order to make decisions about the continuation of examinations, confidence
interval \( RD_j \) is determined for reliability \( R_{jl} \), i.e. reliability in \( j \) – phase and \( l \)
iteration steps:

\[
RD_j = R_{jl} - U_{1-\gamma} \sqrt{VR_j}
\]

where:
\( U_{1/2} \) – quartile of normal distribution of the order \( 1-\gamma \),
\( \gamma \) – confidence interval, \( VR_j \) – reliability variance in \( j \) – testing stage.
The testing should be finished if the following condition is satisfied:
\[ RD_j \geq R_w \]  \hspace{1cm} (3)
where:
\[ R_w \] – required reliability

A simplified calculation algorithm is shown in Fig. 1. The detailed calculation algorithm allowing decision making about the tests continuation or finishing is given in [1]. The reliability function, being in the preset case a basic measure, should be determined after each modernisation enterprise is realised in a given object. Other reliability factors should be determined temporarily, depending on needs conditioned by the number of damages and the type of implemented modernisation changes.

Fig. 1. Simplified algorithm of reliability function calculation
Fig. 2. Modernisation of the construction, including exploitation requirements
2. Construction-technological modernisation of the prototype objects

The set of enterprises realised in the scope of the program should comprise the following:

• suggesting the proposal of the constructional, material or technological changes,
• satisfying formal requirements related to verification,
• cooperation with the object design and manufacturing office in the scope of the design and manufacturing of proposed modernisation changes,
• the execution of needed examinations of the modernised object,
• the gathering exploitation information in form of instructions of the operation and handling of the modernised object,
• filling necessary formal documents allowing the assessment of the influence of the new solution onto its reliability, and
• determining is test should be continued or terminated.

Areas of construction modernisation related to exploitation requirements are shown in Fig. 2.

Each of the introduced modernisation changes should be exposed to a detailed reliability assessment.

Continuous flow of information between exploitation systems and design & manufacturing systems, as well as current cooperation with designer and current reactions to detected damages reducing the object reliability is necessary in the case in question.

Summary

The proposed examination procedure, including the assumed assessment-decision-making model should allow the assessments of the prototype object reliability belonging to the tested class. Particularly, it should allow the making of reliable assessments of each modernisation enterprise, including tribologic associations.

As a result of the conducted examinations and introduced modernisation, the object’s reliability should reach a level corresponding to exploitation requirements.

References

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Modernizacja rozwiązań konstrukcyjnych obiektów prototypowych w aspekcie wymagań eksploatacyjnych

Słowa kluczowe
Modernizacja, obiekty prototypowe, eksploatacja.

Streszczenie

W artykule omówiono zagadnienie weryfikacji rozwiązań konstrukcyjnych obiektów prototypowych w aspektie wymagań eksploatacyjnych. Jako kryterium ocenowe przyjęto niezawodność obiektu. Zaproponowany w opracowaniu model ocenowo-decyzyjny pozwala na dokonywanie miarodajnych ocen każdego realizowanego przedsięwzięcia modernizacyjnego w przypadku, gdy niezawodność prototypu w warunkach rzeczywistych jest niższa od wymagań projektowych.