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Reliability Evaluation of the Activation Machine for the Electric Detonating Caps – EKA 350

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Abstract: *The machine – EKA 350 is designed for the activation of the serial or mixed connected electric detonating caps EK – 40 – 69 in explosive fillings at mining and demolition. For the analyzes of reliability it is important that the machine works in the three regimes of function: LOAD, FIRE and EMPTY. Modeling of reliability was executed for each of the mentioned regimes of the EKA 350 machine. In the machine are incorporated the components dedicated to the professional usage and satisfaction of the MIL standards. The machine is treated as it works in a single – stage mission which lasts 20 seconds.*
Keywords: *EKA 350 machine, reliability, failure, components*

1. INTRODUCTION

1.1 Basis of the reliability theory

The reliability theory became established as a separate technical discipline for the purpose of solving adequate problems of the compound electronic systems. Application of the reliability theory in other technical fields, for example in compound mechanical engineering systems, requires specific additions of the existing theoretical base. In the following part a short reference to the existing thesis of the reliability theory is given.

The best explanation of the reliability concept is **as a system characteristic to work without irregularities under specific conditions in a specific period of time.** A variant of the practical application, with the assistance of the mathematical law, defines the reliability system as **a probability that the system in the allowed variation area will execute a function for which it is assigned in a given area, planned time and given environmental conditions.** Laws of the mathematical statistic are the basic criteria with the assistance of which an irregularity of the technical systems is analyzed. However, the system reliability is an integral part of the effectiveness system studies, and it will be explained in the following part as such.

Every system realizes its function of a goal in an environment. Previously it was usually understood that the projection of some machine engineering system has a task to fulfill the demands of cinematic of mechanism, material resistance, necessary power and system effect. Today, the projection, besides the mentioned demands which provide a possibility of functioning, indicates and provides high quality functioning. According to this follows the definition of the SYSTEM EFFECTIVENESS which represents a probability that the system will start to function and execute the function of criteria for which it was assigned in a planned time and given environmental conditions.

The analysis of problem of the system effectiveness implies the development and certain demands for quality realization:

- The quality of goal function implicates capability of the system to execute a task assigned by the projected function of criteria within the limits of allowed variation.

- The time is an important factor which implicates a probability that the system will fulfill the requested demands of functioning at the given time.
- The environmental conditions are an important factor of impact to the system and implicate the analysis of the system effectiveness taking into consideration: the temperature, humidity, salinity, vibrations, hits, quality standard changes etc., which can require the appearance of cancellation.

The purpose of reliability calculation of the machine EKA 350 is dual:

1. Determination of the quantitative indicators of the machine's EKA 350 reliability;
2. Verification of fulfillment of the requests for reliability given in the preliminary draft PKP.

In the PKP (Regulatoru about kvalitet in military) [1], the requests for reliability and durability of the machine EKA 350 were set. The reliability of the machine was expressed in number of firings (pulling) between failures, and it is demanded to be higher than the minimally acceptable number of firings between failures ($n1=400$ with a risk of a producer and a buyer α = ß = 0,10. The machine should work within the temperature scale from -20°C to +55°C.

The standard SNO 8196 [2] defines the activities that necessarily have to be done during the proper development of the devices of NVO and for the purpose of providing their reliability. According to the mentioned standard, during the development of the EKA 350 machine, a series of activities were realized for the purpose of providing its reliability. The undertaken activities, as well as the achieved results, are explained hereafter.

At the selection of the components of the EKA 350 machine, the attention was paid to the satisfaction of the components on the demanded temperature scale of the function of the machine. Also, a due attention was paid to the disencumberment of the components (by electricity / voltage etc). The components provided for the professional usage or that satisfy the MIL standards are incorporated in the machine. For the purpose of protection from humidity, the components are poured over. In accordance with the demands of the standard SNO 1096 [3], the machine EKA 350 has an indicator of the battery discharge. According to the indication that the battery (E – item) is discharged, the operator of the machine replaces it.

From the viewpoint of the availability, there are 3 important conditions of the EKA 350 machine:
*Machine is in a good repair
-executes or is prepared to execute the function;
*Machine is in a good repair, but the battery is discharged
- machine is not prepared to execute the function, the battery is replaced;
*Machine is out of repair
-does not execute or is not prepared to execute the function.

Analyzing the reliability of the components, two conditions are considered, a component is in a good condition or a component failure.

2.FUNCTIONAL ANALYZES AND DIVIDING INTO SECTIONS OF THE EKA 350 MACHINE

For the needs of the reliability analyzes, it is necessary to establish the structural levels of the machine. The EKA 350 machine is divided into three structural levels:

- device (machine)
- structure or block
- component.

The purpose, as well as the basic function of the EKA 350 machine has been described in the attached documentation and the preliminary draft PKP. For the reliability analyzes, it is important that the machine works in three regimes of function: **LOAD, FIRE and EMPTY.** At the execution of the set assignments, in three regimes of function, various integral parts of the machine participate, meaning that it is about a multi-stage assignment (mission). The complete execution of the machine's mission includes a successive execution, in the first place of the function regime LOAD, then the function regime FIRE and finally of the regime EMPTY. In special cases, when the machine does not fire, after the function regime LOAD, follows the function regime EMPTY. The duration of the function regime LOAD is 10 – 15 seconds and depends of the battery charge. The duration of the function regime FIRE is about 2 milliseconds. It is calculated that emptying through the switch Pr - 3 (function regime EMPTY) lasts about 1 millisecond and between function regimes pass about 2 seconds (extraction of the magnetic key from the switch Pr-1 and plugging the magnetic key in the switch Pr-2). For the further analyzes and calculations it was adopted that all three function regimes together last about 20 seconds.

In the function regime LOAD the E- item and the following components are active: Pr-1, D1, D3..D11, C1..C4, C6..C8, LED-1, LED-2, R1…R15, R18, R19, IC-1, Tr1…Tr3 and TR-1.

In the function regime FIRE participate the E- item and the following components: D9, Pr-2, C5, R16, R17, D2, Tr4, R14, R15 and C3. In the function regime EMPTY participate the following components: C3, R15, R20 and Pr-3. In the functional and structural sense, the machine is divided into the following items:

ITEM 1 - battery (E- item)
ITEM 2 - connecting item between the battery and the item 3 (connector for the battery and wires)
ITEM 3 - printed panel with all incorporated components;
ITEM 4 - connecting item between the item 3 and the network EDK (wires and outgoing links).

According to the standard SNO 1096 [3], the failure does not include the TMS failures, which can be repaired by the TMS user with the individual tools and accessories. The battery replacement, due to the worn – down condition (according to the indication), does the machine operator himself. For that reason, the impossibility of the machine function due to the battery discharge, is not treated as a failure of the EKA 350 machine. When the power – supply is provided, the failures of the item 2, 3 and 4 have the impact to the machine reliability.

3. MODELING OF THE MACHINE RELIABILITY

Concerning that the EKA 350 machine is an electronic device, it can be understood that the failures of the components act according to the exponential division. The reliability modeling was done for each of the mentioned function regimes of the EKA 350 machine. The failure of the items 2, 3 or 4 has as a consequence of the failure of the EKA 350 machine, the items are in the serial connection in the sense of the reliability. The failure of the item appears in case when any of the components of that item fails. The components are in a serial connection in the sense of the item s' reliability.

ITEM 2------------ ITEM 3------------ ITEM 4

The reliability item dijagram of the EKA 350 of the EKA 350 machine

Figure 1. The item– graph of the reliability item dijagram of the EKA 350 machine is shown on at the level of item.

The item -graph of reliability of the machine in the function regime LOAD is presented by the serial connection of the abovementioned components that participate in that regime.The item -graph of reliability of the machine in the function regime FIRE is presented by the serial connection of the abovementioned components that participate in that regime.The item -graph of the reliability of the machine in the function regime EMPTY is presented by the serial connection of the abovementioned components that participate in that regime.

4.EVALUATION OF THE PROPER RELIABILITY OF THE EKA 350 MACHINE

Concerning the recommendations given in TPR 1766/92, since it is about such a device and a purpose where the time of mission`s realization is short (about 20 seconds), an approximative procedure was used for the evaluation of the indicators of the machine reliability. The machine was treated as it was about a single – stage mission which lasts about 20 seconds (collected successive execution of the task in the regimes LOAD, FIRE, EMPTY). During the execution of the mission it is requested that all the items, that is all the components of the machine are in a good repair. The failure of any component leads to the failure of the machine. The components are in a serial connection in the sense of reliability. Such an approach gives the approximative but more severe results for the indicators of the machine reliability.

The reliability is given through the following indicators:

MTBF - medium time between the failures, expressed in hours [H]

λ (FR) - intensity of the failure, expressed in number of failures in 10 6 hours [F/10 6 H]

The indicators of the proper (inherent) machine reliability were obtained on the basis of the calculated indicators of reliability of the machine components. For the calculation of indicators of reliability of the components, the methodology was used, that was given by the American military standard MIL-HDBK-217E. For each component and in accordance with the data regarding the function regimes of the components, firstly were determined the intensities of failures of the components and then the intensity of the failure of the EKA 350 machine in full.

The environmental conditions and the conditions of function of the machine are defined in the preliminary draft PKP. As it is about a portable device, meaning that a user can keep it in his hand during its function, MP (Manpack) was taken from the mentioned standard for the environmental impact.

For the calculation of the intensity of the REED relay failure (Pr-1, Pr-2 and Pr-3) and the connector (connector for the battery and outgoing terminals), it is necessary to adopt or calculate the number of connections / disconnections during the function. The calculations were made in two cases:

A. Machine executes firing every 20 seconds, that is 180 firings in an hour
B. Machine executes 5 firings in an hour.
C. The case A is possible only in theory, numerous firings of the machine are possible only in the conditions of examination of the machine. The case B is closer to the realistic conditions of usage of the machine.

The intensities of failures of the components and the machine were calculated for the temperatures -20°C (minimal functional temperature according to the requests from PKP), 25°C (medium functional temperature) and 55°C (maximum functional temperature according to the requests from PKP).

The calculations were done for each of the three mentioned temperatures and for both cases of selection of number of firings in an hour.

Table1: Results of the calculation of the failure rate and MTBF of the EKA 350 machine were completely

	180 firings in 1 hour		5 firings in 1 hour	
TEMPERATURE	λ[F*10¯6]	MTBF[H]	λ[F*10¯6]	MTBF[H]
-20°C	67.2388	14872.3604	5.7948	172568.2344
25°C	77.2035	12952.7871	11.2295	89051.1797
55°C	100.9333	9907.5361	24.3875	41004.6172

The highest values for the intensities of failure of the components and the machine were obtained for the maximum functional temperature of 55°C and the number of firings 180 in an hour (enclosure 3). The failures of the REED relay with the most percentage influence the intensity of the machine failure, which is a consequence of a large number of the selected firings in an hour. More realistic values for the intensities of the failures of components and the machine are obtained in the case of selection of 5 firings in an hour (enclosure 4).

On the basis of the calculated value of the intensity of the machine failure (λ=100,9333 F*10¯6) and the duration of the mission T=20 seconds (execution of all three regimes of the function), the value of reliability of the mission of the EKA 350 machine was calculated.

$R = e^{-\lambda T} = 0{,}99999944$

On the basis of the achieved results for the indications of reliability, it can be concluded that the EKA 350 machine fulfills the requests for reliability given in PKP.

5.CONCLUSION

For the most unfavorable conditions of function of the machine (55°C and 180 firings in an hour), the medium time was obtained between the failures MTBF = 9907.5361 H. The total number of firings between the failures is equivalent to the product of the value MTBF and the number of firings in an hour and amounts **178326**, which is far higher than the requested number of firings (400).For the more realistic conditions of the machine function (55°C and 5 firings in an hour), the medium time was obtained between the failures MTBF = 41004.6172 H. The total number of firings between the failures is equivalent to the product of the value MTBF and the number of firings in an hour and amounts **205020**, which is far higher than the requested number of firings (400).

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