

# Determination of Correction Values of Operating Reliability of Assembly Components of the Assembly—Front Spinner Spinning Box (R1 Rieter) on the Basis of Operating Data

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## Abstract

The optimal safety model includes the values of the operation of the components with the allowed risk, and it is clearly seen that the belt of absolutely safe operation of the analyzed circuit is located between the values of the displayed dependence curves  $M_i(t)_{BP} = f(t)$ . AND also, analyses have been carried out to ensure the flawless operation of the OE machine and the consistency of product quality.

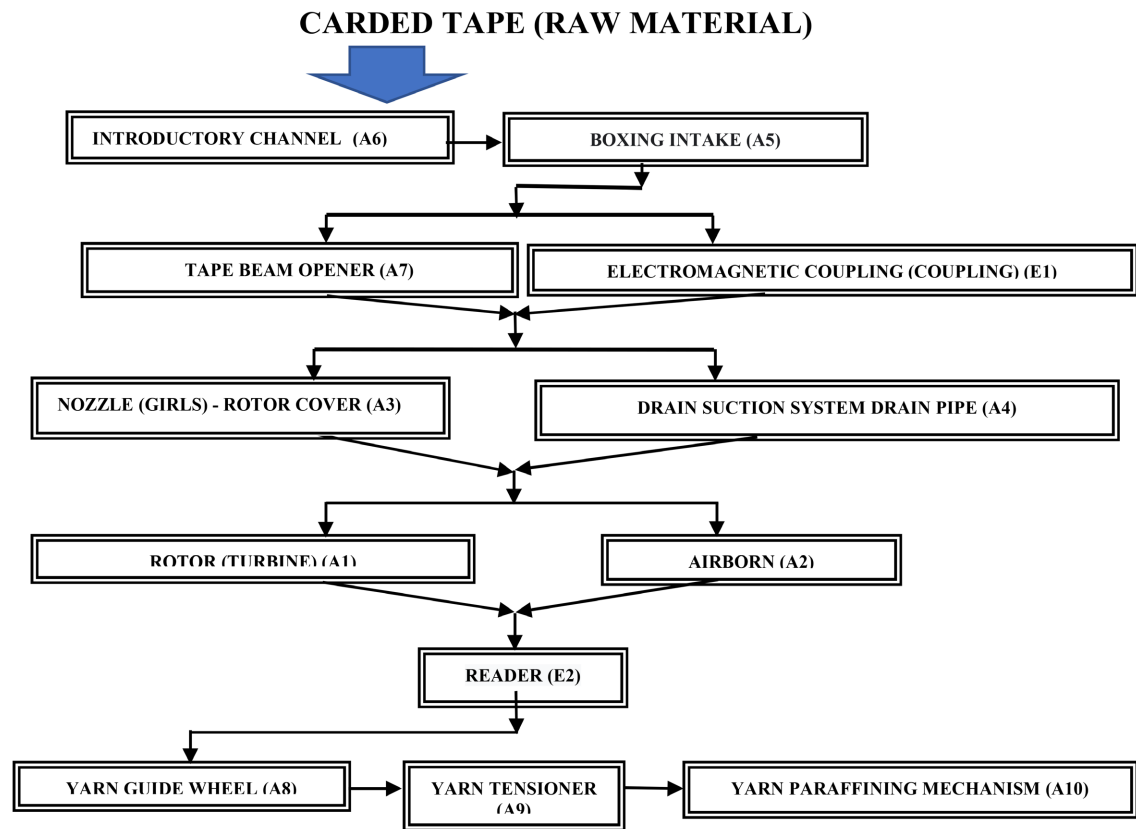
## Keywords

Surrender Box, Open-End (OE), Reliability, Exploitation, Spinning, Yarn, Tension

## 1. Introduction—Description of the Box Spinning Assembly (Heart OE Spinner)

The power transition system of the spinning box assembly is shown in **Figure 1** and consists of the following components which are classified on the basis of the processing flow of the carded sliver (raw material to be processed).

When the operational values of reliability are determined, which express the approximate values of reliability of the components of the analyzed assembly with maximum safety (areas of their safe operation time and areas of reduction



**Figure 1.** Assembly power transmission system—spinning box.

of their reliability), their correction values were used for more precise determination. This was aimed at obtaining the most accurate reliability values for determining the total transfer function of the reliability of the components of the analyzed assembly [1] [2] [3].

The correction values of reliability from the exploitation data are shown in **Figure 2** to **Figure 3**, and their tabular values within the presented figures.

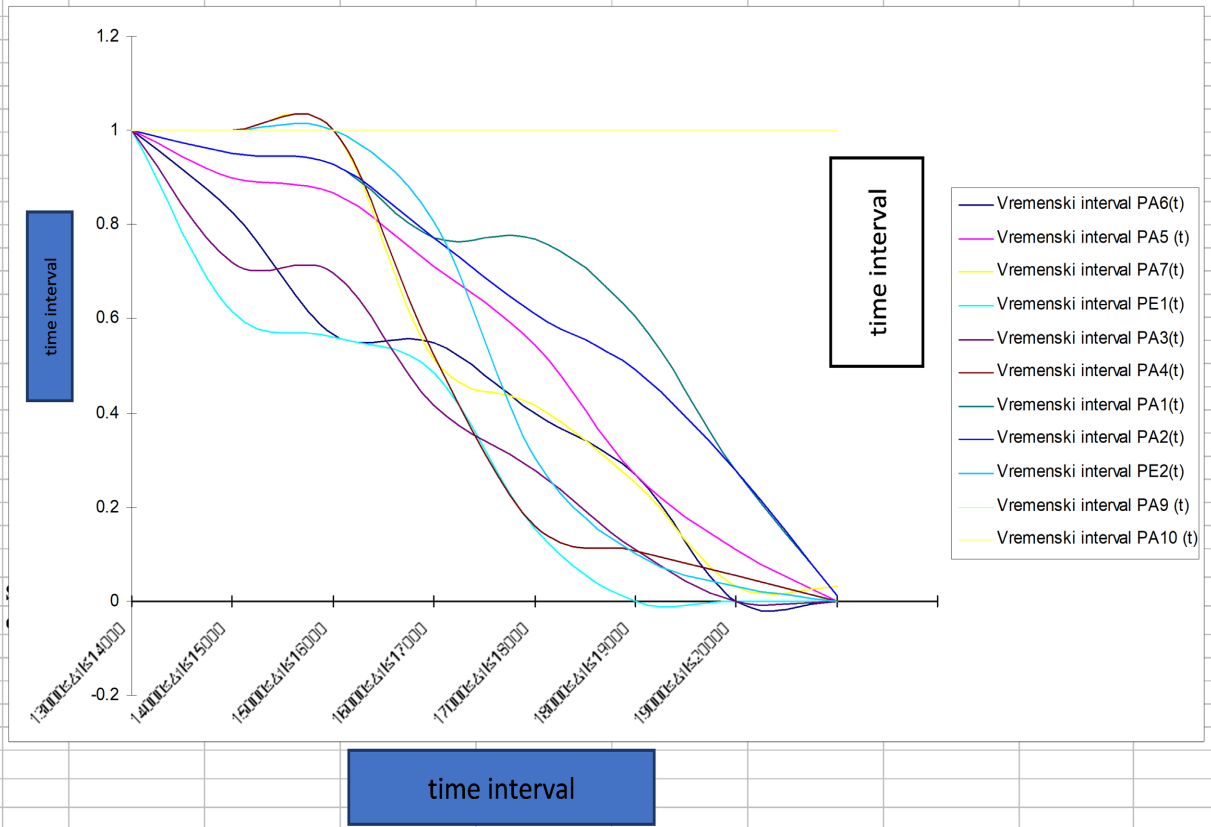
Reliability correction values are obtained as a quotient of the empirical distribution density function from empirical values ( $f_e(t)$ ) and failure intensity functions ( $\lambda_e(t)$ ) for the time interval of the operational operation of the components of the assemblies (the analysis included the service life of the components of the assembly in the duration  $13000 \leq \Delta t_i \leq 21000$  hours) and are determined by the expression:

$$P_i(t) = \frac{f_{e_i}(t)}{\lambda_{e_i}(t)}$$

The obtained correction values will further serve in the formation of tables of values of the transfer functions of the spinning box assembly  $G_{BP}(t)$  on the basis of which the shapes of the curves are determined  $f(G_{BP}(t), t)$  which determine the form of statistical distribution of reliability, *i.e.* the shape of the curve adopts the distribution of reliability that best suits their shape [4] [5].

Conclusion: From the shape of the curve of the correction values of the reliability

Vremenski interval	$12000 \leq \Delta t_i \leq 13000$	$13000 \leq \Delta t_i \leq 14000$	$14000 \leq \Delta t_i \leq 15000$	$15000 \leq \Delta t_i \leq 16000$	$16000 \leq \Delta t_i \leq 17000$	$17000 \leq \Delta t_i \leq 18000$	$18000 \leq \Delta t_i \leq 19000$	$19000 \leq \Delta t_i \leq 20000$
PA6(t)	1	0.828	0.566	0.548	0.4	0.27	0	0
PA5(t)	1	0.9	0.868	0.71	0.542	0.27	0.11	0
PA7(t)	1	1	1	0.514	0.416	0.25	0.0321	0.0305
PE1(t)	1	0.615	0.56	0.485	0.153	0	0	0
PA3(t)	1	0.72	0.697	0.417	0.276	0.11	0	0
PA4(t)	1	1	1	0.523	0.16	0.106	0.0533	0
PA1(t)	1	0.951	0.927	0.773	0.768	0.603	0.276	0.011
PA2(t)	1	0.952	0.927	0.773	0.61	0.491	0.276	0.01
PE2(t)	1	1	1	0.806	0.302	0.1	0.03	0
PA8(t)	1	1	1	1	1	1	1	1
PA9(t)	1	1	1	1	1	1	1	1
PA10(t)	1	1	1	1	1	1	1	1



**Figure 2.** Diagram of correction values of the reliability of the components of the analyzed spinning box assemblies on the basis of empirical data on which the procedures of preventive maintenance technology have not been applied.

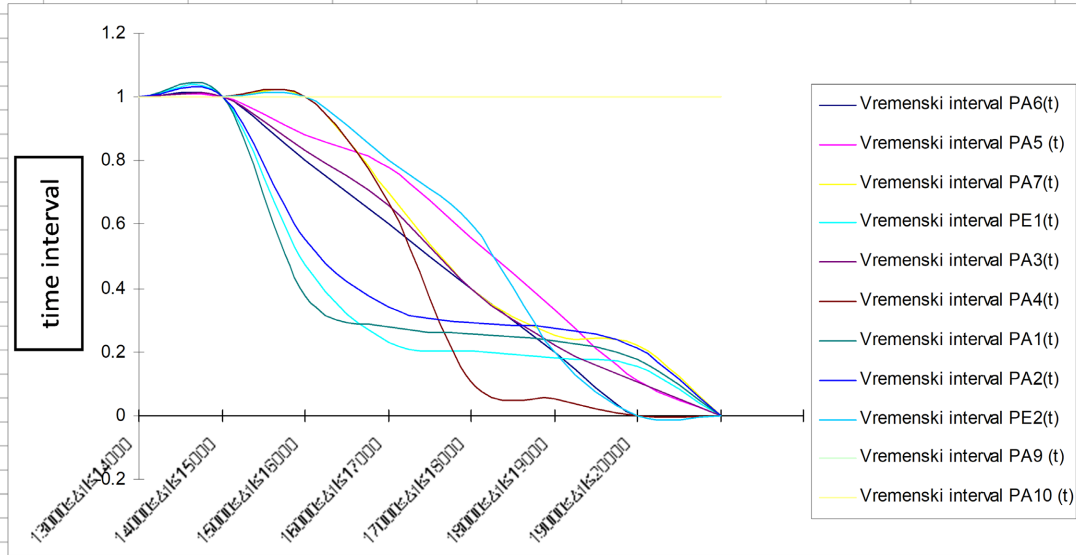
of the components of the analyzed assembly  $P_i(t)$ , i.e. according to the slope of the curve, confidence intervals can be analytically predicted which will later be used as a basis in determining the relevant reliability (reliability obtained from the statistical distribution) [6] [7] [8].

The analysis showed the following conclusions:

1) Analysis of the reliability of the operation of the components of the analyzed assemblies without the application of preventive maintenance technology procedures:

- Components A8, A9, A10 have the highest reliability in operation, whose reliability is maximum and amounts  $P_{A8}(t) = P_{A9}(t) = P_{A10}(t) = 1.0$  and lasts in a time interval over  $\Delta t_i \geq 20000(h)$ .
- Based on the shape of the curve  $f(P_i(t), t)$ , i.e. according to their slope, **Table 1** shows the order of reliability values and component operating times.

Vremenski interval	12000 ≤ Δt ≤ 13000	13000 ≤ Δt ≤ 14000	14000 ≤ Δt ≤ 15000	15000 ≤ Δt ≤ 16000	16000 ≤ Δt ≤ 17000	17000 ≤ Δt ≤ 18000	18000 ≤ Δt ≤ 19000	19000 ≤ Δt ≤ 20000
PA6(t)	1	1	0.8	0.6	0.4	0.2	0	0
PA5(t)	1	1	0.88	0.779	0.556	0.333	0.11	0
PA7(t)	1	1	1	0.7	0.4	0.25	0.223	0
PE1(t)	1	1	0.475	0.23	0.204	0.179	0.154	0
PA3(t)	1	1	0.831	0.66	0.4	0.22	0.107	0
PA4(t)	1	1	1	0.67	0.106	0.0533	0	0
PA1(t)	1	1	0.376	0.278	0.255	0.233	0.178	0
PA2(t)	1	1	0.552	0.342	0.292	0.274	0.212	0
PE2(t)	1	1	1	0.8	0.6	0.2	0	0
PA8(t)	1	1	1	1	1	1	1	1
PA9(t)	1	1	1	1	1	1	1	1
PA10(t)	1	1	1	1	1	1	1	1



Slika 4.19. Dijagram korekcionih vrednosti pouzdanosti sastavnih komponenti analiziranih sklopova boksa predenja na osnovu empirijskih podataka na kojima su primenjeni postupci tehnologije preventivnog održavanja

Figure 3. Diagram of correction values of the reliability of the components of the analyzed spinning box assemblies based on empirical data on which the procedures of preventive maintenance technology were applied.

Table 1. Values of the correction reliability interval depending on the analyzed time interval of operation of the components of the analyzed assemblies on which the procedures of preventive maintenance technology have not been applied.

Component designation	Time interval of the analyzed work of the component $\Delta t_1 \leq \Delta t_i \leq \Delta t_2$	Confidence interval for the analyzed time interval $\Delta P_{t1} \leq \Delta P_i \leq \Delta P_{t2}$
Boxing spinning assembly		
A6	13,000 ÷ 14,000	1.0 ÷ 0.828
A5	13,000 ÷ 14,000	1.0 ÷ 0.9 ÷ 0.868
A7	13,000 ÷ 16,000	1.0 ÷ 0.514
E1	13,000 ÷ 14,000	1.0 ÷ 0.615
A3	13,000 ÷ 14,000	1.0 ÷ 0.72
A4	13,000 ÷ 16,000	1.0 ÷ 0.523
A1	13,000 ÷ 14,000	1.0 ÷ 0.951 ÷ 0.927
A2	13,000 ÷ 14,000	1.0 ÷ 0.952 ÷ 0.927
E2	13,000 ÷ 16,000	1.0 ÷ 0.806

The analysis included confidence intervals after the first lower value than the maximum.

2) Analysis of the reliability of the components of the analyzed assemblies with the application of preventive maintenance technology procedures:

- Components A8, A9, A10 have the highest reliability in operation, whose reliability is maximum and amounts  $P_{A8-0}(t) = P_{A9-0}(t) = P_{A10-0}(t) = 1.0$  and lasts in a time interval over  $\Delta t_i \geq 20000(\text{h})$ .
- And lasts in a time interval over  $f(P_{i-0}(t), t)$ , i.e. according to their slope, the order of values of reliability and operating time of components during these reliability is shown in the table (Table 2). The analysis included confidence intervals after the first lower value than the maximum.

## 2. Determination of the Statistical Method of Reliability Distribution of the Analyzed Assembly

In order to determine the statistical method of reliability distribution, it is necessary to form models and determine the transfer reliability functions of the analyzed assembly [9] [10]. To determine the transfer function tables of the spinning box assembly  $G_{BP}(t)$  reliability corrections were used  $P_i(t)$

### 2.1. Model Formation and Determination of Transfer Functions of Reliability of Analyzed Assembly Based on Empirical Data

The formation of the model included the arrangement of the components of the assemblies according to the processing of the yarn, i.e. according to the labels in the order of the components in the failure tree.

The components are arranged in sequence on the assembly, from the introductory

**Table 2.** Values of the correction reliability interval depending on the analyzed time interval of the components of the analyzed assemblies on which the procedures of preventive maintenance technology have been applied.

Component designation	Time interval of the analyzed work of the component $\Delta t_{i-0} \leq \Delta t_{i-0} \leq \Delta t_{2-0}$	Confidence interval for the analyzed time interval $\Delta P_{i-01} \leq \Delta P_{i-0} \leq \Delta P_{i-02}$
Boxing spinning assembly		
A6	13,000 ÷ 15,000	1.0 ÷ 0.8
A5	13,000 ÷ 15,000	1.0 ÷ 0.88
A7	13,000 ÷ 16,000	1.0 ÷ 0.7
E1	13,000 ÷ 15,000	1.0 ÷ 0.475
A3	13,000 ÷ 15,000	1.0 ÷ 0.831
A4	13,000 ÷ 16,300	1.0 ÷ 0.67
A1	13,000 ÷ 15,000	1.0 ÷ 0.376
A2	13,000 ÷ 15,000	1.0 ÷ 0.522
E2	13,000 ÷ 16,300	1.0 ÷ 0.8

channel to the yarn waxing mechanism in the spinning box.

For these reasons, the block diagram model is shown. The model is more complex and includes the arrangement of components in the spinning box, taking into account their functionality and purpose, so that the reduction of complex block diagram structures has been performed.

Based on the obtained final expressions of the transfer functions of the analyzed circuits  $G_P(t)_{BP}$  for boxing spinning), and in them by replacing the reliability values of the components  $P_i(t)$  for time intervals

$13000(\text{h}) \leq \Delta t_i \leq 20000(\text{h})$  tabular values are obtained by reliability significance belts, from which the reliability curves of the transfer functions of the analyzed assembly are constructed (**Table 3**).

### 1) Block diagram model of the transmission reliability function in a spinning box assembly

For solving reduction of this model, its step-by-step solution will be performed when obtaining the transfer function of the circuit reliability  $G_P(t)_{BP}$ . As can be seen from **Figure 4**, this is an open system of automatic reliability management [11] [12]. The model is shown in **Figure 4**.

#### Step I: Determining partial reliability blocks

$$\begin{aligned} P_{p1}(t) &= P_{E1}(t) \cdot P_{A7}(t), P_{p2}(t) = P_{A4}(t) + P_{A3}(t), \\ P_{p3}(t) &= P_{A1}(t) \cdot P_{A2}(t), P_{p4}(t) = P_{A8}(t) + P_{E2}(t), \\ P_{p5}(t) &= P_{A9}(t) + P_{A10}(t) \end{aligned}$$

#### Step II (Figure 5)

The values of the partial reliability blocks are:

$$P_{p6}(t) = P_{A6}(t) + P_{p1}(t), P_{p7}(t) = P_{p4}(t) + P_{p1}(t).$$

**Table 3.** Values of transmission reliability functions of spinning box assembly depending on the value of its reliability.

Reliability values $P_i(t)$	Portable spinning subsystem reliability function $G_P(t)_{BP}$	
1.0		16
0.9		8.078
0.8		3.775
0.7	Shaded areas represent the ultimate limit of satisfactory reliability in the analysis	1.6
0.6		0.5972
0.5		0.1875
0.4		0.0458
0.2		0.0006
0		0

Note: The shaded areas included values because values below this limit are not taken into account (they include areas in which the assembly needs to be repaired, which will be discussed more when determining the reliability values in cases of selected statistical distribution).

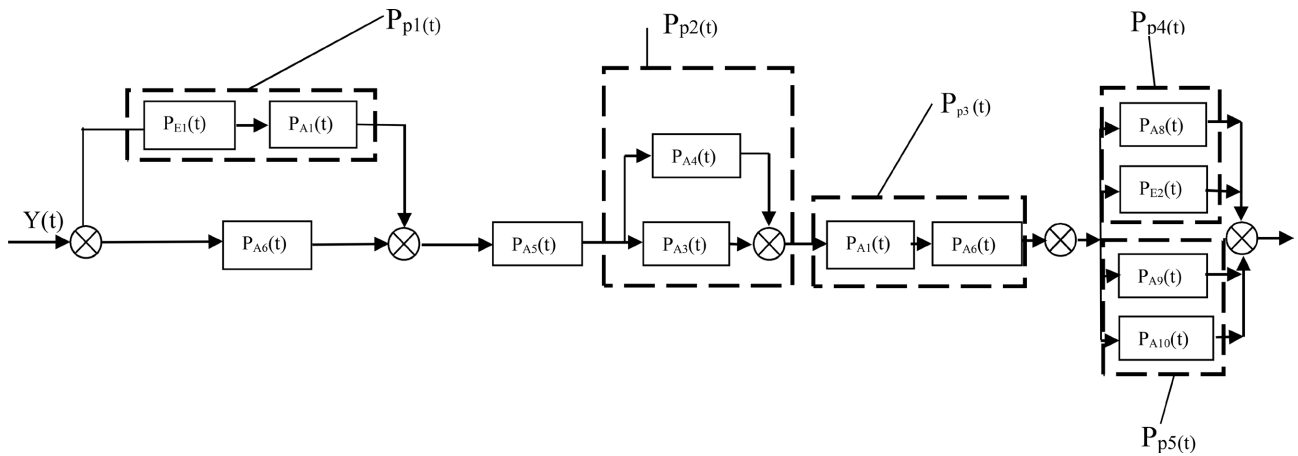


Figure 4. Initial model block diagram of the transmission reliability function of the spinning box assembly.

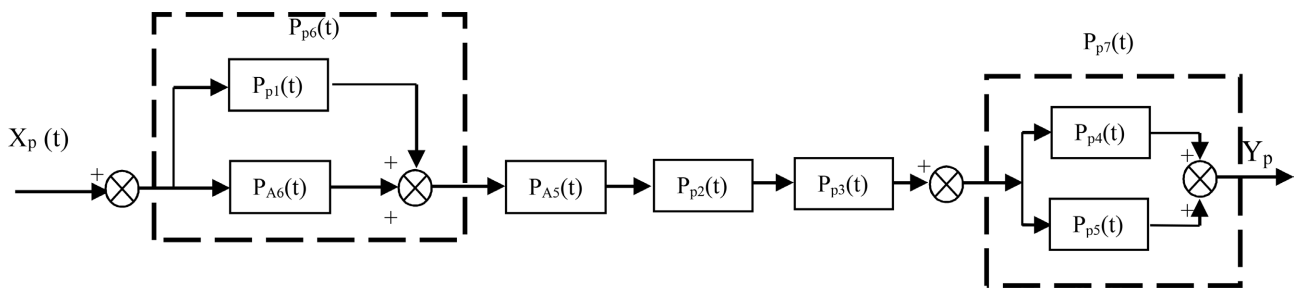


Figure 5. Block diagram reduction in step II for spinning box assembly.

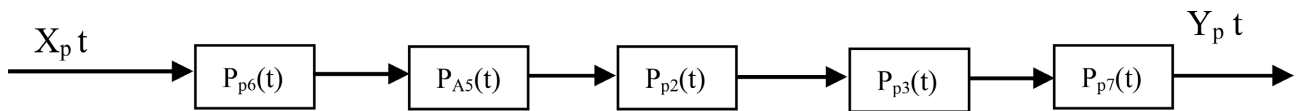


Figure 6. Block diagram reduction in step III for spinning box assembly.

**Step III (Figure 6)**

The values of the partial reliability blocks are:

$$G_{BP} = P_{P6}(t) \cdot P_{A1}(t) \cdot P_{P2}(t) \cdot P_{P3}(t) \cdot P_{P7}(t).$$

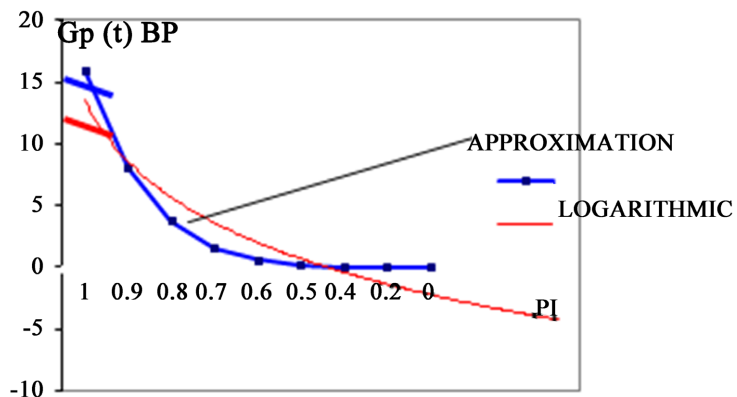
The final equation of the reliability value based on the partial reliability values for the box spinning assembly is:

$$\begin{aligned} G_{BP}(t) &= \frac{Y_p(t)}{X_p(t)} = (P_{A6}(t) + P_{P1}(t)) \cdot P_{A5}(t) \cdot (P_{A4}(t) + P_{A3}(t)) \\ &\quad \cdot P_{A1}(t) \cdot P_{A2}(t) \cdot (P_{P4}(t) + P_{P5}(t)) \\ &= (P_{A6}(t) + P_{E1}(t) \cdot P_{A7}(t)) \cdot P_{A5}(t) \cdot (P_{A4}(t) + P_{A3}(t)) \\ &\quad \cdot P_{A1}(t) \cdot P_{A2}(t) \cdot (P_{A8}(t) + P_{E2}(t) + P_{A9}(t) + P_{A10}(t)) \\ &= P_{A1}(t) \cdot P_{A2}(t) \cdot P_{A5}(t) \cdot \{(P_{A6}(t) + P_{E1}(t) \cdot P_{A7}(t))\} \cdot (P_{A4}(t) + P_{A3}(t)) \\ &\quad \cdot (P_{A8}(t) + P_{E2}(t) + P_{A9}(t) + P_{A10}(t)) \\ G_{BP}(t)_p &= P_{A1}(t) \cdot P_{A2}(t) \cdot P_{A5}(t) \cdot (P_{A4}(t) + P_{A3}(t)) \\ &\quad \cdot \{(P_{A6}(t) + P_{E1}(t) \cdot P_{A7}(t))\} \cdot (P_{A8}(t) + P_{E2}(t) + P_{A9}(t) + P_{A10}(t)) \end{aligned}$$

## 2.2. Table of the Transmission Function of the Spinning Box Assembly with Approximation $G_P(T)_{BP}$

**Table 3** is formed on the basis of the final expressions of the transfer reliability functions depending on the time interval of operation of the circuits.

The value of the transmission function of the spinning box assembly reliability is shown in a table (**Table 3**). Based on the obtained values, a graphical representation of the dependence was performed  $f(G_P(t)_{BP}, t)$  (**Figure 7**).



**Figure 7.** Graph of transfer function of spinning box with approximation  $G_P(t)_{BP}$ .

## 3. Conclusion

Guilty  $f(G_P(t)_{BP}, t)$ , corresponds to long normal curves according to their shape, so for that reason a long normal distribution will be taken for the selection of the statistical reliability distribution. According to this distribution, the reliability of each component of the analyzed assembly will be corrected. The optimal safety model includes the values of the operation of the components with the allowed risk, and it is clearly seen that the belt of absolutely safe operation of the analyzed circuit is located between the values of the displayed dependence curves  $M_{\xi}(t)_{BP} = f(t)$ . And also, analyses have been carried out to ensure the flawless operation of the OE machine and the consistency of product quality.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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