Proceedings of Informing Science & IT Education Conference (InSITE) 2010

Development of Software for Early Failure Detection and Prevention in Technical Systems Subjected to Normal Distribution until Failure

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Abstract

Through the application of the authors' mathematical model developed for early detection and prevention of failures in technical systems a need has arisen to create software that will ease the usage of the model. The development procedure of the mathematical model for early detection and prevention of technical systems failures is not of interest for its application, and the application is, due to its complexity, rather difficult for the final user. Because of this, the aim is to make such software that will take into account all factors of the mathematical model for early detection and prevention of failures in technical systems enabling the user a simple calculation of the optimal moment of diagnostics of the state. Therefore, the starting data herein would be the final formula of the developed mathematical model, and the software user should know only the input data for his system. The output data for the user would be the optimal moment of diagnostics of the state of the technical system. This software would be applicable in most technical systems, but this paper gives an example of its usage in printing presses.

Keywords: mathematical models, software, early detection and prevention failure, technical diagnostics.

Introduction

There are technical systems in which the occurrence of failure must be prevented, such as aviation, military and other industries, where the appearance of failure brings risk to the people lives and goods (Bengtsson, 2002). To prevent a failure, it is necessary to find an alternative solution. In other words, it is needed either to provide the replacement for the defective part that is activated at the moment of failure of the original one, or to predict the moment of failure and respond to it in order to prevent its appearance. It is not always possible to replace the defective part with another one, so in these cases another solution should be found i.e. the failure occurrence should be predicted and prevented.

The aim of the paper is to determine when is the optimal moment to perform the state diagnosis process of the technical system and in this manner to obtain a time picture of possibilities of failure occurrence on a technical system parts. Since the diagnosis requires certain costs, the optimal moment of the diagnosis process regarding the costs decrease is also determined here. In this way it can be detected in which moments during operation of technical systems a failure can occur, and how to react to prevent the failure. All this is done so that the costs will be minimized, too.

The authors developed the model SAV-TT05B, which enables the determination of the optimal moment of state diagnosis of the observed technical system part knowing the distribution law of the part operation until the moment of failure (Powell, 2002). It is also necessary to know the expenses of the state diagnosis process and the expenses of the lost production if the failure is not detected at the right moment. Diagnosis at the right time can predict the possibility of a failure and thus affect its prevention. The final expression for determining the optimal moment of state diagnosis according to the model SAV-TT05B, in case of normal distribution of failure is (Authors, 2005):

$$t_{k+1} = t_k + \frac{C_i}{C_o} + \frac{\int_0^{t_k} e^{-\frac{(t-m)^2}{2\sigma^2}} dt - \int_0^{t_{k-1}} e^{-\frac{(t-m)^2}{2\sigma^2}} dt}{e^{-\frac{(t_k-m)^2}{2\sigma^2}}} .$$

In the previous expression there are the quantities:
t_k - k-th optimal moment to perform status diagnosis of a machine part, where k=1,2,3,...n,
C_i - the costs of diagnosis process of the machine part state,
C_o - costs of lost production due to the failure of the machine part,
σ - standard deviation,
m - mean operation time and
t - moment of failure occurrence.

It is seen from the previous text that the application of the developed model requires knowledge of mathematical functions in a high degree. Hence, the goal of this paper is imposed, i.e. to facilitate the implementation of the model, and that is possible by development of the software package. In this software package the user, i.e. the maintainer who wants to apply the developed model does not need to know the mathematical functions used in the previous expression, but should just enter the required information in certain fields and then by pressing the appropriate button he obtains the optimal moments when to perform diagnosis process for the given part or the system.

Development of Software for the Model Application

The software has been developed using Macromedia Flash Professional 8. After setting up a graphical environment, the program has been written based on the model. Thereafter object linking and the program activation have been performed what is shown in the Figure 1.

Finally, after performing all the activities and tests, the executable program that is shown in Figure 2 has been obtained.

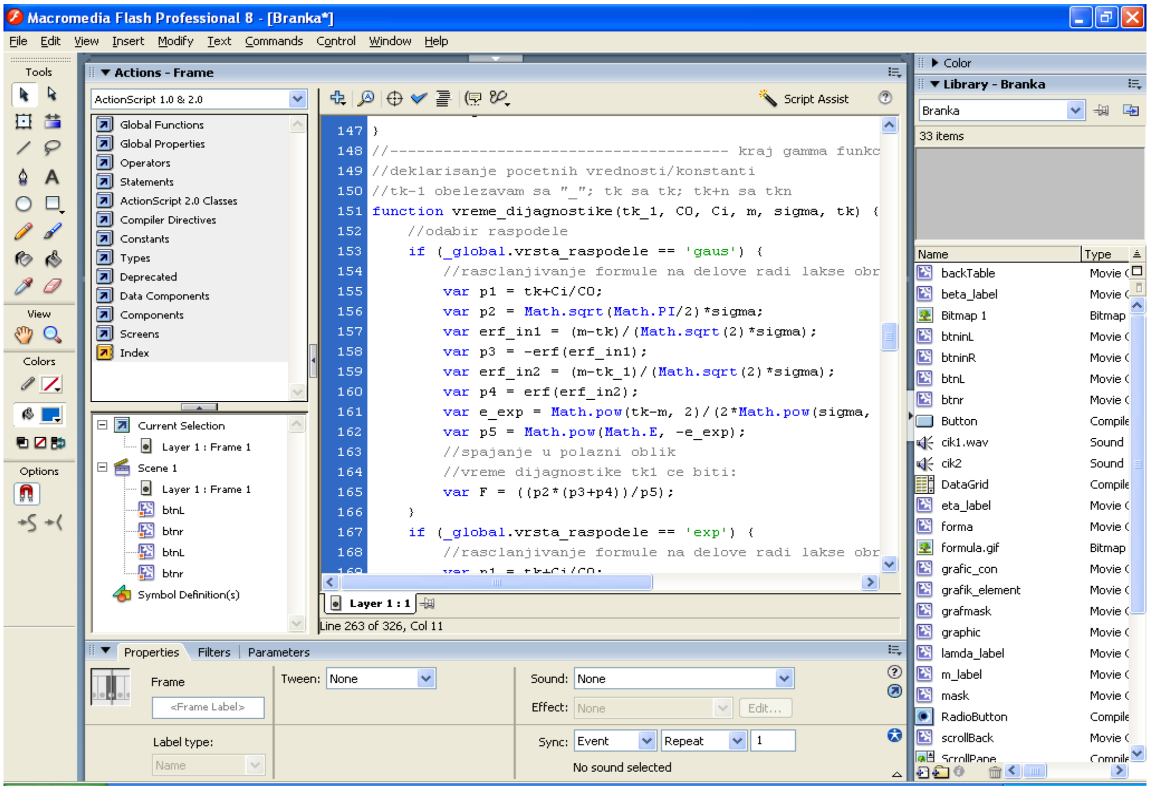

Figure 1. A program page and objects linking in the software package

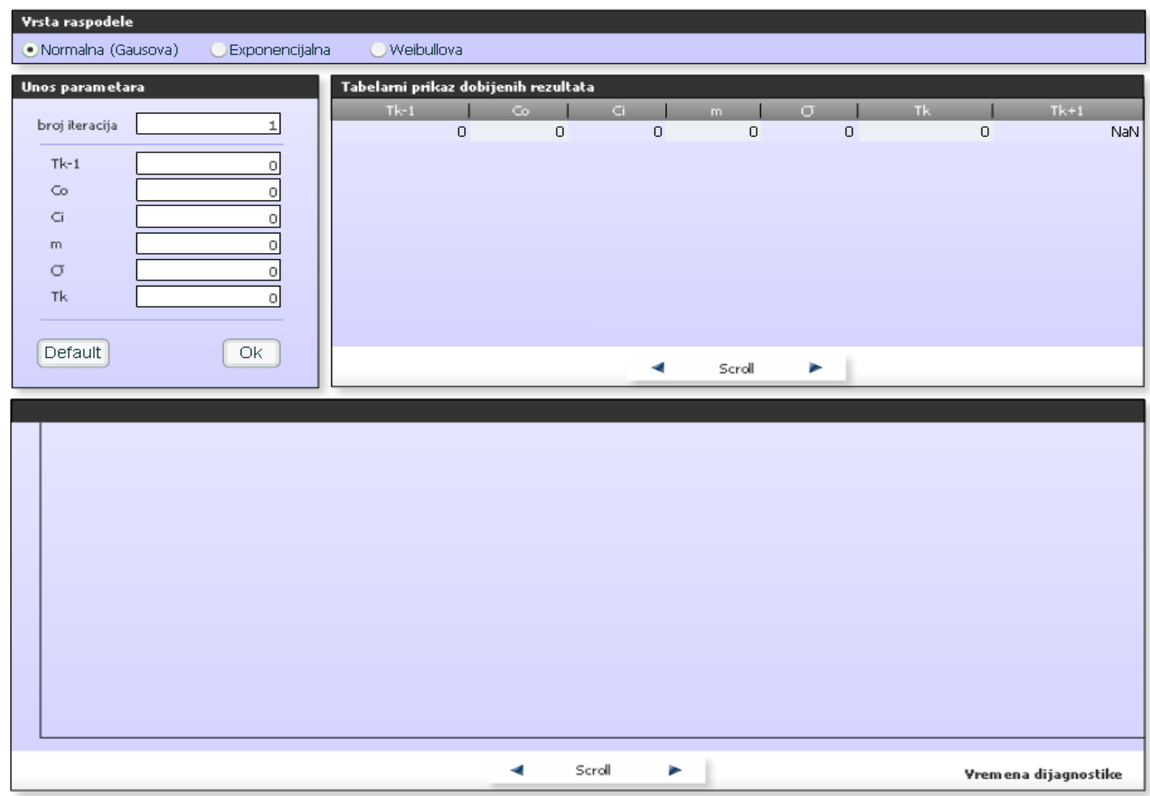

Figure 2. User interface look of the developed software package for determination of the optimal moment of system part state diagnosis

Figure 2 shows that there are four windows in the developed software package, such as: the distribution type, the data entry, the table review of the obtained results and the graphical representation of the results.

Observing the first window one can see that the goal is to develop software for three most common types of distribution: normal, exponential and Weibull distribution. Depending on the established distribution of the observed element the distribution type is selected in the field "type of distribution". When the software is developed for normal distribution, the environment shown in Figure 2 is obtained.

The second window is used for data entry. In the field "number of iterations" an approximate number of state diagnoses is entered, usually higher than necessary. If such a number of diagnoses is not needed, then the software will remove the excessive ones, what will be seen from interpretation of the results obtained.

In the program it is necessary to determine the unknown t_{k+1}, and it is in fact the next moment of diagnosis, or rather the optimal moment of state diagnosis which is calculated. The moment t_{k-1} is taken to be equal to 0, when the first moment of state diagnosis is determined because no state diagnosis is performed until that moment. Furthermore, to determine the first moment of state diagnosis, the t_k is taken to be equal to the moment when a failure occurred for the first time on the observed part.

Application of the Software for Optimal Moment of State Diagnostics Determination

To test the model gear failures on the package printing machine (flexographic printing machine) were observed (Bjelica, 2005; Jardine, 1999), as shown in Table 1.

Table 1: Moments of gear failure occurrences [hour]

4530	12555	19956	24960	28541	33584	42154	54991
6570	13456	20521	25047	29021	34564	44589	58574
7250	15011	22035	25684	29874	35541	45025	
9211	15298	23545	26581	31254	36732	46058	
10521	16521	24547	26965	31599	37852	47052	
11259	19021	24958	27548	32588	39584	50147	

By processing the data and testing the hypothesis of normal distribution (Dovich, 1990), the input data for the program have been obtained: $t_{k-1}=0$, $t_k=4.500$ hours, $m=27.792$ i $\sigma=13.428$ hours and costs $C_i=100$ *m.u*, $C_o=50$ *m.u (m.u. – money unit)*.

By entering these values into the program and assuming the number of iterations 30, and then activating the program, the values of optimal moments for diagnosis of the state appear in the window „table review of the results obtained" in the column t_{k+1}, as shown in figure 3. Also, in the field „graphical review of the results obtained" in the same figure optimal moments of diagnostics of the state of the flexographic machine gears have been shown in the form of time axis.

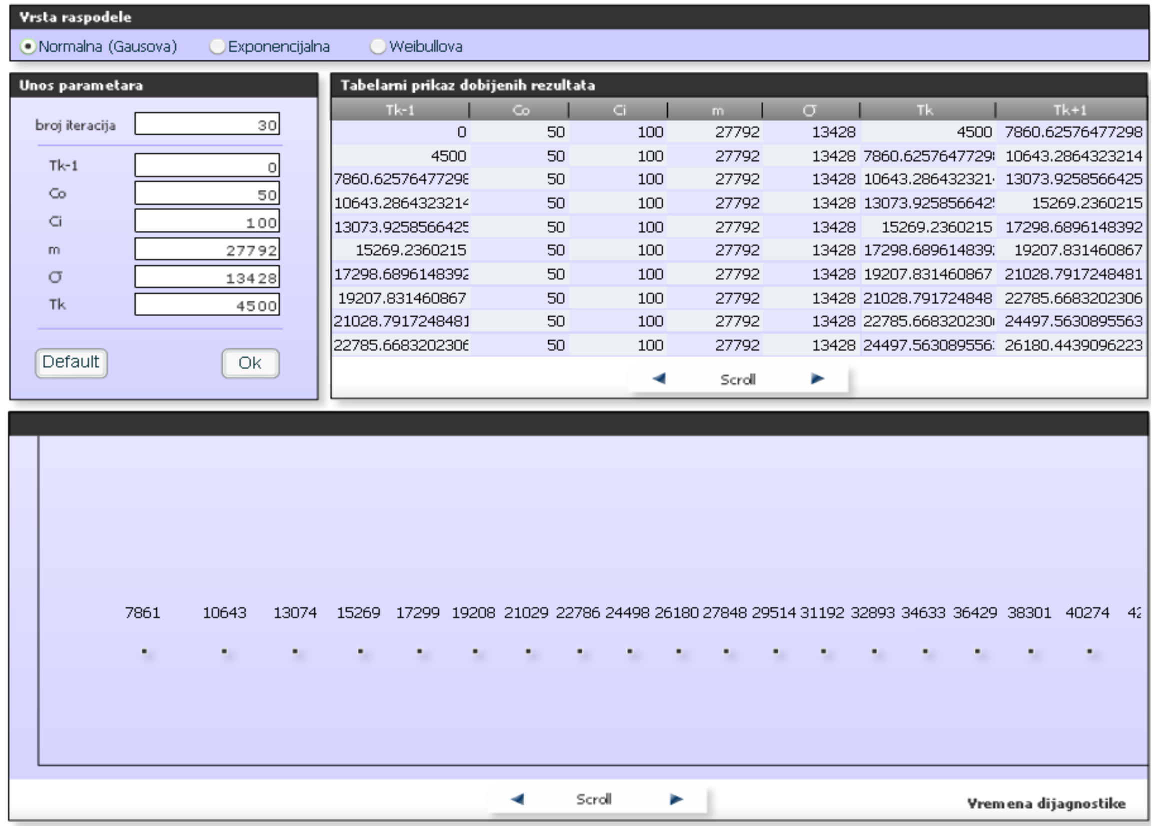

Figure 3: The program overview and its application for optimal moment of diagnostics

Thorough state diagnosis moments calculated according to the model developed SAV-TT05B, after application of the program have been given in Figure 4.

The table also shows the parameters used to calculate the optimal moment of state diagnosis t_{k+1}.

Figure 4 shows that the last two moments of diagnosis are outside the time range. The last four moments of state diagnosis do not have practical application, because the last gear failed after 58,574 hours of work. Hence, it is necessary to reduce the assumed number of the iterations required by six. One can see that 24 state diagnostics of the gears observed are needed in the intervals obtained (column t_{k+1}).

What is important to verify the correctness of the software developed is the result match for the optimal moments of diagnostics in Figure 4 with the of the failure occurrence layout for the gears of the given machine. So calculation of the optimal moments of state diagnostics of this element shows that state diagnoses are most frequent around the mean operation time until failure occurrence, while before and after that time the number of diagnoses decreases (Figure 5).

Tabelarni prikaz dobijenih rezultata						
Tk-1	Co	Ci	m	σ	Tk	Tk+1
0	50	100	27792	13428	4500	7860.62576477298
4500	50	100	27792	13428	7860.6257647729	10643.2864323214
7860.6257647729	50	100	27792	13428	10643.286432321	13073.9258566425
10643.286432321	50	100	27792	13428	13073.925856642	15269.2360215
13073.925856642	50	100	27792	13428	15269.2360215	17298.6896148392
15269.2360215	50	100	27792	13428	17298.689614839	19207.831460867
17298.689614839	50	100	27792	13428	19207.831460867	21028.7917248481
19207.831460867	50	100	27792	13428	21028.791724848	22785.6683202306
21028.7917248481	50	100	27792	13428	22785.668320230	24497.5630895563
22785.668320230	50	100	27792	13428	24497.563089556	26180.4439096223
24497.563089556	50	100	27792	13428	26180.443909622	27848.3860778787
26180.443909622	50	100	27792	13428	27848.386077878	29514.4824196633
27848.386077878	50	100	27792	13428	29514.482419663	31191.5918522043
29514.482419663	50	100	27792	13428	31191.591852204	32893.0437978325
31191.591852204	50	100	27792	13428	32893.043797832	34633.4009352883
32893.043797832	50	100	27792	13428	34633.400935288	36429.3972117498
34633.400935288	50	100	27792	13428	36429.397211749	38301.2180494055
36429.397211749	50	100	27792	13428	38301.218049405	40274.3992869785
38301.218049405	50	100	27792	13428	40274.399286978	42382.8535201528
40274.399286978	50	100	27792	13428	42382.853520152	44674.0428253257
42382.853520152	50	100	27792	13428	44674.042825325	47218.5280875683
44674.042825325	50	100	27792	13428	47218.528087568	50129.3398885309
47218.528087568	50	100	27792	13428	50129.339888530	53606.4413466582
50129.339888530	50	100	27792	13428	53606.441346658	58058.3077095646
53606.441346658	50	100	27792	13428	58058.307709564	64538.669888719
58058.307709564	50	100	27792	13428	64538.669888719	77342.5065499108
64538.669888719	50	100	27792	13428	77342.506549910	168527.524762024
77342.506549910	50	100	27792	13428	168527.52476202	2.68811213752293e
168527.52476202	50	100	27792	13428	2.6881121375229	NaN
2.6881121375229	50	100	27792	13428	NaN	NaN

Figure 4: Optimal moments of performing diagnostic tests of state of flexographic printing machine gears obtained with the help of the software package and based on the developed model SAV-TTO5B

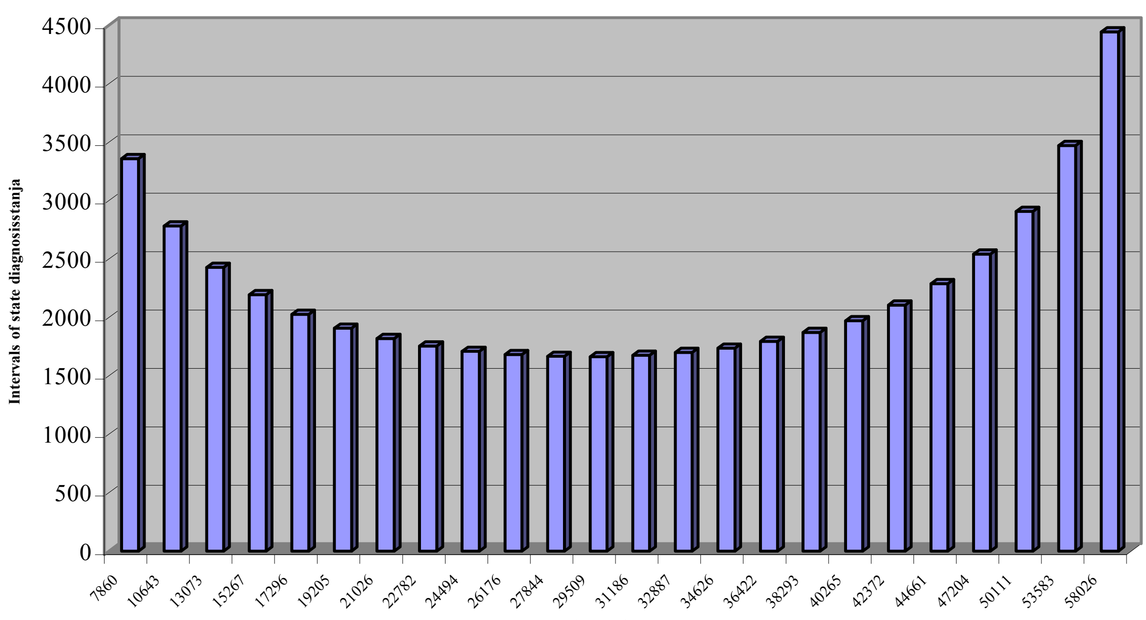

Figure 5: Graphical overview of moments of state diagnostics of the flexographic printing machine gears calculated according to the model developed

Here is also obvious that the optimal moments of state diagnostics obtained with the help of this software package behave in accordance with expectations for normal distribution. So it can be seen that the state diagnoses are more frequent around the mean operation time, while the number of diagnoses decreases as it moves away from that time. Therefore it can be concluded that the developed software package is suitable for determining optimal moment of state diagnosis for those parts that have normal failure distribution law provided that the model SAV-TT05B is used to determine the optimal moment. Application of the developed software on other machines subjected to normal failure distribution confirms correctness of the software in similar way.

Conclusion

Based on the above, it is seen that it is possible to develop software that implements the model SAV-TT05B to determine optimal moment of state diagnosis by minimizing total costs depending on time. The developed software package gives optimal moments of state diagnosis of the elements observed. Thus a failure can be predicted and prevented before it is too late. Application of the model is quite simplified with a help of the software, because a user does not have to deal with complex mathematical operations for determination of optimal moment of state diagnosis but only to enter certain input data into the program. Thereafter by pressing a single button optimal moments of state diagnosis of the elements observed are obtained without getting involved into the model structure and the program functioning. By application of the software and the model developed, number of failures and maintenance costs would be reduced to a great extent, that would contribute to production improvement.

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Biographies

Dr. Branko Savic was born on 03 March 1969th in Loznica, Serbia. He graduated in 1994. at the University of Novi Sad, Faculty of Technical Sciences, Department of Mechanical Engineering Department of manufacturing systems, robotics and automation. At the University he defended his magister thesis in the field of machine maintenance. He is employed at the School of Professional Higher Education Novi Sad, Serbia, as a teaching and research professor. His scientific areas of interest are graphics machines, reliability, from which he published, as an author or a coauthor, more than 55 scientific and professional papers at national and international conferences or in local journals. He participated in realization of several scientific research projects. He is also interested in software development and has taken part in several software development projects with commercial application.

Mr. Nebojsa Nikolic was born on 27 January 1969th in Loznica, Serbia. He graduated in 1994. at the University of Novi Sad, Faculty of Technical Sciences, Department of Mechanical Engineering Department of manufacturing systems, robotics and automation. At the University he defended his master thesis in the field of internal combustion engines. He is currently employed at the Faculty of Technical Sciences as a teaching and research assistant. His scientific areas of interest are dynamics of internal combustion engines and internal combustion engines equipment, from which he published, as an author or a coauthor, more than 35 scientific and professional papers at national and international conferences or in local journals. He participated in realization of several scientific research projects. He is also interested in software development and has taken part in several software development projects with commercial application.