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SYSTEM FOR RELIABILITY ASSURANCE OF THE INDUSTRIAL ROBOTS

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Abstract. In this paper, the reliability assurance was performed. The global reliability analysis of the equipments was performed by the Kolmogorov-Smirnov goodness-of-fit test. After the reliability modeling the inspection planning and renewal policies were achieved.

1. INTRODUCTION

The intense global competition, the development of highly sophisticated systems and the rapid progresses in technology enlarged the scope of the notion of quality, to include aspects concerning the reliability perormance of the systems.

The mathematical modeling reliability may be realized either from a global level, without regard to the equipments stucture or from a structural point of view, taking into account the components of the equipments and their interrelationships. In both cases, the analysis is performed considering the time interval elapsed since the initial moment of equipments operation up to the moment of failure.

In reliability theory, the concept of failure is defined as the event when at least one of the equipment performances exceeds its tolerance limits.

The failure mechanisms are based on physical and chemical processes, which are not governed by deterministic laws, so that the probability theory and mathematical statistics are used to modeling the reliability systems [1,2].

2. RELIABILITY MODELING OF ROBOTS

The mathematical modelling of the industrial robots reliability may be approached either from a global level (ignoring the components of industrial robots) or from a structural point of view (taking into account the structure of the industrial robots).At the global level, the industrial robots is mathematically descriebed by the functional dependence between the outputs and inputs variable[1]:

$$Y = A(U) \tag{1}$$

where Y is the output vector, U is the input vector and A is an oparator. The mathematically modelling at the structural level may be performed by the canonical state equations[1]:

$$\begin{aligned} \dot{X} &= f(t, X, U) \\ Y &= g(t, X) \end{aligned} \tag{2}$$

where X represents the vector of internal variables.

In the global reliability modeling, the reliability measures are defined using the statistical model for the times to failure of the system. The statistical model for reliability is the cumulative distribution function. Denoted by F(t), the cumulative distribution function represents the probability that the system fails after a specified time of function.

The essential step in global reliability description is the adoption of the distribution law, which will model the reliability. Two distribution laws were proposed for the reliability modeling of robots: alpha and power.

The adoption of one of these laws can be performed by a goodness-of-fit test based on the theory of hypothesis testing. One of the most used goodness-of-fit test is the Kolmogorov-Smirnov test which uses the times to failure of the tools under the observation. For this test, the distribution law is accepted if [3]

$$\sup_{1 \le i \le n} \left| F(t) - \widehat{F}(t) \right| < D_n(\alpha) \tag{3}$$

where F(t) is the true cumulative distribution function, $\widehat{F}(t)$ is the estimated cumulative distribution function and $D_n(\alpha)$ is the $1-\alpha$ percentile of the Kolmogorov-Smirnov.

The structural reliability modelling impose the knowledge of the components reliability, taking into account the failure criteria of the industrial robot’s components. Generally, the industrial robot structure is very complex and the analytical reliability modelling becomes difficult. In such cases, a numerical evaluation of the reliability may be performed by Monte-Carlo simulation.The method consists of generating possible states of components according to their reliability functions and evaluating the relaibility of each combination of individual states [1,4]:

$$\hat{R}_S = \frac{\sum_{i=1}^{n} S_i}{n} \tag{4}$$

where S_i is the value of the structural function for simulation i and n is the number of simulations.

3. INSPECTION PLANNING

In order to planning the inspection, the percentile of the time to failure $X_{\gamma;t}$ may be used. This is the solution of equation:

$$\frac{R(t+x)}{R(t)} = \gamma \tag{5}$$

where t is the number of pieces realised previuosly, x is the supplementary pieces and γ is the probablity that the supplementary pieces will be realized in good conditions. If the number of pieces realized previously is known and taking a minimal value of reliability function, from relation (5) results the x number of pieces after the inspection of degradations of the industrial robots must be done.

4. SYSTEM FOR MODELING RELIABILITY. CASE STUDY

The integrad system was developed using Matlab and is presented in Figure 1. The menu of the system consists in:

a) File: work with files (New, Open, Save, Print, Exit).
b) Modeling reliability of the robots: to perform the Kolmogorov-Smirnov goodness-of-fit test for alpha and power law.
c) Inspection robots: to plan the inspection for the alpha and power law.

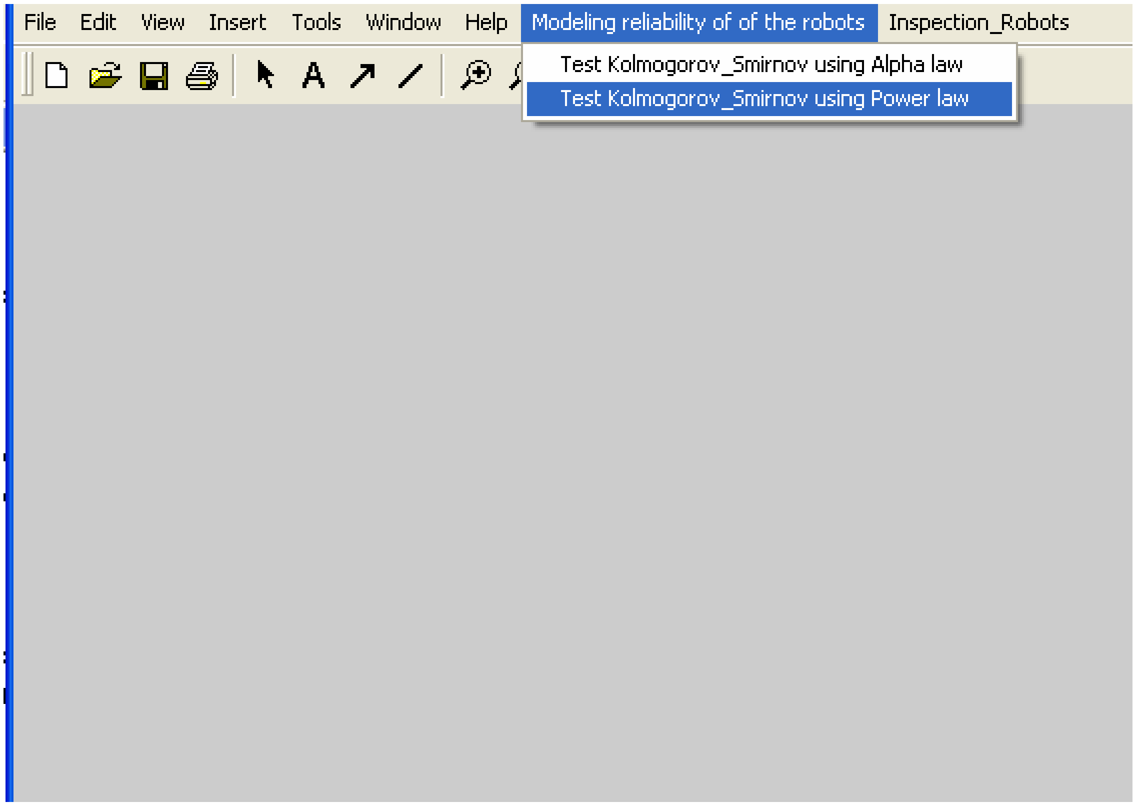

Figure 1. System for modeling reliability

The theoretical considerations presented were applied for a welding robot. The times-to-failure of the equipment are (in cycles of function): 12211, 15441, 16755,17889,18923, 19567, 19876, 20012, 21221, 22362, 22678 and 22894.

The association of a distribution law with the specific failure mechanism of this equipment must be sustained by physical interpretation and the experimental data (which have the last word). Two laws were proposed to describe the time to failure of the equipment: power and alpha.

Using the *Test Kolmogorov-Smirnov* command from *Modeling reliability of the robots menu*, the general reliability model was adopted. The risk of the first order was adopted at 0.20. Because for the power law the relation (3) is true, this law was adopted. The parameters of the power law were also computed: $\delta = 4.10$ and $b = 23053.044$.

Taking into account a minimum level of reliability R=0.85, the number of supplementary cycles after which the inspection planning must be achieved, has been made by *Inspection_Robots* menu, command *Power law*. The first verification must be done after: $X_{0.85,0} = 14374$ cycles. Using the Inspection Planning menu, the time for next verification can be established: $X_{0.85,14374} = 62001$ cycles and so on.

5. CONCLUSIONS

The adoption of the reliability model of the time to failure of the welding robot allows the estimation of the reliability measures of these equipments. Then, an software system was developed and the reliability assurance can be achieved.

6. REFERENCES

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