MODELING OF PROVIDING AVAILABILITY OF A MANUFACTURING LINE

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Abstract

Designing of manufacturing working places supposes a draft of optimal number of machines to provide a planned daily production, or to create stand-by machines that could substitute a presupposed downtime in production caused by failures. In manufacturing systems demanding implementation of setting, maintenance and repairs of smaller range on manufacturing machines there is a need to determine an appropriate number of personnel carrying out maintenance. We use the most often the deterministic or stochastic methods of operational analysis to solve the mentioned problem. However they do not describe a time flow of failure rise eventually additional random effects in providing availability of complex systems in a real operation. Drafts of logistic and maintenance systems and modeling of availability of technical systems use more often connection of knowledge about operational reliability, economic and simulation modeling and they replace traditional approaches of process examination.

Keywords: manufacturing line, availability, maintenance

1 Introduction

Modelling allows comparing of existing maintenance system with a proposed system and to evaluate benefit of a proposed maintenance system based on using individual maintenance men, exploitation of individual machines, time period of machines waiting for repair, time period of repair of particular machines for the reporting period. Simulation is aiming to find an optimal number of personnel providing the maintenance.

2 Analysis of provision of the manufacturing process maintenance

A foreign company with a production program related components of automobile equipment for diesel systems is oriented at production of Common rail diesel injection pumps and accessories to injection systems. The manufacturing process is implemented on three production lines in three shift operation. Maintenance of assembly lines is provided by maintenance personnel of two qualifications, namely repairmen and electro technicians. The electro technicians are competent to repair electric defects and the repairmen deal with mechanical defects on any assembly line in order of priorities. The defects are classified as electric and mechanical ones, these form orders for maintenance: classically reported failure, preventive maintenance, and swift repair without reporting from production. Rise of any request for maintenance is registered; real time worked off by each maintenance man is registered by individual order. The activities relating a rise and removal of defects on machines and equipment are registered through an information system with terminal stations on particular working places in production and in individual workshops of a machine and electro technical maintenance. Based on these facts and after consultation in a company the following conceptual and simulation model has been proposed. The electrical engineers repair electric defects, the technicians repair mechanical defects occurring during operation on any place on an assembly line. As in each shift there is the same number of repairmen with the same competences, we do not consider an input of adjustments to make a model simpler. In a model there are simulated two kinds of defects, electric and mechanical ones, the failures causing machine downtimes and those, which do not cause a machine downtime. These downtimes have no influence on a shutdown of an assembly line due to a failure as a material flow is immediately redirected, so the failures do not diffuse in time and there is no subsequent shutdown of an assembly line due to lack of repairmen. Based on these facts we are going to monitor a working load of individual repairmen. The data represent a time period of 10 months. The simulation model of a working place is composed of a set of three production machines, containers and conveyors for parts with random period intervals between failures, time period of a maintenance provided by repairmen. The machines process the parts with random intervals of manufacturing operations. To simplify a model the personnel servicing the machines is not depicted. A system being reviewed is defined by its structure and links among parts, containers, conveyors and maintenance personnel.

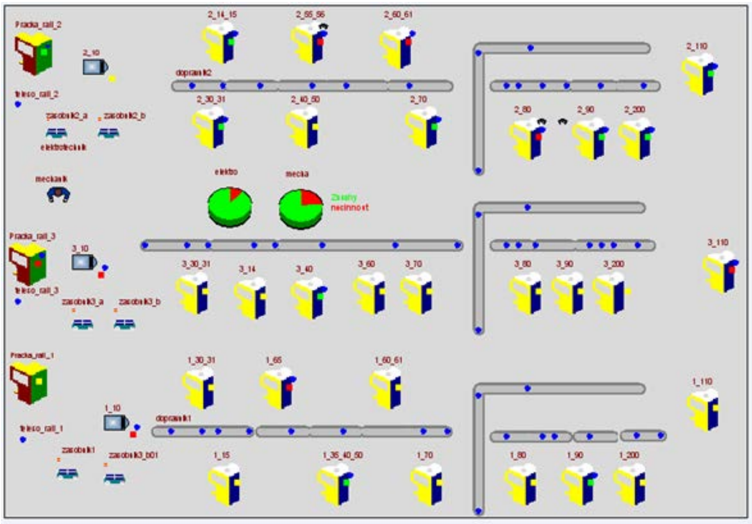


Fig. 1 *Model of a manufacturing system with an original solution of maintenance system*

We define input data according to which the particular system elements and links will behave over time. The data obtained from information system registry of interventions on particular machines were used to define input data. Time periods between interventions by electricians - an indicator analogical to the time period between failures– TBF, Time to repair carried out by maintenance men - TTR. Analogically to determine a time between interventions by technicians , Time period of interventions –Analogically to define a Time period between interventions by technician maintenance men, Time period of interventions by technician maintenance men. We defined a distribution of probability of simulation model input data through methods of statistical processing of input data and with tests of a good conformity within the STATISTICA software.

The tested kinds of distribution were Normal distribution, Weibull distribution, Exponential distribution in the following way:

1. *Hypothesis* H_0 *: A random variable has a tested kind of distribution*

Hypothesis H_1 *: A random variable has no tested kind of distribution*

2. *Significance level* $\alpha = 0{,}05$

3. *Testing statistics* $\chi^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i} = \sum \frac{(n_i - np_i)^2}{np_i}$

Where O_i , or n_i are real rate and E_i , or. np_i are theoretical rates.

We assessed the observed as well as theoretical (expected) rates. As theoretical rates np_i are not in all cases greater than 5, we merge some intervals, so that a term $np_i > 5$ is met.

*****Assessment Test of a good conformity for a normal distribution***

Testing statistics $\chi^2 = 56{,}33580$ .Critical value of χ^2 distribution in such case is equal to $\chi^2_{0,95;5} = 11{,}070498$. Therefore $\chi^2 > \chi^2_{0,95;5}$. As a testing statistics is greater than a critical value of χ^2 distribution, H_0 on a significance level $\alpha = 0{,}05$ is refused, so we can note with 0,95 credibility, that a time period between interventions is a random variable, which does not have a normal distribution.

AssessmentTest of a good conformity for an exponential distribution

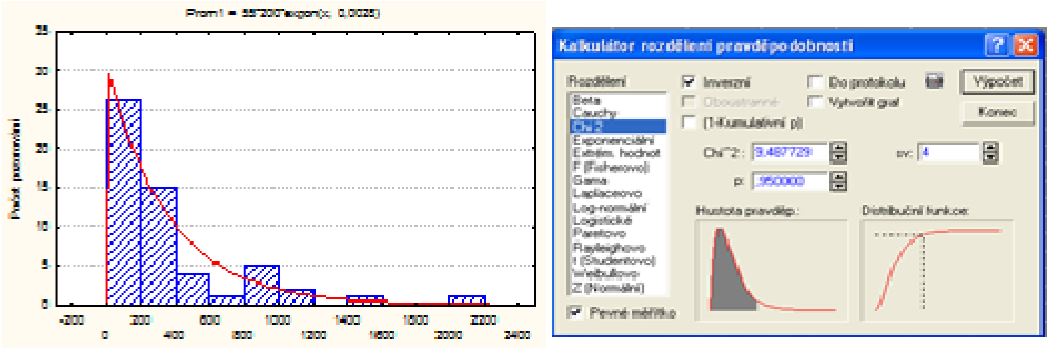


Fig. 2 *Histogram and critical value of a testing statistics at exponential distribution*

Testing statistics $\chi^2 = 8{,}54$ .A critical value of χ^2 distribution in such case has a value of $\chi^2_{0{,}95;4} = 9{,}487729$ .So $\chi^2 < \chi^2_{0{,}95;4}$. As a testing statistics is smaller than a critical value of χ^2 distribution, H_0 on a significance level $\alpha = 0.05$ is not refused and therefore we can note with credibility 0,95 that a time period between failures is a random variable, which has an exponential distribution.

Assessment Test of a good conformity for the Weibull distribution

Testing statistics $\chi^2 = 18{,}27$. Critical value of χ^2 distribution in such case is equal to $\chi^2_{0{,}95;2} = 5{,}99$. So $\chi^2 > \chi^2_{0{,}95;2}$. As a testing statistics is greater than a critical value of χ^2 distribution, H_0 on a significance level $\alpha = 0.05$ is refused and therefore we can note with credibility 0, 95,that a time period between failures is a random variable, which does not have the Weibull distribution.

Based on previous tests of a good conformity we tend towards a statement, that our random variable – a time period between failures has an exponential distribution
Analogically we were proceeding in defining distributions for other statistical input data.

The entry data were defined for elements of a system being reviewed. The particular machines were given the kinds of failures and distributions for time periods between failures, interventions TBF. Kinds and generation of time periods of interventions in removing the failures with distributions of random variables as by results from tested statistical groups. The failures were assigned particular competences of a respective maintenance man and the maintenance men were assigned a respective type of observed data.

Definition of variables was done in optionof „breakdowns“in itemof „action in breakdowns“for input and „action on resume“for output.

2.1 Simulation experiments and their assessment

Initial implementation of maintenance is made by four employees, in groups by two with electrician and technician qualifications / Variant 2x2/.
Next strategy means, that maintenance men are universally qualified and they will remove all defects on any machine on each line / Variant 4U/.
In next simulations we are going to change number of universally qualified maintenance men and to monitor the characteristics of efficiency /Variant 3U, Variant 5U/. Working load of maintenance men for particular variants of simulations illustrated through pie charts is in the Fig. 3.

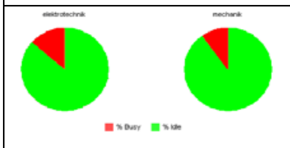
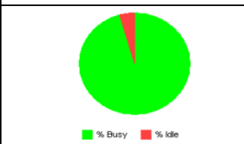
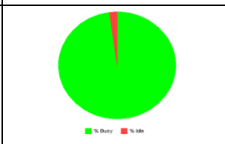
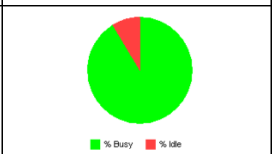
Variant 2x2	Variant 4U	Variant 3U	Variant 5U
			

Fig. 3 *Working load of maintenance men for particular variants of simulation*

Conditions of machines of the first line for particular variants of simulations are illustrated on column graph in the Fig.4.

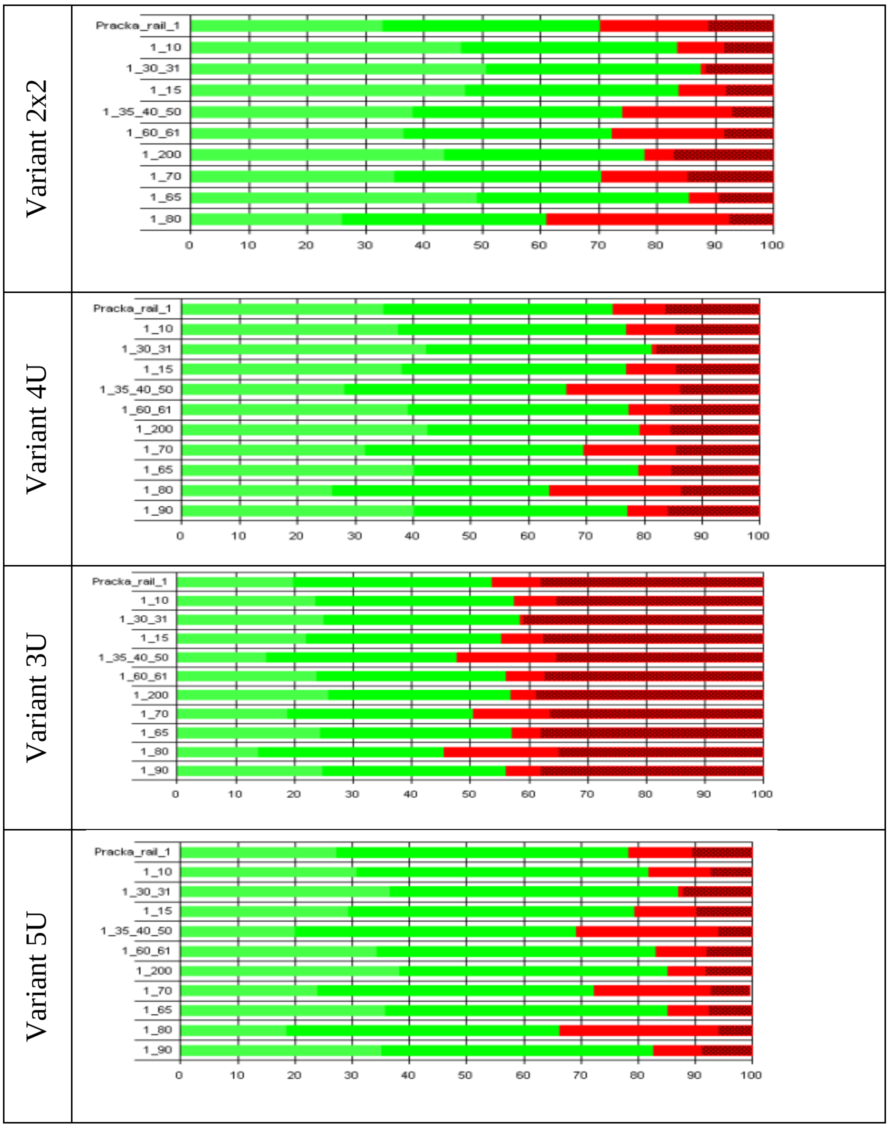


Fig. 4 *Condition of machines of the line 1for particular variants of simulation*

Working load of machines in variants was reviewed by particular lines and is illustrated in a table form.

Table 1 *Caption Working load of machines in the variant 5 x KVP on the line 1*

Line1 Station designation	Washing machine roll1	10	30,31	15	35,40,50	65	60_61
In operation%	78,27	81,82	86,98	79,36	69,17	85,28	83,06
In failure%	11,15	10,54	0,79	10,71	24,79	6,90	8,74
Being repaired by repairmen%	10,58	7,64	12,24	9,93	6,04	7,81	8,20
Station designation	**200**	**80**	**90**	**70**	-	-	-
In operation%	85,22	66,40	82,61	72,28	-	-	-
In failure%	6,46	27,59	8,49	20,25	-	-	-
Being repaired by repairmen%	8,32	6,00	8,90	7,07	-	-	-

Table 2 *Working load of machines in variant 5 x KVP on line 2*

Line2 Station designation	Washing machine roll2	14,15	10	30,31	40,50	70	60,61
In operation%	80,67	83,50	82,52	89,57	67,31	70,18	82,93
In failure%	10,75	10,64	10,20	0,79	26,38	21,02	9,44
Being repaired by maintenance men%	8,57	5,86	7,28	9,64	6,30	8,80	7,63
Station designation	**80**	**200**	**55,56**	**90**	-	-	-
In operation%	67,44	85,21	84,25	82,98	-	-	-
In failure%	26,79	6,34	6,90	8,38	-	-	-
Being repaired by maintenance men%	5,77	8,44	8,85	8,64	-	-	-

Table 3 *Working load of machines in variant 5 x KVP on line 3*

Line3 Station designation	Washing machine roll3	14	10	80	40	60	30,31
In operation%	79,88	76,29	81,44	62,09	65,64	80,11	86,65
In failure%	12,42	12,06	11,65	31,03	26,89	10,18	0,85
Being repaired by maintenance men%	7,70	11,42	6,91	6,88	7,47	9,71	12,50
Station designation	**90**	**70**	**200**	-	-	-	-
In operation%	83,84	67,95	82,54	-	-	-	-
In failure%	9,43	22,98	6,81	-	-	-	-
Being repaired by maintenance men%	6,72	8,30	10,65	-	-	-	-

Illustration of conditions of all lines for particular variants of simulation in sequence of their usefulness are stated in graphs, for line 1 in the Fig. 5.

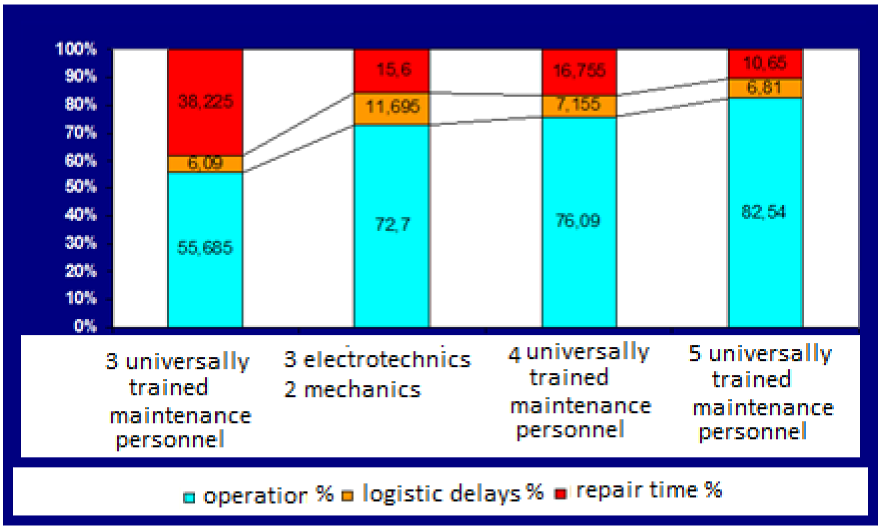


Fig. 5 *Conditions of the line 1 for particular variants of simulation*

Table 4 *Table Caption*

No	Pressure [MPa]	Processing conditions
1a	400	debinding
1b	600	debinding
2a	400	debinding, ECAP-BP
2b	600	debinding, ECAP-BP
3a	400	debinding, sintering, ECAP-BP
3b	600	debinding, sintering, ECAP-BP
4	100	annealing
5	0	hardening

2.2 Assessing the results we can make the following conclusions.

An actual system of the maintenance provision /2x electrotechnicians, 2x technicians/shows acceptable results with regard to provision of optimal function of individual machines in a whole system. A variant 4x fully trained employees is more advantageous comparing with a variant 2x electricians, 2x technicians, because of reduction of an average downtime on particular machines byabout 4 %. However the expenses for training of maintenance personnel will increase. Strategy of maintenance with no competence (presumption of all-purpose special training of an electrician – technician) is in all variants being reviewed more advantageous than assigning the competences. The most advantageous variant appears to be the one with five all-purpose qualified maintenance men, who can repair the equipment, regardless failure category. So an average operational time reached would be 82,84 %, reduction of downtimes of machines with a partial unexploited time of maintenance men, who instead will meet the requirements of control, alignment, lubrication and other actions relating daily maintenance. Current system of maintenance provision is sufficient in given conditions and ways of maintenance. Implementation of other variants of providing a maintenance system depends on a change of a kind of a manufacturing process, a line working load. It is necessary to train the employees in change of a manufacturing process for all-purpose qualified maintenance men. Figures should be presented as shown in Fig. 1. They should be clearly displayed by leaving at least a single line of spacing above and below them.

3 Conclusion

Application of WITNESS product for needs of optimization of manufacturing and maintenance processes is very convenient. It enables linking the knowledge about operations in manufacturing processes, maintenance, operational reliability, optimization economic methods with simulation modelling and replaces traditional approaches of process reviewing. Simulation experiments give a visual overview on a way, how maintenance is ensured, on involving the maintenance men into activity, on periods, when the machines are waiting for maintenance, on a working loading rate of employees and other chosen output parameters. They enable optimizing of number of personnel in considering other external effects of a manufacturing process.

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