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TECHNICAL CONDITION MONITORING OF HOR 6002 PRODUCTION LINE

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Abstract

Article concerns technical condition monitoring procedures dedicated to production line HOR 6002 which are realized during operating and maintenance of the machines. The main goal of the article is to formulate the algorithm of determination of control procedures of the condition of damage location and genesis and prognosis of the machine condition on the production line.

Keywords: *production line HOR6002, monitoring the condition of machine engines, the procedure of the state opinion, procedure genesis and prognosis of the state.*

1. Introduction

Employing the optimum technical state evaluation which is the basis of automation of machines' condition monitoring process in machines' exploitation process, requires optimizing diagnostic parameters set, diagnostic tests, genesis and forecasting methods. State monitoring of HOR6002 production line is the process which should allow to:

a) determine machines' technical states in real time, on the basis of diagnostic examination results, and to identify defects' localization in case of machine breakdown;
b) in the future, predict machines' states, based on not complete historical results of diagnostic examinations, which allows to estimate machines error-free running time;
c) in the future, predict machines' state, based on incomplete historical results of diagnostic examinations, which allows to estimate machines' state, or value of their previous work

This article discusses the above problems in the light of their influence on machines' technical readiness in HOR6002 line, and suggests certain solutions.

2. HOR6002 line production characteristics

HOR6002 line is one of five HOR type production lines, placed in Philips Lighting Poland production plant in Pila, Poland. All HOR lines are capable of producing fluorescent, linear lamps with 8/8” diameter and 0,5 to 1,8 meters long. Thanks to many modifications made by Polish engineers, mechanics, setters and operators, and with significant support from Dutch engineers, HOR6002 is able to produce 7200 lamp pieces per hour. In HOR lines, we can distinguish six modules (Fig. 1): coating module, inside production module, assembling module, control and measuring module, packaging module, cap filing module [5]. Modules are connected via mechanical conveyers adjusted to the kind of the especially to carried products, semi products or materials which are transported.

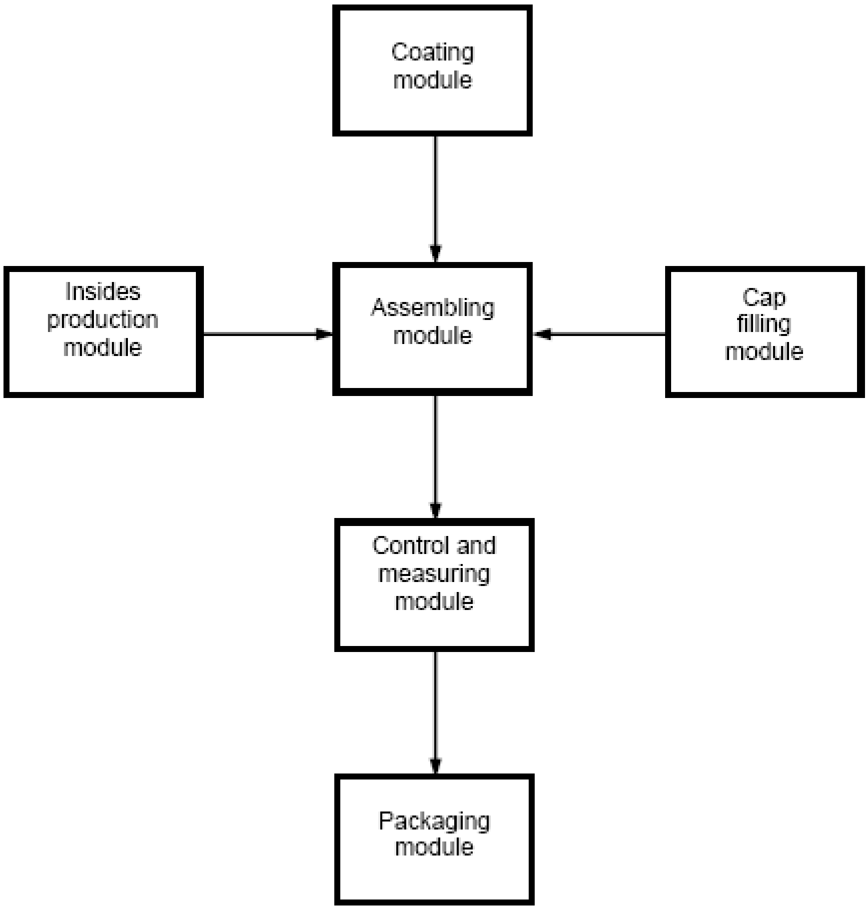

Fig. 1 .Modules of HOR6002 production line

Each of the modules consists of high specialized machines which include sub-assemblies responsible for particular operations made by machines on product. In case of a breakdown, these are replaced so that there is no downtime, and repaired off-line. State monitoring of particular sub-assemblies is done via production process control (each machine product parameters measuring).

In coating module (Fig. 2), the controlled parameters are: coating weight, Top-Bottom (top coating weight – in the injection point, to bottom coating weight ratio), temperature of suspension, in coating and pre-drying chambers), suspension viscosity, color point (correctness of luminofors mixture used in suspension). Among these parameters, only the temperature is controlled automatically, while other parameters are controlled according to statistical process control (SPM). In case of sudden value change of measured parameter, there is no unambiguous answer regarding sub-assemblies states of each machines. There is possibility to correct process parameters, without any certainty if that state was only some kind of disturbance (transient state), or if it is the beginning of breakdown of one of sub-assemblies of modules machines. Measured parameters values are identified, but there is no information about their value changes between measures. If there is any sub-assembly breakdown, the machine or whole line must be stopped to allow its replacement, which causes financial losses.

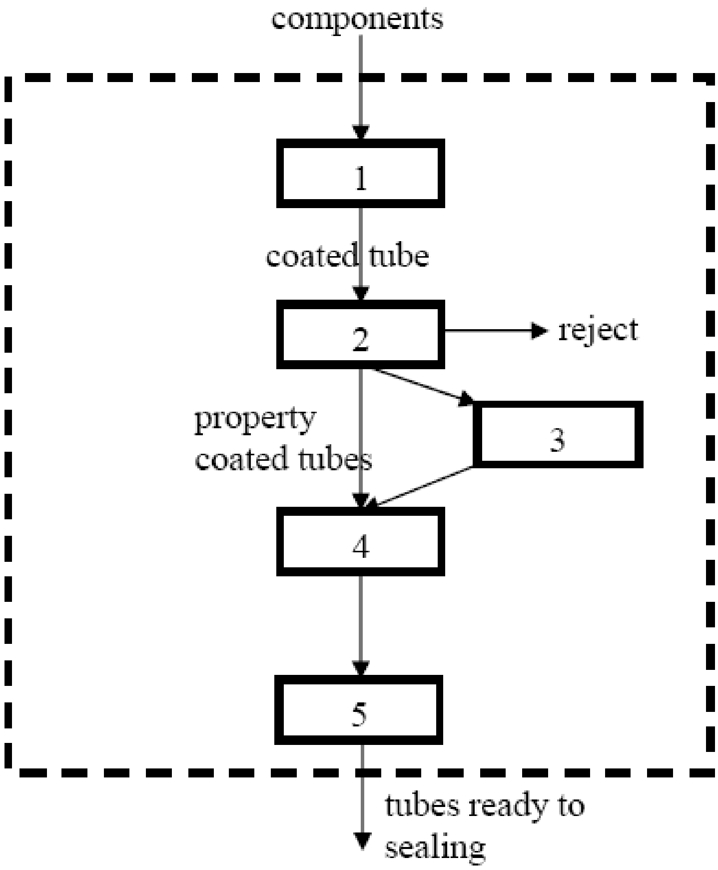

Fig. 2. Coating module: 1 coating machine; 2 –visual controls system; 3 –robotized buffer; 4 –brushing machine; 5 – sintering oven

Interior production module (Fig. 3) is responsible for coated tube closing. Machines' states control in this module is realized via statistical process control. Glass tenses, inside strength, coil coating weight are statistically controlled parameters. Only emitter's viscosity (emitter coats coil) is controlled automatically and continuously. Measurement results are not registered and done only for the sake of continuous, automatic emitter viscosity correction. In case of breakdown any machines of insides production modules, sub-assemblies in broken machine are replaced with fully efficient sub-assembly, however there is not any data which allow to unambiguously determine the cause of breakdown and time of its occurrence.

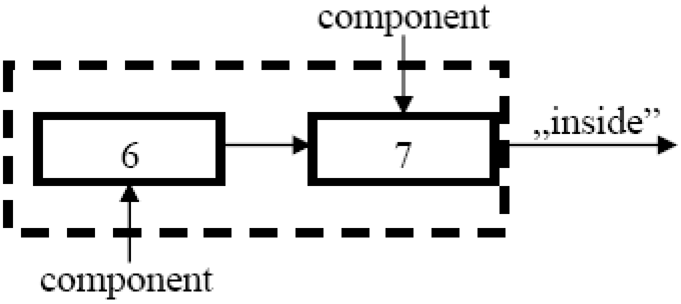

Fig. 3. Interior production module: 6 – steam making machine; 7 – mounting machine

Assembling module (Fig. 4) is responsible for making the lamp from delivered components. It assemblies coated tube with inside (sealing process), which tightens the lamp. After that, the lamp is filled with special gas mixture (pumping process) and coil (part of inside responsible for electrons emission) is prepared (forming process). If the burner complies with its specification, it is transferred to assembling machine in which burner is assembled with cap (this is the moment in which the burner becomes a lamp). By means of high temperature (~200 Celsius degrees) the cap is permanently connected with the burner.

Also, in the assembling module, machine's sub-assemblies state is estimated in accordance with product parameters values, made on each machine. Failures are shown in the binary system, which means that we can only indicate how many laps are discarded because of particular failures, without information about the value of parameter on which lamp was eliminated. For instance, forming process failure can be caused by coil, but the primal reason can be located in pumping machine or in the interior production module. The primary reason can be declared after a careful lamp investigation. The condition of each machine in assembling module is estimated by reject/waste value of each machine, but there is no certainty that the reject/waste is generated because of the machine, component quality or operator fault. If it is assumed that an excessive rise in waste is a result of the machine sub-assembly failure, the machine which generates reject is stopped for the faulty sub-assembly(ies) replacement. It is always related with the whole line stopping and no production. It is obvious that it has some impact on financial results.

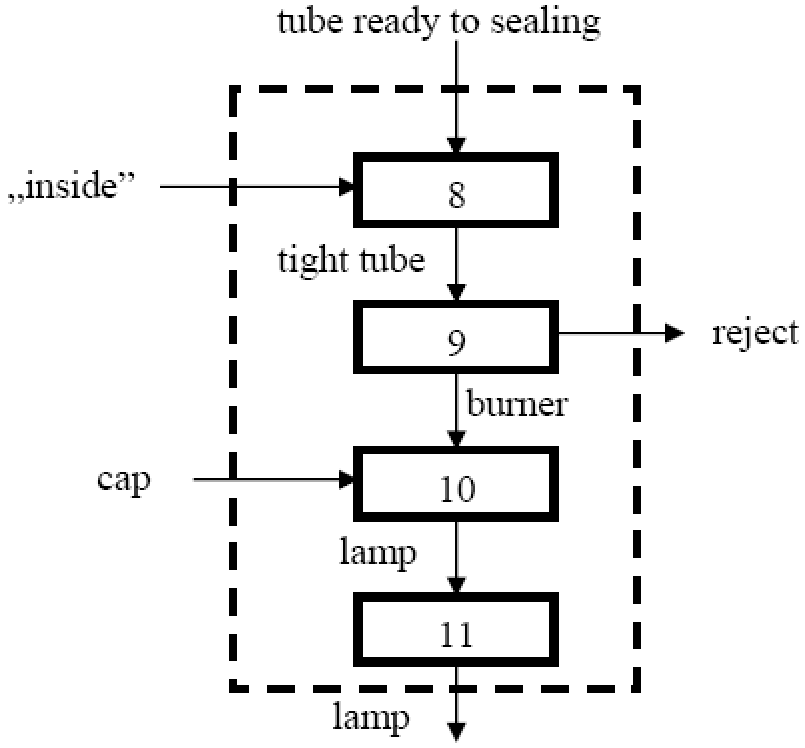

Fig. 4. Assembling module: 8 –sealing machine; 9 – pumping machine; 10 – capping machine; 11 – hardening machine

Control and measuring module (Fig. 5) is the module which, by definition, is not supposed to influence the product and it should only control whether the lamps are compatible with technical specifications (whether the preceding process has gone properly), but it doesn't exclude a situation in which the module becomes inefficient, which can be identified by sudden growth of excluded lamps, qualified by flashing and testing the machine as incompatible with technical specifications (reject).

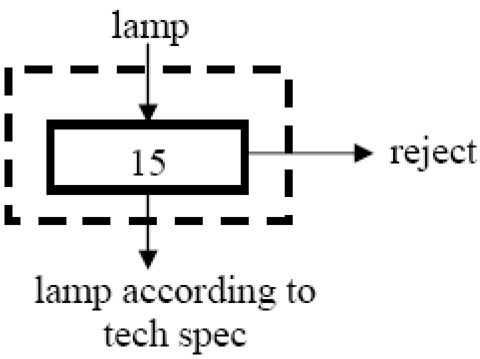

Fig. 5. Control and measuring module: 15 –flashing and testing machine

Inefficient state is easily recognizable by production line setters or operators, because of the appreciable reject. It has got financial consequences, because all eliminated lamps, from the period between inefficient state start and its notification, are qualified as rejects and must be, after the machine becomes efficient, flashed and tested once again. The situation in which proper lamps are wrongly eliminated is better than the situation when incompatible lamps are accepted, which may result in the “call back” (lamps withdraw from the market) and generate the costs of production.

Cap filling module (Fig. 6) is another machine only module. The machine's state is determined on the basis of the products. Visual control system continuously controls cement (glue) layout, done by cementing machine. Caps with improper layout ale eliminated by a special mechanism and gathered in a dedicated container in order to be analyzed. Inefficient state is recognized by a number of eliminated caps, but when it occurs during some time (buffers fulfilled time), the whole line is stopped.

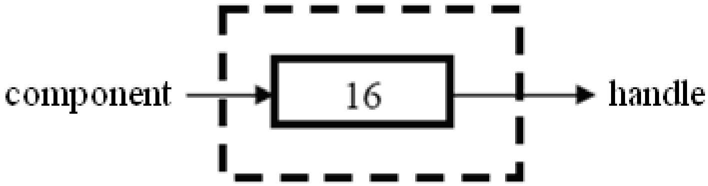

Fig. 6. Cap filling module: 16 – cementing machine

Packaging module (Fig. 7) is the last in HOR6002 line. In this module, proper lamps are packed and prepared to be shipped. The module state is recognized by lamp packaging quality, but it is only a recognition of efficient or inefficient state. This recognition is done by an operator who places group boxes on pallets. Machines which are part of this module are not very complicated, and in case of their inefficiency there is no need for the whole line to cease. By the time packaging machines are functioning again, complete and proper lamps can be gathered by buffer or by operators into special containers. However, such conduct generates extra cost because of bigger labor, additionally, after retrieving the machines’ efficiency, the buffered lamps must be placed on the transporter before the packaging module.

Such conduct generates extra cost because of bigger labour, additionally, after packaging machines have become efficient, the buffered lamps must be placed on the transporter before the packaging module.

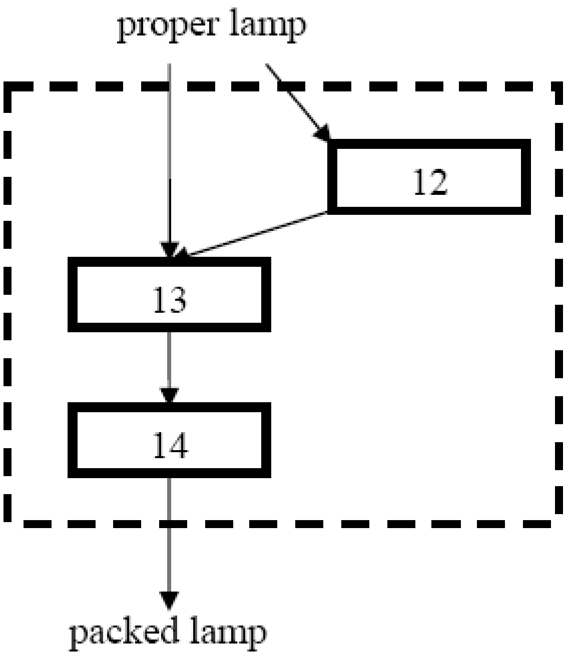

Fig. 7. Packaging module: 12 –robotized buffer; 13 – single packaging machine; 14 – gropu packaging machine

HOR6002 line undergoes regular, weekly checks. Thanks to high-tech industrial Siemens controllers of seventh generation, it is possible to make weekly maintenance plan for particular modules, machines or even sub-assemblies. It is possible because the program is written in the way which allows to sum up machine working hours and the number of products. For the proper functioning of the maintenance process, nine highly specialized mechanics are required. During a maintenance shift, parts of sub-assemblies for which probability of breakdown calculated by producer is very high, are replaced by new or regenerated parts. Replaced parts are generally very expensive, which is noticeable in the maintenance budget calculated only for HOR6002 line (approximately hundreds of thousands Euros). After a sub-assembly, or part, has worked for the producer-calculated number of hours, it is replaced no matter the condition of sub-assembly or part.

HOR6002 production line state monitoring could be alternative to weekly maintenance. However, it needs production line machines' technical state monitoring and suitable sensors deployment (e.g. generated frequencies spectrum, temperatures, dimensions, currents etc.). Thanks to historical values of the diagnostic parameters, it is possible to predict their value in the future, and determine, with a probability dependent on quantity and quality of data, whether a sub-assembly will be efficient until the next maintenance shift, or whether it needs to be replaced. Thanks to such a prediction, high savings can be generated by a lower number of replaced sub-assemblies/parts, no need to keep a large parts storage, maintenance brigade wouldn’t be so large. It would be easy to predict when a particular part will break down, and order the part from a supplier in advance

3. Problem characteristics

The problem of production line state monitoring (state evaluation, state prognosis and genesis of machine) is very essential at the designing stage, as well as production and operation stages. While determining state monitoring procedures which serve as tests of state control and damages localization, machine state prognosis and genesis will encounter certain obstacles which are reflected in the following questions [1, 2, 6, 7, 10]:

a) does the optimal set of diagnostic parameters unambiguously describe machine state; does it correlate with machine state change, does it include enough information on the machine's state?
b) is optimal diagnostic parameters set stable, or does it fluctuate, and if so, what is the nature of these changes depending on machine's operating conditions?
c) what is the influence of characteristic factors on machine operating, over optimal test stability and state control program: machine diagnostic susceptibility, diagnosis reliability
d) level (which can be decided by operator), change of machine operating conditions and change in sub-assemblies reliability?
e) what is the influence of machine operating characteristic factors on optimal forecast stability: value of forecast or genesis range (which can be decided by the operator), change of machine operating conditions and change in sub-assemblies reliability?

Accurate solutions to the indicated problems are essential to highly effective HOR6002 machines' state monitoring and requires necessary examination of sensitivity of procedures to the conditions described. If the examination shows that the determined procedures are stable, they can be used to set programs to state control, damages localization, machine state prognosis and genesis. In other cases, assumptions and limits regarding state monitoring procedure setting should be modified, e.g. by conscious exclusion of the factors which cause solution instability; but it makes the solution less universal.

4. Monitoring state line production HOR6002

We can distinguish in diagnostics examination methodology the following phases of evaluating examination which have the following diagnostic mechanism forms:
a) diagnosis – machine state determination in Θ_b time;
b) genesis – as the machine historical states recovering, e.g. in order to determine the primal reason for damage which appeared during machine examination;
c) forecasting – as future machine state prognosis, e.g. in order to determine the next maintenance shift time (Θ_d);

Main problems which can appear during machine state monitoring task realization are:
a) determination of goals of machine state diagnosing, forecasting and genesis making;
b) machine state changing during operating;
c) machine state description by means of state features and relations between state features and diagnostic parameters;
d) state diagnosis task realization;
e) state forecasting task realization;
f) state genesis task realization;

Main problems occurring during task realization shown above are:
a) most suitable parameters choice, which describe best, actual machine state and its future change;
b) diagnostic test setting;
c) forecasting value of diagnostic parameter setting, for forecast range τ_1, $s_{jp}(\Theta_b+\tau_1)$ with best forecasting method and with the next diagnostic and maintenance time Θ_d setting;
d) determination of the value of diagnostic parameter genesis for genesis range τ_2, $y_{jp}(\Theta_b-\tau_2)$ with the best genesis method and machine state estimating, valuation of the work done by machine, determination of primal reason of machine damage occurring during machine examination.

The term “best” used here relates to the established suitable criteria, and takes them into consideration in optimal solution research, and because of many valuation criteria. There is a need to look at problems in a multi-optimal solution [8] for particular tasks (local optimum) or for machine state monitoring task (global criteria).

5. Conclusion

To summarize, the solutions to certain problems described require formulation and solution to consecutive sub-tasks according to the algorithm shown below:

1) analysis of the production line machine's state monitoring process;
2) development of the production line machine state monitoring model;
3) optimization of the production line machine's state monitoring process;
4) verification of the state monitoring procedures for selected production line machines;
5) employment of monitoring procedures in operating and maintenance of sub-systems of the production line HOR6002.

The algorithm presented above is the basis for future authors' publications in which, thanks to modern diagnostic tools from modeling area, experiments and development of statistical data, one may expect solutions to the problems described in the article.

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