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Total productive maintenance on example of automated foundry lines

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Abstract

Within framework of the presented study one has performed analysis of stoppages in automatic foundry lines operation, and basing on assumptions from complex maintenance system has undertaken himself to develop a service maintenance schedule for machinery installed in the line. Moreover, one has presented general assumptions of TPM system operated in conditions of series and multi-series production of cast iron castings. One has constructed operational database and has elaborated a list of line stoppage causes within a year. One has proposed a possibility of implementation of manufacturing systems modeling and simulating technique in management of production machinery operation in a foundry shop. Within framework of the simulation experiment one has developed schedules of production, schedules of maintenance and has forecasted indices of general productivity of the machinery for a various scenarios of events on example of casting line having in-series structure of operational reliability. In course of the study there was implemented ARENA universal software package to modeling and simulation of the manufacturing systems.

Keywords: Application of information technology to the foundry industry, Automation and robotics in foundry, Total productive maintenance, Modelling and simulation of production systems

1. Introduction

More and more efficient, more and more advanced technically machines and machinery require more and more advanced methods of diagnostics and maintenance. Organization of service maintenance has a decisive effect on operational efficiency of devices, and because of it were developed concepts like the TPM.

Service maintenance systems have developed from very simple systems dealing with removal of breakdowns only, to very complex systems having their superior objective as prevention of incidents (Fig. 1).

Planning of servicing activities is performed in order to keep stoppage of machinery and devices on a minimal level, to prevent stoppages through increased reliability, to assure predefined quality of production, to reduce costs of the stoppage, to reach optimal utilization of production capacity, to assure safety and countermeasures against hazard to working environment. Breakdown prevention in many cases is better and cheaper than later searching after, and removal of damages, or bearing costs due to stoppage of production.

In scope of Preventive Maintenance one performs technical inspection of machinery, together with finding and removal of machinery defects before they could lead to a breakdown, and in result to stoppage of the machine. It points at accomplishment of all activities recommended by manufacturer of the machine, and connected with maintenance during predefined periods of time.

Preventive Maintenance also deals with earlier experience of the workshop in area of maintenance of machinery. One strives at situation when operator of a machine himself monitors conditions of the machine and records all damages.

Preventive Maintenance can be divided into two groups:

- Time Based Maintenance – work specified in time (e.g. quarterly)
- Condition Based Maintenance – work accomplished when need of its performance is confirmed.

Time Based Maintenance (TBM) is used mainly in situations when possibility of occurrence of damage is high. Condition Based Maintenance (CBM), except time, takes into consideration an actual state of the machine.

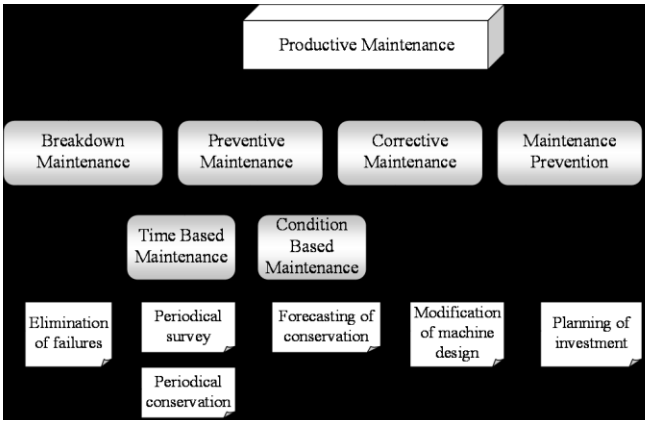

Fig. 1. Types of productive maintenance

Predictive Maintenance consists in forecasting and early prevention of breakdowns, basing on statistic analysis.

Within framework of the maintenance reacting on breakdowns (Breakdown Maintenance) are performed repairs after occurrence of the breakdown, when from economic point of view such repair is more beneficial than preventive actions. Implementation of such form of maintenance is effective in case of failures not having any considerable effect on operation of the machine, safety and continuity of production.

Corrective Maintenance is understood as activities connected directly with improvement of machinery and production devices. Such activities result mainly from knowledge about operation of the machines, about their crucial points and imperfections in project of the device.

Operations performed within framework of Preventive Maintenance consist in monitoring and analysis of technical devices and putting forward motions on purchase of new devices and refurbishment of actual stock of machinery [1, 2, 3, 4].

2. Objective and methodology of the study

Optimization of the maintenance system in foundry shop constitutes the objective of the present work. To analyze the problem, basing on assumptions to TPM system, one has proposed implementation of a tool which could assist in taking manufacturing decisions, based on modeling and computer simulation method (Fig. 2). Such method can be also implemented in stage of planning of investments, elaboration of schedules of manufacturing processes, planning of technical maintenance of devices, and even in course of searching after solutions during emergency situations [5, 6, 7, 8, 9, 10, 11]. The simulation will enable, among others, to verify duration of operations, to find a hidden costs connected with frequent stoppages of the line due to breakdowns, maintenance activities, limitations resulted from manufacturing process, and due to materials shortage.

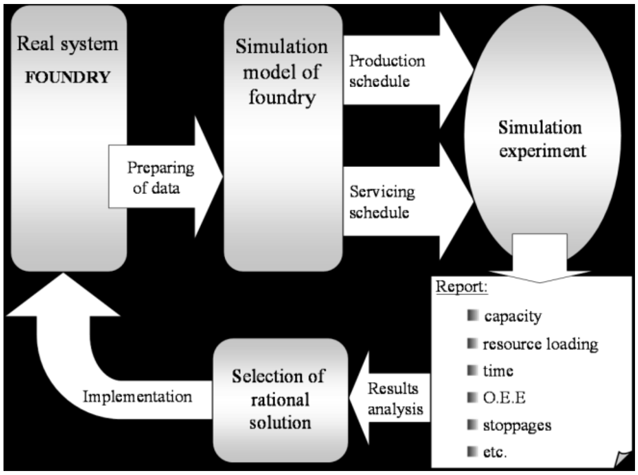

Fig. 2. Simulation of production systems

Modern shaping of the maintenance system is inherently connected with TPM program.

TPM is based on the following five assumptions:

- TPM is oriented on change of enterprise's culture in order to attain maximal total effectiveness of the manufacturing system,
- TPM deals with the whole system in order to prevent all types of loss in the workplace (zero standstill, zero rejects, zero loss of line speed),
- TPM concerns not only manufacturing departments and co-operation, but also the whole of the plant (supplies, sales, development and administration departments),
- TPM engages all employees in its activities (from directors board to production workers),
- TPM, using actions in small autonomous groups, strives after zero loss.

Growing share of maintenance costs forces intensive search after possibilities of their reduction, and selection of a proper strategy of the maintenance. Management of the maintenance requires looking through optics of costs, in order to find a compromise between maintenance costs and production costs (Fig. 3).

TPM philosophy requires rigorous measurement and registration of a phenomena occurring in the enterprise, in order to correct orientation of improvement efforts. It is necessary to establish a common rules to have clearly determined meaning of the indices used in various TPM areas.

The indices connected with TPM, and used to assessment of utilization of production resources are:

- Mean Time Between Failure (MTBF) – index indicating average time between successive breakdowns of a device,
- Mean Time To Repair (MTTR) – index indicating average time needed to removal of a breakdown,
- Overall Equipment Effectiveness (O.E.E.) – index showing general capacity of a device.

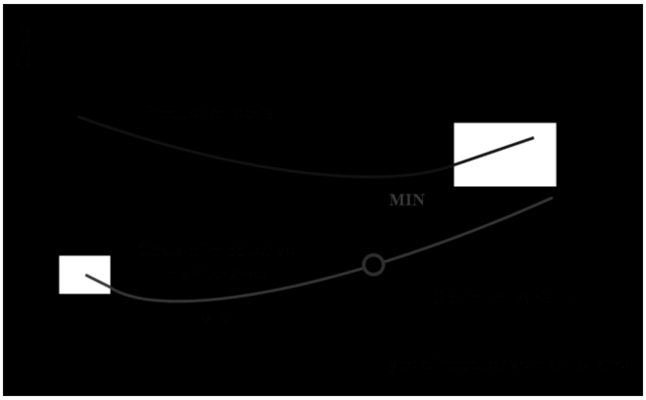

Fig. 3. Diagram showing costs depending on maintenance type

The O.E.E. index is closely connected with preservation and improvement of product quality, and with growth of production capacity of individual technical devices (Fig. 4).

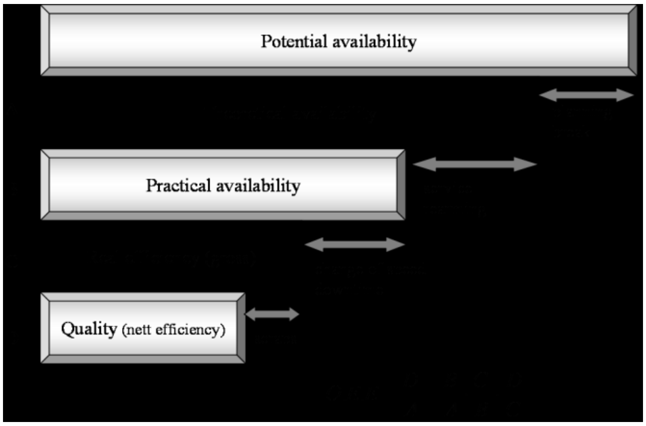

Fig. 4. Overall Equipment Effectiveness - O.E.E. (B/A: equipment availability, C/B: performance efficiency, D/C: quality rate)

Potential availability is understood as a time, when a technical object could be potentially available (e.g. 24h during 31 days per month). Potential availability reduced with off-time (e.g. Saturdays, Sundays, Holidays, and idle shifts of the plant) is called as theoretical availability. Theoretical availability reduced with time needed for planned maintenance, rearming, technological trials and other planned activities is called as practical availability. Real capacity (gross) describes practical availability reduced with loss due to breakdowns and organizational disturbances during accomplishment of the manufacturing processes. Real capacity (nett) is connected with production of good quality castings.

3. Description of the obtained results

Object of interest of the presented study is manufacturing system of cast iron castings on automated casting lines, with horizontal and vertical parting of the mould [12, 13, 14].

On base of historical data there was elaborated a list of causes of line stoppages within one year (Fig. 5).

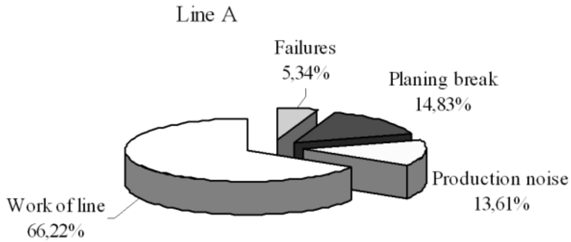

Fig. 5. Groups of causes of casting line stoppages within a year

It has been confirmed that in a big extend on operation of the line have an effect, except breakdowns and necessity of restoration, a factors connected with organization of the manufacturing process. Shortage of supplies of a given cast iron brand, necessity of change of cast iron brand and standstills connected with run of the manufacturing process (e.g. changed assortment of production, maintenance of operated devices) in a considerable extend effected on costs of produced castings.

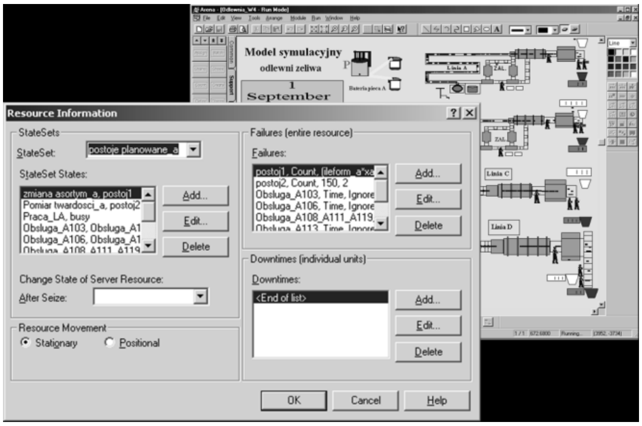

Fig. 6. Simulation model of foundry

Real working time of the line during analyzed period of time (t_{rz}) can be determined through reduction of calendar time (t_k) with accumulated time of planned standstills (t_{pp}), accumulated time of forced standstills (t_{pw}) and total time loss due to perturbations in the production (t_{zp}). In the next succession, one should take into consideration production of defective castings or possible repair of such castings (t_b).

$$t_{rz} = t_k - t_{pp} - t_{pw} - t_{zp} - t_b \quad (1)$$

After performed analysis of the reliability and productivity indices one has commenced construction of maintenance schedules of the casting lines.

Minimization of effects of the stoppages and their rational planning is possible through functional analysis of the systems with use of the developed computer model (Fig. 6).

In scope of the study one has elaborated schedules of work and schedules of maintenance of the lines, and has performed simulation experiment consisting in a few experiments. Exemplary chart from analysis of the simulation report is shown in the Figure 7. The study was performed for a various scenarios of events and covered four automated casting lines.

Overall Equipment Effectiveness -O.E.E.	quantity	%		Sum %
Work of line	57	75,82		75,82
Rearming	8	4,33	downtimes dependent on devices	
Quality verification	5	1,5		6,93
Periodical survey	2	1,1		
Failures	1	5,35	disturbances	
Change of speed	3	3,68		
Downtime	36	8,21		17,24

Produced: (forms)		
	Good	1270
	Scraps	8

Analysis: (one day)

	time [min]		
Potential availability (24 h.)	1440		
Theoretical availability	960		
Practical availability	893	equipment availability	93,07%
Real efficiency (gross)	728	performance efficiency	81,48%
Quality (net efficiency)	723	quality rate	99,37%
		O.E.E	75,4%

Fig. 7. Results analysis on the basis of simulation report

4. Conclusions

Reduction of operational costs and increase of productivity can be attained due to arrangement of organizational structures and methods of taking decisions, proper organization of maintenance service, optimization of circulation of documents between particular organizational cells and implementation of computer-aided system to support the main operational tasks. TPM system, enabling integration of maintenance activities with manufacturing process, can be used as an auxiliary tool to attain the above mentioned objectives.

There exists a possibility to elaborate many variants of the maintenance schedules, which come from organizational possibilities of the plant. As a rational method, assuring correct planning of such activities, one has proposed technique of modeling and computer simulation. Owing to the simulation technique, it is possible to analyze various scenarios of events connected with run of casting production processes and maintenance processes of technical devices in foundry industry.

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