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POSSIBILITIES FOR INCREASING EFFICIENCY OF INDUSTRIAL EQUIPMENTS

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Abstract: *One of the most important indicators for increasing productivity is OEE (Overall Equipment Effectiveness). In order to analyze OEE indicator, some typically performance rates have been established: quality rate, availability rate of equipment for manufacturing and performance rate. The paper presents computing methods for establishing and improving of the indicators, which reflect the actual production process, in comparison with the reference indicators. Generally, the researches revealed about 65% for OEE in the Romanian automotive high-precision parts industry, smaller than the standard OEE value for optimum manufacturing process, which is between 85-90%.*

Key words: *Equipment Effectiveness, OEE, Total Productive Maintenance.*

1. Introduction

A good strategy able to reach company customer objectives related to customer satisfaction consists in changing the business philosophy and culture, the work procedures and practices; these aspects define the company reengineering process. This strategy could be achieved by adopting of efficient management methods and implementing the modern practices, as Lean Manufacturing.

The beginning of the so called "Lean thinking" or "Lean production" was in Japan in 1940 when Taiichi Ohno started his work on the Toyota Production system [5], [6]. Lately basic work and approach of this subject is presented by Womak et al. under the well-known title: The Machine that changed the world [10].

Lean Manufacturing aims to understanding, knowing and satisfy the customer request, having a real impact on company performances. Each company process has to be focused on added value, which is identifying from the customer expectation. Many companies that adopted such "Lean" techniques and are guiding their activity in accordance with these are mentioned under appellation "Lean Company".

Lean manufacturing system creates a production environment based on the quality

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and productivity at the lower cost and price. Figure 1 schematically presents the Lean Manufacturing concept.

Lean Manufacturing is founded on the Japanese idea of Kaizen; "Kai" means change and "zen" means good (for the better). Kaizen is represented by an improvement activity to create more value and remove waste [6]. At Toyota, in order to proceed with their man-hour reduction activities, they divide wastes into the following seven categories [3], [6]: overproduction; waiting time; transportation; inventory, unnecessary stock on hand; unnecessary motion; processing itself; defective products.

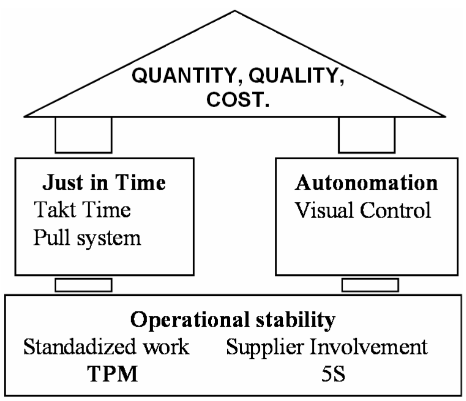

Fig. 1. *The Lean Manufacturing concept*

At the previous list were added two more types of waste, thus, technically, there are now nine 'deadly wastes' [11]. The other two waste categories are:

1. Safety because unsafe work areas create lost work hours and expenses;
2. Information (age of electronic information and enterprise resource planning systems (ERP) requires current/correct master data details).

Many authors showed in their papers, using case-based approaches, how lean manufacturing tools, can help the process industry eliminate waste, maintain better inventory control, improve product quality, and obtain better overall financial and operational control [1], [2], [7], [8]. Some of the most important tools that are used with these purposes within "Lean Production" are: cellular manufacturing, just-in-time, kanban, total productive maintenance, 5S, total quality management and time reduction [1].

Total Productive Maintenance - TPM is a key to lean manufacturing success, is an excellent method for meeting the demands continuous flow manufacturing places on equipment. TPM aims at creating highly efficient production lines through maximum use of existing equipment with "zero breakdowns" [1], [4], [9]. TPM does the following:

- it increases OEE using improvement activities;
- it establishes an autonomous maintenance program performed by equipment operators;
- it establishes a planned maintenance system;
- it requires training to improve operation and maintenance skills;
- it institutes a system for maintenance prevention - MP design and early equipment management.

In different performance companies, TPM transforms conventional maintenance practices into a science of management - Equipment Oriented Management - specialized for equipment maintenance. Today's productive maintenance has moved from conventional Productive Maintenance - PM, centred upon maintenance, to TPM, which emphasizes total participation and the role of manufacturing operators.

The goal of TPM is to improve equipment effectiveness so that it can be operated to its full potential and maintained there [9]. There are two main thrusts to achieving this goal:

- Quantitative, which emphasizes improvement in total end item availability and in improved productivity per period;
- Qualitative, which emphasizes reduction in the number of defective products and stabilization of quality.

Understanding equipment orientated management is crucial because the reliability, security, maintenance and operational characteristics of the plant constitute the decisive elements affected product quality, quantity and cost.

One of the most important indicators for increasing productivity, which dimensioning TPM, is OEE. In order to analyze OEE indicator, a lot of complementary aspects have to be taken into consideration, such as: product quality, downtime equipment reasons, and the right estimation of equipment standard technological parameters.

2. Establishing Overall Equipment Effectiveness

Traditionally OEE alone doesn't generate financial data or make strategic decisions, but is a measure of the availability, performance efficiency, and quality rate of a given piece of equipment:

$$OEE = Ar \cdot Pr \cdot Qr \; [\%], \quad (1)$$

where: Ar - availability rate; Pr - performance rate and Qr - quality rate.

According with Figure 2, the availability gives us what percentage of time the equipment is actually running, at its total capacity. Related to this, the following relations could be written:

$$B = A - Planned\ stoppage, \quad (2)$$

where: A is the all considered working time, planned stoppage represents the contractual breaks (average 30 min./shift) and B is the planned time for equipment working;

$$C = B - Downtime, \quad (3)$$

where: C is the actual working time and the downtime represents total time for unscheduled stops (changeover time, setup time, adjustments).

Taking into account the above relations, the equipment Availability Rate - Ar could be written as follows:

$$Ar = (C/B) \cdot 100 \; [\%]. \quad (4)$$

Regarding the equipment performance, there is necessary to consider the target number of parts (D = *Target Output*) planned to be operate in the running time, according to *ideal cycle time* (D/E) and the actual operated parts (E = *Actual Output*). In this frame, the following relation could be written:

$$E = D - Reduced\ speed, \quad (5)$$

where: *reduced speed* represents the equipment reduced speed losses, the equipment being scheduled to operate at a constant speed.

It could be established the actual cycle time per part, starting from Running Time and Actual Output ratio:

$$Actual\ cycle\ time = C/E \; [\text{time/part}]. \quad (6)$$

The equipment Performance Rate - Pr is given by the relation (7):

$$Pr = \frac{E}{D} \cdot 100 = \frac{idealcycletime}{actualcycletime} \cdot 100 [\%]. \quad (7)$$

In terms of quality, according with Figure 2, the following relation is valid:

$$G = F - (scrap,\ rejects). \quad (8)$$

The Quality Rate is simply the rate of quality products and can be established as follows:

$$Quality\ Rate = (G / F) \cdot 100 \; [\%]. \quad (9)$$

According with the relation (1), the Overall Equipment Effectiveness (OEE) will be:

$$OEE = \frac{C}{B} \cdot \frac{E}{D} \cdot \frac{G}{F} \; [\%]. \quad (10)$$

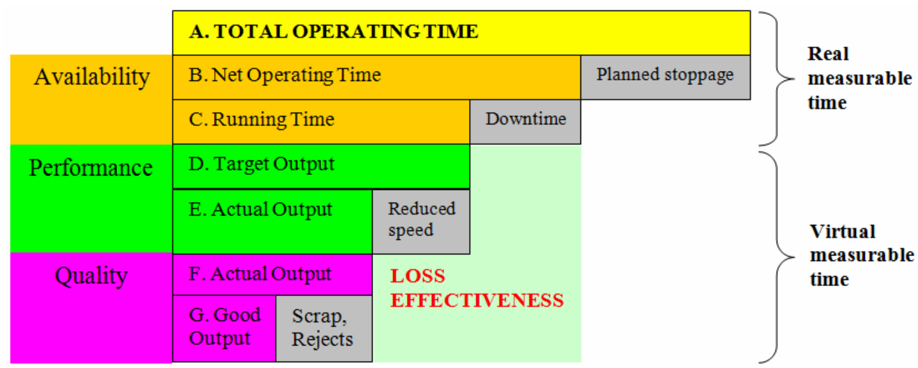

Fig. 2. *The OEE model*

Each of the elements of TPM are significant parts of a foundation for lean manufacturing. Most importantly, they work together to increase Overall Equipment Effectiveness (OEE). Without sufficiently high OEE, lean success becomes much more difficult to achieve.

3. Different Types of OEE Scenarios. Discussion

The industrial manufacturing proficiency in the Romanian automotive industry proved the customer requirements are different from time to time and the production capacities have to present flexibility according with the necessary takt-time. Starting with the customer requirements, two typically examples for production planning and equipment efficiency analyze are presented bellow:

Customer requirements: 25000 parts/ month;

No. of week/month: 4;

No. days/week: 5;

Weekly production planning: 25000 : 4 = 6250 parts/week;

Daily production planning: 6250 : 5 = 1250 parts/day;

Net operating time per shift: 480 – 30 = 450 min/shift;

Takt time: (450 x 60): 1250 = 21.6 sec/part;

Ideal Cycle Time: 64 sec/part;

No. of necessary machines: 64 : 21.6 = 2.96 ≈ 3 machines (or shifts) / day.

Case 1: one type of part, one machine, one type of operation.

Average planned changeover/shift = 1.15 (after 35 parts); changeover time = 17 min.

Case 2: many part types (4 part types: 9000, 7500, 5000, 3500 parts), one machine, one type of operation.

Average planned changeover/shift = 1.15 (after 35 parts); changeover time = 17 min.

Average setup and adjustment time/day = 30.

According with the Table 1 result, there is the possibility to have some conclusions related to the equipments efficiency; thus, in order to improve the efficiency, different corrective action plans are implemented.

Regarding the two analyzed cases, the calculated values for OEE are smaller than the target value at about 20%. For establishing the causes which generate these deviations from the target, it necessary to analyze each OEE factors: the availability, the performance and the quality.

In the first analyzed case, the equipment availability rate is under the target with about 10%, in comparison with the second one, where the deviation is about 28%.

The OEE Estimating and Analyzing Table 1

Steps	**Case 1**	**Case 2**
No. shifts/day	**3**	**3**
Operating time [min./shift]	480	480
Total Operating Time [min./day]	**1440**	**1440**
Planned stoppage [min./shift]	30	30
Total planned stoppage [min./day]	90	90
Net Operating Time [min./day]	**1350**	**1350**
Planned downtime - changeover time, setups and adjustments time [min./shift]	20	45
Downtime - planned and randomly [min./day]	200	400
Running time [min./day]	**1150**	**900**
Target output [parts/day]	1250	1250
Ideal Cycle Time [sec./parts]	**64**	**64**
Actual output - good and rejects [parts/day]	**925**	**800**
Actual Cycle Time [sec./parts]	**74.4**	**67.5**
Rejects [parts/day]	3	10
Good parts [parts/day]	**922**	**790**
OEE components:		
Availability rate [%]	85.18	66.67
Performance rate [%]	86.02	94.18
Quality rate [%]	99.67	98.75
OEE [%]	**73.03**	**62.41**
Target OEE components:		
Availability rate [%]	95	95
Performance rate [%]	92	92
Quality rate [%]	100	100
OEE [%]	**87**	**87**
Deviation from the target:		
Availability rate [%]	**9.82**	**28.33**
Performance rate [%]	**5.98**	**–2.18**
Quality rate [%]	**0.33**	**1.25**
OEE [%]	**13.03**	**24.59**

This deviation appears in the both cases owing to the changeover time, which is to long (redesign the tool support), and, especially in the second case, there are many time losses due to the setups and adjustments (there are 4 different parts, which suppose different setups during the operation, but these losses could be reduced through a good planning of production order).

Taking into account the performance rate, in the first case there is small losses due not only to the reducing of operating speed but also to missing competence for the operator. Related to these, it is necessary to check the equipment operating parameters and, at the same time, to check if the operator knows the work procedures for the analyzed work-place. The result of the second case shows a high performance of the equipment and the operator.

Regarding the quality rate, the performances are acceptable; however, it is recommendable to analyze the material quality. Another important aspect consists in the understanding of the customer requirement by the operator. At the same time, is necessary to emphasize the auto-control process at each operator.

4. Conclusions

This paper tried to quantify the manufacturing performance according to the Lean Manufacturing techniques, towards the increasing the customer's satisfaction and reducing costs.

An important role for the leaning production processes is played by the equipment function monitoring.

Generally, in the automotive industry, which agrees these modern management concepts for manufacturing, the equipment effectiveness is dimensioning by a relevant indicator, Overall Equipment Effectiveness - OEE.

Taking into account the three components of OEE, availability, performance and quality, it is possible to identify the causes which generate losses and different corrective action plans can be applied.

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