Stanisław NOSAL, Tomasz GULCZYŃSKI
Politechnika Poznańska, Zakład Maszyn Spożywczych i Transportu Żywności
ul. Piotrowo 3, 60-965 Poznań, Poland
e-mail: stanislaw.nosal@put.poznan.pl

Received: 2016-11-23 ; Accepted: 2017-01-31

EFFECTS OF IMPLEMENTATION OF TOTAL PRODUCTIVE MAINTENANCE (TPM) STRATEGY IN THE CHEWING GUM PLANT

Summary

The use of after-failure equipment repair strategies in the chewing gum factory in the period 1996-2003 implied their low efficiency and productivity; OEE during this period amounted to approximately 46%. The introduction of TPM contributed to the increase, in the years 2004-2015, of indicator of equipment effectiveness OEE on average by 28%. MTBF, which is a measure of the time between failures, has been extended to 142 minutes, i.e. failure in the factory occurs on average every 2-2.5 hours. MTTR indicator, specifying the time required to repair the damage that has already occurred was reduced throughout the plant to 67 minutes, which should be considered as a good result, given that the earlier removal of failures took on average 4 hours. OEE indicator of the most failure frequent line in the period 1996-2003, amounting to 38% then, after modernization, through the process of introducing TPM, of its most unreliable component (feeder of trays) increased the value to approximately 80%. Much lower failure frequency of technological equipment resulted in a significant increase in productivity of the factory without having to invest in new production lines.
***Key words**: production of chewing gum, TPM strategy, failure frequency*

EFEKTY WPROWADZENIA STRATEGII OBSŁUGIWANIA *TOTAL PRODUCTIVE MAINTENANCE* (TPM) W FABRYCE GUMY DO ŻUCIA

Streszczenie

Stosowanie strategii napraw poawaryjnych urządzeń technologicznych w fabryce gumy do żucia w latach 1996-2003 implikowało małą ich efektywność i wydajność; wskaźnik OEE wynosił w tym okresie średnio 46%. Wprowadzenie TPM przyczyniło się do zwiększenia w latach 2004-2015 wskaźnika efektywności wyposażenia OEE średnio o 28%. Wskaźnik MTBF, będący miarą czasu pomiędzy awariami, został wydłużony do 142 minut, czyli awaria w fabryce występuje średnio co 2-2,5 godziny. Wskaźnik MTTR, określający czas potrzebny do usunięcia awarii, która już wystąpiła, został skrócony w całej fabryce do 67 minut, co należy uznać za dobry wynik zważywszy, iż wcześniej usunięcie awarii zajmowało przeciętnie 4 godziny. Wskaźnik OEE linii najbardziej awaryjnej w latach 1996-2003, wynoszący wtedy 38%, po modernizacji w trakcie wprowadzania TPM jej najbardziej zawodnego podzespołu (podajnika tac) zwiększył się do wartości ok.80%. Dużo mniejsza awaryjność urządzeń technologicznych spowodowała znaczący wzrost wydajności fabryki bez konieczności inwestowania w nowe linie produkcyjne.
***Słowa kluczowe**: produkcja gumy do żucia, strategia TPM, awaryjność*

1. Introduction

Total productive maintenance (TPM) is a strategy of comprehensive, preventive operating the machinery and equipment in the enterprise carried out by operators and staff responsible for maintenance [1, 2, 3]. It is associated with the name of Nakajama, who, through the analysis of the problem of operating the machinery in the US and European companies improved the concept of operation and began to introduce it in the Japanese industry in 1971.

TPM assumes all employees of the plant's responsibility for maintenance of the machinery in a good condition. However, the key problem lies in evoking the interest and involvement of operators in providing machines usability, as these workers are the first to get the information enabling effective avoidance of failure. TPM strategy considers handling (maintenance, inspections) of machines as a priority over the production plan [1].

The production is a joint undertaking of production and maintenance departments of the company. It is a tool that allows to measure various types of production losses and identify potential areas of positive and negative changes- it is an indicator of overall equipment effectiveness (OEE) [5]. It is calculated as the product of three indicators: the availability of equipment, their use and the quality of the manufacturing process.

This indicator, due to its versatility, overstepped beyond the TPM strategy and has become the main measure of the effectiveness of the production plants [5].

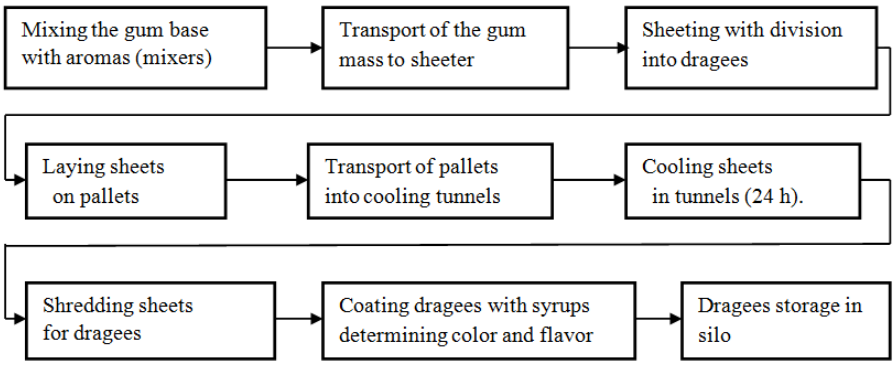
The article [4] shows the effects of TPM strategy on reducing the failure rate and improving the efficiency of one line of packaging of chewing gum and the goal of this study is to determine the effects of the introduction of TPM in the whole plant.

2. Technological process of chewing gum production

The chewing gum includes: gum base and the following substances: sweeteners, humectant, thickening and glazing agents, flavors, emulsifier and antioxidant.

The technological process of chewing gum preparation, which is complicated and requires multiple operations is schematically illustrated in Fig. 1.

The gum base is delivered to the plant as a ready raw material and is sent through devices of pneumatic transport to individual mixers. The mixers mix gum base (1.5 tons at a time) with all kinds of flavors and the elastic material that has the desired flavor is formed. During the unloading onto conveyor belts, the mass is divided into chunks, which are sent to the sheeter. The set of rollers in the machine forms a strip from the mass and presses the grooves forming the dragees.



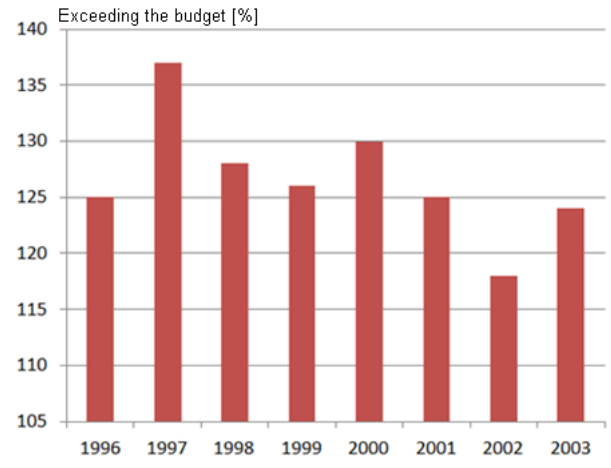
Source: own work / Źródło: opracowanie własne

Fig. 1. Technological process of chewing gum production
Rys. 1. Schemat procesu technologicznego wytwarzania gumy do żucia

Then the strip is divided into sheets that are stacked on pallets by a robot and sent to the cooling tunnel for 24 hours. Seasoning gum sheets in cooling tunnel is aimed at releasing the gases that have accumulated in the mixing process and increasing their susceptibility to breaking into individual dragees. Subsequently, the dragees are coated with a proper juice determining the taste and then they are transported to silos and wait for the packing.

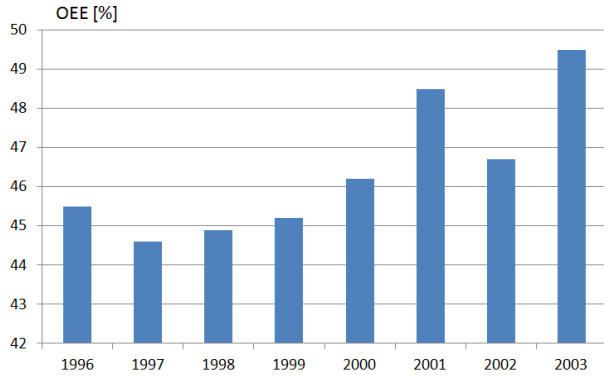
3. Operating and failure of equipment before implementation of TPM strategy

Before the introduction of TPM strategy, machine breakdown was removed only after it occurred. More and more frequently, the maintenance personnel had to take "firefighting" rather than preventive measures. There was no agreement between the technical department and the production department on access to the equipment in order to perform preventive services. Production department enforced continuous operation of the machines, which implied frequent failures and degradation of technical objects. The frequent failures have become a key issue for the functioning of the factory. Each year, the maintenance budget was exceeded due to unscheduled maintenance and repairs - Fig. 2. Operating the machine according to the strategy of after-failure repairs made it impossible to increase the efficiency of the factory - Fig. 3.



Source: own work / Źródło: opracowanie własne

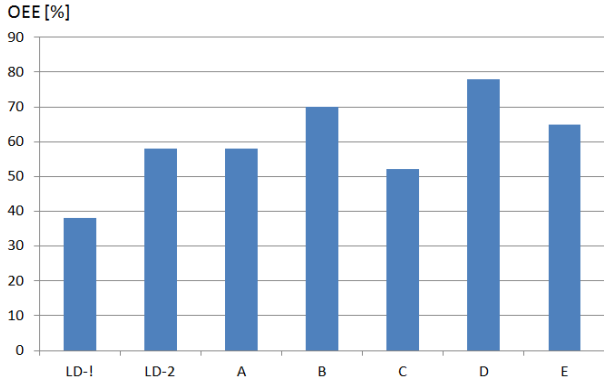
Fig. 2. Exceeding the budget by the maintenance personnel in individual years
Rys. 2. Przekroczenia budżetu przez służby utrzymania ruchu w poszczególnych latach



Source: own work / Źródło: opracowanie własne

Fig. 3. Factory OEE in the years 1996-2003 (target effectiveness - 72%)
Rys. 3. Efektywność wyposażenia fabryki OEE w latach 1996-2003 (efektywność docelowa – 72%)

The management of the factory had to take some steps primarily to reduce the number of equipment failures and reduce production losses, but also to increase safety and improve the quality of products. It was decided to introduce operating strategy of TPM in the factory.
In order to determine OEE, it is necessary for the operators to record the factors which affect its value. These are mainly: failures, downtime and stoppages, quality errors and changes in productivity (i.e. power losses). Fig. 4 shows the overall effectiveness (OEE) of individual production lines operated in the factory in 1996-2003.



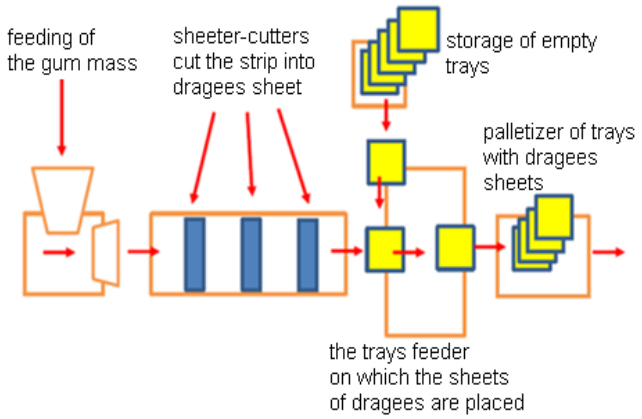
Source: own work / Źródło: opracowanie własne

Fig. 4. OEE of major production lines in 1996-2003
Rys. 4. Efektywność OEE ważniejszych linii produkcyjnych w latach 1996-2003

LD-1 line, which is crucial for the functioning of the plant had the lowest effectiveness of only 38%. Therefore, it was decided that the implementation of the TPM strategy would start from this line.

4. TPM implementation on LD-1 line

LD-1 produces sheets of chewing gum. Its scheme is shown in Fig. 5.



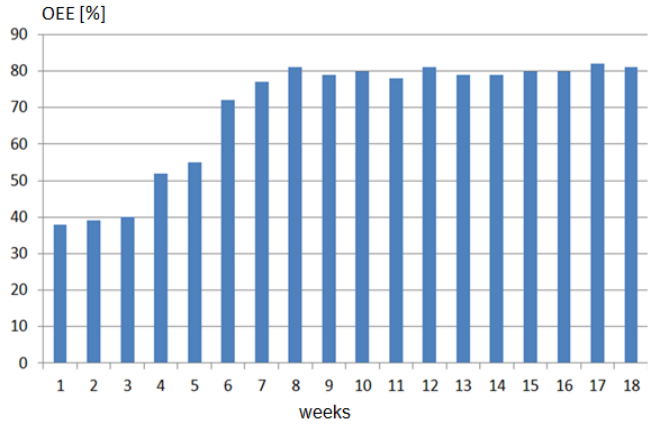
Source: own work / Źródło: opracowanie własne

Fig. 5. Scheme of LD-1 line which produces the sheets of chewing gum
Rys. 5. Schemat linii LD-1 produkującej arkusze gumy do żucia

TPM implementation plan for LD-1 line included the following (most important) actions:

1. Identification of types of breakdowns:
a) introduction of system of breakdown data collection,
b) classification of breakdowns, making Pareto analysis.
2. Restoration of basic working conditions of machines and the introduction of standards:
a) identification of critical elements and events,
b) identification and introduction of standards of cleaning, control and lubrication,
c) the restoration of all the standards at the workstation.
3. Elimination of recurring breakdowns:
a) defining the breakdowns of important elements and mechanisms,
b) making the analysis *5why* for individual breakdowns,
c) defining and introducing preventive measures,
d) implementation of control system for recurring breakdowns.
4. Defining the reasons for occasional breakdowns:
a) introducing the definition of occasional breakdown,
b) introducing breakdown analysis sheets,
c) training of all operators and mechanics working on the machine,
d) introducing the system of breakdown analysis and defining the reasons.
5. The introduction of the schedule of machines maintenance:
a) determining the possible means of preventing breakdowns,
b) introduction of a system of planned inspections of machines and workers responsible for their execution (mechanic / electrician / operator).

On the basis of analysis of breakdowns of lines (Pareto chart, diagram of Ichikawa, 5 × why) critical points were established and the improvement and modifications were carried out. These actions achieved a significant increase in the overall efficiency of the line - Fig. 6. The target value (72%) of effectiveness indicator of the OEE line was achieved six weeks after implementing TPM strategy.



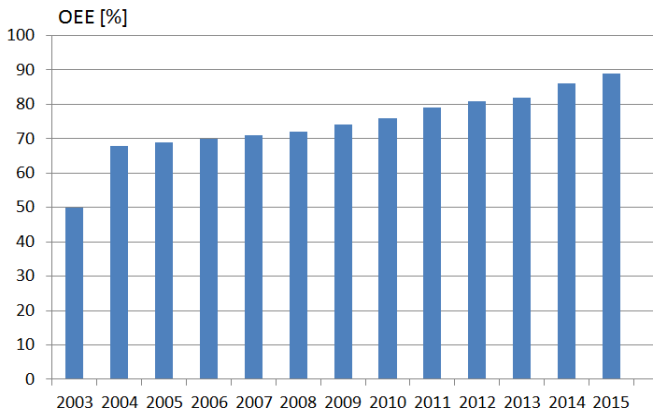
Source: own work / Źródło: opracowanie własne

Fig. 6. The change of OEE indicator at the time of the implementation of TPM on the LD-1 line
Rys. 6. Zmiana wskaźnika efektywności OEE podczas wdrażania TPM na linii LD-1

5. Effects of implementation of TPM strategy in the whole factory

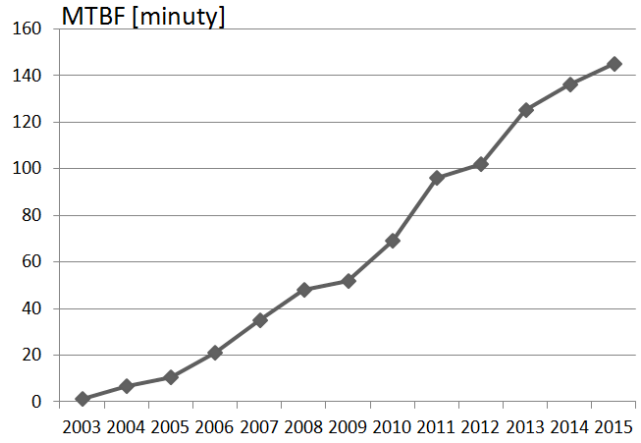
Based on breakdowns data collected in the ORACLE system, the change of the following indicators was analyzed in the factory in the years 2003-2015:

- overall equipment effectiveness OEE - Fig. 7,
- mean time between failures MTBF - Fig. 8,
- mean time to repair MTTR - Fig. 9.



Source: own work / Źródło: opracowanie własne

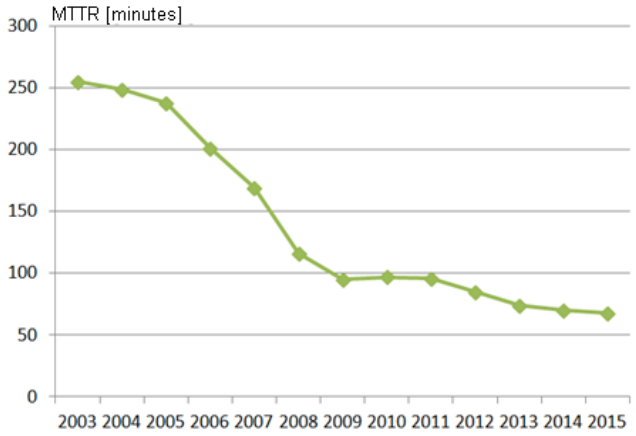
Fig. 7. The change of equipment effectiveness indicator OEE in the factory in the years 2003-2015
Rys. 7. Zmiana wskaźnika efektywności wyposażenia fabryki OEE w latach 2003-2015



Source: own work / Źródło: opracowanie własne

Fig. 8. The change of MTBF for the factory in the years 2003-2015

Rys. 8. Zmiana wskaźnika MTBF dla fabryki w latach 2003-2015



Source: own work / Źródło: opracowanie własne

Fig. 9. The change of MTTR for the factory in the years 2003-2015

Rys. 9. Zmiana wskaźnika MTTR fabryki w latach 2003-2015

6. Summary

1. In the years 1996-2003, due to the post-failure repair strategy:

a) assumed effectiveness of technological equipment was not achieved, and neither was the efficiency,

b) budget for the maintenance of equipment usability was exceeded every year on average by 27%.

2. In the years 2004-2015, after TPM was introduced:

a) OEE increased by 28% compared to the years 1996-2003,

b) MTBF was extended to142 minutes, i.e. the failure throughout the plant occurs on average every 2-2.5 hours (before it was every 1.5 minutes),

c) indicator MTTR, specifying the time required to repair the damage that has already occurred, was reduced throughout the plant to 67 minutes, which should be considered as a good result, given that the earlier removal of failures took on average four hours.

d) OEE for the most failure frequent in the period 1996-2003 LD-1 line, amounting to 38%, after modernization in the process of introducing TPM of its most unreliable component (feeder of trays), increased to the value of approx. 80%.

The results indicate that the introduction of TPM strategy into the factory can be considered a big success. This was achieved thanks to the efforts and commitment of the entire staff. Much lower failure rate of technological equipment has contributed to a significant increase in factory productivity without investing in new production lines.

7. References

[1] Brzeski J., Figas M.: Wprowadzenie do TPM. Utrzymanie Ruchu, 2006, 6 (czerwiec).

[2] Czerska J., Total Productive Maintenance. http://leanmanufacturing.pl/artykuly/lean-w-teorii/total-productive-maintenance.html, (dostęp 7.03.2016).

[3] Dobrowolska A., Wasilewicz M.: Zarządzanie utrzymaniem ruchu w koncepcji TQM. Prace Naukowe Instytutu Organizacji i Zarządzania Politechniki Wrocławskiej, nr 73, Seria: Konferencje nr 23, 2003.

[4] Nosal S., Staszek M.: Failure frequency of candies packing line befor eand after introducing service strategy of total productive maintenance (TPM). Journal of Research and Applications in Agricultural Engineering, 2015, Vol. 60(2), 68-71.

[5] Pawluk A.: Wskaźnik całkowitej efektywności wyposażenia (Overall Equipment Effectiveness) jako miara skuteczności i narzędzie doskonalenia organizacji. http://kolegia.sgh.waw.pl/pl/KZiF/publikacje/Zeszyty%20Naukowe%20KZiF/Documents/134.pdf (dostęp 3.03.2016).