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# THE IDENTIFICATION OF INCOMPATIBILITY IN THE PROCESS OF LASER CUTTING OF THE SEMI-FINDING

**Abstract.** This paper presents selected quality tools that have been used to identify incompatibilities and their causes in the laser cutting process. As a result of the studies and analyzes, it was found that errors made by the TPM Maintenance Services, such as the failure of the laser to be included in the inspection and maintenance schedule and improperly scheduled employee training, led to the production of some 4500 non-compliant products per batch, representing about 30% products in each batch. The research has made it possible to identify the causes of nonconformity and to plan the correct actions to eliminate them.

**Keywords:** TPM, production, quality tools, production management, production process, incompatibilities

# IDENTYFIKACJA NIEZGODNOŚCI W PROCESIE CIĘCIA LASEROWEGO PÓŁPRODUKTU

**Streszczenie.** Artykuł przedstawia wybrane narzędzia jakości, które posłużyły do identyfikacji niezgodności i ich przyczyn w procesie cięcia laserowego. W wyniku przeprowadzonych badań i analiz ustalono, że błędy popełnione przez służby Utrzymania Ruchu TPM, takie jak: nieuwzględnienie lasera w planie przeglądów i konserwacji maszyn oraz niewłaściwie zaplanowane szkolenia pracowników, doprowadziły do wyprodukowania około 4500 wyrobów nie-spełniających wymagań na partię, co stanowi około 30% niezgodnych wyrobów

w każdej partii. Przeprowadzone badania umożliwiły określenie przyczyn niezgodności oraz zaplanowanie właściwych działań w celu ich eliminacji.

**Słowa kluczowe:** TPM, produkcja, narzędzia jakości, zarządzanie produkcją, proces produkcyjny, niezgodności

## 1. Introduction

A well-designed maintenance plan and well-trained operators provide the foundation for maximum efficiency and, in the case of improvements in human work with the machine, it is even possible to increase efficiency from that established by the manufacturer[1]. It is therefore essential to increase the efficiency of machinery utilization by improving work organization, designing and adhering to maintenance standards, effective staff training and improved workflow[2]. An improperly implemented and maintained Total Productive Maintenance system can cause a decrease in the efficiency of an organization related to[3]:

- losses resulting from the preparation of equipment,
- adjustment and reengineering of the machine,
- running slow-moving machines,
- micro idle and machine idle,
- quality defects,
- repairs and production waste.

The purpose of this article was to identify the incompatibility and their causes on the laser cutting line in which TPM was introduced two years earlier. The paper demonstrates that the

[1] Kulkarni V.G.: Modeling and analysis of stochastic systems. CRC Press, 2016, p. 6-23; Mazur A., Gołaś H.: Zasady, metody i techniki wykorzystywane w zarządzaniu jakością. Wydawnictwo Politechniki Poznańskiej, Poznań 2010; Rodrigues M., Hatakeyama K.: Analysis of the fall of TPM in companies. „Journal of Materials Processing Technology", No. 176, 2006, p. 276-279; Skotnicka-Zasadzień B.: Doskonalenie procesu produkcyjnego w przedsiębiorstwie przemysłowym z zastosowaniem metod projektowania jakości, [w:] Knosala R. (red.): Innowacje w zarządzaniu i inżynierii produkcji. Oficyna Wydawnictwa Polskiego Towarzystwa Zarządzania Produkcją, Opole 2013.

[2] Ireland F., Dale B.G.: Study of total productive maintenance implementation. "Journal of Quality in Maintenance Engineering", Vol. 7, No. 3, 2001, p. 183-191; Kamen A., Olivier H.: Development and optimization of an adenovirus production process. "The Journal of Gene Medicine", Vol. 6.S1, 2004, p. 184-192; Kennedy R., Mazza L.: 5S and TPM: working together as one in TPM3. CTPM, 2010; Wolniak R., Skotnicka-Zasadzień B.: Metody i narzędzia zarządzania jakością – Teoria i praktyka, cz. 1. Wydawnictwo Politechniki Śląskiej, Gliwice 2011; Wolniak R., Skotnicka-Zasadzień B.: Zarządzanie jakością dla inżynierów. Wydawnictwo Politechniki Śląskiej, Gliwice 2010; Wolniak R.: Relationship between selected lean management tools and innovations. Zeszyty Naukowe Politechniki Śląskiej, s. Organizacja i Zarządzanie, z. 75, Gliwice 2014, s. 157-266.

[3] Ahuja I.P.S., Khamba J.S.: Total productive maintenance: literature review and directions. "International Journal of Quality & Reliability Management", Vol. 25, No. 7, 2008, p. 709-756; Chand G., Shirvani B.: Implementation of TPM in cellular manufacture. "Journal of Materials Processing Technology", Vol. 103, 2000, p. 149-154; Benneyan J.C., Lloyd R.C., Plsek P.E.: Statistical process control as a tool for research and healthcare improvement. "Quality and Safety in Health Care", Vol. 12.6, 2003, p. 458-464; Chan F.T.S., Lau H.C.W., Lap R.W.L., Chan H.K., Kong S.: Implementation of total productive maintenance: A case study. "International Journal Production Economics", Vol. 95, 2005, p. 71-94.

implementation of TPM to the organization was improperly conducted and was the cause of the decline in business efficiency. As a result of the research, the causes of nonconformities were identified and proposed solutions for TPM adjustment.

## 2. Research problem

The main reason for the increase in quality costs in the analyzed organization was the production of non-compliant laser cutting products. This resulted in an increase in the number of internal complaints in the company, a high percentage of waste and unscheduled downtime and bottlenecks in production process. In order to determine the amount and type of discrepancies arising on the laser cutting line in 2016, the internal document of the company – the register of "Quantities of defects" was analyzed. Based on data (Table 1), it was found that the number of nonconforming intermediates was about 4,500 units per quarter. This means that almost 30% of the blanks produced on the laser cutting line did not meet the quality requirements.

Table 1

Number of defects in 2016

| | Quarter | | | | Average |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | |
| **Number of manufactured semi-finished products [pcs]** | 15000 | 16000 | 18000 | 14000 | 15750 |
| **Number of non-compliant semi-finished products [pcs]** | 4500 | 4550 | 4600 | 4300 | 4487 |
| **Quantity of defects [%]** | 30 | 28 | 26 | 31 | 29 |

Source: Author's own work.

In order to reduce costs, it was necessary to determine the nature of the nonconformity, to determine the reasons for them, and to develop corrective actions[4].

[4] Wolniak R., Skotnicka-Zasadzień B.: Metody i narzędzia zarządzania jakością. Teoria i praktyka, cz. 1. Wydawnictwo Politechniki Śląskiej, Gliwice 2011; Wolniak R., Skotnicka-Zasadzień B.: Zarządzanie jakością dla inżynierów. Wydawnictwo Politechniki Śląskiej, Gliwice 2010; Wolniak R.: Relationship between selected lean management tools and innovations. Zeszyty Naukowe Politechniki Śląskiej, s. Organizacja i Zarządzanie, z. 75, 2014, p. 157-266; Wolniak R., Skotnicka-Zasadzień B.: Wykorzystanie komputerowego wspomagania w zakresie metody 5Why w przemyśle, [w:] Knosala R. (red.): Komputerowo zintegrowane zarządzanie, t. 2. Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, 2011, s. 570-581; Skotnicka-Zasadzień B.: Doskonalenie procesu produkcyjnego w przedsiębiorstwie przemysłowym z zastosowaniem metod projektowania jakości, [w:] Knosala R. (red.): Innowacje w zarządzaniu i inżynierii produkcji. Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, Opole 2013, s. 1003-1010; Zasadzień M., Kwaśna E.: An analysis of work of maintenance department employees. Zeszyty Naukowe AM, nr 32, z. 1. Szczecin 2012, s. 131-135.

## 3. Methodology of research

A team of experts was set up to determine the nature of the inconsistencies and determine their causes. The team analyzed each stage of the process and recorded notes on nonconformities on the sheets. The cards were fastened to the cork board. The brainstorming method has identified the main areas of generated incompatibility. Subsequently, the number of discrepancies in the area was calculated and a Pareto-Lorenz graph was drawn up. It has been determined where the areas of incompatibility are generated in the greatest amount. For identified major problems ISHIKAWA analysis was performed to determine the possible causes of nonconformity and the 5 WHY analysis for detail. Then corrective actions were developed.

## 4. The results of research

As a result of the work of the brainstorming team, the analysis of the problems reported on the cards was firstly conducted, identifying the eight major areas where inconsistencies were identified. These include: dimension, burnt out shape, surface roughness, discoloration, deformation, surface unevenness, differences in the thicknesses of individual components, grinding (grinding) of components (Table 2). Then the number of discrepancies appearing in the various areas was calculated and the Pareto-Lorenz graph was drawn (fig. 1).

Table 2

Incompatibility numer and type

| INCOMPATIBILITY | | Number [Pieces] | percentage [%] |
|---|---|---|---|
| **Designation number** | **Type** | | |
| 1 | Wrong dimensionr | 1879 | 42 |
| 2 | Wrongly burned shape | 1546 | 35 |
| 3 | Material roughness | 251 | 6 |
| 4 | Discolorations | 221 | 5 |
| 5 | Deformation of material | 199 | 4 |
| 6 | Uneven surface | 168 | 4 |
| 7 | Difference in dimensions of element thickness | 116 | 3 |
| 8 | Element shreddings | 68 | 2 |

Source: Warszawski T.: Opracowanie działań korygujących dla zidentyfikowania niezgodności w procesie cięcia półproduktu. WSZOP, Katowice 2017 (promotor B. Szczucka-Lasota).

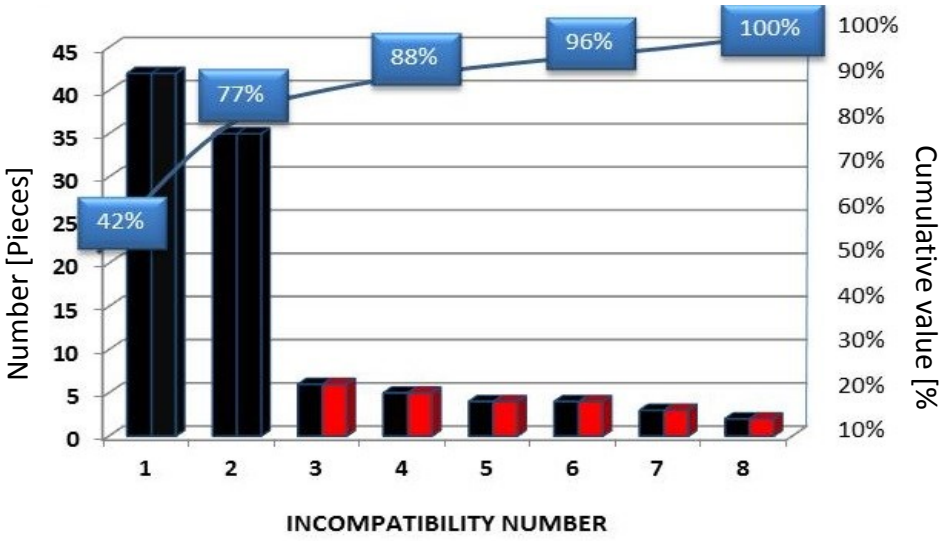


Fig. 1. Incorrect type of products – Pareto-Lorenz chart
Source: Author's own work.

The analysis shows that two types of nonconformity generate more than 50% of the loss in organization resulting from the production of improper intermediates. These include:

- dimensional incompatibilities accounting for as many as 42% of all identified nonconformities,
- incorrectly burned shape that has been observed in more than 1,500 items, representing 35% of all non-compliant products.

It was found that the incompatibilities should be eliminated first, and Ishikawa's analysis was performed (Figure 2-3). The main reasons were sought in five areas: machine, method, man and work environment and management.

Ishikawa analysis has shown that the causes of defects may be: ineffective control or even lack of it; lack of cleaning; maintenance of the machine; errors in the operation of TPM services. On the other hand, in the case of the second problem, a number of reasons have been identified that could cause the product to burn out properly. The most important ones included frequent changes in technology parameters depending on the material used, lack of staff experience and adequate practical training, improper process parameters, and errors in maintaining the TPM. Because Ishikawa's analysis identified a relatively large number of variables that could affect the analyzed problem, to determine the main cause, instead of considering each variant, we should to perform a 5 WHY analysis separately.

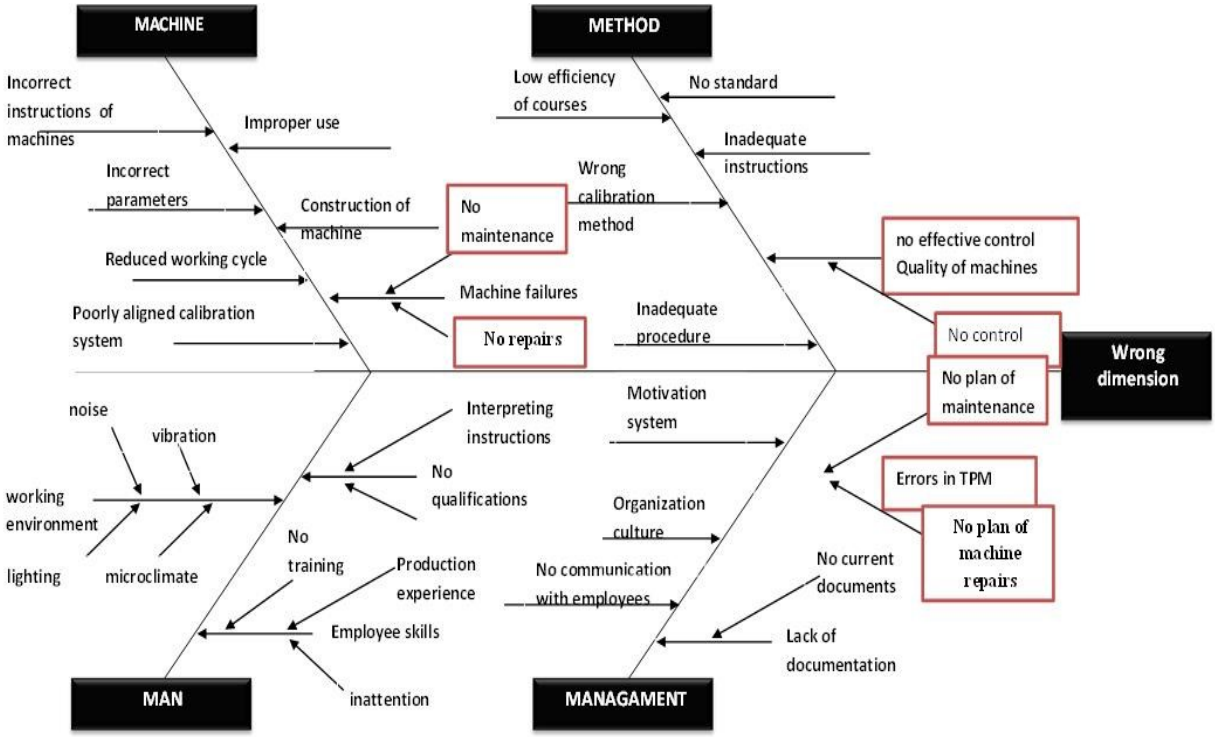


Fig. 2. Ishikawa diagram of incorrect number 1 – wrong dimension
Source: Own work based on: Warszawski T.: Opracowanie działań korygujących dla zidentyfikowania niezgodności w procesie cięcia półproduktu. WSZOP, Katowice 2017 (promotor B. Szczucka-Lasota).

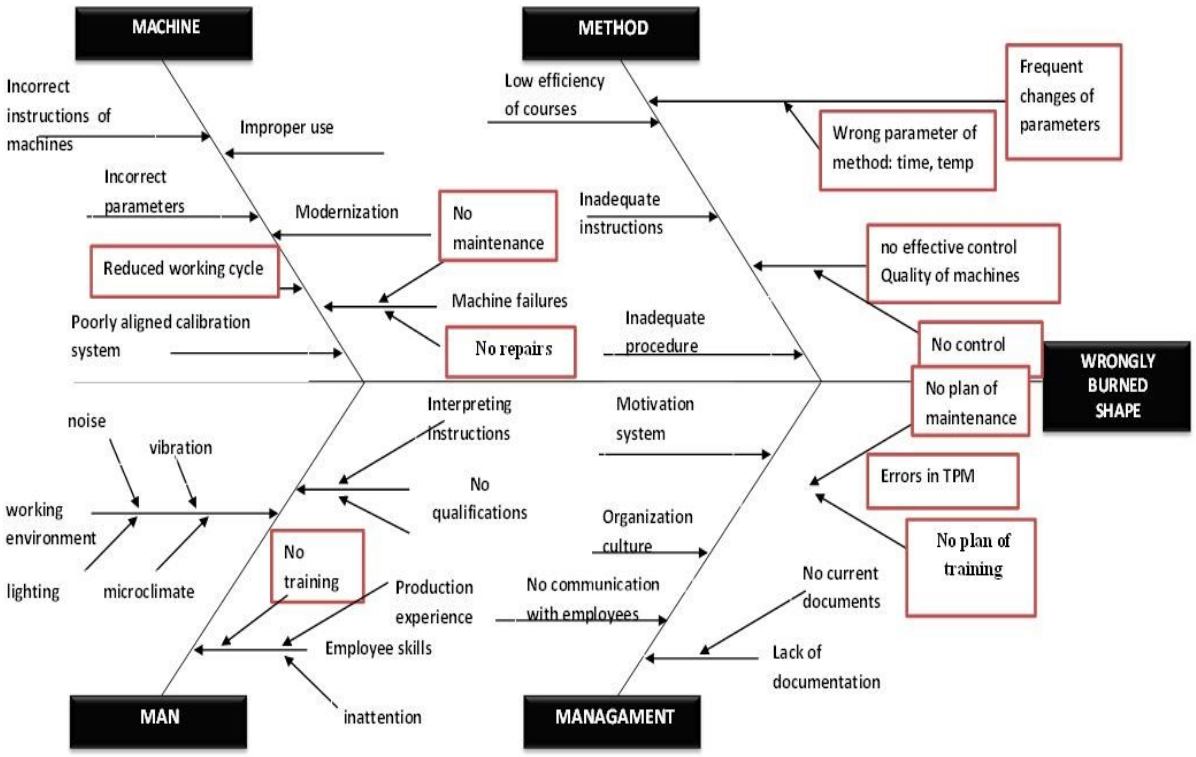


Fig. 3. Ishikawa diagram of incorrect number 2 – wrongly burned shape
Source: Author's own work.

The results are shown in Figure 4.

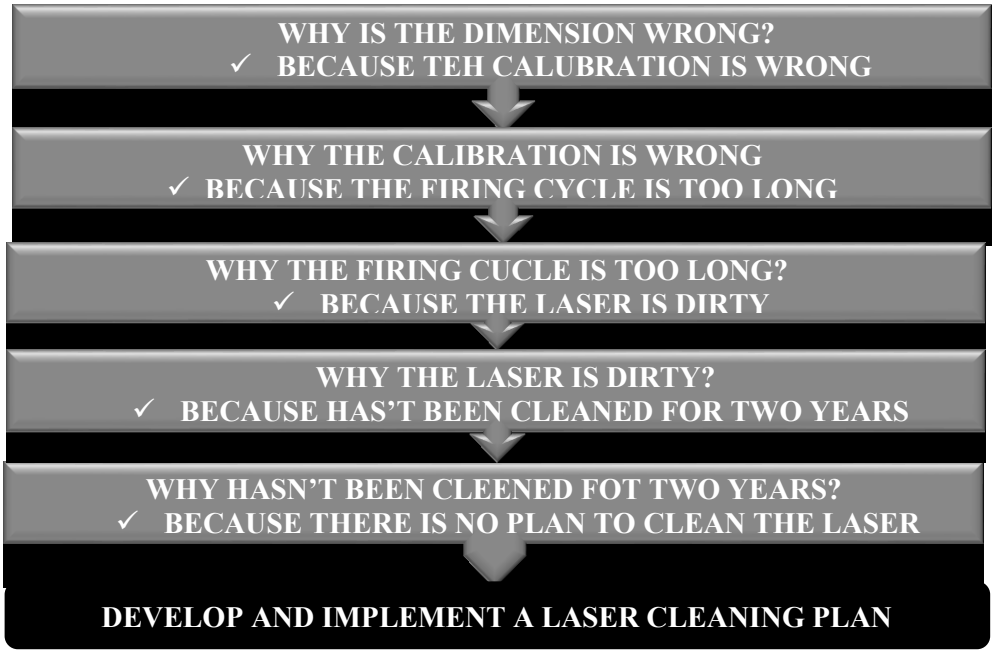


Fig. 4. 5 WHY analysis for the incorrect type of wrong dimensions
Source: Author's own work.

The 5 WHY analyzes have shown that the main reason for the inconsistencies was the lack of a laser cleaning plan.


Fig. 5. 5 WHY analyze for incorrect type of wrongly burned shape
Source: Author's own work.

Machine maintenance and maintenance services have not performed laser inspection and maintenance for the last 2 years, resulting in laser stain and incorrect firing. Similarly, a 5 WHY analysis was performed for the problem: "Why is the shape burned incorrectly?" In this case it was found that the firing time was too short and the temperature was too high. The main cause of the problem is the lack of instruction and cyclic staff training.

## Conclusion

In order to maximize the efficiency of machinery and equipment in many production plants, TPM is implemented, aiming to maximize the available time of the machine for producing good quality products. The TPM system was invented in Japan and its aim is to good maintenance of plant and equipment by operators (autonomous maintenance) and by maintenance personnel (scheduled maintenance).

The research presented in this paper indicates that in the analyzed enterprise the process of implementation of TPM had some incompatibilities. It did not cover all the machines and

equipment in the case of the laser cutting production line. As a result of the lack of maintenance plan for these devices, the company increased the number of non-compliant manufactured products. The dirty laser was the cause of the firing process, so the process took too long. As a result of incorrect calibration of soiled laser, over 1800 non-compliant products were obtained. This represents as much as 42% of all identified inconsistencies. In turn, shortening of firing time and raising of temperature by workers resulted in improper product shape. Corrective measures introduced into the factory proved to be not only ineffective, but increased the number of manufactured discrepancies by 1546 units in the analyzed cycle of equipment. The Ishikawa and 5 WHY analyzes made it possible to identify the main causes of nonconformities: lack of laser cleaning plan and cyclic training for employees. For these inconsistencies, corrective actions were developed, in the plans of TPM services the conservation of all devices were included in the maintenance process of laser cutting equipment, including lasers. Also mandatory training for laser cutting workers was recommended.

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