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Six Sigma methodology as a road to intelligent maintenance

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Abstract
An enterprise which is managed in a modern way should be based on the concept of knowledge management. It is particularly important in the case of processes related to facility maintenance, where the efficiency and effectiveness of work is directly connected with the employees' knowledge. Improvement of processes involved in facility maintenance has a real influence on the productivity of a manufacturing enterprise. High accessibility of technical equipment and its correct functioning influence not only production efficiency but also the quality of products and the safety of operators. The article is a description of an attempt to implement one of quality engineering methods for improving the facility maintenance process. The author decided to use the 8D method to shorten the duration of downtimes caused by breakdowns. Owing to the conducted analysis and the implementation of the improvement and preventive actions, we were able to shorten the duration of a downtime of a machine having a crucial importance for the company. Investigations and implementation were conducted in one of Silesian production plants..

1. Introduction

1.1. Facility maintenance

A proper operational policy should limit the probability of breakdowns. Despite minimizing the risk, it is impossible to guard against breakdowns of machinery park elements. A breakdown of a machine taking part in the production process can cause the impossibility to continue the production, decreased efficiency, that is delays in production, threat to the operating staff or danger to the natural environment, an increased risk of failure to meet the delivery deadlines or worsened quality of the products (PINTELON L., SRINIVAS K.P. 2006). A breakdown is a sudden and, most frequently, an unexpected phenomenon, so the process of breakdown removal is complex – it involves the necessity to act quickly and reorganize the production plans.

The duration of a downtime caused by a breakdown can be influenced by elements the duration of which depends on facility maintenance organization and management (administration delay, the time of waiting for the staff and spare parts), i.e. the so-called support capacity as well as on the duration of particular technical actions, e.g. diagnostics and repair, i.e. the easiness of maintenance (CARREL A. 2000). Maintenance easiness depends first of all on the qualifications, knowledge and competence of the employees, construction of the facility, its technical condition and location. The shortening of a downtime caused by a breakdown will therefore involve shortening the time of a passive and/or active breakdown removal process. Improving the facility maintenance process in this aspect is possible owing to the use of tools and methods applied in quality management.

1.2. The 8D method

Continuous improvement should be included in the strategy of every modern enterprise which wants to meet the requirements imposed by the demanding, competitive market.

Among an array of tools and methods used to improve production processes, one can distinguish the ones which help to identify problems, find the causes and sources of irregularities as well as the ones that support the process of developing and implementing the improvement and preventive actions. The first group includes popular tools, such as the Pareto chart (ABC), check sheet, Ishikawa diagram (4M, 5M, 6M), 5 Why (5W2H), the interrelationship diagram etc. (ISHIKAWA K., 1986, TAGUE N.R. 2005, MIDOR K. 2014, ANDRÁSSYOVÁ Z. ET AL. 2013, GAJDZIK B., SITKO J. 2016). Tools which support the undertaking of improvement and preventive actions include first of all: FMEA (PFMEA, CFMEA), 8 Disciplines (8D), Drill Deep and Wide (DDW) as well as DMAIC

(SOKOVIC M. ET AL. 2010, KRAJNC M. 2012. JAGUSIAK-KOCIK M. 2017).

The method referred to as the 8D Report– 8 Disciplines is most frequently applied to solve problems connected with bad quality of parts produced by co-operators (PAŁUCHA K. 2012). It is a formalized method, which, using additional tools such as e.g. 5Why or Ishikawa diagram (WOLNIAK R., SKOTNICKA–ZASADZIEŃ B. 2011) in a logical and simple way helps to systemize and define the procedure when solving a problem from the first to the eight step. The report can have any graphic form, but it should contain the following elements: 1D – establishing an interdisciplinary team and appointing the leader; 2D– a description of the problem to be solved that is precise and comprehensible for all the members of the group; 3D– developing actions aimed at finding a temporary and immediate solution to the problem; 4D – conducting an analysis in order to identify the root cause of the problem using quality management tools; 5D – developing corrective actions, e.g. changes in the manner of carrying out particular procedures or operations, introducing additional activities etc.; 6D – developing preventive actions aimed at consolidating the changes made to the existing system, e.g. changes in the operating manual and procedures, new elements of employee training etc.; 7D – implementation of corrective and preventive actions as well as verification of their performance in practice, 8D– final report on the actions carried out by the team. It is recommended that the final form of the 8D Report should be a table with elements clearly separated from one another.

1.3. Description of the facility subjected to analysis

The enterprise in which methods for improving the facility maintenance process have been applied is a plant which manufactures polyethylene pipes of various density. The pipes are produced by the extrusion method, so the key machines are extruders.

The element responsible for correct shaping of a product is the shaping system in the form of an extrusion head, the basic components of which have been presented in Fig. 1.

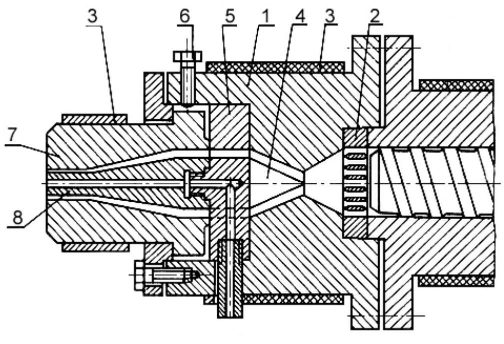

Fig. 1. Head for extruding pipes (DOBROSZ K., MATYSIAK A. 1994)

The extrusion head is mounted on the extruder cylinder and consists of the following elements (Fig. 1): 1 – head body, 2 – compressing sieve, 3 – electrical heaters, 4 – mass separator, 5 – core bracket, 6 – mouthpiece centring screw, 7 – mouthpiece, 8 – mouthpiece core.

Depending on the diameter of the produced pipe, appropriate heads are used. When the diameter of the pipe is changed, the extruder head is retooled and the remaining elements of the production line are subjected to adjustment.

2. Problem analysis

The 8D method was applied to solve a problem related to an excessively long downtime caused by improper work of extruder head heaters. Incorrect functioning can be manifested in the lack of head heating or improper distribution of temperatures on its circumference.

1D – Working group

To solve the problem, a working group was established, consisting of facility maintenance manager and team leaders, production manager and a team leader of the pipe production department. The person approving the team's activities (leader) was the technical director.

2D – Description of the problem

The analysed problem concerns the excessively long downtime caused by a breakdown described in the system as „incorrect temperature of extruder head". This breakdown is reported by the extruder operator based on the observation of the appearance of the extruded pipe's surface.

3D – Immediate action

In the case of this problem, immediate actions to solve the problem were temporarily given up. This part of the method is not applicable to the maintenance process improvement.

4D – Cause of the problem

The causes of the problem were identified by means of the modified 5M method. The basic elements of the diagram, i.e.: man, machine, material, method and management were replaced by elements which better characterized the process subjected to analysis, namely: availability of spare parts, machine operator's mistake, flow of information between employees, availability of facility maintenance employees, availability of consumables, availability of tools necessary for breakdown removal, work of facility maintenance employees.

By means of so conducted analysis (Fig. 2) the two main causes of the problem were identified. The direct reason is a mistake made by the extruder operator, who in the process of head retooling (e.g. due to a change of the pipe diameter) connects the heaters' plugs and the corresponding thermocouples' plugs in a wrong way. As a result, the thermocouple measures temperature in another place than the heater it controls. This leads to incorrect distribution of temperature on the extruder head circumference. The direct cause is the behaviour of FM employees when diagnosing a breakdown. The employee called to remove a breakdown in the first place diagnoses damage to the head heating system elements: heaters, thermocouples, wires and connections. As the last step, having checked the functioning of all the devices, the FM employee analyses the correctness of connections.

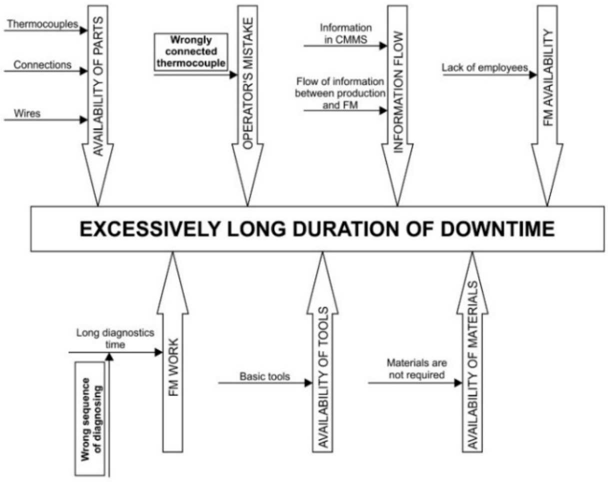

Fig. 2. Ishikawa diagram

5D – Determining the corrective actions

Improvement actions included developing a system of markings for the connections of heaters and thermocouples by means of labels resistant to dirt and damage, which has been presented in Fig. 3.

The solution effectively reduces the probability of making a mistake when connecting the head heaters and thermocouples to the control system and, at the same time, does not generate additional costs involved in its implementation.

Fig. 3. Corrective actions resulting from the 8D analysis

6D – Prevention of another occurrence

The proposed improvement action the implementation of which would prevent the occurrence of the problem in the future was a checklist for the procedure of extruder head retooling, which is completed by the operator upon completion of extruder retooling. The checklist contains a list of all the elements in the extruder line (or their settings) that may change after retooling, which the operator should check before start-up. The checklist is presented in Fig. 4.

7D – Implementation of corrective and preventive actions

In this step of the 8D method actions aimed at preventing problems in the future have been proposed. The actions concern both the production and facility maintenance departments. For the extruder line it is updating of the extruder retooling procedures.

CHECKLIST AFTER EXTRUDER RETOOLING

DEPARTMENT:	PREPARED BY:	DATE:

QUESTION:	EVALUATION:
Compliance of head diameter with the order	☐
Compliance of calibrator diameter with the order	☐
Compliance of brush diameter with the order	☐
Regulation of pipe guide rollers' position	☐
Control of heaters' and thermocouples' connection	☐
Control of saw diameter setting and compliance of pipe length with the order	☐
Marker setting	☐

Fig. 4. Extruder retooling checklist

The update applies to the duty of completing the checklist after the line retooling and a description of the system of markings for head heaters' connections. In the case of facility maintenance department, changes in the procedure of training new employees have been made. The essence of the change in the procedure was introducing the rule that a breakdown cause diagnosis should start with examining the most frequent potential causes. This change resulted in developing a sheet of the most frequent breakdowns and their causes, which is available to facility maintenance employees and updated once a month based on the data collected in CMMS system.

8D REPORT

PROBLEM:	Excessively long duration of downtime due to e.g. head temperature	DEPARTMENT:	Extruder 2 Line

WORKING TEAM:

	FORENAME AND SURNAME	POSITION	TELEPHONE NO.	FUNCTION
1.				
2.				
3.				

CAUSE OF THE PROBLEM:

	IS	EVALUATION
AVAILABILITY OF PARTS	Thermocouple, connections, wires available in the warehouse	OK
OPERATOR'S MISTAKE	Wrongly connected thermocouple after retooling ↓ Incorrect control of heaters or lack of control	NOK
INFORMATION FLOW	Information given in the system	OK
AVAILABILITY OF FM	Breakdown treated as a priority	OK
AVAILABILITY OF MATERIALS	Consumables are not required	OK
AVAILABILITY OF TOOLS	Basic tools available in FM department are required	OK
FM WORK	Long diagnosis time ↓ Diagnostics of the correct functioning of heaters, thermocouples, controller and the correctness of connections ↓ Wrong sequence of breakdown diagnosing	NOK

ANALYSIS RESULT	When retooling the head, the extruder operator connects the plugs of heaters and the corresponding plugs of thermocouples in a wrong way. This causes incorrect distribution of temperature on the extruder head circumference. The FM employee called to remove a breakdown in the first place diagnoses damage to the heating system elements. Only after checking the above mentioned devices' functioning, he analyses the correctness of connections.

CORRECTIVE ACTIONS:

NAME	DESCRIPTION	PERSON IN CHARGE	COMPLETION DATE
Markings for the heater-thermocouple wires	Markings for the connections by means of labels resistant to dirt and damage 	FM manager	

PREVENTION:

NAME	DESCRIPTION	PERSON IN CHARGE	COMPLETION DATE
Checklist	Developing and implementing a checklist in the machine retooling procedure 	Production director	
FM trainings	Updating the FM employee training procedure	FM manager	
Operator trainings	Updating the new extruder operators' training procedure	HR manager	

Fig. 5. Form summing up the 8D analysis

8D – Report on completion of actions

After developing and implementing all the corrective, improvement and preventive actions, the team prepared a report on the undertaken actions based on the 8D method in a form of the sheet presented in Fig. 5.

The form contains all the most important information on the team's work. It describes the effects of implementing all the analysis stages.

After all the improvement and preventive actions were undertaken in a period of 6 months, one error in the connection of head heaters was recorded, the duration of two downtimes caused by improper temperature of the head heaters was 0.56 h. In the corresponding period preceding the actions, the average breakdown removal time was 0.98 h, and there were 5 downtimes.

3. Summary

Application of the 8D method allowed identifying the root causes of the problem subjected to analysis, which were as follows:

- errors in heaters' connections,
- long diagnostics of breakdowns.

Improvement and preventive actions were formulated and implemented as follows:

- introduction of markings for the heater-thermocouple wires,
- implementation of a checklist in the head retooling procedure,
- changes in the breakdown diagnostics manual,
- changes in the employee training procedures.

An additional element influencing the removal of the remaining breakdowns was developing a base of knowledge about the most frequent breakdowns and the ways of their diagnosis. The base, in line with the concept of an intelligent enterprise, is regularly updated and extended, which is an important contribution to the element of learning and exchange of information between employees.

Application of the 8D method for improving the process of breakdown removal allowed obtaining tangible benefits, such as shortening the duration of downtimes, a reduced number of mistakes made by operators and a streamlined system of breakdown diagnosis.

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六西格玛方法论作为智能维护之路

关键词
保养
质量
改进
处理
8D

抽象

以现代管理的企业，应该以知识管理的理念为基础。在与设备维护相关的流程的情况下，这尤其重要 工作的效率和效能与员工的知识直接相关。起色 涉及设备维护的过程对制造的生产率有真正的影响 企业。高技术设备的可及性及其正确的功能影响 不仅生产效率高，而且产品质量和运营商的安全。文章 是对实施改进质量工程方法的一种尝试的描述 设施维护过程。笔者决定用 8D 方法缩短持续时间 故障造成的停机时间。由于进行了分析和实施 改进和预防措施，我们能够缩短机器停机时间 对公司至关重要。进行了调查和实施 西里西亚生产厂之一。