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An analysis of a fracture in a mining excavator arm using quality management techniques

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Abstract: Machinery faults are a problem that incorrectly diagnosed may result in the increase of waste. The fault mentioned in the article was identified at an opencast facility located in Podkarpacie. The purpose of the study was to analyse the defect identified on the excavator arm using quality management techniques. These techniques were the Ishikawa diagram and the 5Why method. In the plant, unit faults on various types of machines were detected. The fracture on the excavator arm was identified, however, the cause of the problem was not known. Potential causes of the fault and the main cause of the problem (material fatigue) were detected using the Ishikawa diagram. The root cause of the material fatigue, the long-term and repetitive operation of the excavator during the excavation of the deposit, was identified by the 5Why method. The proposed processes can be used to identify the root causes of various faults both in the mining industry as well as production and service plants.

Keywords: mechanical engineering, Ishikawa diagram, 5Why, sustainable development

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Introduction

Conducting an effective process of implementing construction works saves time, energy and costs. This development depends on the management's awareness of practising sustainable development. The key element of sustainable development in enterprises is to identify problems and indicate the source of their origin (Pacana et al., 2018). Consequently, after correctly diagnosing the source of the problem, it is possible to take further steps towards improvements to eliminate or reduce the problem in the future. This is possible through the skilful practice of quality manage-

ment techniques. Quality management techniques are a simple and inexpensive way to effectively identify the causes of problems. In addition, these techniques are complementary, and therefore should be used in a sequential manner (Pacana et al., 2019; Hamrol & Mantura, 2002). The use of selected quality management techniques to analyse the problem of a fractured excavator arm was proposed in one of the opencast facilities located in Podkarpackie. This problem caused a reduction in the employees' work safety, and at the same time generated costs resulting from the machine's downtime. The cause of the excavator arm fracture was also unknown. The management of the plant decided that it would be beneficial to analyse the problem using the following quality management techniques (Ishikawa diagram and 5Why method).

1. Methodology

The Ishikawa diagram, which is the first technique used in the analysis and is called the cause-and-effect diagram, enables the identification of potential causes of a problem. Then, from the potential causes, the main causes can be selected (Chączyńska & Klimecka-Tatar, 2017; Zwolińska, 2016). The excavator arm fracture was analysed using all the basic criteria of the Ishikawa diagram, i.e. man, method, machine, management, material and environment (the so-called 5M+E) (Pacana et al., 2019; Zendla & Wolniak, 2015). It was decided that these criteria were adequate and would make for an effective analysis (Bilsel & Lin, 2012). Potential causes of the problem were assigned to these criteria and they were identified through a brainstorm session involving a manager, three excavator operators and a controller. Out of the potential causes identified, the main cause was chosen and the 5Why method was used to specify the source of the problem.

The 5Why method, or "5xWhy?", is a method used for the identification of the source of a problem. By consecutively asking "why?", it is possible to analyse the problem thoroughly and indicate the source of its origin (Pacana & Siwiec, 2019). In the 5Why method the problem is stated at the beginning, in this case, the fracture of the excavator arm and the main cause given: material fatigue. Then, for each of the indirect causes, the question "why?" is asked until the answer provides the source of the problem. Once identified, adequate corrective improvements can be taken (Braglia et al., 2017; Hamrol, 2005).

2. Analysis of the excavator arm fracture

The problem with the excavator arm fracture occurred in the mining excavator, which was used for extracting natural aggregate. The excavator in question was manufactured in 2006. The fracture occurred in November 2018 after 12 years of operation. In accordance with the Operation and Maintenance Documentation (DTR), all inspections of the excavator had been made at 250, 500, 1000, 2000, 5000 hours of work. There were also daily inspections carried out by a plant employee.

The fracture was located on the initial section of the arm attached to the excavator's cabin near the joint of the excavator arm (Fig. 1).



Fig. 1. Example of a mining excavator arm fracture (*own photo*)

The crack was identified by the excavator operator during the extraction of the deposit. The immediate actions taken included reporting the problem to the manager and other excavator operators, securing the excavator against restarting and reporting the defect to an external repair company.

In the first stage of the analysis, the problem was analysed using the Ishikawa diagram (Fig. 2).

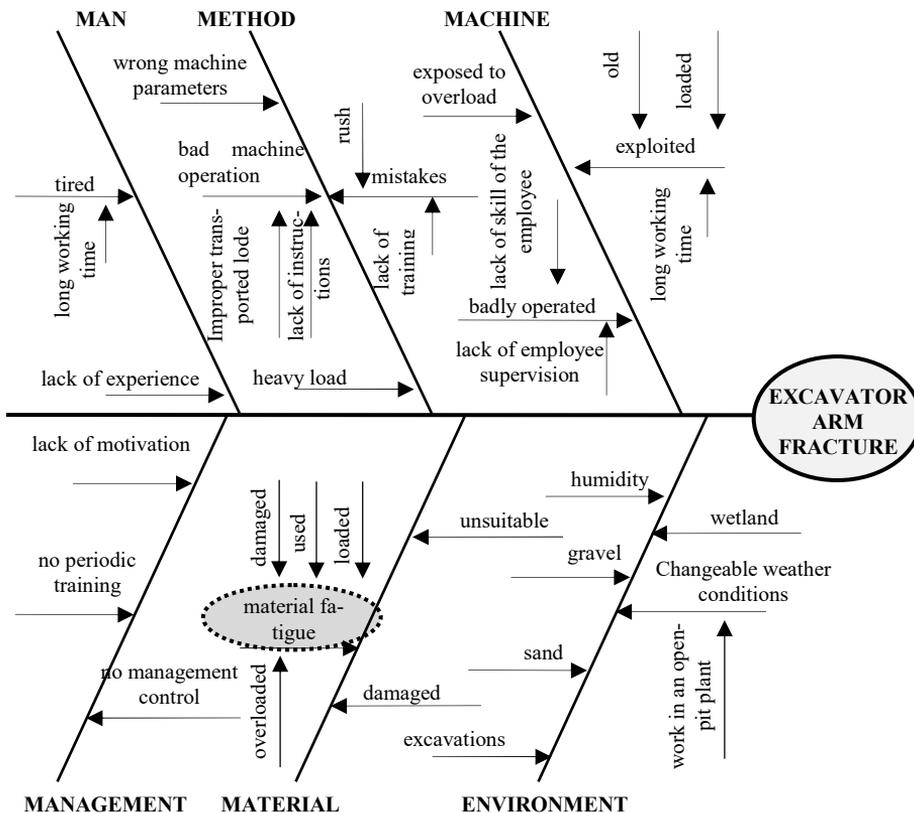


Fig. 2. Ishikawa diagram for the excavator arm fracture (*own research*)

Through brainstorming, the causes of potential fractures of the excavator arm were indicated. Out of which the main cause was chosen, i.e. material fatigue.

In the second stage, the 5Why analysis was performed in order to identify the root cause of the excavator arm fracture (Fig. 3).

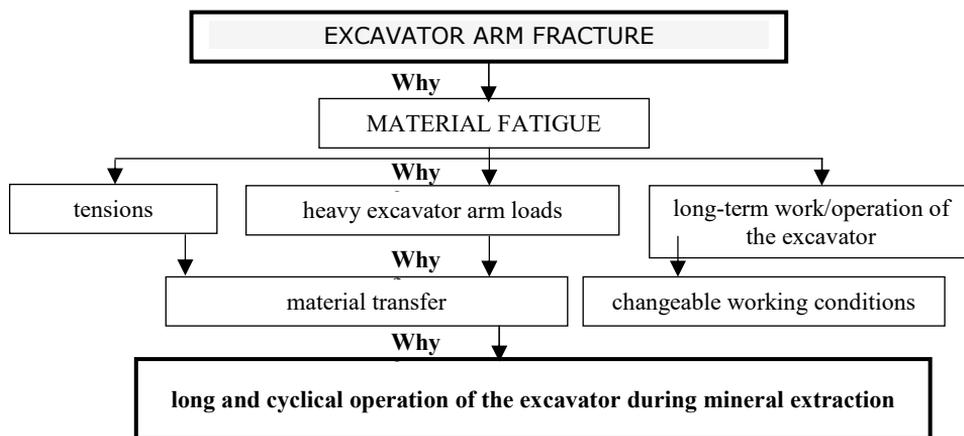


Fig. 3. 5Why analysis of the excavator arm fracture (own research)

For the main reason, i.e. material fatigue, identified with the Ishikawa diagram, the question “Why?” was asked and potential causes such as tensions, heavy excavator arm loads and long-term operation were indicated. A series of other “Why?” questions followed and further reasons were indicated, i.e. changeable working conditions and material transfer. It was concluded that the root cause was a material defect revealed as a result of material fatigue caused by long and cyclical operation of the excavator.

Conclusions

Conducting an effective process of implementing construction works saves time, energy and costs. The practice of such activities was implemented in an opencast facility located in Podkarpacie, where the analysed problem of a excavator arm fracture occurred for the first time and the cause of the problem was unknown. The management acknowledged that it would be beneficial to analyse the fracture in order to identify the source of the problem. The Ishiakwa diagram and the 5Why method were chosen to build a sequence of techniques, as these methods, when properly used, complement each other and allowed the analysis of the problem to be carried out and its source identified. Using the analysis, it was concluded that:

- a brainstorming session involving the manager, three excavator operators and the controller, allowed effective analysis of the problem,
- the Ishikawa diagram enabled the identification of potential causes as well as indicate the main cause of the problem (material fatigue),

- the 5Why method indicated the root cause of the problem, which was long and cyclical work of the excavator during the extraction of the deposit,
- utilising the Ishikawa diagram (along with brainstorming) and the 5Why method in a sequential way allowed the problem to be analysed and indicated the origin of its root cause.

The analysed problem was treated as a one-off event and it was recognized that the root cause was a material defect that was revealed as a result of material fatigue caused by long and cyclical operation of the excavator. The proposed sequence can be used for the identification of the root causes of various problems in the mining, production and service industry.

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