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Innovative solutions in the overhaul of the main fan of the ventillation system in a mine

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Abstract
Considering the specific working conditions of the machines and devices used in coal mining, the selection and exploitation method which takes into account changes of these conditions during the machine's work, is very important. Presented here is the overhaul process of the main fan used for ventilating the mining excavation sites and the innovative solutions applied in the process. The overhaul processes before and after implementing an innovative solution have been compared and the resulting benefits for the company have been pointed out.

Introduction

The term "innovation" comes from the Latin word "innovare", meaning "creating something new". Thus, the most common definition of innovation highlights that "innovation is a process consisting in transforming the already existing possibilities into new ideas and putting them to practical use" [1].

Respectable scientists often use the definition saying, to put it in simple terms, that innovation is a process consisting in transforming the existing possibilities into new ideas and putting them to practical use.

Innovation is a new (for the organisation, society or civilisation) value introduced by man or quality pertaining to its goals and methods or their realisation.

Innovations can be divided into [2]:

- sociological innovations;
- business innovations;
- linguistic innovations.

Business innovations pertain to many areas, including the manner of service (a different standard of relations with users and customers).

One of the conditions for participating in the production/service market is having a quality management system (QMS).

This article presents the overhaul process of a main ventilation system fan before and after the implementation of changes (innovative solutions), consisting in a changed standard of relations with the client due to the introduction of a quality management system.

Having a QMS increases the company's chances of being part of tender procedures, as in the case of mining plants already have quality systems implemented and only a company with such a system can guarantee that the overhaul will be performed according to the ordering party's expectations.

The purpose of fans in a mining plant

Fans are a part of the one-through machine group used for pressurising and moving vapours and gases.

The main objective of fans in mines is to vent all the active mining excavation sites. An example of a ventilation system diagram has been presented in figure 1.

Venting the mine is aimed at:

- providing sufficient quality and amount of air for the people working in the underground of the mining plant;
- reducing the concentration of toxic gases, such as: carbon dioxide, carbon monoxide, nitric

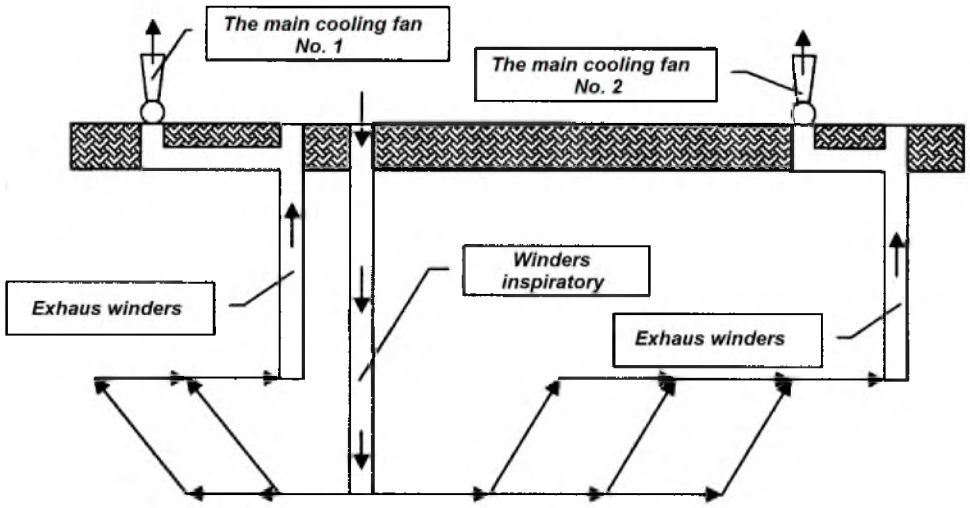

Fig. 1. A model diagram of ventilation network A

oxides, sulphur dioxide, hydrogen sulphide, methane;
- removing the toxic gases from the mine through air flow;
- reducing the air temperature and humidity in the mining excavation sites.

The aim of the main ventilation system fans is to exchange large amounts of air in a small period of time. These fans exchange air in the entire mine or a large part of it. The main ventilation system fans are considered a strategic element in the mining process; they ensure safety of work in the underground mining excavation sites.

The user of the main ventilation system fans (the mining plant) is obliged to:

- use the fans properly, according to the manufacturer's operation and maintenance documentation;
- carry out periodic diagnostic tests in order to get the current technical condition assessment as well as a prognosis of possible emergency states;
- carry out periodic inspections and overhauls in the time and scope specified in the manufacturer's operation and maintenance documentation [3, 4, 5, 6, 7].

Main WPK 3.3 fan

The WPK 3.3 fan (Mine Centrifugal Fan with an outer blade diameter of 3.3 metres) is a fan with a one-way suction rotor designed for main ventilation systems of mining plants. During normal operation it sucks in the air from the mining excavation sites, however, the design of ducts and valve flaps also allows (should such necessity arise) pumping the air into the excavation sites from the atmosphere.

The simple construction of the WPK fans causes no instalment difficulties and ensures long and failure-free operation as well as high efficiency and a vast array of economic operation modes. The WPK 3.3 fan has been shown in figures 2 and 3.

Fig. 2. A view of WPK 3.3 ventilator from the side of control cabinets [7]

Fig. 3. A view of WPK 3.3 ventilator from the side of the oil system [7]

Comparative analysis of the state before and after QMS implementation

Fan overhauls are performed using the "Assembly and repair of power devices" process. One of the main parameters of this process is the sale value – it determines the importance of the process for the operation of the entire company. The analysis of this parameter indicates that the process is a key one for the company. Figure 4 shows the value of this parameter which has been introduced in 2008, for the years 2008–2013.

Introducing the Quality Management System in the company caused significant changes. These

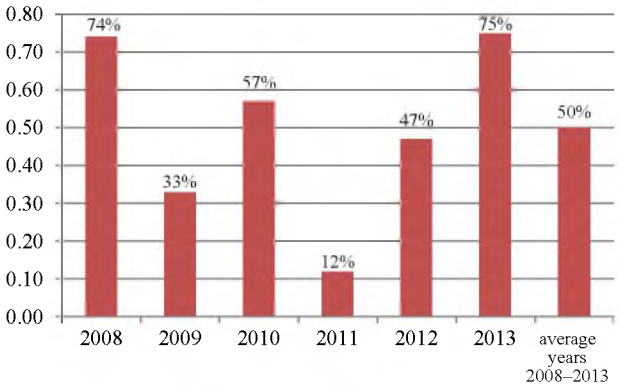

Fig. 4. The index of the process "Installation and repair of power equipment" [7]

Table 1. A comparison of conditions in the overhaul areas before and after the introduction of QMS [7]

Overhaul process areas	Before the introduction of QMS	After the introduction of QMS
Documentation of the fan prior to the overhaul	No description of the contents of documentation. Persons responsible for creating certain parts of the documentation are not specified. The person approving the entire documentation is not clearly specified	The contents of the documentation have been identified and described. The persons responsible for creating parts of the documentation have been determined. The person approving the entire documentation has been determined
Description of activities carried out during the fan overhaul	Conduct according to the rules of the company. The stages of the overhaul are not described. Ambiguity regarding supervision of the overhaul process	The overhaul stages and people responsible for them have been identified. 3 processes have been itemised: 1. assembly and repair of power devices; 2. preparation for production; 3. purchases
Documentation of the fan after the overhaul	Only the measurement results included in the reports. No boundary values for the measurements specified. No conclusion and recommendations for the ordering party. Standards or manufacturer's documents defining the permissible values of measurements are not specified	The reports have been completed with standards and manufacturer's data regarding measurement results. An entry regarding orders and conclusions from the conducted measurements has been added
Purchases of services and materials needed in the overhaul process	Purchases from random contractors. High probability of using materials of poor quality. No contracts with the contractors	A list of qualified contractors has been created. Materials of sufficient quality which have an impact on the overhaul process, have been purchased. Contracts specifying the manner of cooperation with the contractors have been signed
Preparation work connected with the overhaul	Resource planning and arrangements concerning convenient dates of training missing.	Stages which need to be realised before starting the overhaul have been specified. Planning of resources, purchases of products and services, trainings and human resources
Monitoring the ordering party's satisfaction with the overhaul	Talks from time to time. No record of the conversations	Talks with the employer with record of the conversations. Completing a questionnaire. An analysis of the questionnaire and conversation records on the basis of which preventive measures can be taken
Control and measurement tools used during the overhaul	No supervision over the control and measurement tools	A "Supervising the control and measurement tools" procedure has been introduced. A list of control and measurement tools subject to obligatory supervision has been created. A "Using the control and measurement tools" and "Marking the control and measurement tools" manuals have been introduced
Devices and tools used during the overhaul	Problems with determining the date for power tools inspection	A "Supervising the tools and devices" procedure has been introduced. Every device has its own passport. A schedule of device and power tool inspections has been created. The date of the next test has been put on the devices
Corrective measures during the overhaul	No record of the activities. Nonconformities corrected only during the overhaul	A "Corrective measures" procedure has been introduced, in which the manner of dealing with corrective measures has been specified in order to avoid their occurrence in the future
Preventive measures during the overhaul	No record of the activities. Possible nonconformities corrected only during the overhaul	A "Preventive measures" procedure has been introduced, in which the manner of dealing with preventive measures has been specified in order to avoid nonconformities in the future

changes have also had a substantial impact on the "Assembly and repair of power devices" process. Even before that, it had been considered to be one of the main processes carried out by the company; unfortunately, however, its magnitude compared to other realised processes had not been known.

As far as the physical labour related to the overhaul process is concerned, no significant changes have been observed after the introduction of the Quality Management System. The activities connected with disassembly, assessment of the technical condition of individual elements of the fan and its installation are performed by highly qualified workers.

The introduction of QMS allowed maintaining and raising the workers' qualifications through internal and external courses [12, 13]. Employees gain high qualifications regarding the overhaul processes mainly through acquiring the experience and knowledge from other workers, who have been involved in such processes for a long period of time [10, 11].

Table 1 presents the areas of the overhaul process as well as a description of their state before and after the introduction of QMS in these areas.

An analysis of table 1 contents allows concluding that the documentation both before and after the overhaul has considerably improved. Earlier planning of works as well as purchasing of materials and services have been introduced [14]. The materials used for overhaul are delivered from qualified suppliers, hence their quality does not raise any objections. The purchase of services is properly supervised, ensuring adequate quality of the overhaul being performed. The measurement instruments are subjected to periodical inspections (or calibration), which ensures proper performance of control measurements. Proper supervision over the applied devices and tools has been ensured – their use does not pose a threat to workers performing overhaul works. The introduced preventive and corrective measures prevent the occurrence of nonconformities during the overhaul process and eliminate the repetition of identified unfavourable events in the future. The introduced system of customer satisfaction monitoring enables the quality of overhauls being performed to be improved from the ordering party's point of view [8, 9, 15].

Analysis of the introduced QMS functioning

An analysis of the main indices (from the point of view of the company performing the overhaul process) of the process „Installation and repair of power devices" allows concluding as follows:

- the index of the number of complains after the installation and repair in the guarantee period/the number of installations/repairs performed after introducing QMS was zero. This proves a high quality of the services (overhauls) provided by the company;
- the index of repairs / installations of power devices performed within the fixed term/the number of all repairs / installations of power devices was also introduced at the beginning of QMS implementation. The value of this index in the years 2008–2013 reached one, which means that all the overhaul processes were performed within the prescribed time.

The "purchase" index is similar. The number of complaints related to deliveries in relation to the number of purchase orders in all the years (2008–2013) was zero, which means that all the materials used and services purchased fulfilled the requirements.

The "Production Preparation" index for the years 2005–2013 has been presented in figure 5.

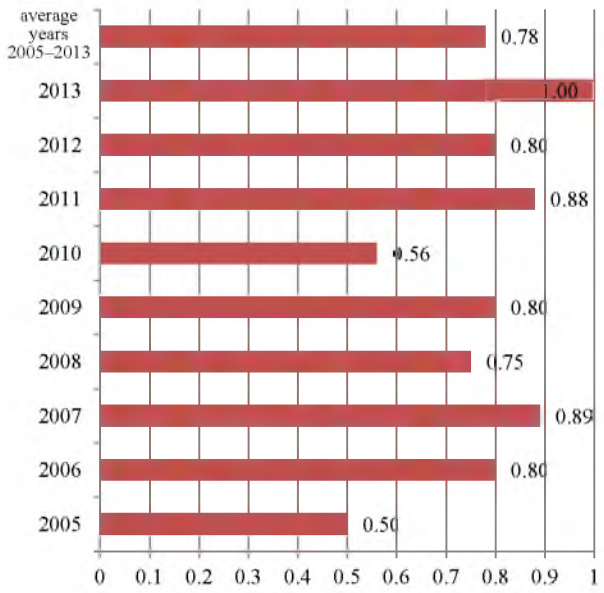

Fig. 5. The index of the process "Production Preparation" [7]

The index regarding the number of tenders won in relation to the total number of participation in tenders for the years 2005–2015 reached an average of 0.78. Hence, only 22% of the prepared tender bids ended in failure (the tender was not won).

Participation in tenders is the only way to obtain orders for the performance of fan overhauls, therefore, preparing an attractive offer, based mainly on the price, guarantees success in winning the tender and signing an overhaul contract. The very preparation of an offer generates costs, hence failure to win a tender results in losses for the company.

An analysis of another index – „Infrastructure supervision" allows drawing the following conclusions:

- the index referring to the number of breakdowns of infrastructure elements in relation to the total number in the years 2005–2013 reached an average of 3%;
- the index referring to the negatively verified measurement instruments in relation to the total number in the years 2005–2013 was 2%.

The reliability of infrastructure elements (including measurement instruments) is important from the point of view of achieving adequate quality of fan overhaul performance. Low values of this index prove proper supervision and show that the employees are using the instruments in a proper way. Only in the year 2010 the index reached an acceptable limit value – 10% (Fig. 6).

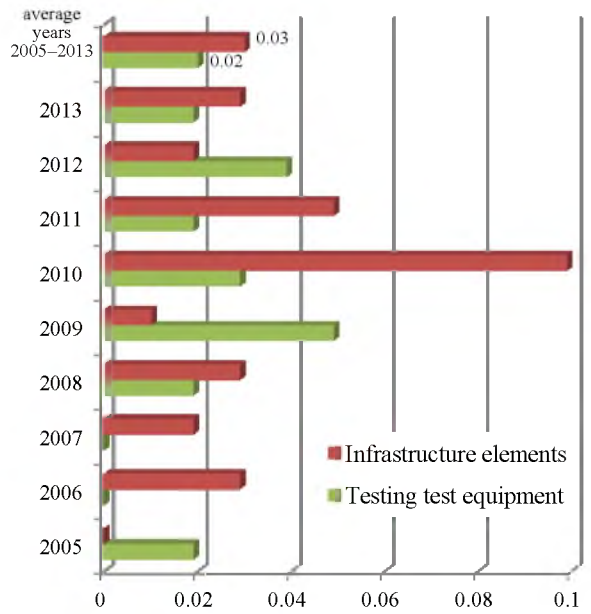

Fig. 6. The index of the process "Infrastructure supervision" [7]

Preventive and corrective measures

The aim of preventive measures is to avoid nonconformities during the process – in this case – the fan overhaul, while corrective measures are aimed at eliminating the nonconformities that have been already identified in the overhaul process.

Both kinds of measures result in the completion of overhaul process according to the customer's expectations. The purpose of the introduced procedures "Preventive measures" and "Corrective measures" is to identify nonconformities, analyse the problem and introduce corrective measures. After completing the programme, these measures are subjected to evaluation. The number of measures introduced in the analysed period (2005–2013) has been presented in figure 7.

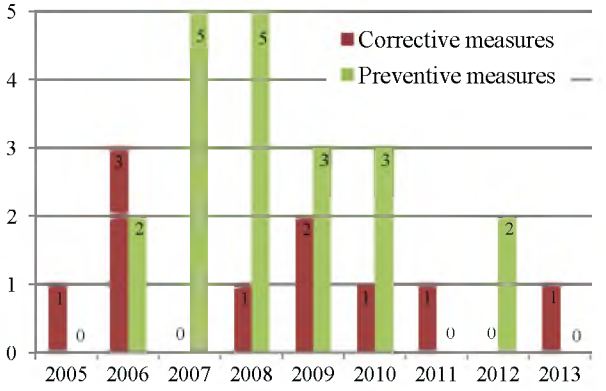

Fig. 7. Corrective and preventive measures in the fan overhaul process [7]

Throughout the period of Quality Management System functioning with regard to the fans' overhaul process, ten corrective activities and twenty preventive ones were undertaken, which means that more nonconformities were prevented than corrected.

These activities were undertaken mainly when performing additional works related to standard overhauls – these were usually works carried out for the first time. Other cases involve works that were not performed in line with technical documentation – the producer's detailed design documentation varied from the one delivered to the user.

Corrective measures involved mainly purchasing additional machines and equipment. The undertaken preventive activities consisted mainly in comparing the actual state and the producer's documentation, ensuring necessary human resources, running additional trainings and ordering additional services.

Conclusions

The introduction of Quality Management System in the company and its continuous improvement strengthened the company's position on the market of mine main ventilation fan overhauls. The company achieved a status of a reliable, competitive, knowledgeable and qualified provider of high quality services in the area of ventilator overhauls.

The conducted analysis before and after introducing QMS allows concluding as follows:

- a map of fan overhaul process and a map of auxiliary processes have been prepared;
- the overhaul process is documented in records;
- the introduced QMS prevents the use of improper materials and strengthens co-operation with service providers;

- the quality of post-overhaul documentation has been improved;
- there are no complaints regarding the overhaul services;
- overhauls are performed within the fixed terms;
- measurement instruments and tools are used and supervised in a proper way;
- materials, outsourced services and human resources are prepared in a manner that is adjusted to the overhaul process;
- proper supervision and control over the process are ensured;
- there are no additional costs involved in the performance of overhaul tasks;
- continuous monitoring of customer satisfaction and expectations is ensured.

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