MIXED REALITY IN MAINTENANCE
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ABSTRACT

We can see changes in technological, socioeconomic and cultural features caused by industrial revolutions. Among the technological features belongs also maintenance management. The approach towards equipment maintenance has changed throughout the revolutions from reactive towards predictive. Instead of fixing breakdowns, companies try to predict them and minimalize the risks and costs associated with it. However, breakdowns still happen and we have to know what to do when they occur. The main objective of this article is to show the changes in maintenance management strategies and to demonstrate a modern technology for effective solution of problems that have already arisen.

KEYWORDS

Maintenance; Mixed Reality; Industrial Revolutions; Risk Management; Breakdown

INTRODUCTION

The maintenance process means the implementation of planned and unplanned operations related to the maintenance, inspection and repair of machines, ie production equipment, during their operation. Maintenance is, according to Valenčík [1], a set of activities that should keep the production equipment in working order or, in case of a failure, return this state quickly.
Maintenance is described in standard EN 13306, "Maintenance - Maintenance Terminology", which states that maintenance is a combination of all technical, administrative and management measures throughout the life cycle of an object aimed at maintaining it or returning it to the state in which it can work properly [2].
The introduction of appropriate maintenance systems will improve operational performance and quality. During the maintenance system, faults and the wear of important components, and the design of logistical purchase of spare parts are monitored and analysed.
The main tasks of the maintenance system are according to Rakyta [3]:
• Determine the main types of repair work according to the nature of the equipment used and operating conditions
• Determine the required period of repair work
• Establish the necessary volume of work on the basis of standards of laborious maintenance performance, material cost, minimize downtime
• Use modern methods of organizing repairs
• Create an appropriate stimulation system for maintenance results
• Ensure appropriate material maintenance organization
• Ensure appropriate maintenance work quality
• Establish a maintenance planning system with the ability to integrate into downstream business activities
Setting the necessary level of control and understanding of all aspects of the business requiring maintenance is the key to building a quality maintenance plan. Then it's about having the right data analysis tools and trained the right people who are actively involved in these activities. But before we got to the current concept of maintenance, it was preceded by a long development.

REVOLUTIONS IN MAINTENANCE

Just as the entire industry has gone through the stages of revolution, maintenance has seen inevitable development. Changes in the maintenance concept are discussed in the following chapter.

Maintenance 1.0

The term maintenance includes any continuous activity undertaken to promote the declining technical condition of the entrusted equipment and to ensure that performance is not adversely affected in the short or long term. Reactive maintenance, as the name itself suggests, is an unscheduled corrective maintenance performed to eliminate a malfunction or incident in order to restore the production facility to the desired state.

Replacing broken machine parts, restarting the conveyor that has stopped due to overload, repairing damaged pipes, and debugging time after a software error, all fall into the category of reactive maintenance.

Choosing the right method depends on the type of process, the application, and the budget. Reactive maintenance is in itself relatively low cost, but depending on the process criticality, the cost of stopping the operation and subsequent removal of the fault can go up a lot.

Maintenance 2.0

Preventive maintenance focuses on the prevention of failures and incidents by immediate replacement or reparation of the equipment during regular shutdowns / inspections before it fails, resulting in operational difficulties.

Preventive maintenance activities are planned in advance, maintenance of the machine or equipment is in practice carried out according to a predetermined schedule (so-called maintenance interval). In order to determine the interval correctly, it is necessary to know the failure rates of the individual components, parts or the whole in order to determine the time schedule correctly. The maintenance schedule is designed to keep the maintenance item in perfect condition. If the interval is too short, maintenance costs and operating costs are unnecessarily expensive. Conversely, if the preventive maintenance interval is too long, there is an increased risk of failure. Detailed technological procedures are also important, they must be designed so as not to cause damage or incorrect repair or replacement during maintenance, which would result in the opposite - ie increased risk of failure.

Replacement of filters every two months, replacement of generator oil every 50 hours and adjustment of low inlet pressure on compressors are typical examples of preventive maintenance. In the case of preventive maintenance, much higher costs are generated by analogy, but the possibility of avoiding downtime and preventing a malfunction can save us a significant amount of operating costs.

Maintenance 3.0

Productive maintenance is referred to as a proactive approach to management by trying to describe all types of failures and placing great emphasis on eliminating machine and equipment losses. It is managed by production people and is supported by production process and maintenance partners to work together and be equal partners. Valenčík's philosophy of this method [1] is based on increasing reliability of equipment, reducing maintenance costs and losses due to downtime.

Some authors say that in productive maintenance we overcome the traditional division of people into machine operators and machine repairers. It is assumed that the machine operator has the chance to first detect any discrepancies during performance and to identify potential sources of future plant failure. Small maintenance activities are transferred from the classic maintenance departments directly to the production and production departments. TPM's motto is: "Protect your machine and take care of it with your own hands". The operator tries to understand his machine, Nakajima [4] and Legat [5].

Its character includes not only the maintenance of the production equipment but also its overall strategy. It can be said that the TPM is a comprehensive maintenance management system that is at the forefront of standardization of activities and is closely related to losses incurred during the operation of the machine and equipment. Losses are modified based on a given method of production, operation and maintenance of the equipment and based on human errors.

The philosophy of productive maintenance is not only to prevent failures, but also to reduce errors, short-term downtime, shorten the time of change of product, etc. This is a proactive maintenance organization approach that objectively requires increasingly complex production equipment, tools and instruments.

Maintenance 4.0

It is important to realize that predictive maintenance means a thorough understanding of how everything works and is related, including with the environment. Often this knowledge can be drawn from the documentation supplied by the original equipment manufacturers and from the experience of the maintenance teams who have worked on similar systems for a long time, so that all the potential problems can be avoided.

The benchmark of any performance measurement is performance benchmarking - making it easier to compare the actual system performance when compared to its maximum performance. Performance ratings help identify key performance issues. The next step is to have a good idea of the root cause analysis and track down the issues to the sources themselves. These sources are usually physical parts, such as proportional-integration-derivative regulators, valves, transmitters, and sensors that can indicate potential problems for equipment and assets.
Thanks to automation systems, tracking changes in these components by Orosz [6] is much easier, with the ability to include alarms and metrics in instant messaging within the control system. A flow meter with a transmitter that controls the outlet pressure can be programmed to generate alarms whenever the pressure is raised or lowered below a certain threshold; similarly, a feedback control valve (via the positioner) can be set to indicate the valve position in response to the control signal. An alarm generated in these situations calls for an inspection of all related equipment.

Many times, alarms are generated when the voltage drops or due to the gradual aging of the sensors or ungrounded lines, but can also indicate serious problems such as limiting process parameters or aging equipment. Early warning indicators help address potential threats and are among the most widely used predictive maintenance methods.

Predictive maintenance then becomes the best tool for ensuring lasting productivity and can be further improved through intelligent planning and thorough analysis. The key to properly performing predictive maintenance is, for example, thorough analysis of data from sensors and probes, observation of the physical appearance of the device, display of device status on display screens, etc. ensuring a high return on investment through the maintenance of the facility.

RISK IN MAINTENANCE

The key to end users is to evaluate which processes are critical and which processes do not affect productivity much. The failure of a water filtration system is probably hardly a kind of fault for most business workers, requiring continuous monitoring when they have clean tap water available. A similar system supplying treated water to an ammonia plant becomes very critical compared to the above example and requires regular monitoring.

The proposed maintenance risk management process is as follows:

- Mapping of all maintenance risks
- Elimination of possible risks or their delegation
- Creating scenarios for residual risks and uncertain events
- Prepare a work guide for the scenarios
- Implementation of strategy and staff training
- Financial evaluation

Given that the ultimate goal of each business owner is to maximize productivity and minimize costs, the general approach to selecting a risk management strategy is to evaluate the average cost of failure removal as compared to average maintenance costs and lower cost choices. Therefore, according to Korecky [7], it is always advisable to calculate the strategy's benefits in advance.

A risk analysis is needed to do this. According to Hnilica [8] and Mern [9], the degree of risk can be determined as the product of the probability of occurrence and the magnitude of the impact. Then we divide the risks into discrete and continuous, define the method of quantification using scales or numerically. Following is the choice of risk approach. If possible, risks need to be eliminated or delegated [10]. Of course, this is not always possible and we need to have a backup plan ready for such situations.

MIXED REALITY IN MAINTENANCE

An important aspect of maintenance is a backup plan in case of unforeseen problems. When it comes to extremely critical applications, it is very important to have a fail-over system or some other back-up mechanism that allows us to ensure minimum damage and the lowest possible loss of productivity. This can be achieved by using mixed reality in maintenance.

The possibilities of creating and displaying mixed reality elements depend not only on the development of software tools, but also on the hardware available to the user. Nowadays, there is rapid progress on the electronics market, so the available technologies are improving. Today, according to Glockner [11], the following HW can be mentioned.

- PC with webcam
- Mobile devices (tablet, smartphone)
- Display devices such as Head Mounted Display (HMD), Smart Glasses
- Digital stationary displays

The proposed solution assumes the use of Hololens from Microsoft [12]. At the moment, this is one of the most advanced devices that allows a person to see a real image that is complemented by virtual elements using a display in the field of view. According to Knizek [13], it is therefore only about the depiction of an expanded mixed reality. Hololens are a so-called wearable device that the user does not have to manipulate with.

Proof of concept

To verify the feasibility of our designs, a printing company that uses complex equipment from abroad was selected. The company faces problems such as failure to follow the rebuilding procedure and preventive maintenance. Furthermore, there are unexpected outages, which are solved by the arrival of a foreign expert. Figure 1 shows the view from the Hololens glasses after the marker is loaded from the machine and the virtual objects are displayed (main menu).

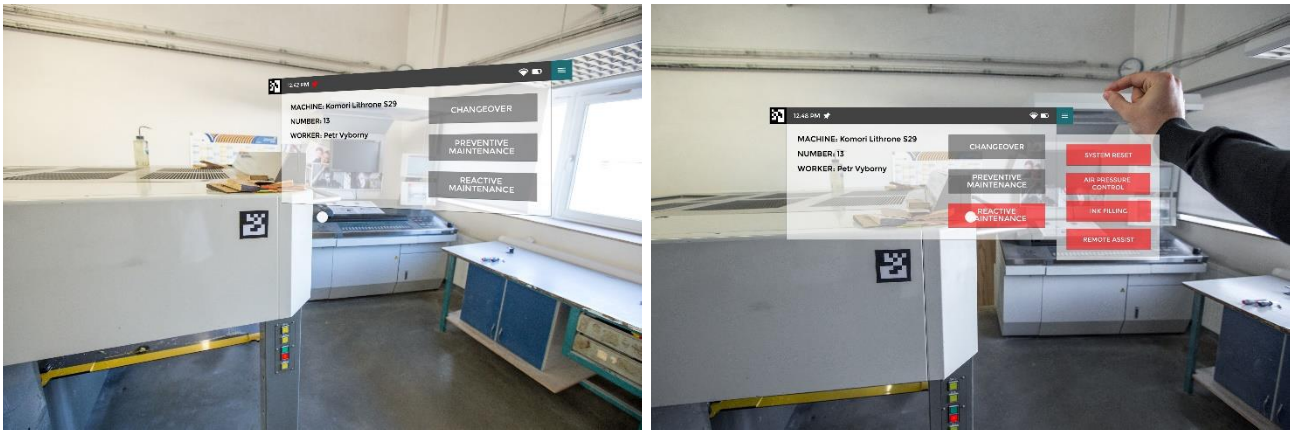

Figure 1: Virtual main menu in real environment

Within the project, we dealt with all three problem areas. We defined the risks and tried to prevent them by following the instructions. A sudden outage scenario has been created, where there is a standard solution, and if the problem is not resolved, you can contact an expert using Remote assist.
The following table 1 shows what work instructions were created in mixed reality. These instructions are divided by problem areas.

Changeover	Preventive Maintenance	Reactive Maintenance
✓ Color change ✓ Paper size change ✓ Binding	✓ Rollers Cleaning ✓ Air Pressure setting ✓ Suction Cups Replacement	✓ System Reset ✓ Air Pressure Control ✓ Ink Filling ✓ Remote Assist

Table 1: Work instructions according to the type of maintenance

See Figure 2 below for a demonstration of work instructions for preventive suction pad replacement that includes 5 steps and includes a virtual demonstration of suction cups. On the right side, there are three steps of checking the air pressure together with the virtual checkpoints of the locations being checked.

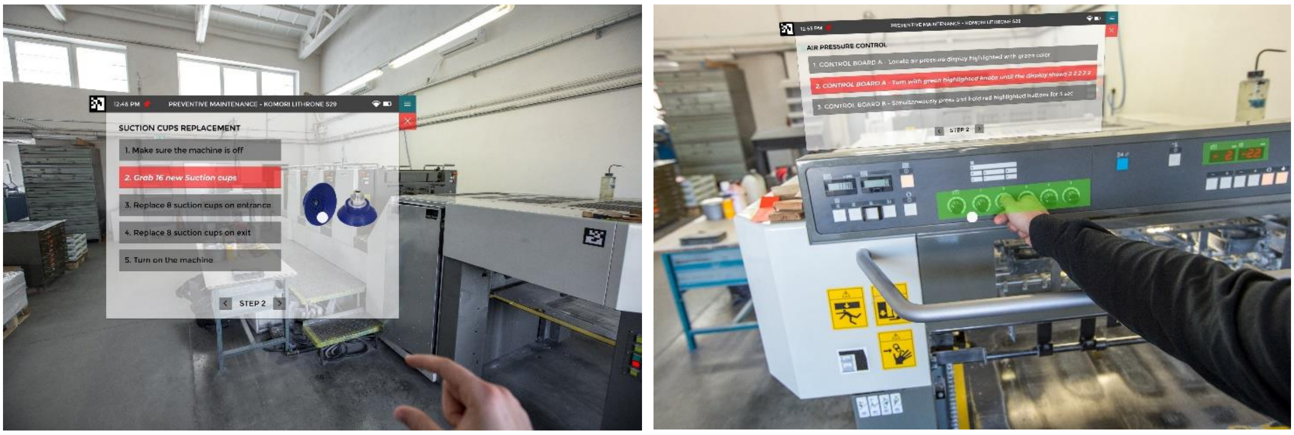

Figure 2: Work instructions for preventive actions

Of course, other embedded files or objects may be part of the work instructions for each step. Or, the whole process or step can be interpreted using animation.

Remote assist

If none of the predefined procedures is successful, then you need to reach an external expert. We will first familiarize the expert with the problem and explain what has already been done.

Figure 3: Remote assist examples

As can be seen from the figures above, the remote assistant can insert virtual objects, which are then projected into the HMD device and help to better understand the problem. The assistant again sees the same thing as a man with glasses.

Summary

During the project, we verified that the use of mixed reality together with Hololens is really good for maintenance. We can better manage potential risks and respond more quickly to machine outages. In addition to the advantages it is necessary to mention the limitations, see Table 2. We can say that the benefits of using mixed reality in maintenance outweigh the disadvantages and limitations. The Proof of Concept has shown us that it can be well prepared for the risk of equipment outages, even with considerable uncertainty. The ability to work with both hands, control with gestures and voice, inserting static and dynamic interactive elements or the possibility of remote assistance are among the main advantages of mixed reality in maintenance.

Advantages	Benefits	Limitations
✓ Inserting virtual elements ▪ Static ▪ Dynamic ▪ Interaction with the environment ✓ Working with both hands ✓ Voice and gesture control ✓ Remote Assist ▪ Same view ▪ Drawing ▪ Inserting objects	✓ Fast reaction ✓ Easier maintenance ✓ Streamlining the process ✓ Lower error rate ✓ Reduction of required qualification	✓ Equipment for Mixed Reality needed ✓ Battery recharging (7 hours) ✓ Internet access for Remote Assist

Table 2: Evaluation of concept

The use of mixed reality has some limitations, such as the need to purchase equipment (in our case Hololens) and connect to the Internet during remote communication. The Microsoft Hololens battery lasts 6-8 hours of continuous operation. In maintenance, however, we expect only occasional use of the device within 1-2 hours per day, which means that it is needed to charge every few days (according to the shift model).

CONCLUSION AND RECOMMENDATIONS

The fourth industrial revolution goes hand in hand with autonomous processes in production. As a result, traditional blue-collar professions are being pushed as well as increasing the complexity of automated manufacturing systems. However, these systems are not trouble-free and their maintenance is much more complex. It is often necessary to invite an experienced specialist directly from the manufacturer or outsource a specialist for maintenance. But the problem is that manufacturing systems providers often reside in a remote country and are not represented in our country. This significantly increases costs during unexpected downtime.

Along with the development of maintenance, the requirements for maintenance personnel are changing. It goes from classic repairman to IT and data specialist. But these changes bring risks. In spite of the quality of predictive maintenance, we cannot say with certainty that there is no fault that would cause great loss and require the support of an experienced technician. Therefore, it is important that companies retain knowledge of not only known failures and their prevention, but also unexpected failures caused by an undefined event. Setting up a scenario for what to do if this happens can protect businesses from major inconveniences.

Using a mixed reality maintenance facility helps us maintain and visually interpret knowledge about how to proceed with preventive maintenance. It also allows the preparation of a scenario for potential failures. Another advantage is the ability to work together to solve a problem with a specialist who may not be physically present. The emphasis in introducing mixed reality into maintenance must be on the initial problem analysis, which is the starting point for successful risk management.

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