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Development of an automated diagnostic and inspection system based on artificial intelligence designed to eliminate risks in transport and industrial companies

Milan SÁGA jr. *[a], Michal BARTOŠ [a], Vladimír BULEJ [a], Ján STANČEK [a], Dariusz WIECEK[b]

[a] *Department of Automation and Production Systems, Faculty of Mechanical Engineering, University of Zilina, Univerzitná 8215/1, 010 26 Žilina, Slovakia*

[b] *Institute of Industrial Engineering , University of Bielsko Biala, Willowa 2, 43-309 Bielsko-Biala, Poland*

Abstract

The article focuses on the definition of risks management in industry and transport, which are associated with development of an automated diagnostic and inspection system based on artificial intelligence designed to eliminate risks in transport and industrial companies. The first part describes the process of risk management with respect to the current ISO standard and the second part of the article summarizes the options that can deal with risk in the company. Next parts are associated with particular technical system.

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Keywords: transport; industry; risk; artificial intelligence

1. Introduction

At present, risk management is becoming increasingly important, especially due to the often changing economic conditions. Adverse market developments and risks affecting society can result in high financial losses and, in extreme cases, the end of the business. It is for this reason that it is essential that risks are not underestimated, and that is why risk management should be built into every company. Despite the fact that on the one hand the company is exposed to risks, on the other hand they have opportunities which, if they can use them properly, it helps them to compete or they can gain a better position on the market. The research is mainly in assessing the degree of risk and the costs associated with implementation of the proposed inspection system in industrial enterprises. Methods will be used and developed to identify risk areas in industrial enterprises and to assess the extent of possible technical, safety, health and hygiene

* Corresponding author. Tel.: 041/513 2833.
E-mail address: milan.saga2@fstroj.uniza.sk

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risks and threats. The paper also deals with a conceptual design of cable driven robot usage possibility in risks elimination in automotive and vehicle making companies.

2. Risk management

We define risk management as a process in which the management try to prevent the impact of existing and future risks, proposes appropriate solutions to help reduce the impact of adverse effects. On the other hand, provides the opportunity to take advantage of positive effects, Moosa (2017) .

Risk management is a tool to identify potential risks that lead to a reduction in the level of safety. The company's risk management is a means of analysing, evaluating and classifying the risks incurred, from which priorities are further set and procedures for measures to reduce them are created. We understand risk management as a constant systematic approach to working with risk and uncertainty, in which we use various tools, methods and techniques. It forms part of the management, aimed at ensuring the safety and stability of the system, process, project or business activity as such, Atef (2005).

The risk management of the organization is used to evaluate and manage the uncertainty of the organization in the form of compliance of business strategy and people, processes, technology. In order for risk management to be implemented in the organization, it is necessary to respect the principles, Šimák (2006):

- full support of top management,
- the application across the enterprise.
- familiarization of all human resources in the organization with the implementation of risk management,
- creating effective tools to monitor risk.

The role of risk management in an organization consists of protecting and enhancing its assets. These goals are achieved by risk management supporting the goals of the organization as follows Šimák (2006)::

- improves decision-making, planning and prioritization based on a comprehensive and structured understanding of business activities, project opportunities and threats;
- contributes to a more efficient use and allocation of capital and resources within the company,
- reduces volatility in non-key areas of business,
- protects and strengthens the assets and reputation of the company,
- develops and supports the knowledge of employees and the knowledge base of the company,
- optimizes operational performance.

Risk management can be implemented in the company in the form of various standards and norms. Each organization individually selects these standards and norms according to their needs, or based on the requirements of its partners.

The international standard that provides general procedures for risk management is ISO 31000: 2018 Risk management. The Slovak version of the standard is derived from it - STN ISO 31000: 2019 Risk management - instructions. The standard is designed for specific categories in the sector, it is therefore useful to any individuals or groups without discrimination statute - private, public and social, Buganová (2019).

In this standard lists are the stages of the risk management process shown in FIG. 1. The stages of the risk management process are consecutive activities and outputs and ultimately represent a cycle. This process is an integral part of business management, and must be adapted to current conditions in practice and corporate culture, Buganová (2012).

Identified risks are recorded in the risk database or in the risk checklist. It is not recommended to use this database and checklist as the only means of risk identification.

The risk database is a collection of organized information from projects implemented in the past. A formal risk information file is a suitable data retention system for use in other projects.

The risk checklist is a list of areas where problems are expected. The problems are specific to a particular company. The list is designed specifically for a particular type of business or industry. We do not take identification as a one-time matter, but as an activity that we carry out periodically or continuously, depending on the purpose. We use monitoring systems or early warning systems for this. On the basis of selected indicators, which monitor the development of selected risks at regular intervals and in case of exceeding the set limits, they draw attention to the increased values of the risk of the responsible person.

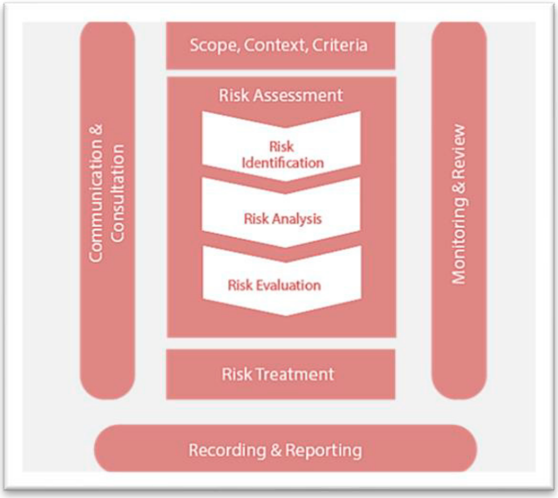


Fig. 1. Process of risk management (Modified from: [6])

In conclusion, I would like to emphasize that risk identification is the most important and time-consuming stage in the risk management process. It requires previous experience, systematicity, the ability to anticipate even such phenomena that we do not expect yet and we have no information about them, teamwork and a priority for the future. [2]

3. Treatment of risks

Risk prevention is one of the risk management techniques. In general, it is possible to prevent risks in the planning phase of operation, for example. by rejecting the dangerous place and then selecting a new one.

Loss reduction is the best technique for dealing with any risk. In this case, steps are taken to reduce the frequency or likelihood of loss by building a safety awareness at all levels of management and using the expertise of external agencies. The costs incurred at this stage bring significant savings in the future with potential losses in the future.

At this stage it is necessary to proceed to the following measures:

- security education and training
- provision of all machines and equipment
- safe design and construction
- safety and protective equipment for employees
- introduction of safe working methods
- prevention or elimination of bad conditions
- fire protection
- pollution control and environmental protection
- maintaining hygiene and health standards
- installation of fire protection system, fire hydrants and fixed fire extinguishing equipment
- installation of hazardous gas leakage alarm devices
- motivating employees to have accident-free work records

Including losses or self-insurance. In this case, the company can take acceptable risks to themselves either ineffective insurance against such risks or the process of self-insurance. In the case of self-insurance, a fund is created, to which any losses are credited. Self-insurance is needed when risks can be maintained and insurance costs are high. Small losses occurring at a high frequency can be left through self-insurance. In large companies, it may be more advantageous not to take out insurance, especially when the cost of insurance is higher than the possible losses caused by accidental risks. Each company has a certain level of tolerance for accepting the maximum loss depending on its cash flow, profitability, liquidity, resources and assets to eliminate losses.

The following five factors must be taken into account by the company when including the risk:

- probability of occurrence of an event causing a loss
- extent of tolerated loss
- possible loss in critical situations
- available remedies
- a fundamental deviation of the actual consequences compared to the estimate

Transfer of losses or insurance. Higher losses occurring at a lower frequency can be transferred or insured. In that case, the company comes into a relationship with the insurance company, which compensates it for any damages incurred. Insurance can be arranged in the form of damages or on the basis of restoration and repair of damaged equipment. The company itself should not be the victim in case of risk.

Some of the risk transfer methods are the following:

- contractually transfer risk-related activities to an external company,
- transfer responsibility for the consequences of the risk through a relief clause in the contract.

The following factors need to be kept in mind when transferring the risk to the insurer:

- insurable risk affecting the business
- frequency of risk occurrence
- types of risk
- compliance with laws such as the law on compensation to employees, the law on motor vehicles and the like.

In any case, the optimal strategy is a combination of self-insurance and risk transfer to insurance companies. [7]

4. Development of an automated diagnostic and inspection system based on artificial intelligence designed to eliminate risks and monitor the production process in transport and industrial companies

At present, we can see a decline in industrial production in almost all the countries affected by the viral disease, which has grown to a pandemic. Significantly reduced customer demand for manufactured products, disrupted the logistics chain of supplies and labor force was attacked by a virus, which is scarce in many sectors, which caused a drop in production. Such but similar situations may recur in the future. Therefore, it is necessary to pay great attention to all critical factors in production - man, machine, energy, etc.

It is appropriate to create a model for crisis assessment of the threat to an industrial enterprise in various crisis situations (viral disease, natural disasters, energy crisis, etc.) in order to quickly and effectively quantify the impact on the enterprise itself (economic and other indicators) and offer alternative solutions.

At present with the development of artificial intelligence methods, camera systems and automation means, it is appropriate to design a concept of diagnostic and inspection automated system based on rope robots, which will use camera systems to monitor material flow in production but also justified migration of people within the production system.

4.1. Production process control

Today, the production process places high demands on the quality and speed of production, in which the production process is sensitive to various factors.

The term quality contains two components, the quality of the product design and the quality of the product in production, which determine whether the product is suitable for its use. Production should produce a quality product with low costs and high work productivity.

Quality management in production therefore applies to:

- **Input control of material -** dimensions and quality of purchased material and semi-finished products, supervision of correct sorting, marking of materials and semi-finished products, monitoring of constancy of quality of deliveries,
- **Output control -** quality of all functions and completeness of finished products before handing them over for dispatch, completeness of deliveries and equipment of products (accessories, accompanying documentation, etc.) finishing of products, conservation, packaging, control documentation of finished products (test reports,

certificates, passports etc.,
- **Production process control -** quality of the first pieces produced after setting up the machine, sorting into good pieces and failures, technological and functional tests of components, control of the production process, control of technological parameters introduced during the production process
- **Work equipment inspection -** when taking over normal and special tools, when making and repairing tools, when making and repairing tools, when taking over technically demanding economic inventory, etc.,
- **Metrological control service -** control of gauges, measuring and testing instruments, verification of special gauges and measuring, testing and control instruments, calibration of very precise meters and instruments, etc. [10]

4.2. Cable driven parallel robot

The basic and biggest difference between cable driven parallel robot(CDPR) and a classic parallel robot is the fixed guide chains are replacement with ropes made of different materials and diameters. The drives and actuators themselves are not part of the guide chain and they are located on the base, platform, or in the corners of the supporting structure. The actuators are usually formed by motors with a winding device, pulleys, ropes and also, they contain components for fastening the rope. The ropes are attached to a platform where an additional device can be placed. Additional device can be used for handling or other technological operation resulting from the desired use of the machine. [12]

The biggest advantage of CDPR is extremely light weight (compared to the size of the workspace) and adaptability to work in huge spaces. Due to the low weight, the platform is able to move at high speed, and high acceleration up to 40g. [12]

As well as, the fixed guide chains used in parallel mechanisms are replaced by ropes, CDPRs are not able to transmit compressive forces, it is not possible to create pressure on the platform and therefore the robot is not able to perform a movement in which it would push the platform in front of it. The ropes must work under constant tension, because bending of the rope would lead to inaccurate positioning and possible complications during winding.

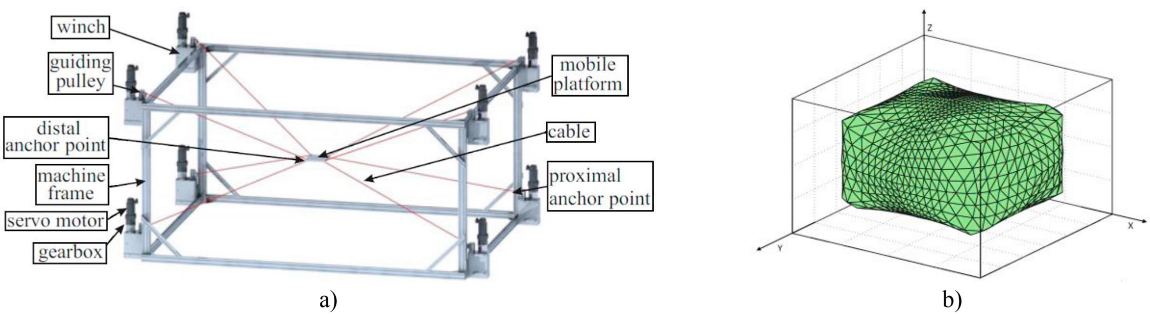


Fig. 2. a) Concept and components of a cable-driven parallel robot [15], b)Workspace of CDPR

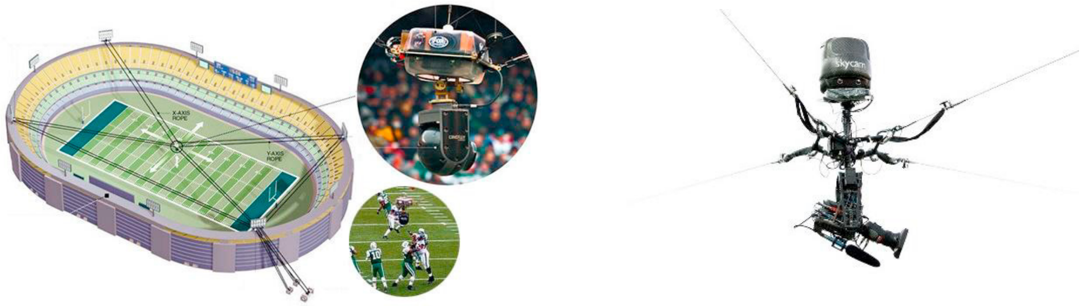
4.3. Use of a Cable Drive Parallel Robot

The use of rope robots is not very common. In practice, however, there are many industries applications where it is possible to deploy a robot. In principle, it is possible to use a rope robot for any activity where the technological requirements (position accuracy, speed, availability of position in the workspace, etc.) will correspond to its construction possibilities Below are listed the activities for which the cable driven parallel robot was successfully applied. [11] [12]
- crane with a large working area (loading of goods on a ship, truck, ...);
- relocating objects;
- measure dimensions, distances and positions;
- flight and other simulators (octahedral arrangement of ropes);

- camera for sports broadcasts over stadiums;
- construction and painting of buildings, bridges, aircraft, ships, etc.

It's possible to see, the shape of a work space of CDPR is a block. On Fig.3 b) is shown a shape of working space of Cable Driven Parallel robot which is made by 8 haul ropes which are placed in each corner.

One of the examples of cable driven parallel robot usage a is the capture of sports broadcasts across stadiums, because as we said in previous part, cable robot driven robot is designed to work in a huge workspace. Excellent examples of cable robot's usage are the SkyCam [17] and SpiderCam systems used in many sports arenas across the world. These systems provide computer-controlled, stabilized, cable supported cameras platforms which are moving above the sports stadiums. The systems are maneuvered through three-dimensional space using a set of four computer-controlled winches. The real-time control system includes static and dynamic active stabilization of camera carriers, which ensure correct camera alignment. [14] The idea of Skycam and Spidercam can also be applied in technical production, where we can place a robot with a cable drive above the production line and use visual inspection to monitor the production process and production parameters using various sensors and probes located on the platform.



a) b)

Fig. 3. CDPR usage, a) Use of CDPR in sports broadcast at the stadium [16], b) Skycam system [17]

5. Design of a Cable driven parallel robot used for inspection tasks and risk elimination in automotive industry

Basic conception of a designed cable driven parallel robot device - Using 4 winding devices located in the corners of the supporting structure, we are able to create a planar rope robot with 2 degrees of freedom. When the ropes are fully tensioned, the rope robot is able to move in a horizontal plane above the production line. The vertical distance of the working plane from the production line can be regulated by tensioning or loosening the haul ropes.

5.1. Requirements associated with the application of a CDPR designed for risks elimination and process control in automotive industry

For the needs of control of the production process and risks elimination in the automotive industry, a proposal for implementation using a robotic device is presented below. A cable driven parallel robot usage was designed as a suitable type for this application, because of its construction the robot device will not interfere to the space of production line. As well as robot is possible to move fast and with high dynamics in a relatively large space. During the inspection process, it will be necessary to perform:

- **Visual inspection of the production process -** during the visual inspection, a camera device will be placed on the robot platform, which will transmit the optical output to the robot operator, the video will be recorded for archiving with the subsequent possibility of retrieving the record.
- **Control of technological parameters of production -** on the robot platform there can be placed sensors for measure various parameters (temperature sensor, flue gas concentration sensor, vapor composition sensor) which will regularly record these parameters according to the operator's requirements to avoid errors in the production process.
- **Control of employees -** with the help of a robot with a camera, it is possible to monitor the movement of

employees in the production hall and control their health using an inspection system that is able to detect certain deviations in the movements and behavior of the employees. If an employee performed movements that could signal health problems, this system would alert the operator and operator could call for medical help.

5.2. Conceptual design

Robot working area - The basic requirement for risks elimination in production process was to design a device that will perform control of the production process in a predetermined workplace, will be fully programmable and its parts and components will not interfere with the built-up area of the production hall and will not limit workers and equipment in performing their tasks. The automotive production line for which the robot usage is designed is a floor plan in the shape of a square. The built-up area is approximately 20 x 20 m. Production CNC machines, which are located in the line, are maximum 3 m of high.

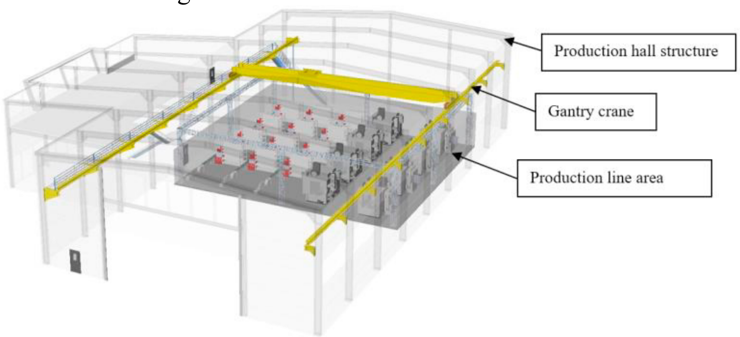


Fig. 4. Working area of designed robot

The robot platform will move above the production line in its workspace. The working space of the robot can be seen in Fig. 5. In ideal conditions, the robot winches could be placed in the upper corners of the production hall, but in the production hall for which the robot is designed there is a gantry crane and therefore it is not possible to place the winders in the corners of the production hall. From the top, the working space is bounded by the supporting structure of the device itself or circumferential dimensions of the structure itself. From below, the working space is bounded by production machines that form a built-up area in which the robot should not interfere.

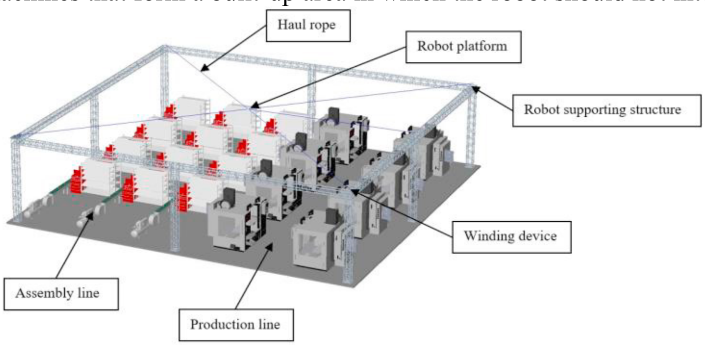
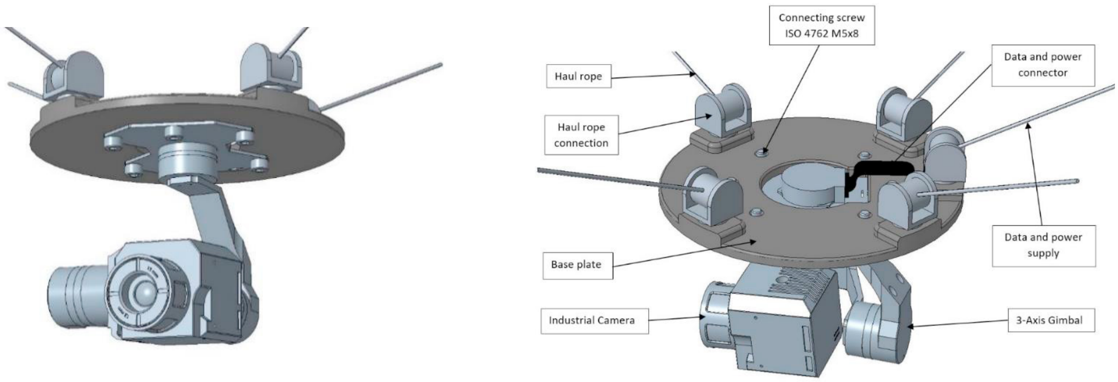


Fig. 5. Design of a Cable driven parallel robot used for risk elimination in automotive industry

5.3. Platform & effector

The platform is basically an effector of the cable driven robot, we can say it's a plate placed and stretched between the haul ropes. The platform can be made sheet metal. At the bottom of the platform can be placed a video capture device with live video transmission to the operator. Different types of sensors can also be placed on the platform to monitor the parameters of the production process. The construction of the robot effector is shown in Fig.6a.



a) b)

Fig. 6. Camera platform, a) Design of an effector, b) Assembly of a camera effector with 3-axis gimbal and industrial camera

To capture the production process in the production line, it is necessary to use an industrial camera that is equipped with a special stabilization device which eliminates shocks and tilts created when moving the platform in the workspace. The device is called a gimbal and it keeps the industrial camera in a stabilized position in all three axes, so that the resulting recording is completely stabilized. The use of a gimbal allows the camera to rotate around the axis and ensures the rotation of the camera to the desired location in the production line when changing the position of the effector in the workspace. Various sensors of the required parameters measured during the production process can also be placed on the robot platform. The platform can be fitted with temperature or gas concentration sensors for various vapors generated during the production process. The platform assembly with the industrial camera and gimbal is shown in Fig.6b.

6. Conclusion

This research is divided in two parts, in the first part were described definition and theory about risk management in transport and industry companies also options that are recommended for the treatment of risk.

In the second part of this research was made an overview of process control and was described what is possible to control and monitor with robotic device. As well as was made a conceptual design of cable driven parallel robot used for monitoring and inspection task for risk elimination in automotive industry.

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