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RISK MANAGEMENT IN MANUFACTURING PRACTICE USING THE POINT METHOD

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Miroslav Žitňák[1] – *orcid id: 0000-0001-6611-8077*
Maroš Korenko[2*] – *orcid id: 0000-0001-6191-1850*
Taras Shchur[3] – *orcid id: 0000-0003-0205-032X*
Paweł Kiełbasa[4] – *orcid id: 0000-0003-0249-8626*
Ľuboš Kazán[1]
Magdalena Mazur[5] – *orcid id: 0000-0003-3515-8302*

[1] Slovak University of Agriculture in Nitra, Faculty of Engineering, Institute of Agricultural Engineering, Transportand Bioenergetics, Nitra, **Slovakia**; miroslav.zitnak@uniag.sk
[2] Slovak University of Agriculture in Nitra, Faculty of Engineering, Institute of Design and Engineering Technologies, Nitra, **Slovakia**; maros.korenko@uniag.sk
[3] Cyclone Manufacturing Inc, Mississauga, Ontario, **Canada**; shchurtg@gmail.com
[4] University of Agriculture in Krakow, Faculty of Production and Power Engineering, Division of Mechanisationand Energy Technologies in Agriculture, Krakow, **Poland**; pawel.kielbasa@urk.edu.pl
[5] Czestochowa University of Technology, Department of Production Engineering and Safety, **Poland**, magdalena.mazur@pcz.pl

Abstract: This study delves into the critical process of risk management within manufacturing environments, emphasizing its role as a perpetual cycle influencing all organizational tiers. The research primarily addresses the identification, analysis, and mitigation of risks in specific occupational roles within a manufacturing company. A comprehensive risk assessment is conducted for these roles both pre and post the introduction of safety protocols. The study's practical application showcased a substantial diminishment of occupational risks, particularly highlighting a 46.37% reduction in the toolmaker-milling role. This significant decrease underscores the efficacy of the implemented safety measures and the importance of continual risk management in maintaining a safe and productive work environment.
Keywords: Risk Management, Manufacturing Safety, Occupational Hazards, Safety Protocols, Risk Reduction

1. INTRODUCTION

The significance of a safe and comfortable work environment cannot be overstated, particularly in the engineering industry, known for its heightened risk of occupational accidents. This industry, continually growing in Slovakia, sees an increase in both job opportunities and associated injuries. However, many preventive measures fall short in practice, emphasizing the need for a continuous cycle of risk management in organizations. Recent studies, like evaluation of ribbed wire manufacturing technology using a 3x3 matrix, shed light on the critical role of effective risk assessment and mitigation strategies in manufacturing (Borkowski et al. 2012). Despite advancements in machine safety, human error remains a major cause of accidents. The integration of findings from research on the effects of alloying methods on the structure and properties of sintered stainless steel highlights the importance of material choice in enhancing equipment safety and reducing risk (Dudek et al. 2017). Additionally, the work (Shyaa and Abbas, 2023) on job desertification explores the impact of cognitive biases and organizational structure on safety and productivity, underlining the importance of leadership in managing workplace hazards. In modern settings with advanced machines, human error remains the predominant cause of accidents, stressing the need for vigilant oversight and control (Ulewicz and Lazar 2019.).

A large part of our lives takes place in the work environment, so it is essential that we feel comfortable and safe there. Employers strive to provide for these needs, as employee satisfaction has a direct impact on employee productivity. The engineering industry is one of the areas with a higher risk of occupational accidents, which is still expanding in Slovakia, leading to an increase in jobs and injuries. However, it is often the case that the preventive measures proposed are ineffective and are only partially or not at all followed in practice. Occupational safety and health (OSH) management must be a continuous cycle of analysing and evaluating the activities already carried out in the organisation or planned for the near future (Patil et al., 2013,). The employer is motivated not only morally but also financially to pay attention to safety, because fewer accidents also mean less time lost during which machines are not standing still and producing profit. Today we have modern machines with a high level of safety, and therefore the greatest risk lies in human failure (Islam - Dong, 2008). Most accidents therefore happen as a result of inattention or lack of control.

2. CURRENT STATUS OF THE ISSUE AT HOME AND ABROAD

In many cases, risk management is often underestimated because many people do not realise its necessity and consider it less important (Tomlein, 2012; Kiselakova et al., 2015). Small businesses often show the greatest hesitation in implementing risk management because they perceive it as financially and time intensive. A common argument is that potential risks are already covered in project management and therefore there is no need to implement separate risk management (Padayachee, 2002; Somjai et al., 2019).

The effectiveness of occupational safety and health (OSH) depends heavily on identifying the causes and taking action to prevent deficiencies (Siddiqui et al., 2014). It is important to realise that workplace problems are not just the result of accidental errors, but are often related to poor task organisation, poor communication, lack of information and lack of a systematic approach (Marhavalis, 2011). Different methods can be used to assess the real state of OSH and to implement an OSH management system in small and medium-sized organisations. Among the criteria to be considered when providing an OSH analysis. (Turňová et al., 2012).

The general principles of prevention include: (Pecek, 2020)

- Elimination of threats and associated risks (Šolc, 2013),
- Risk assessment, particularly in relation to the selection and use of work tools, procedures, materials and substances,
- Implementation of strategies to address risks at their point of origin,
- Providing guidance to ensure occupational health and safety (Wang, 2018),
- Preferring group safety precautions over individual precautions (Sinay, 1997; Sinay, 2007)
- Considering human skills in workplace design and selection of work tools and practices to minimize the impact of hazardous factors on employee health,
- Planning and implementing a prevention strategy that includes the use of safe work technologies, tools and practices, as well as continuous improvement of workplace conditions. Working conditions in workplaces depend on environmental factors such as noise, dust, vibration (Górny, 2017)

The lifecycle of managing a process in an organization does not just end when it is plotted. It is important to continuously improve the process with a systematic approach, and for this continuous optimization it is appropriate to use the Deming cycle (PDCA). This cycle is universal and can be applied in all types and kinds of organisations (Džubáková et al., 2012).

The PDCA cycle represents a simple model with a meaningful concept, composed of four steps, which can be defined as an infinite circle. This cycle has no specific end and can be continuously repeated with the intention of continuous improvement. The model emphasises that the improvement process must begin with careful planning and continue with effective action in a continuous cycle (Marquis, 2009).

It is not usually possible to achieve immediate and significant improvements, because in some cases it is difficult to identify the problem itself, let alone propose solutions and fixes. Thorough use of the PDCA cycle brings some improvements, as this method is aimed at systematically improving any process (Marquis, 2009).

3. THE AIM OF THE WORK

The aim of this study is the management of risks in specific job positions in a company focused on engineering. This process involves the identification of potential hazards and threats that are present in selected job positions and may, in certain situations, endanger the health of individuals. Using a scoring method, we determined the level of risk and based on this level, we proposed safety measures. After the implementation of these precautions, the risk level is reassessed to verify whether the measures taken were effective or not.

4. METHODOLOGY OF THE RISK ASSESSMENT METHOD USED

The simple scoring method works with semi-quantitative risk assessment. Its principle is to describe each risk in writing and assign numerical values for probability (Table 1) and consequence (Table 2). The product of these values defines the level of risk (Table 3). In this way, based on the values identified in the respective tables, the probability of an adverse event occurring and its negative impact on individuals or the environment is identified (Bujna et al., 2018).

The scoring method uses a semi-quantitative approach to risk assessment. It is based on describing each risk in words and assigning numerical values for probability (Table 1) and consequence (Table 2). Multiplying these two values determines the level of risk (Table

3). Based on the defined values in these auxiliary tables, the probability of the occurrence of the negative phenomenon and its impact on persons or the environment is determined (Bujna et al., 2018).
Risk is determined by a basic definition: R = P x D
The value obtained will determine the severity of each risk, whether the risks are acceptable or need to be mitigated by the use of protective measures.

Table 1
Categorisation of probability

P-value	Probability	Occurrence	Threats
1	very low	almost excluded	almost impossible
2	low	unlikely	very rare
3	medium	sometimes during the lifetime of the equipment	rare
4	high	several times during the lifetime of the device	temporal
5	very high	very frequently	continuous

Source: (STN EN ISO 31 000)

Table 2
Categorisation of consequence

D-value	Consequence	Description
1	insignificant	less than minor injury
2	not significant	a minor accident or the onset of an occupational disease
3	critical	serious accident or occupational disease
4	catastrophic	killing

Source: (STN EN ISO 31 000)

Table 3
Resulting risk value

Value	Risk	Description
1 – 3	acceptable	The system is secure.
4 – 11	slightly	The system is safe if the operator is trained.
12 – 15	undesirable	The system is dangerous, protective measures must be applied.
16 – 20	unacceptable	The system is unacceptable.

Source: (STN EN ISO 31 000)

5. RESULTS OF WORK

The analysis presented in the article was made for a toolmaker's position in the milling process. The DMG MORI 75 (Fig.1 and 2) milling centre has been designed and manufactured in accordance with current safety and technical standards and regulations, as well as the requirements and specifications set out in the Machinery Directive 2006/42/EC. The machine is designed with operational safety in mind, however, situations may arise that could endanger health and life.

Fig. 1. Milling centre DMG MORI 75 (Author's archive)

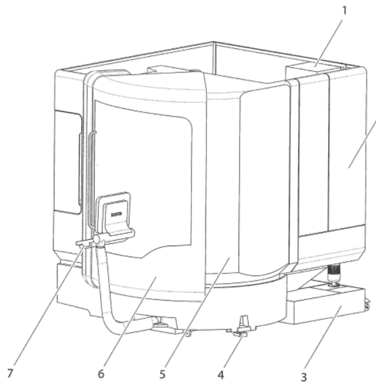

Fig. 2. Main parts of the DMG MORI 75 - 1 - Heat exchanger, 2 - Liquid supply, 3 - Waste tank for swarf collection, 4 - Installation elements, 5 - Cabin, 6 - Safety door, 7 - Control panel (Company's internal documentation)

Table 4

Risk assessment for safety door failure

Hazards	Threats	P	D	R	Measures	P	D	R
Failure of the safety door in the event of deliberate disablement.	Severe bodily injury caused by a limb being caught and dragged by a moving part of the machine.	3	3	15	Regular checking of the functionality of the machine's safety features (Fig. 3 - safety doors). Functional test of emergency unlocking of safety doors every 1000 hours. Functional test of the tool tray door interlock switch every 500 h. Functional test of the work area door interlock switch every 500 hours.	2	3	11

Source: own study

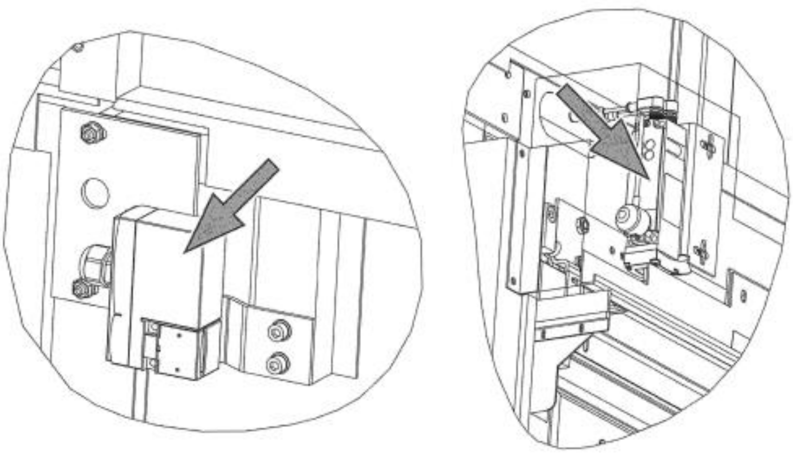

Fig. 3. Door interlock switches (Company internal documentation)

During the machining process, there is a risk of breakage of the tool or workpiece, whereby fragments can be scattered into the work area and may even hit the protective safety shield (Table 5). The shield serves to absorb energy and in most cases deforms. If the operator is in the vicinity, serious injuries can occur. The safety shield consists of a polycarbonate layer that is bonded to a sheet of silica glass throughout. The outer side of the polycarbonate is additionally protected by a protective film that prevents contact with aggressive substances and thus prevents the material from ageing and possible damage.

Table 5
Tool or workpiece breakage risk assessment

<table>
<tr><th>Hazards</th><th>Threats</th><th>P</th><th>D</th><th>R</th><th>Measures</th><th>P</th><th>D</th><th>R</th></tr>
<tr><td>Dislocation, collision or breakage of the fixture, tool or workpiece.</td><td>Serious bodily injury caused by the impact of broken parts in the event of a collision.</td><td>4</td><td>3</td><td>16</td><td rowspan="2">Operate the machine only in accordance with the operating parameters.
Maintain a safe distance from the protective shield (min. 200 mm).
Regular checking of the functioning of the safety features of the machine (protective shield). (Mechanical cleaning of the shield every 8 h).
Only insert and clamp materials into the clamping device whose size and shape allow perfect clamping.</td><td>2</td><td>3</td><td>11</td></tr>
<tr><td>Incorrect or insufficient clamping of the workpiece.</td><td>Serious bodily injury caused by ejection and striking the operator.</td><td>3</td><td>3</td><td>15</td><td>2</td><td>3</td><td>11</td></tr>
</table>

Source: own study

Safety shields must be checked at regular intervals according to the following procedure:

1. The machine shall be disconnected from the mains supply and the disconnection device shall be secured by a padlock.
2. The safety shield must be visually inspected inside and outside for possible damage.
   a) If cracks or severe cloudiness of the shield are found, immediate replacement with a new piece must be made.
   b) If no damage has been found, the safety shield must be replaced every 5 years.

Table 6
Risk assessment for machine set-up

Hazards	Threats	P	D	R	Measures	P	D	R
Control of the machine by setting panel or handwheel and operator contact with the machine axes and working spindle.	Bruising, catching or entanglement of limbs in the work area by moving and rotating machine parts.	3	3	15	Periodic check of the functionality of the machine's safety features (emergency stop button). (Functional test of the emergency stop button every 250 h) Observance of the safety distance. The machine may only be operated in operating mode 3 (with the door open) by an authorised person with appropriate training.	2	3	11

Source: own study

In an organisation, it is essential to define precise competencies that clearly set out the operator's responsibilities and determine who has the right to carry out work tasks on a particular machine. Each person responsible for working on this equipment has a duty to thoroughly read and understand the operator's manual, which includes safety guidelines.

Table 7
Risk assessment for the presence of liquids, splinters and power lines in the vicinity of the machine

Hazards	Threats	P	D	R	Measures	P	D	R
Working fluids (coolant and cutting oils) around the machine.	Injury resulting from a slip or fall.	4	2	12	Avoiding excessive use of these liquids. Fitting the workplace with rubber non-slip grates (Fig. 4). Use of safety non-slip footwear.	2	2	7
Remnants of steel chips found around the machine.	Cutting or puncturing of the lower limbs, in case of penetration of splinters into the footwear.	5	2	14	Use of appropriate personal protective equipment (safety footwear) as specified by Government Regulation No. 395/2006 Coll.	1	2	4
Loose storage of compressed air hoses around the machine.	Injury resulting from tripping.	4	2	12	The hoses must be suitably spaced and stowed. Always store the compressed air gun in its place after work.	1	2	4
Disposal of steel chips.	Cutting by sharp edges of chips and eye contact in case of blowing with compressed air.	4	3	16	Prohibition of cleaning the machine work area with compressed air. Use tools that are designed for cleaning (brush, broom or industrial vacuum cleaner). During disposal, use appropriate personal protective equipment (protective gloves) as specified in Government Regulation No. 395/2006 Coll.	2	2	7

Source: own study

Fig. 4. Rubber grid (Author's archive)

Table 8
Risk assessment for activities in the machine work area

Hazards	Threats	P	D	R	Measures	P	D	R
Residues of working fluids in the work area.	Slipping of the tool in the work area, which can cause bodily injury (cuts, punctures).	5	2	14	The use of appropriate personal protective equipment (safety shoes, clothing and safety glasses) as specified in Government Regulation No. 395/2006 Coll. Ensure control of the use of such equipment (§ 9 Control activities of Act 124/2006 Coll.).	3	2	10
Steel chips located in the working area of the machine.	Bodily injury by sharp splinters (cuts, pricks).	5	2	14		1	2	4
Inserting machine tools into the headstock.	Cutting and stabbing injuries to the extremities by inadvertent contact with the cutting edge of the tool.	4	2	12	When inserting tools into the head, use suitable personal protective equipment (protective gloves) specified by Government Regulation No. 395/2006 Coll.	2	2	7
The drop of the vertical or inclined axes in the no-energy state.	bruises, cuts, punctures, stings, fractures	3	3	15	Operation of the machine with the optional power loss or blackout protection package. Maintaining a safe distance.	1	3	6
Uncontrolled shutdown of machine drive control systems in the event of a power failure.	contusions, fractures	3	3	15	Entry into the space is only permitted after the work spindle has come to a complete stop.	2	3	11

Source: own study

When identifying hazards, we must not forget the activities carried out in the working area of the machine (Tables 8 and 9). The operator is obliged to keep the safety pictograms located on the machine in perfect, clean and legible condition and to replace them immediately in case of damage.

Table 9
Risk assessment for chip evacuation and capture

Hazards	Threats	P	D	R	Measures	P	D	R
Automatic start-up of the conveyor for chip removal from the working area of the machine.	Catching, crushing or trapping of limbs by moving parts of the conveyor.	3	3	15	- Operation of the conveyor is permitted only if a catch basin is constructed under the waste shaft to close off access to the shaft from all sides.	2	2	7

Source: own study

In the case of chip conveyor maintenance, it is necessary to:

a) Before starting the actual maintenance, the machine must be disconnected from the mains supply.
b) The disconnection device must be secured with a padlock to prevent reconnection (Table 10).

Table 10
Risk assessment for the restoration or occurrence of electrical voltage

Hazards	Threats	P	D	R	Measures	P	D	R
Unexpected start-up of the machine after power is restored.	Catching or crushing of the operator by moving parts of the machine.	3	3	15	The use of an additional protective device that prevents the machine from starting up in the event of power being restored. Securing the zero position of the main switch. Regular checking of the functioning of the safety features of the machine (emergency stop button).	2	3	11
Dangerous electrical voltages.	Body contact with living particles.	4	3	16	Marking these areas with a "NO ENTRY" sign. The places must be equipped with a suitable fire extinguisher as specified by Decree No 347/2022 Coll.	2	3	11

Source: own study

Table 11
Risk assessment for machining magnesium alloys

Hazards	Threats	P	D	R	Measures	P	D	R
Machining of metals and alloys with a certain proportion of magnesium.	Fire, explosion or ignition due to the formation of explosive and ignitable particles. Magnesium and swarf particles form hydrogen when mixed with water.	5	3	18	The places must be equipped with a suitable fire extinguisher as specified by Decree No. 347/2022 Coll. Provide the machine with a suitable extraction device and ensure that it is checked regularly (visual check of filter contamination and visual check of exhaust air fan contamination every 250 hours). Use of alkaline emulsions resistant to magnesium (high water hardness). Compliance with magnesium safe machining principles.	1	3	6
Carbon fiber machining.	Health hazard from inhalation of released particles of fibrous dust.	5	2	14	Provide the machine with a suitable extraction device (Fig. 5)	1	2	4

Source: own study

Principles of safe machining of magnesium using emulsion:

- It is essential to ensure effective chip evacuation to prevent chip accumulation. The conveyor must be regularly monitored.
- Containers specifically designed to trap magnesium chips with water must be used and have adequate openings for hydrogen removal.
- The top of the machine must contain openings to ensure that the hydrogen is removed even when the machine and its accessories are not in operation.

- It is essential to ensure a high flow of alkaline lubricating and cooling emulsions to minimise hydrogen generation (Table 11).
- Lubricants having a high flash point may be used.

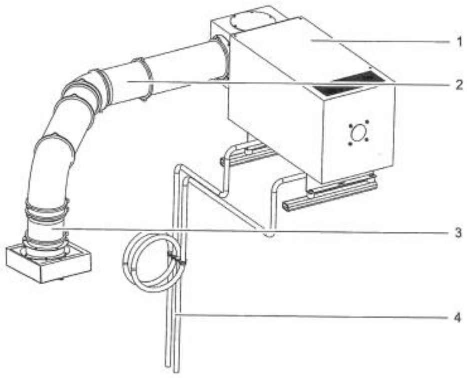

Fig. 5. Extraction equipment - 1 - Emulsion and oil mist extractor, 2 - Suction pipe, 3 - Suction throat, 4 - Return pipe (Company internal documentation)

Principles of safe magnesium machining without the use of emulsion

- The machine must be equipped with an extractor hood and a wet dust and swarf separator.
- Dust deposits must be prevented as dust is explosive.
- Continuous monitoring of the suction power.
- The use of compressed air is strictly prohibited.

Table 12
Risk assessment for poor ergonomic principles, clutter and inadequate lighting

Hazards	Threats	P	D	R	Measures	P	D	R
Inadequate workplace lighting and reduced visibility of the work area.	Visual strain and increased likelihood of making a mistake.	3	3	15	Ensure sufficient lighting of the workplace with an intensity of 300 to 1000 lux according to Decree 541/2007 Coll. Observe regular cleaning of visors and lighting equipment (machine cleaning every 8 hours).	1	2	4
Poor ergonomic principles.	Increased operator fatigue when operating the machine in physiologically inappropriate positions and the onset of occupational disease.	4	2	12	Equipping the workplace with seats that meet ergonomic requirements (seat with backrest and height adjustment).	2	2	7
Lack of order on and around the desk.	Injury to the lower limbs as a result of an object falling from a height.	5	2	14	The use of appropriate personal protective equipment (safety footwear) as specified in Government Regulation No. 395/2006 Coll. Regular cleaning of the workplace.	2	2	7

Source: own study

In our risk analysis, we identified that the toolmaker - milling position faces the most significant hazard when handling magnesium alloys. If basic safety standards are not adhered to, there is the possibility of hydrogen gas formation, which is explosive when particles of swarf and water mix. For this reason, it is crucial to use adequate extraction equipment and to ensure that it is checked regularly (see Table 11). The measures proposed for the toolmaker - milling position proved to be effective as we successfully reduced the risk by 46.37%.

6. DISCUSSION AND CONCLUSION

Žitňák (2020) emphasizes the legal obligation of the employer to regularly inspect the state of safety in the workplace, where we have followed up on this obligation. The regular inspection of the activity is carried out according to § 9 of the Inspection Activity of the Act 124/2006 Coll. The work analyzed hazards on a rotor production line, identifying risks including injuries from sharp and moving machine parts, electrical interference, improper use of compressed air, and inadequate lighting. Similar hazards were identified in our risk assessment: injury from moving machine parts while setting up the machine (Table 6), inadequate lighting with higher visual stress and increased likelihood of errors (Table 12), limiting the use of compressed air to clean the work environment (Table 7), and marking areas with electrical voltage as strictly off-limits (Table 10).

Pačaiová et al. (2019 and 2021) using the FMEA method on a manual lathe, he found that insufficient maintenance of the machine and its structural parts is the main risk of the working process. This finding agrees with our conclusions, where we found that regular and proper maintenance at regular intervals can eliminate a number of hazards. In the work identified the high risk associated with unexpected machine start-up in the presence of a person carrying out maintenance or replacement of machine parts. Similarly, we have noted this risk (Table 12) and classified it as a high hazard risk, which requires a thorough check of the safety features of the machine and the provision of an emergency stop when entering the work area.

Kotus et al. (2017) list protective features such as guards, interlocking devices, safety devices, and tripping devices as the most commonly used types of protective devices. We identified these elements on our evaluated machines and focused on checking them regularly (Tables 4, 5 and 6).

The manufacturer of a new machine assumes gradual wear and tear of its components and therefore recommends precise checks of these parts at certain intervals. Practice shows that these checks are not observed, exposing the operator to unnecessary risks. The main emphasis is on the safety features of the machine on which the operator relies and which should be reliable in the event of danger. Fatal consequences can occur if these elements are not in the correct condition in critical situations. Regular checks and systematic risk management can prevent this problem. This work therefore focuses in particular on the regular inspection of safety features.

By assessing the risk in the toolmaker - milling position, we identified the greatest risk in machining magnesium alloys, where there is a risk of explosive gas - hydrogen. The proposed measures focus on the control of the safety features of the machine, which are often not sufficiently maintained. Other proposed measures include compliance with basic safety rules, the use of personal protective equipment and regular inspections by the employer. These measures have significantly reduced the risk in the toolmaker - milling position by 46.37%. These results indicate a significant improvement in the overall safety performance of the organization and with compliance, a reduction in accidents is likely. The risk management evaluation confirmed the hypothesis that the measures taken were effective.

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