OHS RISK ASSESMENT IN THE EDM PROCESS

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ABSTRACT: This paper evaluates occupational health and safety (OHS) risks in the electrical discharge machining (EDM) process and examines how different operational scenarios affect these risks. Building on a previous study, four scenarios were tested to determine the most efficient setup in terms of machining time, material removal rate (MRR), and electrode wear rate (EWR), and the most favourable one was identified. The methodology includes mapping the EDM process flow, linking activities to potential risks, assessing probability and severity using a risk matrix, and proposing preventive measures to reduce hazards. The study highlights the scenario that best balances efficiency and safety, demonstrating that proper risk management can optimize employee well-being.
KEYWORDS: EDM process, risk assessment, OHS risks

1. INTRODUCTION

The purpose of this paper is to evaluate the occupational health and safety (OHS) risks that are typically associated with the electrical discharge machining (EDM) process, a widely used method for high-precision machining of hard materials. EDM is well-known in the industry for its ability to produce complex shapes and fine surface finishes that are difficult to achieve with traditional machining. However, like any industrial process, it involves certain risks for employees, including electrical hazards, burns, exposure to dielectric fluids, noise, and ergonomic issues. Understanding these risks is essential to ensure a safe working environment while maintaining process efficiency.

EDM raises sustainability challenges related to operator safety, energy consumption, and environmental impact, which is why this research focuses on assessing risks to operators under certain conditions. This study builds on a previous analysis [1] where the EDM process was examined under four different operational scenarios. Each scenario involved changing key process parameters—voltage, peak current, and pulse-on time—to find the most efficient setup in terms of material removal rate, electrode wear, and machining time. The previous results showed that Scenario 3, with minimum voltage combined with high peak current and pulse-on time, offered the best overall performance: it provided the highest material removal rate, the lowest electrode wear, and the shortest machining time.

In this paper, we use the same four scenarios to evaluate the related OHS risks. The goal is to identify which scenario offers the best combination of efficiency and safety. By analyzing the risks in each scenario, we aim to find a setup that ensures both high productivity and a safe working environment for operators during the EDM process.

This analysis is especially relevant for companies where employee well-being and technological efficiency must go hand in hand. By combining risk assessment with process optimization, this paper offers practical guidance for selecting EDM parameters that minimize occupational hazards without reducing machining performance.

2. LITERATURE REVIEW

Into the next lines, we will approach what the specialized literature exists regarding this topic.

The paper [2] highlights the urgent need to adapt EDM manufacturing processes not only to sustainability and climate neutrality requirements, but also to improving operator safety, by reducing toxic fume emissions and creating a cleaner working environment.

EDM process can be highly efficient, but this does not guarantee the safety and health of the operators. For example, [3] the use of kerosene improves performance but creates health risks and handling difficulties. In contrast, environmentally friendly alternatives, such as deionized water or a mixture of powder with water, provide safer and more sustainable processing, even if operational performance is not always optimal.

The authors in [4] address the EDM process with additive manufacturing emphasizing on sustainability and efficiency. They also discuss recent advances in the use of environmentally conscious dielectric fluids, energy-optimized techniques, and dry EDM, highlighting their potential to reduce environmental impact and support green manufacturing on an industrial scale.

Moreover, EDM process is directly connected with major problems related to health of employees. To respond to this challenge, the research [5] tested how different fluids can be more sustainable for the process and risk reduction. Although choosing the right dielectric and process parameters control can increase the productivity, the quality of life and the safety of the operators.

According to [3] and [6] process parameters are negatively influencing the emissions that the operator is exposed to in the EDM process. So, a high peak current and a long pulse on time are increasing the risk of inhaled those emissions. Similarly, the findings in [7] indicate that discharge current and pulse duration are the most important parameters for MRR, and the use of high-conductivity electrodes and powder dielectrics improves both MRR and surface quality. The paper shows that the use of reusable dielectric fluid and optimal parameters allows for reduced energy consumption, high precision surfaces, and large-scale production. [8]

The paper [9] shows that unconventional process audits and real-time monitoring in EDM not only improve accuracy and efficiency but also contribute to operator safety by identifying problems early and reducing process-related risks. The implementation of risk-based methodologies and appropriate staff training are essential to prevent accidents and exposure to hazardous conditions. Thus, EDM process optimization can combine operational performance with employee health protection.

3. METHODOLOGY

The methodology used follows several essential steps for evaluating the OHS risks, as it can be seen in the figure below:

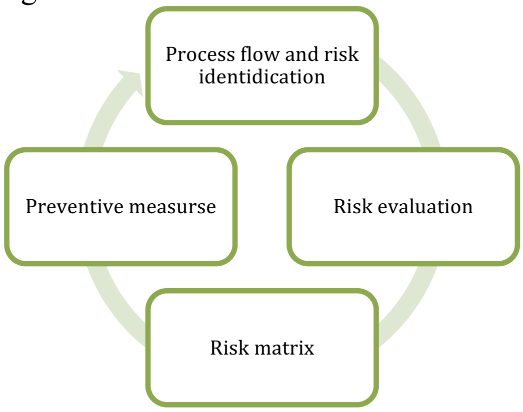

Figure 1 Methodology for evaluation of OHS risks

Step 1 – Process flow and risk identification: In the first step, the process flow of the EDM process is established. Based on the steps of this process, the main activities are correlated with possible risks for the operators, as already identified in the previous paper[1]. As is known, efficiency is very important for a company. Scenario 3 was previously identified as the most efficient, with low machining time, high material removal rate (MRR), and low electrode wear rate (EWR). In this research, we aim to see how different scenarios impact the OHS risks.

Step 2 – Risk evaluation by impact and probability: In the second step, the risks are evaluated by their impact and probability of occurrence. Both impact and probability are linked with the four scenarios already defined in the previous paper, where the process parameters were tested to obtain values for machining time, MRR, and EWR, as it can be seen in the table below.

Table 1 Results from the EDM scenarios

Parameters/scenarios	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Machining time (T)	1.09 Medium	0.3 Low	0.28 Low	3.74 High
MRR	0.67 Low	2.27 High	1.96 High	0.10 Low
EWR	0.11 Low	1.83 High	0.25 Low	0.22 Low

In this step, we will evaluate the risks by impact and probability involving a justification for each score in different scenarios. After, we can draw few hypotheses, and establish which scenario is safer for employees.

In the third step, the risks defined will be evaluated by using risk matrix, where impact and probability evaluation, will place the risk in sustainable, moderate, severe and critical. We will do this, in order to find which is the safer scenario for employees to work.

The next step involved preventive measures sets in order to decrease the risks and reevaluate if the measures are feasible for all the scenarios. Also, we want to see where the measures have the best impact in decreasing the risks.

The purpose of the paper is to be able to draw some conclusion, if the efficiency of the company is directly link with the safer environment.

4. ANALYSIS AND DISCUSSION

- Defining the process steps and the risks in EDM process

The first step is describing the EDM steps of the process and to connect them with the potential risks that operators are facing. Defining the process does not only mean describing the technological operations of EDM, but also to highlight how the operator interacts with the process, because the focus of this research is on occupational health and safety risks. By looking at the process from this perspective, the risks can be identified more precisely and correlated with the actual activities performed by the employees. The process flow for the EDM process is illustrated in the figure below.

The steps included in this flow are focused mainly on the actions performed by the operator rather than on the full set of technical steps of the EDM process itself. The reason is that in this paper the analysis is cantered on the risks related to the safety and health of the people who work with the equipment, and not on describing all the technological risks that EDM as a process may involve.

Based on the sequence presented in the figure, the next table summarizes the main risks that employees can be exposed to during each step of the process, together with the potential reasons those risks can occur.

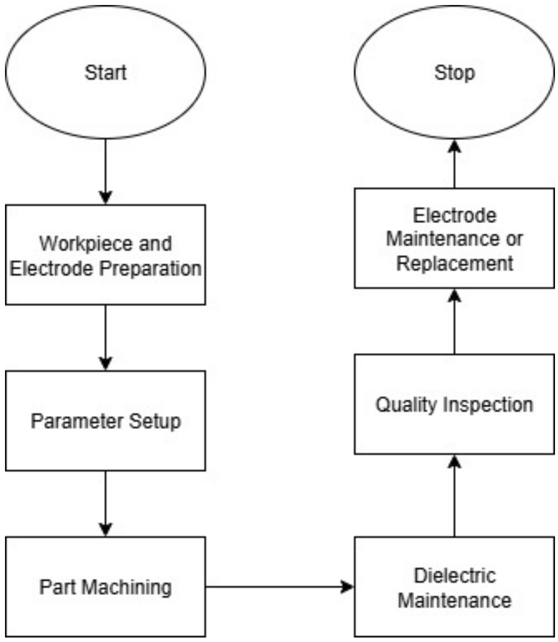

Figure 2 Process flow of EDM

Table 2 Associated risks of EDM process and potential causes

Process steps	Associated risks	Cause
Workpiece and Electrode Preparation	Cutting/crushing when handling parts	Handling without protective gloves, improper lifting of heavy/unstable parts, incorrect clamping of workpiece/electrodes
Parameter Setup	Danger of electric shock	Contact with uninsulated cables, defective insulation, improper grounding, touching energized parts during setup
Part Machining	Accidental burns caused by sparks and hot surfaces,	Contact with the machining zone immediately after discharge, projection of hot particles, absence of protective screens
Dielectric Maintenance	Irritation of the skin/eyes through chemical exposure or inhaling dielectric microparticles	Direct contact with dielectric fluid, vapours generated during EDM process, insufficient ventilation, contaminated/dirty dielectric fluid
Quality Inspection	Noise and vibration, Injuries from bad posture, eye strain	Long exposure to noisy machines, non-ergonomic workstation, prolonged visual effort without breaks
Electrode Maintenance or Replacement	Hot electrode replacement burns	Handling electrodes immediately after machining, lack of thermal protection equipment, improper storage of hot electrodes

In the table above also can be seen the causes of each risk involved to happen. Those causes will help us evaluate the probability of happening of those risks involving the cause and justifying each grade in the next step.

- Evaluating the probability of happening of each risks by different scenarios

In this section, the risks identified above will be evaluated by the probability of happening in different scenarios established in the previous paper.

First scenario

In the first scenario, all process parameters were set at average levels, resulting in medium machining time, low material removal rate (MRR), and low electrode wear rate (EWR).

Given this context, the probability of the previously identified risks occurring is evaluated on a 1–5 scale, where 1 means very unlikely, 2 means unlikely but possible, 3 indicates medium probability, 4 means likely, and 5 indicates very likely.

The table below presents the evaluated risks.

Table 3 Risks evaluation in first scenario

Risk	Impact S1	Prob. S1	Justification
Cutting/crushing when handling parts	3	2	Low MMR and low EWR mean fewer handling operations, keeping probability low, but injuries can still be significant, so the impact is medium.
Danger of electric shock	4	2	Medium parameters and low EWR reduce discharge frequency, but a single electric shock could be severe, making the impact high.
Accidental burns caused by sparks and hot surfaces,	3	2	Low MMR and low EWR reduce the number of sparks and hot surfaces, lowering probability, but burns remain moderately severe when they occur.
Irritation of the skin/eyes through chemical exposure Inhaling dielectric microparticles	3	2	Low EWR generates fewer contaminating particles, decreasing exposure risk, but health effects from irritation can still be moderately harmful.
Noise and vibration, Injuries from bad posture, eye strain	2	2	Low MMR leads to longer monitoring times with limited ergonomic strain, so both probability and impact remain low.
Hot electrode replacement burns	3	2	Low EWR means fewer electrode changes, lowering probability, but handling a hot electrode can still cause moderate burns.

Lower EWR and MRR reduce the frequency of unsafe events and keep the impact of those risks at a medium average in Scenario 1. This happens because an average set of parameters makes the employees' environment safer. However, this scenario is not efficient, as the material removal rate is low and production is not as effective as expected. In addition, machining time is short, so even if the number of workpiece or electrode changes is low, this is still not enough to ensure optimal efficiency.

Second scenarios

In this scenario, all process parameters were set to their maximum values, resulting in shorter machining time, higher material removal rate (MMR), and higher electrode wear rate (EWR). Given this context, the impact and probability of occurrence of OHS risks is evaluated in the table below:

Table 4 Risks evaluation in second scenario

Risks	Impact S2	Prob. S2	Justification
Cutting/crushing when handling parts	3	4	High EWR and MRR require frequent adjustments of the workpiece and electrode, which raises the probability of handling accidents, while the impact remains medium because injuries can still be significant.
Danger of electric shock	5	5	Maximum machining parameters and high EWR increase electrical activity, making shocks very likely, and the impact is severe due to the high currents involved.
Accidental burns caused by sparks and hot surfaces,	5	5	High MRR and strong discharges generate many hot particles and high surface temperatures, leading to very frequent burn risks with potentially severe consequences.
Irritation of the skin/eyes through chemical exposure Inhaling dielectric microparticles	4	5	High MRR and EWR produce large amounts of particles contaminating the dielectric, making exposure highly probable, with a significant impact.
Noise and vibration, Injuries from bad posture, eye strain	2	3	The aggressive machining process generates more noise and vibration and requires more frequent monitoring, raising ergonomic risks, but the impact stays low.
Hot electrode replacement burns	4	5	High EWR leads to more frequent electrode changes, increasing the risk of burns during handling, with a high impact if such burns occur.

In this scenario, the process is aggressive and unstable, requiring frequent operator interventions to maintain proper operation and prevent malfunctions. Each intervention exposes the operator to potential hazards, increasing the likelihood of occupational health and safety (OHS) risks. Moreover, the aggressive process parameters intensify the consequences of any incident, making the impact of all identified risks more severe. As a result, while the process may achieve higher productivity, it simultaneously increases the probability and the impact of accidents.

Third scenario

In this scenario, the EDM process parameters were set as follows: minimum voltage, with peak current and pulse-on time at high levels. These settings result in a short machining time, a high material removal rate, and low electrode wear. Given this context, the impact and probability of each risk is evaluated in the table below.

Table 5 Risks evaluation in third scenario

Risks	Impact S3	Prob. S3	Justification
Cutting/crushing when handling parts	3	3	Low EWR limits electrode handling, but frequent workpiece changes caused by shorter machining time increase accident probability, while the impact remains medium.
Danger of electric shock	4	2	Low voltage reduces the likelihood of shock, but the presence of high peak current and pulse-on time makes the potential impact high if it occurs.
Accidental burns caused by sparks and hot surfaces,	4	3	High MRR and long pulse-on time generate more hot particles, raising the probability of burns, and the impact is high due to severe possible injuries.
Irritation of the skin/eyes through chemical exposure **Inhaling dielectric microparticles**	3	3	High MRR and long pulse-on time contaminate the dielectric with more particles, increasing exposure probability, with a medium impact on operator health.
Noise and vibration, Injuries from bad posture, eye strain	2	2	Shorter machining time requires more frequent inspections, but the lower voltage reduces overall noise and vibration, keeping both probability and impact low.
Hot electrode replacement burns	3	1	Low EWR reduces the frequency of electrode changes, making burns unlikely, although the impact remains moderate if they occur.

In Scenario 3, the overall risk evaluation is moderate. The process is efficient, resulting in a short machining time, which still requires operator interventions for adjustments or workpiece changes, increasing the probability of risks. The high peak current raises the potential impact of electric shock and burns from particles or hot surfaces, even though the voltage is minimal.

Forth scenario

In this scenario, the parameters are set to low peak current and high pulse-on time. These settings result in a longer process with high machining time, low material removal rate, and low electrode wear. The discharges are weak but extended, making the process less harmful but inefficient, with minimal electrode wear and low material removal.

Table 6 Risks evaluation in forth scenario

Risks	Impact S4	Prob. S4	Justification
Cutting/crushing when handling parts	3	2	Low MRR and low EWR reduce the frequency of operator interventions, lowering the probability of cutting or crushing. The impact remains medium because injuries could still occur if an accident happens.
Danger of electric shock	4	2	Low peak current reduces the probability of electrical hazards. The impact is high because, despite the low likelihood, any shock could be serious due to high voltage peaks at discharge.
Accidental burns caused by sparks and hot surfaces,	2	3	High pulse-on time produces weak but prolonged discharges, slightly increasing the probability of burns. The impact is low

Risks	Impact S4	Prob. S4	Justification
			because the weak discharges are unlikely to cause severe injury.
Irritation of the skin/eyes through chemical exposure Inhaling dielectric microparticles	3	2	Low MRR and low EWR generate fewer particles, reducing the probability of exposure. The impact is moderate because irritation could still affect operator health over time.
Noise and vibration, Injuries from bad posture, eye strain	3	4	Longer machining time requires extended monitoring, increasing the probability of ergonomic risks. The impact is medium because prolonged exposure can lead to discomfort or minor injuries.
Hot electrode replacement burns	2	1	Low EWR reduces the frequency of electrode changes, making burns very unlikely. The impact is low because any burns that occur would likely be minor.

Although Scenario 2 may appear more sustainable, it is actually the least efficient. Moreover, risks are still present. Consequently, implementing Scenario 4 is not justified, as it would combine low efficiency with risks of moderate to low probability and impact, making the effort disproportionate to the benefits.

- Risk matrix

After evaluating the risks based on their impact and likelihood of occurrence, we calculate the overall risk level using the risk matrix shown in the figure below.

Rows represent impact on a scale from 1 (low) to 5 (critical), while columns represent probability from 1 (very unlikely) to 5 (very likely). Combining these values gives the overall risk, classified as sustainable, moderate, severe, or critical.

Severe and critical risks are generally unacceptable in organizations and require preventive measures.

Impact:		1	2	3	4	5
Probability	5	Moderate	Severe	Severe	Critical	Critical
	4	Sustainable	Moderate	Severe	Critical	Critical
	3	Susteainable	Moderate	Moderate	Severe	Critical
	2	Sustainable	Sustainable	Moderate	Severe	Critical
	1	Sustainable	Sustainable	Sustainable	Moderate	Severe

Figure 3 Risk matrix evaluation guide

In the next figure, all risks are assessed within the presented scenarios, providing an overall evaluation for each risk in each scenario.

				Impact				Probability				Risk rating			
Unique ID	Process step	Risk Description	Consequences	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
1	Workpiece and Electrode Preparation	Cutting / crushing when handling parts	Handling without protective gloves, improper lifting of heavy/unstable parts, incorrect clamping of workpiece/electrodes	3	3	3	3	2	4	3	2	Moderate	Severe	Moderate	Moderate
2	Parameter Setup	Danger of electric shock	Contact with uninsulated cables, defective insulation, improper grounding, touching energized parts during setup	4	5	4	4	2	5	2	2	Moderate	Critical	Moderate	Moderate
3	Part Machining	Accidental burns caused by sparks and hot surfaces,	Contact with the machining zone immediately after discharge, projection of hot particles, absence of protective screens	3	5	4	2	2	5	3	3	Moderate	Critical	Severe	Moderate
4	Dielectric Maintenance	Irritation of the skin/eyes through chemical exposure	Direct contact with dielectric fluid, vapours generated during EDM process, insufficient ventilation, contaminated/dirty dielectric fluid	3	4	3	3	2	5	3	2	Moderate	Critical	Moderate	Moderate
5	Quality Inspection	Noise and vibration, Injuries from bad posture, eye strain	Long exposure to noisy machines, non-ergonomic workstation, prolonged visual effort without breaks	2	2	2	3	2	3	2	4	Sustainable	Moderate	Sustainable	Severe
6	Electrode Maintenance or Replacement	Hot electrode replacement burns	Handling electrodes immediately after machining, lack of thermal protection equipment, improper storage of hot electrodes	3	4	3	2	2	5	1	1	Moderate	Critical	Sustainable	Sustainable

Figure 4 Risk ratings of each OHS risks in each scenario

The first risk, cutting or crushing while handling parts, is sever is scenario 2. Although, in S1, 3, and 4 is moderate. So between those scenarios, the most efficient one is the Scenario 3.

The second risk, electric shock, is critical in Scenario 2 but acceptable in Scenarios 1, 3, and 4. Among these, Scenario 3 is the most efficient.

Accidental burns from electric shocks are critical in Scenario 2, severe in Scenario 3, and moderate in Scenarios 1 and 4. Even though the risk is moderate in Scenarios 1 and 4, these scenarios are inefficient.

Skin or eye irritation from chemical exposure is critical in Scenario 2 and moderate in the other scenarios. Among Scenarios 1, 3, and 4, Scenario 3 is the best option due to shorter machining time, higher material removal, and low electrode wear.

Noise, vibration, injuries from poor posture, and eye strain are severe in Scenario 4, moderate in Scenario 2, and sustainable in Scenarios 1 and 3. Between the scenarios with sustainable risk, Scenario 3 is more efficient for the company. Combined with low OHS risks and machining efficiency, Scenario 3 stands out as the best choice.

Burns from hot electrode replacement are critical in Scenario 2, moderate in Scenario 1, and sustainable in Scenarios 3 and 4. Between Scenarios 3 and 4, Scenario 3 is the better option. Above (figure 4) is an example of another numbered list.

Among all the assessed scenarios, Scenario 3 proves to be the most balanced and efficient option. While Scenario 4 shows some sustainable risks, it is inefficient in terms of time and material removal. Scenario 3 maintains low or moderate risk levels across most hazards, including cutting, electric shock, chemical exposure, noise, vibration, and posture-related injuries.

The only severe risk—accidental burns from sparks or hot surfaces—can be effectively mitigated with proper safety measures. Moderate risks in Scenario 3 can also be reduced through standard precautions. Overall, Scenario 3 offers the best combination of operational efficiency and acceptable occupational health and safety performance.

- Preventive measures

The next step is to apply the preventive measures in the risk matrix and assess how they affect the impact and probability of each risk. For every OHS-related risk identified, we proposed preventive measures—some of which primarily reduce the probability of occurrence, others primarily reduce the impact, and some reduce both. As shown in the figure below, the evaluation has changed: in particular, many scenarios have shifted toward the green zone, indicating that the risks are now more manageable and sustainable. However, the critical and high-severity risks remain largely unchanged, even after applying preventive measures.

				Impact				Probability				Risk rating			
Unique ID	Process step	Risk Description	Control(s)	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
1	Workpiece and Electrode Preparation	Cutting / crushing when handling parts	Use of clamping devices and workpiece supports.	2	2	2	2	2	4	3	2	Sustainable	Severe	Moderate	Sustainable
2	Parameter Setup	Danger of electric shock	Use of protective isolation equipment (dielectric gloves, isolation footwear).	3	4	3	3	2	5	2	2	Moderate	Critical	Moderate	Moderate
3	Part Machining	Accidental burns caused by sparks and hot surfaces,	Wear appropriate protective equipment (goggles, heat-resistant coveralls) but maintain a safe distance from the unloading area	2	4	3	2	1	4	2	2	Sustainable	Critical	Moderate	Sustainable
4	Dielectric Maintenance	Irritation of the skin/eyes through chemical exposure	Adequate ventilation of the work area and/or local extraction of particles.	2	3	2	2	1	4	2	1	Sustainable	Severe	Sustainable	Sustainable
5	Quality Inspection	Noise and vibration, Injuries from bad posture, eye strain	Ensure proper grounding and isolation of equipment to reduce vibration and noise.	1	1	1	2	1	2	1	3	Sustainable	Sustainable	Sustainable	Moderate
6	Electrode Maintenance or Replacement	Hot electrode replacement burns	Informing and training operators on risks and correct procedures when changing the dielectric.	3	4	3	2	1	4	1	1	Sustainable	Critical	Sustainable	Sustainable

Figure 5 Re-evaluation of OHS risks after applying the preventive measures

As we can see, Scenarios 1 and 4 became the most sustainable after applying the appropriate preventive measures. Scenario 3 presents a mixed outcome, with three risks categorized as moderate and three as sustainable. Scenario 2 remains the most critical, as the aggressive nature of its process leads to high-risk conditions that are difficult to fully mitigate, even with preventive measures.

Scenario 3, which is more efficient from a production perspective with minimum voltage and high peak current and pulse-on time demonstrates that risks can be effectively mitigated if preventive measures are properly applied.

Although Scenarios 1 and 4 are the most sustainable for employees, their low production efficiency limits their practical value. In any company, the primary goal is to achieve productive output, while ensuring safety and sustainability. A process that is safe but not efficient does not fulfil the core objective of production.

5. CONCLUSIONS

In the EDM process, there are risks that can impact the health and safety of operators. Understanding and managing these risks is essential for creating a safe and sustainable working environment.

The methodology applied in this study follows a systematic framework. First, the process steps are identified, and potential risks are associated with each step. Next, risk assessment is performed by evaluating the impact and probability of each risk across different operational scenarios. These evaluations allow the risks to be classified into four categories: sustainable, moderate, severe, and critical. Preventive measures are then proposed, followed by a re-evaluation to determine whether the process is being optimized and safer.

This approach emphasizes occupational health and safety (OHS) risk management across various scenarios, focusing on creating a safe working environment rather than prioritizing operational efficiency. Continuous monitoring of process parameters that directly influence risk ratings, along with real-time updates to preventive measures, enables organizations to enhance both process performance and the safety of the workplace.

Overall, this methodology provides a structured and repeatable approach to minimizing occupational hazards in EDM, supporting process optimization while promoting sustainable and safe operational practices.

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