

Occupational Noise Intensity Analysis of Grinding Operations and Risk Control Evaluation Using the PDCA Method in a Steel Fabrication Industry

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Abstract - Occupational noise is one of the dominant physical hazards in manufacturing industries, particularly in grinding operations involving high-speed rotating machinery. Excessive noise exposure may cause hearing impairment, decreased concentration, communication difficulties, and reduced productivity. This study aims to analyze the noise intensity generated during grinding activities under idle and load operating conditions and evaluate occupational noise control using the Plan-Do-Check-Act (PDCA) approach in a steel fabrication industry. Noise measurements were conducted using a sound level meter positioned near the operator's hearing zone during grinding operations. The results showed that noise intensity ranged from 94 dB to 106 dB, exceeding the occupational exposure limit regulated by Indonesian safety standards. Higher noise levels were observed during load conditions due to increased friction and machine vibration. The evaluation results indicate that current control systems still rely mainly on personal protective equipment, while engineering-based controls remain limited. Therefore, improvements involving preventive maintenance, periodic monitoring, operator compliance enhancement, and engineering noise control are recommended to improve occupational safety performance in manufacturing industries.

Keywords: Occupational noise, Grinding process, PDCA, Manufacturing safety, Hearing protection, Industrial environment.

I. INTRODUCTION

Industrial development has significantly increased the use of machining and fabrication processes involving high-speed rotating equipment. Along with this development, occupational safety and health issues have become increasingly important, particularly regarding physical hazards generated during production activities. One of the most common physical hazards found in manufacturing industries is occupational noise.

Noise in industrial environments is generally generated by mechanical interaction, machine vibration, impact, friction, and rotational movement during production processes. Grinding operations are among the production activities that produce relatively high noise intensity because the process involves continuous friction between abrasive discs and metallic workpieces at high rotational speeds [1]. In fabrication industries, grinding processes are commonly used for weld finishing, surface smoothing, dimensional correction, and cutting operations.

Excessive noise exposure does not only affect hearing capability but also influences worker concentration, communication effectiveness, mental fatigue, and overall productivity. Long-term exposure to high noise intensity may gradually lead to Noise-Induced Hearing Loss (NIHL), which is often irreversible [2,3]. Occupational noise-induced hearing loss remains one of the most common occupational diseases worldwide, particularly in manufacturing industries with continuous machine operation [4]. In addition, noisy work environments may increase the risk of workplace accidents because operators experience communication difficulties and decreased situational awareness during operation [5]. Excessive occupational noise not only affects worker health but also contributes to broader economic and environmental burdens through decreased productivity, increased medical costs, and reduced work efficiency [6].

According to the Regulation of the Ministry of Manpower of the Republic of Indonesia No. 5 of 2018 concerning Occupational Safety and Health in Work Environments, The permissible occupational noise exposure limit regulated by Indonesian occupational safety standards is 85 dB for a maximum working duration of 8 hours per day [7]. According to NIOSH [8], continuous exposure to high occupational noise intensity may significantly increase hearing impairment risk among industrial workers. The regulation also states that higher noise intensity reduces allowable exposure duration significantly. Therefore, monitoring and controlling

industrial noise exposure become essential aspects of manufacturing safety management [9-11].

The grinding activities investigated in this study were conducted in a steel fabrication industry in Indonesia, particularly in the fabrication workshop area of the Water Resources Division. Based on preliminary observations, grinding operations generated relatively high noise intensity, especially during load operating conditions. Operators were exposed continuously to noise generated from hand grinders and cutting grinders during daily production activities.

Several previous studies discussed occupational noise monitoring in industrial environments. However, studies specifically analyzing grinding noise characteristics under idle and load conditions while simultaneously evaluating continuous improvement using the PDCA framework are still limited, particularly in heavy fabrication industries in Indonesia.

Therefore, this study aims to:

1. Analyze the noise intensity generated during grinding operations,
2. Compare noise characteristics between idle and load operating conditions,
3. Identify factors influencing excessive occupational noise,
4. Evaluate existing noise control implementation using the PDCA approach,
5. Provide practical recommendations to improve occupational safety performance in manufacturing environments.

The results of this study are expected to contribute not only to occupational safety improvement but also to sustainable manufacturing management through better environmental and operational control systems

II. METHODOLOGY

2.1 Research Location

This study was conducted at the fabrication workshop area. The company operates in heavy manufacturing and steel fabrication sectors supporting industrial and water resource infrastructure.

Grinding activities observed during this study were mainly carried out in several production lines where fabrication, finishing, and metal cutting processes were performed continuously during operational hours. Figure 1 illustrates grinding activities in the fabrication workshop area.



Figure 1: Grinding activities illustration in fabrication workshop area

2.2 Research Procedure

The research was conducted through several stages:

1. Preliminary field observation,
2. Identification of grinding activities,
3. Noise intensity measurement,
4. Operator interviews,
5. Evaluation of existing occupational safety practices,
6. PDCA-based analysis and improvement evaluation.

The study used a descriptive quantitative approach supported by direct field observation and occupational safety evaluation.

2.3 Noise Measurement Procedure

Noise measurements were performed using a sound level meter to determine the sound intensity generated during grinding operations. The instrument was positioned near the operator's hearing zone to represent actual worker exposure conditions.

The measurements used an A-weighting scale, fast response mode, and a direct environmental monitoring method. Measurements were conducted under idle and load operating conditions

The observed equipment included hand grinding machines and cutting grinding machines. To improve measurement consistency, each measurement was repeated several times during operational activities. Figure 2 shows the noise measurement process using a sound level meter.



Figure 2: Noise measurement process using sound level meter

2.4 Data Analysis

The collected data were analyzed descriptively by comparing measured values with occupational exposure limits, identifying dominant noise sources, evaluating operational and maintenance conditions, assessing hearing protection compliance, and analyzing continuous improvement implementation using the PDCA method.

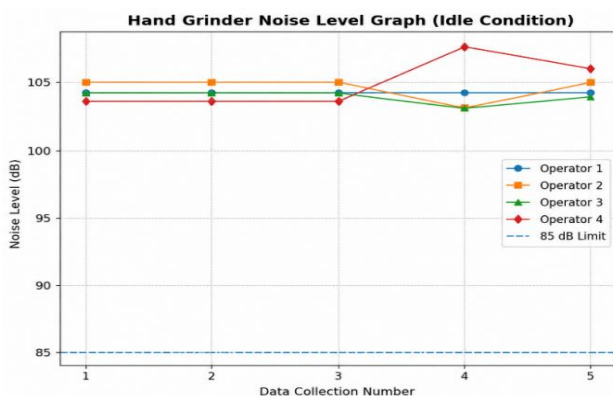
III. RESULTS AND DISCUSSIONS

3.1 Noise Measurement Results

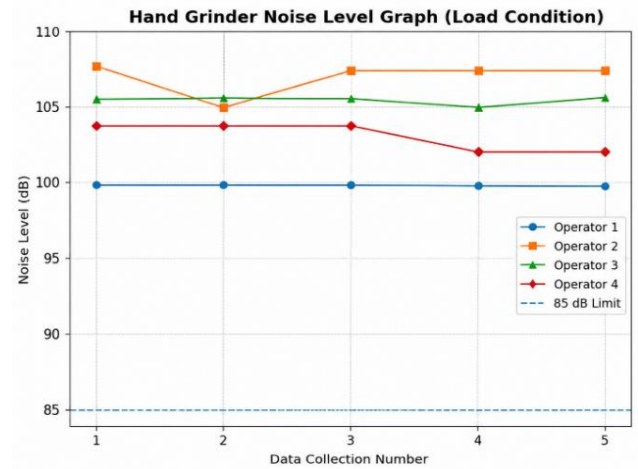
The measurement results indicate that grinding activities generated relatively high occupational noise intensity under both idle and load operating conditions.

3.1.1 Hand Grinding Machine

Under idle conditions, the hand grinder produced noise levels ranging between 94 dB and 99 dB. During load operation, noise intensity increased significantly due to friction between abrasive discs and metallic surfaces. Figure 3 presents the hand grinder noise levels under different operating conditions, consisting of idle condition and load condition.



(a)



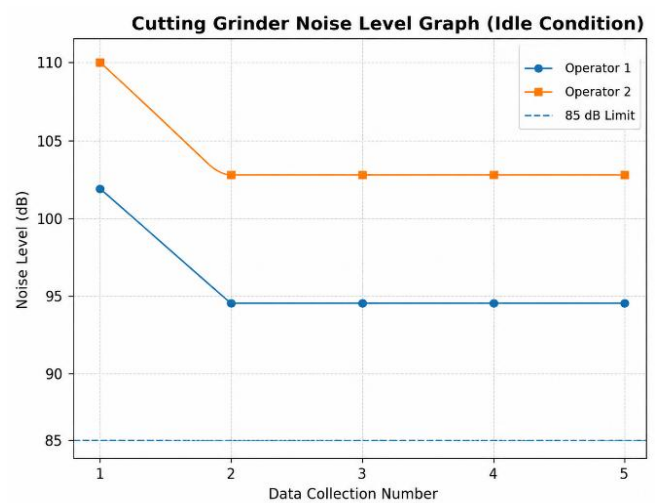
(b)

Figure 3: Hand grinder noise level; Idle condition (a), Load condition (b)

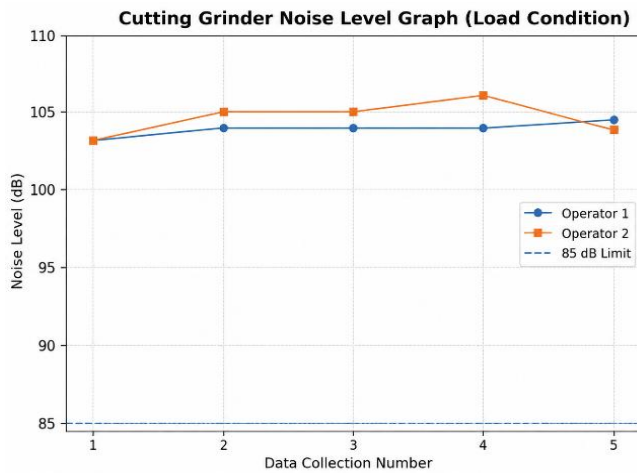
3.1.2 Cutting Grinding Machine

The cutting grinder generated higher noise intensity compared to the hand grinder because the cutting process produced stronger mechanical friction and vibration. During load conditions, the measured noise intensity reached approximately 106 dB.

The results demonstrate that both grinding operations exceeded the occupational exposure limit regulated for industrial environments. Figure 4 presents the cutting grinder noise levels under idle condition and load condition, while the detailed measurement results are summarized in Table 1.



(a)



(b)

Figure 4: Cutting grinder noise level; Idle condition (a), Load condition

(b)

Table 1: Noise Intensity Measurement Results

| Machine Type | Operating Condition | Noise Intensity (dB) | Exposure Status |
|-----------------|---------------------|----------------------|-----------------|
| Hand Grinder | Idle | 94–99 | Above Threshold |
| Hand Grinder | Load | 100–103 | High Risk |
| Cutting Grinder | Idle | 96–101 | Above Threshold |
| Cutting Grinder | Load | 103–106 | Critical |

3.2 Effect of Operational Conditions on Noise Intensity

The measurement results clearly show that load operating conditions produced higher noise intensity compared to idle conditions. This increase occurred because grinding discs directly contacted metallic materials during operation, generating stronger frictional force and mechanical vibration.

In grinding operations, frictional interaction between rotating abrasive discs and workpieces converts mechanical energy into vibration and airborne sound energy. The increase in vibration during load conditions contributes significantly to higher sound intensity [1].

The increase in noise intensity during grinding operations is closely related to frictional interaction and machine vibration. Higher friction force and vibration magnitude generally produce greater airborne sound energy and sound pressure levels [1].

Higher friction and vibration during load operation increase sound pressure levels and produce more dominant industrial noise.

3.3 Factors Influencing Occupational Noise

Based on field observation and measurement results, several factors were identified as dominant contributors to excessive occupational noise.

3.3.1 Machine Condition

Machine condition strongly affected grinding noise characteristics. Worn bearings, unstable rotational shafts, inadequate lubrication, and loosened mechanical components increased vibration and generated unstable sound patterns. According to Mobley, inadequate maintenance conditions contribute significantly to machine instability and vibration amplification during industrial operation [12].

3.3.2 Mechanical Vibration

Mechanical vibration became one of the most influential factors affecting industrial noise intensity. Excessive vibration propagated through machine structures and surrounding air, increasing airborne sound energy around the operator area. Randall explained that vibration characteristics are closely related to industrial noise generation and machine condition monitoring [1].

3.3.3 Operational Load

Load conditions produced significantly higher noise intensity because of direct friction between abrasive discs and metallic workpieces. Stronger friction generated greater vibration and sound pressure.

3.3.4 Workplace Layout

The relatively close distance between operating machines contributed to noise accumulation within the fabrication workshop. Simultaneous grinding operations from multiple production lines increased background noise intensity. Similar findings were also reported by Wegener et al. [13-15], where machine layout and room characteristics significantly affected occupational noise distribution.

3.3.5 Operator Compliance

The effectiveness of hearing protection equipment depended strongly on operator compliance. Several operators occasionally removed ear protection during communication or prolonged operation because of discomfort and communication difficulty. As shown in Figure 5, hearing protection usage during grinding activities was still optional in several operational conditions, which potentially reduced the effectiveness of occupational noise control implementation. Reddy et al. stated that worker compliance is one of the

dominant factors affecting the effectiveness of hearing protection systems in industrial environments [14].

| EARPLUGS vs EAR MUFFS | |
|---|---|
| EARPLUGS | EAR MUFFS |
|  |  |
| <ul style="list-style-type: none"> Typical NRR*: 20-33 dB (varies by type and fit) Small and lightweight Inserted into the ear canal Portable, easy to carry Suitable for use with other PPE (helmet, glasses, mask) Generally lower cost | <ul style="list-style-type: none"> Typical NRR*: 20-30 dB (varies by model and fit) Covers the outer ear completely Forms a seal around the ear Easy to put on and remove Comfortable for long-term use (less insertion required) Generally higher cost |
| <p>BEST FOR</p> <p>Short-term use, hot environments, compatibility with other PPE, and when portability is important.</p> | <p>BEST FOR</p> <p>High noise environments, consistent protection, ease of use, and when frequent on/off is needed.</p> |

*NRR (Noise Reduction Rating) is a laboratory measure of noise reduction.

Figure 5: Optional hearing protection usage during grinding activities

3.4 PDCA-Based Occupational Noise Evaluation

3.4.1 Plan

At the planning stage, excessive occupational noise exposure during grinding operations was identified as a significant occupational hazard requiring systematic improvement.

3.4.2 Do

Existing occupational safety implementation included:

- hearing protection equipment,
- safety briefing,
- workplace supervision,
- and periodic environmental monitoring.

3.4.3 Check

The evaluation stage identified several weaknesses in current implementation:

- inconsistent hearing protection usage,
- limited engineering-based control systems,
- absence of localized acoustic barriers,
- insufficient predictive maintenance implementation.

3.4.4 Act

Based on the evaluation results, several improvement recommendations are proposed:

- implementation of preventive and predictive maintenance,
- installation of localized sound insulation,
- stricter hearing protection supervision,
- periodic audiometric testing,
- operator training improvement,
- optimization of workshop layout and machine arrangement.

The PDCA method provides a practical framework for continuous occupational safety improvement because it integrates monitoring, evaluation, and corrective action systematically. Figure 6 illustrates the PDCA framework for occupational noise control and continuous improvement in grinding operations.

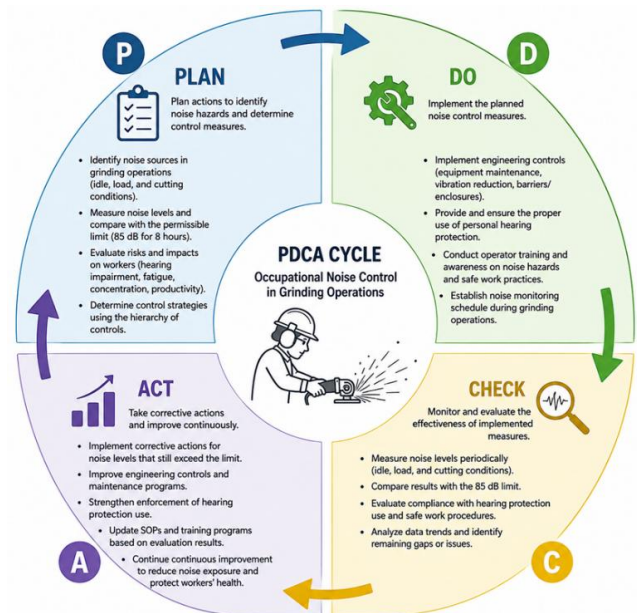


Figure 6: PDCA framework for occupational noise control and improvement in grinding operations

3.5 Discussion

The results indicate that grinding operations in fabrication industries generate occupational noise significantly above recommended exposure limits. Load operating conditions produced higher noise intensity because of stronger frictional interaction and increased machine vibration during operation.

The findings also demonstrate that maintenance quality has an important influence on industrial noise generation. Machines with unstable rotational components and poor lubrication conditions produced greater vibration and irregular sound characteristics. Therefore, maintenance activities should

not only focus on productivity improvement but also support occupational safety and environmental control [12].

Current occupational noise control implementation remains dominated by personal protective equipment and administrative approaches. Although earplug and earmuff usage helps reduce direct exposure, operator compliance issues reduce overall control effectiveness. Similar observations were also reported by Reddy et al., where discomfort and communication barriers reduced consistency in hearing protection usage among industrial workers [14].

Engineering-based noise reduction strategies such as localized acoustic barriers, vibration damping systems, and improved workshop layout are still relatively limited in implementation. Consequently, future occupational safety improvements should prioritize engineering controls combined with predictive maintenance and continuous worker awareness programs [9-11].

From a manufacturing perspective, reducing occupational noise may contribute positively to operational stability, worker comfort, communication effectiveness, and production quality consistency. Excessive industrial noise has also been associated with cognitive fatigue and decreased worker performance [15].

In addition to hearing impairment, excessive industrial noise may indirectly influence company performance through productivity reduction, worker fatigue, and increased occupational health costs. Similar observations were reported by Hänninen *et al.* [6], who emphasized that environmental exposure contributes significantly to the burden of occupational disease and economic loss.

IV. CONCLUSION

Grinding operations in a steel fabrication industry in Indonesia generated occupational noise intensity ranging from 94 dB to 106 dB, exceeding Indonesian occupational exposure limits for industrial work environments. Load operating conditions significantly increased noise intensity due to stronger frictional interaction and mechanical vibration during grinding processes. Several factors influencing excessive occupational noise include machine condition, vibration, operational load, workplace layout, and operator compliance regarding hearing protection equipment usage.

The evaluation results indicate that current occupational noise control systems are still primarily dependent on administrative controls and personal protective equipment, while engineering-based control systems remain limited. The PDCA method successfully provided a systematic framework

for evaluating and improving occupational noise management continuously.

Future improvements should focus on preventive maintenance implementation, predictive monitoring, engineering-based noise reduction, operator awareness enhancement, and periodic occupational health evaluation to improve sustainable manufacturing safety performance.

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