

Measurement and Optimization of Wood Dust and Noise Levels in Table Saw Operations Using Response Surface Methodology

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Exposure to airborne dust and noise during woodworking operations pose serious occupational health risks. This study investigated the influence of key cutting parameters—rotational speed, feed rate, tooth count, and dust collection system status—on PM₁₀ concentration and noise levels during circular sawing. Experimental measurements were conducted on six materials, including solid wood species (Scots pine, Oriental beech) and engineered wood products (plywood, medium-density fiberboard, oriented strand board, and particleboard). The collected data were analyzed using response surface methodology (RSM) to optimize cutting conditions, aiming to minimize emissions while maintaining operational efficiency. The results indicated that both material type and processing parameters notably affected dust and noise levels. Optimized cutting settings led to a measurable reduction in exposure, offering practical guidelines for improving workplace safety in the woodworking and furniture industries. This study contributes to the development of safer and more sustainable machining practices by addressing the hidden risks associated with dust and noise pollution.

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INTRODUCTION

The furniture industry, as one of the key sectors of the global economy, has been undergoing rapid growth and transformation in recent years. Changing lifestyles, technological advancements, and shifts in consumer preferences worldwide continuously reshape and expand the industry's dynamics. The key drivers behind this growth include the expanding middle-class population in developing economies, rising urbanization rates, and advancements in the real estate sector (Koridze 2022). Large-scale manufacturers hold a significant market share, thanks to cost advantages and extensive distribution networks, while small and medium businesses (SMBs) compete by focusing on niche markets. In this regard, although SMBs occupy an important position, they continue to struggle with growth and sustainability. Economic fluctuations, challenges in marketing and financing, and organizational deficiencies create unstable and insecure working environments for SMBs. Under economic pressure, these businesses may underinvest in occupational safety and health (OSH) practices, thereby increasing workplace risks. Additionally, OSH is often perceived as complex and difficult to implement, making it more challenging for owners and managers to fulfill their responsibilities. For many SMBs, OSH is seen as an administrative burden, entailing excessive paperwork, bureaucratic procedures,

increased costs, and rigid regulations, and further discouraging compliance. This perception can prevent small and medium businesses from effectively integrating OSH practices, further complicating their efforts to ensure a safe and stable working environment (Tremblay and Badri 2018).

Employees in the furniture industry face various OSH risks due to the machinery and materials used in production. These risks include heavy lifting, repetitive movements, poor working postures, workplace traffic, machine injuries, and fire or explosion hazards. Without proper preventive measures, these factors can seriously endanger workers' safety. Fortunately, these risks are easily identifiable, and the necessary measures to mitigate them are generally clear and straightforward to implement (Turan and Töre 2021). Conversely, exposure to dust and noise represents hidden hazards that manifest their effects over the long term and are often overlooked (Wiggans *et al.* 2016).

Workers in the furniture industry are heavily exposed to wood dust due to the nature of tasks such as sanding, cutting, and drilling. Studies have indicated that dust emissions from woodworking activities, particularly those involving wood dust, pose significant health risks to both workers and surrounding individuals (Top *et al.* 2016; Dembiński *et al.* 2022; Kargar-Shouroki *et al.* 2022). Respiratory symptoms, impaired nasal mucosal clearance function, and even nasal cancer are among the health issues associated with exposure to wood dust (Andersen *et al.* 1977). Similarly, among certain workers in the furniture industry, the high prevalence of specific IgE sensitization to wood dust precipitates hay fever, thereby accentuating the allergenic potential inherent in wood dust (Skovsted *et al.* 2003). While wood dust is known to cause irritation and allergic dermatitis upon contact with the skin, the combination of high concentrations of fungal spores present in the air of furniture factories with this dust significantly exacerbates health risks (Rogoziński *et al.* 2015). Furthermore, the documented psychosocial impact of dust on workers in furniture production areas underscores its broader effects on health, the environment, and social aspects (Mohammed *et al.* 2020; Kargar-Shouroki *et al.* 2022).

Noise emerges physically as a result of mechanical vibrations causing pressure fluctuations in the environment. For furniture industry workers, the loud sounds of machinery, such as saws, sanders, and drills, are common sources of noise pollution. The continuous operation of these machines often leads to noise levels that exceed safe limits, including the World Health Organization's recommended exposure limit of 85 dB for an 8-hour workday (WHO 2010). Furthermore, the echoes and reverberations in large, open factory spaces can amplify these sounds, exacerbating their impact on workers' health. Woodworkers are frequently subjected to noise levels exceeding acceptable limits (Elsaidy and Mahmoud 2020), which significantly elevates the risk of hypertension, hearing loss, sleep disturbances, and other cardiovascular conditions (Hammer *et al.* 2014; Themann and Masterson 2019; Pretzsch *et al.* 2021).

Table saw machines hold critical importance in the furniture industry due to their speed and efficiency in cutting wooden materials. However, various parameters, such as cutting speed, feed rate, blade type, and material type, directly influence the amount of dust and noise generated during operation. High rotational speeds or low feed rates can lead to increased dispersion of dust particles and elevated noise levels. This situation not only heightens the risks faced by workers but also compromises OSH compliance within the workplace. Therefore, conducting a thorough analysis of how these parameters affect dust and noise generation is crucial for developing effective strategies aimed at risk reduction.

Numerous studies have addressed the risks of dust and noise from woodworking activities (Bielski *et al.* 1976; Shikdar and Sawaqed 2003; Löfstedt *et al.* 2017; Petrova *et al.* 2017). These studies typically focus on the general health effects of dust and noise but have largely overlooked the specific roles of parameters in table saw machines related to these risks. This gap underscores the need to examine how operational parameters in table saw machines influence dust and noise production. To address this, this study systematically analyzes these parameters and evaluates the effectiveness of dust collection systems in the furniture industry. The findings are expected to support the development of practical strategies for minimizing these risks and optimizing machine parameters, ultimately contributing to improved OSH practices in workplaces.

EXPERIMENTAL

Materials

Wood materials

The materials used in the study included both solid wood, namely Scots pine (*Pinus sylvestris*) and Oriental beech (*Fagus orientalis*), and composite wood materials, including MDF (medium-density fiberboard), particleboard (PB), plywood made from poplar veneers, and OSB (oriented strand board). These materials, widely used for furniture, have different densities, fiber structures, and mechanical properties. Thus, they provide a wide variety of effects of materials on noise and PM₁₀ emissions. Table 1 presents the density values and moisture contents of the materials used.

Table 1. Selected Properties of Materials Used in the Study

Factor	Average Density (g/cm ³)	Moisture Content (%)
Scots pine	0.48	11.1
Beech	0.69	11.3
Plywood	0.58	8.9
MDF	0.67	7.7
OSB	0.61	7.4
PB	0.59	8.1

Table Saw Machine and Power Feeder

A 380-volt 3-phase electric motor-driven table saw machine (Öz Yon-Mak, Y.D.T 300, Ankara, Türkiye) was utilized. The machine, featuring two power levels, operates at 3000 rpm at the first level and 6000 rpm at the second level under no-load conditions. These speeds were selected to represent the two distinct operational levels available on the machine, allowing for the investigation of both standard and high-speed cutting conditions commonly encountered in industry. A 4-wheel power feeder, which can operate at different speeds, was installed on the table saw to ensure a consistent feed rate during cutting operations.

Wood Dust Collector

In the study, a three-phase dust collector (Model TEM1800, Destanlı Machinery, Bursa, Türkiye) with a 1.5 kW motor operating at a fixed speed and an air intake capacity of 1800 m³/hour was utilized. Prior to the experiment, the machine underwent thorough cleaning and maintenance. The filter cleaning process was repeated for each variable examined. To evaluate the effect of the dust collector on

noise levels and particle matter (PM) concentrations experienced by the operator, all cutting operations were performed with the dust collector both switched on and off.

Circular Saw Blades

In the tests, saw blades with an alternate top bevel (ATB) geometry and three different tooth counts (28, 48, and 60) were used (Fig. 1). These tooth counts were chosen to cover a range frequently employed in the furniture industry for processing different wood materials and achieving varying cut qualities.

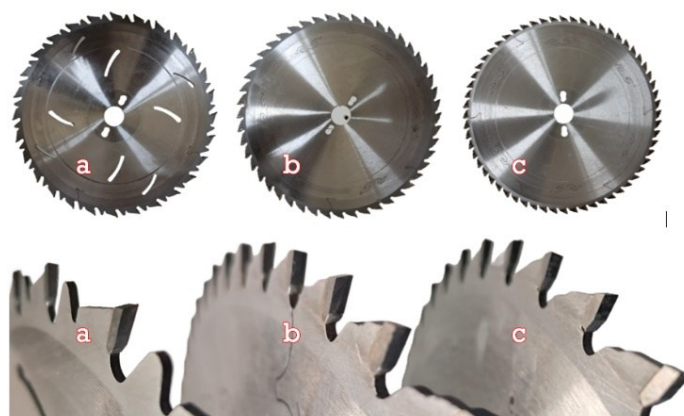


Fig. 1. Circular saws used in the study (a: 28-teeth, b: 48-teeth, c: 60-teeth)

All circular saw blades used had a diameter of 300 mm, a plate thickness of 1.8 mm, and a tooth thickness of 2.4 mm. While the tooth geometries were identical, the 28-tooth saw blade included raker teeth (Fig. 1). Some properties of the teeth are shown in Fig. 2.

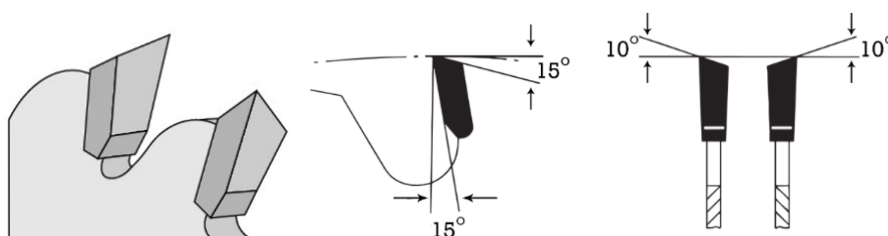


Fig. 2. Some properties of the teeth used in the study

Methods

Preparation of samples

The materials used in the experiments were prepared with consistent properties to ensure reliable results. Specifically, PB, MDF, plywood, and OSB panels were sourced at a thickness of 18 mm. Solid wood materials were prepared to a uniform thickness of 18 mm. Defect-free samples were selected to avoid knots, cracks, and splits. Following preparation, the solid samples were conditioned in a climate chamber at 20 °C and 65% relative humidity until reaching a constant weight to ensure the accuracy of the results. The materials to be cut were dimensioned to a length of 1 m. The cuts were made at 2 cm intervals, with simultaneous recording of PM₁₀ and noise measurements. During the cutting process, the height of the saw blade was set to 10 mm above the material surface to optimize cutting efficiency.

Measurement of Noise and PM₁₀ Levels

A sound meter (Model UT 353BT, UNI-Trend, Guangdong, China) was utilized for measuring noise levels. The device was positioned 50 cm horizontally and vertically from the center of the circular saw blade to simulate the noise level exposure of the machine operator. Thanks to its capability to retain the maximum value within a specific operational period, the maximum value recorded at the end of each cutting operation was noted. All noise values in the study were recorded in A-weighted decibels (dB(A)). PM₁₀ mass concentrations were measured.

Although occupational exposure limits are typically defined for inhalable or respirable dust fractions, this study primarily aimed to compare the relative levels of particulate matter generated under different cutting parameters and material types for optimization purposes, using response surface methodology (RSM). In this context, PM₁₀ was utilized as a measurable indicator to compare the overall amount of particulate matter generated across the different scenarios. Measurements were made with the WP6932 Intelligent Air Quality Detector (VSON, Guangdong, China), which incorporates a Plantower PMS7003 particle matter sensor. This sensor operates on the principle of laser light scattering (at 90°) to determine particle mass concentrations based on Mie theory (He *et al.* 2020). This sensor reports digital concentration values for PM_{1.0}, PM_{2.5}, and PM₁₀ in $\mu\text{g}/\text{m}^3$, with a resolution of 1 $\mu\text{g}/\text{m}^3$ and a manufacturer-specified maximum consistency error of $\pm 10 \mu\text{g}/\text{m}^3$ (within the 0–100 $\mu\text{g}/\text{m}^3$ range), according to the datasheet provided by the supplier. As the main objective of the study was to optimize cutting parameters using response surface methodology (RSM), this sensor was selected to enable comparative monitoring of PM₁₀ levels under different experimental conditions. Described in the literature as capable of detecting relative changes in particle concentrations (Bulot *et al.* 2019), the sensor was considered adequate for the comparative assessments targeted in this study. To enhance the accuracy and repeatability of the measurements, the sensor was allowed to stabilize for at least 30 seconds before each test, as recommended in the datasheet. The device was fixed at the same position as the sound meter. For each factor, three repeated 1-m cutting operations were performed, and the averages of the maximum PM₁₀ and noise values of the three measurements were used in the analyses.

Statistical Analysis

An experimental approach was employed to investigate the influence of various processing parameters on PM₁₀ and noise generation in the circular saw machine. Data analysis was performed using the CoStat statistical software package, and a variance analysis (ANOVA) was conducted at a 95% confidence level ($\alpha = 0.05$) to determine the statistical significance of blade rotation speed, number of teeth, and feed rate, considering the activation status of the dust collector. The Duncan multiple range test was applied to assess significant differences among the groups and identify homogeneity groups. Additionally, response surface methodology (RSM) was used to evaluate the combined effects of the selected variables on PM₁₀ and noise level, allowing for a more comprehensive understanding of their interactions and facilitating the identification of optimal operating conditions. RSM analysis was performed using Minitab 21.4. Utilizing the existing experimental data, a custom response surface design was defined within the software using the ‘Define Custom Response Surface Design’ feature. A quadratic model was then developed for each response, including

terms for main effects, two-way interactions, and the quadratic effect of the numeric factor.

RESULTS AND DISCUSSION

The ANOVA results for PM₁₀ and noise levels generated during the cutting of Scots pine, beech, plywood, MDF, OSB, and PB with different circular saw speeds, feed rates, tooth numbers, and with the dust collector either on or off are presented in Table 2. According to the results, the effects of material type and processing parameters on the PM₁₀ and noise levels were statistically significant ($p \leq 0.05$).

Table 2. ANOVA Results for PM₁₀ and Noise Levels

Factor	PM ₁₀		Noise	
	F-Statistic	P value	F-Statistic	P value
Material Type (A)	17538.57	0.00	193.29	0.00
Cutting parameters (B)	23364.15	0.00	1576.48	0.00
Dust collector status (C)	123229.24	0.00	199.92	0.00
Number of Teeth (D)	2328.72	0.00	2225.79	0.00
A × B	912.03	0.00	35.35	0.00
A × C	1741.75	0.00	10.65	0.00
A × D	1284.31	0.00	35.20	0.00
B × C	3112.73	0.00	10.53	0.00
B × D	1004.86	0.00	377.98	0.00
C × D	1253.97	0.00	18.27	0.00
A × B × C	427.01	0.00	32.42	0.00
A × B × D	510.68	0.00	27.67	0.00
A × C × D	122.24	0.00	33.14	0.00
B × C × D	1099.42	0.00	20.56	0.00
A × B × C × D	345.64	0.00	21.47	0.00
Model	2648.21	0.00	193.29	0.00

Table 3. DMRT Results for PM₁₀ and Noise Levels

Factor	Level	PM ₁₀		Noise	
		Mean ($\bar{x}$)	HG	Mean ($\bar{x}$)	HG
Material Type	Pine	92.58	F↓	93.38	A↑
	Beech	120.83	E	92.28	C
	Plywood	167.10	B	92.58	B
	MDF	145.78	D	90.82	E↓
	OSB	159.11	C	91.08	D
	PB	170.72	A↑	92.09	C
Cutting Parameters (rpm - m/min)	3000 - 5	122.12	C	89.74	D↓
	3000 - 9	177.94	A↑	93.55	B
	6000 - 5	116.58	D↓	90.57	C
	6000 - 9	154.11	B	94.30	A↑
Dust Collector Status	On	109.70	B↓	92.43	A↑
	Off	175.69	A↑	91.64	B↓
Number of Teeth	28	146.25	B	91.37	B
	48	148.13	A↑	94.59	A↑
	60	133.68	C↓	90.16	C↓

$\bar{x}$: Mean, HG: Homogeneity group, ↑: Highest Value, ↓: Lowest Value

To further examine the significant results obtained from ANOVA in detail, Duncan's multiple range test (DMRT) was applied to identify differences between groups. The results are presented in Table 3.

The ANOVA results indicated that material type, cutting parameters, dust collector status, and number of teeth significantly affected noise and PM₁₀ levels during table saw operations. The highest PM₁₀ level was observed in PB samples (170.72 µg/m³), while the lowest was recorded in pine samples (92.58 µg/m³), with PB showing an 84% higher concentration than pine. This can be explained by the fact that the wood chips and binder resins used in PB production generate more particles during cutting. Additionally, the presence of wood particles of varying sizes, inherent to particleboard (PB) structure, may contribute to the generation of dust containing PM₁₀-sized particles (≤10µm) during cutting operations (Hlásková *et al.* 2016). Due to the high loosening factor, which promotes fiber separation during the cutting process, larger pine chip particles may have formed. The increased particle size could then have hindered their aerodynamic transport (Blaga *et al.* 2016). Because the loosening factor is reportedly greater in rip cuts than in crosscuts, the parallel-to-grain cutting orientation of solid woods could be another potential reason for the significantly lower PM₁₀ level (Klamecki 1976). Previous studies indicate that wood processing dust characteristics depend on material properties such as density, hardness, moisture content, and structure. For example, Fujimoto *et al.* (2011) reported higher respirable dust concentrations for composite materials compared to solid wood. Similarly, Lučić *et al.* (2007) observed that processed wood type and cutting conditions influence the generation of finer particles, which may influence the potential for airborne dust formation.

The highest PM₁₀ concentration was measured at 178 µg/m³ under the combination of 3000 rpm and 9 m/min, while the lowest was observed at 117 µg/m³ under the combination of 6000 rpm and 5 m/min. A notable 55% difference was observed between the two values. Upon examining the results, an increase in PM₁₀ values was observed as the feed rate increases. At low spindle speed and high feed rate, the reduced interaction between the saw teeth and the material may lead to higher particle emissions. Conversely, at high spindle speed and low feed rate, the prolonged interaction time results in lower dust emissions. Existing literature indicates that in circular sawing operations, both spindle speed and feed rate have a significant impact on dust emissions, with higher spindle speeds and lower feed rates typically resulting in reduced dust emissions (Lučić *et al.* 2007; Hlásková *et al.* 2016; Nasir and Cool 2020; Pałubicki *et al.* 2021).

The average PM₁₀ level measured when the dust collector was off (176 µg/m³) was 60.2% higher than the value recorded when the dust collector was on (109.7 µg/m³). This finding suggests that the dust collector effectively captured particles, thereby reducing OSH risks. Literature indicates that the implementation of dust collection systems in the woodworking industry plays a significant role in reducing PM levels, thereby contributing to improved protection of worker health (Lazovich *et al.* 2002; Pałubicki *et al.* 2020; Top 2020). The efficiency of dust collection system, on the other hand, depends on factors, such as the design of system, airflow rate, filtration efficiency, and proper planning of maintenance activities (Felgueiras *et al.* 2022). It has been reported in studies that a well-designed dust collection system can reduce the amount of dust in the ambient air to meet clean air standards, even in factories operating within the woodworking industry (Liu *et al.* 2019).

In terms of number of teeth, the highest average PM₁₀ level was observed with the 48-tooth saw (148 µg/m³), while the lowest average PM₁₀ level was recorded with

the 60-tooth saw ($134 \mu\text{g}/\text{m}^3$). A difference of approximately 11% exists between the two tooth counts. The complex physical and mechanical processes during sawing operations influence the resulting sawdust particle geometry; factors such as feed rate, tool wear, and wood pre-treatment have been reported to affect the generation of fine and very fine (e.g., $\leq 10 \mu\text{m}$) particle fractions (Pałubicki *et al.* 2021; Rogoziński *et al.* 2021). These findings indicate that the highest PM_{10} formation is not directly associated with an increase in tooth count, highlighting the complexity of the underlying mechanisms. An increase or decrease in the number of teeth can directly influence the interaction time between the saw surface and the material, the cutting forces, and the size of the chips produced (Kopecký *et al.* 2022; Song *et al.* 2023). Moreover, the relationship between the number of teeth and material type must be carefully examined. The 28-tooth saw used in the study may have generated coarser chips, promoting particle deposition in the cutting environment, and thereby reducing the amount of suspended PM_{10} mass. Conversely, the 60-tooth blade likely produced finer chips, which may have been more effectively removed by the dust extraction system. In contrast, the 48-tooth saw probably generated medium-sized chips, resulting in relatively higher PM_{10} levels compared to the 28-tooth and 60-tooth saws. The literature also indicates that the tooth count of circular saw blades affects dust emissions and chip size, emphasizing that the optimal tooth count should be determined based on the type of material being cut and the cutting parameters (Kminiak and Kubš 2016; Qi and Kang 2021).

When noise levels were analyzed based on material type, the highest levels were recorded in pine samples, whereas the lowest were observed in MDF samples, with a difference of 2.8% between them. Additionally, noise levels in pine samples were 1.2%, 0.9%, 2.5%, and 1.4% higher compared to beech, plywood, OSB, and PB samples, respectively. Findings from a separate study on noise generation during the planing process and another using a bandsaw machine on six different wood species were consistent with the results of this study in terms of material type and noise levels (Gholamiyan *et al.* 2022). The variations in noise levels due to material type can be attributed to the structural properties of the materials and their resistance during cutting. In species, such as Scots pine, where annual ring transitions are distinct and significant density differences exist between seasonal growth rings, the resistance applied to the saw teeth during cutting is known to be distributed more irregularly (Orlowski *et al.* 2020). This irregular resistance may cause fluctuations in the applied cutting force, leading to higher noise generation.

Previous studies have reported that due to its dense and homogeneous structure, formed by compressing fine wood fibers, MDF generates lower levels of vibration during cutting (Szwajka *et al.* 2023). This may result in reduced noise generation. The variations in noise levels among materials, such as beech, plywood, OSB, and PB, can be attributed to factors such as density, hardness, and cutting resistance. Several studies have indicated that material density significantly influences frictional forces (Mckenzie *et al.* 2001; Pichler *et al.* 2018). Additionally, the heterogeneous structures of plywood, OSB, and PB result in irregular resistance during cutting, which can affect noise levels in different ways. Nevertheless, all measured values exceed the regulatory noise limit of 87 dB(A).

The highest noise level was recorded at 6000 rpm rotational speed and 9 m/min feed rate, whereas the lowest noise level was observed at 3000 rpm rotational speed and 5 m/min feed rate. The noise level at 6000 rpm and 9 m/min was 5.1% higher than 3000 rpm and 5 m/min. This expected outcome can be attributed to the increased interaction between the saw teeth and the material, as well as the rise in vibrations as rotational

speed and feed rate increase (Leu and Mote 1984). A higher rotational speed results in more teeth making contact with the material per unit time, thereby increasing the amount of work performed (Pelit *et al.* 2021). Similarly, a higher feed rate causes the saw teeth to move faster over the material, leading to greater vibration. The literature also indicates a positive linear relationship between both rotational speed and feed rate and noise levels (Licow *et al.* 2020; Ajdinaj *et al.* 2023).

Measurements indicated that the average noise level recorded with the dust collector operating was approximately 0.9% higher than when the machine was turned off. This increase is likely due to the additional sound generated by the dust collector contributing to the overall noise level. Such minor increases in noise levels can be explained by the logarithmic scale used in decibel measurements (Hall 1954). This finding aligns with the limited impact of a lower-intensity noise source on a significantly louder source. The relatively small increase in noise levels can be attributed to the fact that the noise generated during the cutting process is substantially higher than that produced by the dust collector. The literature indicates that noise emitted by dust collectors can contribute to overall workplace noise levels, emphasizing the need for noise control measures when designing dust collection and extraction systems (Owoyemi *et al.* 2016; Özdemir and Albayrak 2024).

When the results were examined in terms of the number of teeth, the 48-tooth saw produced the highest noise level, while the 60-tooth saw produced the lowest. The noise level of the 48-tooth saw was 4.9% higher than that of the 60-tooth saw and 3.5% higher than that of the 28-tooth saw. In literature, a limited number of studies examine the relationship between the number of teeth and the noise generated during cutting. Studies generally focus on the noise emitted by a circular saw when idling (without cutting) or during cutting operations performed with pre-determined standard parameters. In studies conducted without cutting operations, a linear relationship between the number of teeth and noise level has been reported (Reiter and Keltie 1976; Leu and Mote 1984). Focusing on noise generation during cutting, Kvietkova *et al.* (2015) investigated the effects of the number of teeth (24, 40, and 60) and number of cuts on wear characteristics and noise levels. Although they reported that a reduction in tooth count led to increased noise level due to wear, the noise findings obtained from the early stages, before the cutters experienced wear, were consistent with the data in this study. The literature also indicates that certain factors, such as saw tooth count, tooth geometry, and chip angle, influence noise levels, and that the optimal tooth count varies depending on the material type and cutting conditions (Droba *et al.* 2015; Kvietková *et al.* 2015; Li *et al.* 2017). However, all cutting operations in this study resulted in noise levels exceeding the noise limit of 87 dB(A). Therefore, it should be considered that noise protectors should be used under all conditions, and controlling noise levels is crucial for OSH.

Optimization of Noise and PM₁₀ Values

Response surface methodology (RSM) is a statistical technique used for optimizing complex systems and processes. This method combines experimental design and regression analysis to model and analyze the effects of one or more independent variables (factors) on one or more dependent variables (responses). The objective is to determine the optimal settings of the factors to achieve the lowest possible values of the responses. Following the analysis of the obtained noise and PM₁₀ values, optimization was performed using the RSM with a full quadratic model for each material type separately, targeting their minimum levels. The RSM allows assigning different levels of importance and weight values to factors based on their impact on

responses. This capability enables fine-tuning of the established model. In this study, the optimization process was conducted using the entire dataset, assuming equal importance and weight for both parameters, with the goal of minimizing both dependent variables. It was observed that the model, in some cases, suggested turning off the dust collector to reduce noise levels. Therefore, during the model configuration process, where parameter weights and constraints were adjusted in RSM, keeping the dust collector on at all times was defined as a constraint. This ensures that the model provides only solutions that comply with safe and appropriate working conditions. The results of the optimization process are given in Table 4.

Table 4. RSM Results for Noise and PM₁₀ Values

Material Type	Optimal RPM	Optimal Feed Rate (m/min)	Optimal Number of Teeth	Predicted Noise	Measured PM ₁₀	Combined Desirability
Pine	3000	5	28	90.53	35.66	0.89
Beech	6000	5	60	90.48	36.42	0.86
Plywood	6000	5	60	91.56	82.38	0.80
MDF	6000	5	28	88.93	65.43	0.88
OSB	3000	5	60	88.8	78.98	0.95
PB	6000	5	28	88.6	104.7	0.86

Additionally, the comparison of measured and predicted noise levels and PM₁₀ concentrations is presented in Fig. 3.

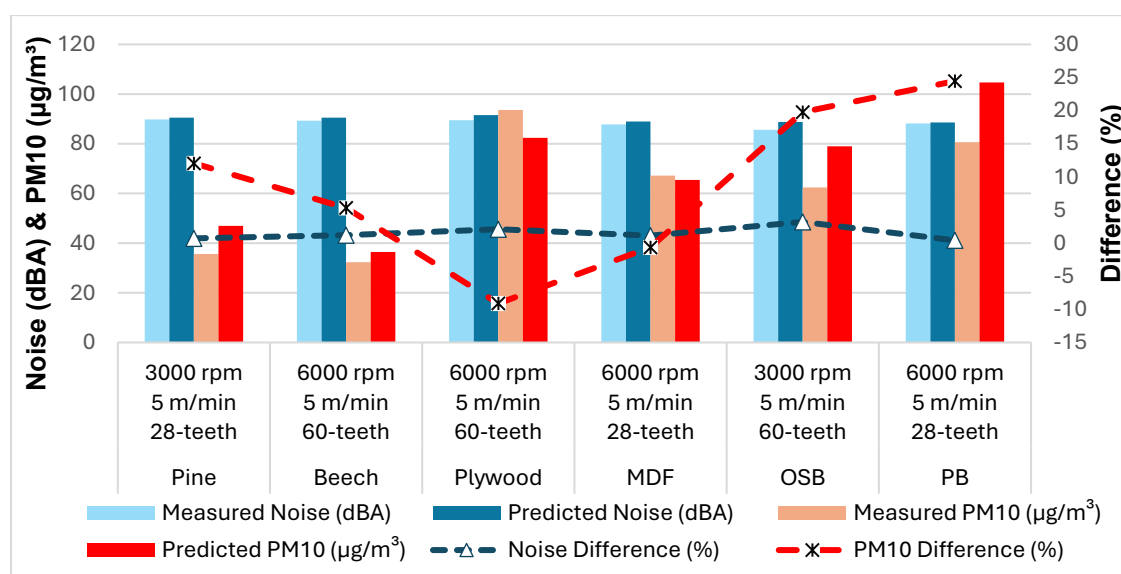


Fig. 3. Comparison of measured and predicted noise and PM₁₀ Levels

The optimal cutting conditions varied significantly across materials, highlighting the impact of wood type on dust and noise emissions. For Scots pine, a rotational speed of 3000 rpm, a feed rate of 5 m/min, and 28 teeth resulted in the lowest PM₁₀ (46.9 µg/m³) and a noise level of 89.8 dB(A), with a high desirability score of 0.89. Similarly, Oriental beech performed best at 6000 rpm, 5 m/min, and 60 teeth, yielding a slightly lower noise level (89.3 dB(A)) and a reduced PM₁₀ concentration (36.4 µg/m³) with a desirability of 0.868. Among the engineered wood products, MDF stood out with the lowest noise emission (67.8 dB(A)) when processed at 6000 rpm, 5

m/min, and 28 teeth, achieving a desirability score of 0.885. In contrast, OSB, optimized at 3000 rpm, 5 m/min, and 60 teeth, produced a moderate PM₁₀ level (79.0 µg/m³) but it showed the highest desirability (0.957), indicating well-balanced performance. A different trend was observed in plywood and particleboard (PB). While plywood, under 6000 rpm, 5 m/min, and 60 teeth, reached 89.4 dB(A) noise and 82.4 µg/m³ PM₁₀ with a desirability of 0.802, PB exhibited the highest PM₁₀ concentration (105 µg/m³), suggesting a need for further optimization despite a relatively high desirability (0.860). These findings emphasize that material composition plays a crucial role in airborne dust and noise emissions. While some materials exhibit well-balanced performance, others may require additional refinements to achieve optimal workplace safety. Observations indicate that the established model occasionally offers unconventional recommendations. For instance, while higher tooth counts are generally preferred in the cutting of composite materials, the model, in certain cases, suggests lower tooth counts. The primary reason for this outcome is that equal weight and importance were assigned to both noise level and PM₁₀ values within the model. The use of the same priority level for optimizing both variables leads the model to prioritize reducing noise levels in some parameter combinations. Through reassessing the weights assigned to noise level and PM₁₀ values or modifying the constraints within the model, different solutions tailored to specific conditions could be generated.

CONCLUSIONS

1. The noise and dust levels generated during the processing of different materials were found to vary significantly depending on the material type. This finding highlights the necessity of considering material selection to minimize its impact on the working environment.
2. Particleboard exhibited the highest dust formation, while solid woods generated lower levels of dust emissions. These differences emphasize the importance of selecting and optimizing appropriate extraction systems during processing.
3. Cutting parameters significantly influenced both noise levels and dust formation. Higher cutting speeds generally increased noise levels, whereas the effect of feed rate variations differed depending on the material type. This underscores the need for comprehensive optimization of machining parameters.
4. The noise levels generated during the cutting process are directly related to the density and fiber structure of the material. The higher resistance encountered when processing denser materials resulted in increased noise levels, necessitating the development of material-specific machining strategies.
5. The findings provide valuable insights for improving occupational safety and working environment quality in the furniture and woodworking industries. Optimizing machining parameters and implementing advanced ventilation systems are crucial for reducing noise and dust exposure, thereby protecting workers' health, and enhancing production efficiency.

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