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Research Article

Analysis of Noise Emission in Table Sawing in Relation to Blade Projection Height and Number of Teeth

Mustafa Korkmaz[1*]

[2] Duzce University, Wood Products Industrial Engineering Department, Düzce, Turkey. (e-mail: mustafakorkmaz@duzce.edu.tr).

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Corresponding author:

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ABSTRACT

Although table saws are widely used in the woodworking and construction industries, they are a significant source of noise pollution and pose hearing health risks for operators. This study aims to systematically investigate the effects of two primary factors influencing noise emission in table saws: blade projection height and number of teeth. During the experiments, 300 mm diameter circular saw blades with three different tooth counts (28, 48, and 60) were used at four different projection heights (5, 10, 15, and 20 mm) to cut various wood-based materials, including particleboard, medium-density fiberboard, pine, and beech. Noise levels were measured in decibels A-weighted (dBA) using a sound level meter positioned to simulate operator exposure. The collected data were statistically analyzed using analysis of variance (ANOVA) and Duncan's multiple range test. The results revealed that material type, blade projection height, and number of teeth had statistically significant effects on noise levels ($p \leq 0.05$). The lowest noise levels (averaging 79.61 dBA with the 60-tooth blade) were obtained when cutting pine with a 5 mm blade projection height. Conversely, the highest noise levels (averaging 84.87 dBA) were generated when cutting particleboard.

1. INTRODUCTION

Table saws are indispensable tools in woodworking and construction industries, yet they are recognized as substantial sources of noise pollution [1]. The noise levels generated during table saw operation can be exceedingly high, often reaching intensities that are well above those considered safe for hearing without protection [2]. These levels significantly surpass occupational safety thresholds, such as the 85 dBA 8-hour time-weighted average exposure limit mandated by the Occupational Safety and Health Administration (OSHA) in the United States [3]. Similarly, in Türkiye, according to the "Regulation on the Protection of Employees from Risks Related to Noise", hearing protection must be provided when noise levels exceed 80 dB(A), and its use becomes mandatory from 85 dB(A) onwards [4]. The prevalence of such hazardous noise levels underscores the critical need to understand and mitigate the various factors contributing to noise generation in table saws, one of which is the blade projection height. Blade projection height refers to the vertical distance of how much the saw blade extends above the superior surface of the workpiece being processed. This parameter differs from the total blade exposure, which is defined as the distance measured from the table surface to the highest point of the blade in the absence of a workpiece. It is directly related to "depth of cut," particularly about the part of the blade that is actively in contact with the material and the part that is exposed to the surrounding air above the workpiece. Operators can adjust this height, and this adjustment has known effects on the cutting mechanics, operational safety, and on the characteristics of the emitted noise.

The noise produced by a table saw originates from several distinct yet interacting physical mechanisms: aerodynamic effects, mechanical vibrations of the tool and workpiece, and the cutting process itself. The blade projection height can modulate the relative contribution and interplay of these mechanisms. Aerodynamic noise is generated by the displacement of air and the creation of turbulent airflow patterns by the rotating saw blade, particularly around its teeth and gullets [2], [5]. This is a significant noise source, especially when the saw is idling (running without cutting material). Key parameters influencing aerodynamic noise include the tip speed of the saw teeth, the depth of the gullets, and the ratio of gullet width to the thickness of the blade plate. Due to the high cutting speeds typical in wood-cutting machinery, often up to 120 m/s, aeroacoustics noise emissions can dominate the overall sound signature [6]. The geometry of the saw blade also plays a key role in aerodynamic noise generation. The size and shape of the gullets—the spaces between adjacent teeth—are especially important. Larger or poorly designed gullets can trap more air and cause greater turbulence, which increases noise levels [7]. In contrast, optimized gullet designs with reduced volume have been shown to lower aerodynamic noise [6]. For example, LEUCO nn-System blades, which use minimized gullets, significantly reduce idling noise by decreasing air turbulence [8]. Therefore, using specific tooth configurations and carefully designed gullets is a known method to control free-running noise. The shape and number of saw teeth also affect noise [9]. Blades with more teeth usually have smaller gullets, which can help reduce noise levels [2], [10], [11]. Although this relationship is frequently observed in practice, the specific mechanisms behind the noise reduction have not been thoroughly investigated. However, it is generally assumed that smaller gullets reduce the volume of trapped air and limit turbulent airflow, thereby decreasing aerodynamic noise. In woodworking tools, greater cutter projection leads to more trapped air and increased noise. This applies to table saw blades as well. A blade set higher above the workpiece exposes a larger surface area, which interacts more with the air and can raise aerodynamic noise.

Saw blades can vibrate due to rotational forces, imbalances, or dynamic forces arising during cutting [12], [13]. These vibrations emit sound energy into the environment, and the blade itself is widely recognized as a major source of noise. Resonant vibrations, which occur when excitation frequencies align with the blade's natural frequencies, are particularly problematic. These often result in a high-pitched "screaming" sound, especially in blades that are undamped or poorly maintained. To address this issue, many modern blades incorporate vibration control features such as damping slots filled with polymer or laser-cut expansion slots. These features modify the blade's vibrational behavior and help dissipate vibrational energy. While such designs are widely used and appear effective, the exact contribution of each design element to noise reduction is still not fully understood. The workpiece itself can also become a source of vibration when it is excited by the periodic impact of the saw teeth. As the workpiece vibrates, it radiates sound. The extent of this noise depends on the material's properties, such as stiffness and damping, as well as its dimensions. This effect is particularly noticeable when cutting thin panels or materials prone to vibration, such as metals. However, it is also a relevant factor in wood cutting. Although this phenomenon is well-documented, the complex interactions between material type, tooth frequency, and resulting sound output warrant further study.

Considering the foregoing discussion, it is evident that noise emissions in table saws result from a complex interplay of aerodynamic effects, mechanical vibrations of the blade and workpiece, and the dynamics of the cutting process itself. These mechanisms are strongly influenced by key parameters such as blade projection height and the number of teeth. To address these factors, this study aims to systematically investigate the effects of blade projection heights (5, 10, 15, and 20 mm) in combination with circular saw blades having 28, 48, and 60 teeth on noise generation during the cutting of various wood-based materials, including particleboard, MDF, Scots pine, and beech. Through rigorous experimental analysis, the individual and interactive impacts of these parameters on noise levels will be evaluated. The findings are expected to inform recommendations for optimized blade designs and operational settings to achieve quieter working environments. Ultimately, this research seeks to support compliance with occupational health and safety regulations while promoting sustainable and user-friendly practices within the woodworking industry.

2. MATERIAL AND METHOD

2.1. Materials

2.1.1. Wooden Materials

The materials used in the study include both solid wood, such as Scots pine (*Pinus sylvestris L.*) and Oriental beech (*Fagus orientalis L.*), and composite wood materials, including MDF (medium-density fiberboard) and particleboard (PB). These materials, which are widely used in the furniture manufacturing industry, exhibit different densities, fiber structures, and mechanical properties. Thus, they provide a wide variety for examining the effects of testing parameters. To ensure standardized test conditions, all materials were prepared to uniform dimensions. Prior to testing, the solid wood samples were conditioned to a constant weight at a temperature of 20°C and 65% relative humidity, in accordance with the TS ISO 13061-1 (2021) standard. The thickness for both solid wood (Scots pine and beech) and composite panels (MDF, particleboard) was set to 18 mm. Each sample was prepared with a length of 1 meter to standardize the cutting operations. For the noise measurements, successive cuts were made at 2 cm intervals along the length of these samples.

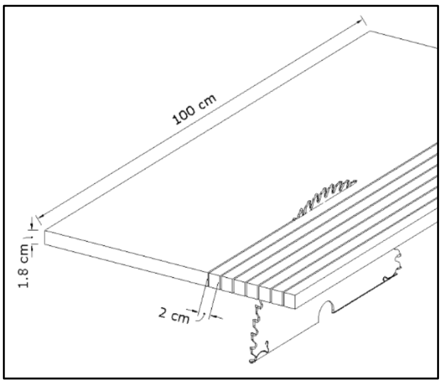

Figure 1. Cutting operations

Table 1 presents the density values and moisture contents of the materials used.

TABLE I
DENSITY AND MOISTURE CONTENTES OF MATERIALS

Material	Average Density (g/cm^3)	Moisture Content (%)
Scots pine	0.46	11.6
Beech	0.65	11.9
PB	0.58	8.9
MDF	0.68	7.8

2.1.2. Table Saw and 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 operates at 3000 rpm at the first level under no-load conditions. 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.

To ensure consistency in cutting operations, the feed rate was set to 9 m/min, maintaining a constant feed speed throughout the experiments. In this study, no dust collector was employed during the experiments to ensure accurate measurement of noise levels associated with blade projection height. The presence of a dust collector, commonly used in woodworking environments, was found to interfere with the precise assessment of noise generated by the saw blade due to its own operational sound and airflow effects. Despite the well-documented importance of dust collectors for worker health and safety by reducing airborne particle matter (PM) concentrations, their use was omitted to eliminate potential confounding factors in noise measurements. All cutting operations were conducted in a controlled environment, with thorough cleaning and maintenance of the table saw performed prior to each experimental run to maintain consistency.

Figure 2. Testing set-up.

2.1.3. 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).

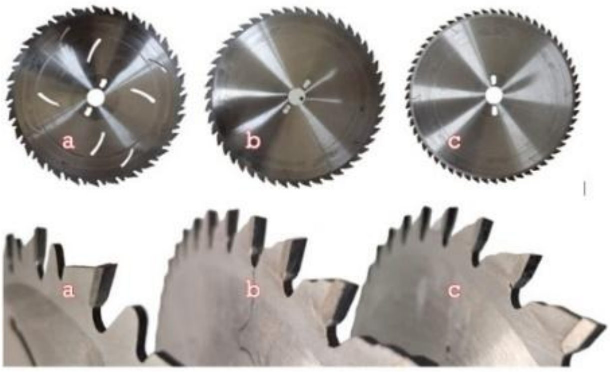

Figure 3. Circular saws used in the study (a: 28-teeth, b: 48-teeth, c: 60-teeth)

To ensure consistency and eliminate variability from material sources, all saw blades were procured from a single manufacturer (Finish Brand). These blades consist of a high-strength steel body fitted with Polycrystalline Diamond (PCD) cutting teeth, which provide high wear resistance. All circular saw blades used have a diameter of 300 mm, a plate thickness of 1.8 mm, and a tooth thickness of 2.4 mm. While the tooth geometries are identical, the 28-tooth saw blade includes raker teeth (Fig. 1). Some properties of the teeth were shown in Fig. 2.

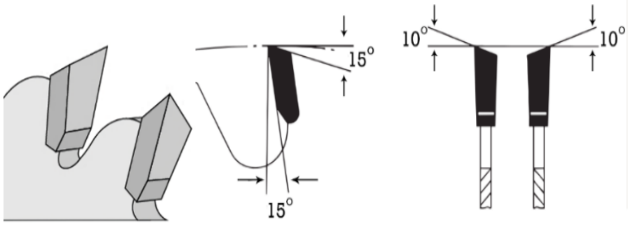

Figure 4. Properties of the blades used in the study

2.2. Methods

The materials used in the experiments were prepared with consistent properties to ensure reliable results. Specifically, particleboard and MDF 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, etc. The materials to be cut were dimensioned to a length of 1 meter. The cuts were made at 2 cm intervals, with simultaneous recording of noise measurements. During the cutting process, the height of the circular saw blade was adjusted to 5, 10, 15, and 20 mm above the material surface to investigate the effects of varying blade projection heights on noise generation.

A sound meter (Model UT 353BT, UNI-Trend, Guangdong, China) was utilized for measuring noise levels. This device is capable of measuring A-weighted sound levels within a range of 30 to 130 dBA with a resolution of 0.1 dB. The device was positioned 70 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)). For each factor, 5 repeated 1-meter cutting operations were performed, and the average of the maximum noise values of the 5 measurements were used in the analysis.

2.3. Statistical Analysis

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 projection height, number of teeth, and material type on noise generation. The Duncan multiple range test was applied to assess significant differences among the groups and identify homogeneity groups.

3. RESULTS AND DISCUSSION

The ANOVA results for noise levels generated during the cutting of particleboard, MDF, Scots pine, and beech with varying blade projection heights (5, 10, 15, 20 mm) and tooth numbers (28, 48, 60) are presented in Table 2. According to the results, the effects of material type, blade projection height, and number of teeth on noise levels were statistically significant ($p \leq 0.05$).

To further examine the significant results obtained from ANOVA in detail, Duncan's multiple range test (DMRT) was applied to identify differences between groups. Duncan test comparisons performed for Material Type, Projection Height, and Number of Teeth factors are shown in Figure 3 ($p < 0.05$).

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TABLE II
ANOVA TEST RESULT

Source	df	SS	MS	F	p
Material Type (A)	4	2934.47	733.62	844.10	0.00
Projection Height (B)	3	35.68	11.89	13.69	0.00
Number of Teeth (C)	2	338.01	169.01	194.46	0.00
A × B	12	5.11	0.43	0.49	0.92
A × C	8	83.48	10.44	12.01	0.00
B × C	6	12.60	2.10	2.42	0.03
A × B × C	24	3.27	0.14	0.16	1.00
Error	120	104.29	0.87		
Model	59	3412.61	57.84	66.55	0.00

Note: df: Degrees of Freedom, SS: Sum of Squares, MS: Mean Square, F: F-statistic, p: p-value (≤0.05).

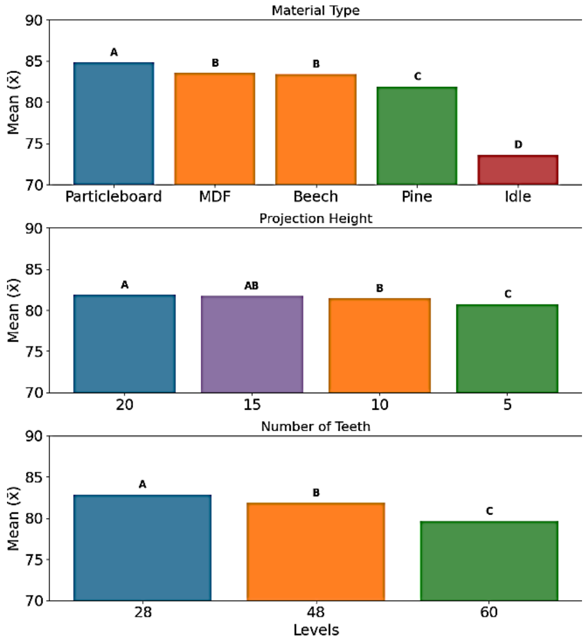

Figure 5. DMRT results

According to the DMRT results, in the level material type, the highest average noise level was recorded during the cutting of particleboard samples, measured at 84.87 dBA. In contrast, the lowest average noise level was obtained during the cutting of pine samples, measured at 81.87 dBA. Compared to the idle condition, the lowest value (pine) was found to be 11.24% higher, while the highest value (particleboard) was 15.31% higher. It was determined that the noise levels generated during the cutting of all samples were all below the legal exposure limit of 87 dBA. The reason for the lowest noise level being observed in pine samples may be attributed to the fact that pine has a softer and less dense structure [14] compared to the other materials, which facilitates easier penetration of the saw teeth into the material during cutting, resulting in reduced vibration and, consequently, lower noise generation [15].

According to the table, the highest average noise value, 81.88 dbA, was obtained during cutting operations at a projection height of 20 mm. The lowest average noise value, 80.72 dbA, was recorded during cutting operations at a projection height of 5 mm. The highest value was found to be 1.44% higher than the lowest value. It was determined that the noise values generated during cutting at all projection heights (20 mm, 15 mm, 10 mm, and 5 mm) were below the legal occupational exposure limit of 87 dbA. The reason for the lowest noise value being observed at a 5 mm projection height can be attributed to the reduction in the exposed portion of the saw blade outside the material at lower projection heights; this condition likely reduces both the aerodynamic noise of the saw body air resistance and whistling sound and the vibrations during the cutting process, thereby lowering the overall noise level [16], [17], [18].

According to the table, the highest average noise level was recorded at a saw blade projection height of 20 mm, measured at 81.88 dBA. The lowest average noise level was obtained at a projection height of 5 mm, measured at 80.72 dBA. The difference between these two values corresponds to approximately 1.44%. It was observed that the noise levels measured at all blade projection heights remained below the legal exposure limit of 87 dBA. The lowest noise level at 5 mm projection height may be attributed to the fact that a larger portion of the saw blade remains within the material being cut, providing better guidance, and thereby reducing blade vibration [19], [20]. Additionally, fewer teeth are exposed in the air simultaneously, which may result in lower aerodynamic noise. Conversely, the highest noise level at 20 mm projection height may be due to a greater portion of the saw blade remaining outside the material, making it more susceptible to vibration [16]. Furthermore, a higher number of teeth are exposed to the air, increasing aerodynamic noise, and the steeper entry and exit angles of the teeth into the material may enhance impact forces, contributing to elevated noise levels [20].

4. CONCLUSION

In this study, the effects of material type, blade projection height, and the number of saw teeth on noise emissions generated during cutting operations on table saws were investigated. The statistical analysis confirmed that all three factors, along with some of their interactions, were significant drivers of noise generation in table sawing operations.

It was concluded that material properties are a primary determinant of noise emission. Denser, composite materials like particleboard consistently generated the highest noise levels, whereas cutting lower-density solid woods, such as Scots pine, resulted in significantly quieter conditions. This is attributed to the softer structure of less dense woods, which facilitates easier cutting and reduces material-induced vibrations, a finding consistent with other research on wood machinability and noise.

The study also confirmed the critical role of blade projection height, a key operational parameter adjustable by the operator. Lowering the blade projection consistently led to a reduction in noise. This inference is based on the principle that minimizing the blade's exposure above the workpiece reduces both the aerodynamic noise from the spinning blade and the mechanical vibrations during cutting. This aligns with findings from other studies that highlight the link between blade exposure, vibration, and aerodynamic noise.

Furthermore, the number of saw teeth was identified as a highly influential factor in noise control. It was determined that blades with a higher tooth count produced substantially lower noise levels than those with fewer teeth. This is explained by a smoother cutting action due to a lower chip load per tooth, which minimizes impact forces and vibration. Concurrently, the smaller gullet spaces on high-tooth-count blades likely reduce aerodynamic noise, a mechanism also suggested in related literature.

The findings of this study are particularly critical when analyzed in the context of occupational health regulations. For instance, the highest average noise level recorded, 84.87 dBA when cutting particleboard, dangerously approaches the 85 dBA mandatory action level for hearing protection in Türkiye [4]. This study demonstrates that by making informed equipment choices—such as using a 60-tooth blade instead of a 28-tooth blade—operators can reduce noise levels by more than 3 dBA. As sound pressure is on a logarithmic scale, a reduction of this magnitude nearly halves the sound energy exposure and can lower the noise to levels well below the mandatory protection threshold, even approaching the 80 dBA level where initial action is required. Therefore, these optimizations are not merely minor improvements; they are crucial strategies to protect employee health, reduce the risk of noise-induced hearing loss and related workplace accidents, and ensure compliance with safety standards, ultimately fostering more sustainable and comfortable working conditions in the woodworking industry.

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BIOGRAPHIES

Mustafa Korkmaz obtained obtained his Bachelor of Science degree in Furniture and Decoration Teaching from Karabük University in 2010. He subsequently received his Master of Science and Doctor of Philosophy degrees in the same department from Karabük University in 2012 and 2018, respectively. His research interests include wood materials, non-destructive testing (NDT) of wood, and wood modification. In 2013, he joined the Faculty of Technology at Düzce University as a research assistant and is currently serving as an assistant professor.