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Optimizing Diode Laser Performance: Effective Noise Reduction in a Three-Dimension Printing Machine

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Abstract

This research focuses on reducing noise in 3D laser printers, commonly used in businesses and home offices. By fine-tuning printer components and analyzing noise levels, the primary goal is to minimize the noise produced by a 3D laser printer. The study involves modifying various printer parts and using a Raspberry Pi 4 as an AI control system. Noise reduction is tested by adjusting the speed and acceleration of the machine while maintaining precision. A sound level meter and analysis program are employed to measure and analyze the noise levels. Results indicate that altering components, such as stepper motor drivers, significantly reduces noise. Findings suggest that further noise reduction can be achieved through additional component tuning and noise insulation strategies. This approach improves the user experience by providing a quieter operation and enhances the overall performance and efficiency of 3D laser printers. By focusing on minimizing noise, this research provides practical solutions for creating quieter and more efficient 3D laser printers, benefiting both businesses and home offices. Insights from this study can be applied to develop advanced 3d laser printers with optimized noise levels.

Keywords: Acceleration Value; Laser Printer; Noise Tests; 3D Printer’s Technology; Raspberry Pi 4

1. Introduction

Laser 3D printers are well used for home offices and corporate businesses because of their efficiency and great quality prints. However, the noise produced by these printers disrupts the working environment, particularly for individuals working in a shared office space. The following paper describes a technique for controlling the noise of a laser printer through a component-based approach. Minimizing the noise of a 3D laser printer is made by selecting the printer's components and studying the noise created by the printer. This will go a long way in minimizing the disturbances created by the printer in a workplace environment and the efficiency of the printer [1]-[4]. The method concerns varying the operational parts of the printer and acceleration settings to decrease the noise level produced by the printer. Moreover, the paper also discusses the evaluation of the noise made by the printer using acoustic analysis and determining the noise source. Lastly, the paper suggests measures to minimize the noise produced by the laser printer to enhance work productivity.

Laser 3D printers are one of the Artificial Intelligence (AI) resources that have changed the way of printing on various materials. It is adaptable to generate excellent prints at a minimal cost. Laser printers use laser beams to print an image on the sample. It has been used to produce high-quality prints within a short time, which has improved the business's productivity. Laser printers are also more environmentally friendly than other types of printers and are thus suitable, especially for environmentally sensitive organizations. Modern AI technology has meant that laser printers are continuing to become more sophisticated and enabling rapid and high-quality printing [5].

Recent technical advancements in the manufacturing industry are accelerating the transition of industrial systems into a new period characterized by greater digitization and connectivity. The concept of a technology-oriented manufacturing paradigm, which can achieve flexibility, agility, customization, and decentralization of the production processes, has recently emerged thanks to the Fourth Industrial Revolution (also known as Industry 4.0) and smart factory concepts. Also, Industry 4.0 necessitates a paradigm change away from the conventional lean thinking theory and toward a strategy centered on production management [6]. Industries are searching increasingly for fundamental digital transformations in which their systems can become intelligent and react to continuously shifting business dynamics and the discerning tastes of customers. In addition, clients continually demand that business systems be flexible and responsive enough not only to carry out their daily workload but also to provide them with additional insights to enable them to make decisions that are informed and more trustworthy [7]. Artificial intelligence (AI), which encompasses machine learning (ML) and deep learning (DL), is viewed as a potential game-changer in a wide variety of industries and sectors, including telecommunications, construction, transportation, healthcare, manufacturing, advertising, and education, amongst others. Because it enables students to take a tailored approach to learning challenges based on their own specific experiences and preferences, artificial intelligence (AI) will play an increasingly crucial role in higher education in the coming years [8],[9]. A key technology of the contemporary age of the Fourth Industrial Revolution (also known as Industry 4.0 or 4IR), artificial intelligence (AI) has the potential to incorporate human behavior and intelligence into machines or other systems [10]. Artificial Intelligence (AI) is the science that enables computers and machines to learn, judge, and use their reasons [11].

2. Methodology

Manufacturing a laser printer is a complex process requiring great precision and expertise [12]. Laser printers are a type of printer that uses a laser beam to create an image on any material. A laser printer machine with a diode laser that uses the 3Dprinter's boards has been designed and manufactured. This gives more options to control the print quality, and the laser printer is made up of aluminum bars 40x20 mm, which are very suitable for such a machine because they give good stability. Using 3D printer board ramps 1.4 and programming with marlin language and adding a Raspberry Pi 4 as a control system for the machine and as an artificial intelligence board to control the machine using this board. This work measures the noise of this machine and tries to reduce it to get a silent machine that prints on various materials using a diode laser. The noise control is achieved by changing the stepper motor drivers and the machine's acceleration, affecting the machine's noise. A Noise meter, as shown in Fig. 1, is used in this study to measure the noise of the machine, UNI-T UT353; its frequency response is between 31.5Hz~8kHz, and Noise (A-weighting) is between 30~130 dBA. The machine is placed into an isolated box (1.0m*1.0m*0.75m) to get accurate results. A simple print is loaded into the software, adding some acceleration values to the software, and then the machine will start printing. While the machine is printing, noise measures and data are taken and registered using the noise meter. Graphs are plotted from the registered data; from the various graphs, the average lowest noise values are taken and set to the machine. Each Noise measurement is repeated five times for each acceleration to check for errors, and the average is taken for each acceleration value and plotted to see and compare with the other measures. The laser beam is directed into the wood sample. They are creating the printed image. Manufacturing a laser printer involves several steps, from designing the printer to assembling the components and testing the finished product. It is a highly technical process that requires a great deal of skill and knowledge [13].

Figure 1. Noise meter

The control system is utilized to direct the operation of a physical system to achieve the desired purpose [14]. A Control system is a collection of diverse elements that function as a unit to direct or regulate itself or any other system to produce a specific output. As depicted in Fig. 2, Raspberry Pi is a series of small single-board computers that function as micro-personal computers by connecting peripherals.

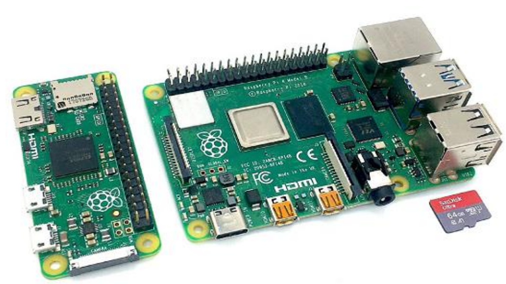

Figure 2. A Raspberry Pi zero (left) and 4B (right) with a micro-SD card for scale

Using Raspberry Pi to operate Linux and making GPIO (general purpose input/output) ports available [15]. This enables control of electronic components for physical computing and Internet of Things searching (IoT). The current monitors on the USB ports signify that the B+ now supports hot-plugging, and the current limiter on the 5V for HDMI indicates that HDMI cable-powered VGA converters are possible. Fourteen additional GPIO pins with EEPROM support have been added to the new HAT expansion modules. Higher drive capacity for analog audio output, provided by a distinct regulator, results in a superior audio DAC. Four mounting holes are positioned precisely for a more rigid attachment to cases.

3. Results and Discussion

Noise charts of laser printers effectively determine the noise levels of the particular printer. These two graphs depict the noise level of a printer and will enable users to understand the printer's various models and be able to decide when to use the printer. The noise chart of a laser printer is usually a graph that indicates the decibels at different acceleration rates. The noise levels are measured in terms of the decibels, which are abbreviated as DB. As acknowledged, the louder the sound, the higher the dB level is [16]. This chart also shows the level of noise that is produced by the printer when it is at a certain distance. This helps users know how noisy the printer will be at specific points within the printing zone [17]. Printers have their noise levels; hence, the noise charts help distinguish the right printer for the given type of work. For example, sometimes one may need a printer with a dB level that is lower or a printer with a dB level that is higher [18]. Noise charts are also helpful in finding out the best possible printer for the execution of a particular type of printing. For instance, if the user is choosing the most appropriate printer for photo printing and comes across a specific model of that printer with a certain dB level, they will consider using that printer. This is because the photos require detailed printing, and the process will most likely produce some noise.

The application of noise charts can be appropriate for assessing the noise produced by a printer. It gives a user, or any person, for that matter, a graphical representation of the sounds produced by a printer and can be used to evaluate several models of a printer in use. The sound meter should be used to record noise produced by the printer on different possible acceleration states. The readings should then be compared to check which settings will likely produce the most diminutive noise spikes. Therefore, in most cases, it becomes necessary to analyze the noise to find out whether the noise is produced by a particular component or setting to improve the efficiency of the machine [19]. This can be achieved by varying the speeds and frequencies of the machine and measuring the noise intensity produced [20],[21]. The results can then be compared to determine which component or setting is causing the noise. Once the noise source has been identified, the element or setting can be adjusted to reduce the noise [21].

Figs. 3 to 22 illustrate the noise charts of the noise—values at different values of accelerations. Fig. 3 displays the average noise values at an acceleration of 1000 mm/s^2, with the peak value being 62.9 dBA and the lowest value being 56 dBA (which occurred in the first second when the machine was about to print). Since the print time was 35 seconds, the noise level at the end of the print job was 58.2 dBA.

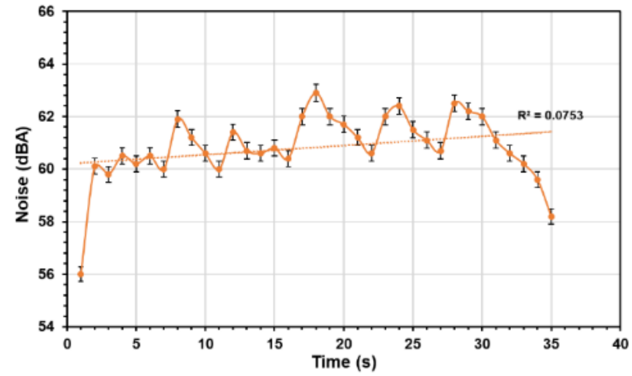

Figure 3. Noise values at 1000 mm/s^2 acceleration

Fig. 4 shows the average noise values at acceleration reading 2000 mm/s2. The peak noise value is above 62.8 dBA, and the lowest is 56 dBA, so at 35 seconds, the noise is 59.3 dBA.

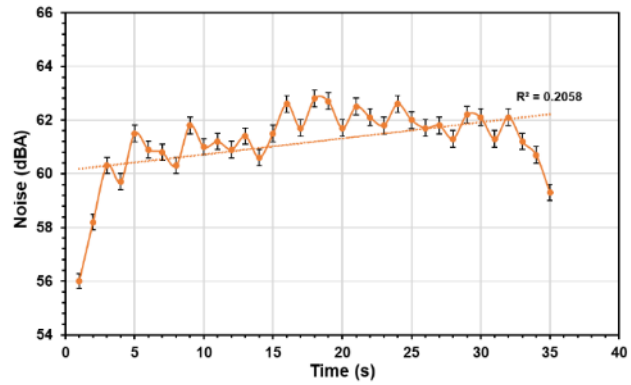

Figure 4. Noise values at 2000 mm/s^2 acceleration

Fig. 5 shows that when the acceleration reading is 3000 mm/s2, the peak noise value is 62.4, and the lowest is 56 dBA (which is the first second when the machine is about to print). The print time is 35 seconds, so at 35 seconds, the noise is 58 dBA.

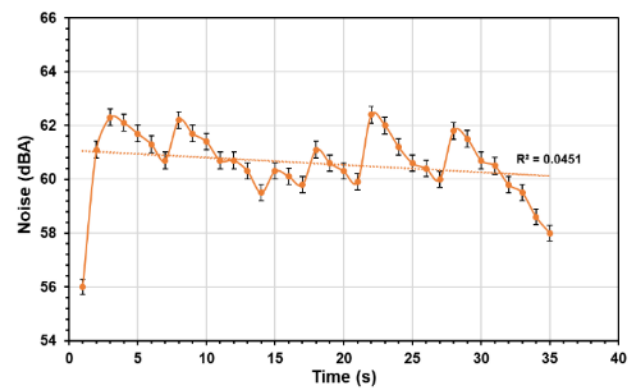

Figure 5. Noise values at 3000mm/s^2 acceleration

Fig. 6 shows when the acceleration value is 4000 mm/s2. As shown, the peak noise value is 64, and the lowest is 56 dBA (which is the first second when the machine is about to print). The print time is 35 seconds, so at 35 seconds, the noise is 59.2 dBA.

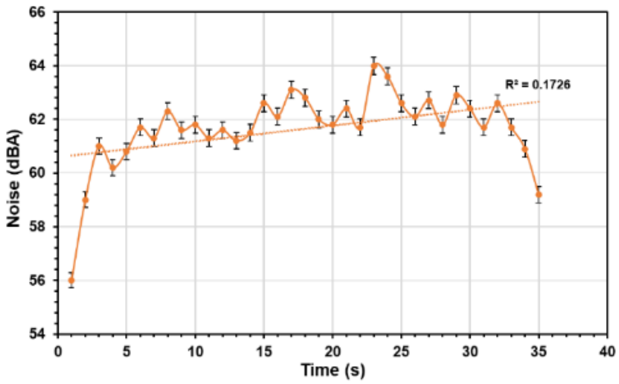

Figure 6. Noise values at 4000mm/s^2 acceleration

Fig. 7 shows that when the acceleration value is 5000 mm/s2, the peak value is 63.4 dBA, the lowest is 56 dBA, and the print time is 35 seconds. Thus, at 35 seconds, the noise is 59.1 dBA.

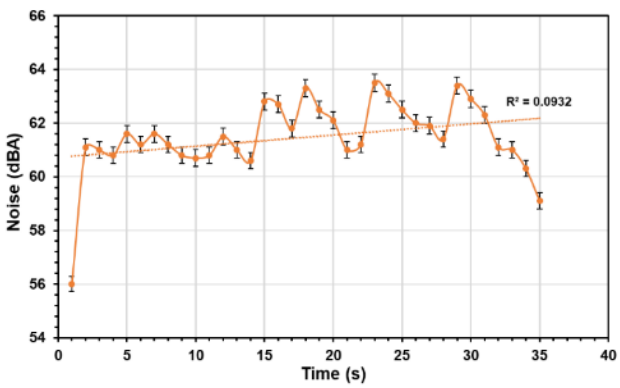

Figure 7. Noise values at 5000 mm/s^2 acceleration

Fig. 8 shows that when the acceleration value is 6000 mm/s2, the peak value is 61.8 dBA, the lowest is 56 dBA, and the print time is 35 seconds. Thus, at 35 seconds, the noise is 57.3 dBA.

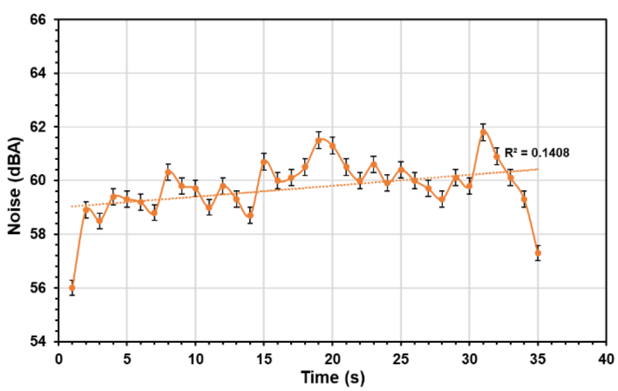

Figure 8. Noise values at 6000 mm/s^2 acceleration

Fig. 9 shows the acceleration value at 7000 mm/s2. As seen from the graph, the peak value is 64.1 dBA, the lowest is 56 dBA, and the print time is 35 seconds, so at 35 seconds, the noise is 57.9 dBA.

Fig. 10 shows that when the acceleration is 8000 mm/s^2, the peak value is 63.7 dBA, the lowest value is 56 dBA, and the print time is 35 seconds, so the noise is 59 dBA at 35 seconds.

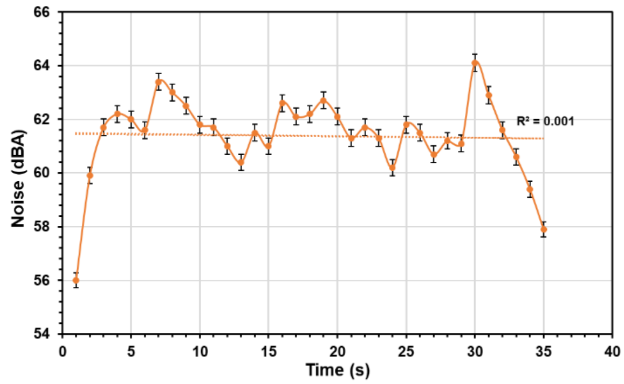

Figure 9. Noise values at 7000 mm/s^2 acceleration

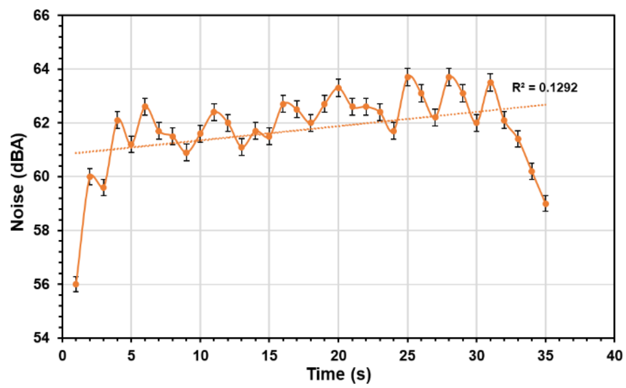

Figure 10. Noise values at 8000 mm/s^2 acceleration

Fig. 11 shows when the acceleration value is 9000 mm/s^2, and as seen from the graph, the peak value is 65.3 dBA, the lowest is 56 dBA, and the print time is 35 seconds, so as we can see at 35 seconds, the noise is 59 dBA.

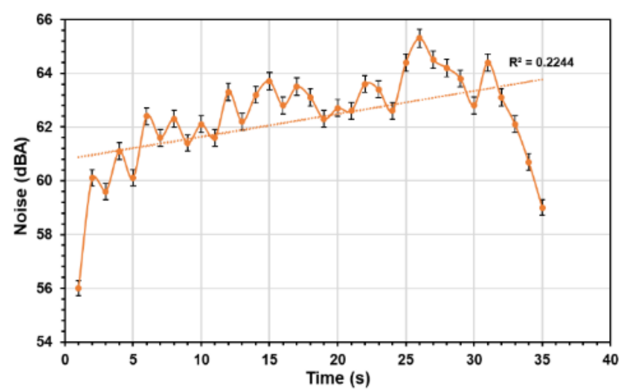

Figure 11. Noise values at 9000 mm/s^2 acceleration

Fig. 12 shows when the acceleration value is 10000 mm/s^2, and as seen from the graph, the peak value is 62.3 dBA, the lowest is 56 dBA, and the print time is 35 seconds, so at 35 seconds, the noise is 58 dBA.

Fig. 13 shows the acceleration value at 11000 mm/s2. As seen from the graph, the peak value is 62.5 dBA, the lowest is 56 dBA, and the print time is 35 seconds, so at 35 seconds, the noise is 57.4 dBA.

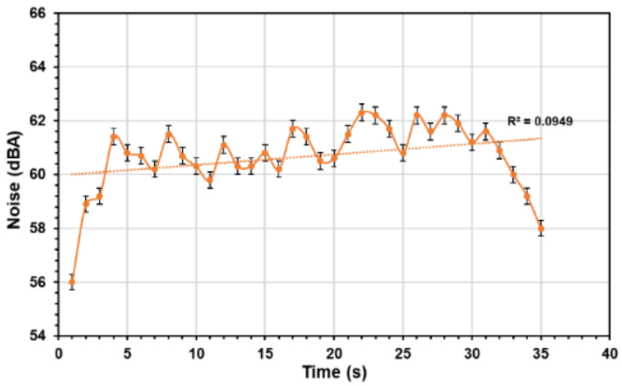

Figure 12. Noise values at 10000 mm/s^2 acceleration

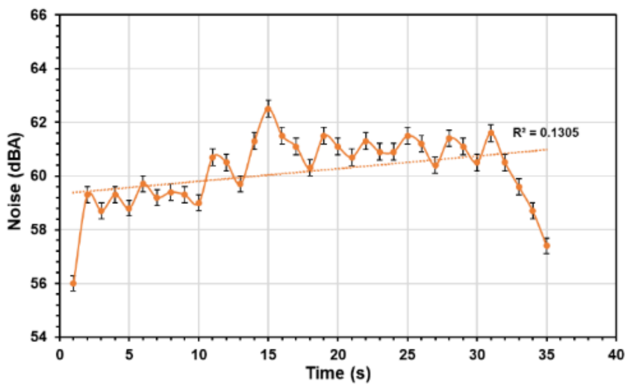

Figure 13. Noise values at 11000 mm/s^2 acceleration

Fig. 14 shows when the acceleration value is 12000 mm/s^2, and as seen from the graph, the peak value is 62.6 dBA. The lowest is 56 dBA, and the print time is 35 seconds, so at 35 seconds, the noise is 57.7 dBA.

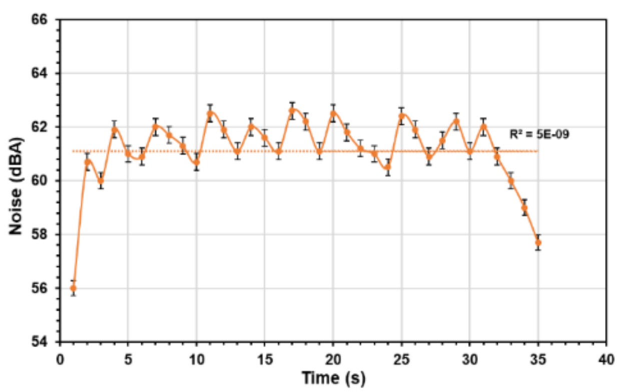

Figure 14. Noise values at 12000 mm/s^2 acceleration

Fig. 15 shows when the acceleration value is 13000 mm/s^2, and as seen from the graph, the peak value is 62.7 dBA. The lowest is 56 dBA, and the print time is 35 seconds, so at 35 seconds, the noise is 57.8 dBA. Fig. 16 shows when the acceleration value is 14000 mm/s^2, and as seen from the graph, the peak value is 63.3 dBA, the lowest is 56 dBA, and the print time is 35 seconds, so at 35 seconds, the noise is 58.8 dBA. Fig. 17 shows when the acceleration value is 15000 mm/s^2, and as seen from the graph, the peak value is 64 dBA, the lowest is 56 dBA, and the print time is 35 seconds, so at 35 seconds, the noise is 58.6 dBA.

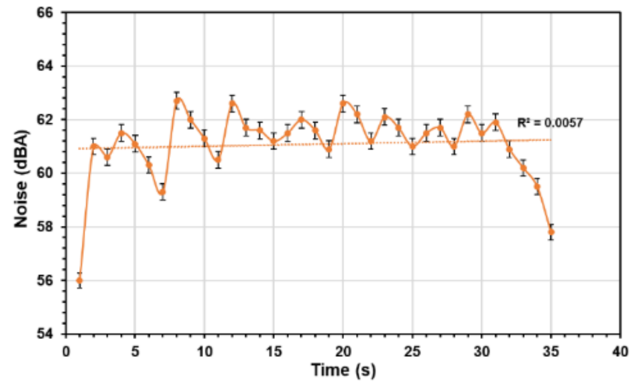

Figure 15. Noise values at 13000 mm/s^2 acceleration

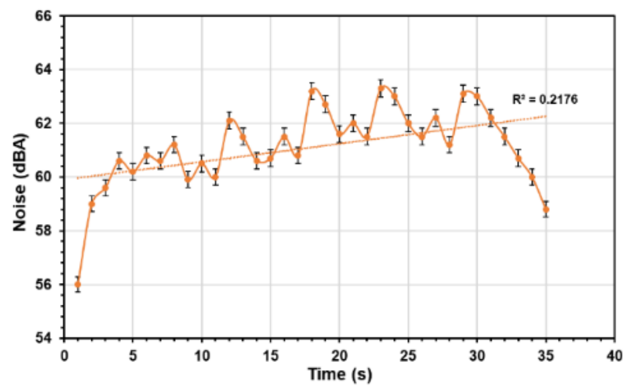

Figure 16. Noise values at 14000 mm/s^2 acceleration

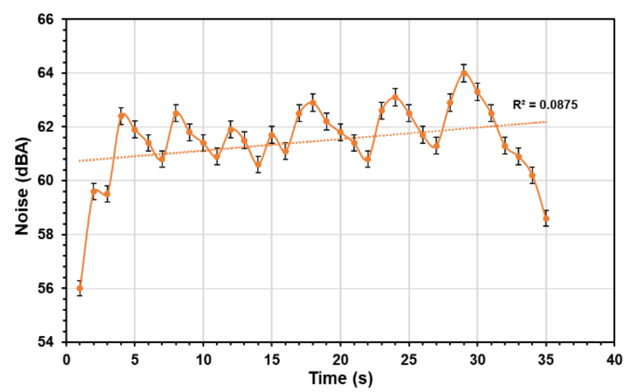

Figure 17. Noise values at 15000 mm/s^2 acceleration.

Fig. 18 shows when the acceleration value is 16000 mm/s^2, and as seen from the graph, the peak value is 63.6 dBA, the lowest is 56 dBA, and the print time is 35 seconds, so at 35 seconds, the noise is 58.7 dBA. Fig. 19 shows when the acceleration value is 17000 mm/s^2, and as seen from the graph, the peak value is 63.6 dBA, the lowest is 56 dBA, and the print time is 35 seconds, so at 35 seconds, the noise is 58.4 dBA. Fig. 20 shows when the acceleration value is 18000 mm/s^2, and as seen from the graph, the peak value is 63.4 dBA, the lowest is 56 dBA, and the print time is 35 seconds, so at 35 seconds, the noise is 58.5 dBA.

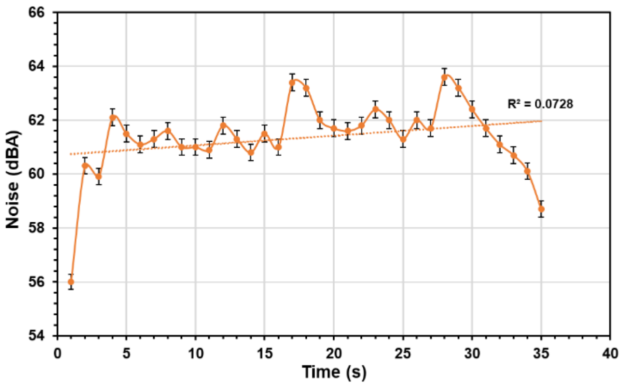

Figure 18. Noise values at 16000 mm/s^2 acceleration.

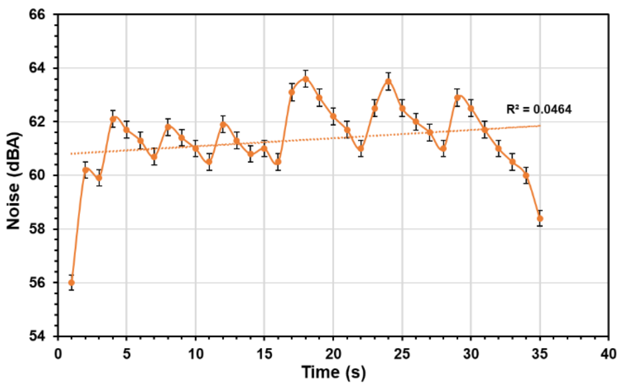

Figure 19. Noise values at 17000 mm/s^2 acceleration

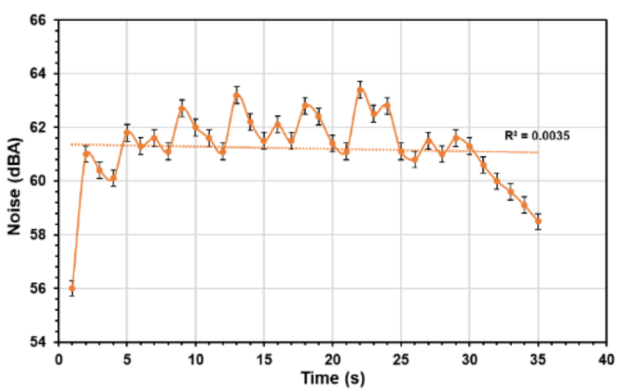

Figure 20. Noise values at 18000 mm/s^2 acceleration

Fig. 21 shows when the acceleration value is 19000 mm/s2. As seen from the graph, the peak value is 63.3 dBA, the lowest is 56 dBA, and the print time is 35 seconds, so at 35 seconds, the noise is 58.2 dBA. Fig. 22 shows when the acceleration value is 20000 mm/s2. As seen from the graph, the peak value is 65 dBA, the lowest is 56 dBA, and the print time is 35 seconds, so at 35 seconds, the noise is 59 dBA.

From the results, the noise charts of the laser printer at an acceleration value of 6000 mm/s^2 are a more suitable, relatively quiet machine. It produces a low noise level when printing and does not increase significantly when printing at higher speeds. This makes it an ideal choice for use where noise levels need to be kept to a minimum. Furthermore, its noise peak value was 61.8, while the other readings have a high peak value, indicating more noise.

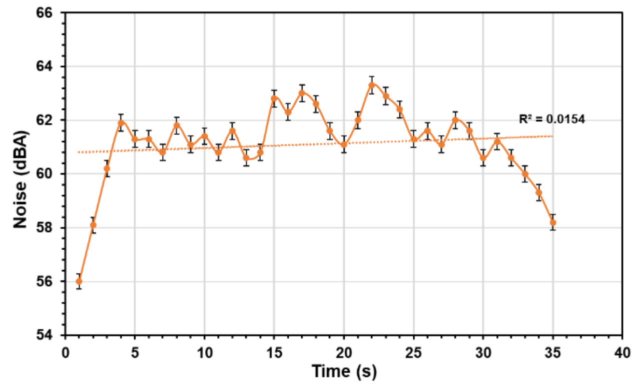

Figure 21. Noise values at 19000 mm/s^2 acceleration

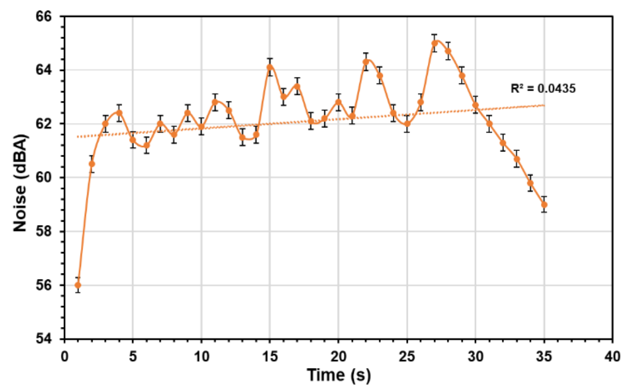

Figure 22. Noise values at 20000 mm/s^2 acceleration

4. Conclusions

Laser printer noise is one of the significant issues experienced by most industries today. There are many causes, and it may result from the wrong alignment of the components, low acceleration, or wrong setting. Since noise is always due to some factors, finding the noise source and arranging the elements is always helpful. After identifying what causes the noise, the next thing that one has to do is to adjust the component or setting to reduce the noise. This can be accomplished by changing the speed values or the accelerating values of the machine, and, at the same time, the accuracy will not be affected. It is also essential to make sure that the settings are correct. Once the printer's components have been adjusted, it's time to estimate the sound produced by the printer. Slowing down the laser means the printer will make less noise because the laser will move at a slower pace. Decreasing the acceleration of the machine will also minimize the amount of noise emitted by the printer since the laser shall be less forceful and, consequently, less noisy. The results show that high acceleration values provide high noise values, and shallow acceleration values have instabilities in some points where the noise spikes. After comparing the results, it could be concluded that the noise charts of the laser printer at an acceleration value of 6000 mm/s^2 are more suitable and stable because it has the lowest peak value, which is 61.8 dBA, a relatively quiet machine. It produces a low noise level when printing and does not increase significantly when printing at higher speeds. This makes it an ideal choice for use where noise levels need to be kept to a minimum. Furthermore, its noise peak value was 61.8, while the other readings have a high peak value, indicating more noise. So, it's more suitable to work with.

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Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Author Contribution Statement

Mohammed F. Farhan: Conducted the experimental work, including mechanical testing, and contributed to the data analysis.
Suhad D. Salman: Conceptualized the research problem, designed the experiments, contributed to the data analysis, and supervised the overall project
Z. Leman: Developed the theoretical framework and assisted in interpreting results.
M.F.M. Alkbir: Verified the analytical methods, contributed to the experimental design, and provided critical revisions to the manuscript.
Fatihhi Januddi: Investigated the degradation mechanisms, performed additional computations, and helped draft and revise the manuscript.
All authors discussed the results, provided input on the analysis, and contributed to the final version of the manuscript.

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