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Innovative 3D-Printed Suppressor Designs: Enhancing Safety and Efficiency in Firearm Use

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Abstract: Advancements in 3D printing technology have enabled the creation of highly efficient and cost-effective suppressors, offering significant safety benefits for firearm users. Exposure to firearm noise, even in controlled environments such as shooting ranges, poses serious health risks, necessitating improved noise reduction measures. This study explores the potential of 3D printing to produce novel suppressor designs that effectively reduce sound pressure levels in firearms, specifically focusing on their application with a .22 LR caliber rifle. Suppressors capable of reducing sound levels to below 135 dB, making them safe for adult use without hearing protection, were the primary focus. The research was conducted in two phases: initially, optimal suppressor designs were modeled using SolidWorks computational fluid dynamics (CFD), featuring innovations such as perforated baffles, additional expansion chambers, deep and curved expansion chambers, and perforated tubes extending along the suppressor's length. Following the simulation of these designs, live fire testing was conducted in a controlled shooting range environment. The results demonstrated that all tested designs effectively reduced sound pressure to safe levels. However, the suppressor with a conventional baffle layout supplemented by partitioned expansion chambers proved to be the most efficient, particularly when paired with subsonic ammunition. This study highlights the potential of 3D printing technology to revolutionize suppressor design, offering customizable solutions that enhance both user safety and environmental protection.

Keywords: Firearm suppressor; Silencer; Gun; Sound pressure; Suppressor design; 3D printed

1 Introduction

Modern firearms have come a long way toward providing exceptional performance as well as safety to the shooter. Most military or leisure rifles can also be found with different suppression systems at different price and performance levels. Today's suppressors are superior to earmuffs or similar ear protection and are the only possible form of suppression to lower the intense soundwave produced by a firearm to levels that are objectively safe for the shooter [1, 2]. Even a single but high enough impulse noise from a small-arm rifle may cause partial or full hearing loss to an ear that is not being protected [3–7].

Acoustic trauma is inevitable when near the place of the gunshot because, however short in duration the soundwave may be, it is usually greater than 160 dB and can reach as much as 180 dB in some instances. Normally, impulse sound wave levels from firearms are 140 dB in small arms, up to 160 dB in medium-sized rifles, and up to 180 dB in large rifles [8–10]. The safe levels for exposing one's ear to firearm shockwaves are up to 140 dB for adults and 120 dB for children [11]. The most common method of protecting one's hearing is by using personal hearing protection. However, a better approach is to lower the sound wave at its source before trying to control the outcome with further measures, such as personal hearing protection. The initial explosion inside the barrel of the firearm is something we can't easily change because of the force the bullet must carry. Shooting a large, hefty target requires adequate force from the bullet to produce any kind of useful results. Smaller calibers, a lesser amount of gunpowder, using subsonic ammunition, or similar approaches when trying to save one's hearing are suitable for small critter shooting (e.g., rabbits) or leisure shooting (e.g., target shooting). For this reason, using a specific large caliber with bullets

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carrying a lot of force (meaning they will not be sub-sonic and bullets breaking the speed of sound will also cause acoustic sound waves) is not negotiable in most circumstances [12, 13]. Due to these reasons, firearms themselves are modified in such a way that they produce less sound for the shooter and the environment.

Firearm parameter modifications are usually done with attachments such as flash suppressors (flash guards), flash hiders, flash eliminators, flash cones, muzzle breaks, and suppressors. These attachments can change the flash effect coming out of a firearm (a light source that is highly avoided in military applications because it gives out the shooter's location), recoil (reducing the forces that hit the shooter's shoulder, preventing injury, and improving accuracy due to better stability), and sound wave pressures (lowering the risk of noise-induced hearing loss and also not giving out the shooter's location in a military application) [14, 15]. In general, all these parameters are crucial for military applications, as flash signatures, recoil, and the and the sound of a gunshot are all parameters that must be addressed to improve survivability and mission capability. In a more civilian application, recoil is favorable because it improves results, but safety is the only mandatory requirement in all situations. For this reason, the scientific community is trying to develop and produce affordable and approachable solutions for all firearms, from pistols, rifles, and machine guns to tank systems or similar strategic military equipment.

To make firearm use safe, modern firearms usually have suppressors attached to them. Usually, the main purpose of a suppressor is to camouflage the location of the shooter and make him hard to locate, but for use not in a military application, providing a safe environment for hearing becomes the new goal and purpose. A suppressor greatly silences the shot from a firearm. The soundwave comes from the action of exhaust gases leaving the barrel. A suppressor stops the gases from leaving, obstructing the fluent flow and swirl of the gases. The speed and temperature at which the gases leave the barrel decrease, as do the soundwave and its energy. A modern suppressor shall protect firearm users hearing better and more effectively than any other personal hearing protection solution [16, 17].

A suppressor is a great weapon attachment that can reduce not only the pressure of the sound wave exiting the barrel but also achieve different properties and be easily tuned for a specific outcome. To produce better acoustics and other desired properties, a multi-chamber suppressor is usually used. It has become the standard de-sign in the industry. The efficiency and dependability of these designs have been proven through long years of military use and testing. However, when seeking additional effectiveness or somewhat different properties of the suppressor, different, more complex designs are developed. Making these models can become costly; therefore, computer-simulated models are used first as a cost-saving measure as well as as a possibility to try and evaluate their effectiveness in a very short period of time. Different properties can be achieved and a lot of different design can be considered, but there are no hard guidelines of how the design process should be done therefore it is up to the developers wants and needs [18].

A suppressor design must consider the firearm, the weight and length of the firearm, maneuverability, stability during shooting, and other operation requirements a client might have. Ammunition and the rate of fire also play a big role in determining the end design of a suppressor. To build the correct suppressor for the situation, one must consider all the possible design choices, advantages, and disadvantages to be able to develop something that is needed [19, 20]. A suppressor consists of an outer shell, usually made out of some sort of metal like aluminum or titanium, and a lengthy hole for the bullet to pass through. Between the shell and the hole for the bullet is the actual design of the suppressor. Here we can see different expansion chambers, differently shaped and angled baffles, and other design ideas the developer might want to try out [3, 10, 21]. The whole principle of how to exhaust gases can be slowed; the introduction of expansion chambers, lowering the temperature of the gases themselves, and keeping the whole structure as cool as possible must now be picked while trying not to make the suppressor too big and cumbersome, hard to manufacture, or too expensive. When all the operational requirements, dimensions, weight, price, and other factors are known, the specific baffle design should be considered.

A suppressor can work in all weather conditions, work with specific or multiple rifles and/or calibers, work with precision or high-rate fire firearms, and still be able to suppress sound waves as much as 37 dB [9, 10, 13]. After pairing a well-made suppressor with secondary personal hearing protection and/or environment considerations (not shooting in tight spaces or being near hard, echoey surfaces), you can achieve hearing-safe levels of shooting any firearm, even the largest possible.

This study analyzes suppressors for recreational use and target practice at the shooting range. The biggest problem with recreational shooters using any kind of firearm is their limited knowledge of firearm safety, lack of a serious view towards hearing safety, and general expectations that it can't be that dangerous. Therefore, we see a lot of instances of gunshots where the shooter or people at the same shooting range were not wearing personal hearing protection or were wearing them incorrectly (wearing personal hearing protection incorrectly when it doesn't make a good seal is the same as not wearing them at all). Separate instances of suppressor and muzzle break designs are somewhat described in the scientific literature, but new design ideas as well as new manufacturing methods and materials are hard to find. Suppressors fall under strict laws and guidelines and therefore require rigorous testing to be performed. Precise measuring devices as well as well-defined methods are needed to produce convincing research results and produce effective and permitted products.

Various suppressor designs with typical baffle displacement have been researched with significant results and insights [22–24]. The .308 caliber firearms require substantial material to withhold the high temperature and pressure of sound waves leaving the barrel at speeds greater than the speed of sound.

This article presents a computational study of four suppressor designs that are generally typical but altered in a unique way due to new manufacturing capabilities in 3D printing. 3D-printed designs provide the ability to produce unique design ideas that would be too complex, expensive, or impossible to produce with conventional methods like machining. Instead of manufacturing baffles in pieces and assembling the sup-pressor, one can produce a single-piece suppressor with various holes, different cuts, and different angles, which are impossible to produce by conventional means. The designs are well defined, produced, and tested on a closed shooting range. Experimental studies help to prove the effectiveness of the best designs as well as the manufacturing concept. The scientific novelty of this work is defined as a new way to produce suppressors as well as the structural optimization of their design. This was created using new production methods, trying out new designs, and optimizing for efficiency.

2 Methodology

The design of a suppressor is chosen from relatively well-known baffle designs but modified to try to determine how different traits further influence the suppressor's efficiency. In general, suppressors use baffles to divide zones to direct gas flow. Gases dissipate in these zones, losing some of their initial energy and temperature. The more energy the gases lose, the more efficient the suppressor is.

The sound pressure p was calculated using the Helmholtz Eq. (1) [10, 25, 26].

$$\nabla\left(\frac{1}{\rho_0}\nabla p - q\right) + \frac{k^2 p}{\rho_0} = 0 \tag{1}$$

where, $k = 2\pi \mathrm{f}/\mathrm{c}$ is the wavelength, ρ_0 is air density, f is the frequency, c is the speed of sound, p is sound pressure, and q is acceleration per unit volume. With this equation, using a parametric solver, a solution can be determined. The transmission loss of a suppressor is calculated in Eq. (2) [27].

$$TL = 10log\left(\frac{P_{in}}{P_{out}}\right) \tag{2}$$

P_{in} and P_{out} determine acoustics at the start and outlet of the suppressor. Eqs. (3) and (4) produce the acoustic effect of a suppressor [10, 25]. *in* is for incident wave, *out* is for transmitted wave.

$$P_{in} = \int \frac{p_0^2}{2\rho c_0} dA \tag{3}$$

$$P_{out} = \int \frac{p_{tr}^2}{2qc_0} dA \tag{4}$$

Eqs. (2)-(4) can have a varying result and the input pressure value (p_i) was assumed to be 101325 Pa. Sonic boundary conditions at the solid boundaries are used and further shown in Eq. (5) [10]:

$$\left(-\frac{\nabla p}{\rho}\right) n = 0 \tag{5}$$

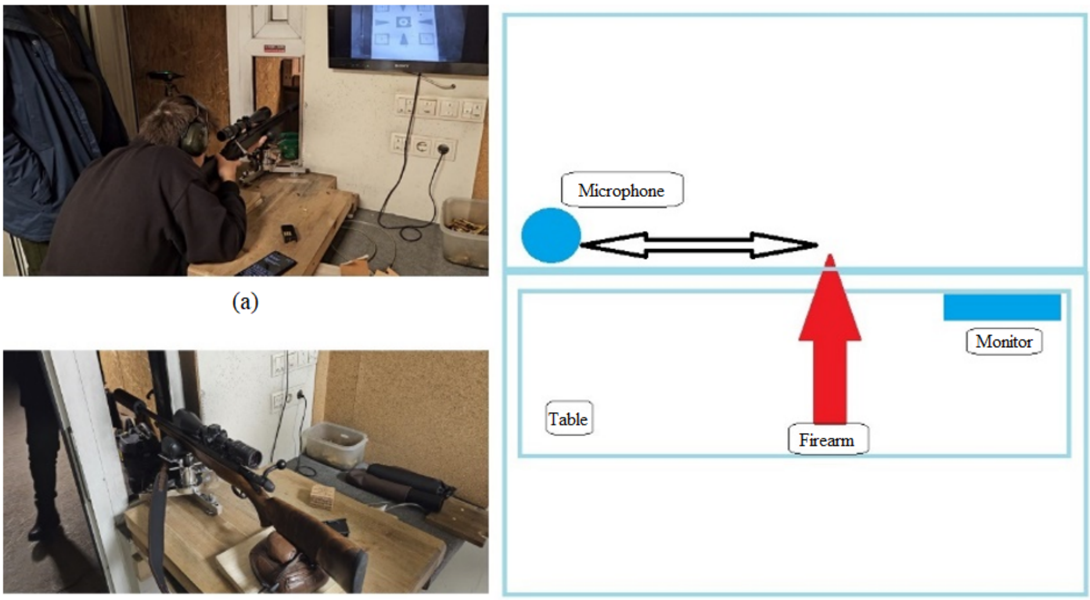
The computational part of this study was done with a CFD solution embedded in SolidWorks. The program is well known for reliable designs and fast amendments to the models and drawings. The CFD environment can simulate gas flow in each space. A total of four models are simulated in this environment. Each model is identical on the outside but quite different on the inside. The CFD solution enables fast, repeatable testing to be done in a fraction of the time required for experimental tests to be carried out. The inlet pressure, as per ammunition specs, is set to 170 MPa, and the atmospheric pressure is set to 101325 Pa. Temperature effects are not measured in this study. After setting an identical testing environment for each suppressor, multiple simulation passes are done to ensure reliable results. A photo of the simulation results, together with the graph of relative pressure, is taken. Relative pressure results are exported to Microsoft Excel. Pressure values in Pa are converted to dB via online calculators (at atmospheric pressure settings).

The tested suppressors shown in Figure 1 were made out of plastic. The design replicated a standard baffle suppressor and therefore resembled an outer casing with different expansion chambers inside to easily obstruct the path of expanding gases. Also, one side had a thread for mounting the suppressor to the firearm. The object of the research is a molded chamber design for the suppressor to separate gases into different chambers, thus lengthening the path of the gases and lowering the temperature and force of the gases exiting the barrel. The goal is to lower the sound pressure level to a level considered safe for use even without personal hearing protection.

Since the suppressor will be exposed to gases breaking the speed of sound at high pressures and temperatures, a reliable and resilient material should be considered. However, the .22 caliber firearm does not possess very high exit velocity. When taken into consideration that the fire rate is semi-auto and not fully automatic, the intent is to just thicken the molded walls in the hope of producing a reliable suppressor.

Rather than producing suppressors for the.308 caliber or other high-pressure calibers, this study skipped the usual modeling and simulation done on the SolidWorks Flow environment package. This saves time and effort. The modeling software inside 3D printers is made in a simpler way to appeal to non-engineers and can produce a model in a fraction of the time used to model a design in SolidWorks and then transfer it to a format understood by common 3D printing hardware. The construction of these suppressors follows the same principle, where gases are trapped in chambers and the energy is dissipated. Different designs are considered, but in general, these designs work best with low-energy calibers and cannot be used with much higher energies found in large calibers. The size difference between a suppressor made from metal and one used to suppress .308 caliber bullets is much bigger than a 3D printed suppressor, used to suppress .22 caliber bullets.

Figure 1. 4 non-typical suppressors for the .22 caliber rifle that are made with a 3D printer



(a)

(b)

(c)

Figure 2. (a) Testing site with microphone and monitor; (b) Testing site for rifle; (c) Principal scheme for testing site

To be able to achieve reliable and reoccurring results, a basic instruction set was determined. In all the shooting drills, the same firearm was used. It was a Tikka T1X MTR .22 LR rifle with an accurate daylight sight. The accuracy effect was not measured in this experiment, but general accuracy was observed via a monitor installed at the shooting range in subgraph (a) of Figure 2.

The type of shooting range can help produce very reliable results because environmental sounds are minimized. The shooting range is closed off, and rifles with calibers of .223 or .308 up to 100 m can be shot. Personnel are guarded by a window that stands in the way between the tip of the rifle's barrel and the shooter, while microphones can be placed on the other side. This also ensures that no one can walk in front of the target, further ensuring safety. The shot was not affected by wind or fast changes in temperature.

The firearm was placed on a small sandbag and an adjusting lever to ensure that the rifle is safe and secure and does not move or change its position in any way. The microphone used in this experiment was a Brüel & Kjær Mobile Diagnostics Toolbox Type 7927. The microphone shows a fixed maximum sound wave pressure level at a given time frame, which is written in the results sheet. The microphone was placed at the same height as the firearm, 1 meter to the left side, and directed at the barrel tip of the firearm's barrel as shown in subgraphs (a) and (c) of Figure 2.

The test setup ensures sufficiently high accuracy for the experiment, even when shooting with multiple suppressors and a high shot count. The ammunition used in this test was Winchester's coper-plated Wildcat .22 LR. The grain weighs 40 gr, has a has a velocity 382 m/s at muzzle and 310 m/s at 91 m, and has an and has an energy 190 J at muzzle and 125 J at 91 m. Subsonic-type ammunition used in this test was RWS low-noise effective impact subsonic HP .22 LR. The grain weighs 40 gr, has a has a velocity 315 m/s at muzzle and 264 m/s at 100 m, and has an and has an energy of 129 J at muzzle and 89 J at 100 m.

3 Results

The initial model (Figure 3) is drawn in a SolidWorks environment. The basic test environment is then applied. The initial pressure coming from the shot of the firearm is set to 170 MPa (the maximum pressure level available for the .223 caliber bullets), and the environmental pressure on the other end is set to 101325 Pa. A line at the center over the length of the suppressor is drawn as a position for calculating relative pressure levels.

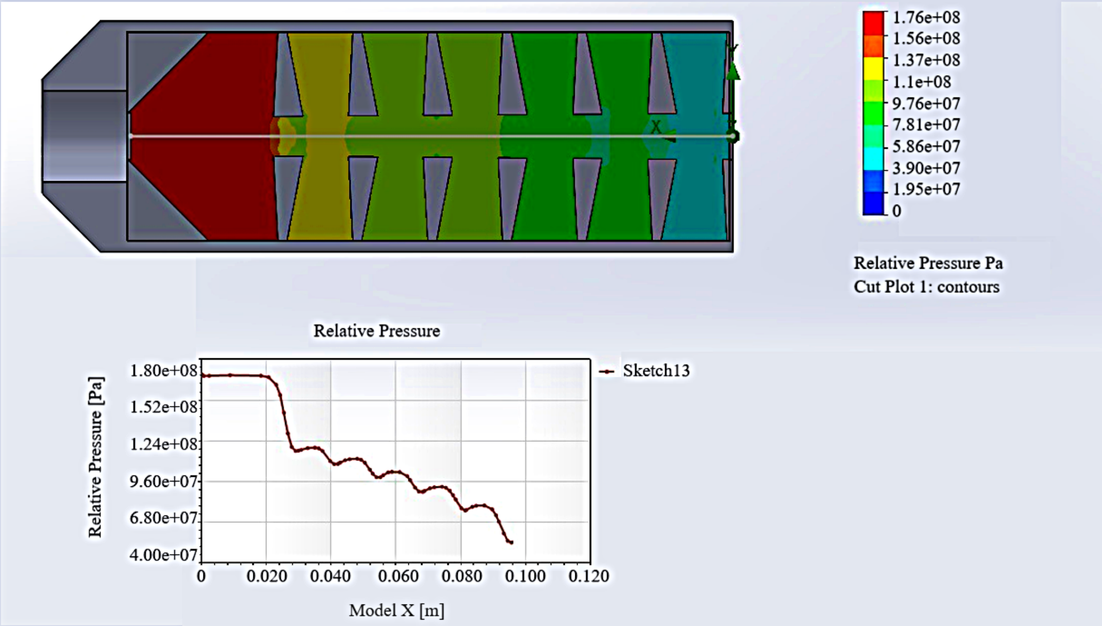


Figure 3. Relative sound pressure distribution over the length of the suppressor "1"

Analyzing the relative pressure distribution in the geometry of the suppressor number "1", a huge pressure buildup in the initial, larger than other space, is observed. The suppressor is modeled after the idea of further separating each expansion chamber into multiple triangle-shaped chambers to further obstruct the way gases travel over the length of the suppressor. The manufacturing process of a 3D printer lets the engineers produce designs that would be nearly impossible or costly to manufacture with a more industry-standard approach to metal machining. The drop in relative pressure levels after gases pass each baffle and dissipate into expansion chambers is observed. The initial large chamber does a lot more suppression than other, smaller chambers. The last chamber also has higher than usual efficiency and suppresses gases pretty well. The results of the suppressor labeled "1" are average: the initial 170 MPa pressure was lowered to 53.99 MPa, with a delta of 116 MPa. This results in a suppression from 258.59 dB to 248.63 dB, with a delta of 9.96 dB.

The second model of the suppressor, named “2”, is drawn in SolidWorks in the same environment with the same parameters as the suppressor “1”. The drop in relative pressure after gases pass through expansion chambers is observed (Figure 4). Since the overall size of the suppressor is the same as the “1” suppressor, having more baffles means the expansion chamber must be smaller in volume. Each of the nine baffles is also separated into nine smaller expansion chambers that are placed every 40 degrees. Since the initial chamber is similar in size, the relative pressure drop is like what is observed in suppressor number “1”. The following relative pressure drops are more gradual, but there are more of them. The overall suppression of the suppressor number “2” was better than that of the that of the suppressor “1”, with the relative pressure at the end of the suppressor measuring at 46.80 MPa and a delta of 123.2 MPa. This results in suppression from 258.59 dB to 247.38 dB, with a delta of 11.21 dB.

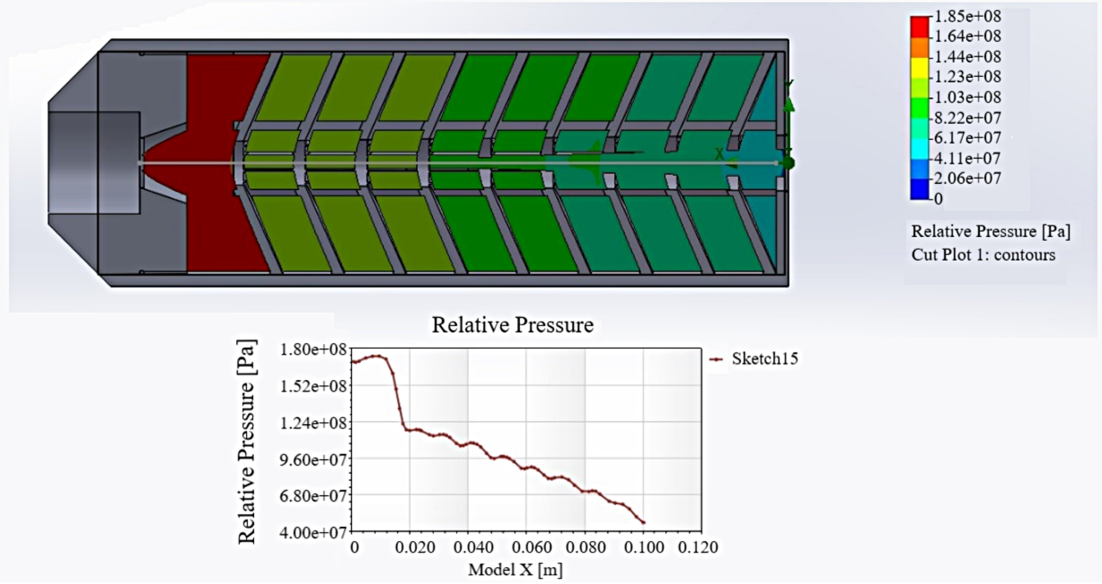


Figure 4. Relative sound pressure distribution over the length of the suppressor “2”

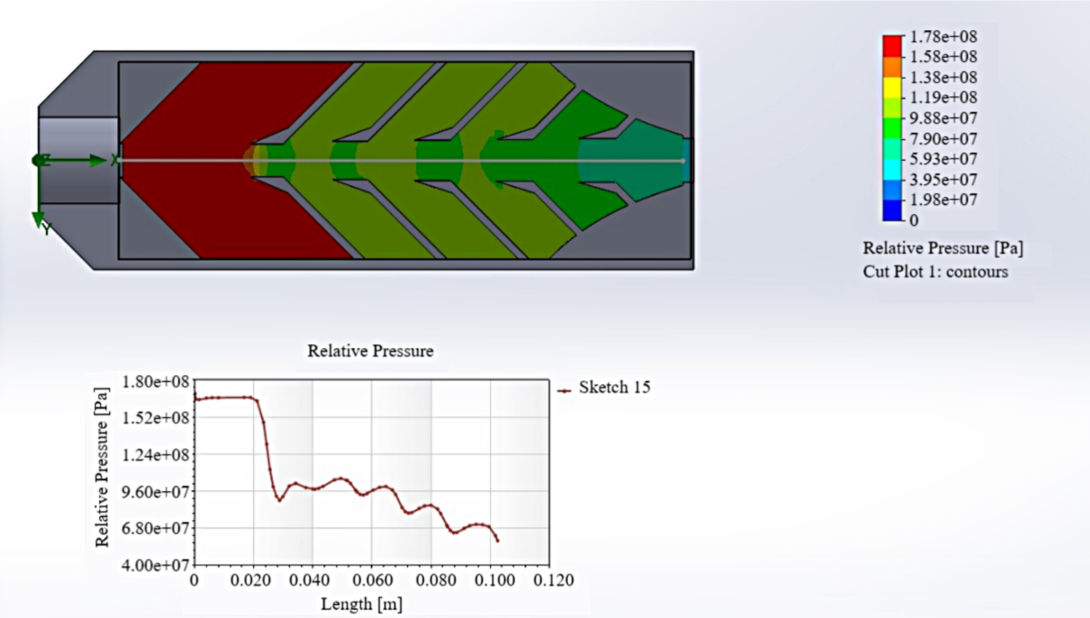


Figure 5. Relative sound pressure distribution over the length of the suppressor “3”

Suppressor number “3” are modeled in SolidWorks; in the same environment, a CFD model is produced, and changes in relative pressure are observed (Figure 5). The initial pressure drop is observed due to the larger than before initial expansion chamber. However, a slight increase in pressure when exiting the first chamber and entering the second one can be seen. The possible explanation is that gases, when exiting the chamber, have to go backwards and form a bottleneck, resulting in increased pressure. The increased relative pressure later is suppressed, as we saw before, but the increases in pressure before exiting every baffle are still seen. This indicated that deep expansion chambers that result in gases having to backtrack to their respective exits produce unfavorable results. The overall suppression of the suppressor number "3" was worse than suppressors "1" and "2", with relative pressure at the end of the suppressor measuring at 58.58 MPa and a delta of 111.42 MPa. This results in suppression from 258.59 dB to 249.33 dB, with a delta of 9.26 dB.

The fourth and final suppressor, named "4", is modeled in SolidWorks in the same environment, and CFD model simulations are observed (Figure 6). The initial relative pressure drop is above average, but as seen before, since the expansion chamber is very deep, gases when coming back condense and increase the relative pressure level when exiting the first baffle. Then the suppressor number "4" is constructed in a way to have a single, perforated tube inside the suppressor. Perforations are made in a way to ensure the fast exhaust of gases to the outer chamber, where they lose a lot of their energy. This concept perfectly reflects the results; we see that large initial expansion chambers ensure very good suppression results. Observing suppression over the whole length, great efficiency happens only at the last stage. On their way to the back of the suppressor, gases don't seem to lose a lot of energy. The overall suppression of the suppressor number "4" was better than suppressors "1", "2", and "3," with the relative pressure at the end of the suppressor measuring at 36.25 MPa and a delta of 133.75 MPa. This results in suppression from 258.59 dB to 245.17 dB with a delta of 13.42 dB.

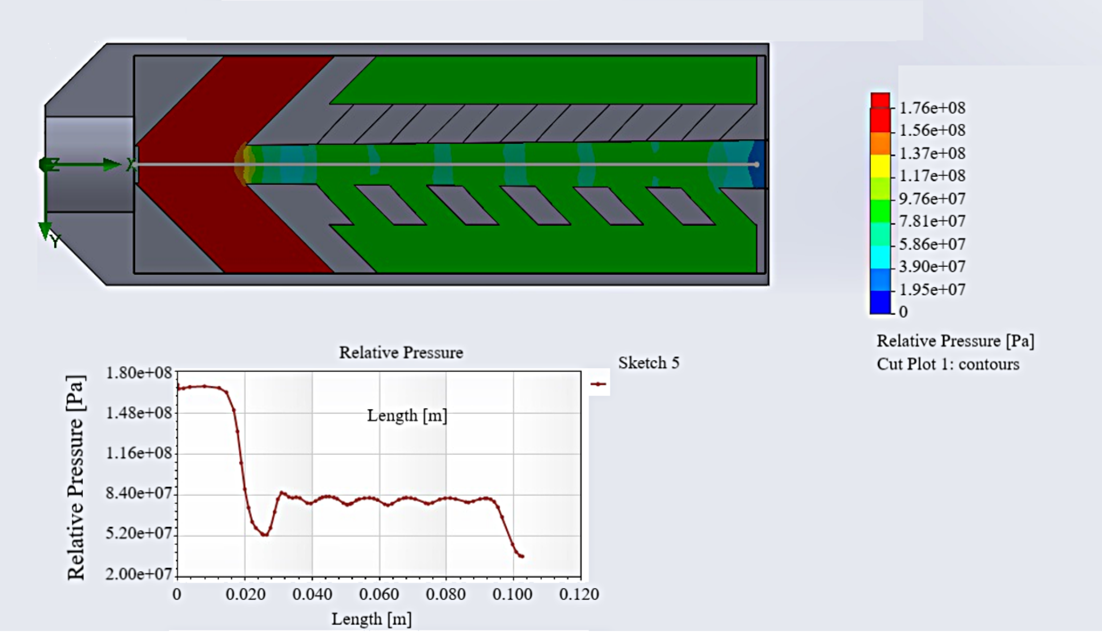


Figure 6. Relative sound pressure distribution over the length of the suppressor "3"

The results of live fire shooting (Figure 2) showed very comparable results to the ones observed during the SolidWorks CFD simulation. Initially, a few rounds with no suppression were shot to determine the baseline for calculations. After each suppressor for 4 consecutive shots: 2 with normal ammunition, 2 with subsonic ammunition. After all, four suppressors have been tested, the results are then written down in a table for ease of comparison (Table 1). The time between each shot was 5–10 seconds (10 seconds when changing from normal to subsonic ammunition).

Table 1. Testing results of live fire shooting

Suppressor Ammunition	None, dB	Number "1", dB	Number "2", dB	Number "3", dB	Number "4" , dB
Normal ammunition	144.0	134.3	130.9	133.1	132.5
Normal ammunition	141.7	133.0	132.3	134.4	132.1
Subsonic ammunition	140.9	130.2	125.4	131.0	130.5
Subsonic ammunition	141.6	131.9	123.6	132.7	130.5

Also, a thesis on how the first and consecutive shots affect sound suppression of the suppressor was tested, where 8 shots were fired with a time difference of 1 s between shots and 5 s when changing from normal to subsonic ammunition. The total of 8 shots were made with the suppressor number “4”. The results captured are presented in Table 2. The results showed that the first shot always results in the biggest pressure wave, and later shots are quieter. However, the observed sound wave values are still within the tolerance of error and are not that substantial.

Table 2. Testing results of 8 consecutive shots

Shot Number	1st, 5th (below), dB	2nd, 6th (below), dB	3rd, 7th (below), dB	4th, 8th (below), dB
Normal ammunition	132.5	132.1	130.6	131.9
Subsonic ammunition	130.5	130.5	129.1	128.9

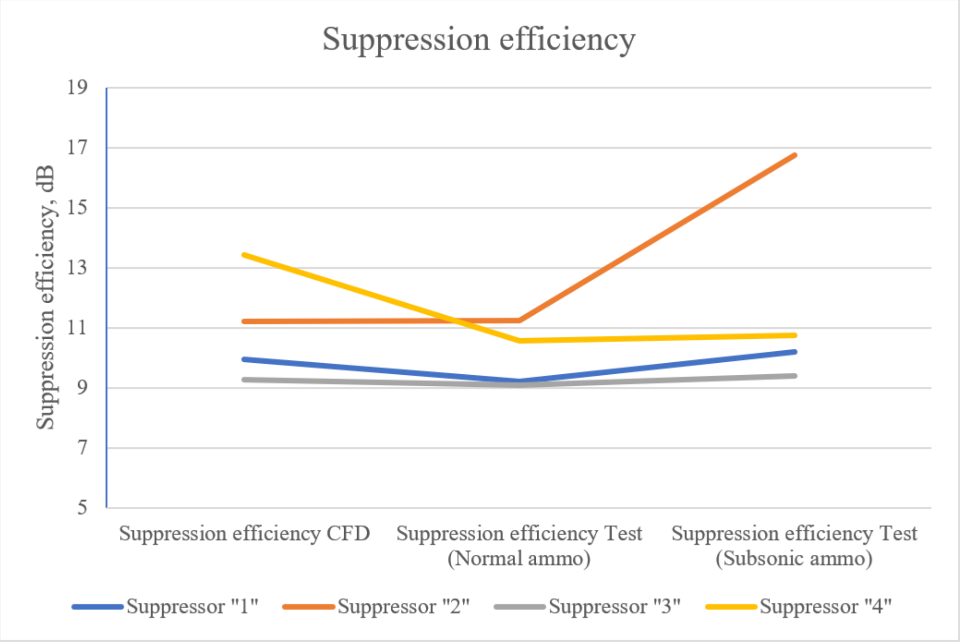


Figure 7. Suppression efficiency results between computational and live fire testing

After the simulation and live fire testing results were gathered, a more in-depth comparison of the results could be made. The SolidWorks CFD simulation showed that the suppressor number “4” was the most efficient at 13.42 dB. The suppressor number “2” was worse with 11.21 dB suppression, and suppressor numbers “3” and “1” were the least efficient with 9.26 dB and 9.96 dB, respectively.

Live firing results showed comparable results to the ones observed in the SolidWorks CFD simulation. When averaged out, the firearm produced a sound wave of 142.85 dB with normal ammo and 141.25 dB with subsonic ammo, without any kind of suppressor applied. This acted as a baseline for further calculations. Suppressor number “1” achieved a result of 133.65 dB with normal ammunition and 131.05 dB with subsonic ammunition, with deltas of 9.2 dB with normal ammo and 10.2 dB with subsonic ammunition, respectively. Suppressor number “2” produced a result of 131.6 dB with normal ammunition and 124.5 dB with subsonic ammunition, with deltas of 11.25 dB with normal ammo and 16.75 dB with subsonic ammunition, respectively. Suppressor number “3” produced a result of 133.75 dB with normal ammunition and 131.85 dB with subsonic ammunition, with deltas of 9.1 dB with normal ammo and 9.4 dB with subsonic ammunition, respectively. Suppressor number “4” produced a result of 132.3 dB with normal ammunition and 130.5 dB with subsonic ammunition, with deltas of 10.55 dB with normal ammo and 10.75 dB with subsonic ammunition, respectively. The results and discrepancies are shown in Figure 7. Suppression efficiency is a result in dB that can be obtained when subtracting sound pressure levels in dB from the initial sound blast in dB.

When comparing the suppression results from the SolidWorks CFD simulation to live fire testing at the shooting range, slight differences are observed. Live fire testing results tend to indicate a lower suppression efficiency figure. The suppression efficiency differences between results from the SolidWorks CFD simulation and live fire testing, as shown in Figure 7, were 8.2% (suppressor number “1”), 0% (suppressor number “2”), 1.7% (suppressor number “3), and 27.2% (suppressor number “4”).

When comparing the suppression results from live fire testing when using normal ammunition to subsonic type ammunition, the results show that subsonic ammunition produces higher efficiencies than using normal ammunition at 10.86% (suppressor number "1"), 48.89% (suppressor number "2"), 3.3% (suppressor number "3"), and 1.9% (suppressor number "4").

4 Conclusions

A research study of different firearm suppressors was carried out and analyzed. Different and unique suppressor designs were considered and simulated in a controlled CFD environment in SolidWorks. During the theoretical simulations, different approaches were considered, and very unique geometries were modeled. The best results achieved from the CFD simulations with the suppressor number "4" were 13.42 dB and 11.21 dB with the suppressor number "2".

In the live fire test and analysis, all four of the modeled suppressors were produced with a 3D printing machine and then exposed to .22 LR caliber live fire rounds (normal and subsonic). The best result obtained in live fire testing was 11.25 dB with the suppressor number "2" and 10.55 dB with the suppressor number "4". This shows that the better efficiency design produced with a large initial chamber and a perforated tube through the whole suppressor did not translate exactly to live fire shooting and is not as efficient as "normal" baffle designs. The scientific novelty of this study is the unique design that has been simulated and tested, as well as a relatively new way of manufacturing such suppressors with 3D printing machines.

Pressures that were recorded at a distance of 1 m from the muzzle of the riffle were unsafe when shooting without a suppressor and exceeded the adult-safe 140 dB and child-safe 120 dB limits. When the rifle was paired with a suppressor of any design, the resulting sound waves were all below 135 dB; therefore, the firearm was made safe to be used without any hearing protection (children would still have to use personal hearing protection).

Also, the suppressor number "2" when used with subsonic-type ammunition performed substantially (48.89%) better than when used with normal ammunition. This meant that using subsonic ammunition with suppressor number "2" would drastically reduce emitted sound waves and make the firearm almost safe for child use and perfectly safe for adults to use without any hearing protection.

Additionally, two series of four consecutive shots were made (4 with normal ammunition and 4 with subsonic ammunition) to find out what impact oxygen has on the soundwave. The first shot of the series produced the biggest soundwave, as expected, due to having more oxygen in the barrel for better explosion potential. However, other shots did not produce drastically lower soundwaves; therefore, the general influence of oxygen in the barrel should be considered minimal.

All in all, the best results were achieved with a "standard" displacement 9 baffle design where each expansion chamber after each baffle was partitioned into 9 additional expansion chambers, resulting in good suppression efficiency when using normal ammunition and substantial suppression efficiency when using subsonic ammunition. Also, this proved that 3D-printed suppressors are a viable option for .22 LR caliber rifles and can be used for recreational shooting with high efficiency.

Author Contributions

Conceptualization, A.K. and V.G.; methodology, A.K.; software, V.G.; validation, A.K. and V.G.; formal analysis, V.G. and A.K.; investigation, A.K.; resources, A.K.; data curation, A.K. and V.G.; writing—original draft preparation, V.G. and A.K.; writing—review and editing, A.K.; visualization, V.G.; supervision, A.K.; project administration, A.K.; funding acquisition, A.K. All authors have read and agreed to the published version of the manuscript.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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Nomenclature

$\boldsymbol{c}$	the speed of sound
$\boldsymbol{E}_0$	the bullet energy
$\boldsymbol{f}$	the frequency
$\boldsymbol{\rho_0}$	the wavelength
$\boldsymbol{p}$	the sluid density
$\boldsymbol{P_0}$	the input pressure value
$\boldsymbol{TL}$	the transmission loss of the suppressor
$\boldsymbol{V_0}$	the bullet speed
$\boldsymbol{P}_{in}$	the acoustics at the inlet of the suppressor
$\boldsymbol{P}_{out}$	the acoustics at the outlet of the suppressor