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Experimental Investigation of the Projectile type on Sound Pressure Levels Fired with 9 mm Gun

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Abstract

Throughout of the firing process, too much noise is occurred in the form of an blast wave caused by the discharged gas. An instantaneous and high amplitude sound pressure is created by the explosion and this pressure causes a harmful noise to the human ear. The main sources of the generated sound can be categorized as the explosion at the barrel exit, projectile velocity and the sound produced when the projectile hits the target. Subjects such as subsonic and supersonic projectiles, projectiles with different geometries, silencer systems are very important to reduce this explosion noise created by gun systems. Within the scope of this study, the peak sound pressure levels after firing the subsonic and supersonic projectiles from a 9 mm gun were experimentally measured at different positions. The measurements were realized at 23 different positions. The results of this study showed that in all measurement positions, supersonic projectiles have higher peak sound pressure levels (db) than subsonic projectiles. The peak sound pressure levels decreased with increasing distance from the gun barrel exit a as expected. Also, it has been determined that subsonic and supersonic projectiles give close results to each other in the measurements made at the same level with the barrel at y-axis direction.

Keywords: Sound pressure level; subsonic projectile; supersonic projectile; gun**.**

Introduction

Gun ammunition, also known as cartridges consists of four basic parts: the cartridge case, the ignition system (primer), the propellant powder and the projectile (bullet). The cartirdge case mainly keeps the gunpowder filler and the primer, and holds the projectile. The primer is located behind the cartridge case and provides ignition. The main parts of a cartridge shown in Figure 1.

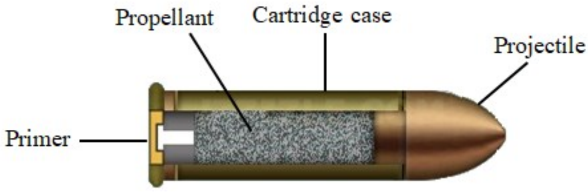

Figure 1. The main parts of the gun cartridge (Anonymus-a, 2022)

In firearms, with the combustion of gunpowder in the case, the transition from solid phase to gas phase and chemical energy is converted into heat energy. With the heating of the gunpowder gases, there is an expansion in the barrel, and this causes an increase at temperature and pressure inside the barrel. As a result, the initial movement of the projectile is ensured and it continues its movement by accelerating along the barrel. The movement of the bullet inside and outside the weapon and the effect on the target as a result of this movement is known as ballistics. While the internal ballistics field is related to all the events that occur from the start of firing until the projectile leaves the gun barrel, the events that occur during the time that the projectile leaves the barrel and reach the target are related to the external ballistics. Experimental testing of internal and external ballistics are difficult, expensive and time consuming.

With firing a gun, two main sources of noise occurred. These are the muzzle blast (impulse) and sonic boom (bow shock). Muzzle blast occurs when the projectile uncorks the high-pressure propellant gases and caused by many factors such as turbulent fluctuation in the mixing zone of the expanded jet at high speeds or the unstable shock wave in muzzle flow. Most of this kind of noise attenuates and disappears in the early stage of muzzle flow field formation. It is known that the main impulse noise in the muzzle system is generated by the propelled gas turbulent jet. The second source is sonic boom and this occurs with supersonic projectiles (Pater & Shea, 1981; Zhao et al., 2019).

Many studies have been conducted in the literature on the projectile motion on the flow field and the noise after explosion. Jiang Z et al. (Jiang, 2003) used a flat-nosed projectile to investigate the shock-wave and jet-flow interactions of the flow field. Zhuo et al. (Zhuo, Feng, Wu, Liu, & Ma, 2014) used a cone nose projectile and numerically analyzed the non-equilibrium Euler equations with dynamic overlapped grids. Trabinski et al. (Czyżewska & Trębiński, 2015) analyzed the dynamic characteristics of the flow field around a cone-nose projectile exited the barrel with and without the muzzle device, respectively. The instability and production mechanism of the bow shock wave (BSW) at the projectile front both experimentally and numerically investigated by Kikuchi (Kikuchi, Ohnishi, & Ohtani, 2017). Kang et al. (Kang, Ko, & Lee, 2008) carried out a numerical study on the attenuation of sound propagated from a shock tube to the surrounding environment for a high pressure explosion. In this study, a numerical analysis is developed for high pressure explosion flow field analysis.

Studies in the literature have generally focused on projectile geometry. In this study, the effects of subsonic and supersonic projectiles on the sound pressure level of the 9 mm gun were investigated. In this context, shots were made for each projectile and the results were evaluated by taking measurements from 23 different points.

Materials and Methods

One of the basic measurement for the pressure fluctuations made by sound waves as they propagate in the air is the Sound Pressure Level (SPL), which is given in db units (Zhao et al., 2019). The SPL for the gun muzzle noise generally determined by peak sound pressure level. All the results given in this study are the results obtained in the case of a peak sound pressure level. The general formula of SPL is given in Eq. (1):

$$SPL = 20log\frac{p'}{p_{ref}} \qquad (1)$$

where p' is the sound pressure, p_{ref} is the reference sound pressure ($p_{ref} = 2\,x\,10^{-5}\,Pa$).

A number of arrangements and planning are required to realize shooting tests and obtain the results. The experimental system mainly consist of sound pressure level measurement device with microphone, table, gun and gun stabilizer as illustrated in Figure 2. The photo of the experimental setup was given in Figure 3. To measure the sound pressure level Larson Davis LXT model was used with its microphone. Before the experiments, the calibration of this device checked with CAL200 sound level calibrator. The microphone was mounted on a tripod vertically and the height of the tripod was in level with the gun barrel axis in all experiments. The height of the table where the shooting test realized was 1 m above the ground level to prevent the sound reflection.

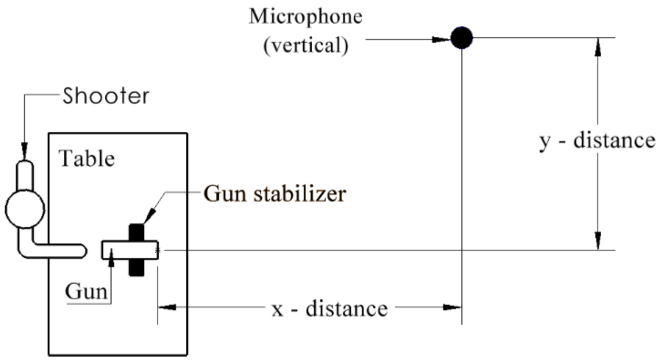

Figure 2. Schematic diagram of the experimental setup

Figure 3. A photo of the experimental setup

For each projectile type, sound levels were measured at 23 different points. These measurement points were illustrated in Table 1. A shooter was required to perform the firing process. The shots were carried out with 6 projectiles for each point at intervals of 10 seconds.

In addition, the velocities of subsonic and supersonic projectiles at the exit of the muzzle were also measured and Labradar Ballistic Velocity Doppler Radar Cronograph was used for velocity measurement.

Table 1. Sound pressure level measurement positions

Measurement number	X (m)	Y (m)
1	0.0	0.2
2	0.0	0.4
3	0.0	0.8
4	0.0	1.0
5	0.0	1.5
6	0.0	2.0
7	0.0	2.5
8	0.0	5.0
9	0.2	0.2
10	0.4	0.2
11	0.8	0.2
12	1.0	0.2
13	1.5	0.2
14	2.0	0.2
15	2.5	0.2
16	5.0	0.2
17	10.0	0.2
18	20.0	0.2
19	30.0	0.2
20	0.8	0.8
21	1.5	1.5
22	2.5	2.5
23	5.0	5.0

Table 2. Technical properties of the subsonic and supersonic cartridges (Anonymus-a, 2022; Anonymus-b, 2022)

Properties	Subsonic	Supersonic
Maximum pressure (bar)	1500	2850
Bullet weight (g)	9.50	12.15
Mean radius (cm)	Max 5.0 @ 25 meters	Max 7.6 @ 46 meters
Velocity (m/s)	290±10 @ 16 meters	370 ± 10 @ N/A

As said before two types of cartridge was used in the experiments which were named as subsonic projectile and supersonic projectile. The technical properties of these cartridges were given in Table 2.

Results and Discussions

In this study, the effects of projectiles with subsonic and supersonic characteristics on the sound pressure level of a 9 mm pistol were studied. In this context, shots were taken for each case and measurements were taken from 23 different points. For the measurement at each point, 6 shots were taken and the average of the values obtained from these shots was given. In this sense, a total of 276 projectiles were used for both cases (subsonic and supersonic). Figure 4 illustrates the SPL values varying with distance along the x-axis direction. Higher SPL values were obtained in experiments with supersonic projectiles at every distance. The highest SPL values were obtained at nearly 0.2 m positions with both projectiles which was 178 db at supersonic projectile and 176 db at subsonic projectile. Then, the SPL values decreased with increasing distance. In addition, the differences between subsonic and supersonic projectiles increased with increasing distance. At a distance of 30 m, the SPL value that appeared in experiments with subsonic projectiles was about 133 db, while this value was about 143 db in the case of using supersonic projectiles.

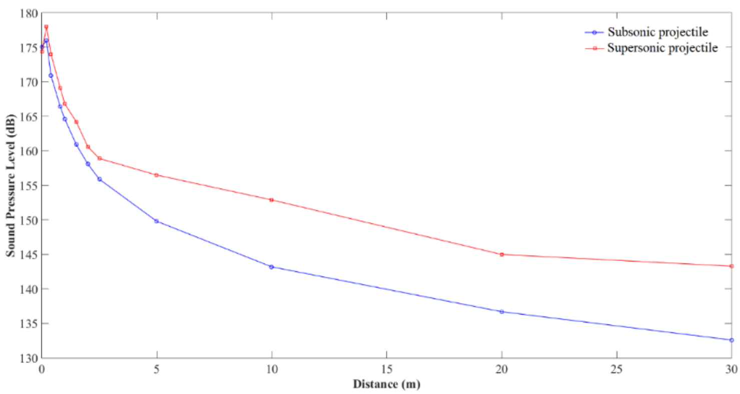

Figure 4. Sound pressure level varying with distance along the x-axis direction

The SPL values varying with distance along the y-axis direction was given in Figure 5. Unlike the measurement results taken at x-axis direction, the experiments performed with both projectiles gave similar results at y-axis direction. This can be explained by the projectile bow shock noise only occurs forward of the gun, in a region determined by the supersonic velocity of the projectile (Rehman, Hwang, Tamtomo, Chung, & Jeong, 2011). However, with increasing distance, it is seen that the supersonic projectile has relatively higher results than the subsonic projectile. Especially after neraly 0.8 m, the differences between the results obtained from both projectiles increase.

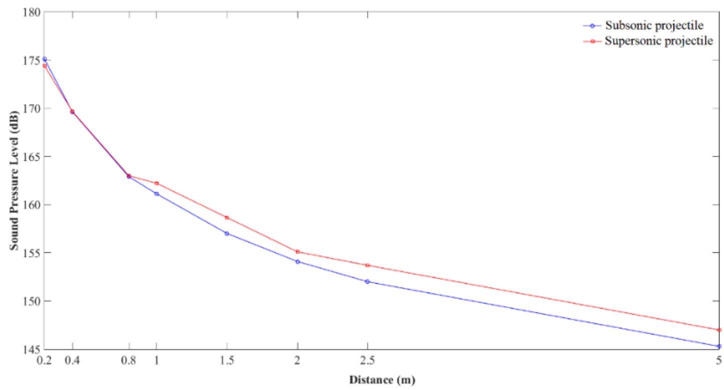

Figure 5. Sound pressure level varying with distance along the y-axis direction

Figure 6 shows the SPL values varying with distance along the 45° angle directions. As shown from this figure, in all distances supersonic projectile has higher SPL values than subsonic projectile. The SPL values were lower than the results of x-direction in all cases.

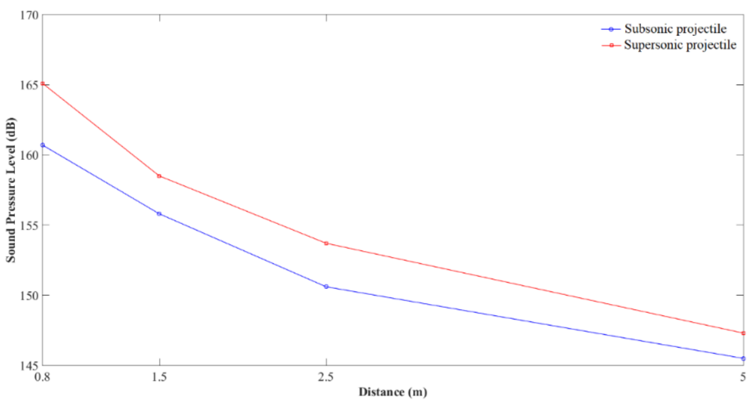

Figure 6. Sound pressure level varying with distance along the 45° angle directions

As stated before, velocity measurements were also made within the scope of the experiments. For each projectile type, 6 shots were made and the results were taken in level with the gun barrel axis and the average of these results were recorded. Results showed that the subsonic projectile velocity was 317 m/s and the supersonic projectile velocity was 382 m/s.

Conclusion

Basically, it is required of a gun is to have a destroying effect and when the destruction effect is desired to be increased, the sound levels also increase and this situation needs to be examined. This study aims to investigate the effect of subsonic and supersonic projectiles on SPL at 9 mm gun. In this context microphones inserted to 23 different positions and the results of these measurements evaluated.

From the results of this study it was concluded that,

- Supersonic projectiles have higher peak sound pressure levels than subsonic projectiles in all measurement positions.
- The peak sound pressure levels decreased with increasing distance from the gun barrel exit.
- The highest SPL values were obtained at nearly 0.2 m positions with both projectiles which was 178 db at supersonic projectile and 176 db at subsonic projectile.
- Subsonic and supersonic projectiles give close results to each other at the same level with the barrel in the y-axis direction.
- With increasing distance, it is seen that the supersonic projectile has relatively higher results than the subsonic projectile at y-axis direction.
- Especially after neraly 0.8 m, the differences between the results obtained from both projectiles increase at y-axis direction.
- The subsonic projectile velocity was 317 m/s and the supersonic projectile velocity was 382 m/s in level with the gun barrel axis.

In future studies, to reduce the SPL values, projectiles with different geometries, shapes and properties can be experimentally analzed. Also, the numerical calculations of these systems can be realized and comparison of the experimental and numerical results can be made.

Acknowledgments

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