Comparative Computational Analysis of NATO 5.56 mm, APM2 7.62 mm and AK-47 7.82 mm Bullet Moving at Mach 2.0 in Close Vicinity to the Wall

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Various rifles require unique bullets. Each bullet has its capability, speed, and impact on the target. In metropolitan warfare, several bullets are shot close to the solid walls. These near walls affect the pressure distribution over the entire asymmetric bullet. The influence of a reflected shock depends on the angle at which it was reflected and the altitude from the ground to the body of the bullet. The current research emphasizes three bullets of varying diameters used in different types of guns. The first bullet is of NATO 5.56 mm, the second is APM2's 7.62 mm bullet, and the third is a 7.82 mm bullet from an AK-47 rifle. For 2-D steady computations, the supersonic speed of Mach 2 is considered to analyze the flowfield across all three bullets. The heights of the bullet are taken considering the height-to-diameter ratios (h/D ratio) from 0.5 to 3.0. The Mach contour drawn from the numerical simulations is used to analyze the flowfield, and aerodynamic coefficients like lift, drag, and moment are also plotted to analyze the ground effects on the projectile. The comparative analysis showed that the trend of shock wave reflections was similar in the bullets till h/D of 1.5. The APM2 bullet experienced maximum drag, followed by AK-47's 7.82 mm and NATO's 5.56 mm bullet. The 7.82 mm bullet experienced maximum lifting force at h/D = 1.0 due to its larger surface area than the other two ammo. The 7.82 mm bullet experienced a nose-up moment, whereas the other two faced a nose-down moment. As the altitude of the bullets from the ground increased, the ground effect appearing on the bullets reduced. The present comparative analysis research shows that it is suitable to fire an AK-47 bullet from h/D greater than 2.0 and the other two bullets from an altitude greater than or equal to h/D of 3.0.

Keywords: *Bullet's Computational Aerodynamics, External Ballistics, Ground Effect, Urban Warfare, Near Wall Proximity.*

1. INTRODUCTION

When the bullet travels from its loading point to the muzzle, it is referred to as internal ballistics. Once it moves out of the muzzle to hit the target, this part of the ammo is known as external ballistics. The rising number of urban warfare taking place in today's world makes it necessary to achieve a precise target without external disturbances from walls or ground. Shock reflections from these solid objects can deviate the projectile's trajectory and lead to misguidance. To prevent such occurrence, it is crucial to study in depth the forces acting on several bullets in a very close vicinity to the ground. Ground shooting from rifles or snipers, shooting sports, military drills, and guns attached to drones for targeted terrorist killings are also important practical applications where the ammo is close to the ground. Plotting the pressure distribution over the surface of the bullets and getting the aerodynamic coefficients like lift, drag & moment is essential to achieve minimum distractions to hit the right target. This is necessarily obtained from computational aerodynamic simulations around the bullet. Wind tunnel tests for different diameter bullets placed in a very close vicinity to a solid wall at a speed of Mach 2.4 were carried out by Purdon et al. [1].

The wake region flowfield and the recompression shock were the only factors that were affected as the altitude from the wall increased.

The projectile's path was affected at closer distances as it gave rise to unsteadiness in the area of influence. The live range tests and the wind tunnel testing data were compared with the one equation Spalart Allmaras turbulence model. Doig et al. [2] stated that a noticeable lifting force was achieved when the altitude between the ground and the ammo was less than the bullet's diameter.

A nose-up movement is caused in a very close vicinity to the near wall as the base region of the bullet is induced with more pressure [3]. NATO ball 7.62 mm bullet was used to perform an experimental and numerical study by Borvik et al. [4].

In this research, an aluminum plate was used with a thickness of 20 mm to go through the impact of the shot

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fired in a normal and oblique direction. It was observed that the moment and forces had minimal consequence inside the transonic region. The forces acting were reported to have a very small magnitude. Figure 1 depicts ammo in free-flight form and that of the solid ground; the shock wave reflections are formed at the tip's leading edge [5]. Doig et al. [6] illustrated their findings when a bullet passes near a nearby wall at transonic speeds. The flow pattern was analyzed from Mach 0.9 to Mach 1.2. The lowest altitude cases had 30% more drag than the higher altitude ones. Maximum fluctuations in the flow physics were in the case of Mach 1.2. Target accuracy was said to be impacted due to a lower velocity of the bullet when it crosses very close distances to the wall. The higher disturbances in the wake flow region are another reason which leads to a higher drag [7]. Tran et al. [8] found that an angle of 14° in the boat tail gives a minimum drag at low speeds. Pressure drag has more consequences on the afterbody before complete flow separation occurs. Reddy et al. [9] reported that as the projectile moves a longer trajectory, gravity reduces the bullet's altitude from the height it was initially fired. Hence, during computational simula–tions, flat firing approximation is mostly considered. The density of the air also influences the dynamics of the bullet in the atmosphere; density decreases as the altitude from the ground increases. After moving up to an altitude of 4 kilometers from the mean sea level, air density is said to be reduced by 37%. This factor inc–reases the range of the shot by 16% and the terminal velocity by 13%, respectively. Damljanovic et al. [10] performed comparative experimental wind tunnel tests on an AGARD-B model at the transonic range of Mach numbers 0.77, 1.0, and 1.17. The scatter of aerodynamic coefficients along the average was found. Milicev [11] executed an experimental study over a hemispheric geometry. The tests were done at various angles of attacks starting from 0° to 10°. The flow physics was analyzed at transonic and supersonic speeds of 1.03 and 1.89, respectively, to investigate the effect of a spike. The Schlieren technique eyed visualization of the flow conditions in the domain. Overall, 5 Besides bullets, several kinds of research have been performed experi–mentally and computationally to analyze the aerody–namic forces over different streamlined bodies like cone, spiked, and ogive bodies [12-15]. Models were tested, and in four of them, various designs of spikes were taken; one of the cases did not have a spike in the geometry. In transonic flow conditions, it was evident that the presence or absence of spike did not affect the flow. The performance in terms of aerodynamics was improved in the supersonic flow condition tests only. However, in the current research, specific focus is placed on bullets traveling at supersonic speeds close to the wall or the ground. The authors Gholap et al. [16] conducted a preliminary investigation in which they examined the impact of shock reflection generation on the AK-47 bullet at a specified h/D ratio. It involved testing the bullet's flow physics in close proximity to walls at a height-to-diameter ratio (h/D) ranging from 0.25 to 5, revealing that firing the bullet from a h/D greater than 2.0 was preferable for the best results [17].

To the best of the authors' knowledge, comparative computational aerodynamics based on different diame–ter bullets moving close to the ground has yet to be studied, as seen from the preceding literature review. Most recent studies focused on something other than larger-diameter bullets' aerodynamic behavior, which is, in general, extensively used in modern urban warfare. Therefore, a comparative study of smaller and larger diameter projectiles is crucial for compilation in a single research. This will also help to understand the change in the flow physics pattern with altitude for different bullet designs of varied diameters. This inspired the authors to study flow characteristics on a NATO 5.56 mm, APM2 7.62 mm, and an AK-47 7.82-mm bullet moving at a supersonic speed of Mach 2.0 and different vicinities from the ground.

The present research emphasizes the minimal safe height from the ground at which the bullet can be fired without the bullet's trajectory being affected. The Mach contour has been visualized for all the cases, along with the pressure distribution, moment, lift, and drag coef–ficients captured, analyzed, compared, and elaborated.

2. COMPUTATIONAL METHODOLOGY

2.1 Model Geometry

For the comparative analysis, three different bullets have been selected. Firstly, standard ammo fired from ADI AUSSTEYR A1/A2 rifle's NATO 5.56 mm bullet;

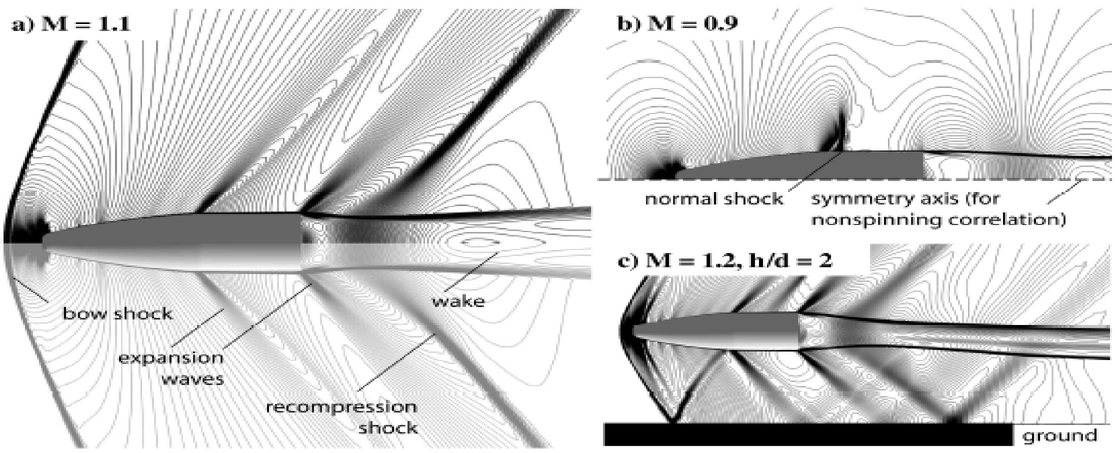
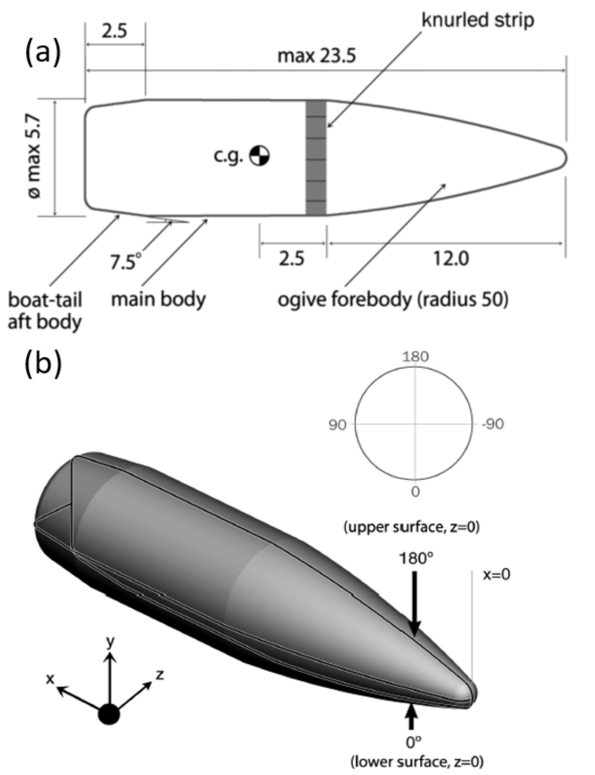


Figure 1: NATO 5.56 mm bullet moving at freestream transonic Mach 1.1 and 0.9 in a free flight condition depicted in (a) and (b). In case (c), the bullet is moving at a vicinity of h/D = 2 with respect to the ground at Mach 1.2 [5].

secondly, a 7.62 mm APM2 small arms bullet and thirdly, a 7.82 mm bullet of an AK-47 rifle is consi–dered. The illustrative dimensions of the bullets menti–oned above are referred from Doig et al. [2], Borvik et al. [4], and Reddy et al. [9], respectively. All the projectiles have a boat-tailed after body along with the main base region, ogive region, blunt tip, and a flat base. The schematic geometrical data of the bullets are displayed in figure 2. Figures 2(a) and (b) show the NATO 5.56 mm bullet with a maximum length of 23.50 mm, a flat base region of 9 mm, and a taper of 7.5°. Figures 2(c) and 2(d) show the 2-D and 3-D view of the NATO 7.62 mm bullet along with the gunpowder part and aluminum core. In the current investigation, only the outer core 2-D structure is considered as per the relevance of the research. The detailed 2-D and 3-D geometry of the AK-47 Assault rifle 7.82 mm bullet are showcased in Figure 2(a) and (b) of Gholap et al. [17].

2.2 Computational Solver

The RANS (Reynolds Averaged Navier Stokes) equa–tions are solved using a 2-D structured mesh. An explicit density-based solver is used along with a 3-coefficient Sutherland viscosity model and the ideal gas. Ansys® software is used for running the computations.
is set to density to obtain a steady-state solution with which the fluid material is fixed as air. A second-order upwind scheme is implemented to get accurate data in turbulence. No-slip condition is put on the wall domains. In order to compute the intricate ground shock reflections, Reddy et al. used the standard k-ε turbulence model [9]. For spatial discretization, the Green Gauss cell-based method is harnessed. Once the residual convergence is under 10^{-3}, the solution is considered.



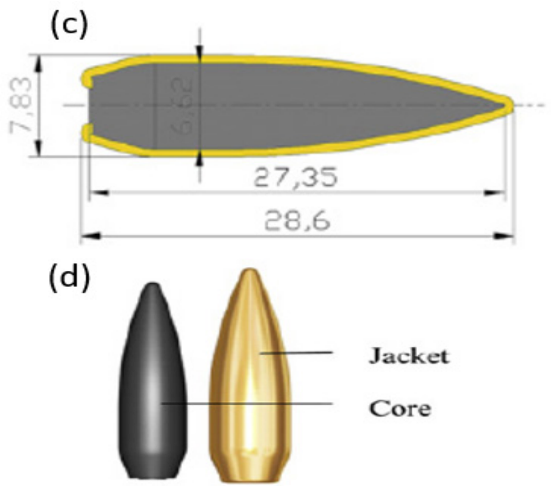


Figure 2: a) Geometrical details of NATO 5.56 mm ammo. b) 3-D isometric view of the 5.56 mm bullet. [2] c) 2-D schematics of APM2's 7.62 mm bullet d) Visuals of the jacket and the core of the 7.62 mm bullet [4]. All dimensions are in millimeters.

2.3 Meshing and Boundary Conditions

The full domain adopted in the present computational study has approximately 100,000 cells (see figure 3 of Gholap et al. [17]). The boundary condition of no slip is set on the near wall on the lower side of the domain. The top boundary is elongated ten times the diameter of the bullet. The pressure outlet region on the domain's right side is fifteen times the diameter of the ammo. The pressure inlet or the left side boundary is five times the projectile's diameter. Solver validation and a grid inde–pendence test were carried out and described in the authors' earlier paper [17]. However, in the further sections, the validation and grid independence study are reported again to converge to the endorsed mesh in the present investigation.

The current research investigation is carried out at freestream Mach 2, with a freestream Reynolds number 3.6 x 10^5 based on the bullet's diameter [9]. The inlet (left) and the domain's top boundary are set to Pressure far-field boundary conditions. The right side (outlet) boundary is set to pressure outlet; see Figure 3 of Gholap et al. [17]. To carry out the comparative analysis study of the three bullets from the near wall, compu–tations are done at several altitudes to ratios of the height to diameter (h/D). 'D' is the bullet's diameter, and 'h' is the shortest distance from the near wall to the bullet's lower region flat base. Table 1 showcases the altitudes of all three bullets' cases at which the compu–tations are simulated.

Table 1: Various h/D ratios ranging from 0.5 to 3.0 for all three different ammos are carried out in the current research

Sr. No.	h/D	Case I (5.56mm)	Case II (7.62 mm)	Case III (7.82 mm)
1	0.5	2.78	3.81	3.91
2	1	5.56	7.62	7.82
3	1.5	8.34	11.43	11.73
4	2	11.12	15.24	15.64
5	2.5	13.90	19.05	19.55
6	3.0	16.68	22.86	23.46

2.4 Validation and Grid Independence Test

Axisymmetric two-dimensional simulations were carried out on the 7.82 mm AK-47 projectile at freestream Mach 2 for validation with reference to the base paper by Reddy et al. [9]. The data is validated with the surface pressure distribution on the ammo's surface. Figure 4 of Gholap et al. [17] shows the validation plot, which is fairly tallying. Moreover, a grid independence test has been done to converge to an advisable grid. Five varying grids (with respect to the density of the grid), starting from very coarse to very fine, are computed. The number of cells adopted and the wall Y+ value obtained from the grid independence test are tabulated in Table 2 of Gholap et al. [17]. Figure 5 of Gholap et al. [17] displays the grid independence test surface pressure distribution results with the base paper's computed data. Hence, a fine mesh with approximately 100,000 cells is selected for the current research based on analyzing varying wall Y+ and pressure distribution on the bullet.

3. RESULTS AND DISCUSSIONS

The altitudes of the ammo from the wall vary in height-to-diameter ratios from 0.5 to 3.0 to analyze and study the changes that occurred in the flowfield. For the three bullets of different sizes near a solid wall, the effect due to closeness is studied by computational simulations at freestream Mach 2. Qualitative analysis is illustrated by imaging the Mach contours and analyzing simulated cases. Further, quantitative analysis is attained by computing the surface pressure distribution and the aerodynamic coefficients, namely drag, lift, and the moment. All these parameters are compared and discussed in depth.

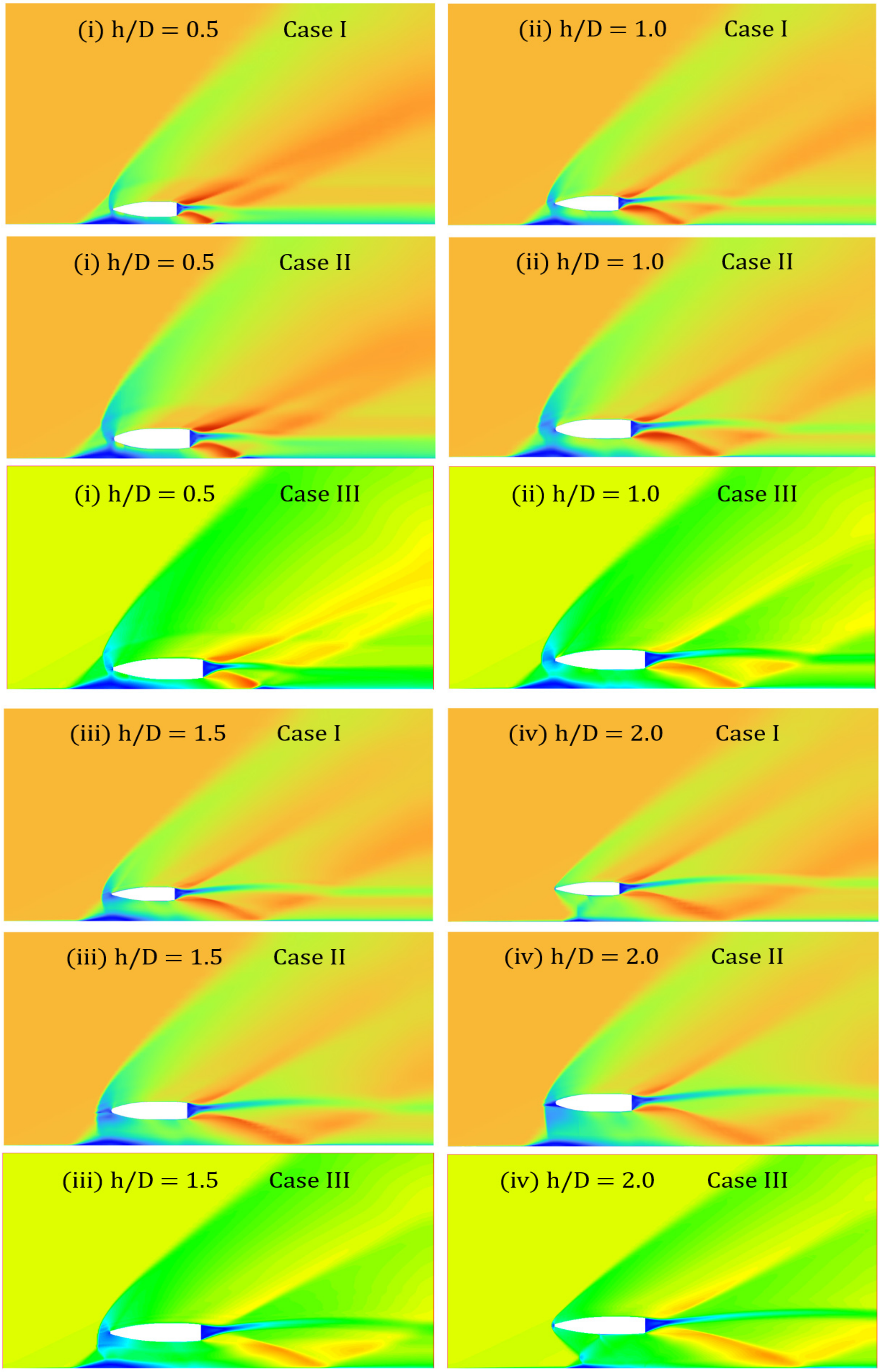
3.1 Flowfield in Mach Contour

Three bullets of different diameters and shapes were taken to conduct a comparative analysis. These are termed as cases for easier understanding. Case I is named for the bullet of 5.56 mm diameter, Case II refers to 7.62 mm ammo, and the final projectile, Case III, is 7.82 mm. Figure 3(i-vi) shows the computed Mach contours for the three bullets changing h/D from 0.5 to 3.0 at freestream Mach 2 speed. In the start region of the projectile, bullet tip, a detached bow shock wave is seen to be generated in all three bullets' cases. For all the projectiles under h/D=1.5, it is clear that an area of flow separation is occurring close to the ground surface in front of the bullet. A separation shock is produced as a result of this. When the bow shock and the separation shock interact, the flow phenomena are changed. Firstly, in Figure 3(i), all the projectiles are located relatively close to the near wall under h/D=0.5 circumstances. The bow shock is perceptible. A high drag coefficient will result from the bow shock and separation shock existing in the region between the wall and the bullet. The shocks (separation and bow) are visible from condition iv, i.e., h/D>1.5. Bow shock will be more prominent because the area where the bow shock interacts with the separation shock is away from the bullet. The amount of drag experienced by the bullet with respect to the bow shock wave will be more than that of the separation shock. From all the cases, it is seen that the shock reflected from the ground hits the bullets' lower surface. The maximum amount of lift is generated in Cases I and II from h/D=0.5 to 2; in the third case, h/D=1.0, 1.5, and 2.0 will amount to the maximum lift. For h/D = 2.5, the reflected shock wave hits the aft region of the bullet's lower surface in Case I. Case II experiences the reflection between the middle and aft arena of the bullet. In Case III, the reflection from the solid wall hits the wake region; hence, a minimum lift, drag, and moment value are expected than the other two cases. For h/D = 3.0, it is discernible that the reflected shock wave angle from the ground for the higher bluffness bullets (first two cases) is not hitting the geometry of the bullet. In both cases, the shock wave reflected from the ground strikes the early wake region. In Case III, the reflected shock wave has moved further downstream than the previous altitude case, further minimizing the disturbances caused in the wake region. The wake pattern for all three cases is similar, as the shock reflects from the ground at a certain angle, and the force leads to an upward deviation in the wake region. It is noticeable that the wake aligns parallel to the bullet once it stabilizes downstream because the impact of the shock reduces. As the shock wave reflections interact with the wake region or the bullets' lower surface, a moment coefficient can be generated on the projectile. It is important to keep it minimal as it directly affects the target's accuracy when the shot is fired.

3.2 Pressure Coefficient

Figure 4 displays the simulated pressure distribution for the three cases at different h/D ratios. The comparative analysis is showcased by tallying the pressure distribution for all three bullets at respective heights. The surface length distribution of the bullets' lower body is considered as the reflected shock does not disturb the upper surface. When the ammo is closest to the ground in h/D = 0.5, all three cases follow a similar pattern; one elongated spike over the surface is observed. The cause of this pattern might be due to the intermixing of the bow shock formation at the tip of the bullet with the separation shock. For h/D=1.0 and 1.5, all three bullets follow a similar trend; a spike is developed at mentioned (surface length to diameter ratio) s/D = 3.0, and a stable decrease is observed in the trend after this point in the aft region.

The dual peaks in the graph verify that the reflected shock hits the bullet after reverting from the wall. The sonic line causes a peak at the start of the pressure coefficient plot. An expansion fan gives rise to a sudden drop in pressure at the base region in some cases. For h/D=2.0, the 7.62 mm bullet experiences a sharper peak compared to the other two cases; this is visible from the Mach contour, too, that the separated shock and the bow shocks collision are impacted more in the front of the bullet. 5.56 mm and 7.82 mm ammo experience shock at s/D = 2.3, whereas the 7.62 mm ammo spike at s/D =3.0. When h/D = 2.5, the 7.82 mm bullet does not tender a specific spike as the shock reflection hits the wake region and not the bullet's surface. In the 7.62 mm bullet, a major hump in the trend is visible. This is due to the shock reflection hitting the bullet at s/D = 2.4 at its maximum angled strength after reflecting from the wall. In 5.56 mm ammo, at s/D = 3.6, a spike is depicted, and the shock is reflected at the aft region of the bullet's lower body. When h/D = 3.0, all three bullets show a similar trend; no strong shock wave impact can be seen to cause a major shift in the pressure distribution.



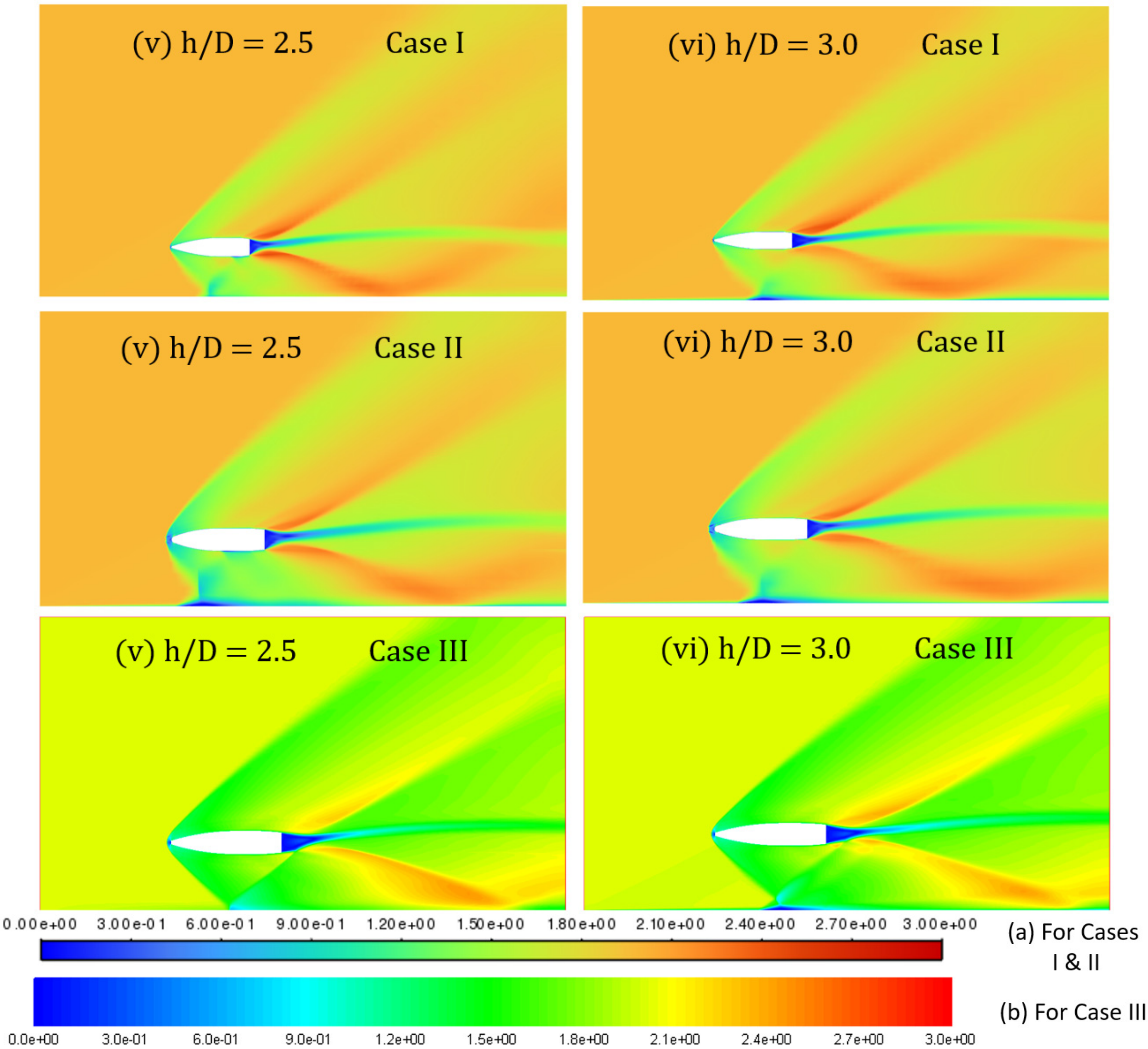
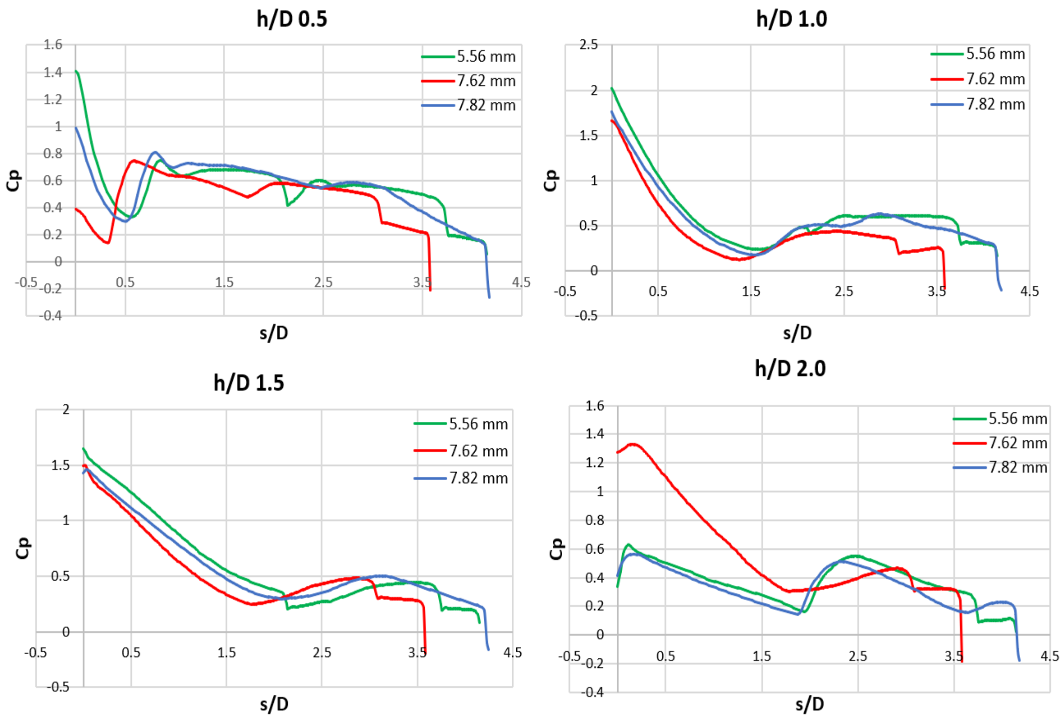


Figure 3: The Mach Contour distribution across the three bullets in the domain is displayed. The freestream flow direction is from left to right. Case I corresponds to the NATO 5.56 mmm bullet, Case II here refers to the APM2 7.62 mm bullet, and Case III results are that of the AK-47 rifle's 7.82 mm bullet. The case III data is taken from Gholap et al. [17].



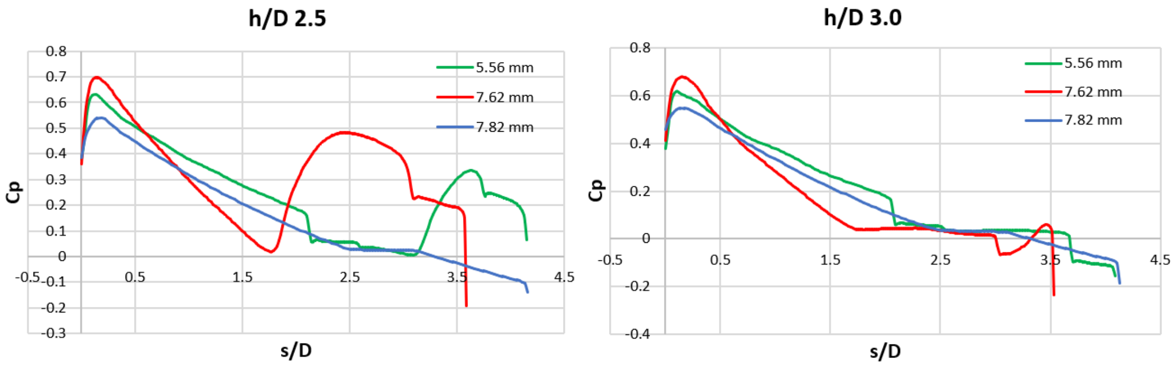


Figure 4: Pressure coefficient distribution computed at the lower surface of the bullets for the cases of different heights from the ground ranging from h/D=0.5 to 3.0.

3.3 Force and Moment Coefficients

Lift, drag, and moment coefficients at different h/D ratios are computed to analyze the quantitative result. The numbers drawn out after computation are tabulated in Table 2 (i), (ii), and (iii), and the trend followed is plotted in Figure 5. In the first case, the lift increases as the altitude increases to h/D=1.0, then as the bullet moves to higher h/Ds, the impact of the shock acting on the bullet's projectile to produce lifting force decreases. In case III, the bullet experiences maximum lift at h/D = 1, which is at the height of 7.82 mm, the lift value in the Case II gradually declines as the projectile shifts away from the wall. The maximum amount of lift is experienced by the AK-47 bullet, followed by 7.62 mm and the 5.56 mm bullet.

The schematic geometry of the 5.56 mm bullet is the shortest in length and diameter; hence, due to less surface area, the amount of drag experienced by the body is lesser compared to the other two bullets. The highest amount of drag at all the respective heights is accounted for by Case II, 7.62 mm bullet, then by Case III- 7.82 mm bullet, and finally by the 5.56 mm bullet. In all three cases, the drag coefficient is maximum at h/D =0.5, half the height of the bullet's diameter.

The value of drag coefficients is observed to decrease gradually from h/D > 1.5; this might be due to the reduced strength of the bow shock wave and separation shock interaction as the altitude of the bullet increases. Hence, the bullet experiences lesser drag force in all the different cases when it moves further away from the wall.

The aerodynamic moment coefficient for all three bullets is also considered. Table 2 (iii) shows the moment coefficient values for all the cases. Case I refers to a 5.56 mm bullet, Case II refers to 7.62 mm, and Case III refers to a 7.82 mm bullet. Figure 5 (iii) shows the trend of the moment coefficient at different h/D ratios. The center of the bullet's diameter is the point of reference for calculating the projectile's moment coefficient.

Table 2 uses the bullet's center of gravity as the reference line. For cases I and II, the value of the moment coefficient is negative; this portrays the bullet facing a nose-down pitching moment. This phenomenon occurs only when the bullet experiences a higher force on its upper surface ogive region and lower body aft region. The moment coefficient is maximum at h/D =0.5. The moment coefficient reduces when the bullet is at a distance greater than h/D = 1.5. In case I, the moment coefficient sharply dips after h/D = 1.5; hence, it is safe to shoot this bullet after this altitude of 8.34 mm. For Case II, this sharp drop in the moment coefficient occurs after h/D = 2.0. For Case III, the value of moment coefficients is positive. This indicates that the bullet will experience a nose-up movement. This is due to a higher force experienced by the lower ogive region of the bullet and upper aft region of the boattail area. To achieve proper target accuracy, it is recommended to shoot the Case III ammo from heights greater than or equal to h/D = 2.5 and the Case I and II bullets from h/D =3.0 as the moment coefficient is nearly equal to zero, thereby, shooting from this altitude will not lead to any deviation from the target.

Table 2 (i): Computed aerodynamic lift coefficients from h/D = 0.5 to 3.0 for all three bullets.

h/D	Lift (Case-I)	Lift (Case-II)	Lift (Case-III)
0.5	0.00911	0.0103	0.0139
1	0.01137	0.0104	0.0157
1.5	0.01073	0.0120	0.00148
2	0.00435	0.0119	0.0060
2.5	0.00183	0.0048	0.0006
3	0.00048	0.00063	0.0006

Table 2 (ii): Computed aerodynamic drag coefficients from h/D = 0.5 to 3.0 for all three bullets.

h/D	Drag (Case-I)	Drag (Case-II)	Drag (Case-III)
0.5	0.00516	0.00798	0.0073
1	0.00499	0.00784	0.0066
1.5	0.00514	0.00781	0.0064
2	0.00384	0.00782	0.0051
2.5	0.00394	0.00665	0.0051
3	0.00400	0.00671	0.0054

Table 2 (iii): Computed aerodynamic moment coefficients from h/D = 0.5 to 3.0 for all the three bullets

h/D	Moment (Case-I)	Moment (Case-II)	Moment (Case-III)
0.5	-0.00009778	-0.000115	0.000240
1	-0.00014642	-0.000169	0.000227
1.5	-0.000155	-0.000187	0.000204
2	-0.00003203	-0.000178	0.000134
2.5	-0.0000096	-0.000038	0.000004
3	-0.0000067	-0.000007	0.000009

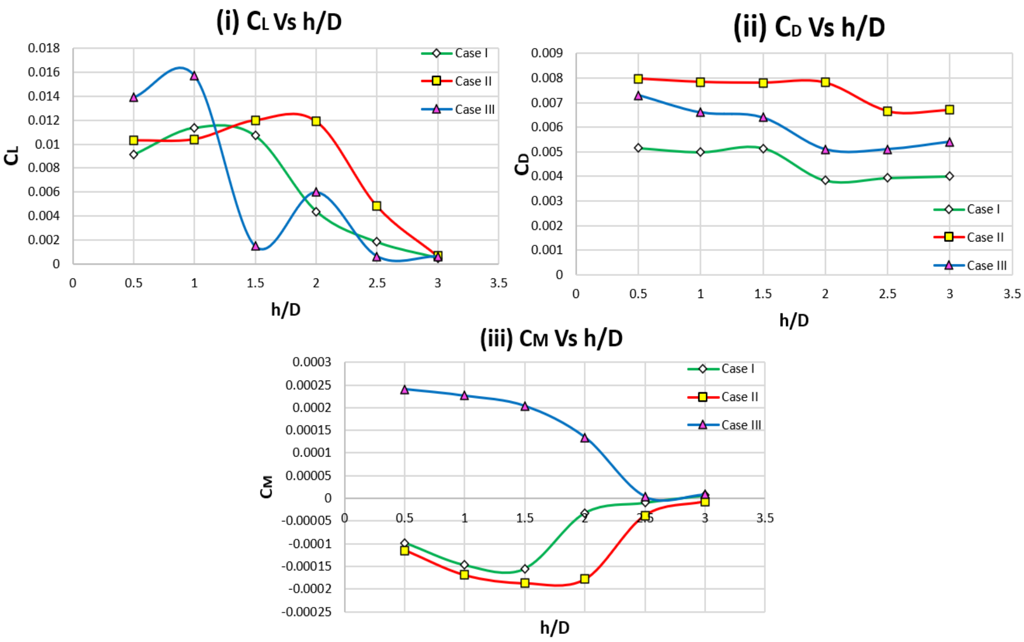


Figure 5: Trends of the aerodynamic coefficients like lift, drag, and moment are depicted for all the h/D ratios taken for the comparative analysis.

4. CONCLUSION

In the present investigation, a steady two-dimensional comparative computational analysis of three different bullets in close vicinity to a nearby wall was conducted. the first bullet was 5.56 mm in diameter, and the rest two were 7.62 mm and 7.82 mm, respectively. The study was concentrated on six different altitudes based on the height-to-diameter ratio from the solid wall, starting from h/D = 0.5 up to 3.0. The flow around the bullets was evaluated by studying the flow field through the Mach contour, the pressure coefficient on the lower half surface of the bullet where the bow shock reflections from the ground hit, and aerodynamic coefficients like lift, drag, and moment. for the first altitude case, H/D = 0.5, the drag reported was highest for all three bullets; as the altitude increased, the drag induced on the bullet reduced. overall, the bullet of 7.62 mm experienced the highest amount of drag at all altitudes, followed by the 7.82 mm bullet of AK-47 rifle's. The NATO 5.56 mm bullet experienced the least drag compared to the other two ammo due to its lower total surface area. In terms of the lift force, the 7.82 mm bullet experienced the highest amount of lift at h/D = 1.0. The 5.56 mm bullet saw a steep decline in the lift after h/D = 1.5. The values of the moment coefficient in all three bullets at different altitudes were minimal. The first two cases (5.56 mm and 7.62 mm) followed a nose-down movement, whereas the 7.82 mm bullet suffered a nose-up pitching. it is suitable to shoot the 7.82 mm bullet from an h/d ratio of more than 2.0, as the reflected shock does not hit the body of the bullet. but, in the case of the first two bullets, the shock reflections persist at H/D = 2.5, which could lead to a shift from the accurate target. In the scenario of the first two bullets, the reason H/D = 2.5 not being the safe height is a consequence of the higher bluffness of the bullet compared to the 7.82 mm bullet; the strength of the shock increases, causing the shock wave angle to increase. this accounts for the shock generated to hit the ground earlier, leading the reflected shock to hit the projectile and disrupt the trajectory. Hence, it is more feasible and safer to shoot the 5.56 mm and 7.62 mm bullets from an H/D ratio greater than 2.5, which is an H/D of 3.0, at which the reflected shock wave is not affecting the trajectory of the bullets at this altitude.

For the future scope of work, a comprehensive three-dimensional comparative analysis can be carried out to illustrate the effect of the reflected shock wave on the surface of the bullet for all three cases by attaining more pragmatic and precise data on the impact.

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КОМПАРАТИВНА РАЧУНАРСКА АНАЛИЗА НАТО 5,56 мм, АПМ2 7,62 мм И АК-47 7,82 мм МЕТКА КОЈИ СЕ КРЕЋЕ БРЗИНОМ ОД 2,0 МАХА У НЕПОСРЕДНОЈ БЛИЗИНИ ЗИДА

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Различите пушке захтевају јединствене метке. Сваки метак има своју способност, брзину и утицај на мету. У метрополитанском рату, неколико метака се испаљује близу чврстих зидова. Ови близу зидова утичу на расподелу притиска по целом асиметричном метку. Утицај рефлектованог удара зависи од угла под којим је одбијен и висине од тла до тела метка. Тренутно истраживање наглашава три метка различитог пречника који се користе у различитим типовима оружја. Први метак је НАТО калибра 5,56 мм, други је метак АПМ2 калибра 7,62 мм, а трећи је метак 7,82 мм из пушке АК-47. За 2-Д стабилна израчунавања, сматра се да надзвучна брзина од 2 Маха анализира поље струјања сва три метка. Висине метка су узете с обзиром на однос висине и пречника (однос х/Д) од 0,5 до 3,0. Махова контура извучена из нумеричких симулација се користи за анализу поља струјања, а аеродинамички коефицијенти као што су подизање, отпор и момент су такође исцртани за анализу утицаја тла на пројектил. Компаративна анализа је показала да је тренд рефлексије ударних таласа био сличан код метака до х/Д од 1,5. Метак АПМ2 је доживео максимални отпор, а затим метак АК-47 од 7,82 мм и НАТО метак од 5,56 мм. Метак од 7,82 мм је имао максималну силу дизања при х/Д = 1,0 због своје веће површине од друга два муниције. Метак калибра 7,82 мм доживео је тренутак подизања носа, док су се друга два суочила са моментом спуштеног носа. Како се висина метака од земље повећавала, ефекат тла који се јавља на мецима се смањивао. Ово истраживање упоредне анализе показује да је погодно испалити метак АК-47 са х/Д веће од 2,0 и друга два метка са висине веће или једнаке х/Д од 3,0.