An Observation Regarding: "Fireworks Shell Drift due to Shell-to-Bore Clearance"

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ABSTRACT

Some empirical evidence is presented in support of a recent suggestion by R. K. Norton that a significant portion of aerial shell drift may simply be the result of shell-to-bore clearance. The support for this stems from the observation that aerial shells, during the very earliest portion of their free flight, were occasionally found to deviate from approximately 2.5 to 4 degrees from the axis of the mortar that fired them. At such an early stage in their flight, other possible mechanisms sometimes cited in an attempt to account for aerial shell drift (the magnus effect and other aerodynamic effects) cannot provide the explanation. However, Norton's suggestion regarding shell-to-bore clearance does provide a ready explanation for this observation. If the effect of shell-to-bore clearance operates during this early portion of a shell's flight, then certainly it will continue to play a major role in producing deviations from a shell's trajectory from the mortar's axis.

Keywords: aerial shell drift, shell clearance

Observation and Comment

Recently R. K. Norton suggested[1] that a significant fraction of aerial shell drift is probably due to simple bore balloting as a result of the clearance between the aerial shell and the inside mortar wall. This is quite consistent with an observation the author has occasionally made during testing to measure aerial shell muzzle velocities. In these tests, mortars were used that were specially configured with a pair of eight foot (2.44 m) rails extending upward from the mouth of the mortar and having a wide circular steel band at the top to stabilize the rails. Additionally, a series of trip wires were run between the rails at four locations along the length of the rails. (See Reference 2 for a photograph of one test mortar.) In these measurements, the shells' velocities were determined using timing circuits started by the ignition of the lift charge and stopped by the breaking of each of the series of the electrically conducting trip wires.

Occasionally during the course of testing, an aerial shell would fail to break the trip wire at the top, and on rare occasion, an aerial shell would strike the wide circular steel band at the very top. For this to happen requires a deflection of the aerial shell of at least 2.5 to 4 degrees, depending on the orientation of the cylindrical shell. That an aerial shell would deviate so far from the axis of the mortar tube, so early in its course, clearly seemed not to be attributable to magnus forces[3] or other aerodynamic forces.[4] There are two reasons for this. First, during this portion of the flight of the shell, it is still traveling upward in an escaping column of lift gases moving at approximately the same velocity as the shell. Accordingly, any aerodynamic forces on the shell at this time will be minimal, and these forces do not substantially increase until the rising aerial shell leaves the column of lift gases behind. Second, even if fully developed aerodynamic forces were operating at this time, the approximately 25 ms that it takes the shell to travel the first eight feet (2.44 m) is not sufficient to produce the necessary amount of lateral displacement. [To further demonstrate this point, assume aerodynamic forces could somehow produce the observed displacement during the first short portion of the shell's flight. If that were the case, then the total shell drift (displacement) manifested over the total flight time of aerial shells would be on the order of 100 times greater than observed experimentally.]

It is of interest to note that, under the conditions stated in his article,[1] Norton suggests maximum shell deflections in the range of approximately 2.5 to 5 degrees for aerial shells experiencing zero and one ballot (shell to mortar wall contact), respectively. Accordingly, the empirical observations made during the author's measurements of aerial shell muzzle velocity are quite consistent with Norton's shell-to-bore clearance explanation for at least a major portion of shell drift observed over the total flight path of an aerial shell.

References

1) R. K. Norton, "Fireworks shell drift due to Shell-to-Bore Clearance", *Journal of Pyrotechnics*, No. 13 (2001) pp 31–34.

2) K. L. and B. J. Kosanke, "Measurement of Aerial Shell Velocity", *American Fireworks News*, No. 154 (1994). Also reprinted in *Selected Pyrotechnic Publications of K. L. and B. J. Kosanke, Part 3 (1993 and 1994)* Journal of Pyrotechnics, Inc. (1996) pp 56–61.

3) K. L. and B. J. Kosanke, "Aerial Shell Drift Effects", *Proceedings of the First International Symposium on Fireworks* (1992). Also reprinted in *Selected Pyrotechnic Publications of K. L. and B. J. Kosanke, Part 2 (1990 and 1992)*, Journal of Pyrotechnics, Inc. (1995) pp 67–79.

4) R. L. Schneider, "Aerodynamics of Aerial Display Shells", *Proceedings of the Fifth International Symposium on Fireworks* (2000) pp 461–465.