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Peak Mortar Pressures when Firing Spherical Aerial Shells

K. L. and B. J. Kosanke

The Pyrotechnics Committee of the National Fire Protection Association (NFPA) recently revised the *Code for Fireworks Displays,* NFPA 1123. The revised code included recommendations for wall thickness for fiberglass mortars and for larger sizes of high-density polyethylene mortars. In anticipation of the committee's discussions of the needed strength of mortars, the authors decided to assemble data on typical peak mortar pressure as a function of aerial shell size. Because of the limited amount of data located, one could not be overly selective (i.e., essentially all available data was used[1–4]). Obviously, it would have been preferred to have had an abundance of data for a wide range of typical shells fired under a wide range of known conditions. Nonetheless, the amount and type of data (136 measurements for spherical shells) is felt to be sufficient to establish approximate averages of peak mortar pressure for spherical aerial shells as a function of their size. This short article was prepared in the hope that some readers would find this data useful (or at least interesting).

Figure 1 is a mortar pressure profile that illustrates internal mortar pressure as a function of time during a typical shell firing. First there is an extended period of time (t_0 to t_i) during which there is effectively no pressure rise. This length of time is commonly 15 to 20 ms (thousandths of a second). This would seem to be the time taken for fire to spread among and ignite the grains of lift powder, before there is sufficient gas production to cause a detectable pressure rise in the mortar. Then a rapidly accelerating increase in mortar pressure occurs up to some peak value, generally occurring over a period of 5 to 10 ms. Next, as the shell accelerates upward and the rate of gas production decreases, mortar pressure drops during the time before the shell exits the mortar. This pressure drop generally continues for 10 to 15 ms. Finally, the exiting of the shell (at time t_e) causes an even more precipitous drop in pressure back to ambient levels. The total time taken for shells to exit (t_0 to t_e) typically ranges from approximately 45 ms for small shells to less than 30 ms for large shells.[5]

Averages of peak internal mortar pressure data, as a function of spherical shell size, are presented in Table 1. (Also included in Table 1 are the numbers of individual measurements used for each size shell.) These data are also plotted in Figure 2. The curve in Figure 2 assumes the data is linear and passes through zero—an assumption that appears generally valid. Using this linear relationship, refined estimates for typical peak mortar pressures can be determined, and are included as the last column in Table 1.

For the most part, these data are presented without comment. It is left for the reader to decide what (if any) use they wish to make of this information. For example, these data might be used for such things as estimating the appropriate wall thickness of mortars to fire spherical aerial shells. However, if this is done, it must be understood that this data cannot be applied directly to mortar strength required for cylindrical

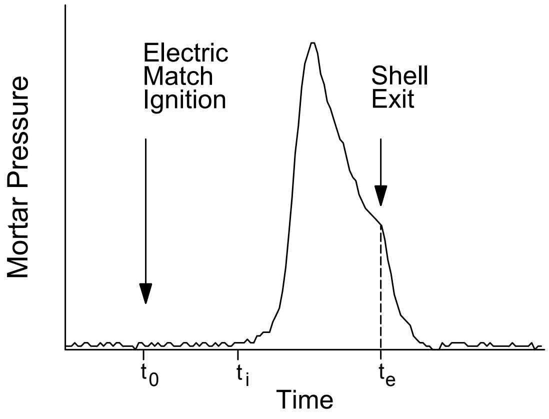

Figure 1. Typical internal mortar pressure profile during the firing of an aerial shell.

Table 1. Average Peak Internal Mortar Pressure Data.

Shell Size[a] (in.)	Num. of Meas.[b]	Meas. Pres.[c] (psi)	Fitted Pres.[d] (psi)
3	22	32	41
4	12	65	54
5	5	78	68
6	20	78	82
8	34	114	106
10	28	129	136
12	15	154	163

(a) Nominal spherical aerial shell size.

(b) The number of measurements used for this size shell.

(c) Average measured peak internal mortar pressure.

(d) Peak internal mortar pressure from the straight line visually fitted to the measured data.

aerial shells. The reason is that cylindrical shells produce considerably greater internal mortar pressures. This is the result of the combined effect of their greater shell mass, greater lift mass, and generally reduced dead volume under the shells.[6] (Limited testing by the authors suggests that the peak mortar pressures for typical cylindrical shells are roughly twice that for typical spherical shells of the same size.) Obviously, multibreak cylindrical shells produce even greater internal pressures, stressing their mortars to still higher levels and requiring even stronger mortars.

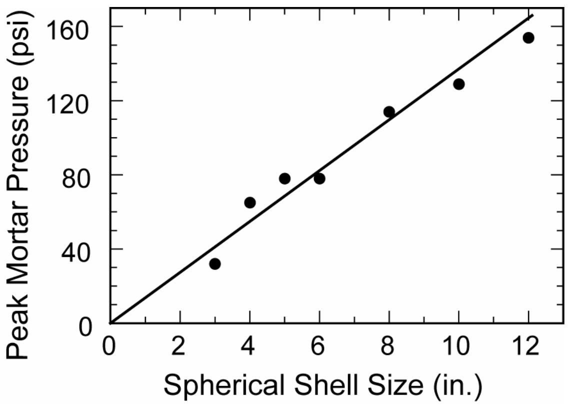

Figure 2. Graph of average peak internal mortar pressure as a function of spherical shell size.

References

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