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Economics of Plastic Shell Construction

K. L. Kosanke

Introduction

One hears a number of reasons why some manufacturers are reluctant to seriously consider the use of plastic shells. Among these are a feeling that it would somehow represent a betrayal of tradition and aesthetic values; the problem of long lasting debris; that it requires the learning and application of significantly different techniques, which translates into development costs. I understand all of these reactions quite well; I felt and expressed them myself in the past. It was a slow and sometimes trying metamorphosis from the position I expressed in the past to the one I now take.

About seven years ago I reached the conclusion that traditional paper and string shell construction, after having served the industry so well for so long, had essentially reached the end of commercial viability in this country. Certainly the technique produced excellent results but labor costs would soon make it impossible to continue to use these methods. My initial efforts to find an economic alternative were relatively minor deviations from traditional methods, such as the elimination of stringing. We made a small machine that wrapped pasted paper on traditionally formed shell cans. This eventually produced shells that performed well but resulted in only insignificant savings of assembly time. Our next efforts, which spanned several years, focused on the use of multiple pre-made paper components, inner and outer tubes with disks held in place using paper rings. This resulted in useful savings of assembly times, but shell performance was too unpredictable and the cost of the paper components consumed most of the savings from reduced assembly times. Next we worked for a while with paper tubes with plastic end caps. This produced better results than the all paper version, but the cost was higher and there were some operational difficulties associated with gluing on the second end cap.

During this same time frame we started using all plastic 2" canister shells and breaking them with loose sodium benzoate / potassium perchlorate whistle mix. The results were surprisingly good and assembly times were very short. By this time the extreme aversion I initially felt toward plastic shells had been replaced by a strong desire to have larger diameter all plastic canister shells available for our use in manufacturing. Unfortunately, none were available. After another year of wishing that someone would manufacture such shell casings, we decided to take the initiative. We took what we had learned and designed the RAP (Rapid Assembly Plastic) Shell. We are convinced that plastic will eventually replace paper/string shell making in the US. The reason we feel this way is simply a matter of economics. True, plastic shells must perform well in order to replace paper/string shell construction, but they do. True, plastic shell construction requires applying some new techniques, but they are easily learned and taught to employees. True, in order to learn to optimize

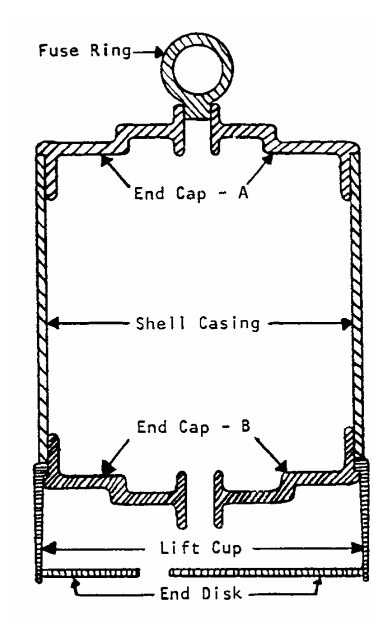

Figure 1. RAP shell components.

Table 1 Shell Assembly Time Comparison.

Relative shell assembly times assembling 1000 hard breaking canister shells with comet tail, including lifting and finishing.

Task Description	Time (sec.) Paper	Time (sec.) Plastic	Explanation
Preparation of materials (summation of preparation times).	20	13	Fewer materials to prepare and assumes all pieces are precut.
Time fusing, including cross matching.	20	17	Fuse held more securely and larger surface facilitates more rapid gluing.
Case forming, including chipboard lining and attachment of end disk.	30	5	Case already formed and lining not required.
Contents Loading.	25	15	Exact filling and compacting are unnecessary.
Second end closing.	10	5	Paper pleating not necessary.
Stringing shell.	80	0	Not necessary.
Pasting-in and paste wraps.	60	0	Not necessary.
Removal to storage for drying, turning and retrieval after drying.	20	0	Not necessary.
Comet formation and attachment.	35	20	Comet formed already attached to shell.
Leader attachment, final wrap, lifting and tie off ends.	40	20	Lift cup already formed, leader held in place automatically.

the performance of plastic shells, it will require the investment of some time and effort, but this investment is rapidly repaid. Plastic shells will largely replace traditional shells made in this country simply because not making the conversion will make the present difficult competitive situation impossible in the future.

To assist readers who may not be familiar with plastic shells such as RAP shells, Figures 1 and 2 have been included. Figure 1 shows the way in which RAP Shell components fit together, and Figure 2 is of a typically completed RAP Shell.

Assembly Time Comparison

Table 1 is a comparison between estimated times for assembling conventional paper/string shells and RAP shells (or similar all plastic shells). The shells are assumed to be single, hard breaking three or four-inch shells with a comet attached. It was assumed that 1000 shells would be mode; however, times will not be much different for assembling 100 or 10,000 shells. The times are intended to be those for reasonably experienced personnel with reasonable motiva-

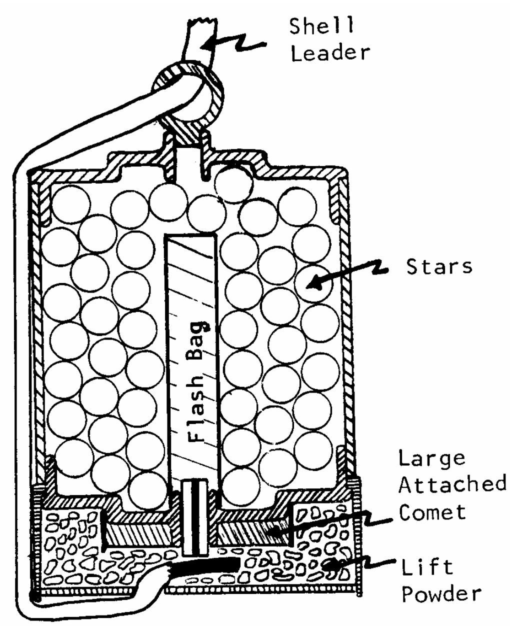

Figure 2. Typically completed RAP shell.

tion and are assembly times that workers would be expected to be able to maintain day after day throughout a prolonged production period.

As can be seen from Table 1, the time savings resulting for plastic shell assembly will amount to about 255 seconds (4.25 minutes) per shell. Most of this results from elimination of case forming, stringing, pasting-in, addition of a paste wrap, and the necessity for drying. However, times required for many of the other operations are also reduced as the result of simplified assembly processes, such as elimination of the necessity for careful contents loading and tying-off the shell ends after leader and lift have been added.

Labor Cost Savings

To convert these time savings into cost savings, consider the information in Table 2. First are estimates of base hourly labor rates for assembly workers. Three rates are given, the lowest being minimum wage. Next are estimates of burden rates, the multiplier for base hourly rates that will account for additional employer costs for unemployment insurance, FICA, workman's compensation insurance, etc. The lowest assumes a combined federal and state unemployment rate of 3%, FICA of 7% and workman's compensation rate of 18%. Finally are facility overhead rates, the multiplier for hourly rates that will account for employee benefits (such as vacations, sick leave, training, work clothing, production and safety equipment, etc.), breaks (such as scheduled breaks, calls to nature, wash times before lunch and quitting, etc.), and facility costs (such as heat, light, laundry, maintenance, security, rent, management supervision, office expenses, etc.). The lowest rate assumes there are no employee benefits at all, that employees are productively occupied 50 minutes each hour and facility costs are zero except for supervision which is at a rate of one supervisor per 18 production workers. The result is that actual labor costs probably range between about $5.65 and $14.40 per hour and averages approximately $8.90. Accordingly, if plastic shell assembly techniques save 4.25 minutes per shell as compared with conventional paper/string shell methods, there will be a savings of labor costs of from about $0.38 to $1.02 per shell and an average savings of approximately $0.64 per shell.

Table 2 Labor Costs.

	Lowest	Average	High
Base hourly rate	$3.35	$4.25	$5.00
Burden rate (Fed. & State Unemployment, FICA, Workman's Comp., etc.)	1.3	1.3	1.8
Facility overhead rates (Benefits, Breaks, Utilities, Set-up time, etc.)	1.3	1.4	1.6
Resultant hourly rate	$3.66	$8.92	$14.80
Resultant cost/min.	$0.09	$0.15	$0.24
Plastic shell cost savings	$0.38	$0.64	$1.02

Comparison of Material Costs

Table 3 presents estimated costs for pre-cut components needed to assemble conventional paper/string, shells (three and four-inch). Because costs vary substantially depending on quantity, information has been presented assuming one hundred, one thousand and ten thousand shells will be made.

Table 3 Estimated Costs for Precut Paper Shell Components.

	Cost Per Unit for Production Runs of Quantity Shown					
	100 Shells		1000 Shells		10000 Shells	
Items	3"	4"	3"	4"	3"	4"
3 end disks	$0.15	$0.18	$0.12	$0.14	$0.06	$0.08
Shell case(60#) and Chip liner	0.12	0.20	0.06	0.12	0.05	0.10
Paste, String, Paste Wrap & Final Wrap	0.10	0.15	0.07	0.11	0.03	0.08
Totals	$0.37	$0.53	$0.25	$0.37	$0.16	$0.26

Table 4 Component Costs for Paper vs. Plastic.

	3"			4"		
Type	100	1000	10000	100	1000	10000
Paper	0.37	0.25	0.16	0.33	0.37	0.26
Plastic	0.60	0.44	0.41	0.71	0.53	0.31
Difference	0.23	0.19	0.23	0.18	0.18	0.25

Table 4 is a comparison of the costs for paper and plastic components. On average, the plastic components cost approximately $0.21 more than do the paper components. Accordingly, this reduced the cost savings for plastic shell construction to a range from $0.16 to 0.81 per shell and averaging about $0.43 per shell.

Other Cost Considerations

There are a few other savings that can be realized for manufacturers using all plastic shells. First, if the shells have a lift cup, such as RAP Shells do, that functions something like the wad in a shot gun shell, then significantly less lift powder is required. Our tests suggest that three and four-inch RAP Shells can be propelled to adequate heights using only 0.6 and 1.1 ounces of lift powder, respectively. This is a savings of 0.4 and 0.9 ounce compared with conventional shells. Assuming a delivered price of $2.00 per pound for Black Powder, this corresponds to an additional savings of $0.05 and $0.11, respectively for three and four-inch shells.

Current BATF requirements are that all in-process shells be removed to a magazine (or a secured building meeting the distance requirements of a magazine) at the end of every work day. All plastic shells can easily be completed and boxed, ready for shipment on the same day. Thus the requirement for magazine storage at the end of every day is no problem at all. For conventional paper/string shells, the necessity of shell drying is incompatible with storage in magazines for finished products. Thus it is necessary to have available another highly secured building exclusively used for drying. Clearly there are costs associated with the necessity for this additional building, to say nothing of the energy costs for heating the drying building. Because of the time of year when most shells are made and OSHA/BATF safety requirements on the type of heating equipment that must be used, both the cost of the heating equipment and the energy cost of shell drying are certainly significant. The combined costs for shell drying probably average at least $0.05 per shell.

Because of the uniformity of plastic components and the simplicity of their assembly, it is fairly certain that significant additional time (cost) savings may be possible by the use of assembly line, semi-automated or automated assembly techniques. However, because these savings are speculative at this time, they will not be Included in this discussion.

Accordingly, the saving in lift powder and eliminating the cost of drying, increases the cost savings of all plastic shell construction about $0.13 on average. Thus the savings should run from $0.29 to $0.94 per shell and will average about $0.56 per shell.

Conclusion

Shell manufacturers are reluctant to give information on their profits. However, it is certain that the net profit is less than $0.50 per shell (small single break shells). Even if profits were this great, the conversion to all plastic shells would still represent a two fold-increase in profit. This increase in profitability is simply too great to be ignored; there will be increasing economic pressure to make the conversion to plastic shells.

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An Evaluation of "Pyro-Flake" Titanium for Use in Fireworks

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Several months ago, our company was approached by the Suisman Titanium Corporation. They told us that they were considering introducing some new titanium products specifically intended for the fireworks trade, and that their materials would be priced below that of titanium sponge. They asked whether we would perform an evaluation of their "Pyro-Flake" titanium and make recommendations concerning the introduction of their products to the fireworks trade. We performed that study, and one of our recommendations was that a condensed report of our study be published. This article is that condensed report and was in part subsidized by Suisman Titanium. However, Suisman Titanium has asked us to be completely candid, and they have not exerted any editorial control over the content of this article.

Material Description

As its name suggests, Pyro-Flake titanium materials are flakes of titanium metal; this is in contrast with traditionally used titanium sponge which is granular. The flaked material has two dimensions (length and width) that are roughly equal, but its third dimension (thickness) is substantially less. The first Photo is of 20–40 mesh Pyro-Flake titanium. We were asked to evaluate both pure titanium flakes as well as flakes made of a common aerospace alloy (90% titanium, 6% aluminum, and 4% vanadium).

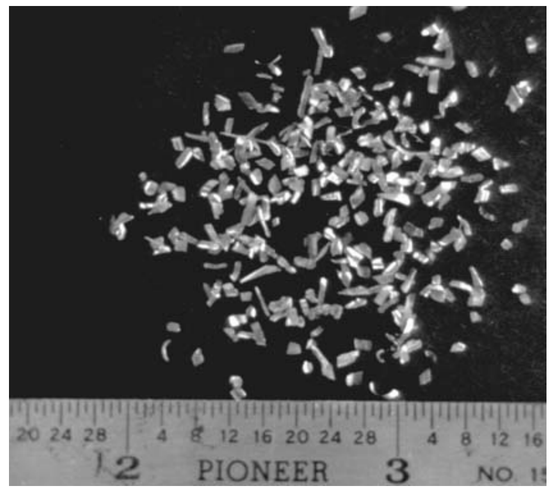

Photo 1. 20–40 mesh Pyro-Flake titanium.

Ignition and Burn Characteristics Test

Some of the first tests we performed were intended to discover how easily the two types of flaked titanium ignited in comparison with sponge. Also, during these tests, observations were made of relative spark color, intensity, and duration as well as the sound produced during burning. In these tests, 16 small tubes (½" ID × 1½" long) were loaded with ¼ tsp. of 4 Fg Black Powder and ¼ teaspoon of various types and mesh sizes of titanium. The tubes were individually raised to a height of 15 feet, fired with the aid of an electric match, photographed (time exposure), and personal observations of the effects were recorded. The test results are summarized below:

1) In all tests, both the pure and 90-6-4 flakes produced roughly an equivalent number of sparks, with probably a slight advantage to the 90-6-4 flakes. More significantly, however, both types of flakes produced considerably more sparks than did the same mesh size of sponge. The difference was most clearly seen for the 10–20 mesh materials which are shown in Photos 2, 3 and 4.