Chapter 2 — Construction of Chrysanthemum Shells

Japanese firework shells are of two principal types, the so-called *poka* and the *warimono* (chrysanthemum). The *poka* breaks just hard enough to disperse its contents into the air. The shell is made only as strong as it needs to be to withstand the shock of being fired. In contrast, the chrysanthemum shell must be strong enough to allow the bursting charge to distribute the stars far from the point of explosion. The quantity of the bursting charge must be great enough to meet this requirement. There are, however, shells having characteristics between those of *warimono* and *poka*.

A typical *warimono* is shown in Figure 1. It consists of four main parts: shell casing (A), stars (B), bursting charge (C), and time fuse (D). The shell casing holds the contents and enhances the effect of the bursting charge. The stars are ignited and fly radially, producing a chrysanthemum image. Initially, the bursting charge is ignited by the time fuse, then the expanding burning gas breaks the shell and ejects the stars. At the same time, it ignites the stars. The time fuse is ignited by the flame of the lift charge and provides the delay before the explosion of the shell after it is fired from the mortar. The construction presently used is as follows:

The shell casing consists of two layers: the outside (a) and the inside (b) shell. Often, only the inside shell is called "the shell" (*tamakawa*). The inside shell holds the contents and keeps the stars arranged to produce a chrysanthemum pattern when the finished shell explodes. Consequently, the inside shell does not need to be particularly strong. The best material for the inside shell is newspaper, which is layered to a certain thickness on a wooden ball, and then it is cut into two pieces (hemispheres). The thickness depends upon the size of the shell, but usually it is 2 to 3 mm. The role of the outside shell is to strengthen the effect of the bursting charge, and it must have great tensile strength. The thickness of the outside shell is obtained by pasting narrow strips of strong paper over and over again on the inside shell to obtain the desired strength. In the old times in Japan they

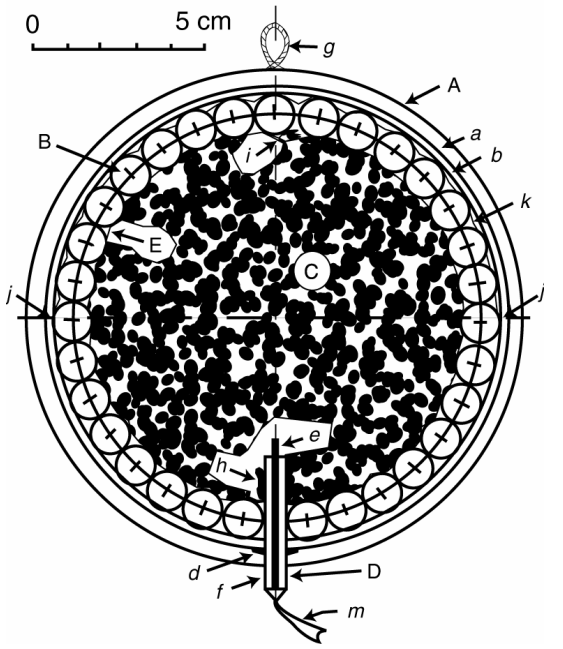

Figure 1. Section of a chrysanthemum shell.

used fairly thick Japanese paper; however, at present, Kraft paper is used. An example of the pasting operation is as follows:

Firstly, to avoid separation of the inside shell, in which the bursting charge and stars are arranged in a pattern, a long paper tape is pasted along the joint between the two hemispheres. We call the operation *dobari*. Then taking two poles —A and A— on each hemisphere as guides, the paper strips are pasted on the surface of the sphere like the stripes of a watermelon. (See Figure 2.) The paper strips are cut so that the direction of the fibers is at a right angle to the length of the strip so that it conforms well to the inside shell. To make the outside shell strong, the width of the paper strips, if possible, should be constant. In Figure 2, (A) is the side view and (B) the top view. The numbers on each strip show the order of pasting. Pastings 1, 2 and 3 are pasted at one time. Next, new poles are taken at positions that are perpendicular to the first pole axes. After two or three pastings, the shell is placed

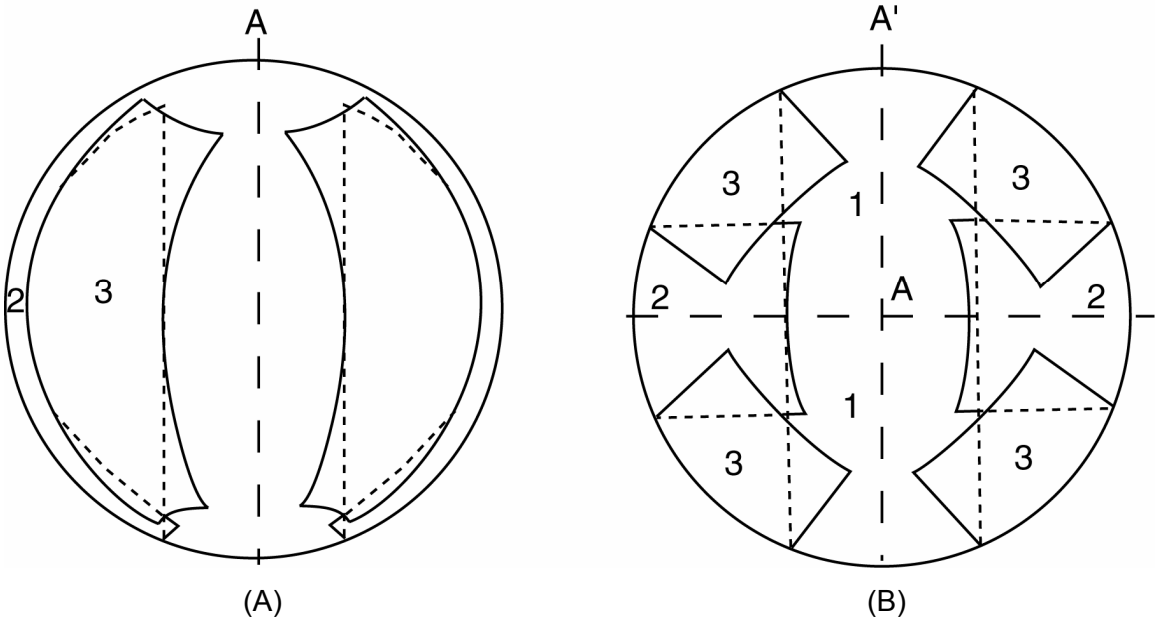

Figure 2. Outside view of pasting on the shell.

between two thick wooden plates, and rolled to remove any projections and make the surface smooth. The operation is called *gorokake*. After this operation, the shell is dried in the sun. When the shell is well dried, the same processes are repeated until the desired thickness of the outside shell is obtained. The last pasting is finished very carefully for good appearance. The number of layers of paper for each *sun*, using Japanese paper, is 8 or 10, based on the tradition of Japanese fireworkers. (*Sun* is a Japanese unit, 1 *sun* = 3.03 cm.) For example for a 5 *sun* shell (15 cm shell): '*sun* 8' means 5×8 = 40 layers. This method (i.e., to increase the strength of the shell in proportion to the diameter of the shell) is theoretically correct, as described later.

Fireworkers put their greatest effort into making the stars, because they are the main component of the beauty of fireworks. The stars that are used for fireworks are divided into three types: pumped cylinder stars, cut stars, and round stars. (See Figure 3.)

The pumped star is shaped using a cylinder and a piston. For this manufacturing process the star mixture is dampened with a small amount of water, using glutinous rice starch, etc. as a binder. Cut stars are manufactured by making a cake of composition on a wooden board that has edges of the desired height. A dampened mixture is placed between the edges and the composition is flattened by tapping with a wooden hammer. The cake is cut into cubes and

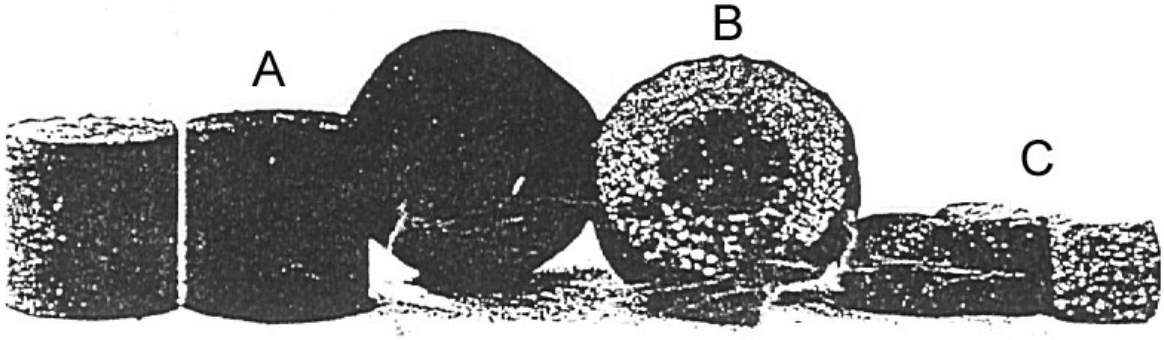

Figure 3. Fireworks stars: (A) pumped cylinder star, (B) round star, and (C) cut star.

well dried. Cut stars are often used for *warimono* because the color-changing stars are manufactured by covering 3–5 mm cubes with some colored mixture to form large, spherical balls.

The operation is as follows: the cut stars are placed in a container with a spherical bottom. Some dry mixture is added to water to make a gruel (it is called *toro*). First the *toro* is sprinkled over the cut stars and then it is uniformly spread over the stars, and a small quantity of the dry mixture is spread on the stars, and the container is shaken. The stars are somewhat round shaped. This operation is repeated two or three times. The stars should be dried quickly in the hot sun to prevent moisture from soaking into the already dry part of the star. When the stars are dry, they are cooled in the shade. These operations are repeated until the stars reach the desired diameter.

A sample star that was made using such a process is shown in Figure 4. This star burns with a color change from red to blue and then flash. In Figure 4, (A) is the core (cut star) that is covered with an easily ignitable mixture to become (B). If (A) is not difficult to ignite, the same mixture (A) is used. This operation is called *tomokokake*, which means to cover the stars with the same mixture.

The stars are next covered with a mixture of dark prime, which is the outer layer in (C). This layer is called "changing relay". It used to produce a good visual effect that makes the color change clearer. Then (C) is covered with a blue mixture of the proper thickness as shown in (D). Then (D) is covered with changing relay as shown in (E). Then (E) is covered with a red mixture as shown in (F). Finally, to ensure a perfect ignition, three steps are taken. The first is to apply a layer of relatively slow burning black powder type mixture on (F), the second is to add a layer of medium burn rate, the last is to add layer of fast burn rate to complete the star (G).

The bursting charge is shaped into grains to be easily ignited. The bursting powder is mixed with 3 to 4% glutinous rice starch and a little water is added. This gruel mixture is poured over some grains of 4–5 mm, for example cottonseeds, to obtain round grains with a kernel in the middle. If cottonseeds are used, the grains must be dead and well dried for at least one

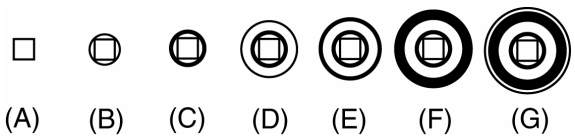

Figure 4. The order of growth of the round star.

year. (See Figure 5.) For small shells, rice chaff is often used for the kernels. The weight ratio of cottonseeds to powder is 1:1 to 1:5.

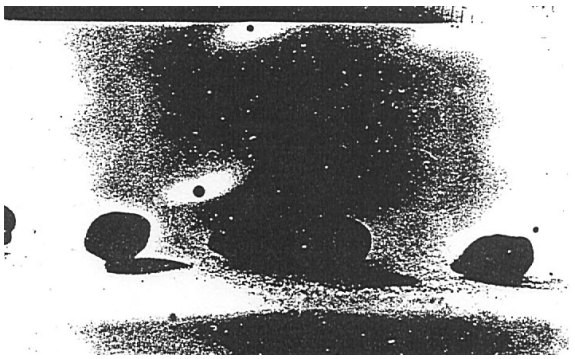

Figure 5. Bursting charge grains with cottonseeds as kernels.

The fuse for chrysanthemum shells is handmade. The handmade fuse has a greater time delay and higher cost than commercial fuse. However, it has very good ignition properties, ignites other materials well, and causes the fewest 'black' shells ('blind' or 'dud' shells). Therefore, fireworkers willingly use the handmade fuse. The core of this fuse generally consists of Japanese paper tape to which black powder is applied and which is firmly wound on a hard stick. This core is shown as *e* in Figure 1. When the cover is removed, the core holds its shape. The flame from this bare part of the fuse becomes long and large, which can ignite even the least ignitable mixture. Also in Figure 1, the part marked *f* is split down the middle to ensure ignition from the flame of the lift charge. With this fuse, there is no dropout of powder from the fuse. With commercial fuse, such a procedure is impossible. The manufacturer can easily regulate the burn time of handmade fuse by changing the composition of the

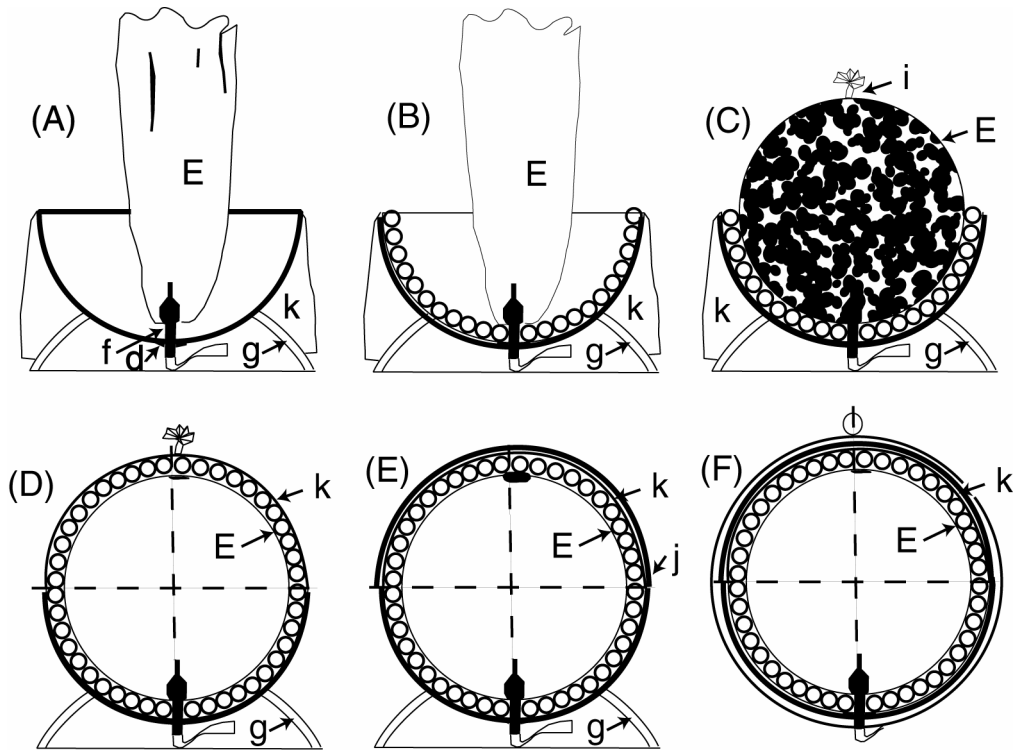

Figure 6. An example of assembling a chrysanthemum shell.

fuse mixture as required. This is not easy with commercial fuse.

The fuse of the chrysanthemum must be longer than a certain defined length, adapted to the size of the shell. Commercial fuse, therefore, is not often acceptable.

Handmade fuse can be made as follows: Using a brush, both sides of a sheet of Japanese paper are pasted with dampened black powder gruel and then dried in the sun. It is called *yakushi* (powdered paper). This is cut into narrow paper strips, about 80 mm wide and 250–300 mm long, both sides are spread uniformly with powdered black powder. Then a thin bamboo stick is attached to the edge of one side and the paper is rolled around the stick. The powder becomes the core. Then a sheet of *kozo* paper of the same length as the core and of a proper width is attached to the core and rolled on the core. Then on a worktable it is slightly tightened by hand. Then the bamboo stick is removed. The *kozo* paper becomes the core cover. The paper stick with the core powder is then placed on a worktable and, using a thick wooden plate, the paper stick is pressed and rolled in one direction repeatedly. This is continued until the stick is rolled firmly. The worker should perform about 100 of these rolling operations on a fuse that is 250 mm long. The first rolling operation is finished in this way. The second rolling process should be continued as it was for the first rolling. The fuse manufactured in this way burns 1.0–1.2 seconds per 1 cm length.

An example of assembling an ordinary chrysanthemum shell is shown in Figure 6. First the inside shell is punched at the center, and a piece of time fuse is inserted, and it is attached with a piece of hemp twine (*d*). Then a short paper tape is pasted over the outside end of the fuse to protect the end of the fuse. In the corner of the paper, the name of the shell or its contents is recorded. On the interior end of the time fuse, a paper bag (*E*) is attached that contains the bursting charge. The outer bag (*k*) is pasted on the inside of the shell casing, and it is turned inside out. This is used to hold the stars of the upper hemisphere.

For the bursting charge bag (E) and the outside bag (*k*) strong Japanese paper is used. These are placed on a stand (*g*) as in (A); (B)

shows the stars arranged along the inside of the lower hemisphere. The appropriate weight of bursting charge is then placed in the bursting charge bag and it is tapped on the outside with a piece of wood until there is no clearance between the bag and the shell. The top of the bag is closed with hemp twine at (*i*), forming the upper part of the bursting charge bag that is spherical in shape. Then the bag (*k*) is turned up. The upper stars are arranged with the help of the bag (*k*) as shown in (D). The upper inside hemisphere is put on as shown in (E), and the upper hemisphere is tapped with a piece of wood to settle the position of the stars until both hemispheres make contact with each other as shown in (F). The marks on each hemisphere coincide with each other. The assembled shell is then pasted with paper tape to protect it from falling apart, and it is sent to the next operation of pasting the outside with paper strips.