Chapter 9 — Discussion and Conclusion

Tests of bursting warimono shells that were manufactured under various conditions were conducted on the ground, and the position of moving stars were analyzed by a photographic method. To make the analysis easy, ring star shells were employed as test shells. The results showed the quantitative relations among design factors, which were not clear until this study. These data were introduced into empirical equations concerning the ballistics of stars, which are useful for designing the chrysanthemum shell.

Convenient tables to give clear information concerning designing, characteristics of stars and shells were prepared.

From the above effort the following information was obtained:

1) The burning velocity of the stars is the same whether in the air or on the ground. Therefore, for designing the star, we can use the burning velocity on the ground.

2) The characteristics of the star moving in air depend on the two values A_s and b. The smaller the value of A_s and the larger the value b, the better the characteristics of the star. The term A_s is proportional to $1/\omega\delta$. Therefore, larger burning velocity and larger density δ result in better star characteristics. The desirability of a large burning velocity has been commonly known, but the effect of larger density was first shown in this paper. And b is denoted as:

$$b = \left(1 - \frac{\delta_3}{\delta_1}\right)\left(\frac{R_2}{R_1}\right)^3 + \ldots$$

   Therefore, the larger the inside density, the better the star characteristics. If we design long burning stars, such as willow, it must be thought to be quite the opposite.

3) From experiments, we find that air resistance to the motion of the star is proportional to the square of the velocity of the star. However, for very slow moving stars, future studies are needed.

4) On the bursting charge, the force of explosion f was obtained by calculation, and the relative value of the vivacity A was obtained. The relative values coincided closely with the reciprocals of the burning times of the bursting charge grains. Therefore, when planning the bursting charge, the value of A is determined by the burning time in air on the ground. On the calculation of the values of f, it is better to compare with the values that will be obtained in the future by bomb tests.

5) For the design, the value A should be as high as possible. Therefore, when using a bursting charge of low burning velocity, like potassium perchlorate powder, it is necessary to select a reasonable grain size. Specifically, slow burning powder may be useful with a proper grain size. However, it must be noted that too large a value of A causes ignition failure or breaking of stars. In this study, it is thought that the value of A should be from 3 to 5.

6) Many layers of pasting paper increase the efficiency of the bursting charge. However, if there are too many layers, it has the reverse effect. This effect may be caused by unnecessary consumption of energy to break the thick-pasted shell.

7) The ratio of the break strength of the Japanese paper and that of the Kraft, which was tested by a tensile strength instrument, was slightly different from that from the bursting experiment. However, when there are no values from bursting experiments, the tensile strength test will be effective in deciding the value of a.

8) In the above experiments the differences between ring and full star shells were not clear because there were too few full star shells. This point may be clarified in the future.

9) In this study the loading density was set as a constant. This problem remains for future investigation.

10) The use potassium perchlorate bursting charge in place of potassium chlorate bursting charge, which has been though to be much more dangerous than the former, was clarified.

11) An example of designing a chrysanthemum shell is shown. It shows that the fundamental method to plan the chrysanthemum shell, which has previously been made only by application of some traditional ideas, has been developed to use physical or chemical science.

References

1) For example, *Okamoto, Fluid Mechanics* (1953) p 66.

2) T. Shimizu, *Interior Ballistics*, 2nd ed., Artillery and Engineering Academy (1944) p 172.

3) *Handbook of Chemistry*, Maruzen Co. (1952) p 514.

4) *Handbook of Chemistry*, Maruzen Co. (1952) p 537.

5) Kubo, *Statistical Mechanics* (1952) p 66.

6) Kubo, *Statistical Mechanics* (1952) p 172.

7) N. Yamaga, *Denawa*, Kaheigakukashi (1940) pp 33 and 435.