The Basic Research for Pulverization of Rice Using Underwater Shock Wave by Electric Discharge

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1. INTRODUCTION

In recent years, the food self-support rate of Japan is 40%, and this value is the lowest level in major developed countries. This reason includes decreasing of diverting rice consumption in Japan and increasing abandonment of cultivation. Therefore, these problems are solved by using rice powder instead of expensive flour, and we manage to increase the food self-support rate.

Previously, the rice powder is manufactured by two methods. One is dry type, and the other is wet type. The former is the method getting rice powder by running dried rice to rotating metal, and has a problem which that starch is damaged by heat when processing was performed. The latter is performed same method against wet rice, and has a problem which a large quantity of water is used. As a method to solve these problems, an underwater shock wave is used. Shock wave is the pressure wave which is over speed of sound by discharging high energy in short time. Propagating shock wave in water is underwater shock wave. The characters of underwater shock wave are long duration of shock wave because water density is uniform, water is low price and easy to get and not heat processing.

Thinking of industrialization, the electric discharge is used as the generating source of underwater shock wave in the experiment. As the results, the efficiency of obtaining enough grain size, 100μm, of rice powder was too bad only using the simple processing using underwater shock wave. Therefore, in Okinawa National College of Technology collaborating with us, obtaining rice powder with higher efficiency by using converged underwater shock wave is the goal of this research.

In this research, the underwater shock wave with equal energy of the experimental device of underwater shock wave is measured by the optical observation. In addition, the appearance converging underwater shock wave is simulated by numerical analysis, and the pressure appreciation rate between the first wave and converged underwater shock wave is calculated by using the pressure history of 2nd focal point.

2. EXPERIMENTAL METHOD

2.1 THE OPTICAL OBSERVATION OF THE DISCHARGE PHENOMENON

The experimental outline is shown in Fig. 1. Cu-W which is difficult to melt by electric discharge is used for electrodes, and distance between electrodes (Gap) is able to be changed by fixing nut. Polyoxymethylene and polyethylene, strong against shock wave, are used to the other parts. By changing the Gap into 1.0mm, 2.0mm, 3.0mm, 4.0mm and performing the experiment until succeeding five times, the comparison about these velocity and pressure.

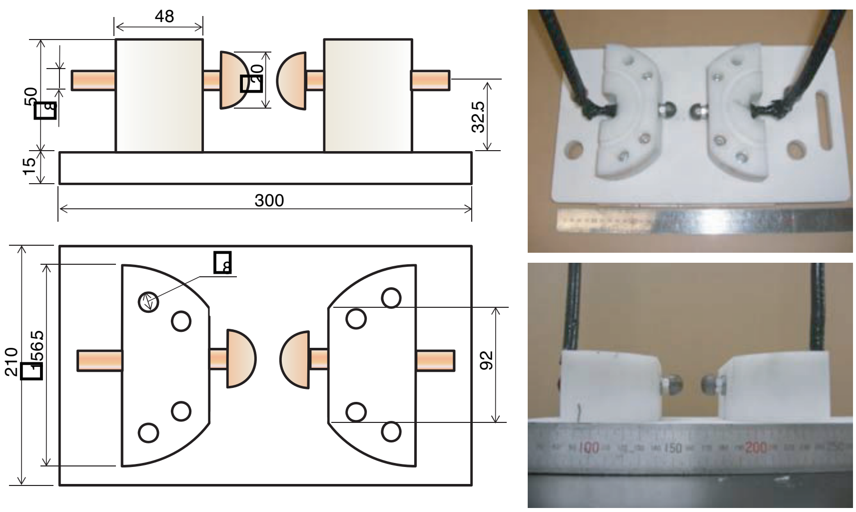

Figure 1 Experimental device for electric discharge

The photograph and spec of the capacitor used in Okinawa National College of Technology are shown in Fig. 2, Table 1. The photograph and spec of the capacitor used on this experiment are shown in Fig. 3, Table 2. In this experiment, charge voltage is configured 28kV for adjusting charge energy to the value (4.9kJ) of Okinawa National College of Technology experiment. This experimental condition is shown in Table 3.

Table 1 Specs of this capacitor

Manufacturer	**NICHICON CORPORATION**
Maximum voltage	3.7kV
Capacitance	4700µF
Maximum charge energy	4.9kJ

Figure 2 The capacitor of new device

Figure 3 The capacitor of this experiment

Table 2 Specs of this capacitor

Manufacturer	NICHICON CORPORATION
Maximum voltage	40kV
Capacitance	12.5μF
Maximum charge energy	10kJ

Table 3 Experimental conditions

Experimental No.	Charge Voltage [kV]	Gap [mm]
1	28	1.0
2		2.0
3		3.0
4		4.0

Fig. 4 shows the optical observation using shadowgraph method. This is the observation method of shadow by density change of medium. By this, underwater shock wave velocity and pressure can be calculated. The specs of high speed camera, HPV-1, is shown in Table 4.

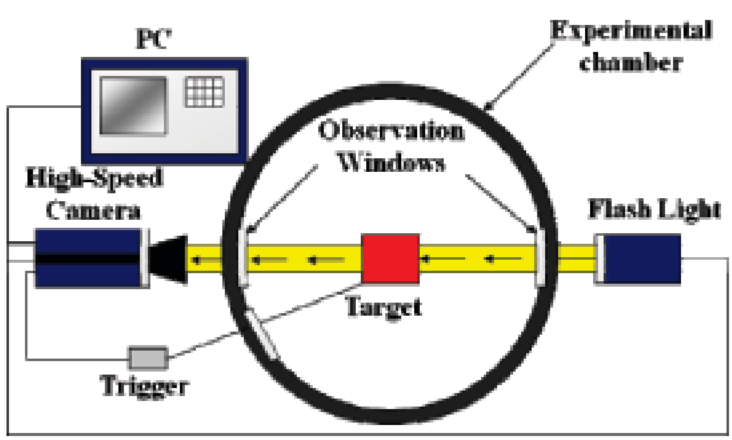

Fig. 4 Shadowgraph method

Table 4 HPV-1 spec

Recording method	IS-CCD image sensor
Resolution	312 (horizontal) × 260 (vertical) pixels
Frame storage	100 frames
Lens mount	Nikon F mount
Color, gradations	Monochrome, 10 bits
Recording speed	30 fps to 1,000,000 fps
Exposure time	1/2,1/4,1/8 × recording period
External trigger input	TTL (positive/negative), switch closure
Trigger mode	Set trigger point at any desired frame
Recording format	10-bit dedicated format, BMP, TIFF, AVI

2.2 THE OPTICAL OBSERVATION OF UNDERWATER SHOCK WAVE CONVERGING

The photograph of used optical observation device about converging underwater shock wave is shown in Fig. 5. The detail of ellipse is shown in Fig. 5. Ellipses have a character which the wave generated from 1st focal point converges 2nd focal point. In this experiment, the spherical high explosive SEP (detonation velocity: 6970 m/s, manufactured by AsahiKASEI Co., Ltd.) 2g is set up on 1st focal point, and detonated by No.6 electric detonator (manufactured by AsahiKASEI Co., Ltd.).

3. NUMERICAL ANALYSIS

The numerical analysis model of underwater shock wave converging using LS-DYNA3D is shown in Fig. 7. Because the purpose of numerical analysis is calculation of pressure appreciation rate on 2nd focal point, 1/5 model is used. The numerical analysis condition is shown in Table 4. When the model of device having ellipse shape is made, Solid Works (manufactured by Solid Works Japan Co., Ltd.) is used for making IGES data. After that, Hyper Mesh (manufactured by Altair Co., Ltd.) is used for meshing of the IGES data.

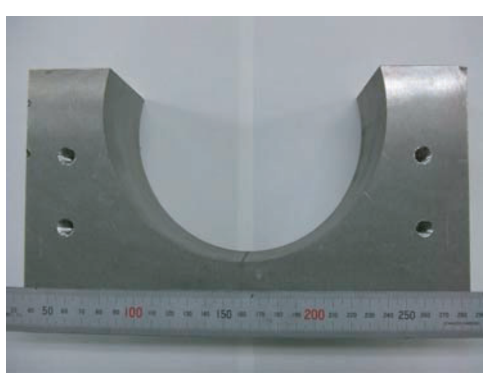

Figure 5 Experimental device for the optical observation of underwater shock wave converging

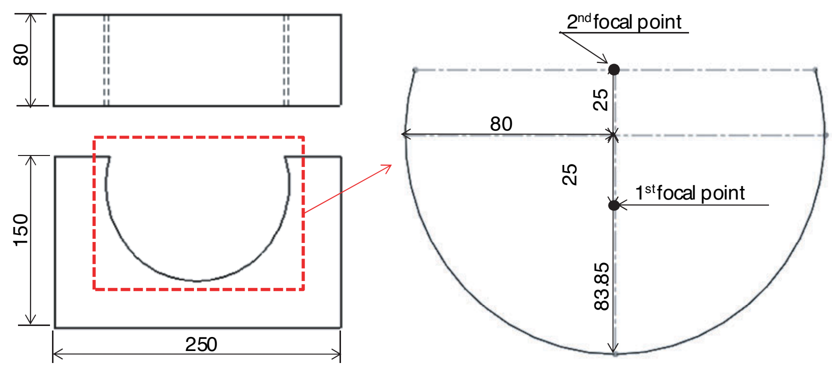

Figure 6 The detail of experimental device

4. THE RESULTS OF THE OPTICAL OBSERVATION

4.1 ABOUT ELECTRIC DISCHARGE

The framing photographs of No.1 at 5µm intervals are shown in Fig. 8. Herewith, underwater shock wave generating was confirmed.

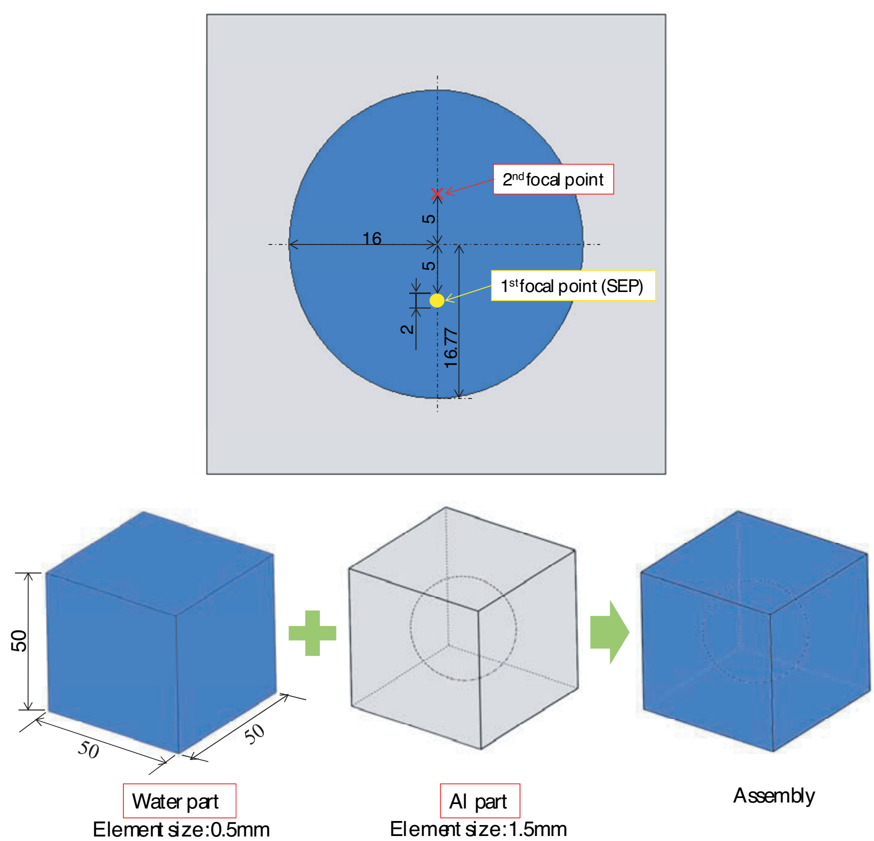

Figure 7 Numerical analysis model

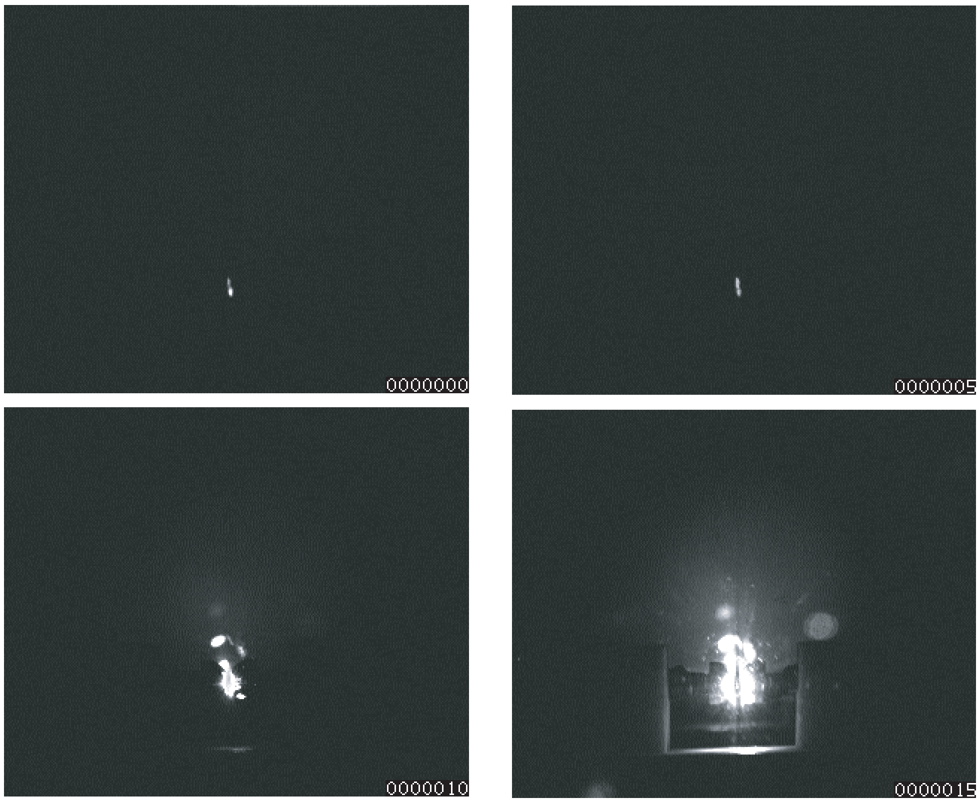

Figure 8 Framing photographs of electric discharge (No.1)

In addition, the velocity values of underwater shock wave were calculated by plotting these photographs using Digital Digitizer (manufactured by Akinori Motomiya). The results of calculation are shown in Fig. 9. The pressure values of underwater shock wave were also calculated by using velocity values and (4.1) equation. The results of calculation are shown in Fig. 10. Because No. 3 could succeed only twice in spite of performing experiment more than 10 times, it was thought that No.3 condition was boundary whether to discharge. On the other hand, the discharge phenomenon could not be confirmed in No.4 condition.

According to Fig. 9 and 10, the underwater shock wave generating could be confirmed because all velocities is over the sonic speed in water,1450m/s,. And, the highest velocity and pressure was obtained in case of experimental No.2. Herewith, it is thought that the best Gap is 2mm when the charge voltage is 28kV. There were a lot of energy losses to water on No.3 condition because the condition was boundary whether to discharge. In addition, uneven to the whole of the value, it is thought that the energy losses to water or not discharging of all charged voltage are caused.

$$P = \frac{\rho U_s (U_s - c_0)}{S}$$

4.2 ABOUT CONVERGING EXPERIMENT

The framing photographs of converging experiment are shown in Fig. 11. According to these photographs, it is found that the underwater shock wave generated from 1st focal point

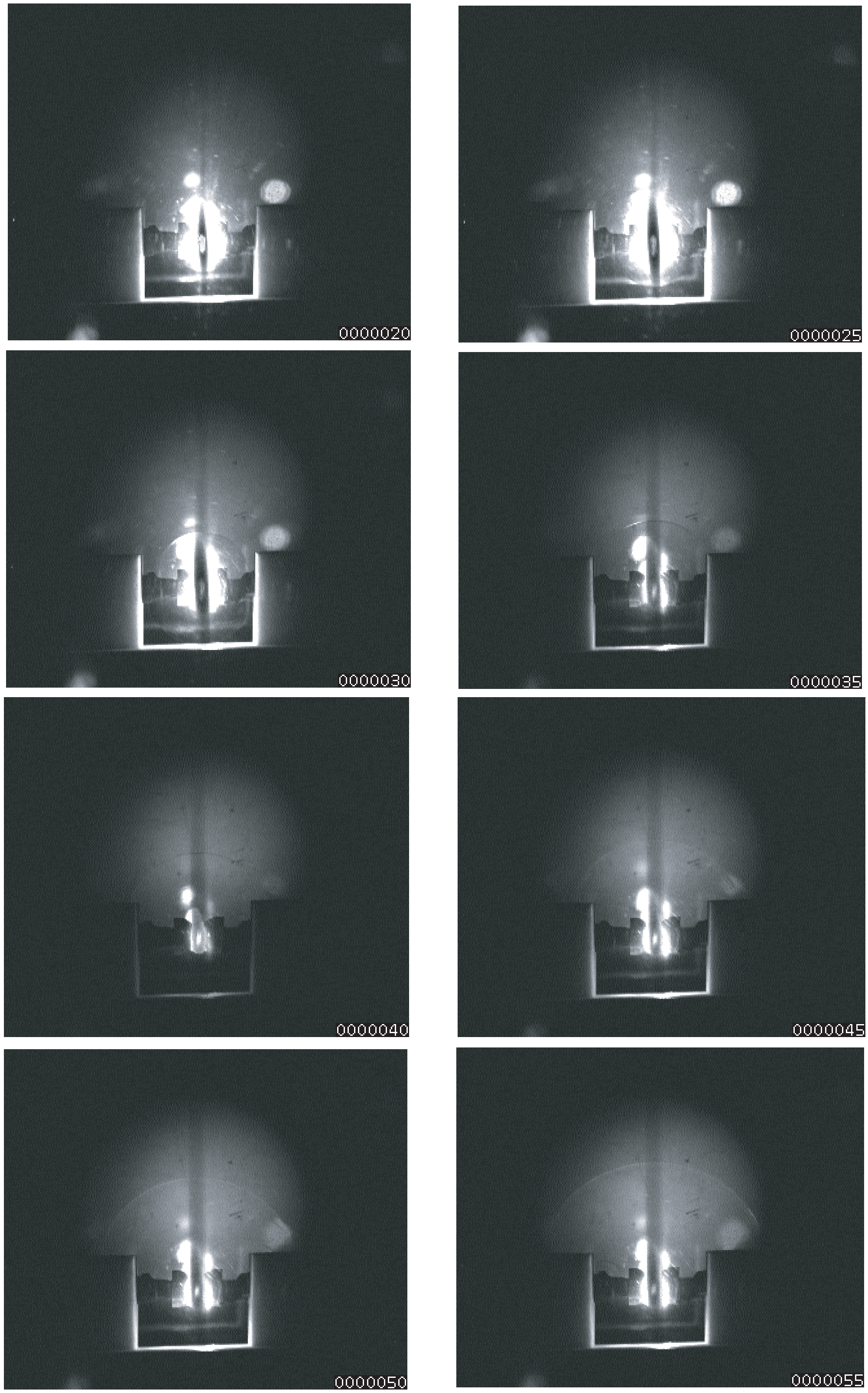

Figure 8 Framing photographs of electric discharge (No.1)

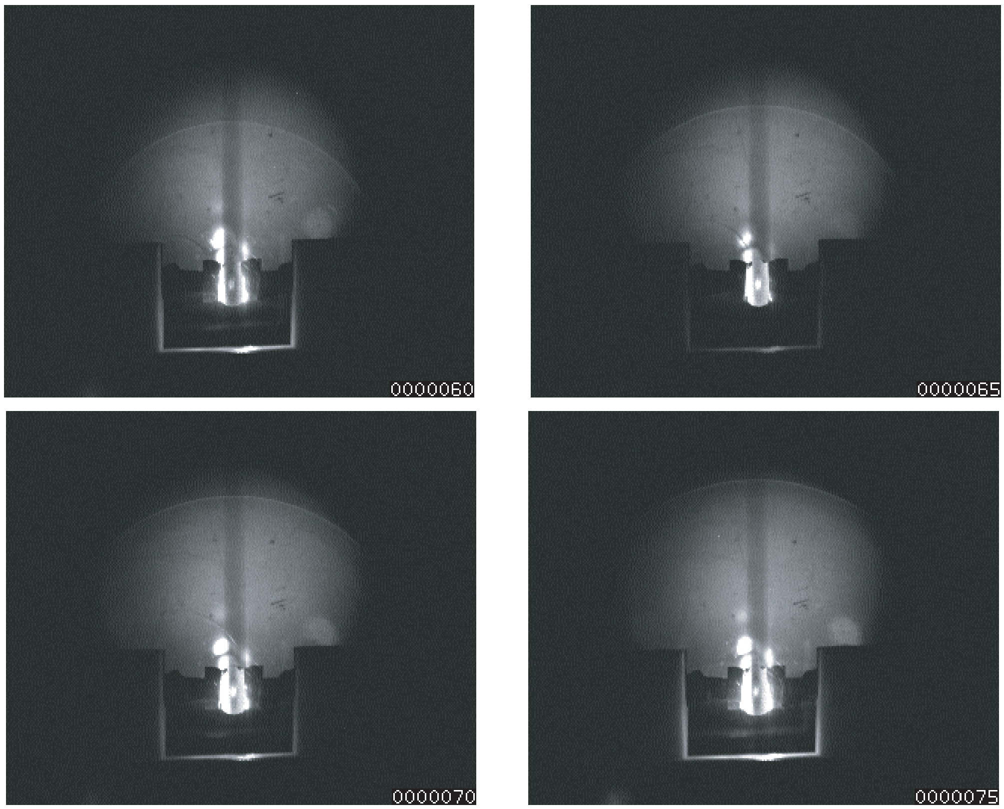

Figure 8 Framing photographs of electric discharge (No.1)

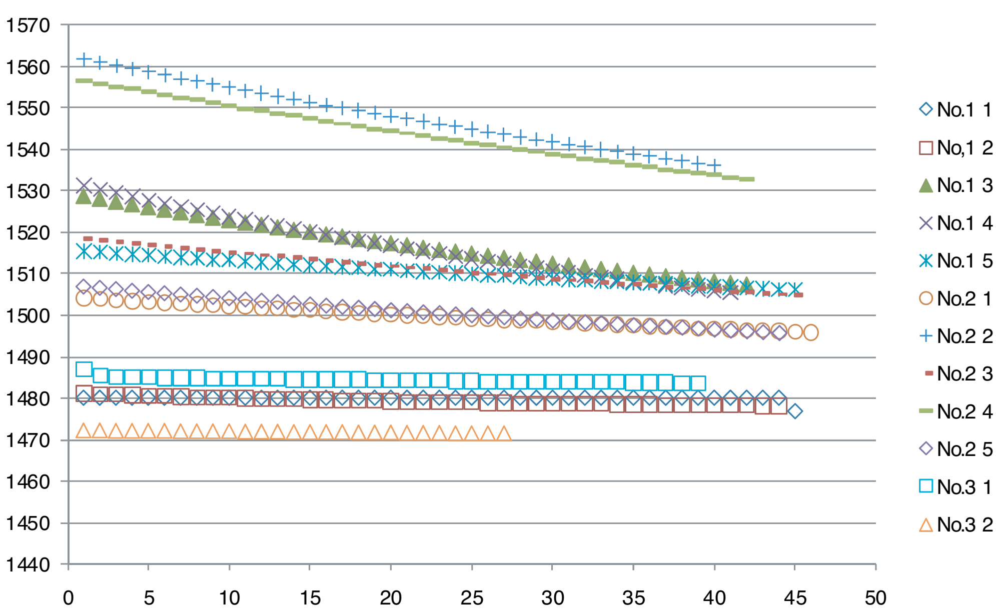

Figure 9 Velocities of underwater shock wave by electric discha

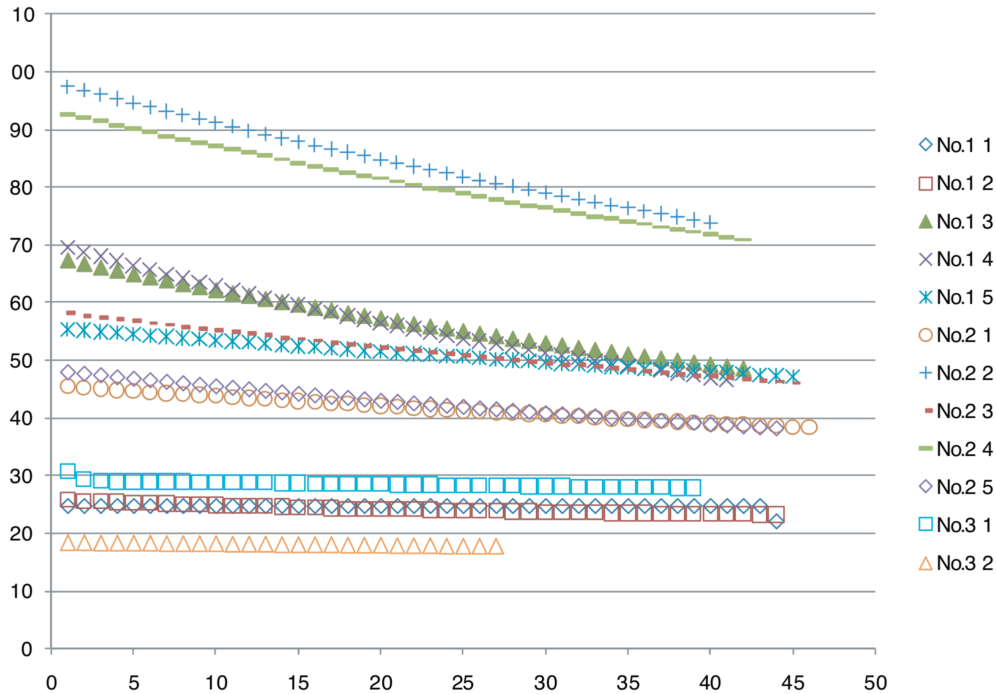

Figure 10 Pressures of underwater shock wave by electric discharge

manage to converge on 2nd focal point. However, it was not possible to judge accurately because the detonation gas prevents the reflecting underwater shock wave from converging.

5. THE RESULT OF NUMERICAL ANALYSIS

The result of numerical analysis is shown in Fig. 12. According to this result, it is confirmed that the underwater shock wave generated from 1st focal point by detonating SEP converged twice on 2nd focal point.

Additionally, the time history graph of 2nd focal point is shown in Fig. 13. The pressure value of 1st shock wave was 37.1MPa. The pressure value of 1st converging shock wave was 96.3MPa whose value was 2.59 times bigger than that of 1st wave. The pressure value of 2nd converging shock wave was 170MPa whose value was 4.57 times bigger than that of 1st wave.

6. CONCLUSION

- From optical observation, the underwater shock wave generating by electric discharge was confirmed
- Experimental No.2 was the best condition of the 4.
- Experimental No.3 condition was border whether to discharge
- From optical observation, the phenomenon of shock wave converging could not be confirmed accurately
- From numerical analysis, the phenomenon of shock wave converging could be confirmed
- The device using the shape of ellipse let shock wave converge twice
- The values of the converging pressures 2.59 and 4.57 times the 1st shock wave were obtained

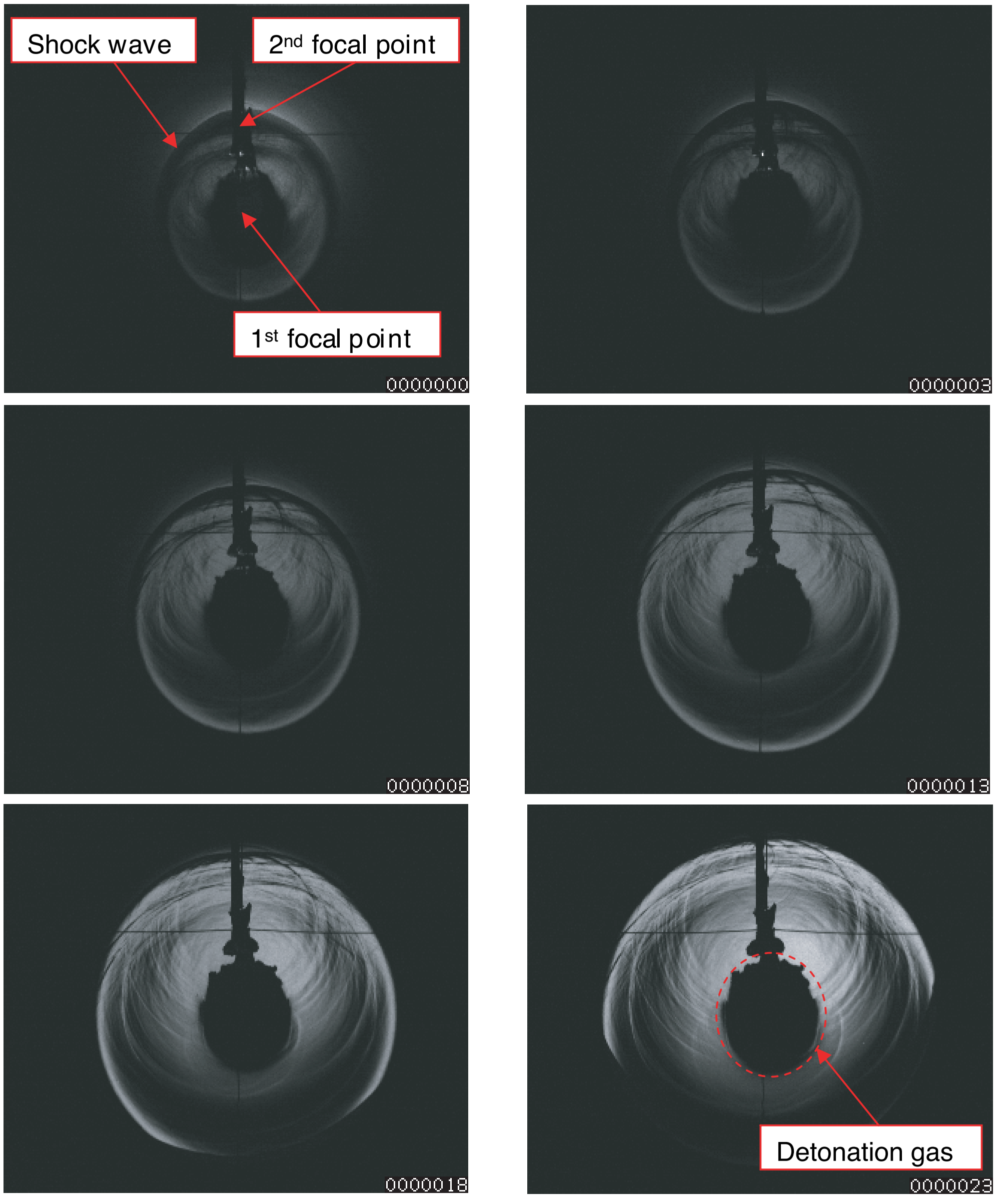

Figure 11 Framing photographs of converging shock wave

ACKNOWLEDGEMENTS

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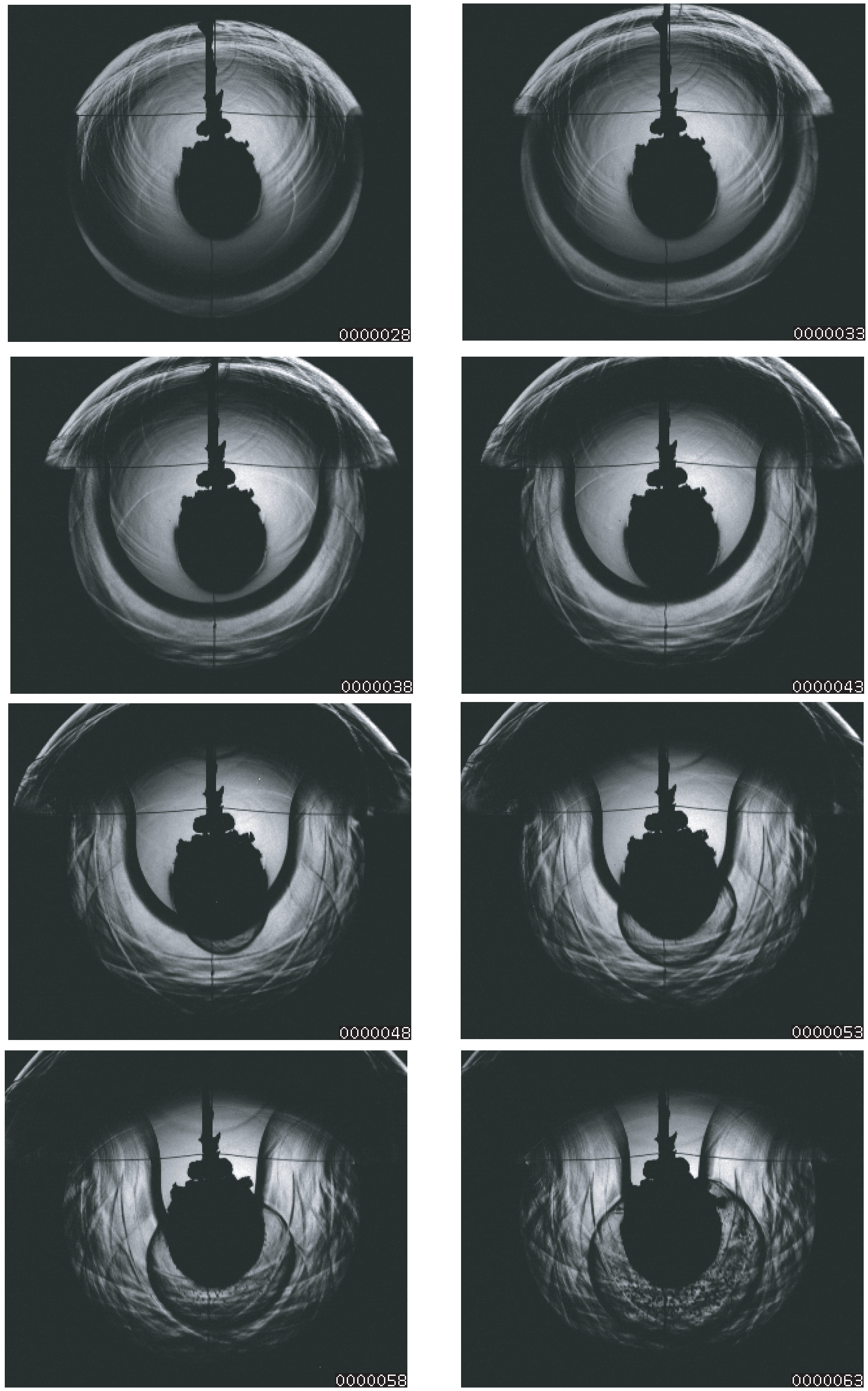
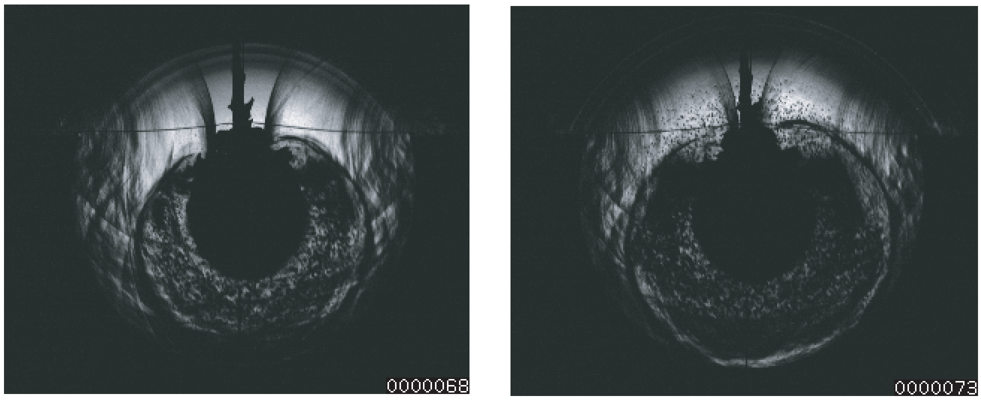


Figure 11 Framing photographs of converging shock wave



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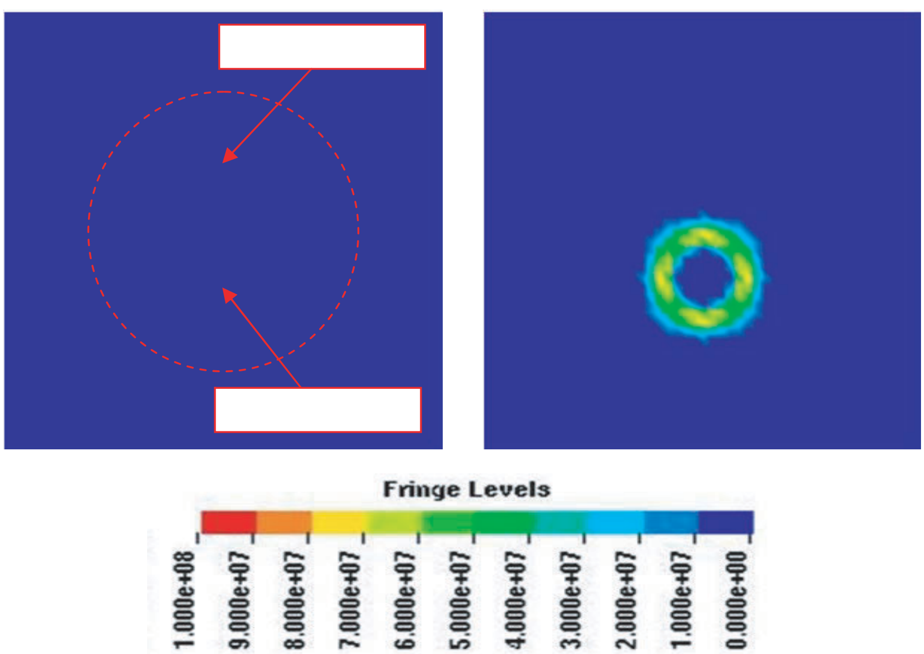


Figure 12 Framing photographs of converging shock wave

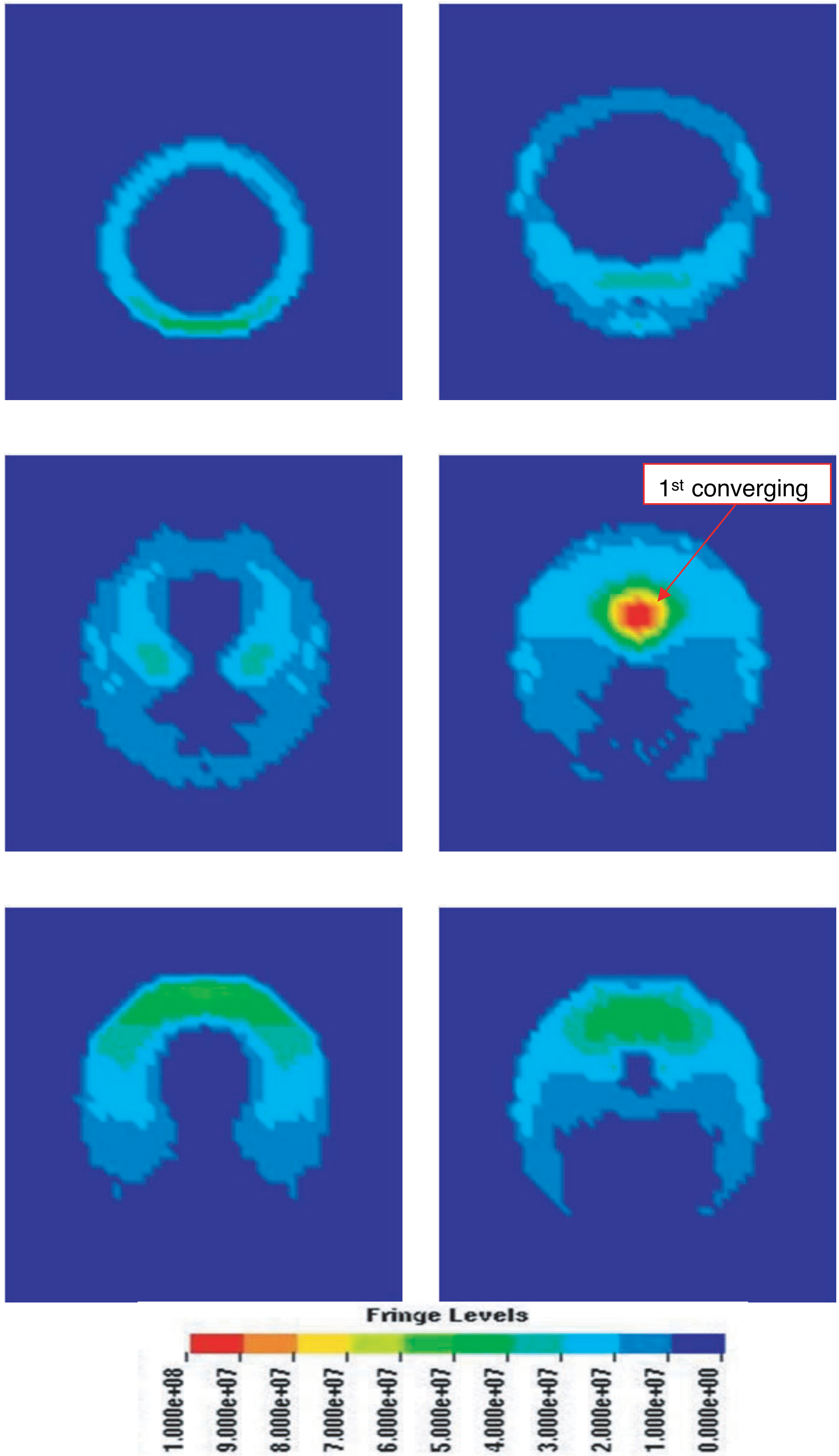
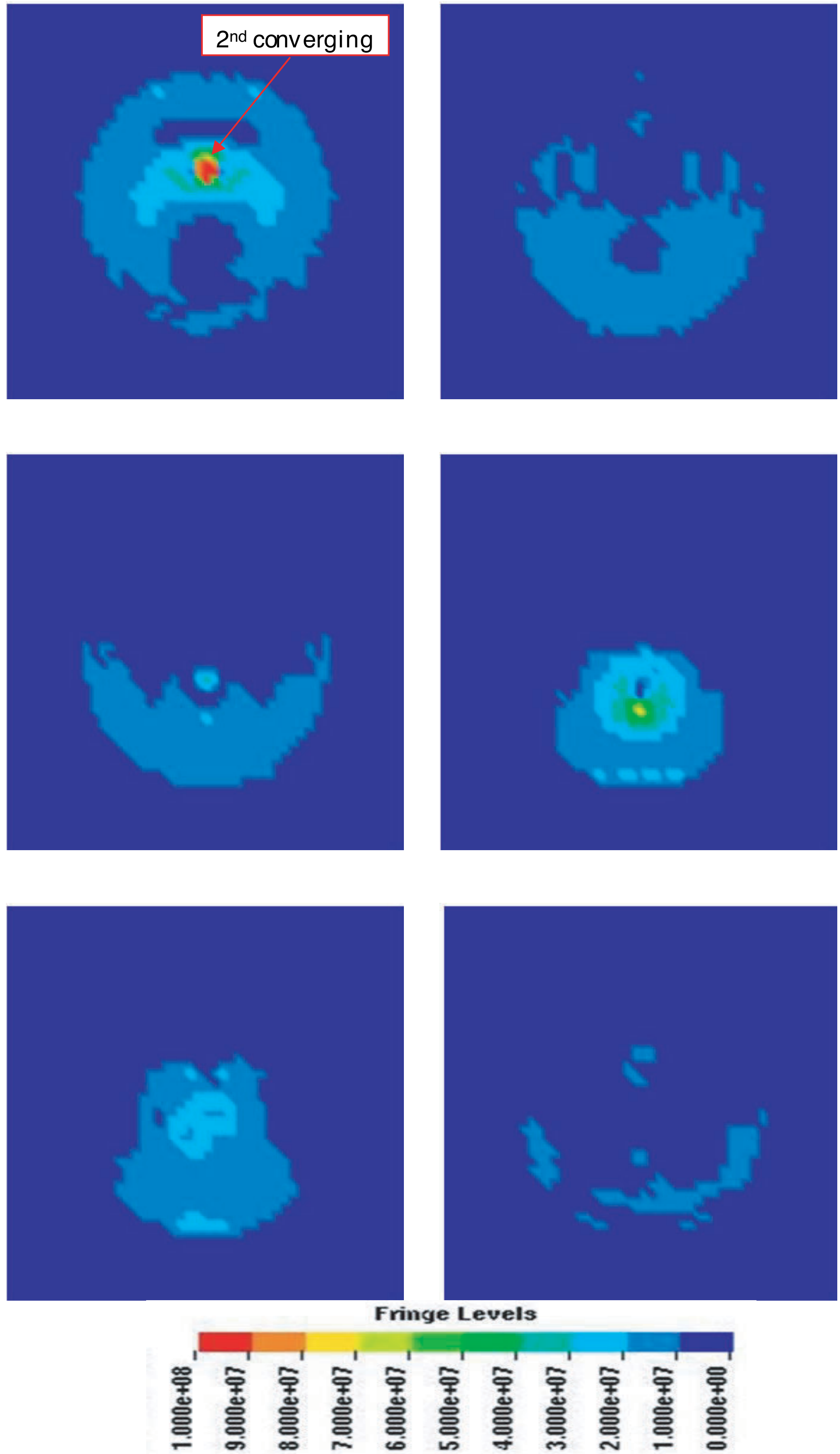


Figure 12 Framing photographs of converging shock wave



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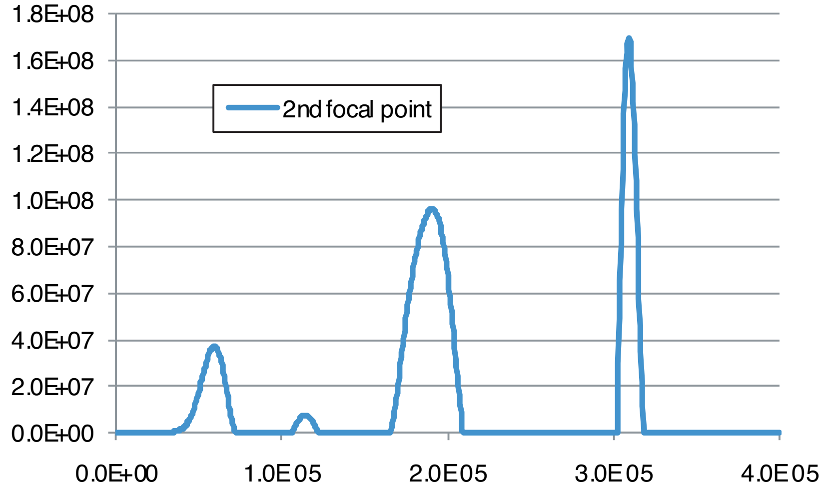

Figure 13 Time history graph of 2nd focal point

REFERENCE

[1] Characteristics of bread prepared from wheat flours blended with various kinds of newly developed rice flours. J.Food Sci., 2009

[2] About promotion of the rice powder using, The Ministry of Agriculture, Forestry and Fisheries of Japan, 2011