Design and Development of Pressure Vessel for Improvement of Manufacturing rice-powder Efficiency using Underwater Shock wave

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ABSTRACT

The rice-powder paid to attention in Japan, because the various food made by rice-powder. But, conventional method of manufacturing rice-powder generates heat when crushing of rice. One the other hand, the pressure vessel of oval structure for manufactured rice-powder using underwater shock wave has been developed in Okinawa National College of Technology. The merits of this system manufacture rice-powder without heating.

But, the efficiency of this system is low. Therefore, in this paper, we propose new design of pressure vessel for the highly effective rice-powder manufacturing. To design a new pressure vessel, it is clear that the performance of the oval structure pressure vessel. And, we design and manufacturing new pressure vessel for the highly effective rice-powder manufacturing.

1. Introduction

Figure 1 shows comparison of flour milling of conventional method and mill method newly developed using underwater shock wave. The conventional method of the rice-powder manufacturing is contact destruction using the millstone and current of air etc., The conventional method produced heat when the rice-powder manufacture. As a result, a poor quality rice-powder manufactured that ruins the flavor. Moreover, rice is softened by soaking in water. Therefore, the bacterium breeds, and big energy is needed the rice-powder is dried. So, we used an underwater shock wave. The destruction of rice doesn't accompany generation of heat because the underwater shock wave propagates at very fast more than the sound speed. In addition, even when rice is not soaked in water, rice is able to crush. As a result, the energy consumption is a little more than conventional method.

Fig 2 shows crushing mechanism of rice by the underwater shock wave. The speed of the shock wave exceeds acoustic velocity. The shock wave will divide into the penetration wave and the reflected wave in the interface by the density difference in the inside of the substance. And then, the tension by shock wave occurs at the surface of rice by the difference of density. Furthermore, the phenomenon in which density changes is repeated at the interface of the boundary where density is different. The shock wave pulls surface of the rice and produces the high-speed destructive phenomenon inside the rice. It is called spalling destruction. Rice manufactured the rice-powder by spalling destruction.

In Okinawa National College of Technology, the pressure vessel for the rice-powder manufacturing that used an underwater shock wave has been developed. To need a lot of energy for crushing rice, the pressure vessel adopted the pressure vessel of the oval structure, However, the volume of the hose in the pressure vessel is low.

Then, in this paper, we propose new design for pressure vessel for the highly effective rice-powder manufacturing.
Degradation of quality
Rice powder milling
Immersion by water
Flour milling
Drying
Rice-powder

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**Fig. 1** The comparison of rice-powder manufacturing method

Degradation of quality: Immersing by water
Generation of heat: Flour milling
Energy expenditure: Drying

2. Pressure vessel of oval structure

2.1 Pressure vessel of oval structure

Fig. 3 shows the cross section of the developed oval structure pressure vessel. The material of the oval structure pressure vessel is A2017. Because A2017 has sufficient machinability. The appearance measurement of the pressure vessel is 250 × 250 × 300 mm. Shape of inside of aluminum block is oval shape that the length of major axis is 167.7 mm, the length of minor axis is 160.0 mm and focus length is 50 mm. There are two screws (M10) of brass in position of first focus point of the vessel. Fit copper electrode of diameter 20 mm in the tip of screw. The water is filled inside the oval shape. Therefore, the shock wave generated by the spark at the time of electric discharge is transmitted in the underwater. The generated shock wave reaches the wall of aluminum and repeats reflection, and the shock wave gather in the second focus. It is confirmed that shock wave gathered second focus point by shadowgraph using high speed camera and numerical simulation. Rice passes in the silicone tube and three silicone tubes are set up in the vicinity of the second focus. The inside diameter of a silicon tube is 25 mm and thickness of a silicon tube 3 mm. The water and rice in a pressure vessel of the elliptical shape never contact by using silicone hose.

![Fig. 3. The cross section view of the developed oval structure pressure vessel](image)

2.2 Performance evaluation of Pressure vessel of oval type

To examine the performance of the oval type pressure vessel, we have investigated as follows.

1. It is clarified that the relation between the weights of manufactured rice-powder and charge energy.
2. The weight of rice-powder per an hour is expected using the result of expression (1). Therefore, charge energy necessary for generating an underwater shock wave is expressed as follows.

\[ E = \frac{1}{2} CV^2 \]  

\( E \) is charge energy [kJ], \( C \) is synthetic capacity of capacitor of shockwave generation device [µF], \( V \) is charge voltage [kV].
(1) Relation between the energy necessary for generating underwater shockwave and the weight of rice-powder

To examine the performance of the oval type pressure vessel, it is clear that relation between energy necessary for generating underwater shockwave and weight of rice-powder per five times. Fig. 4 shows relation between energy necessary for generating underwater shockwave and weight of rice-powder. The horizontal axis of fig.4 shows the weight of rice-powder by five times and, the vertical axis of fig.4 shows the charge energy. As the result, the weight of rice-powder increases when the charge energy is 5~8.5[kJ]. When the charge energy is 8.5~12[kJ], the rate of a more increase improves.

Fig.4 The relation between charge energy and weight of rice-powder

(2) Forecast of weight of rice-powder per 1 hour

The weight of rice-powder per hour is forecast by weight of rice-powder per five times. The forecast value of the weight of rice-powder per 1 hour is as follows.

\[ M = \frac{3600 \times m_c \times n}{t_c} \]  \hspace{1cm} (2)

\( m_c \) [g] is weight of rice-powder per five times
\( t_c \) [s] is charge time
\( n \) is number of silicon tube of oval type pressure vessel.

Fig.5 shows the relation between the calculated amount of milling flour and charge energy. The horizontal axis is the weight of rice-powder per hour and, vertical axis is the charge energy of underwater shock wave. It is clear that the amount of the mill of per hour is 450g.

3. The new pressure vessel

3.1 The design guide of new pressure vessel

To improve the amount of the milling flour more, we design the new pressure vessel. design guideline is shown as follows.

(1) The number of the silicone tube that rice passes is increased.
(2) The silicone tube is brought close from the generation point of the generated shock wave.

The energy of the shock wave decreases along with the distance. The power of the shock wave changes in the distance of the shock wave generation point.

3.2 The design of new pressure vessel

Fig.6 shows new pressure vessel for the highly effective rice-powder. New pressure vessel for the highly effective rice-powder manufacturing is welded and manufactured the thick walled pipe of the standard product and the flange of the standard product. The diameter of the pipe is 165.2mm, thickness of the pipe is 7.1mm. And, the diameter of the flange is 270mm. The inside of this pipe is a screw of M30, and the insulating resin and the electrode are set inside. The water leak because of the insulation part is prevented by using the screw conclusion.
The polyoxymethylene (POM) of 150mm in the diameter is inserted in this pressure vessel. Internal shape of POM is manufactured by two or more patterns. The following design factors and the effects of the improvement of the milling flour efficiency are clarified.

(a) Distance of hose and electrode
(b) Concentration of energy by shape
(c) Capacity of internal water
(d) Capacity of hose

4. Conclusion

Following shows the conclusion of this paper.

(1) It is clear that ration relation between the weight of rice-powder and charge energy using pressure vessel of oval type
(2) It is clear that the calculated weight of rice-powder per hour in pressure vessel of oval type is 450g/h.
(3) We proposed new design of pressure vessel for the highly effective rice-powder manufacturing.

In the future, the following are clarified for the new pressure vessel for the highly effective rice-powder manufacturing. And, pressure vessel of oval type and new pressure vessel are compared.

REFERENCES
