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Process Monitoring of Cast Explosive Solidification Molding by on-line Multichannel Ultrasonic Measurement

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Abstract

The process of cast explosive solidification molding has been dynamic monitored by multi-channel ultrasonic transmission method. It presents the regular pattern of ultrasonic attenuation, velocity and waveform in this process. The results show that velocity values and waveform are relative to solidification speed and physical characterization on the phase border, and ultrasonic attenuation is relative to the density and structure of the explosive that contains blowholes and cracks. The data indicate that ultrasonic transmission method can be used to reveal the regular of the solidification and to monitor production's quality in real-time effectively.

Keywords: Ultrasonic, Process monitoring, Explosive casting, Solidification molding

1 Introduction

Explosive casting is loading technique widely used in armament in and abroad. It is a molding method that makes explosive melt under calefaction and injects mould or cartridge afterward cooling and solidification in a certain shape and dimension. At usual condition, interior quality test of mould product mainly adopt dissection for density equality and radial test for blowholes, cracks and shrink hole. A lot of loading technique have been developed for the problem of cracks and shrink hole and a great deal of highly effective research has been done on flow characteristic of melt explosive, grain distribution of crystal explosive and shrink hole repair. But for the complicated thermodynamics process of solidification molding, knowledge on the change rule of structure and performance and the producing time and mechanism of blowholes and cracks is short. Ultrasonic can transmit in almost any medium. It is very sensitive to the physical characteristic and it can be monitored on line non-inbreakingly so it is prospective to measure the parameter of interior of cast explosive in the process of molding.

Ultrasonic technology has been widely used in many fields. But ultrasonic method is becoming research hotspot in inspect on line in recent years. In the field of product molding, H.K. Lee et al have used ultrasonic to monitor the setting process of high-performance concrete[1] and W. Michaeli, C. Starke investigated ultrasonic on the thermoplastics injection moulding process[2], I. Alig et al. have researched on monitoring of film formation, curing and ageing of coatings by an ultrasonic reflection method[3], Elmira Kujundzic et al monitored ultrasonic of earlystage biofilm growth on polymeric surfaces[4], process monitoring of polymers[5] and lactic acid fermentation[6] are also carried out. In the aspect of product of storage, there are research on ultrasonic of the complete dehydration process of orange peel[7] and frozen model food solutions[8] and phase transitions of monoglyceride emulsifier systems in pearlescent cosmetic creams[9] and in the process of product machining, there is also ultrasonic monitoring on the state of seam side[10] and so on.

For revealing molding rule of casting explosive solidification and judging the quality of product, we monitor the process of cast explosive solidification molding by multichannel ultrasonic transmission method in this paper and expect to obtain dynamic relationship between ultrasonic parameter and solidification characteristic, structure change and interior quality, thereby realizing online estimate for the physical characteristic of solid-liquid phase border, transfer velocity and structure change (blowholes and cracks included) and density distribution.

2 Explosive molding and ultrasonic monitoring

2.1 Explosive casting

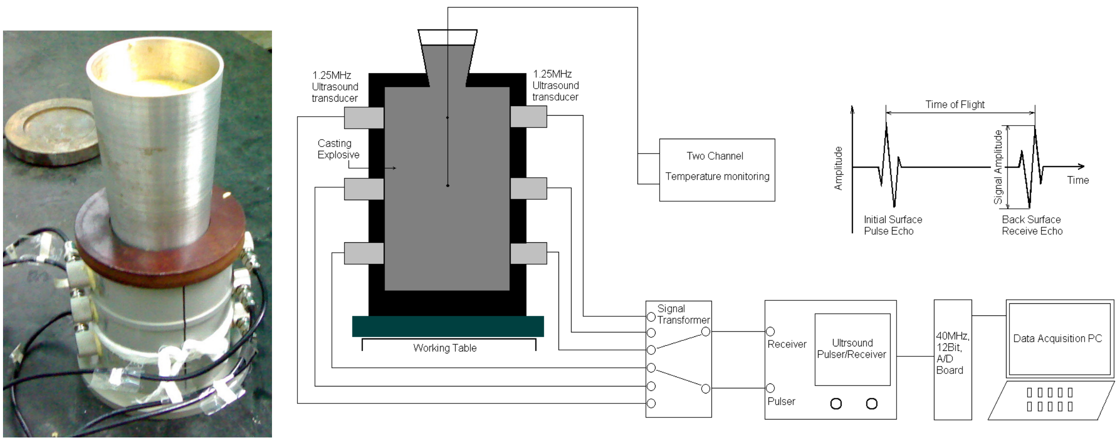
Usually, explosive casting is a molding method that makes TNT or other explosive mixed melt under calefaction over 90ºC and injects mould or cartridge fix the temperature of mould in a certain range and then cooling and solidification in a certain shape and dimension after repair of shrink hole by an additional mould. The freezing point of TNT is 80.2ºC.

The cast explosive is mainly made of two kind of explosive in this paper, namely TNT and TNT, RDX with a small quantity of additive. Their ratio of TNT admixture is 33.8:65:1.2. The dimension of mould is Φ110mm×130mm with wall 10mm. The temperature of molding is 86ºC and 20ºC of circumstance. RDX is solid under 100ºC.

2.2 Devices and methods

The devices designed in this investigation are illustrated in figure 1. Ultrasonic sensors are distributed in the sidewall symmetrically and equably. Their diameter is 20mm and three emitters and three receivers. Coupling solvent is coated on the surface and the sensors can resist high temperature up to 120ºC. Ultrasonic is collected and transferred into computer as digital signals. The temperature change is monitored with double channel thermoelectric couples distributed in the center of top and midst of sensors. The temperature is exact in ±0.1ºC.

The experiment is carried out in anti-explosion lab with non-disturbance and constant temperature. The waveforms are collected per two minutes with consistent attenuation. The time and range of wave are recorded for six hours.



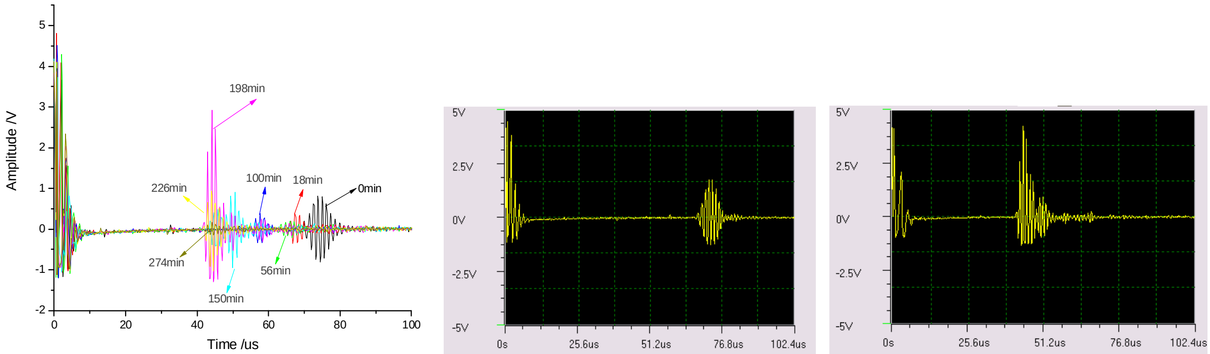
(a) (b)

Fig.1 Schematic diagram of the molding device (a) and ultrasonic measurement (b)

3 Results and discussions

3.1 Waveform characteristic

The typical characteristic of waveform in the process of solidification is illustrated in Fig. 2. The transmission time of wave is long when solidification starting shown in Fig.2(b) and becomes shorter as solid expanding outwards which indicates velocity of sound increased. Finally, transmission time is stable (see Fig.2(a)) and indicates freezing is completed. The waveform appears to be double crests when solidification expanded upwards (Fig.2(c)) indicates that solid-liquid interface is obvious during solidification. Solidification characteristic reflected from waveform agrees with traditional theory.

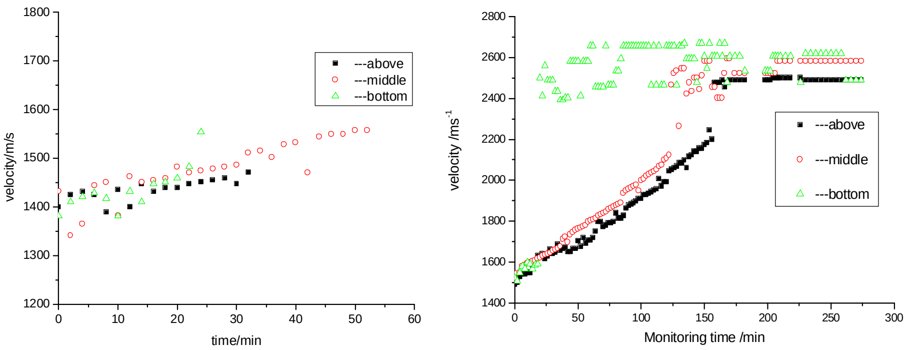


(a) (b) (c)

Fig.2 The change characteristic of waveform (a) typical waveform at starting (b) and at the solid-liquid border (c)

3.2 Relationships between ultrasonic velocity and quality characteristic

Ultrasonic velocity in the process of solidification is illustrated in Fig.3. The results show that ultrasonic velocity of bottom jumps at about thirty-minute and becomes stable and the middle and above ascends slowly in the initial stages jumping only a little range at 125-minute and 170-minute. The velocity descends from bottom to above. The result indicates that solidification of cast starts from bottom and quality is better and better from top to bottom. Otherwise, the move rate of phase interface or solidification velocity can be obtained from the relationship of position of sensors and ultrasonic velocity. The solidification velocity is illustrated in Tab.1.



(a) (b)

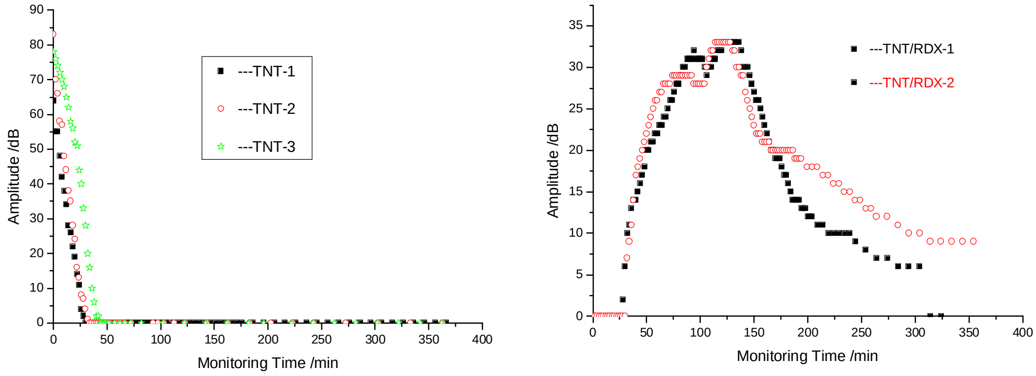
Fig.3 The ultrasonic velocity along with freezing time (a) TNT (b) TNT mixture explosive

Tab.1 The freezing velocity along radial measured by ultrasonic

Casting explosive	Radial freezing velocity/ mm·min^{-1}	
	Middle of mould	Above of mould
TNT mixture	0.43	0.35

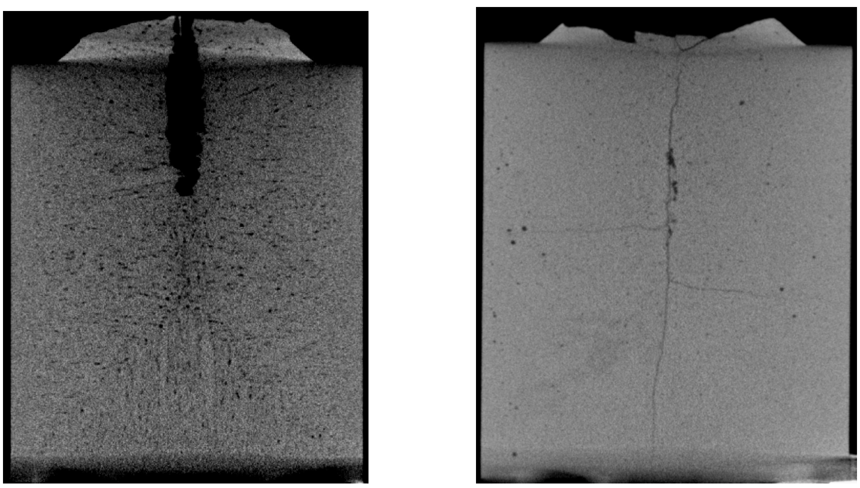
3.3 Relationships between ultrasonic attenuation and molding characteristic

Ultrasonic attenuation in the process of solidification is illustrated in Fig.4. The results show that attenuation of TNT descends quickly from the beginning 60dB~80dB and no signal accepted in thirty minutes while attenuation of TNT mixture ascends from no signal and descends from maximum to a stable value. The result indicates that a great many of blowholes are produced when freezing of TNT while the TNT mixture is tight. Crack will appear at the end of solidification, which is the cause of attenuation descent and approved in the succeeding experiment (illustrated in Fig.5).



(a) (b)

Fig.4 The ultrasonic attenuation along with freezing time (a) TNT (b) TNT mixture explosive

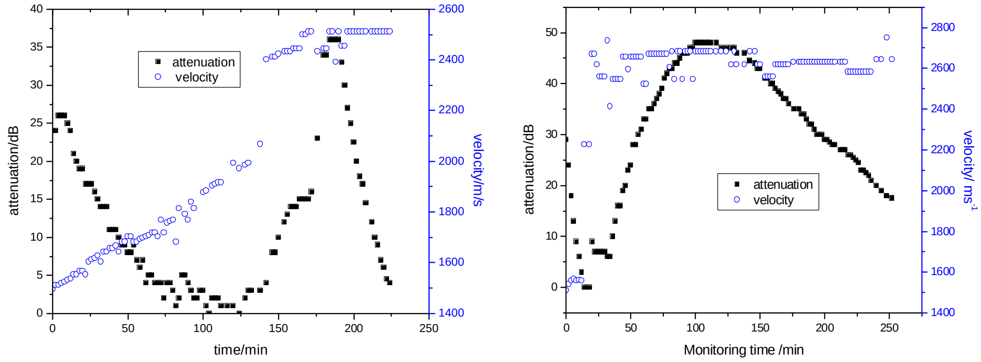


(a) (b)

Fig.5 CT images of inter structure of explosive after solidification. A great deal of interspaces are produced in TNT explosive (a) and crack is produced in TNT mixture explosive (b)

3.4 Relationships between ultrasonic characteristic and crack

Ultrasonic velocity and attenuation during the solidification is illustrated in Fig.6. The velocity stabilization interval is shorter obviously than that of attenuation maximization shown in Fig.6. The result indicates that the quality is improved temporarily after entire solidification and attenuation descends for the crack produced subsequently, and also indicates crack is produced after solidification.



(a) (b)

Fig.6 The ultrasonic velocity and attenuation trend along with solidification (signals from sensors above (a) and underside (b)

4 Conclusions

Ultrasonic velocity and waveform are relative to solidification velocity and physical characterization on the phase border, and ultrasonic attenuation is relative to the density and structure of the explosive that contains blowholes and cracks. The data indicate that ultrasonic transmission method can be used to reveal the regular of the solidification and monitor production's quality in real-time effectively.

Acknowledgements

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