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INFLUENCE OF INITIAL TEMPERATURE OF CASTING MOULD ON ACOUSTIC EMISSION OF SOLIDIFYING METAL ALLOYS

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Abstract: *The paper deals with applicability of acoustic emission (AE) testing methods to real-time evolution of thermal stresses and accompanying them plastic strains which can generate AE signals during solidification and cooling of metal alloy castings that may affect casting quality. During the consolidation and cooling process of aluminium AK9 and zinc Z41 alloys the temperature and the envelope of AE signals coming from two different casting micro-regions have been permanently recorded. The research included as well the effect of initial temperature of casting mould on RMS (Root Mean Square) value of the continuous AE envelope.*

It was shown that controlling the changes of RMS of the AE envelope obtained during solidification and cooling of the castings may be useful for non-destructive method of determining the type of initial layer of metal structure.

Key words: metal alloys, solidification, cooling, acoustic emission, thermal stresses

Introduction

The research of the metal alloy solidification includes the process of passing from the liquid to the solid state. In solidifying and cooling metal alloy under specific temperature-pressure condition thermal stresses arise due to uneven temperatures of parts of the casting. The phenomenon depends on the alloy type, on the rate of carrying away of heat from the solidifying area, and on the thickness of casting walls and initial temperature of the mould.

To identify the phenomena occurring in a real time in solidifying alloys, researches have looked for unconventional methods. The acoustic emission method, which consists of recording and analyzing the AE time signals generated in a solidifying alloy, is one of them.

Generally acoustic emission can be defined as a phenomenon that consists in the generation and propagation of elastic waves, inside or on the surface of a medium, which can be characterized by a broad frequency band within the limits of 1 Hz to 100 MHz.

In [1] the authors dealt with a problem of application of AE signals for determination of initial temperature of casting mould. Solidification of metal alloy castings undergoes in layers or in volumes.

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Therefore, the paper includes an attempt of interpretation of AE signals received from solidifying micro-regions of metal castings with respect to solidification mode.

Research procedure

Components of a synthetic AlSi8,6 (AK9) alloy were melted in a graphite melting pot under deoxidising and covering slay (degasal T200) in a chamber furnace. Metal oxides in the liquid alloy were refined by means of degasal T200, which in a quantity of 0.1% of charge was immersed and mixed with the metal. For gas refining "probatem fluss Al 224" in a quantity of 0.1% of the charge was used and placed in a graphite bell. The process was carried out at the temperature of 740^{o}C – 745^{o}C. The mould was poured with the alloy of which the temperature was 755^{o}C – 760^{o}C.

The zinc alloy Z41 was melted in a graphite melting pot under the cover of charcoal. The mould was poured with the alloy at 490^{o}C.

Castings were made in a truncated cone mould with a volume of 79 cm^3 (castings solidifying with a free contraction) and a cone-with-rings mould with a volume of 97 cm^3 (castings solidifying with an inhibited contraction). Application of different materials for different parts of the mould allowed the authors to obtain directional solidification of the castings.

The researches were carried out in different technological conditions. The castings made of AK9 alloy solidifying with a free contraction were tested changing in the consecutive experiments the initial temperature of mould: 22^{o}C, 155^{o}C and 270^{o}C. The initial temperature of the mould for castings solidifying with an inhibited contraction was 20^{o}C. The Z41 alloy castings were tested in the mould with the initial temperature of 22^{o}C for both solidification with a free contraction and solidification with an inhibited contraction.

The temperature measured in two points of the casting axis were recorded during solidification. The elastic wave of AE was received by means of two steel wave-guides, the top of which were placed in the casting axis with a distance of about 3 mm from, the tips of thermocouples.

A diagram of measuring system of temperature and AE signals coming from the solidifying alloy is shown in Fig. 1.

The wave-guides were placed 17.5 mm and 52.5 mm from the base of the casting respectively. The AE signal was recordedas an envelope in the frequency band to 20 kHz.

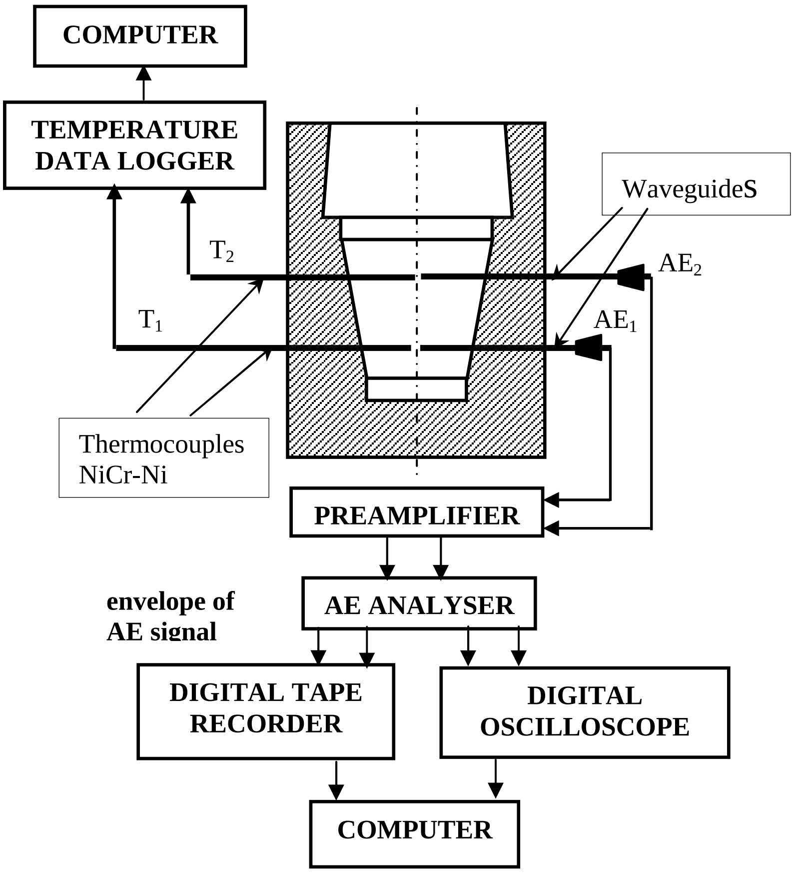

Fig. 1. Diagram of measuring system of temperature and AE signals coming from the solidifying cast alloy

Results of the experiments

During solidification of AK9 castings a slow increase in RMS value of continuous AE envelope was observed. A sudden decrease in RMS value of AE was observed during their cooling (see Fig. 2 A, B, D – time patterns of AE signals received by means of waveguides 1 and 2). The biggest decrease occurred in the castings, which solidified with an inhibited contraction, and it was not observed in the case of solidification in the mould with the initial temperature of 270^{o}C (see Fig. 2 C). In this case the RMS value of continuous AE was slowly decreasing.

For the Z41 castings solidifying both with a free and with an inhibited contraction any sudden changes of the AE envelope were not observed (see Fig. 3). The influence of the contraction inhibition in the solidified layer (the resistance of the mould) can be seen as continuous AE (see Fig. 3 B). The inhibited contraction of the solidified layer is observed in the form of subsequent AE impulses. In the casting solidifying without contraction inhibition this phenomenon is less intensive (see Fig. 3 A).

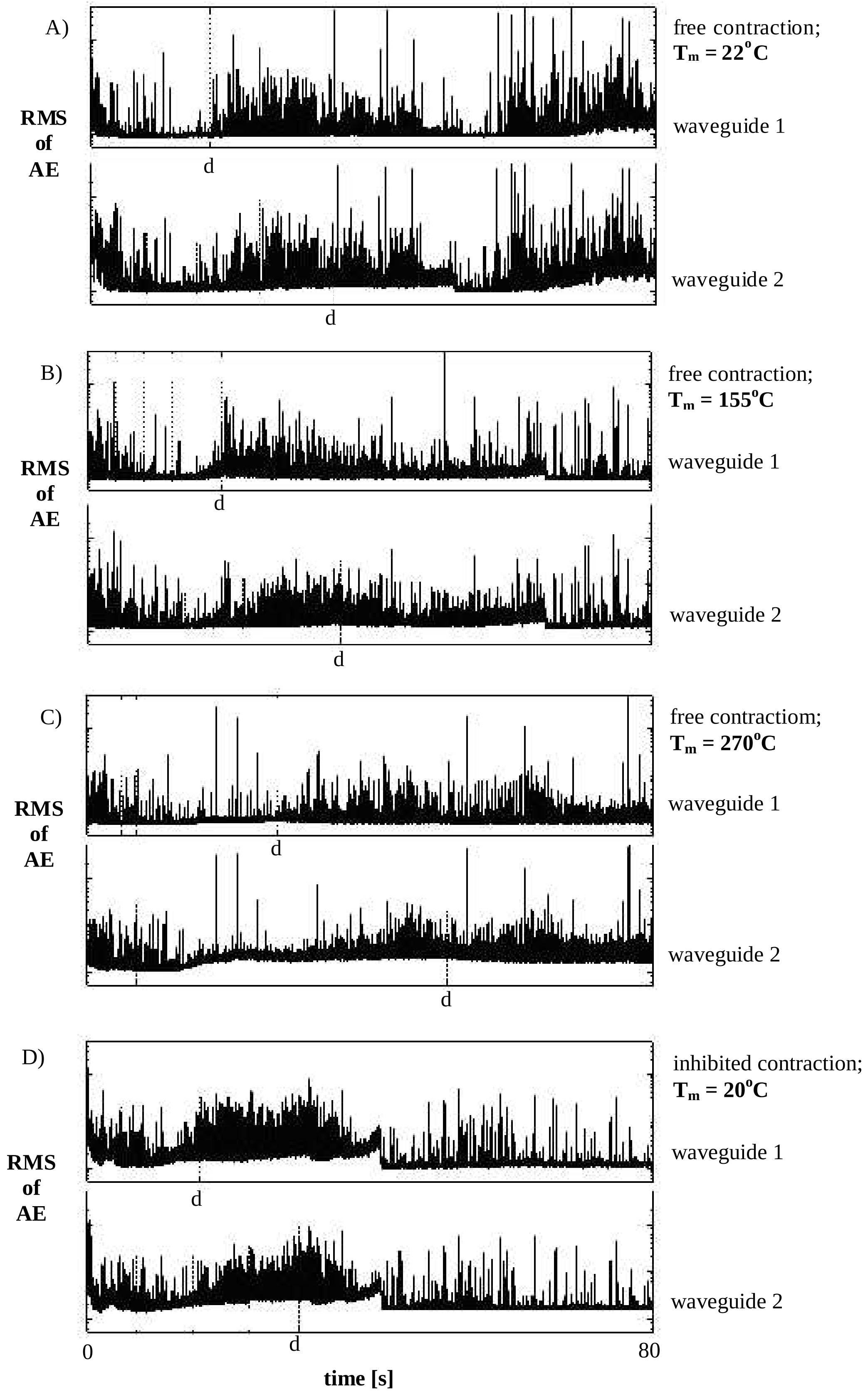

Fig. 2. AE signal envelope generated during solidification of AK9 alloys.
d – the end of solidification.

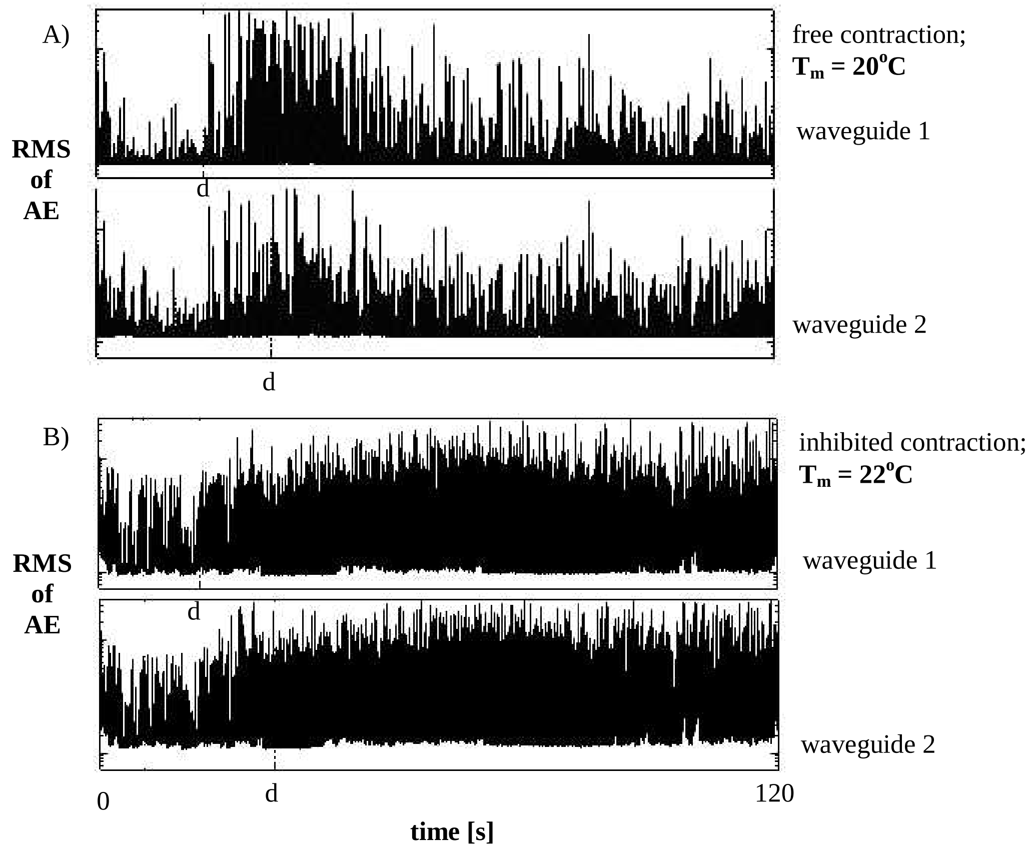

Fig. 3. AE signal envelope generated during solidification of Z41 alloys.
d – the end of solidification.

Conclusions

Distribution of thermal stresses in solidifying metal alloys depends, among others, on solidification mode of the casting, i.e. laminar (linear) solidification, bulk solidification, or mixed laminar-bulk solidification. During the laminar solidification thermal stresses in solidifying alloys slowly increase up to a certain value, while in the case of bulk solidification their values remain nearly unchanged. In the alloy solidifying according to the mixed mode the distribution of thermal stresses is more complex.

Therefore, based on time patterns of AE signals received from solidifying AK9 and Z41 alloys a hypothesis has been made that the signals depend on the distribution of the thermal stresses in the castings. Taking into account the analysis of changes in RMS value of continuous envelope of AE signals an attempt has been made at explaining the changes in distribution of thermal stresses with reference to the established initial structure (columnar for laminar solidification, or directional for bulk solidification) in examined castings made of Ak9 and Z41 alloys.

Under the conditions of carrying the heat away from the casting applied in the study the Ak9 alloy initially solidified probably laminarly (up to a certain width of the casting) and afterwards bulk solidification occurred.

Sudden change in RMS AE value (Fig. 2 A, B, D) observed in the samples of AK9 alloy may be caused by different cooling shrinkage's at the border between the areas of laminar and bulk solidification (the border of columnar and directional structures).

The sudden change in the stresses may be minimised by changing initial temperature of the mould (Fig. 2 C). In the experiment in order to minimise thermal stresses, the initial temperature of the mould should be between 155^oC and 270^oC.

The sudden change in RMS of continuous AE has not been remarked during solidification and cooling of the castings made of Z41 alloy. The RMS of continuous AE was nearly constant during the whole observation of the process. This may signify that the Z41 alloy solidified in bulk.

However, for explanation of the phenomenon additional research of solidification of the castings made of different metal alloys is required, as the distribution of thermal stresses arising during the solidification may be affected by the type of crystal lattice.

References

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