Material Science – Chemical Analysis and K-test with Zone Melting of Metals and Alloys

Anna MANEVA, Stefan BUSHEV

Institute of Metal Science, Equipment and Technologies With Hydro- and Aerodynamics Center „Acad. A. Balevski“ at the Bulgarian academy of sciences
Sofia 1574, 67 „Shipchenski prohod“ blvd. Bulgaria
e-mail: anna13@abv.bg; stbushev@abv.bg

Abstract
Mathematical experiments are presented for the first-order phase transition process in the formation of test bodies for chemical melt analysis and K-test. The effect of the initial temperature of the mold is shown. It is suggested that the two approaches be used to evaluate the technological process of a first-stage phase transition in a small volume.

Keywords: first-order phase transition, chemical test of liquids, K-test, little volume

1. Introduction – material science by special Stefan-Schwartz tasks

Figure 1 presents the general methodological idea of using data from powerful tool not only for scientific but also for technological research mathematical experiments through Stefan-Schwartz's tasks for describing the temperature field of a first-order phase transition. The idea of the methodology is based on the fundamental knowledge in Physical Metallurgy and Materials Science [1 and 2]. Foundry with the main scientific and technological processes is presented in [3 and 4]. Standard practices for good casting quality were taken on samples for [3]: chemical analysis very important test; K-test for use of secondary alloy [12]; zoning to purify by refining and obtaining fresh material [3].

Chemical analysis is the most important for the formation of the casting structure in a first-order phase transition [4 and 12]. The K-test is important for the use of secondary metal (alloy) [12]; The process of refining by zoning is used to clean secondary metals and alloys. For good casting quality were taken on samples for [3]: chemical analysis very important test; K-test for use of secondary alloy [12]; zoning to purify by refining and obtaining fresh material [3].

Under modern circumstances, the mathematical experiment is a new essential tool for research not only in scientific but also in engineering studies. The mathematical experiment is very important in modifying a material or article. An example of a mathematical experiment is any software for solving Stephan type problems. For example, Stephen-Schwartz's 3D task allows to calculate the solidification technology, i.e. technology first-order phase transition.

The mathematical experiment is a complex set of mathematical models, mathematical theories, mathematical physics, theoretical physics, computational mathematics, and physics. Formed in the structure of the new phase, it is necessary to evaluate such parameters of the foundry process, which can be considered technological parameters. In Fig. 2 we present such performance parameters [3, 1, 2, 10, 11 and 13]; for example the local solidification time in a small characteristic volume.
a) Stefan-Schwarz's specific tasks for obtaining material data 10 such as: standard first-order phase transition processes and low volume crystallization – chemical analysis and K-test with Zone-melt;

b): b, 1) Fundamental science (engineer) mathematical experiment on the base of data 10 from (a) for technological process of 3D first-order phase transition (on macro-level solidification) in simple geometry (3D cylindrical symmetry); b, 2) The obtaining results from (b, 1)) are date for little volume which should be repeated in every little volumes $\Delta V_{corr}$ of casting with complex geometry.

Fig.1 General methodological idea is Stefan-Schwarz tasks and mathematical experiments for technological first-order phase transition.
2. Specific instructions preparation of melt casting

Technological parameters (Fig. 2) are in Stefan-Schwarz's 3D task and the information about them is extracted by mathematical experiments – the 3D phase transition phase field of first order in the above mentioned tasks. The following results of mathematical experiments are presented in the paragraph [4, 3, 7 and 12]: influence of the initial temperature of the mold on the type of the first-order phase transition temperature field.

2.1 Chemical analysis – mathematical experiment is solidification of sample [4, 3 and 12]

Fig. 3. The cast of sample for chemical analysis is disk. Geometric kind of the open thermodynamic (cast and mold and boundaries W, Γ) system for chemical analysis (OTS, CA) with numerical calculated temperature field of solidification by the task of Stefan-Schwarz in the moment of time t=0.0259 s and coefficient of heat transfer at the surface cast-mold $\alpha = 3400 \text{ w/m}^2 \text{ K}$. 
The most important part of the process is the formation of the disk (the chemical sample). Phase conversion parameters are determined by the staging of each end of the disk volume. Then, chemical analysis in the volume may allow experimental testing of the chemical composition in the sample material volume. The link between the parameters in the mathematical task and the search for the most sensible possibility of easy research is clearly stated.

2.2 **K-test – mathematical experiment solidification of sample**

The temperature test through a mathematical experiment in the K-test is interesting with much more complex geometry and observation through chemical analysis. The combination between the two methods will much better address the question of the permissible use of secondary alloys with competitive and safe application.

![Fig. 4. K-test: cross section of the mod and the open thermodynamic (cast and mold and boundaries W, Γ) system (OTS, Kt). High intensity of heat exchange: \( \alpha_W = 56000 \text{ w/m}^2\text{K} \) \( \alpha_r = 28000 \text{ w/m}^2\text{K} \). Numerical calculated temperature field of solidification by Stefan-Schwartz task at two different initial temperatures of the mold.](image)

Chemical analysis primarily determines a limitation on the use of secondary metals and alloys, or the possibility of mixing with primary (fresh) materials to achieve beneficial use without compromising safety. Chemical analysis also allows the use of refining by zonal melting. K-test and first-order phase transition at maximum heat exchange \( \alpha_W = 56000 \text{ w/m}^2\text{K} \); and data from mathematical experiments also allows for a limit assessment for the use of secondary materials, which is linked to an optimal number of consecutive refinements.

3. **Numerical results of preparation of melt casting and methodology**

The influence of the initial temperature of the form is one of the factors with its influence and capabilities. Forming the casting structure in the chemical analysis sample depends on the feed of the disk from the dead head. This is the natural organization of the foundry process. The influence of initial mold temperatures of 20°C to 500°C is investigated.
Initials temperature 20, 50, 70, 100, 150 and 200°C;

Initials temperature 300, 400 and 500°C

Fig. 5. Influence of the initial temperature of the chemical analysis mold

Fig. 6. Influence of the initial temperature of the K-test mold.
Fig. 7. Heat conduction equation (1), boundary condition of heat transfer at boundary $W_{CM}$, boundary condition of heat transfer $\Gamma_{ME}$ environment are base of the Stefan-Schwartz task. (4) Latent heat of melting $Q_m$ with function of heat source $S_F$. Interesting is the interaction of the first-order phase transition processes and the crystallization processes in the volume of one final element and the correlation volume as $\Delta u_{corr} > \text{or} \gg \Delta u_{corr}$.

From Fig. 7 we have complex interaction for mathematical description of first – order phase transition processes in at $\Delta u_{corr} > \text{or} \gg \Delta u_{corr}$.

Fig. 8. Mathematical experiment: Technological first-order phase transition only by the initial temperature field.
The results of the mathematical experiments are presented methodologically based on: physics of metals and solid state physics [5 and 6]; metal science and solid state physics [7 and 8]; machines and technology created in the institute of [9]; quantum mechanics for atoms with one and two electrons [14 and 15].

Conclusions
Mathematical experiments describing the first-order phase transition through Stefan-Schwarz's problem in the formation of probes for chemical analysis and K-test are presented. The joint mathematical examination of the melt chemical analysis and the K-test allows to define a first-order technological transition. Natural linkage exists between the methods of chemical analysis of melt, K-test and refining by zone crystallization.

References
5. G. Schulze, Physics of metals, Peace, Moscow, 1971, (In Russian)
7. A. Balevski, Metalscience, Technics, Sofia, 1962. (In Bulgarian)
12. A. Maneva, These of PhD, Investigation of the structure and properties of castings from subeutectic aluminum alloys depending on the ratio of primary and secondary alloys, Bulgarian academy of sciences, Institute of metal science, equipment and technology with hydro- and aerodynamic center „acad. A. Balevski“, Sofia, 2013. (In Bulgarian)
13. S. Bushev, Theoretical model of structure formation in die casting, XXII International scientific technical conference „FOUNDRY 2015“, 16-17 April 2015 Pleven, Bulgaria (In Bulgarian)