Process control and analysis in the case of systems with phase transformations from mathematical simulation to (re)insurance issues

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The present paper, preponderantly based on practical experience in the field of aluminium processing, aims to delineate the complexity of the fabrication processes in the case of systems with phase transformations; their control and analysis methods have a strong influence on the economic output.

To analyse a complex industrial fabrication chain in order to control it means, actually, information processing. The implementation and fulfilment of actual socio-economic trends such as digitalization [1] or Industry 4.0 in the case of processes with phase transformations require solutions tailored to the very specific process. These solutions, although specific, have to match into a global control system.

Primary aluminium production amounted to 63.4 million tonnes in 2017 [2]. For 2020, the global aluminium foundry production is expected close to 17 million tonnes. [3] Such figures reflect the huge socio-economic impact of aluminium processing. In this context one has to mention that the fabrication chain of the very large majority of the aluminium products contains a heat treatment process which is also a process with phase transformations (solid state phase transformations).

Since the fabrication chain contains two distinct steps showing phase transformations (casting and heat treatment) with their inherent complexity, the process control and analysis is more intricate than a machining process. This complexity has a major impact not only on the direct economic output, but also on the other ancillary financial aspects such as (re)insurance conditions/risk/hazard, deferrals and accruals.

Metallurgical aspects

From the very beginning one has to emphasize that all these metallurgical processes based on phase transformations are sensitive to initial conditions. Modern metallurgy studies provided arguments beyond recall regarding the "structural metallurgical heredity" [4-5]. To downplay the influence of these effects on the long-term process stability would be a mistake.

"Modelling of casting solidification stochastic or deterministic?" [6] The character of the process is extremely important for its control and has decisive influence on the risk assessment (e.g. (re)insurance).

"Physical laws that are described by differential equations represent deterministic systems…" [8] A process able to be described by differential equations: the present should contain both the prediction of the future and the reconstruction of the past. Due to numerous defects the physical process of the casting solidification has a stochastic nature. Modern modelling uses stochastic differential equations to describe physical systems submitted to thermal fluctuations.

The modelling of the processes with phase transformations is merely one component of the global metallurgical fabrication chain. Especially in the case of large production volume the interaction machine – process plays a seminal role. The state of the equipment and the information transfer will influence the process output. Predictive maintenance and digitalization are becoming the most important dimensions within the framework of the global concept Industry 4.0.

The practical (under actual real industrial conditions) evaluation of the interaction machine – material and the correlation (if any performed) between the various process steps in the case of systems with phase transformations are stochastic processes.

Improving the overall quality of the control data leads to better (re)insurance conditions

Discussions about the (re)insurance conditions implying processes with phase transformations (such as casting and heat treatment) have to appeal to a very sound scientific, technical and statistical base.

The improvement of the information transfer during the complete fabrication chain has to envisage the fundamental theme of optimizing the defalcation-aggregation effect and interdependency [11].

The main beneficiary of products fabricated through processes involving systems with phase transformations are traditional and high-tech industries, such as automotive, aerospace, building, defense. In all these cases the overwhelming product majority are parts produced in large series and parts having a high-risk relevance. This, again, emphasizes the important role of a sound correlation between all the fabrication steps and the (re)insurance conditions. Probability transfer, measurement accuracy transfer, establishing an as narrow as possible confidence interval of a continuous function describing the global process correlation are the condio-sine-qua-non for a close to reality projection of the manufacturing processes into the information space. In this context one has to reaffirm the fact that the nature (continuous or discrete) of the probability distribution of the data describing the process has to be also analysed. These aspects play an important role especially in the context of predictive maintenance and in the case of the planning of a technical and economical sustainable supply.

Instead of a conclusion

Under pressure of large series production and continuously growing technical requirements, the above-mentioned processes need a more modern information processing able to provide a higher degree of stability and consequently much better (re)insurance conditions.

The existing quality assurance and quality management norms and methods should not impair the implementation of other control, analysis and assessment methods.

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