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INTRODUCING CASTING SIMULATION IN INDUSTRY: THE STEPS TOWARDS SUCCESS

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Introduction

The industrial world is moving towards the "digital factory" - a prototype-less automated production environment based on virtual engineering. In terms of productivity, quality and innovation, the expected benefits of this transition are spectacular. In this "digital factory", manufacturers, their suppliers and partners simultaneously work on the same numerical prototype (see Figure 1), allowing for continuous improvement in design and immediate decision-making. This "extended enterprise" marks a revolutionary departure from the time-consuming and costly trial-and-error processes of physical prototyping. Casting simulation is one small piece of that new technology. However, the introduction of a casting modeling package in a foundry is not a simple task and often the result is mitigated by the challenges of implementation. This paper will try to identify what are the key parameters ensuring success when introducing a casting simulation software in a foundry and why more than 90% of casting foundries are still not using simulation.

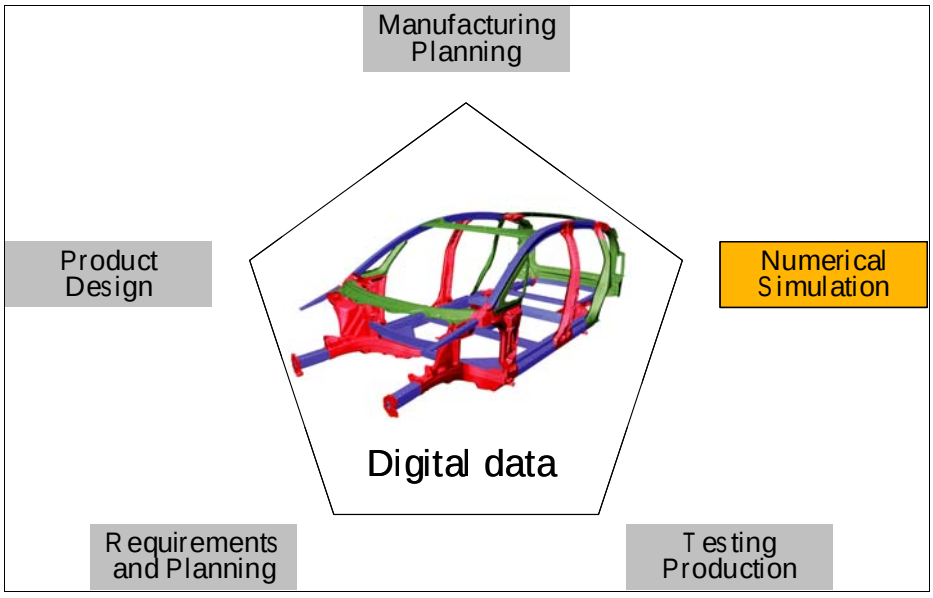

Figure 1. The new digital factory.

Software life cycle

Before considering introducing simulation software in a foundry, it is pertinent to think about the main ingredients of a software life cycle as indicated in Figure 1. These steps will be described below.

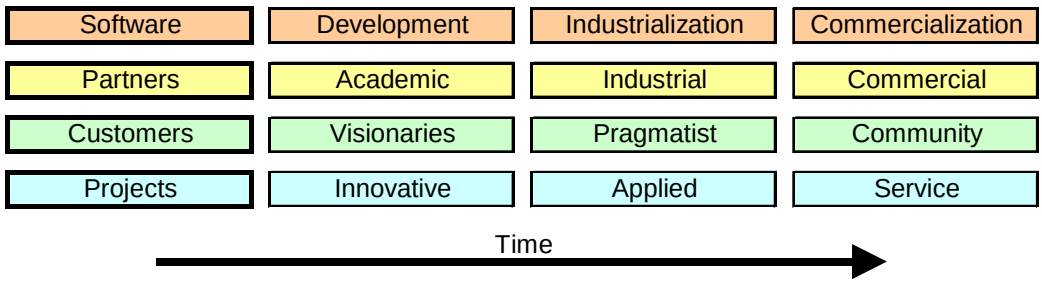

Figure 2. Partners, customers and projects as a function of software development stages.

Development stage

At this stage, software does not exist yet under any form. Software development projects are usually linked with a team of academic researchers expected to be creative and with a few selected industrial partners who can be qualified as visionaries. Very often funding of these projects is partially ensured by governmental institutions. In order to secure the industrial focus of such projects, commitment from industry is needed along with the personnel from industrial R&D centers who are normally included in the project team [1]. These R&D centers are usually centralized units of big companies with employees which have a high degree of education and with the same approach, language, understanding and mindset as academic researchers. Software introduction at this level is easy because no discrepancy exits between reality and expectations.

Industrialization stage

At the beginning of this stage a piece of software exists but its use is restricted to a few specialists. The next step of a software life cycle is industrialization, i.e. the transformation of a physically sound software into a product that any application engineer can use. Software houses try to ensure this evolution through applied projects involving selected pragmatic industrial customers expected to contribute with first exploitation of the software results. Industrial partners expect that, at the end of these projects, the software tool is implemented at their various production sites. Moreover, in this case software introduction is not really an issue because industrial partners have no surprise: through the various steps of the project they have learned how to use the software and they are aware of its capacities and limitations.

Commercialization stage

Software can only be successful in the long term if it is fully commercialized. This seems to be evident but still today software houses frequently have to deal with specific demands for developments which should be kept secret. After a few years these developments are no longer maintained any more and their extinction is natural.

Success implies the use of software by the whole industrial community. In the following pages of this paper, only the commercialization in the community is considered and discussed. The two steps described above have their own logic, which is completely different from the one pertaining to introducing a software in the "real" world.

Software capacities

Any software house is in some ways following the steps described above. As industries are involved during the development and industrialization stages, one could imagine that the resulting software will match the main needs of the market and as a consequence it should be easy to sell it to the community. Or even better for a software house, the community is anxiously expecting such a software.

The reality is different. A recent study [2] shows that less than 5% of castings produced today have been the subject of a solidification simulation analysis. The reasons for this could be as follows:

- The conversion of a provided geometry for analysis requires significant engineering time.
- The optimization of the casting process is not automated.
- The cost of software and hardware continues to be a concern for small foundries.
- Surface defects, leaking prediction, casting soundness as indicated by radiography, casting service performance and many other practical issues are not simulated today.

Therefore, it is important to understand that a foundry buying a software will find a mismatch between its need and the results that a software can provide. This explains the difficulty in introducing software in foundries.

Buying a casting simulation software

The thinking stage

A critical part of the technology planning process is to determine the optimal moment when to invest seriously in a technology like casting simulation. This is not an easy task and every company has a specific answer to that question. If a company delays action for too long, it runs the risk of being left behind by its competitors that have succeeded in making casting simulation work to their advantage. If the company launches its effort too soon, it will suffer unnecessarily through the painful and expensive lessons associated with deploying a technology for which the company is still immature (no CAD system, lack of educated people, …).

Before providing a company with a casting simulation software, the following questions should be raised:

- As no software can predict everything, what are the priorities? Filling, thermal, microstructure or stress calculations?
- Is the upstream information available, typically the CAD information? Is the output of the CAD software compatible with the input of the casting software?
- Are the educated people available? Is there a need to hire someone new?
- Are the foundry employees ready to integrate a new tool? Do they recognize that a software will enhance their competence rather than replacing them? Do they fear that they will be made redundant by the new tool?

The buying stage

Companies often wish to run a test case before buying a software. However, the goal of the test case is seldom clearly defined: is a test needed in order to check the compatibility of a software with the existing in-house software and employees' skills, or is the test needed in order to check the quality of the results delivered by the software? In the buying stage, it is also extremely important to understand the technology on which the software is based. Each technology has its own limitations.

Customers often mention the following criteria when choosing a software:

- Clarity of the software: – Concept
  – Extension possibilities
- Reliability of the results: – Stability of the results versus mesh quality
  – Quality of the thermal computation (cooling)
  – Quality of the flow computation (filling)
  – Quality of the microstructure computation
  – Quality of the stress computation
- Pre-processing: – Automatic mesh generation
  – Openness of databases (materials and boundary conditions)
  – Quality of the material database
- Post-processing: – Control of calculation set-up
  – Dynamic post-processing (animations)
- Computation time: – Speed
- User interface: – Friendliness of the graphical interface
- Data exchange: – CAD towards simulation software
  – Software towards CAE
- Various: – Quality of support during evaluation
  – Reference customers in the same kind of industry
  – Price

Many small and medium size foundries will establish at this stage that they are not ready to introduce casting simulation in their working scheme. The main reason for this finding is usually linked with human resources. During the buying stage, the company discovers that casting simulation is not a press-button operation and that someone in the company should be devoted (at least partially) to this new tool. The corresponding effort is often believed to be out of proportion with the potential benefits of casting simulation and the decision to stop all further investigation is taken at this stage. This explains why still today an important number of foundries are not using solidification modeling in-house. However, they sometimes appoint a consulting company to run one specific case and they often also start an active monitoring of the domain.

The introduction stage

When a software is first introduced in a company, the tendency is to use it immediately for troubleshooting the most complex cases, or at least the cases presenting a problem in production. This is probably not the best way to operate. In fact the introduction of simulation software into a company should start with simple cases (if possible even reduced to two-dimensional situations) and move on gradually to more complex ones.

It is extremely important at this stage that the managers of the company understand the "hype cycle" [3] of new technologies, which follows a predictable pattern of hype, disillusionment,

realism and eventually productivity, as shown in Figure 3, and that they allow the new technology to grow in its new environment. This stage will normally last between 3 to 6 months, depending on the efforts devoted to the integration of the new casting simulation tool.

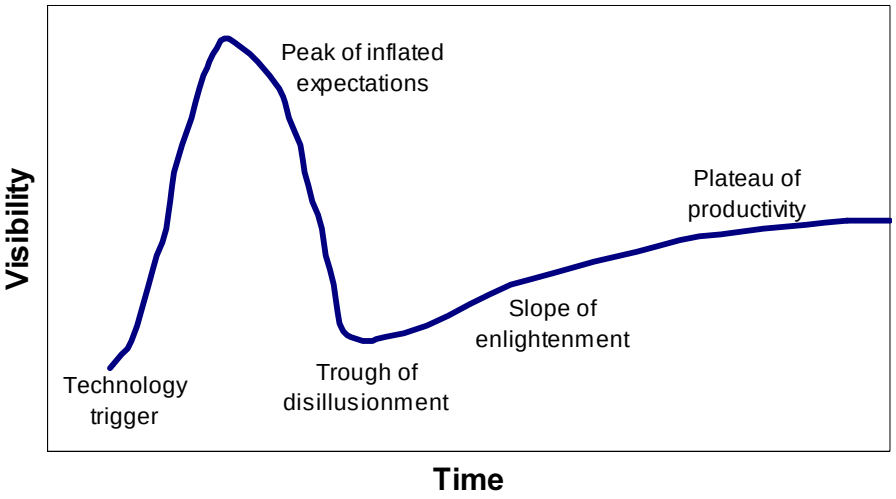

Figure 3. The hype cycle.

Ending casting simulation

When a company stops its modeling activities, the reasons are always to be found in a mismatch between the resources allocated to casting simulation and the expected results, and seldom in the intrinsic quality of the software. Specific reasons could be found among the following:

- The software is implemented in the design department where no foundryman is available to analyze the simulations and to bring the correct modifications to the casting design. Possibly also, the software is implemented in the production unit itself where timing problems do not allow for the use of the software. This means that the introduction of a software in a company requires the creation of new communication chains in the company itself.
- The software is not used by the right people and a problem of education and/or training is not solved in due time.
- The software delivers information on physical entities while the foundryman needs information on casting soundness and this discrepancy is not accepted and mastered.

The Outlook

Leading engineering software editors are now paving the way towards the second generation of casting simulation solutions. As the industrial world is steadily moving towards a production environment based on computer simulation where suppliers and partners simultaneously work on the same numerical prototype, casting simulation is not an isolated tool anymore. Unlike the first generation of software where the goal was essentially to have a tool limited to foundry applications, the second generation is used in combination with other software and requires several levels of integration:

- From macroscopic results (distortion, porosity) to microstructure predictions (phase compositions, material properties).
- From casting to heat treatment.
- From prototype design, to assembly and finally to performance simulation.

Combining the three levels of integration, one achieves a comprehensive solution where casting simulation enables the prediction of microstructure and defects, leading, after heat treatment, to local material properties. These local material properties can be used further by performance analysis software (see Figure 4), such as for instance crash simulations for car designs.

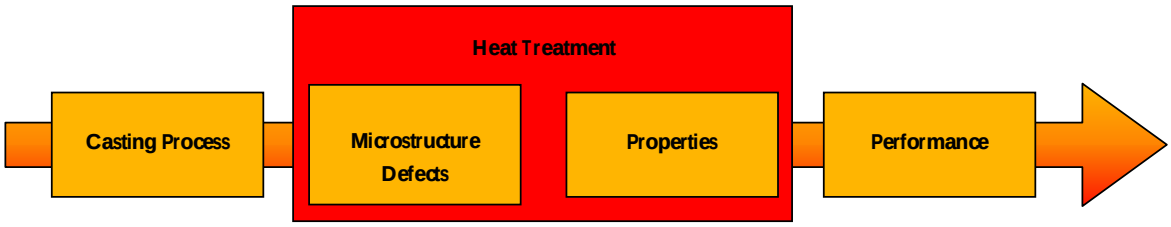

Figure 4. Full integration from casting simulation and heat treatment, to microstructure modeling and defect analysis, through the prediction of material properties and component performance.

Conclusion

The computer revolution, which is sweeping the globe, brings inexorable changes to all companies. Some of these changes are beneficial, some are questionable. It is up to every company to embrace those changes, which can significantly improve certain aspects of their business. Casting simulation is one small piece of that new technology which offers the potential to drastically alter the way in which foundries deal with the design and the production of cast parts to meet the demands of the global marketplace for quality, delivery and low cost. When casting simulation is cleverly and timely introduced in a company, when its limitations are understood and accepted, results can be really astounding on a technical and economical level. One example of success of the same kind of technology is the CAD: how many companies would seriously think about stopping CAD activities although tools are also complex and their introduction in a foundry is never straightforward?

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