e2e: Collaborative Engineering as the foundry's gate to casting development

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Abstract

In order to be successful in a more and more global competition, foundries have, among other things, the option of distinguishing themselves as casting consumers’ development partners. The increased value for casting consumers results from the fact that the essential and often very complex influences of the casting production method are taken into account at an early and timely state during the design process. However, this can only be done in close development collaboration between the foundry and the casting consumer. One essential requirement for such development partnership is the existence of an appropriate platform for communication and project management. In this article the usage of the Virtual Reality technology as a powerful communication platform for complex three-dimensional problems will be presented.

Casting Simulation and 3-D Visualisation

Using casting simulation software, one first creates numerical results, i.e. a vast number of figures, which are then processed and converted into visual information in a postprocessor. Based on these images, the user wishes to obtain knowledge of how to cast his casting under the chosen circumstances, of the problems that may occur during production and of the properties that can be expected for the respective casting. Of course, these images already represent more comprehensive information for the foundry man than, for example, micrographs or images from computer tomography. However, there still is a certain probability and, with complex casting technique problems, even a high probability that information hidden in results could
be beyond human understanding: Details could be overlooked and existing important information could thus remain unused. For this reason, three-dimensional presentation of results often is useful and sometimes is surely necessary to analyse casting simulation results. Two examples of the above are given in the following:

*Filling of a thin-wall aluminium casting*

Structural components must be cast very quickly because of their little wall thickness. In the high-pressure die casting process, filling times for large castings such as truck dashboards (Figure 1) often are below 100 ms. As multiple ingates are normally used, there are several melt fronts, many areas in which melt fronts run against each other, areas with turbulences, etc. During analysis of simulation results, any two-dimensional presentation quickly comes up against limiting factors. The user needs a lot of time to carry out his analysis thoroughly. Otherwise, it is quite probable that he will overlook critical details such as cold laps. Analysis of three-dimensional filling simulation results can be carried out in a significantly more reliable and quicker way.
Figure 1. The mould filling of a casting can be so complex that the usual 2-D view from the screen may be not sufficient for the evaluation of simulation results.

Convection during solidification of a thick-wall steel casting

Large steel castings such as press stamps take hours and sometimes days to solidify. During solidification, convection takes place in the liquid inner areas (Figure 2). This is due to density differences in the residual melt, which result from different temperatures and segregations. The degree of convection indicates how concentration differences may be compensated in the residual melt. It thus indicates the formation of macro segregation. Many details only become visible in a three-dimensional animation of convection.
Figure 2. The convection during solidification of a thick walled steel casting can hardly be shown in a 2-D view.

Collaborative Engineering: A definition

The term “Collaborative Engineering” is used in various different meanings; in order to avoid any misunderstandings we would like to give a definition beforehand.

**Collaborative Engineering**

The most general and probably most widely used meaning is that “a large number of people are working on the same product”. This is the case for many of today’s manufacturing companies like for example in the car industry: several thousand engineers in different departments, countries and even companies work at different times at different locations at different or the same parts of one common product. The main purpose of the collaborative engineering here is to make sure that in the end all
components are working together properly. The core software that is used in this context is the so-called Product Lifecycle Management software (PLM).

**Collaborative Visualisation**

The second, more special, interpretation is “a certain number of people is working simultaneously in front of a large screen” Here the number of people involved is considerably smaller (they naturally have to fit into a single room) and they are at the same time at the same location and look at the same data. The focus in these working sessions is on communication; usually people from different groups or departments meet in front of a large screen in order to discuss and solve problems in a common data set. The large screen has the simple advantage that everybody has a good view on the data; however, in most cases the data is of three-dimensional nature and a stereo projection is used to allow a more intuitive perception.

**Computer Supported Collaborative Work**

The third collaborative engineering variant is “two or three people are working simultaneously at different sites”. Simultaneously people at different sites are looking at the same data in a synchronised way. The idea behind this scenario is to allow remote meetings that have the same quality as personal meetings. Therefore, it is extremely important that the images on both sides are identical in order to allow a meaningful discussion. This is also known as Computer Supported Collaborative Work (CSCW).

Of course, all three variants are important for the cooperation of a foundry in the development process. The main focus in this article however is on the second interpretation of Collaborative Engineering, also called collaborative visualisation.

**Virtual Reality and Collaborative Visualisation**

The basic idea behind collaborative visualisation is the following: a number of people, in our case mostly engineers or craftsmen, need to discuss a certain problem that is
related to a three-dimensional product. In the case of a casting simulation, this not only includes the three-dimensional shape (geometry) of the product, but a significant number of physical properties that are related to the casting process (like for example the temperature of the melt front and other properties as mentioned above).

The human sensorial channel that has the highest bandwidth is the visual one. Already little children learn how to live and move in a three-dimensional world. This leads to a very high developed eye-brain complex, that allows us to much better understand three-dimensional aspects, although our eyes are basically only working in two dimensions.

The Virtual Reality (VR) technology utilizes these capabilities in order to have a very efficient display of computer generated data: On one side it uses the stereo display on screens that fill a large field of view for the user in order to create a feeling of being imbedded into the virtual world. The user has the feeling that he can even touch the virtual product that is floating freely in front of him. In combination with special input devices that allow a three-dimensional interaction the user can not only walk through this virtual world, but he can perform actions in this world. Of course, the current state of the Virtual Reality development is far from making the user forget that he is in a computer generated world, but the way he can navigate and interact in this world is very intuitive.

This leads to a big advantage with respect to the “ease of use” compared with standard computer software. It has been demonstrated often that even computer-inexperienced people can very quickly learn to work in such a virtual world. By replacing monitor, keyboard and mouse by a large screen and a direct three-dimensional interaction with the virtual object, the learning curve is very steep. Less than 30 minutes of training will allow any user to perform all tasks that are relevant to his duty in such a virtual environment.

The emphasis of such collaborative visualisation can be on either of two aspects: Communication or Exploration. In the following paragraphs, we will show the advantages of the new technology for both aspects.
Communication

It is already a truism that today’s engineering process shall be shortened as much as possible, in order to be faster than the competition. One way to shorten the overall process is to accelerate each of the process steps; however, this has already been achieved to a large extent, so that it is more and more difficult to further shorten these already optimised process steps. Therefore, it is increasingly important to parallelise tasks that have been more or less sequential before. In Figure 3, a schematic overview of the former (in the background) and the future development process is shown. Although the reduction for the single steps is mostly small, an overall reduction is clearly visible. In addition the more intensive simulation activity in an early phase of the development cycle will help to save a significant amount of money: errors that occur are much cheaper to fix, the earlier they are discovered in the development process.

Figure 3. The parallelisation of the development process

The increasing parallelism in the development phases makes it crucial to co-ordinate the efforts of all people that are working on the same parts of the product. A growing
problem in this communication is that these people will have more and more different backgrounds. At the end of the concept phase in Figure 3 we have besides the marketing and research people of the concept group design engineers, simulation engineers and production engineers working at the same time. In order to assure that the communication between all these different specialists works well, it must be very clear and unambiguous. It is obvious that two-dimensional drawings of complex three-dimensional parts are not a sufficient basis for meaningful discussions, especially taking into account that casting problems are not static, but have an extremely high degree of dynamics (even if we only look at the flow process and the temperature development).

*Exploration*

While the communication aspect is relevant for discussions or review meetings with several users, the Virtual Reality technology can also be helpful for the individual developer or researcher who looks at data that is new to him. It is already a well-known fact, that one picture tells more than thousand words. Applied to the Virtual Reality this can be translated that one Virtual Reality session is worth more than thousand pictures. Although this might be slightly exaggerated in general it is definitely true for the display of three-dimensional data.

Particularly important for an efficient exploration is the direct interaction in the three-dimensional world. The possibility to address any point of interest in a three dimensional world by simply pointing there is of tremendous value for the specialist. A specialist that is familiar with a certain kind of problem and/or product has a very good “feeling” about critical areas; it has never been easier to quickly check these critical areas by directly scrutinising them with the 3-D interaction device.

*The Cost of Virtual Reality*

In the past, Virtual Reality technology has been known either for basic research or costly high-end installations that only car manufacturers can afford. However, the technical development of the last years together with the experience that especially
the car manufacturers have created in the productive usage of their Virtual Reality installations has changed the economical aspects of this technology drastically. The most important aspect still is the cost for such an installation. In Figure 4, a standard configuration of a Virtual Reality installation can be seen. Such an installation always has four components:

- the graphics computer
- the projection system
- the tracking system
- the Virtual Reality software

If we look at the different components the first two show, how the development of hardware in general in the last two years has helped to make Virtual Reality affordable: in the rack on the left side, two standard PCs with widely available graphics cards do all the rendering for the virtual product. The tremendous increase of graphics as well as compute power has brought a performance to this price level, that was at least ten times more expensive only two years ago. Also positive has been the impact of the development of presentation beamers/projectors on the cost of the projection system. Where only a few years ago expensive and large CRT projectors created fairly dark images, today high-end office projectors create bright images at a fraction of the price. Two of these projectors make sure that the graphics rendered by the two PCs are visible for the left and the right eye of the viewer (separated through polarization filters in front of the projectors and through spectacles that the users wear). In the configuration shown in figure 4, all components have been optimised for maximum compactness and transportability. The tracking systems are still a special technology, but also have reached price regions that are acceptable.
Figure 4. The PC-based Virtual Reality solution

So finally, we have to look at the software. While standard visualisation software is already available together with most simulation programs, the control of the more complex Virtual Reality technology needs software that has been fine-tuned for these configurations. VirCinity’s software COVISE VR has first been developed for general visualisation tasks like Computational Fluid Dynamics or Structural Mechanics; however since mid of the 1990s it has been optimised for Virtual Reality installations, with special emphasis on 3-D-interaction and intuitive usage. The key properties of good Virtual Reality software are efficient interfaces to the simulation programs where the data is computed and an easy to use 3-D-user interface.
Advantages for Foundries

Already in the first paragraph, we mentioned that an essential requirement for a good development partnership between foundries and their customers is the existence of an appropriate platform for communication and project management. We are convinced that the Virtual Reality technology in combination with casting simulation is an ideal platform for these tasks.

During the development of a part that will finally be produced by casting, often several iterations between the designers of the part and the foundry are necessary. While the foundry men usually have a good understanding of the impact that the casting process has on the creation of the product, they are usually not familiar with the context that lead to the current design. On the other side are the designers that of course know this background, but in many cases do not know enough about the casting process in order to design their parts correctly (e.g. design parts that are physically impossible to cast).

The numerical simulation now provides a powerful way to help both parties to understand what is really going on during the casting process. Together with Virtual Reality both, foundry men and design engineers, have a good three-dimensional view on the future product and its behaviour. This allows for example the founders to explain to the design engineers, why the geometrically correct form leads to the wrong results (for example due to different solidification conditions). Both groups are in the shortest possible time on the same level of understanding, thus minimising the danger of misunderstanding. In addition to this, the confidence of the participants in the decision will be higher, which in turn forms a significantly better basis for future decisions. In addition, the relation between foundry and customer will be improved, since the customer is much better integrated into the development process.