Today, Virtual Reality (VR) applications are a natural component of industrial product creation processes, being regarded as a supplement to digital product development tools and modern information and communication technologies. It is particularly well used in the automotive and aerospace industries, and now increasingly in metal forming technologies for process development, where it is evolving from being simply a means of presentation to becoming a medium for supplementing classical computer-aided design (CAD) and finite element modelling (FEM) systems.

The cast-rolling mill for Compact Strip Production (CSP) is an example of an integrated plant where hitherto separate process steps, namely the casting of liquid steel into thin slabs in a caster and the rolling of the slabs to steel strip in a rolling mill, are combined into one unit. To guarantee cost-effective design and dimensioning of such a plant, a wide range of different types of simulation is required. These include simulation of the cooling and solidification processes of liquid steel in the caster using FEM, as well as logistic simulations to examine the movement of the products within the plant.

**PROJECT DESCRIPTION**

The Institute of Metal Forming and the Center for Computing and Communication of the RWTH Aachen, in cooperation with SMS Demag AG, are implementing a joint project which utilises the advantages of the VR tool. In a preliminary project, initial investigations were made into the utilisation of VR technology in the field of metallurgical plant and rolling mill technology. One of the project activities was to create a three-dimensional functional model of a CSP cast-rolling mill for presentational and marketing purposes. The aim of the continued cooperation is to make use of new information and visualisation techniques as aids to this process, and to make it more efficient.
technologies to enable an overall visualisation and simulation of the CSP cast-rolling mill to be realised in an integrated technological context with the utilisation of different media in a virtual environment (see Figure 1).

Initially a visualisation portal was created to enable the observer to “become immersed” in individual plant areas or components (see Figure 2). To aid this, the plant and the environment are displayed and supplementary information is then provided to supplement the pure visualisation. Simulation results are incorporated and online simulations performed, the results of which are displayed directly in VR.

The portal provides an insight into plant areas which, owing to the machine cladding or excessive heat, are simply not accessible when visiting a steel plant. Furthermore, it makes it easier for the designers to examine their design than with conventional simulation technology. The areas of application of this portal at SMS Demag AG include marketing, technical sales, instruction and training of customers and employees, improvements in communication between customers, SMS Demag corporate divisions and suppliers, and project planning of new plants.

**VISUALISATION**

On the basis of CAD models from the SMS Demag design departments, a virtual CSP cast-rolling mill was generated. Until now the models had been reworked manually, but automatic processes are now being developed to be able to convert and optimise the CAD models relatively easily. The portal is visualised using the VR software ViSTA (Virtual Reality for Scientific and Technical Applications) from the RWTH Aachen with the objective not only to merely display the plant, but also to present and provide the technology. This takes place on various visualisation levels as shown in Figure 3.

Starting from the integrated plant level (level 1) it is possible to select individual objects. After selection the observer automatically approaches the selected plant area and reaches the second level. From this second level onwards, a 3D menu appears in the application where supplementary information and detailed models or calculation results can be selected. The structure makes it possible to integrate random information, such as photographs, pictures, dynamic 3D graphs, videos, animations, tables, panorama view pictures and FEM simulation results. Due to the extensive range of different types of information and the ability to combine information, it is possible to explain complicated subjects in a comprehensible manner. Furthermore, the portal can be expanded in terms of modelling depth (further levels/vertical) and in terms of modelling width (linking of upstream or downstream process steps/horizontal).

**AUTHORS’ TOOL**

Models and supplementary information can be incorporated in the portal and tailored towards certain target groups, for example, customers or technical personnel. The integration of information is also possible as the models are being operated. The supplementary information is entered or its composition modified via a user interface (see Figure 4) with the display in the VR environment shown on the left and the hierarchy of the model shown on the right. The user sets up the virtual plant in a hierarchical structure then selects the position, orientation and graduation of the models. This enables the user to put together any desired plant layouts or, by replacing models, to incorporate the current data from the design departments. The bottom window shows the currently available supplementary information and its hierarchical structure. Here also, the user can influence the hierarchy and define those points in the model where the information appears.

**SIMULATION**

Certain results such as FEM can, due to the long...
calculation times, only be incorporated as supplementary information. Here the result data can be analysed as part of a post-processing operation. However, the portal should also make it possible to deal interactively with simulations and their results, enabling users to perform simulations both for the entire plant or for selected sections. As with the visualisation levels, the simulations are classified into a hierarchical structure (see Figure 5).

In its horizontal extension, the matrix shows the individual sections of the plant, from the casting machine to the coiler area. The observation level is represented in the vertical extension and extends from a global resolution to the atomistic resolution. The previously existing simulations have been incorporated into this matrix.

**LOGISTIC SIMULATION**

The topmost level constitutes a logistic simulation throughout the overall process to determine the product position within the plant on the basis of calculations for constancy of volume. This enables, for example, the material flow and plant capacity to be optimised by means of parameter variation. InControl’s logistic software Enterprise Dynamics (ED) is used for this.

The logistic simulation of a production plant is oriented according to objects and events in ED. It contains modules (atoms) which represent active or passive devices of the production plant, and product atoms which represent products. Special features of the CSP cast-rolling mill compared with standard plants in logistic simulation are the deformation of the products and the stretching of the product over several modules. Consequently, a product is no longer defined by a single product atom but by two atoms, which represent the tail end and the head end of the slab. These may have several positions, orientations, speeds or geometries. Within the logistic simulation, it is possible not only to simulate the material flow in the plant but also to assemble any plant as desired by using the plant components made available. By means of ‘drag & drop’, plant components can be withdrawn from a so-called module library and inserted into a model view. Here, the position, size and further parameters are specified and then automatically correspond to a representation in VR. An example is shown in Figure 6. The respective model layout can be seen at the top, and the representation in VR at the bottom. At first, only the ladle turret framework is present in the layout, then on inserting the module for the casting machine, the model appears automatically in VR and plants can be assembled as desired. Communication between the logistic software ED and ViSTA takes place via a TCP/IP connection.

**SIMULATION OF MULTI-FIELD PROBLEMS**

It is not meaningful to perform detailed calculations for the entire plant. Such an approach would greatly exceed the currently practicable limits for both computation times and data quantities. At certain locations, therefore, the option is available for performing more detailed simulations for sub-areas of the plant (e.g., pass schedule calculation for the rolling mill or FEM simulations for a mill stand). The calculations are made in the simulation programs and the results are then communicated to the VR software. As well as logistic simulation, all the other simulations are at present linked offline to the VR. Two examples are described below.
Examination of flow effects in continuous casting

The interest in optimisation of flow technology in continuous casting is increasing in accordance with growing demands relating to productivity and quality of the cast product. Thus, for example, the internal and surface quality of cast products can be improved by influencing the flow in the tundish. An example of such examinations is the design of the flow configuration in such a way that during the unsteady operating phases (filling, ladle changing and emptying) no flow conditions can arise which would impair the product quality due to an increased quantity of non-metallic particles in the slab. The ‘FlowLib’ module of the ViSTA software makes a comprehensive set of functions available for the interactive exploration of simulated flow phenomena in virtual environments. Figure 7 is an example of the visualisation of the results in the virtual model of the plant. By means of the interplay between the plant and the results, the results of the simulations are very clear, even to non-technical observers. By making changes which can be illustrated at the model (eg, a different cooling strategy), the effects on the product can then be made visible by visualising the new results.

FEM examination in the mill stand

As with casting there is a growing interest in FEM calculations to provide a better understanding of the processes involved in the various plant areas: furnace, mill stands, cooling section and so on. For the stand area, initial results have already been calculated and have been incorporated through result visualisation. In this case an alteration to the parameters such as roll positioning can then be displayed in the virtual model with visualisation of the resulting changes in the product.

The simulations shown here, as well as the logistic simulation, flow effects in continuous casting and the FEM examinations in the mill stand, have already been integrated into the portal and can be incorporated via the authors’ tool. It is intended to implement further calculations.

CONCLUSIONS

A visualisation portal has been created to enable the observer to ‘become immersed’ in individual plant areas or components. Additional information can then be incorporated into this portal providing simulations such as a logistics variation with real-time ability to be conducted. Time-consuming simulations, for example FEM calculations, are integrated offline via result files. The results are directly displayed in VR and can be analysed in a post-processing system.

The areas of application of this portal at SMS Demag AG include marketing, technical sales, instruction and training of customers and employees, improvements in communication between customers, SMS Demag corporate divisions and suppliers, and project planning of new plants. The examples of detailed simulation presented illustrate that the hierarchy used makes it possible to integrate any desired expansions both in terms of further levels and further plant components.

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