Fast simulation models of rolling processes for online applications in process computers

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Most of today's manufacturing and production processes would be unthinkable without extensive automation and control. In order to meet or even to top today's product quality levels, the knowledge of the processes as well as the devices, machines and plants realising these processes is essential.

In general, a "process" may be understood as the realisation of state changes of physical objects (e.g. materials, workpieces, pieces etc.). As integrated components of devices, machines and plants, actuators are to take appropriate action on processes, hence, they may be regarded as parts of a process as well as the machine realising this process.

If we want to understand processes and machines at least roughly, if we want to make predictions of their behaviour and to develop significant knowledge of them, we always have to use some kind of models or at least exemplary idealised images. Such models may be seen as maps of reality onto a significant representation of reality in order to make valid predictions of reality. Of course, the maps are dependent of the specific view on reality in terms of interesting effects, detailing degree etc..

The use of appropriate models is essential and becomes extremely helpful, unless indispensable, if the processes get more and more complex. This is especially true for metallurgical plants and the according manufacturing processes such as sheet rolling processes, which due to rolling speeds up to 40 m/s are highly dynamic.

Deep insight into these processes and plants may be extracted from mathematical models. Hence, they serve as an excellent basis for design, automation and control and are therefore widely used for (not only) rolling technologies in order to predict the behaviour of the material during production and respectively of the plant during operation. This helps to improve the design of the plant (offline calculations) and to guarantee exact presetting of controllers and automation systems during operation (online calculations performed in process computers) in order to manufacture a specific product with the narrowest tolerances.

Due to the high speed of these processes and the fact that each coil may differ from the previous coils, the amount of time for the online calculation of preset values in process computers is very limited. More than this, some of the parameters of the used models have to be identified and adapted by "post-calculations" representing classical inverse problems, the solution of which may multiply the computational effort. This situation shows that the requirements for fast online simulation models of "high speed" manufacturing processes are extremely high.

For some specific examples it will be shown how the combination of tailor made physical models and the tuning of numerical algorithms may help to reduce the calculation time drastically. Small, pretendedly unimportant modifications of the physical model may have severe consequences on calculation time showing the strong interaction between physical model basis and numerics. The utilisation of a priori information from the physical model may be of great benefit to the numerical algorithms being a big chance for the improvement of the performance of online simulation models.

Despite the significant progress in computer science and numerical methods, for a lot of online calculation problems of highest relevance to manufacturing, no satisfactory solution is available up to now.