Parallel computing of temperature fields on layered finite-element mesh

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Computer aided simulation of foundry technologies is an important part of product life-cycle engineering and digital production. WinCast is the software for simulation of cast metal solidification and has been developed by RWP GmbH (RWTH Aachen University), Germany. It's possible to use it in the next generation of automated technological equipment for process control in the real-time operation mode. The results of instantaneous simulation could be used to adjust the technological parameters in accordance with current sensor readings and predicted metal defects. In this connection, the acceleration of temperature computing and metal quality simulation is an actual problem to be solved. Improving the parallel algorithms and using the parallel computing systems can effectively accelerate the simulation.

TFB module of WinCast program is solving transient heat conductivity equation by finite-element (FE) method to calculate temperature distribution in the casting and in the mould during solidification. For this purpose the WinCast preprocessor creates the layered finite-element mesh following the strategy of breaking down (slicing) 3-dimensional STL geometry into several 2D/3D layers by horizontal cutting planes. In WinCast finite element is a pentahedral prism with changeable angles which could be variated to approximate any relief surfaces by element faces. Acceptable variations of the prism angles could be achieved by changing X- and Y-coordinates of nodes in cutting plane and Z-coordinates within the layer. The number of nodes is a constant for the plane and could be changed simultaneously for all the planes of the mesh. The number of prisms has the same value in each layer. Dimensions of prisms in Z-direction usually coinciding with the direction of gravity could differ.

Iterative solution of equation system proceeds using Gauss-Seidel method or PCG. Gauss-Seidel procedure is not proper method for parallel system since it uses the intermediate results of two consecutive steps. On the contrary, solver PCG (+ MPI) can reduce the computation time by 50% using four cores. Increased productivity is also achieved with the automatic generation of layered mesh from the contours of the cross section in each layer. Layered mesh is a precise presentation of cast object for simulation of melt behavior and also, it's suitable for parallel processing.

Finally, the total time required to obtain the calculated temperature field and solidification defects can be reduced to some minutes. The achieved acceleration of temperature computation permits to embed WinCast module into automatic control system equipment. The objective of simulation module is to get operational forecasts of the expected quality for control unit making a decision to change the process parameters.