# Exploit the Casting

## Optimized design processes by exploiting the full material performance: Computing local properties and residual stresses empowers engine casting development

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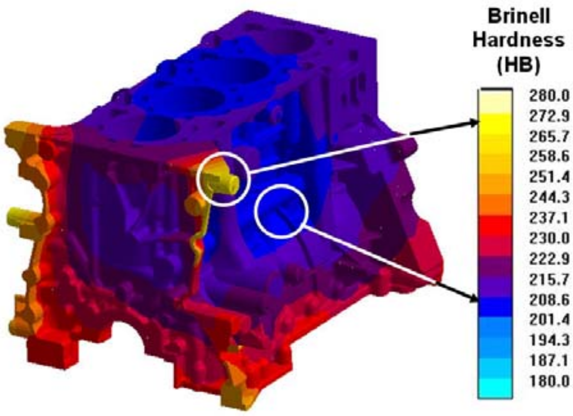
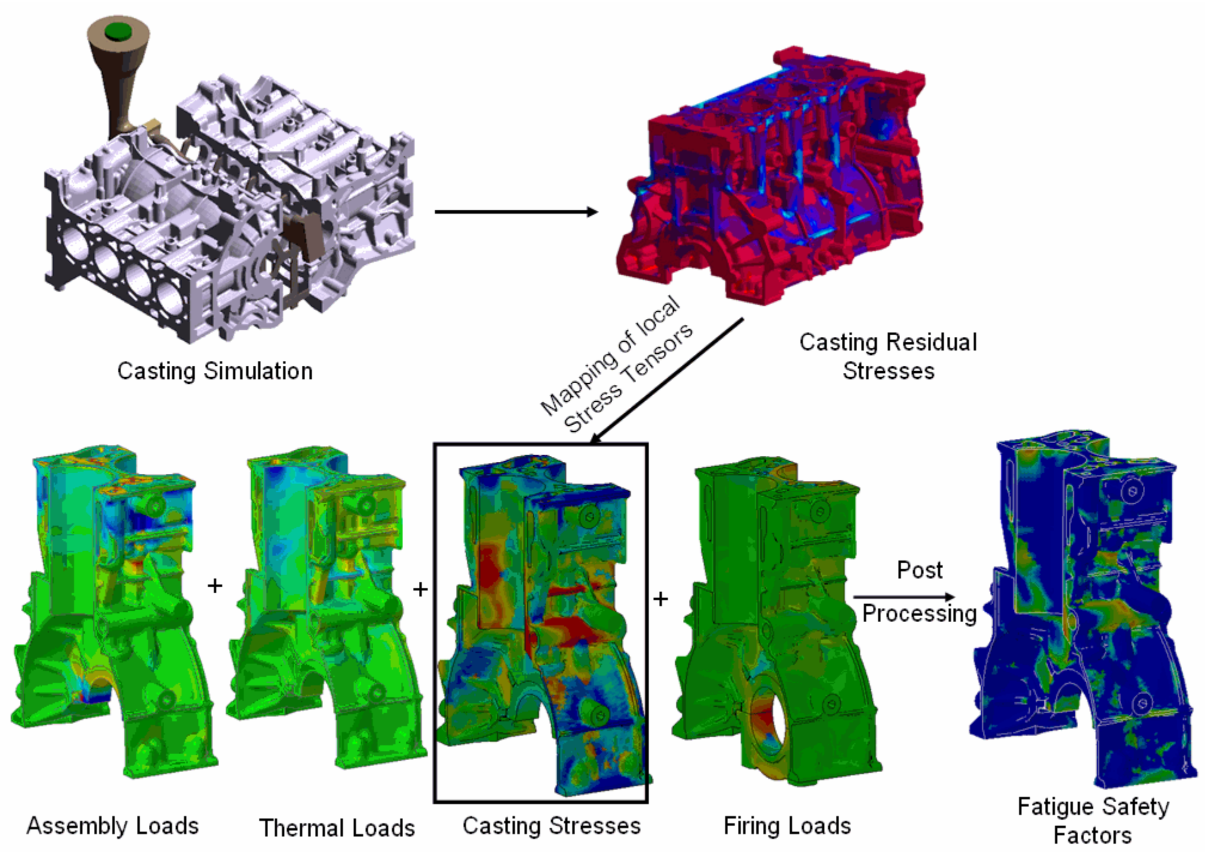
**The properties of cast iron cylinder blocks are never uniform.** In cast iron components, differences in wall thickness and other shape factors result in inhomogeneous cooling, solidification, microstructure, and properties throughout the casting. The same factors also produce residual stresses.
The experienced foundry man will have some ways to smooth out inhomogeneous microstructure and to moderate residual stresses, but often the effect is too small.
Standard CAE procedures for engine castings typically do not account for inhomogeneous properties and residual stresses, while advanced engine design optimization suffers increasingly from a mismatch between CAE durability prediction and test bed results in the context of ever increasing performance / weight ratios. These manufacturing process related characteristics need to be known and considered early in the design process.
The key to success is “Integrated Casting Process Simulation”. This technology allows to predict local properties and residual stresses and to feed them into the FE analysis and durability calculations.

**Excessive hardness causing machining problems? They can be predicted and avoided.** This cast iron prototype engine block features peak hardness values of HB 260 compared to an overall value of HB 200 (calculation with MAGMASOFT®). The only way to stay within FORD specification limits turned out to be a design change. Casting simulation provides all this information early in the process, avoiding time- and budget-intensive modifications.



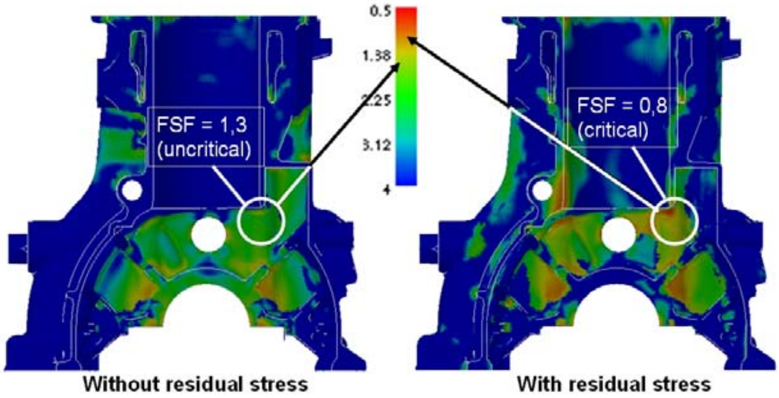

***Predicted hardness is outside the specification***

**Residual stresses impact the casting's durability.** Inhomogeneous cooling and other effects during shrinking of the casting in the mold inevitably produce residual stresses. The local stress values can only be predicted by casting process simulation, utilizing advanced non linear elastic/plastic material models. In this cast iron prototype cylinder block they range from 130MPa tensile stress to 100MPa compressive stress (calculated with MAGMAstress). These values are not necessarily disadvantageous, but can even be beneficial, especially where compressive stresses are involved. The real impact of residual stresses on fatigue life of the casting can only be predicted by integrating the casting process simulation into the CAE durability analysis.




***The value proposition: "Integrated Casting Process Simulation"***

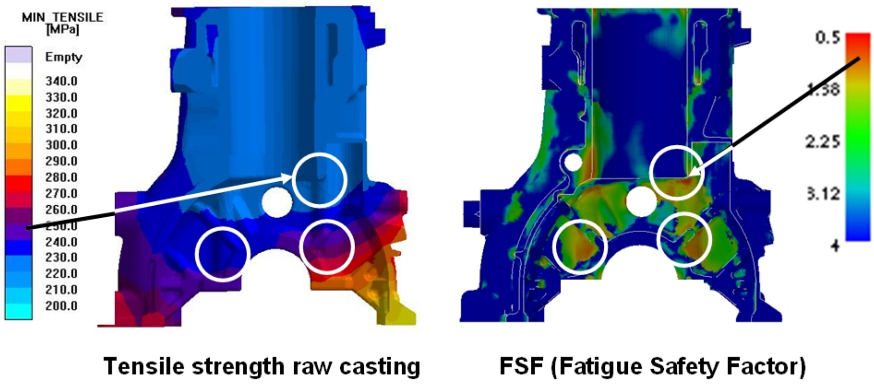
The durability analysis including residual stresses showed Fatigue Safety Factors (FSF) different from an analysis without residual stresses. In some sections, especially where tensile stresses were predicted by the casting process simulation, the FSF values reach limit values. This "new picture" of failure probability correlates well with engine test experience, proving the significance of the integrated procedure and the potential to avoid time- and budget-intensive test based modifications.




***Makes durability calculations more reliable: residual stress under consideration***

The accuracy of the casting simulation has been validated by strain gage measurements. Calculated and measured values were found to be in a range of +/-50MPa, which can be rated as a satisfactory match.

**High strength supports, low strength jeopardizes fatigue life.** Due to the functional relationship between process, microstructure, and properties, all manufacturing processes form characteristic distributions of mechanical properties. Typically, the designer assumes a uniform distribution of e.g. tensile strength according to the specification, but the reality is different. The foundryman takes care, that e.g. in a GJL250 cast iron cylinder block the required 250MPa will not be underran. At the same time, due to inhomogeneous microstructure, in some areas of the casting this value will be exceeded. This leads to the situation, that uncritical sections (high strength – low load) are sometimes unproportionally oversized, offering new potential for weight reduction.




***Local strength should support fatigue safety***

**So what is it all about?** Castings are characterized by inhomogeneous mechanical properties and residual stresses. Due to local solidification and cooling conditions, a typical GJL250 crankcase experiences local tensile strength values from 220MPa up to 340MPa, and residual stresses between 100MPa compressive stress and 130MPa tensile stress.

The inhomogeneous distribution of properties does significantly influence the behavior of castings under load as well as their durability performance. To reduce development cost and time, the inherent risks and the potential of production processes need to be identified and exploited long before SOP.

The solution is *"Integrated Casting Process Simulation"*, implementing casting simulation into FE analysis and fatigue calculation.