>Forge3® v6.2 simulates heat treatment...

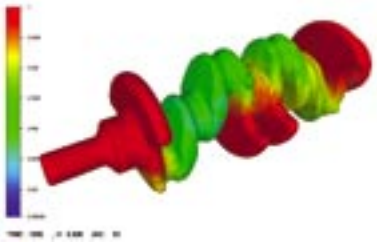
Heat treatment is a very important step in the series of processes used to manufacture a metal part. It gives to the material most of its final characteristics (micro structure, strength, hardness,...). The features of Forge3® have been extended to simulate the quenching of carbon steel. This heat treatment consists of heating the part above the autenisation temperature (about 800°C) followed by cooling to room temperature. During cooling, the microstucture evolves, residual stresses are generated and the part may distort. Thus, the quenching simulation will predict the final microstructure of the part, the residual stresses and distortion.

The inputs required for a quenching simulation are easily entered through the quenching template in the Forge3® pre-processor.

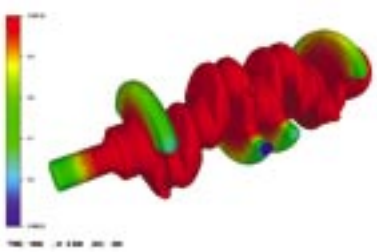
> Quenching of a Crankshaft with Forge3®

The main objective for any company is to optimize the quality of forged parts together with a reduction in production costs. In this example, we illustrate the use of simulation to define a shorter cooling time to give a bainitic structure of a crankshaft made of 35MnV7 Steel.

Several FORGE3® simulations have been completed in order to obtain the optimised configuration. The following figures show the bainite results for 2 different cooling conditions.

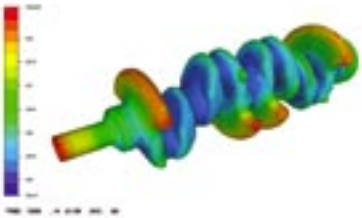


Strong cooling condition
52% < % Bainite< 100%

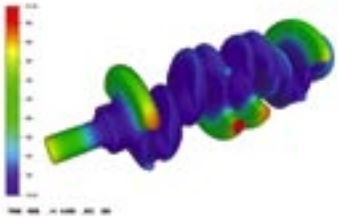


Optimised cooling condition
99.8% < % Bainite< 100%

Forge3® is also able to predict hardness. In the case, of the strong cooling condition, the martensite induces higher hardness in some zones of the crankshaft.

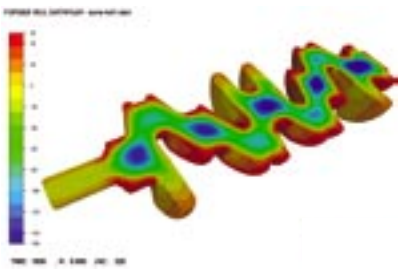


Strong cooling condition
320 <Vickers Hardness< 520



Optimised cooling condition
280 <Vickers Hardness< 290

Another important result is residual stress. The pressure is presented on the following figures for both configurations.
The strongest cooling conditions produce higher residual stresses.



Strong cooling condition
-150 Mpa <Pressure< 50 Mpa

Optimised cooling condition
-25 Mpa <Pressure< 15 Mpa

Courtesy of PSA (France)

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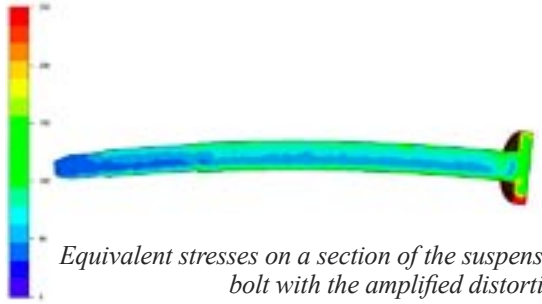
> Prediction of distortion with Forge3®

A feature of the Forge3® v6.2 simulation is the ability to predict residual stresses and distortion resulting from quenching operations.
This example shows bending which occurs during the quenching of a suspension bolt. Several FORGE3® simulations with different thermal conditions have been carried out and the deflexion of the suspension bolt has been measured at different points.

The results show that non-uniform heat exchange during quenching influences the distortion of the part.

This is illustrated on the following figures: the equivalent stresses are presented on the distorted suspension bolt. The value of the deflection may reach 0.2% of the suspension bolt length.

Two sets are defined with 2 different thermal exchange coefficients



Equivalent stresses on a section of the suspension bolt with the amplified distortion.

The conclusion is that a good control of cooling for this process is necessary to avoid bending.

> Forge2® v3.1 and Forge3® V6.2 technical features for quenching:

Forge2® v3.1 and Forge3® V6.2 include new technical features for the quenching of carbon steels.

The metallurgical structure evolution during quenching is represented through the TTT (Temperature-Time-Transformation) diagram - also called IT diagram.

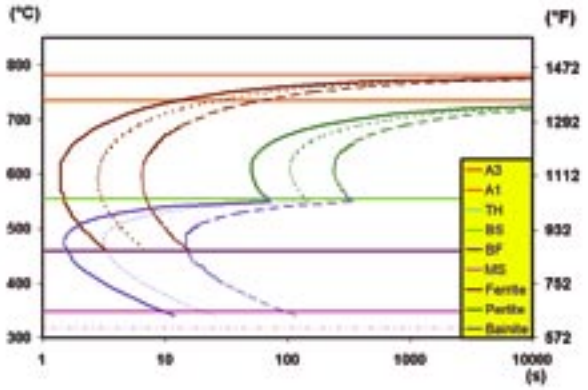
This diagram is obtained from a series of isothermal quenchings. To obtain a global behaviour law of the material for any transformation evolution, Austenite, Ferrite, Pearlite, Bainite and Martensite are each characterised as a function of temperature.

A data base is included in the Forge3® package that enables users to run quenching simulations for a large range of low alloyed carbon steels.

The GLPre pre-processor in Forge3® uses a specific quenching project template. This means that the user can easily setup a quenching simulation in a matter of minutes.

Due to its fully thermo-elasto-viscoplastic coupled model, Forge3® enables the users to perform very accurate simulations.

Example of data available within the data base:



These curves represent the TTT diagram for 4140 (40CrMo4) steel with an initial ASTM grain size of 7-8.

Results from the computation include:

> the percentage of each phase
> hardness of the part
> residual stresses in the part
> shape change of the part and distorsion

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