

CATCHING UNCERTAINTIES IN STEEL WIRE DRAWING

Multilevel Monte Carlo to the rescue

H2020 SOCIETAL CHALLENGES: Climate action, environment, resource efficiency and raw materials

PRODUCTIVE SECTOR: Materials

PROBLEM DESCRIPTION

Bekaert is a world market and technology leader in steel wire transformation and coating technologies, processing about 3 million tons of steel wire each year. To further increase the steel wire quality, Bekaert wants to reduce the various uncertainties in the wire drawing process using novel methodologies from uncertainty quantification (UQ).

CHALLENGES AND GOALS

High-dimensional: the presence of many uncertain parameters render classical UQ techniques impractical

Expensive simulations: a single simulation with fixed parameters takes several hours to even days

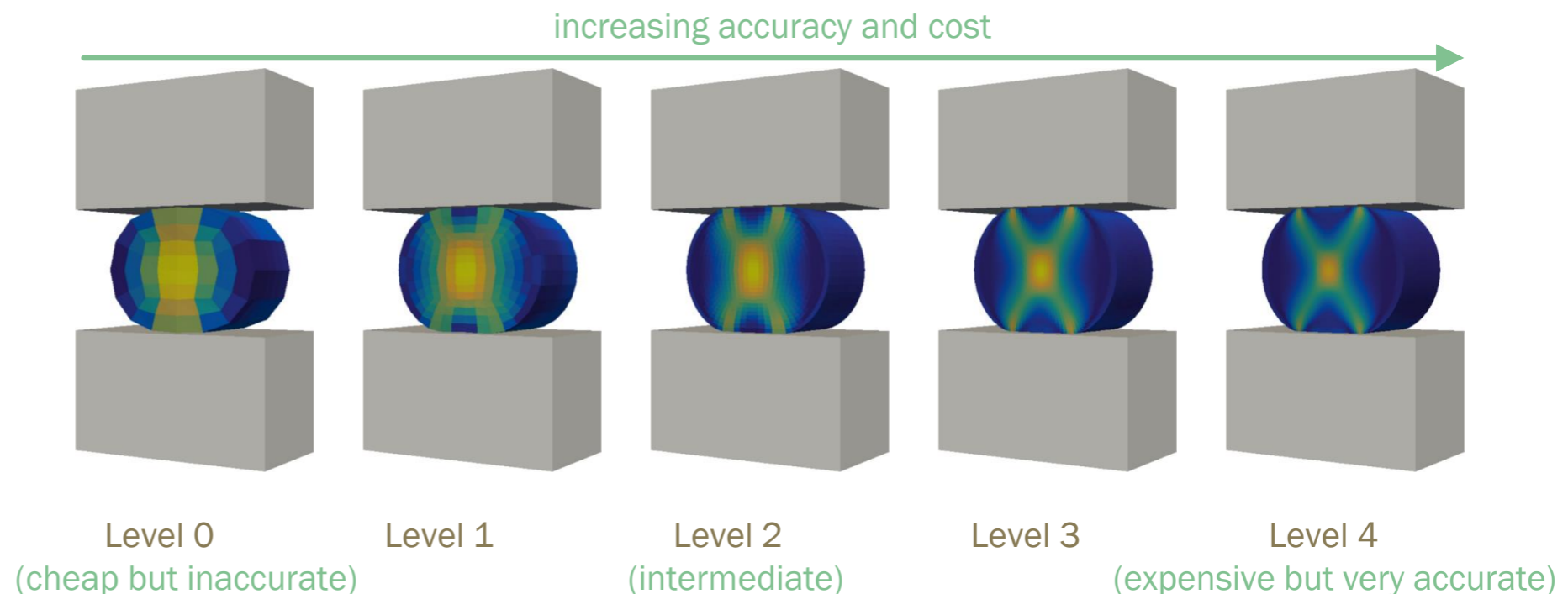
Industrial test case: not every parameter combination is feasible for the deterministic solver

MATHEMATICAL AND COMPUTATIONAL METHODS

Wire drawing reduces the cross-section of a steel wire by pulling it through a single (or a series of) drawing die(s). A mathematical model describes the non-linear plastic deformation of the wire. In this model, **many uncertainties** are present: geometrical (wire diameter, wire shape), physical (wire strength, yield) and process-related (approach angle, drawing speed).

Sampling techniques, such as **Monte Carlo**, repeatedly pick random values for the uncertain parameters and evaluate the associated model output. However, such techniques are too expensive to analyze the impact of uncertainties, since many model evaluations are needed.

Instead, a **multilevel sampling strategy** is used: if the model is accessible on different levels of accuracy (e.g., by using different finite-element grids), samples on different levels can be combined, such that many computationally cheap samples are taken on the coarse grid, and only few expensive samples are required on the finest grid.



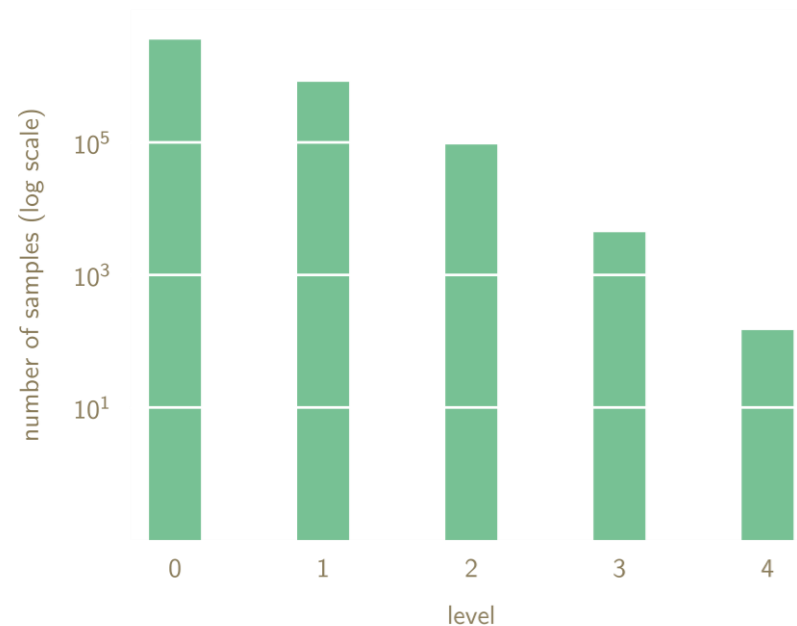
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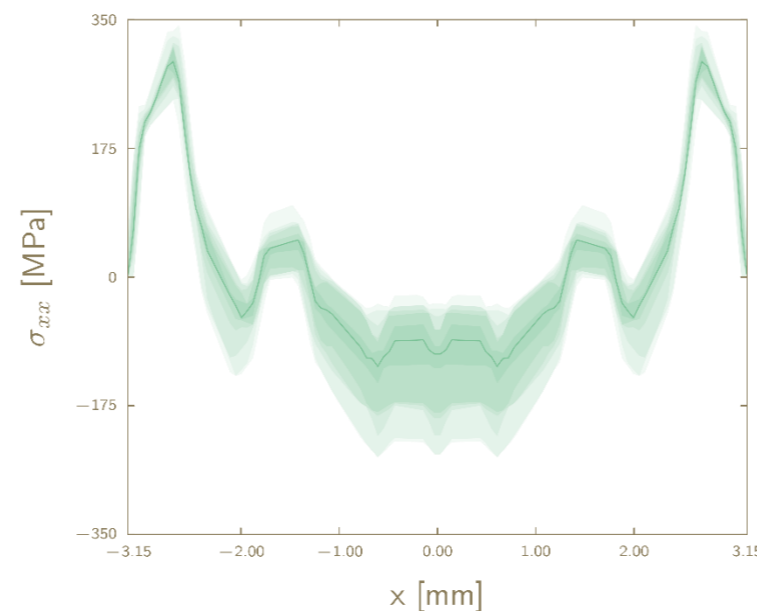
Results and Benefits

Using the multilevel sampling approach, statistics of a quantity of interest can be computed much faster compared to previous UQ methods.

- Our **Multilevel Monte Carlo** method takes **12 days** to compute the expected value of the drawing force (relative error of 1%)
- Our **Multilevel Quasi-Monte Carlo** method takes only **4 days**
- On the same hardware, classic **Monte Carlo** approach would take **1.5 years!**

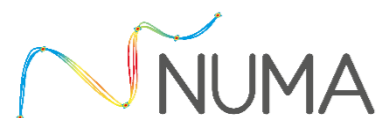


Distribution of the number of samples across the levels



Example outcome: uncertainty on the tensile stress in a cross-section of the wire

Using novel multilevel sampling techniques from uncertainty quantification that dramatically reduce the cost of a numerical simulation, the steel wire company Bekaert can produce steel wire with more reliable properties.



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