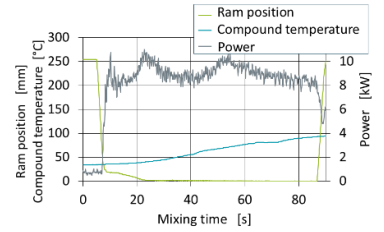
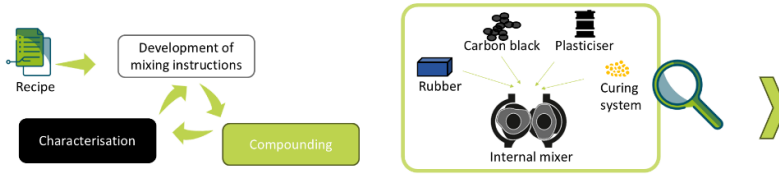




Challenges in rubber compounding

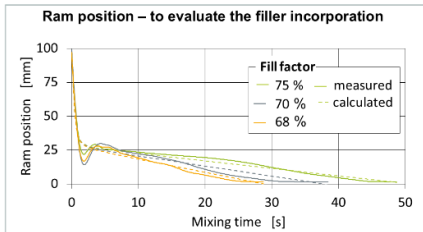


- Components such as rubber, fillers, plasticisers and chemicals, which differ for example in their chemical composition, aggregate state, viscosity or particle sizes are added to the discontinuous internal mixer.
- The development of mixing instructions is time-consuming and often knowledge-based, so that in most cases only local optima can be found.
- The mixing process aims to break up the filler agglomerates (dispersion) and to distribute all components homogeneously.
- For the evaluation and thus the prediction of mixing processes, mixing curves are used, which are recorded for each mixing process and show the development of power, ram position and rotor speed over time. These mixing curves can be used to analyze and optimize mixing parameters.

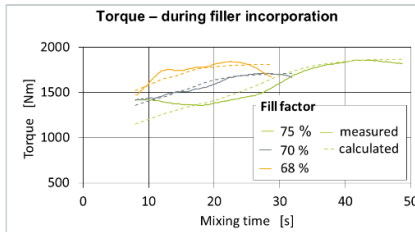
Simulation

To establish a correlation between the process parameters, the recipe components, and the mixing process, models are developed that describe, for example, the incorporation of fillers or the temperature development of the compound. The models are based on structured data sets and physical material parameters. By integrating these models into the InSuKa database, a transfer to other mixing processes is made possible.

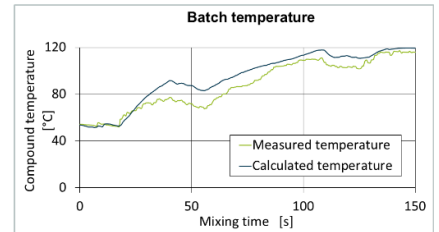
Predicting the development of mixing curves



- Carbon black is used as a filler in the production of compounds.
- The incorporation of carbon black into the polymer matrix is described as carbon black incorporation.
- As a practical indicator of the carbon black incorporation time, the ram down time is used.
- The ram position as a function of the fill factor is presented as an example (measured: based on experiments, calculated: based on simulation data).

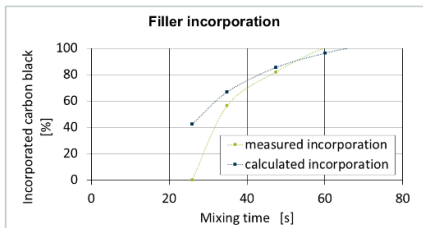


- The calculation of torque is essential for determining the parameters resulting in the lowest possible energy input while ensuring sufficient filler dispersion.
- The incorporation of fillers increases the viscosity of the mixture, which leads to an increase in torque.
- In addition, process parameters such as the fill factor influences the torque.

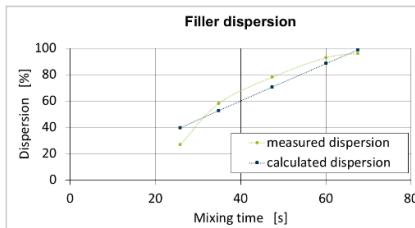


- Batch temperature control is essential.
- The temperature curve is calculated based on the energy balance of the mixing chamber.
- The temperature curve depends on the recipe and the process parameters.

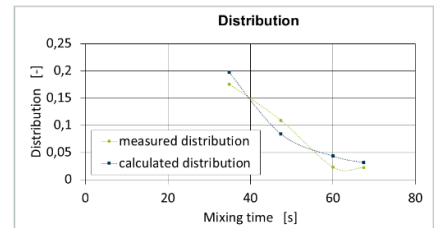
Predicting the mixing quality



- Here, incorporation is defined as the amount of incorporated carbon black compared to the amount of carbon black added.
- A value of 100% would therefore correspond to complete incorporation.



- Insufficiently dispersed fillers cause defects in the product, resulting in a reduction of product properties.
- Dispersion is defined as the area of undispersed carbon black agglomerates in relation to the measured sample surface area.
- A value of 100% would correspond to complete dispersion.



- The calculation assumes that the distribution can be described by the distribution of carbon black agglomerates.
- For this reason, the standard deviation of the dispersion is divided by the mean value.
- A smaller value represents a better distribution.



Outlook

The developed correlations and model equations are being expanded with structured data sets so that these can be adapted to further compounds. The simulations already developed and planned as part of the project offer the possibility to identify the best fitting recipes, including the corresponding processing, process, and material parameters, using ontology and intelligent search algorithms. For this purpose, the material parameters available in the InSuKa material database provide a basis for the simulation.

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