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Scientific line:

Digitalization and AI in forging

Title: Advanced Microstructural Prediction for Multi-Step Forging based on AI modelling

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Abstract:

Predicting the microstructural state resulting from any manufacturing process is crucial, as it directly determines the material's performance characteristics. However, existing analytical models have significant limitations in predicting complex technological processes. Their predictive capacity is restricted by the small number of process variables they can accommodate and the necessity of time-consuming and costly laboratory experiments for development and calibration.

A particularly challenging aspect is modelling multi-step processes that involve a sequence of forging and heat treatment operations. One of the main difficulties lies in determining which microstructural parameters should be transferred from one operation to the next and how best to correlate microstructural evolution with material properties.

To address this challenge, a predictive model based on a Long Short-Term Memory (LSTM) artificial neural network was developed and trained using experimental data from hot forging of Inconel 718 double-truncated cones. A dedicated, extensive dataset was created for this purpose, comprising comprehensive data from approximately 60 multi-step forging trials, including microstructural inspections at all intermediate stages.

The developed model was then blindly tested against experimental data obtained from the hot forging of disks and bevel gears, the data of which was not used in the model training phase. The predictions demonstrated superior accuracy compared to conventional analytical models.

The implementation of AI-driven modelling for microstructural prediction provided several key advantages:

- Enhanced prediction accuracy.
- Ability to capture certain observed effects that analytical models failed to describe.
- Direct utilisation of industrial data for model training.
- Significantly reduced simulation time.