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Scientific line: Lubrication in Forging

Title: Advanced Friction Modelling for Cold Forging: Comparison of Analytical and Neural Network-Based Friction Models

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Jonas Launhardt is a Research Associate and PhD student at the Institute for Production Engineering and Forming Machines (PtU) at TU Darmstadt. His research focuses on developing advanced friction models for cold forging, integrating machine learning techniques to improve simulation accuracy. His work covers tribological systems, finite element modelling, and environmentally friendly lubricants.

Holding an M.Sc. in Mechanical Engineering from TU Darmstadt, he also gained international research experience as a visiting researcher at Shanghai Jiao Tong University. In addition, he is pursuing a second M.Sc. in Computational Engineering. In 2023, the Industrial Association for Bulk Metal Forming awarded him the Karl-Diederichs Scholarship.

Abstract:

Cold forging is a highly efficient and sustainable manufacturing process, offering advantages such as improved material properties through strain hardening, high dimensional accuracy, and reduced energy consumption. Additionally, its lower CO_2 emissions make it an attractive option for environmentally friendly production.

However, one of the key challenges in cold forging is lubrication. Traditionally, black lubricants, for example based on zinc phosphate, are widely used due to their effectiveness in reducing friction and wear. However, they also generate significant heavy metal waste and contribute substantially to the process's carbon footprint. As a result, there is growing interest in sustainable alternatives so called white lubricants, for example based on polymer.

For accurate process design using FE simulation, realistic friction modelling is required. However, studies have shown that these environmentally friendly lubricants are highly sensitive to the extreme tribological loads encountered in cold forging—some of the highest in metal forming technology. Consequently, conventional friction models, such as the Coulomb friction law, are insufficient for accurately predicting frictional behaviour especially in FE simulation. Instead, advanced friction models that account for locally acting tribological loads are necessary.

This study compares two advanced friction models—an analytical model and a neural network-based model—against each other and the conventional Coulomb friction law. The applicability of the friction models is validated using two real reference processes. This diverse set of forging scenarios allows for a comprehensive evaluation of the general applicability and robustness of the friction models.

The results reveal significant performance differences between the models. While conventional friction models fail to capture the complex tribological effects accurately, the ML-based friction model significantly improves the predictive accuracy of numerical simulations. Specifically, it reduces the error in finite element (FE) simulations by 59% compared to Coulomb friction law. Moreover, the ML model is not limited to specific forging processes but can be flexibly applied across different forging operations.

These findings highlight the potential of modern, data-driven friction models to enhance simulation accuracy and process design in cold forging. By improving predictive capabilities, these models contribute to the advancement of sustainable and efficient metal forming processes using white lubricants.