Design of profile rolling processes

Semi-automated, numerical design and extension of the process limits with regard to output and shaping during profile rolling

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Abstract

The use of FEM significantly increases cost and time efficiency in the design of forming processes. However, it has so far only been used to a very limited extent in the field of profile rolling due to the demanding simulations involved. In this project, a contribution was made to ensuring that FEM simulations will be able to predict process failures caused by workpiece slippage in the future. Based on optical measurements in an industrial environment, the process boundary was comprehensively recorded and characterised. By implementing a multi-dimensional friction model in the FEM, the simulation was able to predict the rolling behaviour of the workpiece.

Project description

This research project deals with the digital process design of profile rolling processes, focussing in particular on component slippage as a common rolling defect. In view of shortened product life cycles and increasing component complexity, a transformation from empirical, iterative process design to knowledge-based and FEM-supported design is necessary. However, FE simulations face challenges, particularly in the inaccurate mapping of rolling behaviour in flat-die profile rolling. The assumed constant coefficients of friction for cold forming impair the validity of the FEM in the design process. There is also a lack of industrial experience and fundamental knowledge of the process limit due to slippage.

The main objective of the project is to characterise the process limit due to slip in detail and to record the influence of rolling strategies, tribological systems and the number of strokes. The identification of optimal rolling strategies is intended to maximise the output of flat-die profile rolling. The ability of the FE simulation to simulatively predict the process limit due to slippage is central.

The research procedure is divided into two parts: In the first part, the slip behaviour is recorded using force measurements and optical slip measurements in an industrial environment. In the second part, the FE simulation is enabled to reproduce the slip behaviour by numerically mapping the system behaviour recorded in the first part. Tribometer tests and simulations for measuring speed-dependent coefficients of friction are carried out, followed by the mathematical description of these coefficients of friction in a friction model. Finally, the friction model is integrated into the FE simulation to enable the desired prediction of the process limit due to slip.

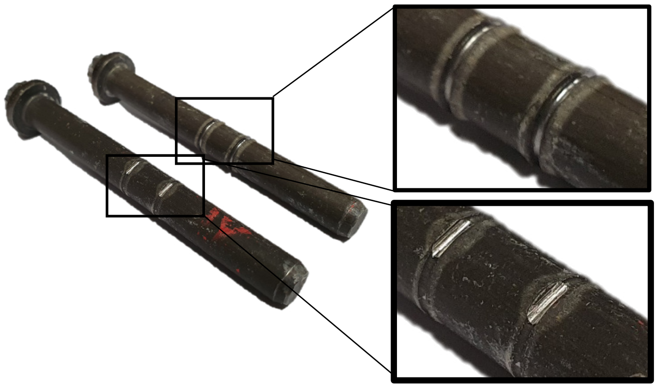
Results

Figure [1] shows the test tool used, the detailed geometry of the groove and the rolling strategies investigated. In addition to the rolling strategies, the tribological system was also varied according to the systems listed in Table 1 and the number of strokes between 10 and 70 strokes/min. The tests were carried out with the TR4 and TR 6 rolling die sizes.

The shape of the groove was categorised as OK and not OK by visual inspection using a projector as shown in Figure 1. Components in the „OK“ category have fully rolled grooves and no signs of slippage, while „not OK“ components have at least partially incompletely rolled grooves. parts have at least partially incompletely rolled grooves.

Table1: Tribological systems

surface	lubricant		surface	lubricant
phosphatet	oil *)		pickled	oil *)
phosphatet	dry		pickled	dry
phosphatet	polymer		pickled	polymer
*) industrial standard				



[1] Comparison between “okay” and “not okay” part with detailed view of the groove

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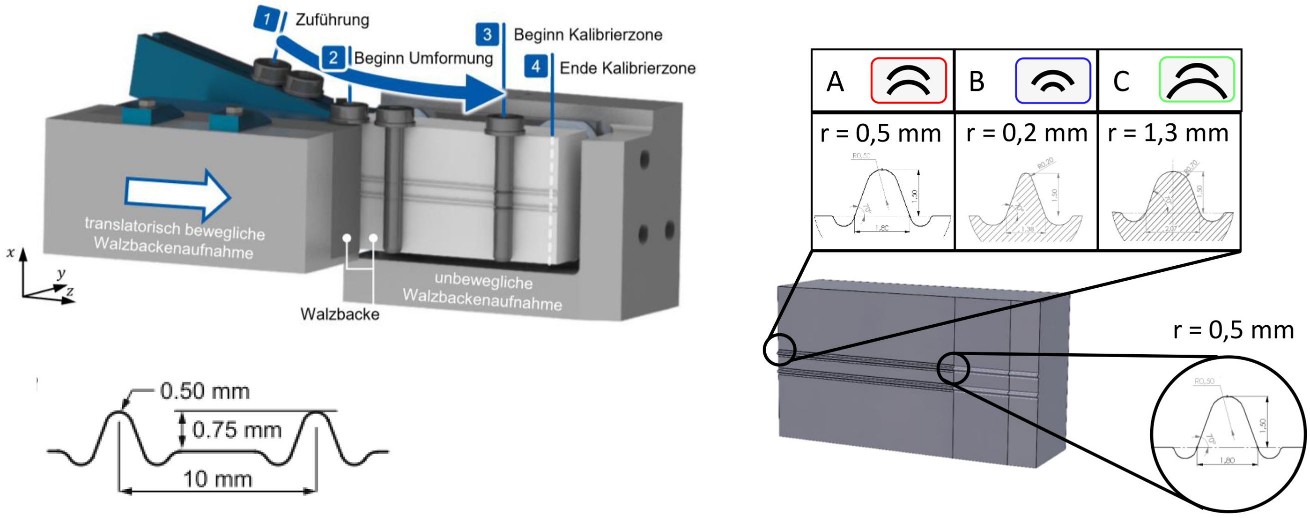
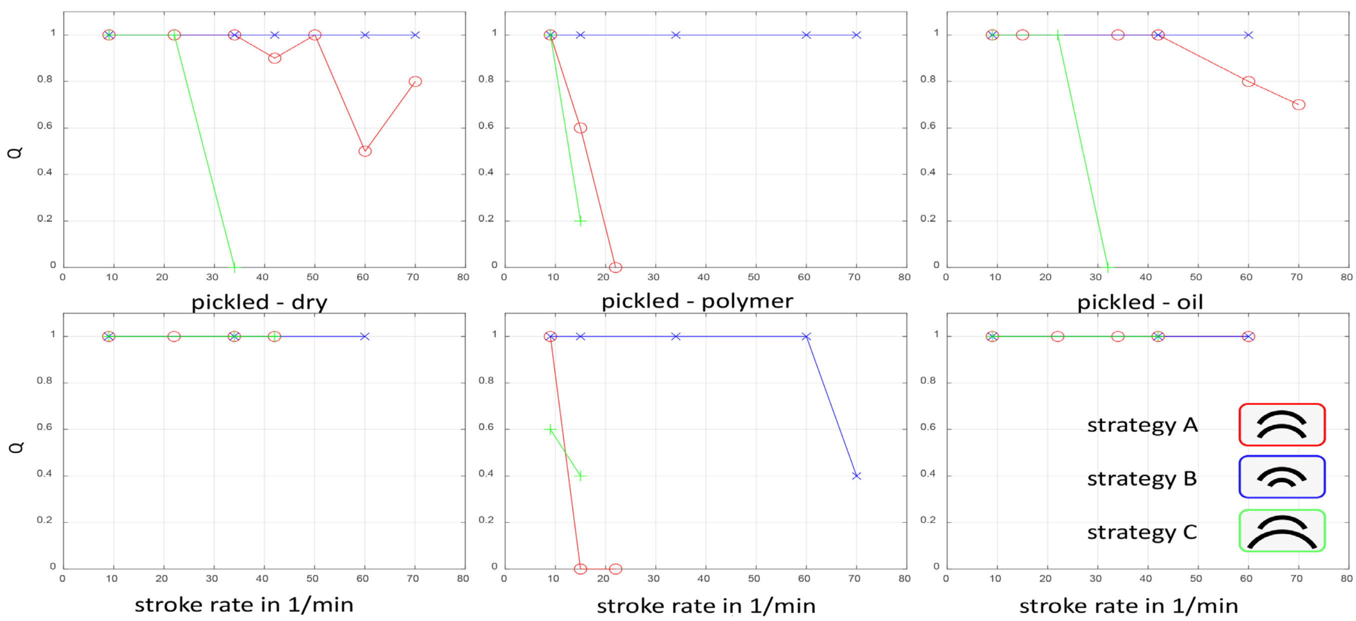


[2] Schematic depiction of the test tool, detailed view of the groove geometry, representation of the investigated rolling strategies with variable groove radius along the inlet zone

Figure 3 shows the proportion of i.O. parts (quotient Q) over the number of strokes for the six tribological systems and three rolling strategies investigated. It is noticeable that rolling strategy B allows higher stroke rates than strategies A and C before the process limit is reached due to slippage. Furthermore, it can be seen that the tribological system has a significant influence on reaching the process limit, whereby systems without phosphating can withstand higher stroke rates than systems with phosphating before slippage occurs. Systems with polymer lubricant show early slippage, which is why their suitability for profile rolling can be questioned. The tests with roller die size TR 6 confirm the results achieved with TR 4, whereby the process limit is generally shifted by approx. 10 strokes/min towards a higher number of strokes.



[3] Overview of the quotient Q as a function of the rolling strategy, the tribological system and the number of strokes. Rolling die size TR 4

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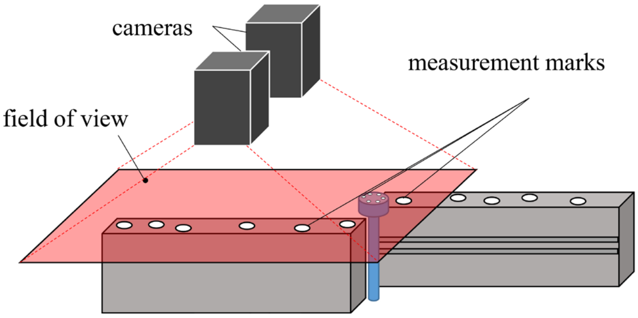
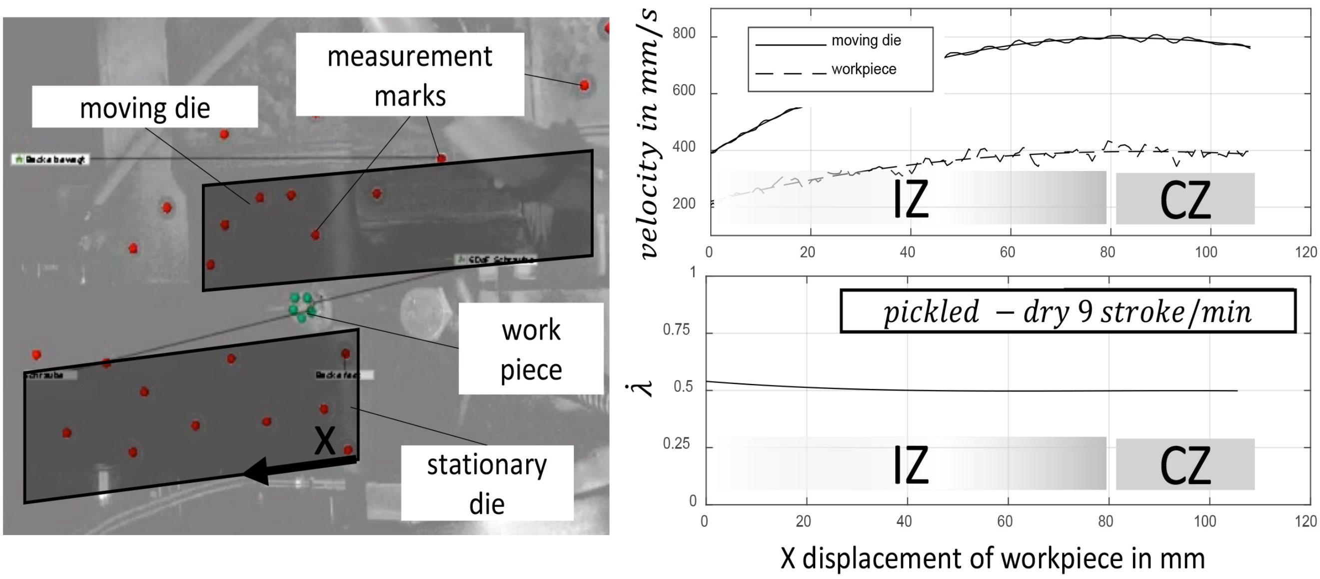
Optical Measurements
In order to analyse the rolling behaviour of the workpiece more precisely, optical measurements were taken using the Pontos system from GOM. Figure 4 shows a schematic of the optical measurement setup. The formation of the quotient from the speeds of the workpiece and the moving rolling jaw in the x-direction allows the rolling/slip behaviour to be analysed.

FE-Simulation and Tribometer
In order to map the experimentally determined process limit numerically, the coefficient of friction was defined as a function of the tribological loads, contact normal stress, relative speed and temperature instead of a constant coefficient of friction μ. The process limit due to workpiece slip could thus be modelled in the FE simulation as a function of temperature



[4] Schematic depiction of the GOM Pontos optical measuring system



[5] left: example from the optical measurements, right: displacement and speed in x-direction as well as quotient over the workpiece displacement in x-direction

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