Adaptive calculation of pass sequences for open die forging SFU 2023

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Abstract

Open-die forging is one of the oldest forming processes in history, which has been continuously developed through technical innovations. The rapid development in the fields of measurement and control technology and the computing capacity of IT systems in recent decades offer the opportunity to take open-die forging to a higher level. In order to establish a fully autonomous forging process, a forging cell is being set up at the Institute of Metal Forming at TU Bergakademie Freiberg. It consists of two forging presses, a furnace and a KR 360 L280-2 robot arm from KUKA as a manipulator with a load capacity of up to 280 kg. A 3D scanning system allows to capture the workpiece geometry between individual pass sequences or even single press strokes. Additionally, the scanning system is equipped with three thermal imaging cameras, which record the surface temperature during a scan. A central computer controls all individual components of the forging cell. The structure of the cell is shown in Figure 1.

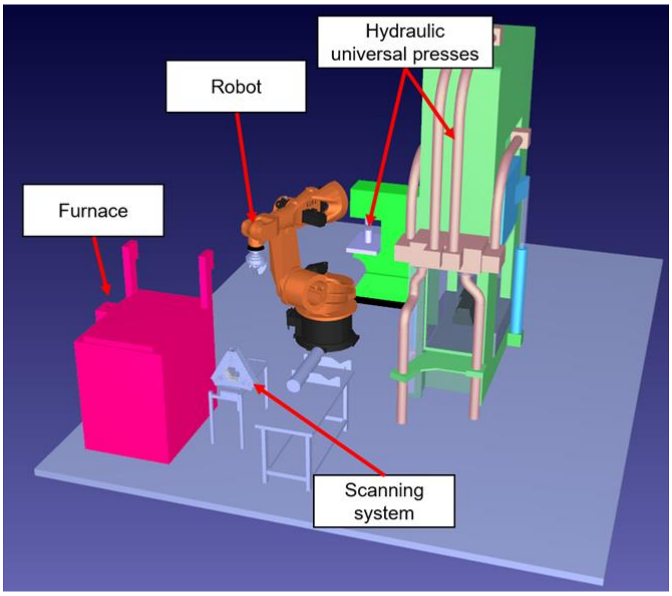

Figure 1: Structure of the forging cell

Based on the scan data, a digital twin of the workpiece is generated, which makes it possible to calculate the cross-sectional area at any measuring point along the workpiece axis. Besides calculating the pass sequence, the geometrical data are used to determine the total volume of the workpiece. The model used to describe the workpiece geometry of the digital twin is based on a cylindrical coordinate system. This enables a comparison of the cross-sections of any two geometries, in this case the actual geometry with the calculated target geometry. If the longitudinal axes of the workpiece and the target geometry are aligned, the increment for the cross-section positions to be determined are known and their angles are specified, resulting in a firmly structured data set in which two of three dimensions are already defined. Therefore, the geometry data of bot cross-sections to be compared differ only in the resulting vector lengths (see Figure 2). By comparing the vector lengths at any point, the required local reductions can be determined as shown in Figure 2 c).

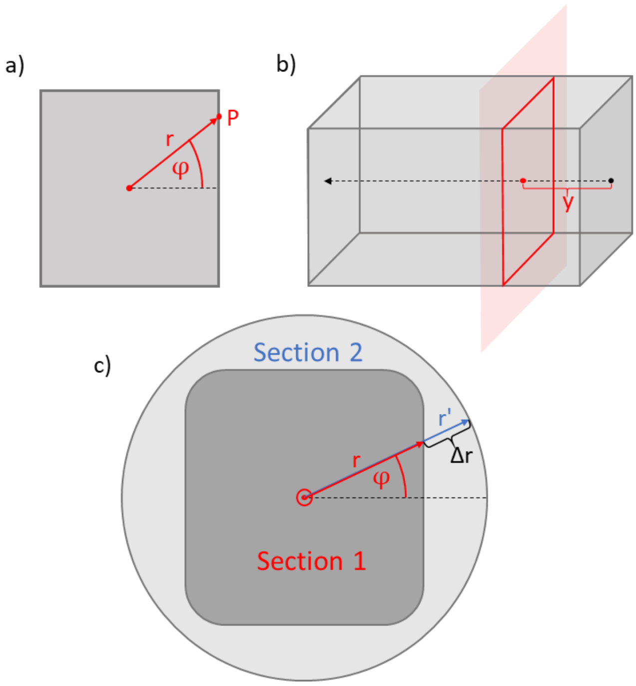

Figure 2: a) Vectorial geometry description of a square cross-section, b) Representation of the third dimension (longitudinal direction), c) Description of the difference in geometry between the initial geometry (cross-section 2) and the target geometry (cross-section 1) using vector length difference

The local forming requirements are used to generate a pass sequence using an algorithmic approach. Firstly, this algorithm weights the theoretically required reductions for all vectors in one cross-section. Secondly, it determines the most relevant angle at which the next pass sequence is to be made. To predict the forming, a material flow model based on the Tomlinson-Stinger equation is implemented. Considering volume constancy, the cross-section-specific spreading and the elongation for each stroke of the press is calculated. If a geometry violation occurs outside the workpiece-specific geometry tolerances, an alternative pass sequence will be calculated. The pass sequence is in turn executed directly by the robot arm and the forging press. Furthermore, the results of pass sequences are documented by automatically performed 3D scans between forging steps and the following sequences are constantly adapted. Monitoring the temperature during the measurements will allow algorithm extensions, with the aim to calculate heating strategies. At the current stage of development, stretch forging is initially being implemented as an example for a dynamic process. The current approach for calculating the forging process enables the implementation of further processes like open-die forging.

Keywords *Open-die forging, automation, forming technology, hot forming*