Summary

Hot press forming is an attractive technology for the manufacture of continuous fiber-reinforced thermoplastic parts in high volumes at low cost. The forming process can be challenging, however, as excessive friction between adjacent plies can inhibit material deformation, which may lead to defects. These forming-induced defects can be mitigated or even avoided beforehand by using process simulation software, although this requires an accurate description of, among others, the ply-ply friction. This thesis addresses the understanding and modeling of the transient ply-ply friction response of unidirectional thermoplastic composites.

The friction for two unidirectional (UD) carbon fiber-reinforced poly(aryl-ether-ketone) (C/PAEK) tapes in melt is investigated for different sliding rates, temperatures, and normal pressures. The experimental and modeling work demonstrates that the transient friction response, exhibiting a peak followed by a lower steady-state or long-time friction, can be explained with the concept of slip relaxation. This slip relaxation leads to the emergence of wall slip in the fiber-matrix interphase, gradually relaxing the shear stress. Novel friction experiments, where the sliding rate is varied during a test, further substantiate this notion.

The matrix viscosity and matrix interlayer thickness distribution at the ply-ply interface are used to successfully predict the peak shear stress. The addition of a critical shear stress for the onset of wall slip also enables the prediction of the long-time shear stress. Both are combined in a transient friction model with a description for the evolution of wall slip in the fiber-matrix interphase to describe the transient friction response, including stress growth at start-up and the transition from peak to long-time shear stress. The model correctly describes the key aspects of the measured varying-rate friction.

Finally, a 2D framework to describe the in-plane traction for arbitrary ply-ply sliding is proposed and the first steps are taken to implement this model in commercially available simulation software. Ultimately, this work contributes to first-time-right defect-free manufacturing of UD ply-based thermoplastic composite components.