An Approach for Rapid Prediction of Textile Draping Results for Variable Composite Component Geometries Using Deep Neural Networks

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Abstract. Continuous fibre reinforced plastics (CoFRPs) offer remarkable mechanical properties at low density and have thus drawn increasing attention in weight-sensitive industries over the last decades. Contrasting metals, manufacturing of CoFRPs consists of multiple steps, often comprising a forming process of a textile (draping). However, managing the inherently complex, anisotropic and non-linear material behaviour during textile forming and avoiding forming defects is a great challenge in serial production. To assess formability prior to manufacture, virtual process simulations can be applied [1]. For optimum part quality, component design and applied process parameters must complement each other, which in turn requires a high number of optimisation iterations and quickly exceeds reasonable computation times. Considerable effort has been made with respect to obtaining optimum process parameters, see e.g. [2-3], however considering geometry variations to achieve manufacturability is rarely addressed [4]. Deep Learning techniques using convolutional neural networks (CNN) are capable of learning complex system dynamics from supplied samples, see e.g. [5]. In the work presented here, CNNs are used to rapidly predict the textile forming result of variable component geometries. A large data base of highly variant geometries and corresponding draping examples is generated, on which the CNNs are trained. The paper shows, that CNNs are capable of reproducing the underlying forming dynamics and that they generalise well to unknown test geometries. Contrasting traditional meta-model approaches, the presented method estimates not just a scalar part quality attribute, but predicts the complete shear strain field, which facilitates engineering interpretation. The method is demonstrated on different geometries ranging from simple shapes to complex geometries. Being computational inexpensive, CNNs give immediate feedback for real-time geometry iterations during component design. Thus, CNNs are considered to be a promising and time-efficient tool to reflect manufacturability during part and process design.

Keywords:
Deep Learning, Textile Forming, Optimisation, Part Design, Machine Learning

REFERENCES

[1] P. Bussetta, N. Correia, “Numerical forming of continuous fibre reinforced composite material: A review.” in Composites Part A, Vol. 113 (2018), pp. 12-31.

[2] J. Pfrommer, C. Zimmerling, J. Liu, L. Kärger, F. Henning, J. Beyerer, „Optimisation of manufacturing process parameters using deep neural networks as surrogate models“ in Procedia CIRP, Vol. 72, 2018, (2018), pp. 426-431,

[3] S. Chen, L. T. Harper, A. Endruweit, N. A. Warrior, „Formability optimisation of fabric preforms by controlling material draw-in through in-plane constraints” in Composite Part A, 76 (2015), pp. 10-19

[4] C. Zimmerling, D. Dörr, F. Henning, L. Kärger, „A meta-model based approach for rapid formability estimation of continuous fibre reinforced components“, AIP Conference Proceedings 1960, 020042 ESAFORM (2018)

[5] X. Guo, W. Li, F. Iorio, “Convolutional neural networks for steady flow approximation”, in: *Proceedings of the 22nd International Conference on Knowledge Discovery and Data Mining*, (2016), pp. 481–490.