A scalebridging approach to quantitatively link microstructure and machinability of steels

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Turning operations on steels can be divided into the phases of chip formation, flow and breakage. Controlled breakage of relatively small chips is the most favoured material´s behaviour, but so far there are only few measures that would result in the desired behaviour, e.g. additions of sulphur.

In general, turning operations can be understood as dynamic ductile fracture phenomena under non-proportional strain paths. In this study, a new coupled damage mechanics model which considers the stress state and strain path is proposed for the steel C45E+N. The influences of stress triaxiality and Lode angle parameter on both damage initiation and subsequent damage propagation are investigated by a series of mechanical tests and numerical simulations. The damage evolution law is extended based on a weighting method for modelling the progressive damage evolution during complex loadings. A cut-off value concept is also taken into consideration to correctly describe the damage behavior under high hydrostatic pressure. The model is validated by various tests and shows high potential for failure predictions. It is implemented for modelling the chip breakage behavior in a machining process.

The outlook presents an approach to calibrate most of the parameters of the phenomenological damage mechanics model by virtual experiments on statistically representative volume elements. Influences of the state of stress on yielding are quantitatively predicted by these virtual experiments, and also the equivalent plastic strain to ductile damage initiation is predicted with high accuracy for selected states of stress. In future parametric studies, the influence of non-metallic inclusions on the chip breakage behaviour shall be investigated.