FEM Based Digital Twin for Online Estimation of Remaining Useful Lifetime of Mechanical Press Structures

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Mechanical presses are expensive investment goods. They are used for mass production of metal parts in automotive and other industry sectors. Uninterrupted operation and stable conditions to ensure constant quality of the stamping parts are crucial for the return on investment. During operation the press structure is exposed to high and oscillating loads which depend on the geometry of the die, the material, and the cycle time. This can result in the formation of cracks in frame components which can lead to a reduction in the stiffness of a press machine, which in turn can have a negative effect on the process result. To ensure a safe operation very often the loads are measured, for example using pressure sensors within the overload protection system at the press points of the slide. In our presentation we describe a method to use these measured data for estimating the crack formation based on computational fatigue assessment of components to estimate the remaining useful lifetime of the press structure.

The measured loads are fed to a surrogate model of the press (a part of the digital twin) which computes the maximum stresses at critical regions. This surrogate model was generated automatically out of a detailed FE-model of the press structure. The detailed model consisted of 2 million shell and volume elements. It contains rigid connections to model the weld seems and several contact regions including friction for the moving parts. The model was validated by a measurement campaign. The original model needs around 2 hours computation time on a cluster of 16 processors for one load case. The surrogate model computes faster than real time, which is necessary for its application as digital twin. It represents the response surface of the original model and was generated using ESI's AdMoRe tool for non-intrusive model order reduction of FEM and CFD-models. The tool automatically generates the design-of-experiment and launches the necessary solvers to compute the results at some sampling points of the detailed models to generate a parametric solution.

Using the PGD (proper generalized decomposition) method the response surface is generated and stored in one result file. This surrogate model is deployed on an Edge device. It is connected via an API to the IoT-system of the press to stimulate it with the

sensor data and to return the computed stresses within the critical regions as time series for one cycle. This data is fed to a rainfall counting algorithm to extract and accumulate stress values being important for the fatigue assessment (so-called load collectives). These load collectives are assessed using the Component Lifetime Line, computed according to the “FKM Guideline” developed by the German Mechanical Engineering Research Federation (FKM – Forschungskuratorium Maschinenbau).

This allows for the estimation of the remaining useful lifetime of the press, assuming a continued operation under the current load conditions. In addition to that the surrogate model can be used to compute strains at the positions of strain gauges of the press. In this way, the divergence between the real press structure and the model due to stiffness reduction over time can be monitored. Our approach predicts the remaining useful life and enables actions for its extension. Maintenance actions can be planned considering the actual state of the press structure. This helps to avoid unexpected downtimes and increases machine availability. The work has been carried out within the research project Level Up (Protocols and Strategies for extending the useful life of major capital investments and Large Industrial Equipment).

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