Karlsruhe Institute of Technology

Division III – Mechanical and Electrical Engineering

Institute of Production Science (WBK)

Camera-based Spindle Control

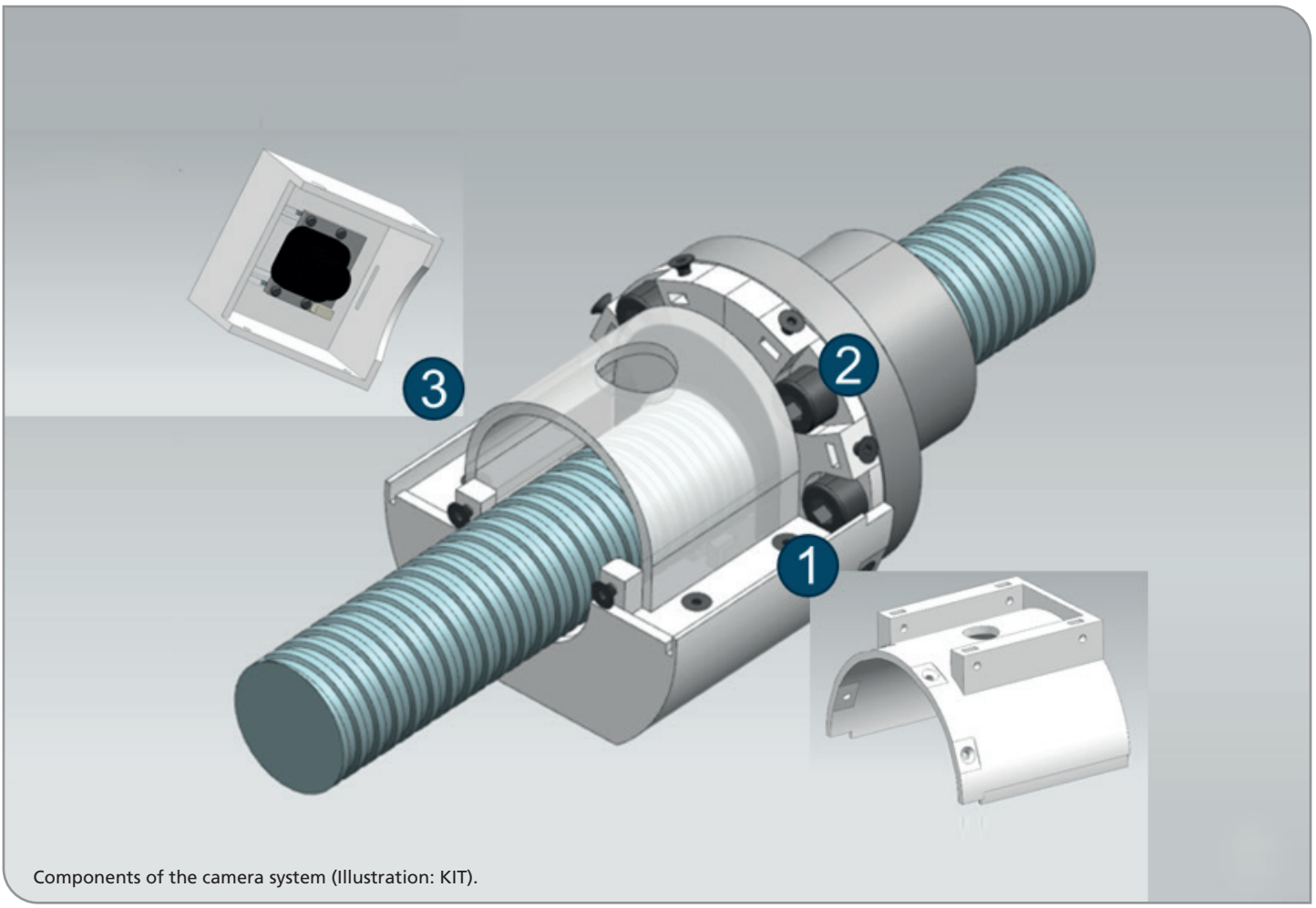
Learning Model for Image-based Wear Quantification

Quantification of surface defects on ball screw drives is the prerequisite for timely exchange of the component in operation and the basis of knowledge gain in case of failure. Frequently, wear is detected manually on the spindle or by indirect sensor systems. Use of recorded images, combined with machine learning methods, enables image-based direct and smart evaluation of the spindle surface. By integrating an intelligent camera system, the user is given a direct damage analysis in the form of automatically evaluated image data. Such a smart camera system has been developed by researchers of KIT's Institute of Production Science. The camera system is mounted on the ball screw nut and provided with lighting. It is combined with a machine learning model trained with image data for image data evaluation.

Camera System

The smart camera system to record the spindle surface is fixed to the ball screw nut and looks down onto the spindle. Nearly the complete surface of the ball screw drive, including the transmission from rotatory to translatory motion, is captured by the camera. In the next step, the image data are evaluated with a smart algorithm. The camera system consists of three main parts:

1. Housing, including lighting.
2. Connecting piece between camera system and ball screw nut.
3. Camera for recording images.



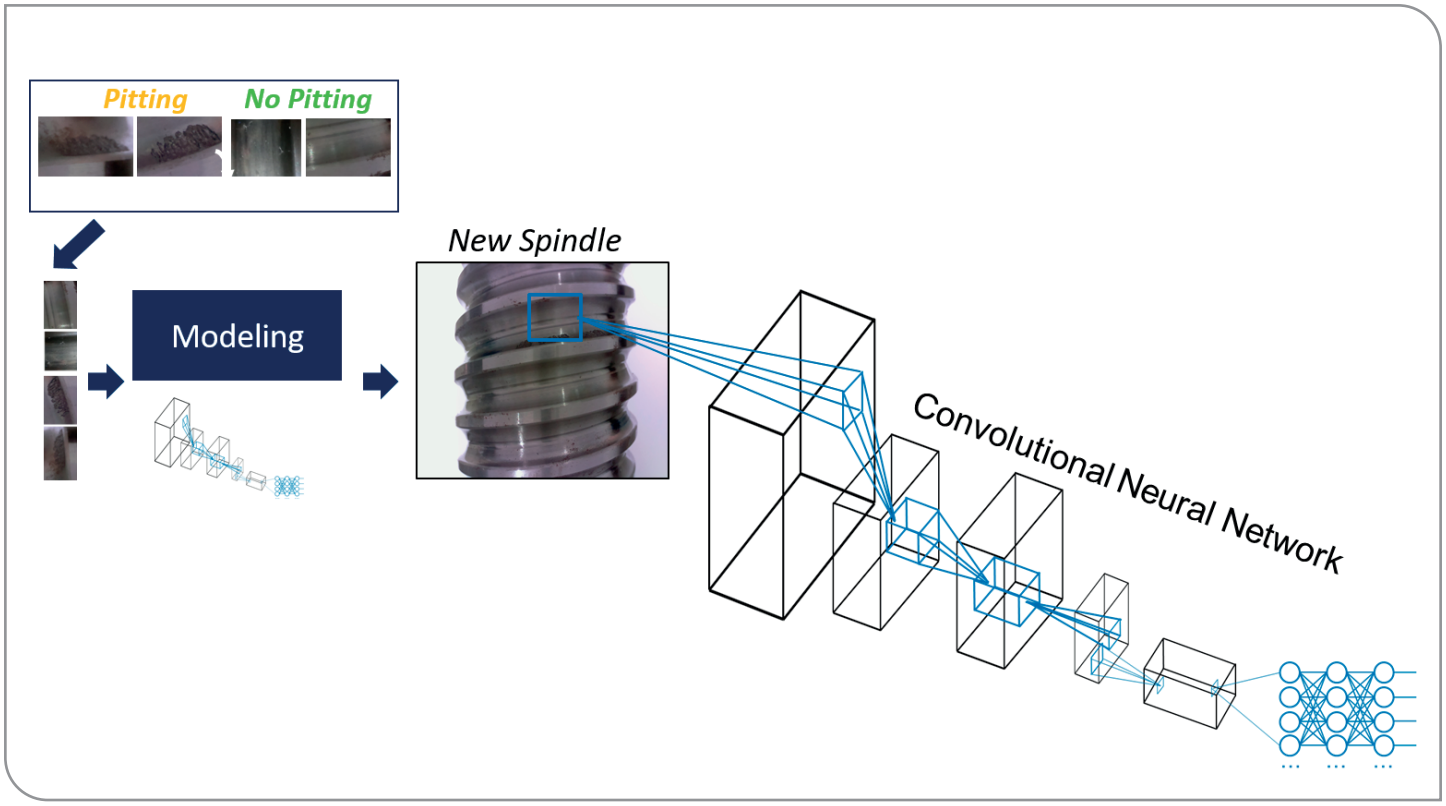
Components of the camera system (Illustration: KIT).

Smart Image Evaluation Model

The model used for the smart evaluation of the images recorded is a convolutional neural network (CNN) based on machine learning methods. First, the image features are extracted from the image data. Then, the model uses a classifier in the form of an artificial neural network to classify these features into image data with and without defect. Evaluation of the image data allows a statement to be made with respect to the wear of a complete spindle surface. Using several thousand images, the model was trained for image data of worn ball screw spindles and can distinguish between image data with and without defect. The image data reflect all potential cases in reality to ensure maximum generalization. The model was validated using a cross validation approach and a test dataset consisting of new image data never seen before by the model.

Spindle states: Left: Small pitting, middle: Heavy contamination, right: Pitting-like contamination (Photo: KIT)

The model is suited for any applications in which defects on a spindle surface are to be extracted in an image-based manner. Transferability to other applications is possible.



Basic functioning of the smart image evaluation model (Illustration: KIT).

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