Milling diagnosis using machine learning approaches

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The Industry 4.0 framework needs new intelligent approaches. Thus, the manufacturing industries more and more pay close attention to artificial intelligence (AI). For example, smart monitoring and diagnosis, real time evaluation and optimization of the whole production and raw materials management can be improved by using machine learning and big data tools. An accurate milling process implies a high quality of the obtained material surface (roughness, flatness). With the involvement of AI-based algorithms, milling process is expected to be more accurate during complex operations.

In this work, a smart milling diagnosis has been developed for composite sandwich structures based on honey-comb core. The use of such material has grown considerably in recent years, especially in the aeronautic, aerospace, sporting and automotive industries. But the precise milling of such material presents many difficulties. The objective of this work is to develop a data-driven industrial surface quality diagnosis for the milling of honey-comb material, by using supervised machine learning methods. Therefore, cutting forces and workpiece material vibrations are online measured in order to predict the resulting surface flatness.

The workpiece material studied in this investigation is Nomex® honeycomb cores with thin cell walls. The Nomex® honeycomb machining presents several defects related to its composite nature (uncut fiber, tearing of the walls), the cutting conditions and to the alveolar geometry of the structure which causes vibration on the different components of the cutting effort.

Given the low level of cutting forces, the quality of the obtained machined surface allows to establish criteria for determining the machinability of the honeycomb structures. Nearly 40 features are calculated in time domain and frequency domain from the raw signal in steady state behavior (transient zones are not taken into account). The features are then normalized. The input parameters for each experiment are: the tool rotation speed, the cutting speed and the depth of cut. It is then necessary to make a dimensional reduction of that feature table in order to avoid overfitting and to reduce the computing time of the learning algorithm.

In this work, several classification algorithms have been implemented such as : k-nearest neighbor (kNN), Decision trees (DT), Support Vector Machine (SVM), … The different supervised learning algorithms have been implemented and compared. Each AI-based model has been applied to a set of features. From the prediction results, SVM algorithm seems to be the most efficient algorithm in this application.

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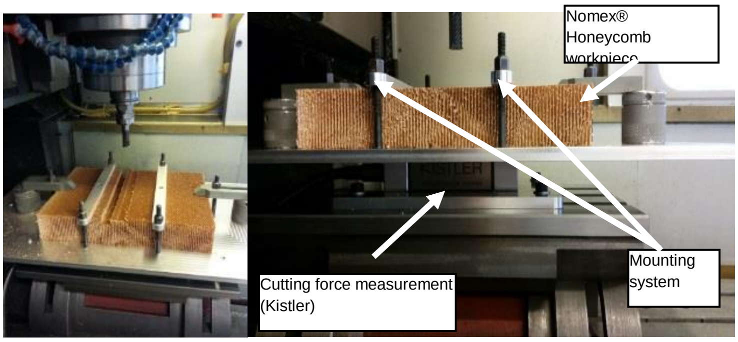

Fig. A.1. Experimental test setup

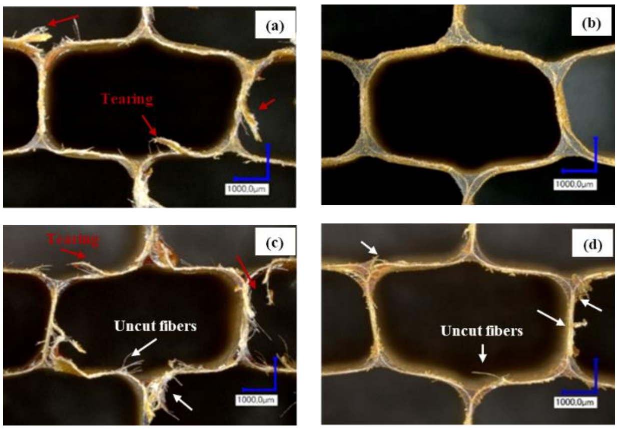

Fig. A.2. Obtained honeycomb machining surfaces. The case (b) represents the best milling result

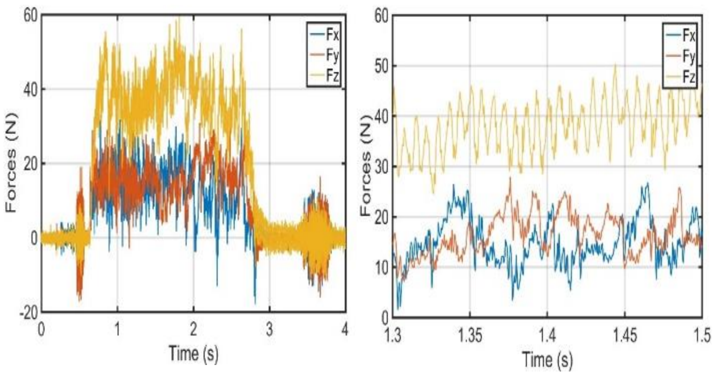

Fig. A.3. *Milling force measurements for 2000 rpm spindle speed and 3000 mm/min feed rate: (a) during all process; (b) during 0.2s (zoom)*