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platform-enabled KITs of arTificial intelligence FOR an easy uptake by SMEs

Quality Control in manufacturing operations in the Pilot Line GAMHE 5.0: Micro-mechanical milling

1. General Description

Quality is defined as the extent to which a product conforms to the design specifications and how it complies with the requirements of component functionality. For some industries, such as automotive and aeronautical, the quality of of manufactured parts is very important due to the high requirements. However, difficulties arise from the fact that a measure of quality can only be evaluated "out-of-process", resulting in losses because there is no alternative to removing defective parts from the production line. Therefore, it is necessary to incorporate AI-based kits/solutions that provide in-process estimation to predict quality from some measured variables.

The main goal of these datasets is to enable monitoring of final quality of the manufactured components or parts by estimating surface roughness from vibration signals and cutting parameters information. Surface roughness is an essential feature in quality control defined by the deviation in the direction of the normal vector of a real surface from its ideal form. Because the roughness measurement is an offline and post process procedure, being able to estimate this value online brings a series of benefits in terms of time and cost reduction in manufacturing lines, energy efficiency, unnecessary wear of tools and machines, etc. Once a part has been detected with a surface quality below what is desired, a series of corrective measures can be applied for the following operations, such as: reducing the feed rate percentage, increasing the percentage of spindle speed or reducing the axial depth per pass, etc.

Several parameters of cutting processes are recorded according to specific characteristics of the corresponding manufacturing process/data set (micro-milling and macro milling processes). The main measured variable is the acceleration signal. The monitoring system platform is equipped with a Deltatron 4519-003 Brüel & Kjaer monoaxial accelerometer on the x,y,z-axis, with a sensitivity of 10.58 mV/g and bandwidth of 20 kHz. The sensor was connected to a PCB PZT 482A22 amplifier to supply power, in order to obtain an acceptable voltage measurement, easily processed by most data acquisition systems. The vibration signals (Vz) were fed into an NI 6251 National Instruments data-acquisition card, with a sampling frequency of 50 kHz, processed in a National Instruments high performance PXI 8187 embedded controller.

The most used index to characterize quality of manufactured parts related with the surface roughness is the roughness average, Ra that represents the arithmetic mean of the absolute ordinate values $G(w)$ within a sampling length (L) as follows:

$$Ra = \frac{1}{L}\int_{0}^{L} \left|G(w)\right| \, \mathrm{d}w$$

The unit of measurement of roughness is the micrometre (um), and, according to ISO:1302 4288:1996, machining processes are able to produce ranges of Ra from 0.006 um to 50um. This parameter is primarily used to monitor the production process, which may gradually change the surface due, for example, to the wear of the cutting tool. As Ra is an average, the defects on the surface do not have much influence on its results.

Once each manufactured part is finished, the surface quality is measured. These measures were captured by an Ultra Precision Range of Form Talysurf PGI instruments. This device brings a flexible and highly accurate metrology solution in surface analysis features, specifically developed for the optics industry, operates with nanometric accuracy.

2. Micromilling Dataset

Dataset ID: Micromilling_dataset_1

Dataset Title: Surface quality data in micro-milling process

Dataset description

Workstation 4 (WS4) of the GAMHE 5.0 pilot line is a Kern Evo high-precision machining centre, with a maximum spindle speed of 50 000 rpm and Blum laser system and is used to run micro-milling and micro-drilling operations. In this experimental dataset, five cutting parameters were considered in the processes: spindle speed, n; feed rate, f; and axial depth of cut, a_P. The radial depth of cut, a_e; was equal to the mill tool radius, r, in all of the slots.

These tests were micro-milling operations with 0.3 mm, 0.5 mm, 0.8 mm and 1 mm-diameter mills on a sintered tungsten-copper alloy (W78Cu22). The data collected for each micro milling operation was the rms and peak value of the vibrations in the three-machine axis. In addition, five cutting parameters were also collected: position in X of the last point of the sample, feed rate, spindle speed, tool radius and axial depth.

Column	Data Name	Definition
Column1:	*PosX* [mm]	Position in X of the last point of the sample.
Column2:	f [mm/min]	Feed rate
Column3:	n [min^-1]	Spindle speed
Column4:	r [mm]	Tool radius
Column5:	a_p [mm]	Axial depth
Column6:	*Accel_rms_X* [g]	rms value of X-axis vibrations
Column7:	*Accel_rms_Y* [g]	rms value of Y-axis vibrations
Column8:	*Accel_rms_Z* [g]	rms value of Z-axis vibrations
Column9:	*Accel_max_X* [g]	Peak value of X-axis vibrations
Column10:	*Accel_max_Y* [g]	Peak value of Y-axis vibrations
Column11:	*Accel_max_Z* [g]	Peak value of Z-axis vibrations
Column12:	*Samples/section*	Number of samples used for RMS in each subsection
Column13:	R_a [nm]	Mean value of surface roughness
Column14:	R_q [nm]	RMS value of surface roughness
Column15:	R_v [nm]	Maximum valley depth of surface roughness
Column16:	R_p [nm]	Maximum peak altitude of surface roughness

Table 1. Variables and parameters of the micromilling dataset

The vibration signals were pre-processed with a 6th order Butterworth high pass filter with frequency cut-off = 0.5 x n / 60 Hz, where n is the spindle speed. Subsequently, the rms and peak value of the vibrations were calculated for a window width equal to a 2.33mm- tool diameter.

Figure 1. KERN Evo micromilling machine

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