Mechanical Systems and Signal Processing 99 (2018) 873–885

Contents lists available at ScienceDirect

Mechanical Systems and Signal Processing

journal homepage: www.elsevier.com/locate/ymssp

Acoustic emission analysis for the detection of appropriate cutting operations in honing processes

Irene Buj-Corral [a,*], Jesús Álvarez-Flórez [b], Alejandro Domínguez-Fernández [a]

[a] Department of Mechanical Engineering, Universitat Politècnica de Catalunya, Av. Diagonal, 647, 08028 Barcelona, Spain
[b] Heat Engines Department, Universitat Politècnica de Catalunya, Av. Diagonal, 647, 08028 Barcelona, Spain

ARTICLE INFO

Article history:
Received 19 January 2017
Received in revised form 8 May 2017
Accepted 28 June 2017

Keywords:
Honing
Acoustic emission
Roughness
Material removal rate
Hilbert Huang transform
Fourier transform

ABSTRACT

In the present paper, acoustic emission was studied in honing experiments obtained with different abrasive densities, 15, 30, 45 and 60. In addition, 2D and 3D roughness, material removal rate and tool wear were determined. In order to treat the sound signal emitted during the machining process, two methods of analysis were compared: Fast Fourier Transform (FFT) and Hilbert Huang Transform (HHT). When density 15 is used, the number of cutting grains is insufficient to provide correct cutting, while clogging appears with densities 45 and 60. The results were confirmed by means of treatment of the sound signal. In addition, a new parameter S was defined as the relationship between energy in low and high frequencies contained within the emitted sound. The selected density of 30 corresponds to S values between 0.1 and 1. Correct cutting operations in honing processes are dependent on the density of the abrasive employed. The density value to be used can be selected by means of measurement and analysis of acoustic emissions during the honing operation. Thus, honing processes can be monitored without needing to stop the process.

1. Introduction

As a general trend, machine tool users choose CBN (cubic boron nitride) tools for machining hard materials like the hardened steel used in molds. Although they are quite expensive, they allow high material removal rate with low wear [1]. This is also the case for abrasive tools. In grinding processes, if grit volume or density is reduced, weaker structures are obtained for grinding wheels [2]. Grit concentration is related to the number of active surfaces that will enhance material removal rate. In addition, higher concentrations are associated with lower chip thicknesses and lower roughness [3]. As for honing processes, in industry, the selection of grain size depends mainly on the type of process to be used: rough, semi-finish or finish honing. After selecting the grain size, the abrasive density is also defined. Once the honing stone has been selected, several tests are performed in which pressure, linear speed and tangential speed are varied, in order to obtain the appropriate roughness, material removal rate and tool wear [4]. If the selected density is too low, tools will suffer premature wear and will show low productivity, regardless of the cutting conditions employed. Since CBN abrasives are expensive, high densities are usually preferred in order to increase productivity, in the same way as for grinding. However, an excessively high density will not allow proper material cutting, because of clogging of the honing tool.

The shape of acoustic waves produced in abrasive machining processes depends largely on whether the cutting tool is cutting properly or not. In the past, several authors have used acoustic emission for determining tool failure in different

---

[*] Corresponding author.
E-mail address: irene.buj@upc.edu (I. Buj-Corral).

http://dx.doi.org/10.1016/j.ymssp.2017.06.039
0888-3270/

machining processes [5,6], including grinding [7]. In abrasive processes such as grinding, wavelet packet transform of acoustic emission has been used for detecting grinding burn [8]. Acoustic emission also allowed measuring the wheel-workpiece contact length in grinding operations [9]. The amplitude of the sound signal is known to vary with different cutting conditions in the grinding processes [10]. As for the honing processes, few papers are known. For example, Schmitt et al. measured acoustic emissions on different surfaces although they did not find significant differences among the signals measured [11]. Kanthababu et al. monitored acoustic emission for rough, semi-finish and plateau honing for fresh and worn out tools. They found that the dominant frequency of the signal is sensitive to the cutting conditions [12].

The acoustic signal is usually analysed in the frequency domain, by means of Fast Fourier Transform (FFT), and also in the time-frequency domain (TFS) [13]. Other time-frequency (TF) methods are available for analysing the acoustic signal, such as Hilbert Huang Transform (HHT) and wavelet transform. Hilbert Huang Transform (HHT) decomposes nonstationary signals obtained from nonlinear systems in individual oscillatory modes [14]. It allows analysing nonlinear and nonstationary signals. In the wavelet transform, a family of translates and dilates of one basic primitive mother wavelet is used [15]. As a result of the computational processes, it is possible to obtain the spectrogram (TF plane), the scalogram (TS plane), and the smoothed Wigner-Ville distribution [16]. Nevertheless, wavelet is not appropriate for nonlinear signals. It is usually employed for linear but nonstationary signals.

Several time-frequency (TF) methods have been used in the past for analysing nonstationary or stationary signals with high nondeterministic components, such as those obtained in this work. The time-frequency-scale (TFS) transform concept has been used, for example, for monitoring the milling process and detecting surface irregularities [17]. Wavelet transform allowed finding material damage in civil infrastructures [18,19] or in wind blades [20], as well as detecting low speed bearing failure [21]. Hilbert-Huang Transform (HHT) has also been used for determining the mechanical properties of refractory materials [22]. As for machining processes, HHT has been applied to detect tool breakage [23,24] and chatter [25,26]. However, most papers address milling processes. Regarding abrasive processes, HHT was applied to detect the burn feature in grinding operations [27]. In contrast, few papers are known about the application of HHT to honing.

In the present paper, semi-finish honing tests were performed at different abrasive densities. In order to detect correct cutting, 2D roughness, material removal rate and tool wear were used in the first analysis. A more refined analysis involved determining 3D roughness and surface topographies. Once the most appropriate density had been selected, the acoustic emission of the honing process was analysed by means of two methods, Fast Fourier Transform (FFT) and Hilbert Huang Transform (HHT). A new parameter S was defined, which allows the proper abrasive cutting operation to be determined. It will provide a quick way of determining whether the abrasive is cutting properly or not, without needing to analyse the surface finish of the workpiece nor the final state of the abrasive. This monitoring of the honing process will lead to a reduction in the number of tests and abrasive stones that are required in previous honing tests.

2. Materials and methods

2.1. Honing experiments

The honing machine used was an experimental equipment composed by an oscillating table, with acceleration up to 4.9 $m{\cdot}s^{-2}$, on which a honing stead provided with three tool supports is placed (Fig. 1). The table moves thanks to a linear motor.

The rotation movement is applied to the cylinders, by means of a rotary motor and a belt transmission (Fig. 2).

Pressure of the honing stones against workpiece wall is provided by a pneumatic cylinder, which has a pressure sensor, an electrovalve that controls pneumatic pressure.

Steel St-52 cylinders of internal diameter 80 mm and length 100 mm were used in the honing tests. The honing machine used was a prototype in which the workpiece rotates, providing tangential speed, and the honing head has a linear reciprocating movement, leading to linear speed. Oil was used as cutting fluid. CBN stones with metal bond were employed. Abrasive stone dimensions are 20 mm × 3 mm × 3 mm.

Experimental tests performed are listed in Table 1. Grain size GS, tangential speed VT, linear speed VL and pressure against the workpiece wall PR were fixed, while density of abrasive DE was varied. Two replicates were performed of each experiment.

Experiments were named using the pressure value followed by the density value. For example, 700–15 stands for an experiment with pressure 700 N/cm^2 and density of abrasive 15 according to the Federation of European Producers of Abrasives (FEPA) nomenclature.

2.2. Roughness, material removal rate and tool wear measurement

Average roughness Ra, areal average roughness Sa, areal average maximum height of the profile Sz, areal skewness Ssk, areal kurtosis Sku and surface topographies were obtained with a Taylor Hobson Talysurf Series 2 roughness meter. Material removal rate was determined by means of the weight of the workpiece before and after the honing operation. Tool wear was calculated by the weight of the honing stones before and after each honing test. Pictures of the honing stones were obtained with a Leica S8AP0 magnifier, with x80 magnification.