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Feature extraction and pattern recognition in acoustic emission monitoring of robot assisted polishing

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Abstract

Polishing processes are to date gradually evolving from basically manual operations to automated processes. To achieve more accurate, steadfast and dependable automated polishing processes, sensor monitoring offers as a creditable tool for process and product quality control. In this study, an acoustic emission sensor monitoring system was employed for surface roughness assessment during robot assisted polishing of steel bars. After sensor signal pre-processing, feature extraction procedures were applied to the conditioned acoustic emission signals. The scope was to extract relevant signal features to input to pattern recognition paradigms in order to identify correlations between process generated acoustic emission and polished workpiece surface roughness.

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Keywords: Polishing; Surface roughness, Sensor monitoring; Acoustic emission; Feature extraction; Pattern recognition

1. Introduction

Surface finishing processes are widely used as the final step in the fabrication of a part in order to realise on it an extremely smooth surface [1]. At present, one of the most accurate surface finishing processes is polishing [2], defined as the process of creating a surface smoother than the one of the initial workpiece [3].

Polishing has traditionally been a manual process performed by skilled operators but becoming an automated process [4]. Polishing automation is a fundamental issue for process improvement in terms of required operational time and achieved surface quality. Robot assisted polishing (RAP) employs a robotic arm to perform polishing on a given workpiece [5].

To inspect the surface of a manufactured workpiece, surface metrology is traditionally based on tactile methods which gather data through physical contact with the surface [6]. This direct inspection method requires halting the polishing process to allow for dismounting the workpiece and move it to the metrological instrument where surface roughness is measured.

Polishing sensor monitoring allows for product quality monitoring and process control in order to improve the solidness, dependability as well as the automation of manufacturing operations [7]. The most widely used sensors for polishing process monitoring are force, acoustic emission (AE), motor current, and vibrations, that can detect process relevant sensor signals to be further analysed. Feature extraction procedures need to be applied to the detected and conditioned sensor signals with the scope to provide a signal characterisation as concise as possible while maintaining the relevant information about process conditions [8].

The application illustrated in this study focuses on the improvement of the repeatability characteristics of a robot automated polishing process. For this purpose, an experimental campaign was carried out on a robot assisted polishing (RAP) machine developed by Strecon A/S [9] during polishing of AISI 52100 alloy steel under variable process conditions. During polishing, acoustic

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AE raw signals were detected and conditioned, and feature extraction methodologies were applied to the conditioned signals: statistical analysis and wavelet packet transform (WPT) [10, 11]. The aim was to construct pattern feature vectors to be fed to neural network (NN) pattern recognition paradigms for correlating AE sensor signal features to polished workpiece surface roughness [12].

2. Experimental tests

Experimental polishing tests were conducted at Strecon A/S within the activities of the FP7 European project (FoF NMP – 285489) - Intelligent Fault Correction and self-Optimizing Manufacturing systems (IFaCOM) [13]. Strecon's RAP machine was utilized to polish 75 mm long cylindrical bars of AISI 52100 alloy steel (Fig. 1) with a Gesswein #800 polishing stone.

During the experimental tests, the polishing parameters were as follows:

- Main spindle rotational speed = 300 rpm
- Feed speed = 5 mm/s
- Polishing force = 1800 or 1000 g
- Oscillation = 500 pulses per min
- Stroke = 1 mm

Six polishing sessions, each composed of 60 passes, were carried out with session duration ~ 15 min and 50 s. During each polishing session, the full length of the alloy steel bar was polished over and over using alternated polishing force values:

- 1800 grams 1 × 60 passes
- 1000 grams 3 × 60 passes
- 1800 grams 2 × 60 passes

For each polishing session, AE raw signals were acquired using a Fuji Ceramics Corporation sensor (R-CAST M304A); they were then pre-amplified with A1002 AE pre-amplifier and digitised by an A/D board with sampling frequency 1 MHz. In Fig. 2, the RAP machine is shown with the AE sensor installed on it. A total number of 5580 AE digital signal files were obtained, each containing 131,072 AE signal samplings.

Fig. 1. Workpiece: AISI 52100 alloy steel bar

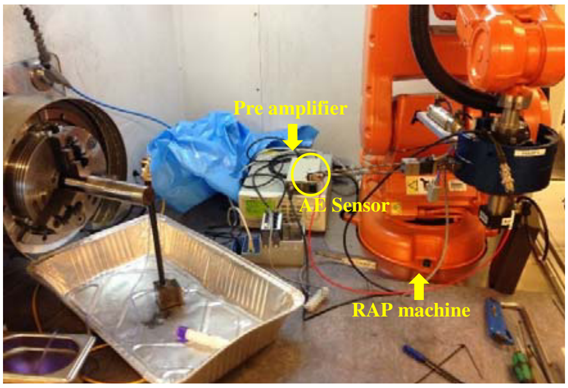

Fig. 2. Strecon's RAP machine with AE sensor and pre-amplifier

3. Roughness measurements

After each polishing session, the surface roughness values R_a, R_z and R_t (total height) [14] were measured on a Mahr profilometer by halting the polishing process and dismounting the workpiece. After measurement, the workpiece was re-mounted and the polishing process continued. The measured average surface roughness values are reported in Table 1 and plotted vs. polishing session number in Fig. 3.

Table 1. Surface roughness measurements (the final surface roughness measurement after session number 6 was not carried out).

Polishing session	**Roughness values**		
	R_a	R_z	R_t
1 (60 passes with 1800 g)	0.111	1.131	1.684
2 (60 passes with 1000 g)	0.081	0.984	1.582
3 (60 passes with 1000 g)	0.083	0.908	1.065
4(60 passes with 1000 g)	0.053	0.603	0.742
5 (60 passes with 1800 g)	0.107	1.076	1.643
6 (60 passes with 1800 g)	N/A	N/A	N/A

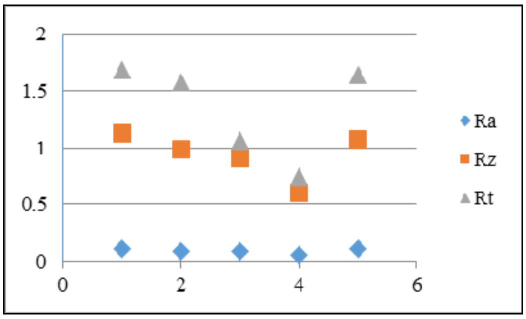

Fig. 3. Measured average surface roughness values vs. polishing session number.