Traceology for polishing process control

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Abstract

Final finishing operations of dies and moulds e.g. in the plastic industry, are conventionally performed by manual polishers. With ever increasing demands of shorter lead times and reduced costs, efforts have been made to automate the finishing process. This paper presents the first step towards a built-in surface inspection system for automated polishing processes, designed to indicate when it is time to shift from one preparation step to the next one. It is based on an evaluation procedure for mirror-like steel surfaces, and a characterisation method used to study scratch patterns on cylinder liner surfaces. This method was further developed/adapted to polished steel surfaces. The results showed that scratch width and height were strong indicators for surface quality evaluation.

1. Introduction

For an automated system, it is important to know when defects start to appear and when to end the polishing process [1]. To secure high quality mould surfaces both local surface deviations and scratch patterns, i.e. 'traceology' [2], need to be detected and analysed. A method for scratch analysis has been developed and successfully used to study the quality of cylinder liner surfaces [3]. The aim of this paper was to investigate if this procedure, modified to polished steel surfaces, could be a useful tool to e.g. decide when it is time to shift from one preparation step to the next one or when demanded surface quality is achieved. Such system could also be helpful for manual polishing e.g. to get early signs of arising defects.

2. Materials and methods

This work is based on heat treated powder metal tool steel samples, ground (Al_2O_3, 60 Mesh) and prepared to a high gloss quality in two different polishing shops (denoted PA and PB in this text). The samples were divided into smaller fields, one for each preparation step. The polishing procedures were as follows, for

PA: 1. Polishing stones (manually) with diminishing grit size to make sure that the surface structure left from the grinding step was removed; 2. Sand papers (manually); 3. Diamond paste (grain size 9 down to 3 µm) using a hand-held unit in both linear and rotary mode; 4. Diamond paste (grain size 1 µm) using cotton – 'to make the surface smooth and shiny'. In total 11 steps.

PB: 1. Sand papers; 2. Diamond abrasives (grain size 6 to 1 µm). In total 6 steps, all with the use of a hand-held unit in rotary mode.

The surfaces were measured by an interferometer (phase-shifting mode, 10x objective, measurement area: 0.6x0.8 mm) with a quoted vertical resolution of 0.1 nm and a sampling interval of ~1 µm. All measurements were levelled with respect to the least square plane, and the form was removed by fitting and subtracting a 2nd order polynomial in the MountainsMap software [4]. A morphological filter was applied for profile and image analysis in Matlab [5] in order to detect the scratch patterns. The patterns were then applied to the Gaussian filtered version of the measurement to calculate width and height of detected scratches (see Fig. 1).

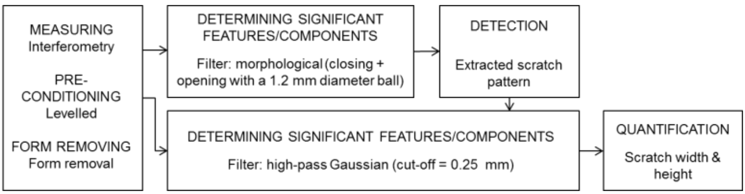

Figure 1: Describtion of the procedure to extract and quantify relevant scratches.

3. Results & discussion

The final steps, the preparation steps involving diamond abrasives, were considered to analyse when the surface quality was good enough to stop the polishing procedure. PA used five steps, but started to use diamond abrasives on a rougher surface topography than PB did. PB used three steps.

After the first diamond-step, step 4, PB failed to reduce the width and height of the scratches, which can be seen in the figures below (see Fig. 2 & 3); both the width and the height of the scratches tend to exceed the ones from the previous step – indicating that step 5 was not properly chosen.

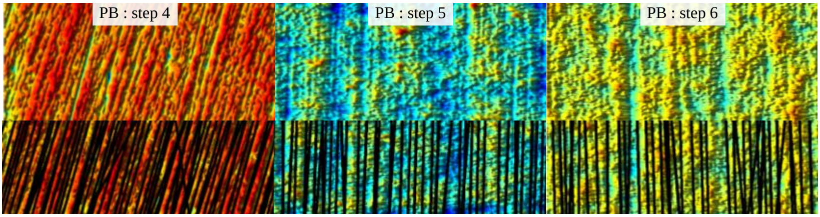

Figure 2: Surface (texture) evolution and detected scratches from 10x phase shift measurements (image size: 400x400 µm). Lower parts indicate captured grooves.

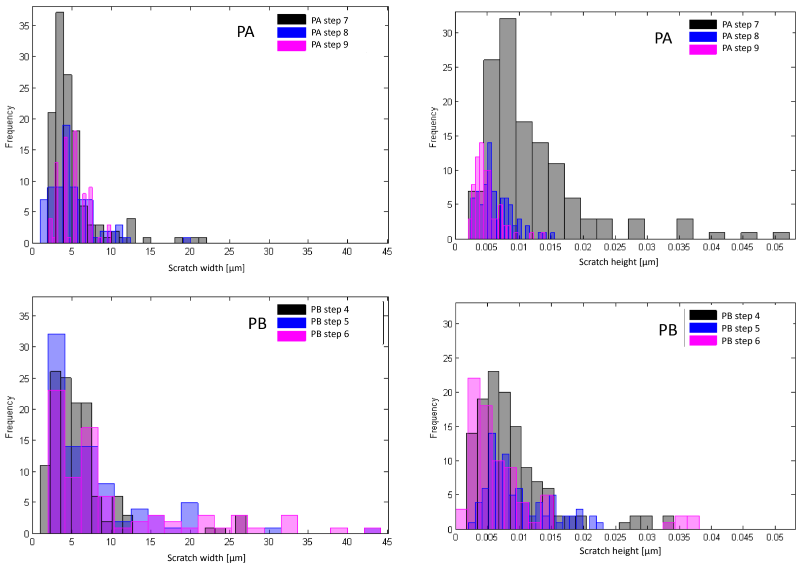

Figure 3: Histograms of the scratch width and height of the final polishing steps. Upper: PA; Lower: PB; Left: Scratch width; Right: Scratch height.

PA reduced the width and especially the height of the scratches step-by-step (see Fig. 3). At step 10, all scratches were reduced to an acceptable level, and simultaneously no polishing defects occurred (see Fig. 4, the right image). As a consequence, no results from this step, or step 11, are shown in the histograms in figure 3.

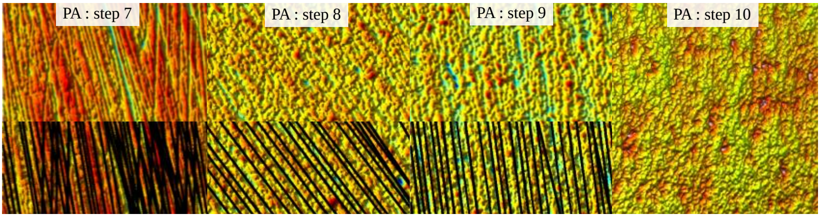

Figure 4: Surface (texture) evolution and detected scratches from 10x phase shift measurements (image size: 300x400 µm). Lower parts indicate captured scratches.

4. Conclusion

- The method to study scratch patterns on cylinder liners worked well for polished steels after it had been modified and adapted to this type of surfaces.
- The scratch patterns, on the polished samples, quantified in terms of width and depth are important parameters that indicate if the topography of a polished tool steel surface has reached a sufficient quality level, and if applied polishing steps were properly chosen.
- In future, the developed characterisation method will be applied to study the effect of process parameters on surface finishes generated by robot assisted polishing equipment.

References:

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