euspen's 16th International Conference & Exhibition, Nottingham, UK, May 2016
www.euspen.eu

Investigation of pre & post plating surface roughness of electroless nickel phosphorus coated substrate for diamond turning application

Peter Xia[1], Heather Almond[1], Sue Impey[2]
[1]*Precision Engineering Institute, Cranfield University, UK*
[2]*Surface Engineering and Nanotechnology Institute, Cranfield University, UK*

p.xia@cranfield.ac.uk
Building 90, Cranfield University, Bedford, MK43 0AL, United Kingdom

Abstract

In an overarching project to reduce the number of defects found in electroless nickel phosphorus alloy (EN-P) coatings on large diamond-turned components used in the next generation of reel-to-reel (R2R) printing stations, the significance of the coating surface on achieving a wear resistant and optically smooth surface has been investigated. This paper presents an investigation that focuses on the substrate roughness variation achieved through different pre-treatment methods prior to coating using a commercial plating solution. It looks at the number of features observed pre and post plating. The results provide some suggestions with respect to the diamond machining of a 100 micron thick EN-P coating.

Electroless nickel, nickel phosphorus alloy, EN-P, surface feature, defects, pre-treatment, diamond turning

1. Introduction

Electroless nickel plating (EN-P) has been widely applied in many applications [1] due to its physical characteristics such as hardness, wear resistance, uniformity of thickness and corrosion resistance that make this coating the first choice in many aerospace, automotive and chemical processing applications. Currently, diamond turning of micro-features into electroless nickel coatings has been investigated for the production of moulds for use in Reel-to-Reel (R2R) printed electronics [2]. The high phosphorus nickel alloy (EN-P>10%) is the only type of EN-P coating that is diamond machinable and represents a significant reduction in tool wear [3]. Despite studies on the effect of various additives on the coating quality [4] and existing manufacturing standards [5], there are still some issues affecting the manufacture of EN-P coatings.

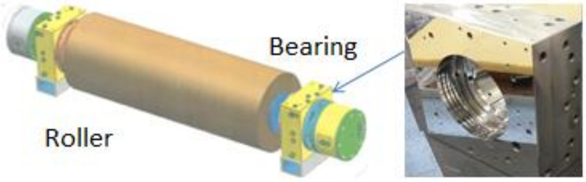

Figure 1. Diamond turned rollers and Hydrostatic bearings &housing.

Manufacturers normally undertake several jobs at a time, and use frequent replenishment of their chemistry to maintain the plating bath activity. However, the underlying problem is the inconsistency of coating quality achieved in the production of "low volume, high value [6]" components such as diamond turned hydrostatic bearings and printing rollers (Figure.1). Such components have been shown to demonstrate not only aesthetic imperfections on the coating surface itself, but also within its thickness, witnessed as the presence of micro-pitting and micro-vias. During diamond turning, the defects as such are revealed as the surface is removed layer by layer. The irregular size and shape of defects cause a difficulty in estimating the cutting depth/amount of material removed. Other major coating failures (macro-defects) such as delamination and blistering (Figure.2) are forms of lost adhesion between coating and substrate which may be easily detected via visual inspection. However, in some cases, defects would only be apparent after applying diamond machining.

Figure 2. Coating delamination over bearing housing.

The advantage of electroless nickel coatings is the coating thickness uniformity. This is an essential requirement for coating such complex components. It is generally agreed that nickel-phosphorus alloys containing less than 7% phosphorus are microcrystalline and those in the 7% to 14% phosphorus range show a mixture of microcrystalline and amorphous microstructure [7].

2. Research motivation

In this paper the type coating is an EN-P coating, containing 10 weight percent phosphorus, plated on both low carbon steel and aluminium alloy A6061 coupons. The intention is to investigate what effect the initial surface roughness of the substrate, as created by different pre-plating treatments has on the ultimate roughness of the deposited coatings in order to reduce coating defects and pre-plating machining process, hence identify the suitable substrate roughness that is ideal for EN-P plating.

3. Mechanical pre-treatment

The traditional mechanical pre-treatment consists of grinding and bead-blasting. Each process is applied to physically remove substrate surface material to achieve the desired topography. To replicate the mechanical pre-treatment method applied in the plating factory, a test coupon was used (Figure 3) using the identical material as the substrate used in rollers and bearings. A total of 3 coupons were prepared for each level of pre-treatment process for more accurate date sampling.

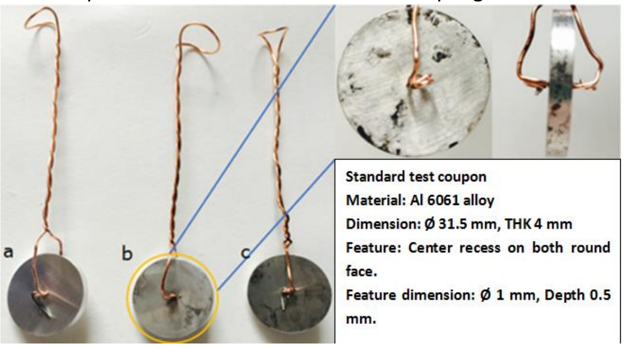

Figure 3. Standardised testing coupon for diamond turning performance experiment.

3.1. Grinding

The grinding process provides accurate control in the formation of the surface morphology by rapid abrasion wear. Water was used as coolant in the process to reduce the effect of heating and grinding burns.

The surface of Al6061 alumininium alloy substrate has been ground with five different level of grit size, ranging from 125 micron to 5.6 micron (P120 – P4000). The resultant surface can be classified from 'coarse' to 'smooth'.

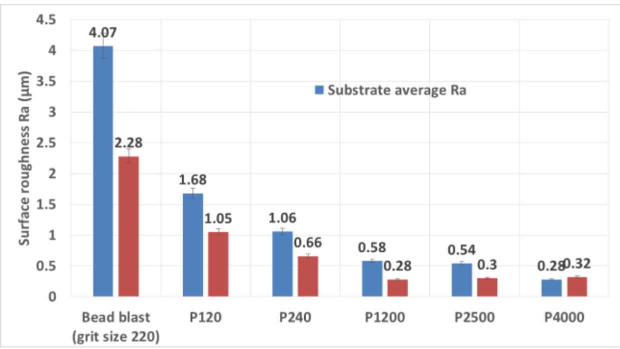

Figure 4. Coating roughness comparison (Ra) – note that the best that can be achieved in around 0.3 µm. Error bar indicates the maximum and minimum measurement per surface profile.

The roughness (Ra) of both substrate and coating was measured after 4 hours of electroless plating using laser confocal microscopy with 10 measurements per sample surface (area of scanning 800 x 720 μm^2) in order to identify the saturation point where the average roughness no longer follows a decreasing trend. It appears that the best Ra can be obtained as plated is 0.3 µm.

3.2. Bead-blasting

Bead-blasting is widely accepted in the plating industry due to its fast processing rate and simultaneous elimination of surface contaminants.

Both substrates were submitted to bead-blasting with 220 grit size (particle diameter 68 micron).

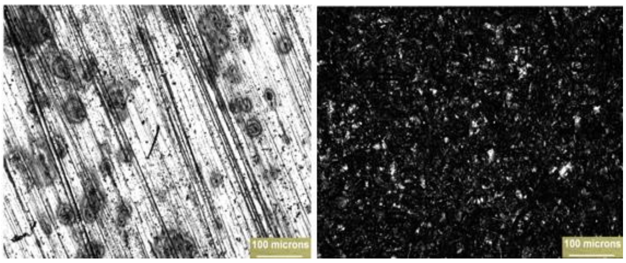

Figure 5. Microscopic view of steel substrate, (Left) P240 ground and (right) bead-blasting with 220 grit.

The samples are examined under microscope prior and post to plating. Individual features and pores were registered. The initial comparison was made through the quantitative evaluation of measurement in number of pores/pits shows that there is a significant reduction in features and pores observed in the bead-blasted sample surface.

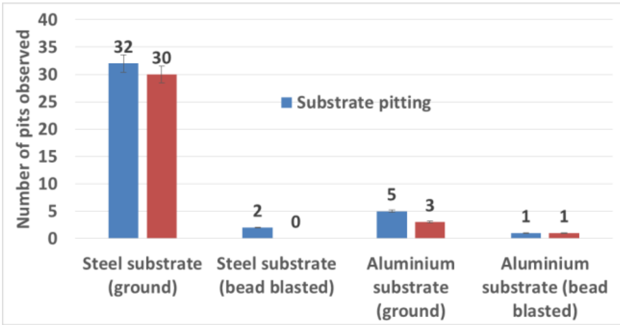

Figure 6. Pores observed after grinding and bead-blasting versus the number of pores detected as-plated. Error bar indicates the maximum and minimum number of pores observed per sample surface.

4. Conclusion

A best surface roughness for the substrate of 0.3 µm has been observed post plating. Evidence indicates further processing to reduce final coating Ra by reducing the substrate Ra is inappropriate (such that diamond machining prior to plating in order to reach a 'mirror' finish becomes superfluous). This suggestion does not indicates that pre-plating diamond turning is unnecessary for other machining requirement reasons. Bead blasting appears to be an ideal process to help reduce significant features and micro-pores in the coating.

Acknowledgments: This work was supported by the UK EPSRC under grant 1363271, and the Centre for Innovative Manufacturing in Ultra-Precision, Cranfield. Thanks also go to Dr Lin Zhang (Nanjing University of Aeronautics and Astronautics).

References

[1] R. Parkinson . Nickel Dev. Inst., vol.**37**, 1997
[2] A. Pramanik, et al. J. Mater. Process Technol., **140** (1–3) (2003), pp. 308–313
[3] A. Pramanik, et al. J. Mater. Process Technol., **208** (1–3) (2008), pp. 400-408
[4] R. Taheri. Evaluation of electroless nickel-phosphorus (EN) coatings PhD thesis, Saskatchewan, 2003
[5] ISO 4527:2003 Metallic coatings Edition 2., 15-05-2003
[6] J. Allsop "Private conversation", UPS^2, North Wales
[7] Keong, K.G; Sha, W; Malinov, S J. Akkiys Compd. 2002 vol. **334**(1-2) p. 192-199

Investigation of pre and post plating surface roughness of electroless nickel phosphorus coated substrate for diamond turning application

Xia, Peter

2016-06-30

Peter Xia, Heather Almond and Sue Impey. Investigation of pre and post plating surface roughness of electroless nickel phosphorus coated substrate for diamond turning application. 16th International Conference of the European Society for Precision Engineering and Nanotechnology, 30 May - 3 June 2016, Nottingham, UK.

https://dspace.lib.cranfield.ac.uk/handle/1826/10594