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Investigation of pre & post plating surface of electroless nickel phosphorus (EN-P) coated substrate for diamond turning application

Peter Xia[1], Heather Almond, Sue Impey

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

Research motivation

In this work we deal with 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. This will assist in identifying a suitable substrate roughness that is ideal for EN-P plating.

Diamond turned EN-P coating

Electroless nickel plating (ENP) 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 ENP coating that is diamond machinable and represents a significant reduction in tool wear [3]. Despite studies on the effect of various plating additives on the coating quality [4] and existing manufacturing standards [5], there are still some issues affecting the manufacture of Ni-P coatings.

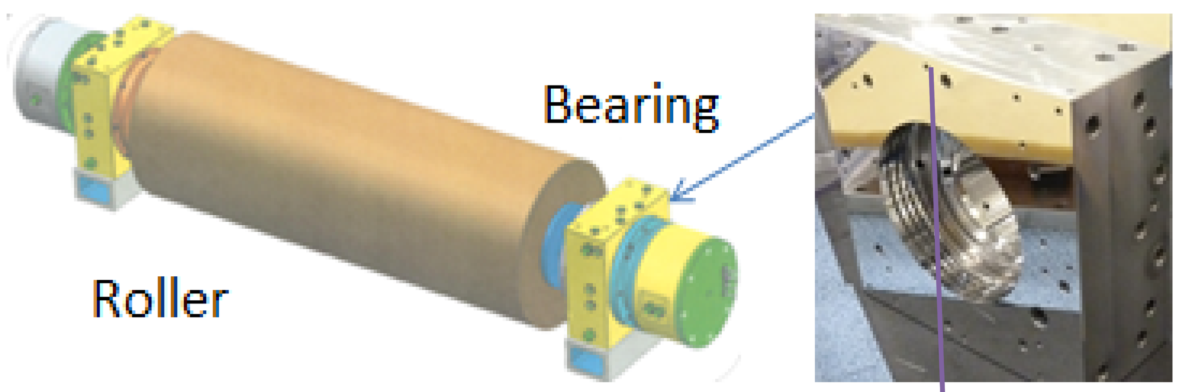

Figure 1. Diamond turned rollers and Hydrostatic bearings & housing

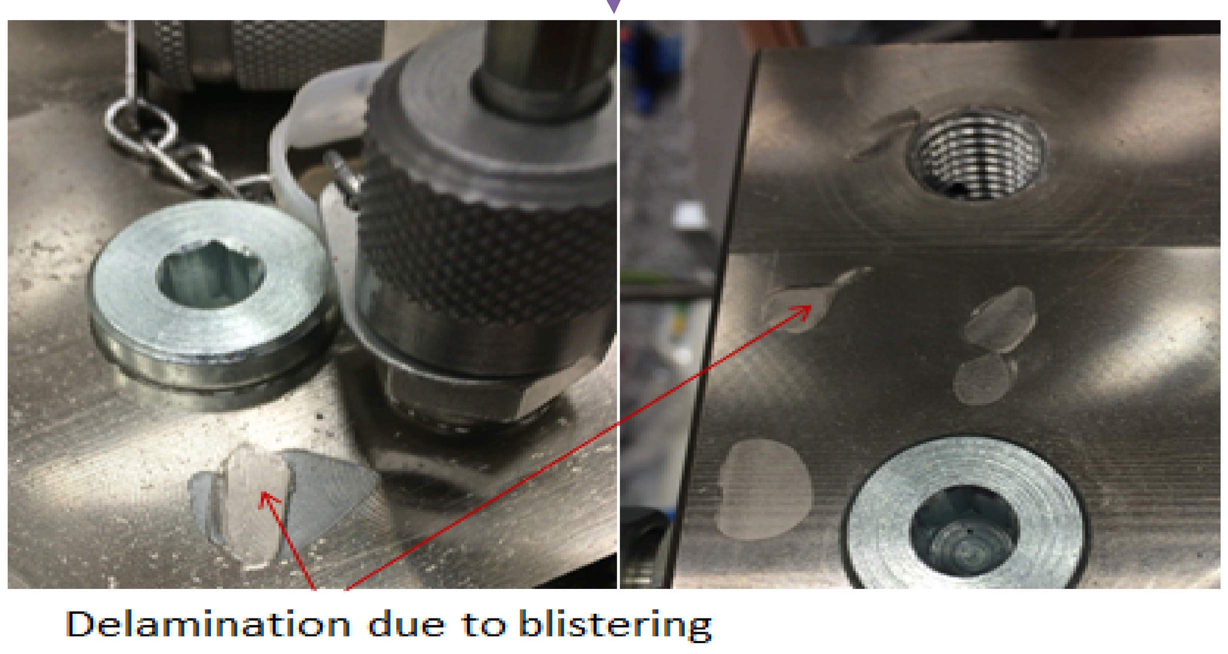

Figure 2. Coating delamination over bearing housing

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 [6].

Research challenge

Commercial plating shops 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" 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 subsequent diamond turning of the ENP coating to create ultra-smooth or micro-featured surfaces, 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.

Methodology

Aim: To observe the surface morphological change subject to different surface pre-treatment.

1. Physical pre-treatment. This includes the conventional process such as grinding and bead-blasting.
2. Deposit 50 µm of EN-P coating over the surface.
3. Inspect and compare the surface morphology (including roughness Ra and number of pores developed).

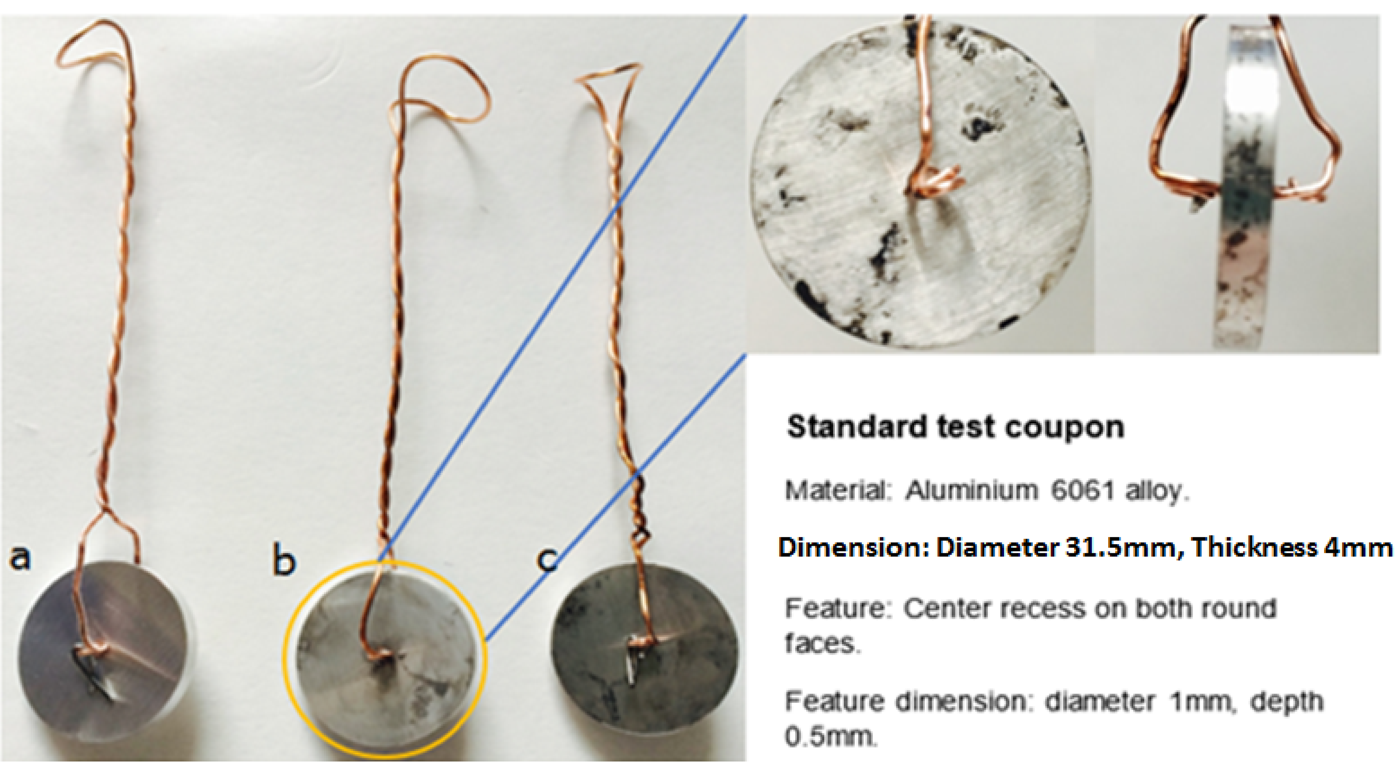

Figure 3. Standardised testing coupon for diamond turning performance experiment

Results

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.

Grinding

The grinding process provides accurate control in the formation of the surface morphology by rapid abrasion wear. Coolant in this case water was incorporated in the process to reduce the heat and grinding burns.

The surface of Al6061 aluminium alloy substrate was polished with five different level of grit size, ranging from 125 micron to 5.6 micron (P120 – P400). The resultant surface can be classified from 'coarse' to 'smooth'.

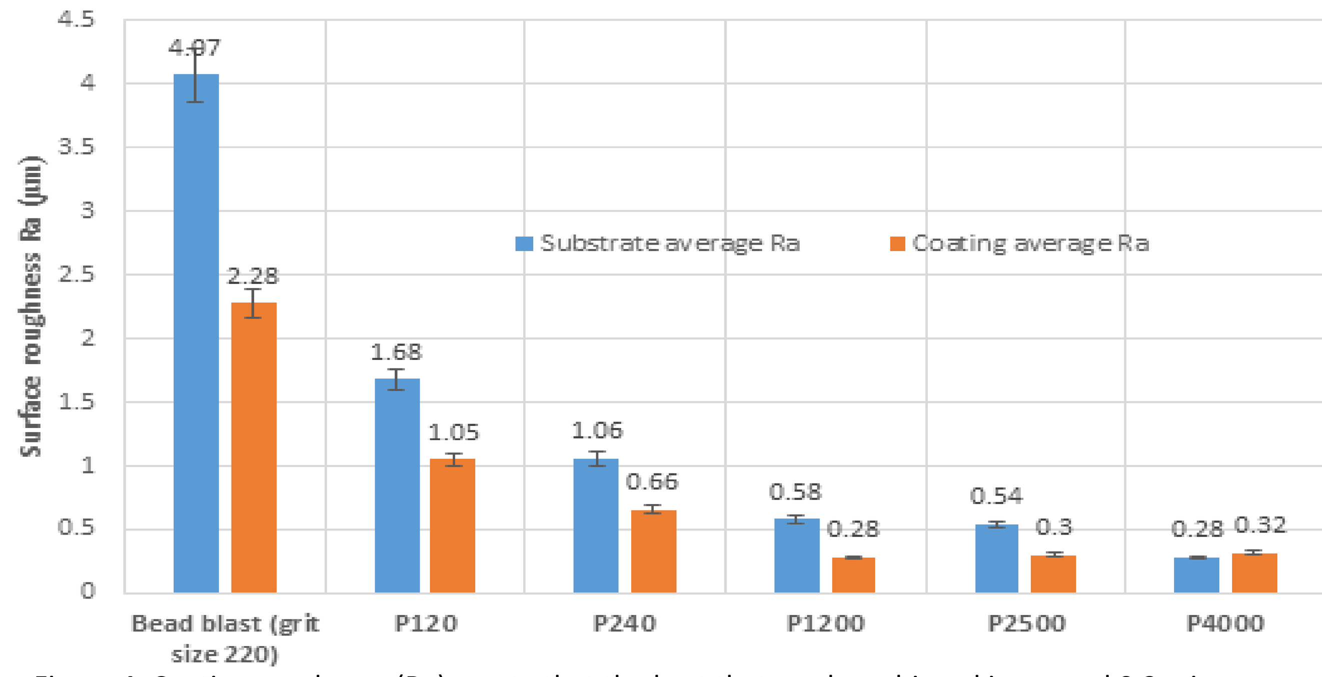

Figure 4. Coating roughness (Ra) – note that the best that can be achieved in around 0.3 micron.

The roughness (Ra) of both substrate and coating (after 4 hours of electroless plating) was measured in order to identify the saturation point where the roughness no longer follows a decreasing trend. It appears that the best Ra can be obtained "as plated" is 0.3 µm.

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 µm).

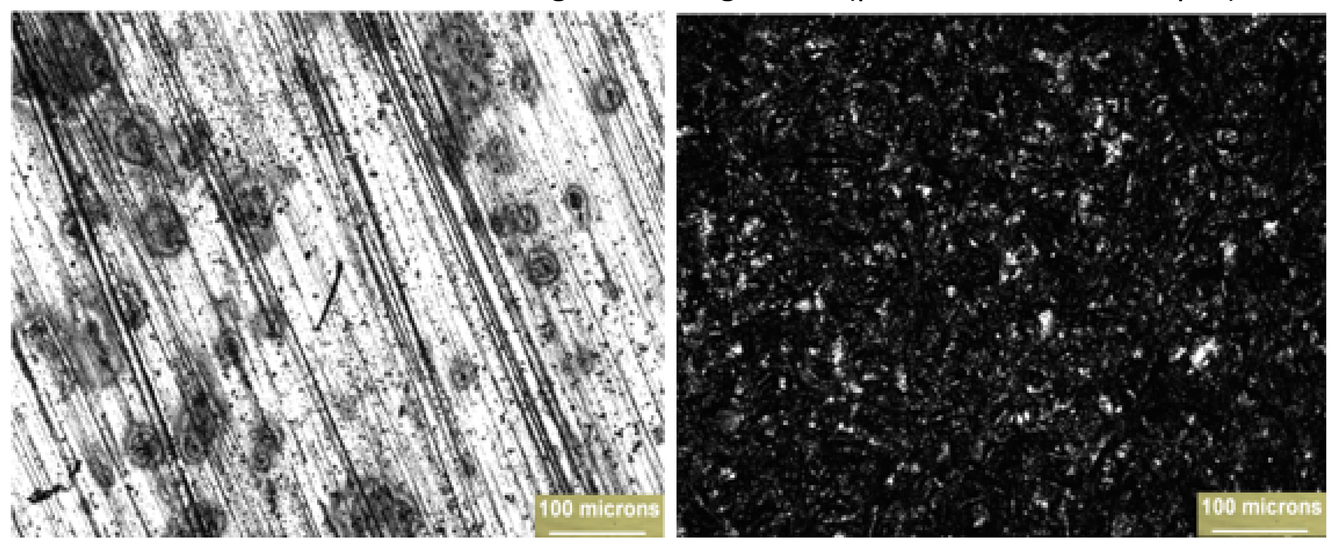

Figure 5. Microscopic view of steel substrate, (Left) P240 ground and (right) bead-blasting with 220 grit

The samples are examined under microscope prior to and post to plating. Individual features and pores were registered. The initial measurement shows that there is a significant reduction in features and pores observed in the bead-blasted sample surface.

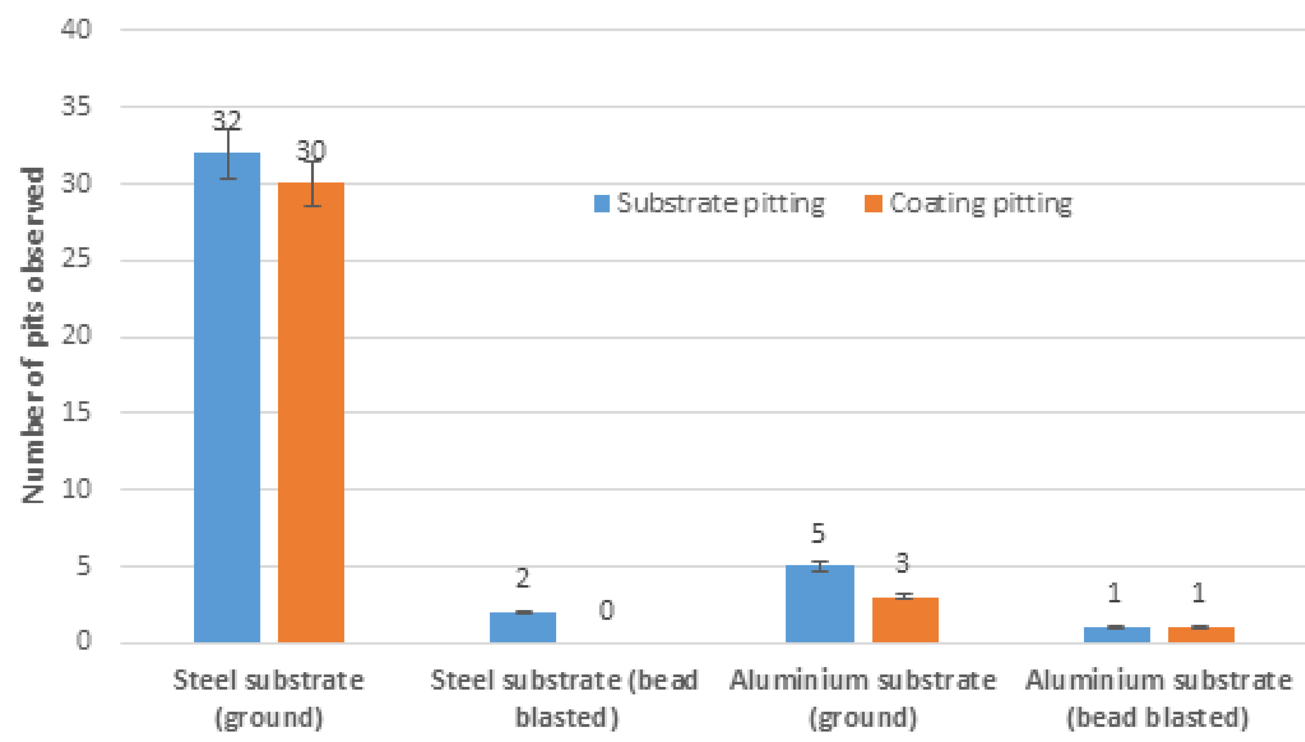

Figure 6. Pores observed after grinding and bead-blasting versus the number of pores detected as-plated.

Conclusion

The best observed post plating surface roughness for the substrate was 0.3 µm. Thus the findings here indicate further processing to reduce the final coating Ra by reducing the substrate Ra is inappropriate (such that diamond machining prior to plating, in order to achieve a 'mirror' finish becomes superfluous as you can't improve on 0.3 µm). However, this does not indicate 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.

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info@ultraprecision.org
cip-admin@eng.cam.ac.uk

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