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Note: This document is best accessed as a Word file, since the images are in color, and the original electronic version allows magnified views of the images.

Zygo Optical Profilometer Measurements of Hard Nickel Coupon: Sample Tests for Mach-6 Quiet-Flow Nozzle Throat

1. Introduction

A hard nickel coupon was fabricated to test the performance of GAR's hard electroformed nickel, which is an option for use on Purdue's Mach-6 quiet nozzle. The total cost of the throat section is about $100K, and the largest flaw in the finish controls the tunnel performance. Our concern is our ability to maintain the low initial roughness, despite operating temperatures of about 400-550F. The vendor, DEI, sent me a specimen of the subcontractor's (GAR) standard hard sulfamate nickel bath. The specimen was about 2x2x1/4 inches.

The specimen appeared mirror bright, with some cracks around the edges, a wavy surface, and many pits in the finish. There were no cracks evident in the middle of the specimen, only at the edges. It was examined in detail under the 40X binocular microscope. It was then placed in the oven at 422F for 24 hours. There was no obvious degradation of the finish. It was then provided to Chris Tieche for sample Zygo measurements of the finish.

2. Results of Zygo Profilometer Measurements

Figure 1 shows the results of the first Zygo image. The rms is 8.81 nm (0.34 microinches), Ra = 6.96 nm, the max. deviation is about 40 nm, and the image size is 0.36 x 0.27 mm. This section has a very good finish.

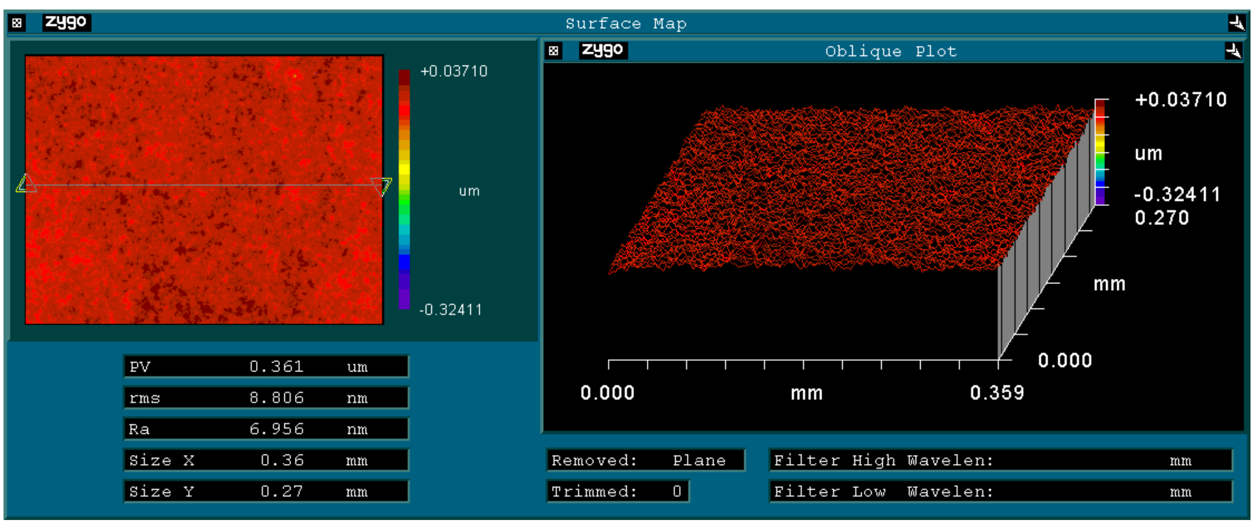

Figure 1: Area 1, Main View

Figure 2 shows a surface profile along the line indicated on the left-hand side of Figure 1. The peak deviation is roughly 20-25 nm (1 microinch) along this line.

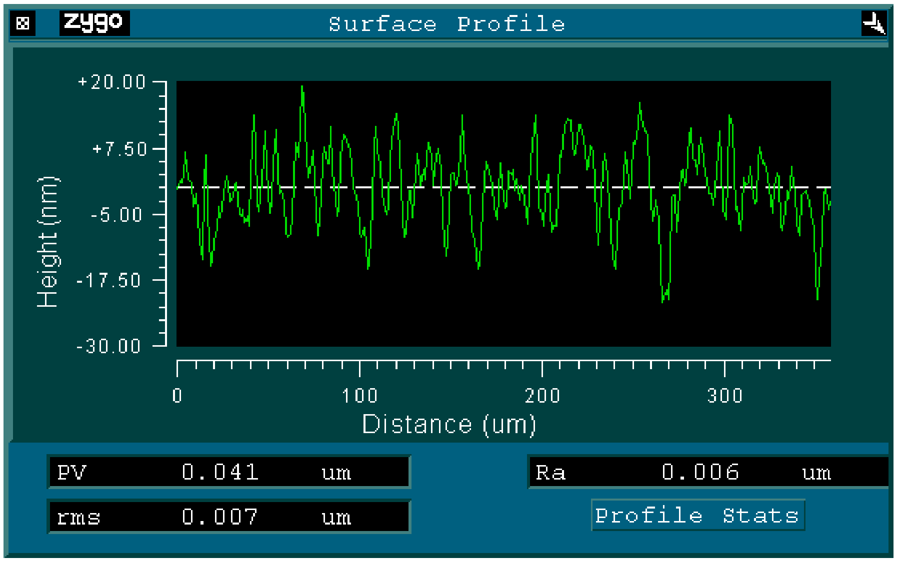

Figure 2: Profile of Area 1 along Indicated Line

Figure 3 shows the main view of the second area. The roughness is similar.

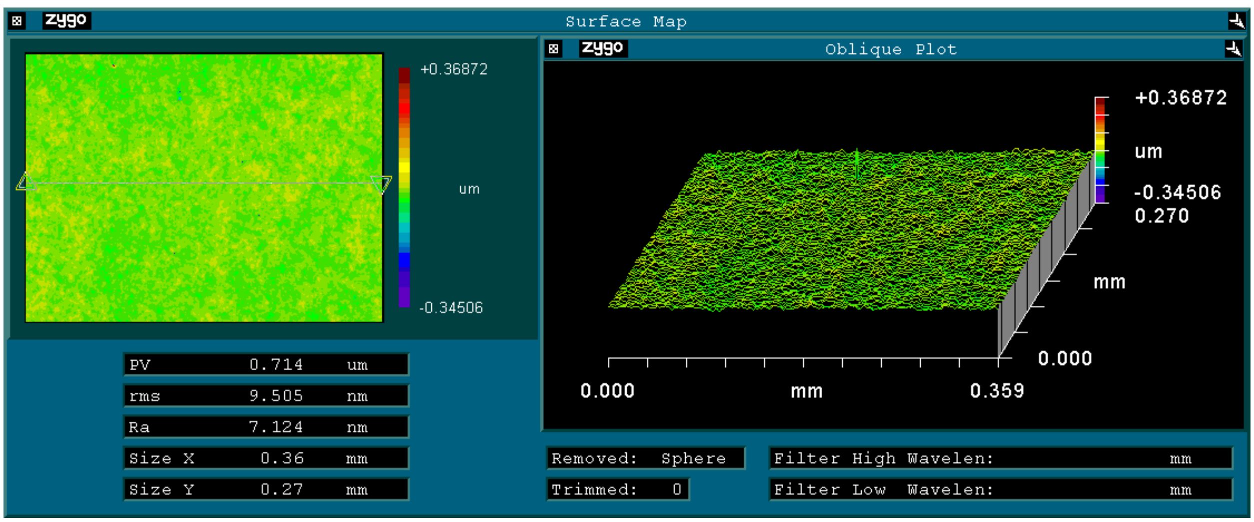

Figure 3: Main Image of Second Area

Figure 4 shows the profile along the line drawn on Fig. 3. The profile again looks similar.

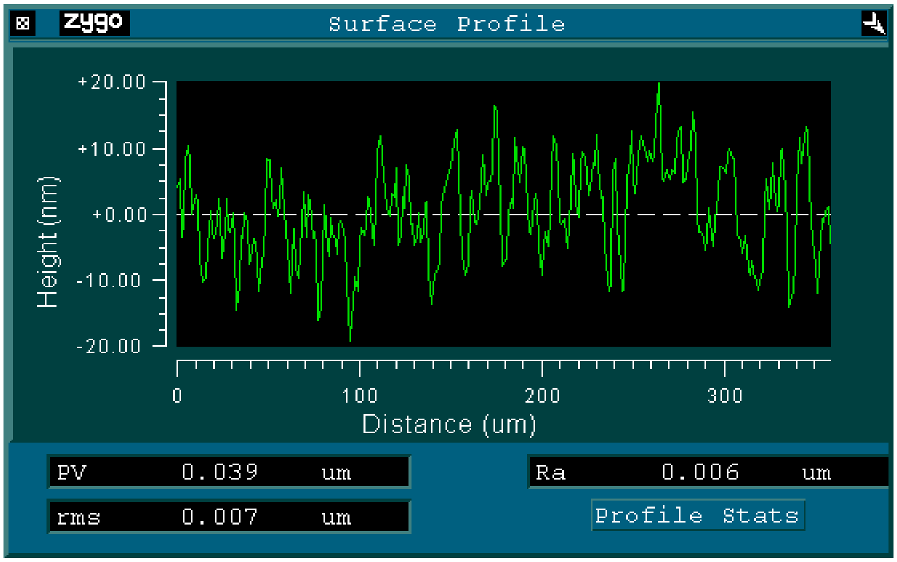

Figure 4: Profile of Second Area

Figure 5 shows the main view of the 3rd area, which again is similar. It appears rougher in the image because of the scaling.

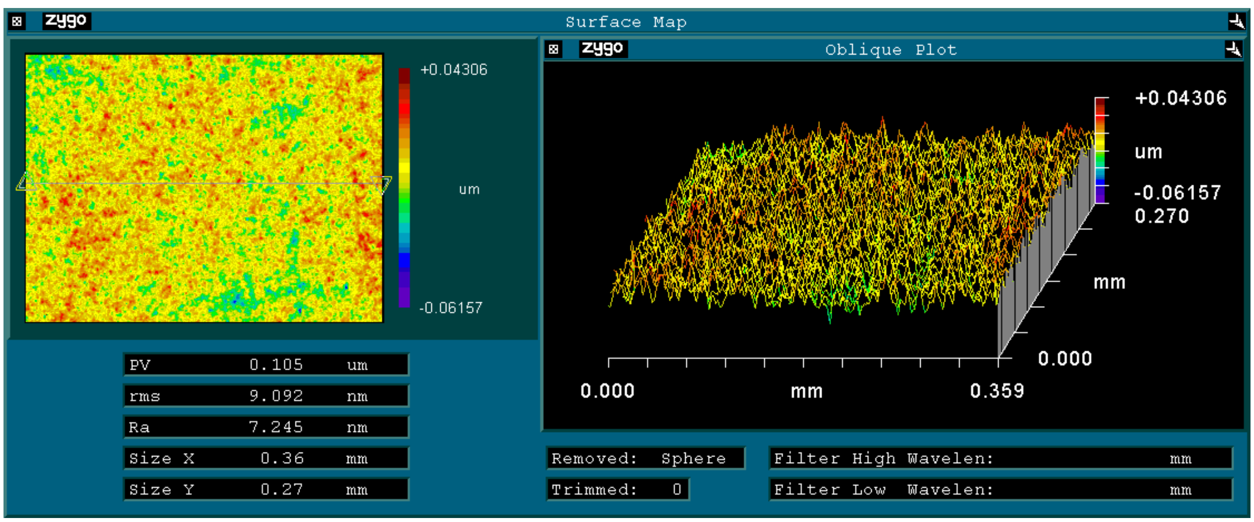

Figure 5: Main View of 3rd Area

Figure 6 is the profile along the line in Fig. 5, again similar.

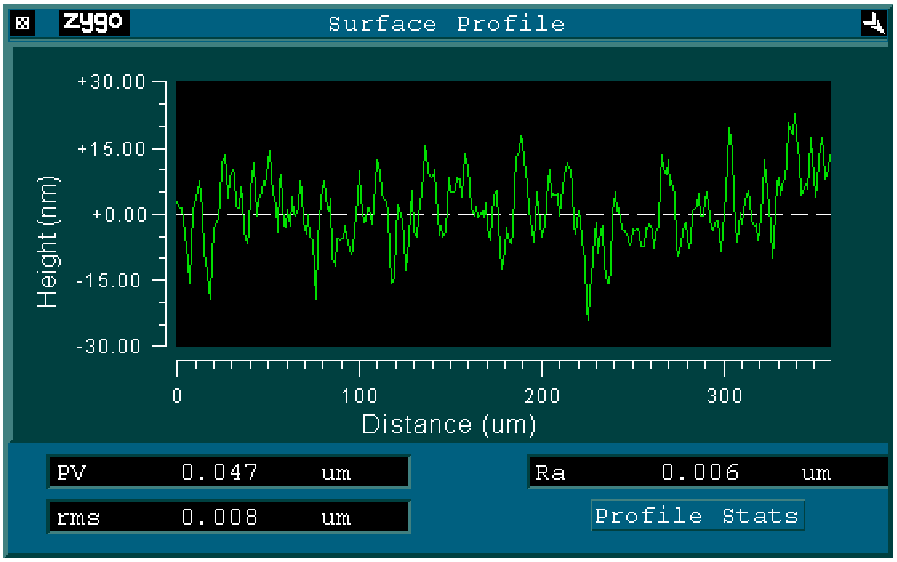

Figure 6: Profile of Area 3

Figure 7 shows a region with a large deep pit, of which there are many in the sample. The pit is about 800 nm deep (about 31 microinches). This is the 4th region imaged.

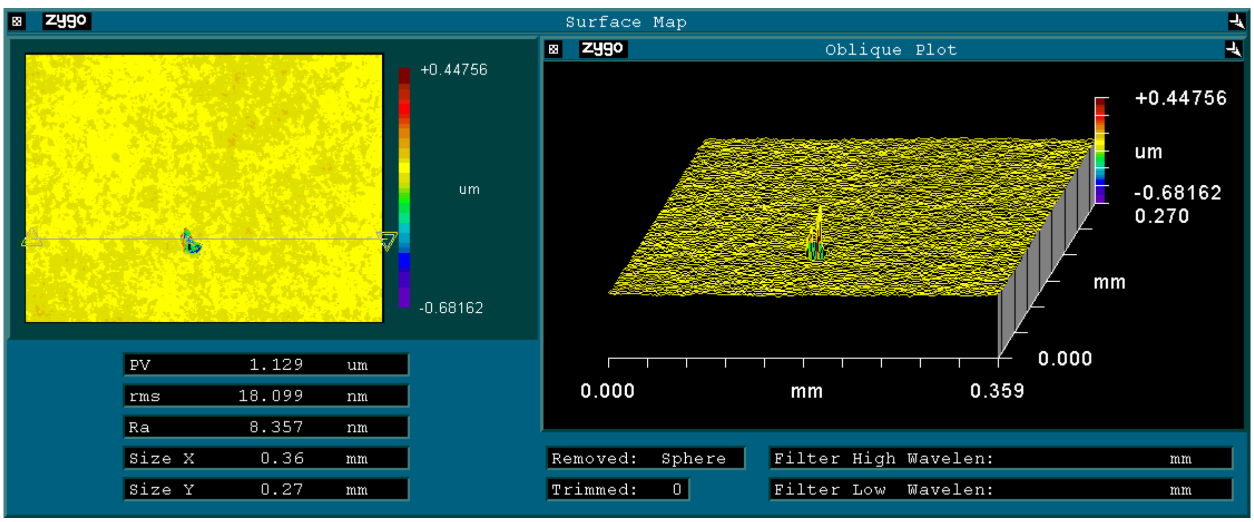

Figure 7: Main View of Area 4 with Pit

The pit depth can be seen in Fig. 8, the profile along the line shown on Fig. 7. Chris says that the Zygo cannot image the shapes of these deep pits very well, so the details of the pit geometry are not reliable.

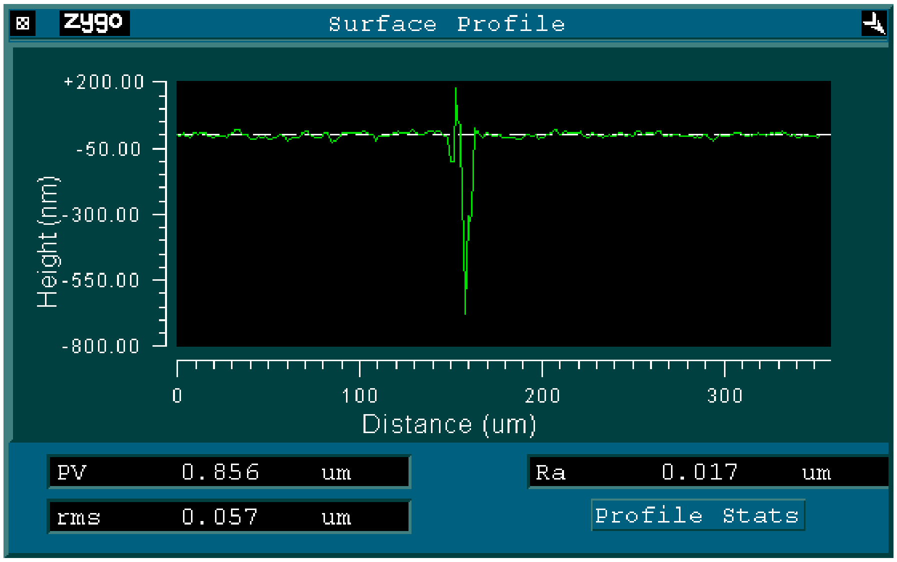

Figure 8: Profile of Area 4 Across Deep Pit

Figure 9 shows the 5th and final area. This shows significant waviness, causing a significant increase in rms roughness to 13.1 nm or 0.5 microinches.

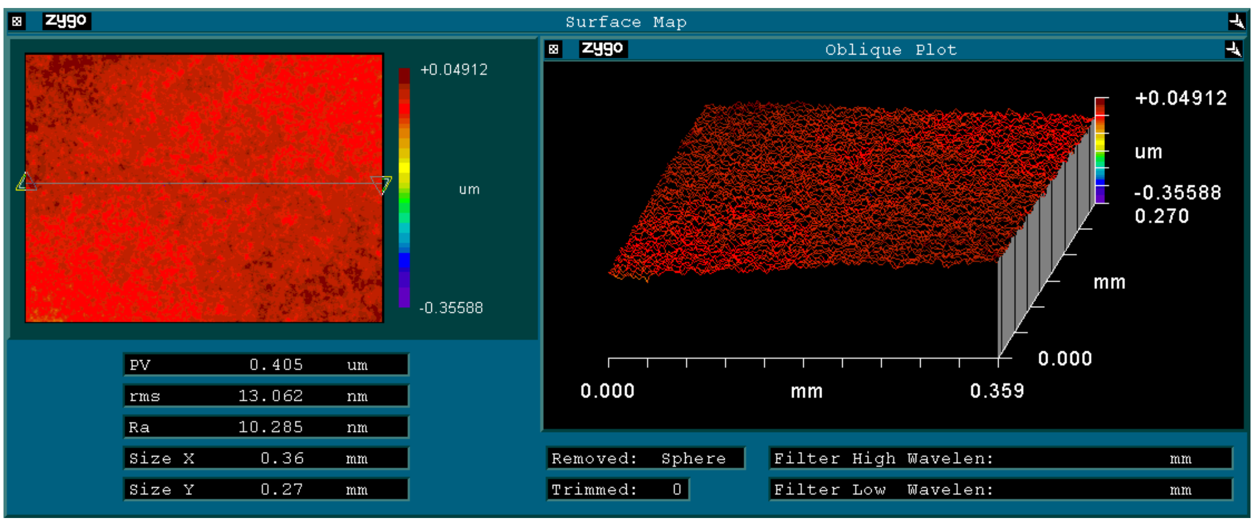

Figure 9: Main View of Area 5

Figure 10 shows the profile across the line. Peak roughness of about 25 nm is also visible (this is about 1 microinch).

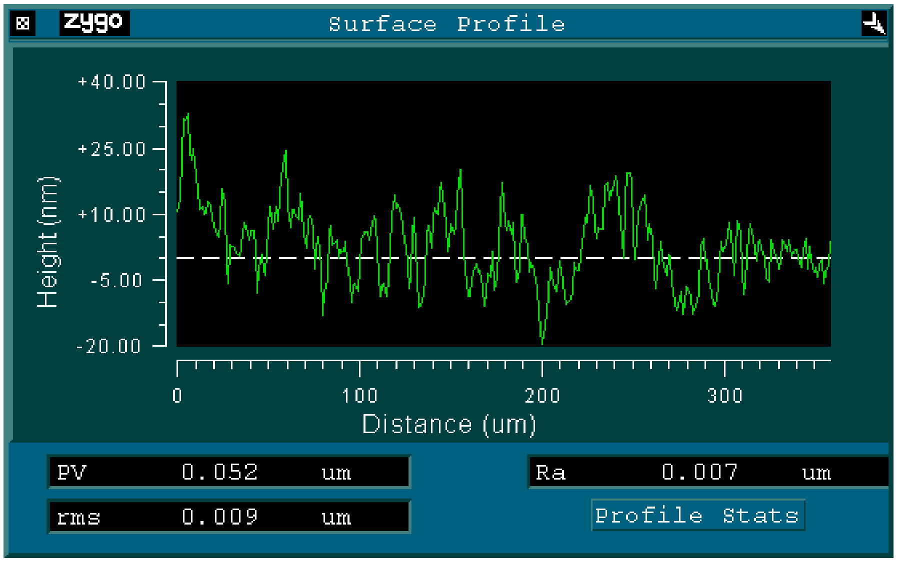

Figure 10: Profile Across Area 5

3. Conclusions

This sample had a flawed surface, due to the way it was deposited. However, much of it had a mirror finish. This mirror finish did not degrade during the heating to 425F (one day), unlike the original soft nickel sample.

This tends to suggest that the problem with the soft nickel sample was surface contamination from the silver used to begin the plating, or the alkaline silver-removing solution. It is possible that the hard nickel is just more resistant to corrosion, but it seems unlikely.

The hard nickel sample had cracks along the edges, as did the 6x6 hard/soft nickel sample. These cracks are fairly long (1/8 inch?) and deep (0.050 inches had to be milled off to get rid of most of them). This is a concern for the more brittle hard nickel, although GAR says this is due to sanding performed to clean up the coupon. Prof. Skip Grandt looked at the sample, and is checking to see if his group can perform a fracture toughness test on it. In addition, a test mandrel is being fabricated of the same material to be used for the real mandrel, so a better test of the electroforming technique can be performed.