IE 312 Metrology Lab #2: Surface Roughness Measurement

Technical Report Submitted to: Dept. of Industrial and Manufacturing Engineering

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Assessment of Measured Surfaces

The first goal of our lab was to assess the measurement surfaces that we took. The specimens we measured in this lab were a piece of cast iron (Figure 1) and a cube with a multitude of different surfaces (Figure 2). The different surfaces on the cube are listed as followed: (According to Metrology Lab Report #2)

- Surface (E) created via an extrusion process external to PSU
- Surface (B) created via a bead blasting process in the FAME lab
- Surface (R) created via a face milling process in the FAME lab using a feed rate of .01 in/tooth
- Surface (S) created via a face milling process in the FAME lab using a feed rate of .005 in/tooth
- Surface (F) created via a face milling process in the FAME lab using a feed rate of .0025 in/tooth
- Surface (G) created via a surface grinding process in the FAME lab

Figure 1. Cast Iron

Figure 2. Cube with Multitude of Surfaces

After taking our measurements, we were given a set of surface specifications as shown in Figure 3. Our task was to determine which measurements they matched up with according to the average roughness value (R_a) and roughness width cut-off value (λ_c) determined in this lab. The results are shown in Table 1.

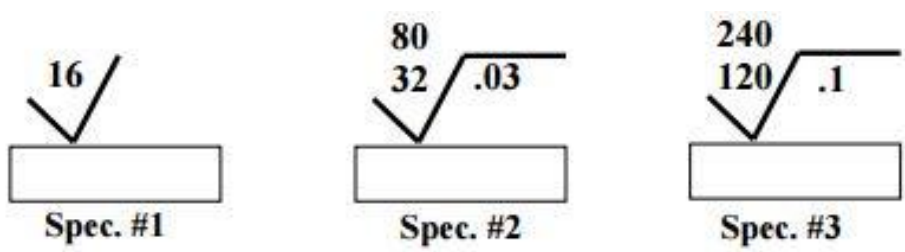

Figure 3. Measurement Specifications

Table 1. Surface Roughness Assessment

SURFACE TYPE	λc (in)	Ra (uin)	Spec #1	Spec #2	Spec #3
Ground Surface (G)	**0.03**	5	YES	NO	NO
Milled Surface(F)	**0.03**	9.9	YES	NO	NO
Milled Surface (S)	**0.03**	57.1	NO	YES	NO
Bead Blasted Surface (B)	**0.03**	113.7	NO	NO	NO
Extruded Surface (E)	**0.03**	31.7	NO	NO	NO
Milled Surface (R)	**0.03**	80.0	NO	YES	NO
Milled Surface (R)	**0.1**	184.4	NO	NO	YES
Sand Cast Surface	**0.1**	463.4	NO	NO	NO

Effect of Roughness Cut-Off on Trace Topography and Measured Surface Roughness

The Roughness cutoff value is the value for the filter that's used as a means of splitting and filtering the wavelengths. A cutoff's numerical value will reduce or get rid of the surface's undesirable wavelengths. Depending on the type of filter, either low pass or high pass, certain wavelengths above and below the cutoff value will be filtered out and others will be used to create either the waviness or roughness trace. A roughness filter cut-off with a numeric value of 0.3 mm using a short pass filter, for instance, will allow wavelengths below 0.3 mm to be measured with wavelengths larger than 0.3 mm being filtered out. The larger the wavelength, the more likely it is to be filtered out. This evens out the raw data into a more desirable trace. You can see below in figure 5 that the larger Roughness Cutoff Value, λc allows more wavelengths to pass through. This translates to a much higher Ra value that for the lower roughness cut off in figure 4. By doing this, it is clear that choosing the correct roughness cutoff value is extremely important because you can get drastically different values. In general, the cut off value should be around 10 times the wavelength of the anticipated wavelengths to be produced by the machining process. Obviously this is difficult to determine, so often times one must play around with the roughness cut off values to find the best trace.

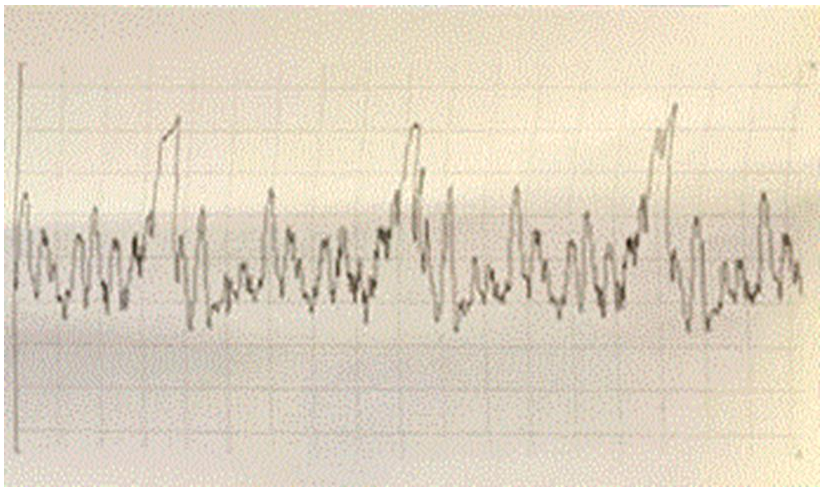

Figure 4. Trace with λc = .03 inches and Ra = 80.0 µinches

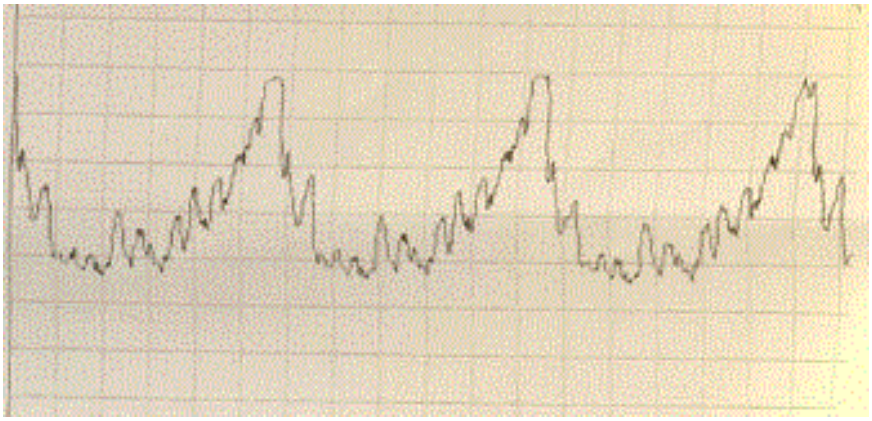

Figure 5. Trace with λc = .10 inches and Ra = 184.4 µinches

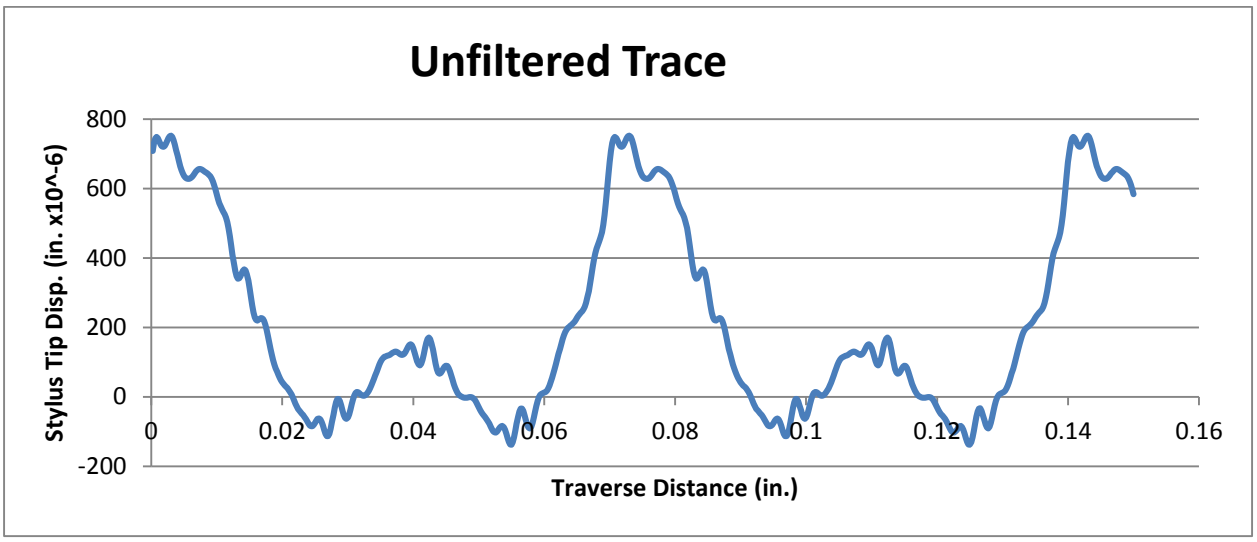

Figure 6. Unfiltered Trace

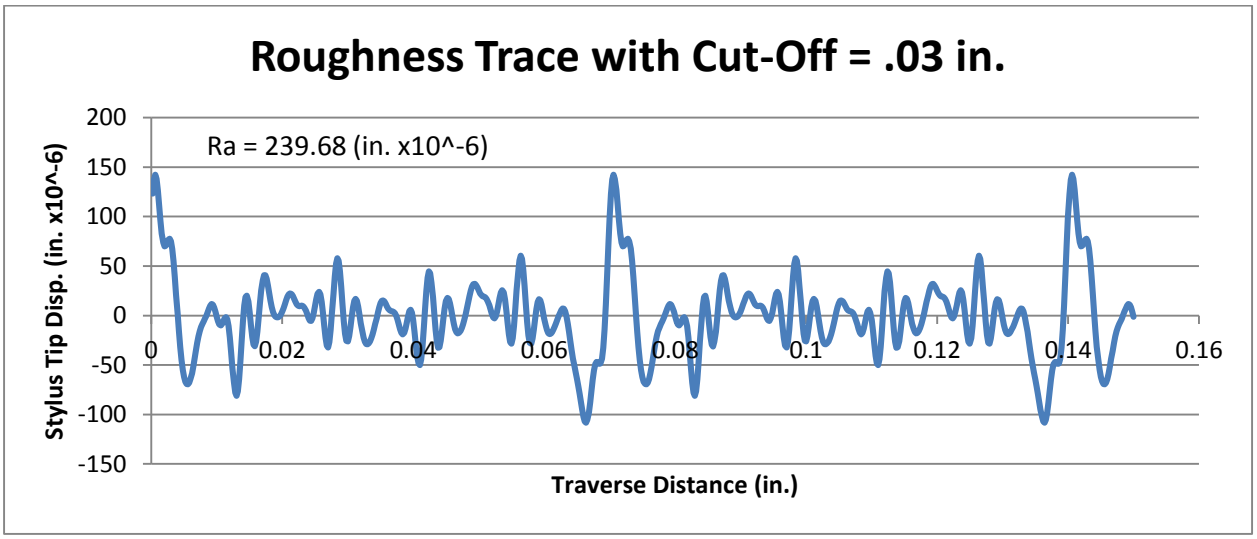

Figure 7. Roughness Trace with Cutoff Value =.03in

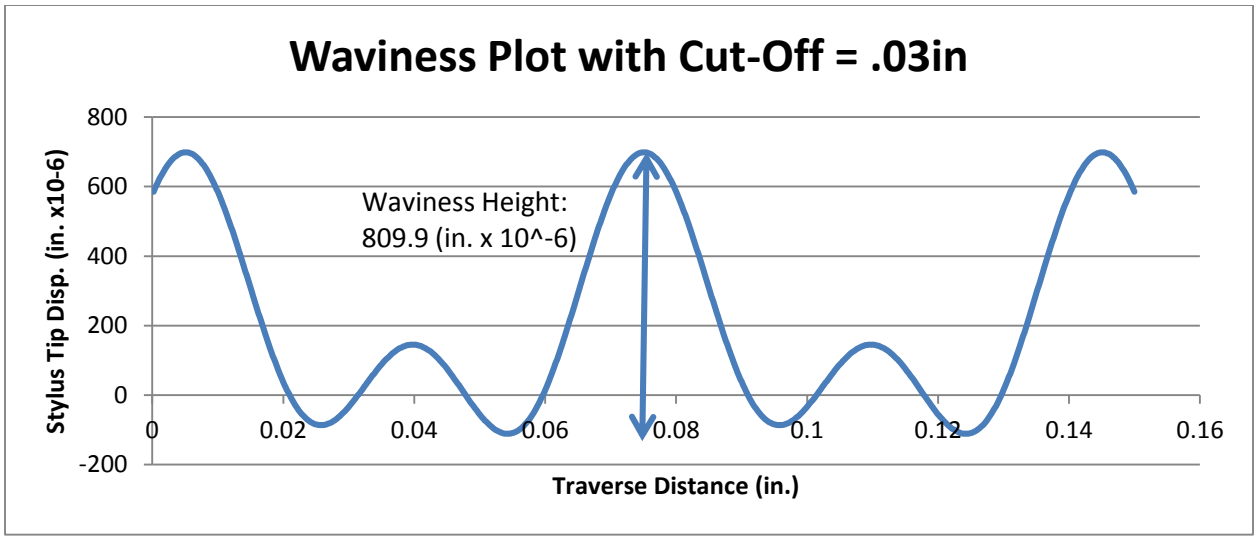

Figure 8. Waviness Plot with Cut-Off = .03in

The Ra value is the arithmetic average roughness of a parameter. It is the average height of roughness-component irregularities (peak heights and valleys) from the mean line, measured with the sampling length, L. The measurements were taken with a fine point stylus on a profilometer which moves along the sampling length on the surface being measured. We used multiple equations in this lab to assess this value and the maximum waviness height value. The waviness height is a measurement of the more widely spaced surface texture component. Waviness height can also be measured with a fine point stylus using a profilometer. The equation we used to calculate the roughness trace with cut-off value 0.03 is shown below:

$$G = Z - A_0 - A_1 \cos(\frac{2\pi * X}{\lambda_1}) - B_1 \sin(\frac{2\pi * X}{\lambda_1}) - A_2 \cos(\frac{2\pi * X}{\lambda_2}) - B_2 \sin(\frac{2\pi * X}{\lambda_2})$$

In order to use this equation, we first had to determine the fourier series coefficients. The value for A_0 and A_1 are shown below:

A_0 = Average Value of Z in one Wavelength

$$A_1 = \frac{2}{L} * \Delta X * \sum_{j=1}^{N} \cos(\frac{2\pi * X_j}{L_1})$$

Where L is the length of one single wavelength, L1 is the first modal wavelength, is delta X is the change in X. Now with all the fourier coefficients, we used the equation that we stated above and shown again below to calculate the roughness trace:

$$G = Z - A_0 - A_1 \cos(\frac{2\pi * X}{\lambda_1}) - B_1 \sin(\frac{2\pi * X}{\lambda_1}) - A_2 \cos(\frac{2\pi * X}{\lambda_2}) - B_2 \sin(\frac{2\pi * X}{\lambda_2})$$

In order to calculate the Waviness Plot, we used the equation below, and plotted it against X:

$$W = A_0 + A_1 \cos(\frac{2\pi * X}{\lambda_1}) + B_1 \sin(\frac{2\pi * X}{\lambda_1}) + A_2 \cos(\frac{2\pi * X}{\lambda_2}) + B_2 \sin(\frac{2\pi * X}{\lambda_2})$$

In order to calculate the maximum waviness height we took the maximum of W minus the minimum value of W.

In this lab, our Ra value was 239.68 x 10^-6 in. We found this by using the Roughness trace equation above and taking the average peak values.

Our maximum waviness height was equal to 809.9 x 10^-6 in, which was found by taking the max waviness value and subtracting it from the minimum waviness value.

The rest of the calculations can be found on the attached Excel Spreadsheet titled “Met Lab #2 Section 2 and Team 4”.

Product Design Requirements and Manufacturing Capability Analysis

Table 2. Surface Roughness Requirements

Functional Surface	Ra Requirements (uin)	Reference ID #
Brake Rotor	60	1
Bearing Race	7.8	2
Artificial Knee Joint Bearing Surface	59.1	3
Optical Lens	0.2	4
Food Processing	11.81	5
Electrical Contact	1	6
Auto Engine Cylinder Bore	20	7

Table 3. Process Compatibility Assessment

Functional Surface	Applicable Manufacturing Processes
Brake Rotor	Surface S, face milling process feed rate of 0.005 in/tooth
Bearing Race	Surface F, face milling process feed rate of 0.0025 in/tooth
Artificial Knee Joint Bearing Surface	Surface S, face milling process feed rate of 0.005 in/tooth
Optical Lens	None of the surfaces we analyzed have this small of a roughness
Food Processing	Surface F, face milling process feed rate of 0.0025 in/tooth
Electrical Contact	None of the surfaces we analyzed have this small of a roughness, closest to Surface G
Auto Engine Cylinder Bore	Surface E, extruded surface

The brake rotor rated at 60 µin needs that roughness to create the friction that slows vehicles down. The brake rotors can not be too course though as to damage the brake pads while stopping, i.e. cause gouges on the pads and wear them down quickly. The Bearing race has a relatively low roughness because you want to reduce the friction as much as possible in order to improve the efficiency of the system. Artificial knee joint Bearing Surfaces have a very high roughness value. This is to ensure that the lower and upper portion of the knee have maximum friction so they do not slip. This allows the user to move their legs effectively. The roughness value on the portions of the joint that touch the real bone are not as high as they do not want to have too much friction on the real bones, but there needs to be enough to have the bond bind to the prosthetic. Optical Lenses have extremely low roughness to prevent the beam of photons from scattering, the roughness value is far below any of the surfaces we measured in the lab. Food Processing products have a relatively low roughness to facilitate the cleaning process. If the roughness value was too high, there would be many small cracks and edges for germs and bacteria to live, and it would be difficult to clean effectively. At the same time, the value can not be too low as this adds extra cost. Electrical Contacts have very low roughness to allow the flow of current, and to ensure that there is no lose in the contacts. Engine cylinder bores have roughness that wears down overtime. They use oil to keep the friction low enough to keep things running smoothly. The roughness can't be too high or there would be a lot of loss when driving the engine due to the friction and heat of the piston going up and down in the cylinder. In the end, most of these applications have locational contact or sliding contact, but some have much more precise roughness values as to be most efficient for their uses.

References

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2) http://www.efunda.com/designstandards/bearings/bearings_rotary_lubrication.cfm

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4) http://www.edmundoptics.com/resources/application-notes/optics/understanding-optical-specifications/

5) https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwippsXfuILLAhXDOCYKHcF6DjUQFgghMAA&url=http%3A%2F%2Feprints.soton.ac.uk%2F199703%2F1%2F3.S14StainlessSteelFST10.pdf&usg=AFQjCNE6HHpy0Lz7i_4q69nSkBEDlIKsPw&sig2=SMHWklx7SCGQl_0GGsVOGw

6) https://hal.inria.fr/file/index/docid/670045/filename/FPENNEC_IEEE_CPMT_301109.pdf

7) http://www.enginebuildermag.com/2000/09/cylinder-bore-surface-finishes/

Appendix

APPENDIX MEASUREMENT DATA SHEET

SURFACE TYPE	λ_c (in)	R_a (µin)	R_q (µin)
Ground surface (G)	.03	5.0	7.2
Milled surface (F)	.03	9.9	11.7
Milled surface (S)	.03	57.1	71.9
Bead Blasted surface (B)	.03	113.7	140.5
Extruded surface (E)	.03	31.7	40.3
Milled surface (R)	.03	80.0	104.9
Milled surface (R)	.10	184.4	228.9
Sand Cast surface	.10	463.4	558.3

Table 4. Appendix of Values taken in Lab