Deep Patel
Section 2

Measurements: Metrology & Error Analysis Lab 2

SID: 159000639
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Lab: D123b
Date: 2/14/17
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1.) Room

Room Measurements						
Length (in.)	288.9	289.0	289.3	289.2	289.1	289.1
Width (in.)	227.5	227.5	227.3	227.4	227.5	227.6

2.) L-Block

L-Block Measurements								
Measurement #-> / Trial #	1 (in)	2 (in)	3 (in)	4 (in)	5 (in)	6 (in)	7 (in)	8 (in)
1 (tape measure)	0.61	0.52	1.04	2.37	0.25	0.25	2.01	2.02
2 (tape measure)	0.59	0.52	1.04	2.36	0.25	0.25	2.01	2.01
3 (tape measure)	0.60	0.53	1.04	2.37	0.25	0.26	2.01	2.01
4 (caliper)	0.602	0.521	1.043	2.366	0.251	0.254	2.011	2.009
5 (caliper)	0.595	0.520	1.041	2.361	0.253	0.254	2.010	2.010
6 (caliper)	0.600	0.519	1.042	2.364	0.249	0.254	2.012	2.012

Measurement # Details (same as what was drawn on the board in Lab):

1. Diameter of hole
2. Distance from hole edge to nearest block edge
3. Distance from top hole edge to top of block
4. Width of the block
5. Thickness of bottom part of block
6. Thickness of top part of block
7. Length of top side of the block
8. Length of bottom side of the block

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3.) Five_Hole Block

Five-Hole Block Measurements (w/ Coordinate Measuring Machine)							
	1 (in)	2 (in)	3 (in)	4 (in)	5 (in)	6 (in)	7 (in)
Measured	0.4920	0.6340	0.6337	0.6342	0.6331	0.8738	1.7489
Actual	0.500 +- 0.003	0.6325 +- 0.007	0.6325 +- 0.007	0.6325 +- 0.007	0.6325 +- 0.007	0.875	1.750 +- 0.005
	8 (in)	9 (in)	10 (in)	11 (in)	12 (in)	13 (in)	14 (in)
Measured	0.8747	1.7511	1.557	1.559	3.1183	3.1137	0.2689
Actual	0.875	1.750 +- 0.005	1.500	1.500	3.000	3.000 +- 0.010	0.260 +- 0.005

<u>Measurement # Details:</u>

1. Center hole diameter
2. Top-left hole diameter
3. Top-right hole diameter
4. Bottom-right hole diameter
5. Bottom-left hole diameter
6. Horizontal distance from center of center-hole to center of top-right hole
7. Horizontal distance from center of top-left hole to center of top-right hole
8. Vertical distance from center of center-hole to center of bottom-right hole
9. Vertical distance from center of top-right hole to center of bottom-right hole
10. Distance from center of center hole to bottom edge of block
11. Distance from center of center hole to left edge of block
12. Top length
13. Side Length
14. Thickness

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IV. RESULTS

1. Room

a. See attached
b. See attached
c. See attached
d. Repeated measurements can decrease uncertainty because there will be more values closer to the mean and the weight of outliers will do down because you are dividing by a bigger N (# of measurements).
e. The tape measure is great for home construction because although the uncertainty is higher than other, more advanced tools, an extremely precise measurement is not so necessary for this work because all the elements have a larger room for error and still work; this is, of course, a non-moving structure. On the other hand, small errors in dimensions in an engine fabrication can greatly affect the performance of an engine because there are a lot more complication processes happening in this.

2. L-Block

a. See attached
b. See attached
c. Systematic errors are consistent in their error in a certain direction and rough amount, while random errors are imprecisions in measurements that is caused by imprecision in measurement, thus they fluctuate in different directions, in different amount. Thus, it is harder to measure or detect systematic error because all the data is shifted in one direction, whereas random error can be determined through statistical analysis and be minimized through more averaging over a larger number of observations. I would estimate the size of the systematic error in both the ruler and the caliper to be very small. It would be smaller for the caliper than the ruler, because it has a greater accuracy. Systematic error in both can be caused by not holding the device straight or flush with the block, reading from different angles, or misjudgments in reading the measurement values. This occurs more for the ruler because you have line it up and make it straight while reading, whereas in the caliper, you can line it up and tighten it so it stays in place and then read. I would incorporate this error into the total estimate of the error by taking the sum of the squares of systematic and random errors and take the square root to get the total error.
d. See attached calculations. At most 1 part per 100000 parts based on the 0.001" SD and +-0.005" tolerance. The extra money wasted from this additional part would be at most $1.85.

3. Five-Hole Block

a. Faro Edge Specifications
   i. Accuracy: +-0.034mm (+-0.0013in)
   ii. Repeatability: +- 0.024mm (+-0.0009in)

iii. Accuracy is a measure of how close a measured quantity is from a standard or agreed upon "actual" or "true" quantity. On the other hand, repeatability is a measure of how well a device can reproduce an outcome (the same measurement) given that no other conditions have been changed. In general, repeatability is more important that accuracy because if you have repeatability, then you can map the error that is occurring and compensate for it. Also, in general if a device is not repeatable, then it cannot really be accurate.

b. Yes, there are dimensions that do no fall within the dimension tolerances, some by a little and some by a lot. All the circle diameters were out of the tolerance by about 0.01 in. On the other hand, the side dimensions were off by as much as 0.11in. We consulted with you to ask why some dimensions were so off, but were not able to find a solution for more accuracy with the machine.

c. Benefits vs disadvantages of a coordinate measuring machine over tools like calipers and rulers.
   i. Benefits: After calibrating, you can get dimensions by just clicking the gun on different planes, lines, etc. It is more accurate and precise than most devices, and there is a lot less human judgment error involved. There is also robustness against external forces and error accumulation.
   ii. Disadvantages: they can be complicated to handle, and if calibrating is not done properly, all the measurements done thereafter are wrong. Also, you have to clamp down that whatever you are measuring to make sure it does not move or rotate with respect to the radius and not all shapes (like a sphere) can be easily clamped. Also, some parts are too big or may not be portable to be measured by the CMM, whereas a tape measure you can take wherever you want.
   iii. Thus, in certain situations it is better to use CMM and in others, better to use other simpler tools like calipers, rulers and tape measures.

```
% Measurements Lab 2 Results
```

1. Room

```
clear all, close all, clc

% Part a
L = [288.9, 289.3, 289.1, 289, 289.2, 289.1];
W = [227.5, 227.5, 227.3, 227.4, 227.5, 227.6];

% Mean dimensions of room
Lm = sum(L)/size(L,2)
Wm = sum(W)/size(W,2)

Ld = 0; Wd = 0;
for i = 1:size(L,2)
    Ld = Ld + (L(i)-Lm)^2;
    Wd = Wd + (W(i)-Wm)^2;
end

% Standard Deviation
Ls = Ld^0.5
Ws = Wd^0.5


% Part b
```

```
Lm =

  289.1000


Wm =

  227.4667


Ls =

    0.3162


Ws =

    0.2309
```

2. L-Block

```
% Part a
```

```
% Tape Measure
T1 = [0.611 0.591 0.597];
T2 = [0.521 0.522 0.518];
T3 = [1.041 1.042 1.041];
T4 = [2.3689 2.3641 2.3664];
T5 = [0.250 0.250 0.2495];
T6 = [0.251 0.251 0.254];
T7 = [2.010 2.013 2.010];
T8 = [2.014 2.010 2.011];

% Mean dimensions for tape measure (in inches)
mT1 = sum(T1)/3
mT2 = sum(T2)/3
mT3 = sum(T3)/3
mT4 = sum(T4)/3
mT5 = sum(T5)/3
mT6 = sum(T6)/3
mT7 = sum(T7)/3
mT8 = sum(T8)/3

uT1 = 0;
uT2 = 0;
uT3 = 0;
uT4 = 0;
uT5 = 0;
uT6 = 0;
uT7 = 0;
uT8 = 0;
for i = 1:size(T1,2)
    uT1 = uT1 + (T1(i)-mT1)^2;
    uT2 = uT2 + (T2(i)-mT2)^2;
    uT3 = uT3 + (T3(i)-mT3)^2;
    uT4 = uT4 + (T4(i)-mT4)^2;
    uT5 = uT5 + (T5(i)-mT5)^2;
    uT6 = uT6 + (T6(i)-mT6)^2;
    uT7 = uT7 + (T7(i)-mT7)^2;
    uT8 = uT8 + (T8(i)-mT8)^2;
end

% Uncertainty in inches (2 standard deviations)
uT1 = uT1^0.5
uT2 = uT2^0.5
uT3 = uT3^0.5
uT4 = uT4^0.5
uT5 = uT5^0.5
uT6 = uT6^0.5
uT7 = uT7^0.5
uT8 = uT8^0.5

% Caliper
C1 = [0.602 0.595 0.599];
C2 = [0.521 0.520 0.519];
C3 = [1.043 1.041 1.042];
```

```
C4 = [2.366 2.3612 2.3612];
C5 = [0.251 0.2525 0.2495];
C6 = [0.254 0.254 0.254];
C7 = [2.011 2.010 2.012];
C8 = [2.009 2.010 2.012];

% Mean dimensions for caliper (in inches)
mC1 = sum(C1)/3
mC2 = sum(C2)/3
mC3 = sum(C3)/3
mC4 = sum(C4)/3
mC5 = sum(C5)/3
mC6 = sum(C6)/3
mC7 = sum(C7)/3
mC8 = sum(C8)/3

uC1 = 0;
uC2 = 0;
uC3 = 0;
uC4 = 0;
uC5 = 0;
uC6 = 0;
uC7 = 0;
uC8 = 0;
for i = 1:size(T1,2)
    uC1 = uC1 + (C1(i)-mC1)^2;
    uC2 = uC2 + (C2(i)-mC2)^2;
    uC3 = uC3 + (C3(i)-mC3)^2;
    uC4 = uC4 + (C4(i)-mC4)^2;
    uC5 = uC5 + (C5(i)-mC5)^2;
    uC6 = uC6 + (C6(i)-mC6)^2;
    uC7 = uC7 + (C7(i)-mC7)^2;
    uC8 = uC8 + (C8(i)-mC8)^2;
end

% Uncertainty in inches (2 standard deviations)
uC1 = uC1^0.5
uC2 = uC2^0.5
uC3 = uC3^0.5
uC4 = uC4^0.5
uC5 = uC5^0.5
uC6 = uC6^0.5
uC7 = uC7^0.5
uC8 = uC8^0.5

% Part b

% Tape measure

vT  = (mT8*mT5*mT4)+((mT7-mT5)*mT6*mT4)-(pi*mT1*mT1/4*mC5)

pT1 = uT1/mT1;
pT4 = uT4/mT4;
pT5 = uT5/mT5;
```

```
pT6 = uT6/mT6;
pT7 = uT7/mT7;
pT8 = uT8/mT8;

uT = ((pT1*2)+(2*pT4)+(3*pT5)+pT6+pT7+pT8)*vT

% Caliper

vC  = (mC8*mC5*mC4)+((mC7-mC5)*mC6*mC4)-(pi*mC1*mC1/4*mC5)

pC1 = uC1/mC1;
pC4 = uC4/mC4;
pC5 = uC5/mC5;
pC6 = uC6/mC6;
pC7 = uC7/mC7;
pC8 = uC8/mC8;

uC = ((pC1*2)+(2*pC4)+(3*pC5)+pC6+pC7+pC8)*vC


% Part d
format long
% number of parts defective per 100000 parts
x = 100000 - ((1 - 1/(3.5*10^6))^8 * 100000)
format short
% Money wasted, at most
m = vC*0.85
```

```
mT1 =

    0.5997


mT2 =

    0.5203


mT3 =

    1.0413


mT4 =

    2.3665


mT5 =

    0.2498
```

```
mT6 =

    0.2520


mT7 =

    2.0110


mT8 =

    2.0117


uT1 =

    0.0145


uT2 =

    0.0029


uT3 =

   8.1650e-04


uT4 =

    0.0034


uT5 =

   4.0825e-04


uT6 =

    0.0024


uT7 =

    0.0024


uT8 =

    0.0029
```

```
mC1 =

    0.5987

mC2 =

    0.5200

mC3 =

    1.0420

mC4 =

    2.3628

mC5 =

    0.2510

mC6 =

    0.2540

mC7 =

    2.0110

mC8 =

    2.0103

uC1 =

    0.0050

uC2 =

    0.0014

uC3 =

    0.0014
```

```
uC4 =

    0.0039

uC5 =

    0.0021

uC6 =

     0

uC7 =

    0.0014

uC8 =

    0.0022

vT =

    2.1687

uT =

    0.1487

vC =

    2.1779

uC =

    0.1025

x =

   0.228571199972066

m =
```

```
1.8512
```

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