MEEM 5650 – Advanced Quality Engineering

Workshop 2 Assignment

INSTRUCTOR

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Team 1

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Executive Summary:

Introduction:

In This Workshop, TURNSIM Software Is used to analyze a lathe-turning process to detect such Statistical methods and enhance the process stability and capability, TURNSIM is used to model only one operation of single – point lathe Turing which is used for bronze bushings. this workshop focuses on the collection of samples on Process chart creation and analysis, special cause detection and validation and a process capability study shall be conducted.

And from the Workshop 2 Guidelines we get to know that the Surface Roughness of the Bushing is measured, and the Specification is given as 70±µin, whereas the Lower Specification Limit is 55µin and the Upper specification Limit is 85µin. And the Diameter Specifications is given as 2.250±0.002in.

Solving the special causes is critical for two reasons, firstly to achieve consistent quality as well as to guarantee the process delivers on the specification required.

The statistical tool used in this workshop is Minitab in which we use the Xbar chart and the R control charts to establish the connection of the process variations to specific causes in order that the required results are been validated.

The analysis of the process concludes with a process capability study to determine if the process meets the prescribed specifications and or if it is statistically capable.

And we have given a table of 10 Potential special causes and the level of variation which can occur during this turning operation which are specified as: Cutting Speed, Feed rate, Set-up Person, Operator, Tool type, Tool condition, Depth-to-Shoulder, Machine, measuring Device and Rake Angle.

And as we already know that the Depth-to-shoulder or else the Measuring Device cannot be a cause affecting the Surface Roughness of the Bronze Bushing, so we must check for the other 8 special causes which can be the factor affecting the surface roughness.

The results of this workshop will help us to understand the effects of the special causes on the process behavior and identifying the opportunities for enhancing the process control and capacity

Procedure:

This workshop 2 was studied in several logical as well as iterative approaches to analyze and improve the process. and the following procedure was followed.

Firstly, we start with the data collection which was done with the help of TURNSIM software where we collected the sample data from the turning process. And for this the sample size n =5 was collected with the number of sampled (k) determined based on the need to observe sufficient variations in the process. This data was collected in the excel file for further analysis. In our test case we took a total of 40 samples.

Secondly the X bar chart and the r chart were constructed with this data to see the performance of this process. These charts were used to verify the statistical signals and in analyzing whether the process was out of control or having any special causes.

The Correlation of Special Causes identified statistical signals, and the patterns were correlated with the ten possible special causes given, the most probable cause for each signal was determined using Scatter plots and the set of data.

Iterative Date Collection. When with the help of scatter plots some special causes were suspected, additional data were collected with the identified special cause which was been checked as a major factor. The iterative process ensures that the special cause was verified and allowed for the collection of additional sampled for other variations.

Verification and Identification of Special causes. For every special cause found was validated using Physical reasoning and evidence from the control charts. the repetitive process was done until all the three special causes were identified and verified.

Process Capability Analysis: A Process Capability study was performed using percent conforming, Cp and Cpk values based on part specifications and the assumptions of normality in the distribution of normality in the distribution of individual measurements. As well as would test the ability to process to maintain its specifications.

Report Preparation: The results, conclusions and recommendations were collected and made into a report. This report included an executive summary, a detailed explanation about the procedure findings in this study, conclusions and an appendix which contains all the raw data and all the control charts

Trail 1:

To Start with the Workshop, we installed the TURNSIM Software and For the First Trail a total of 40 samples were taken as per the guidance of the instructor, which was taking 30-40 samples. using Minitab Software, we were able to get the X bar chart and the R charts to verify the Process. These Controls Charts were useful in finding the points of violation of the Statistical control points which are out of the control limits and the presence of nonrandom patterns. Even such kind of Violations may be due to some Potential special causes that will be a problem for the Process stability. With the help of this Software the X bar and R chart of these 40 samples are depicted below.

The X bar Chart with an Upper Control Limits of 80.41 and the Lower Control Limit as 54.79, and in this region, we can visualize that the Two Extreme points are out of the Control limits that is sample point 20 which is above the UCL and the point 38 which is below LCL both are a factor of deviation from the expected process behavior.

As well as in the R chart the samples 10 and 15 exceed the upper control limit, which is 43.91, which indicates that there is high variation in these samples. This tells us that the variation in the points is higher than what is expected for a stable process.

Furthermore, we move on to the Scatter plots to verify the process factors and the identified violation points. This analysis helps us to find out the potential special causes contributing to the variation observed in the First Trail. With these results we can proceed with additional iterations to further refine the process and validate the suspected causes.

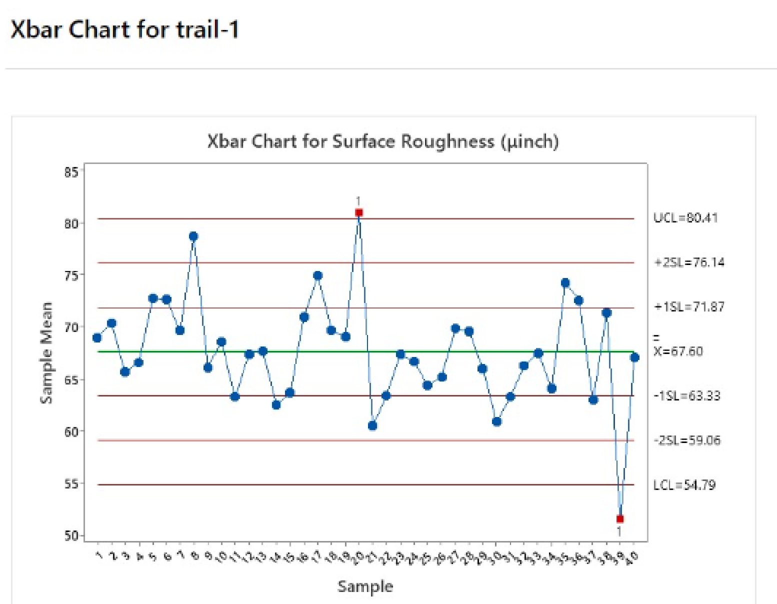


Fig 1.1 $\overline{X}$-Chart – (1-40) Samples

R Chart for trail-1

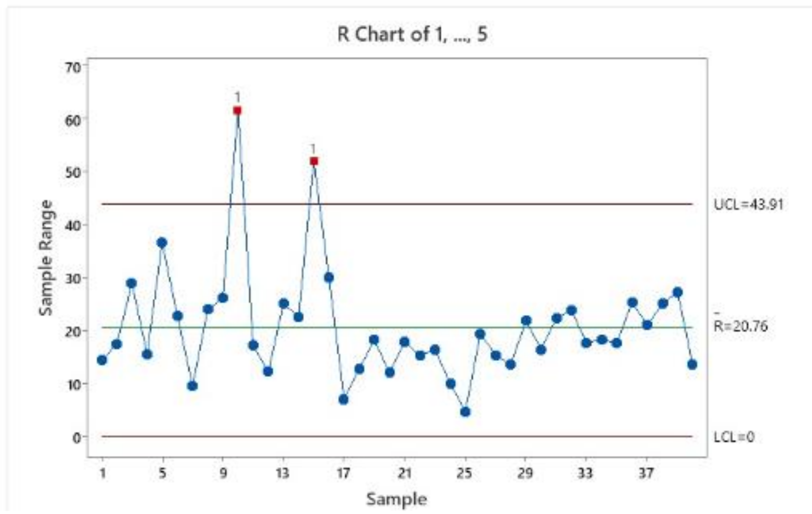


Fig 1.2: R-Chart - (1-40) - Samples

After finding out the Results of Trial 1, Scatter plots were made to check the data based on the 10 potential causes.

First Case: Rake Angle

for the first case of the scatter plot of Rake angle Vs the Range which is the surface Roughness Measured in µin, we could see from the two cases where the rake angle is 5º and 10 degrees. This scatter plot shows the position of range about the rake angle and most of the data fits in between 5 degrees to 10 degrees. Moreover, there is a certain variation in range for both the angles which means there is some sort of inaccuracy or other factors that may affect the results. From it, there is probably a more likely and secondary impact of rake angle on surface roughness, and therefore no effect in connection with this is detectable. Since it is not marked considerably, a conclusion could easily be made regarding the insignificance of a rake angle as a deciding parameter of surface roughness. Thus, this cause can be ruled out from the list of factors attributable to the variations in the surface quality, and other variables that might be more effect can be focused.

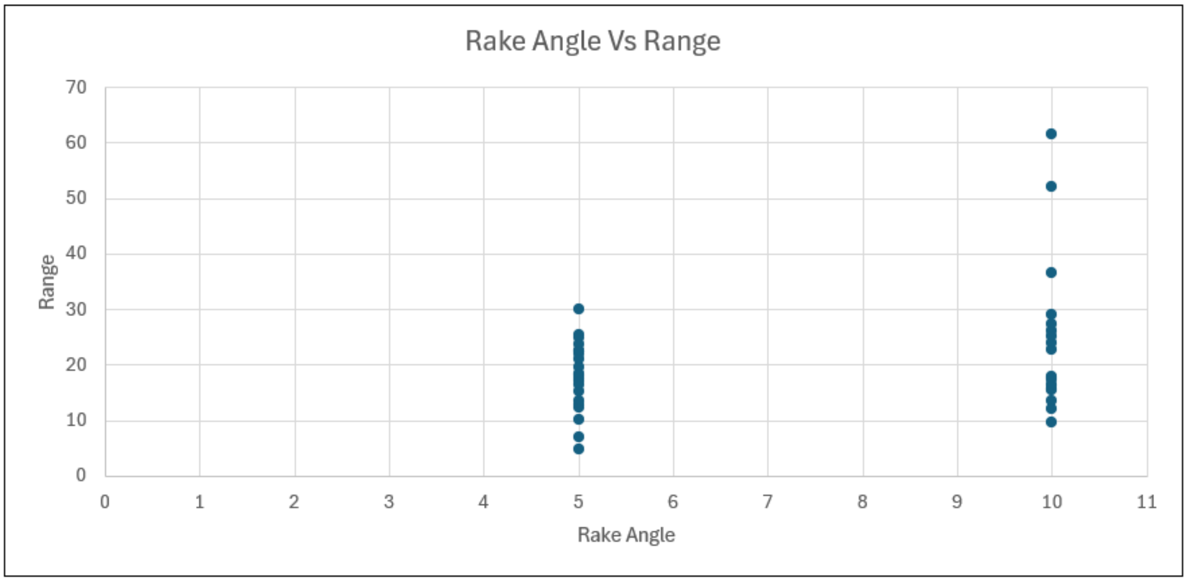


Fig 1.3: Rake Angle° Vs Range (Surface Roughness) µin

Second Case: Measuring Device

The scatter plot below represents the measuring device ID and range of measurement; the two device IDs are Surfcheck 3-1 and Talymeas 5-2. The set of numbers around these two device IDs are quite out of their range value of the two devices. Though for Surfcheck, the device with ID 1, there are a couple of high ranges which are nearly 70, the remainder of the values are scattered in between the 10 to 30 range. Similarly, for Talymeas, the device with ID 2, data points are in a similar range but there is no high peak or a deep valley.

The variability in the range values of both devices indicates an irregularity in the measurements; nevertheless, this irregularity is general to both devices. This would, in turn, indicate that it is the object measured itself, rather than the measuring device, that plays the largest role in explaining fluctuations in range. The differences could therefore be attributed to variations in calibration, changes in environment, or differences in the kind of measurement used by either device.

From this scatter plot results we can say that the measuring device does not significantly affect the variability of the range values.

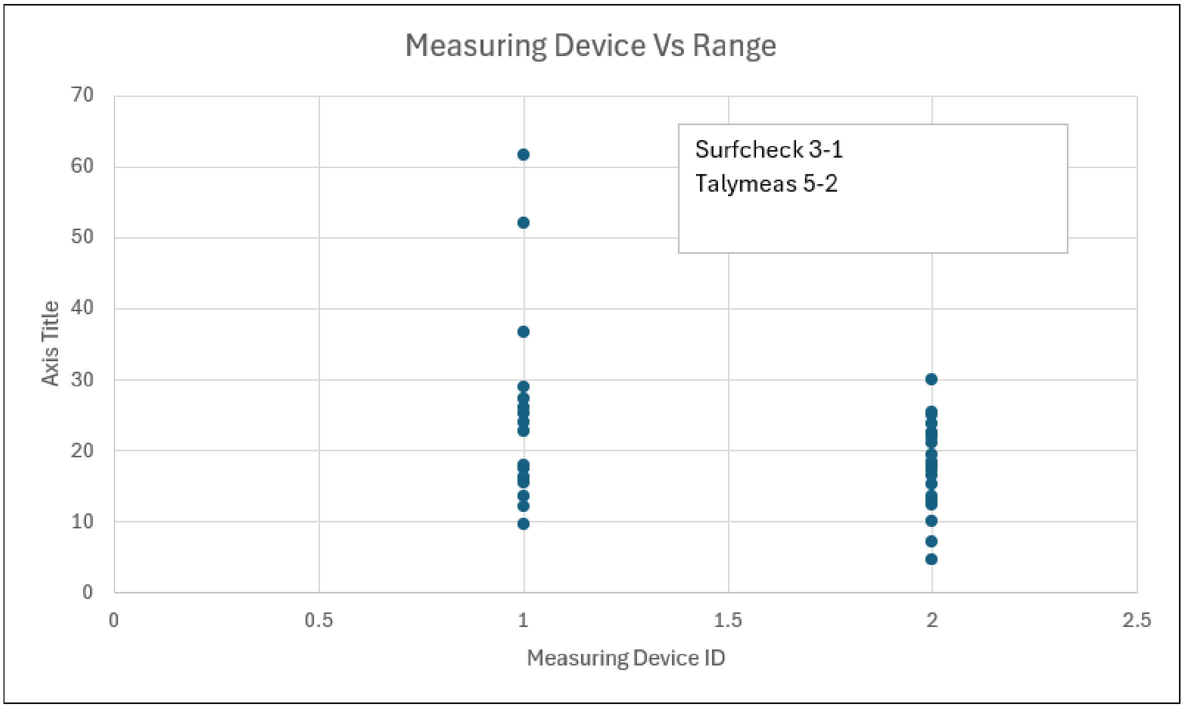


Fig 1.4: Measuring Device Vs Range (Surface Roughness) µin

Third Case: Machine

In this Scatter Plot it is the representation of the plot between Machine ID and the Range value, which is nothing but the Surface Roughness in µinches, so in this scatter plot we have used three different machines grouped together which is 1) Nacirema 2) Le-Lathe 3) Rex. But however, the Variation in the range values is significantly different among these two variables. Comparing the date for Nacirema, Le-Lathe and Rex there is less difference, but we can see the aggregation of values because Rex has a wider range of higher values. The major impact is that ID 3 is different from other machines in that its behavior corresponds so closely with that of Rex and it is a major cause of this variation.

And while collecting the Data for the three different machine to find out special causes, after entering the date and there was a message box asking that

Continue Sampling Consecutive Subgroups from all three machines

Collect Subgroups from the same machine for all three machines separately

So in this case we selected the first option and gave a data range of 15, so that we got 15 data per machine and the Corresponding X-bar chart and R chart was plotted to check whether there were any test rule violation points.

Such variability indicates that there could be operational/maintenance problems for Rex that impact its performance and therefore yield such variable outputs. They may be **due to calibration problems such as worn-out parts, or some variations in the machining process for Rex**. Since this has a very big impact on the range values, it may also mean that rex can be a **Potential special cause**.

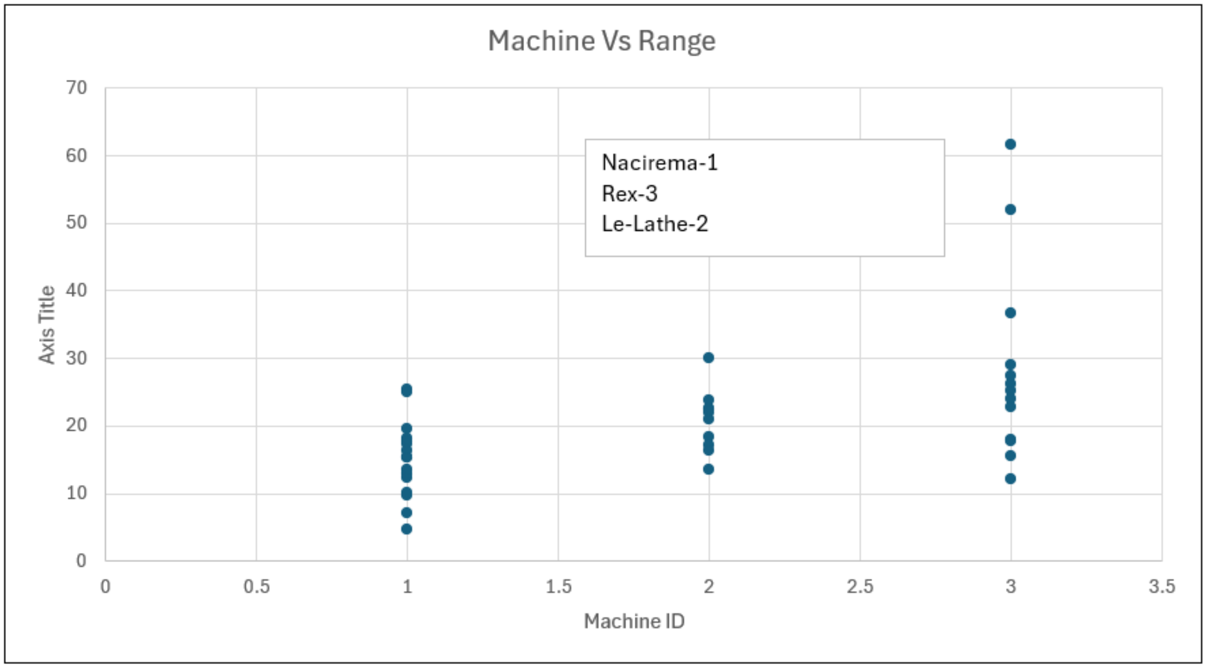


Fig 1.5: Machine Vs Range (Surface Roughness) µin

Fourth Case: Tool Condition

For the analysis of the tool condition versus range, tool condition ID 1 was assigned where the tool was sharp while tool condition ID 2 was assigned when the tool was dull. From the analysis of the range values depicted in the tools and through the aid of a scatter plot, it is well illustrated that the sharp tools, Condition ID 1 have maintained a steady and relatively higher range while ID 2 exhibits a wider spread and relatively higher increase in range.

The high variability between these two groups implies that tool condition is a special cause of variation in the process. This could be so because the several dull tools may be giving variable measurements because of reduced cutting performance of the tools in the range. It shows that sharp tools have a more standardized range which means that they do their work in a better way compared to Dull Tool.

From that perspective it can be concluded that the state of the given process being in dull tool condition creates special cause variation whereas the sharp tool condition is within the common cause variation zone. The above insight provides necessary improvement in process control in that such tools will either be replaced or else cleaned when they reach its highest wear levels, which can reduce this source of variation and improve results.

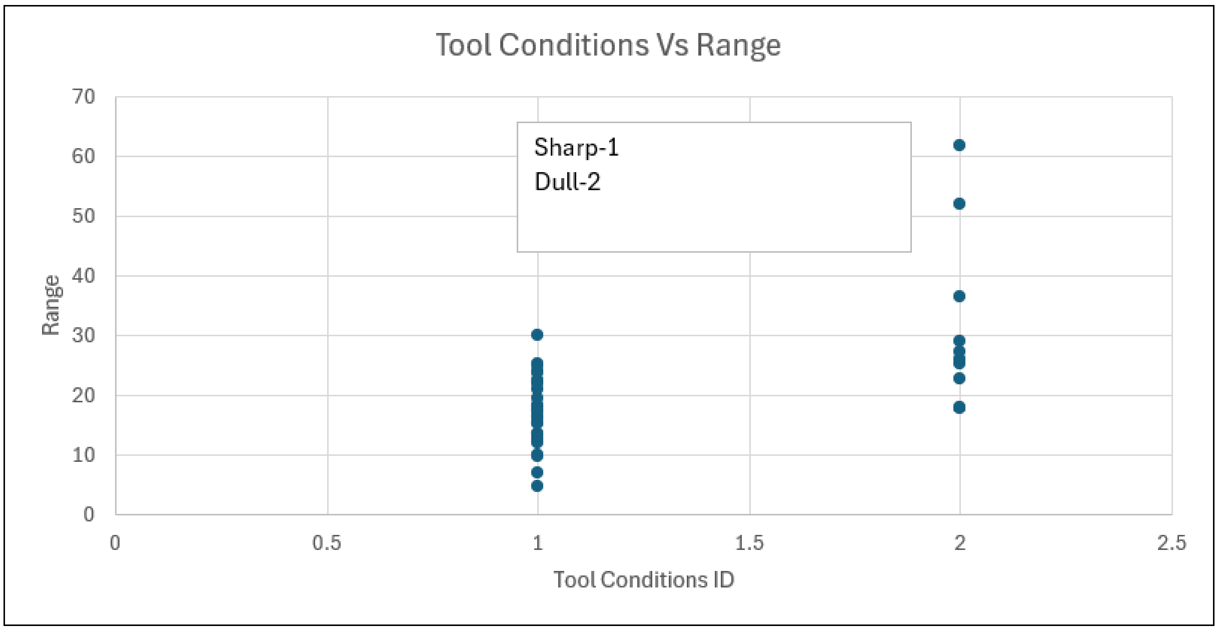


Fig 1.6: Tool Condition ID Vs Range (Surface Roughness) µin

Fifth Case: Tool Type

The next case of the Tool Type vs Range where we can say that there are three different tools that is 1) Cutgo-T 2) Nork-V 3) Roved Cube, we can talk about the deviation in detail which are as follows.

Cutgo-T (ID 1) has range values between 0 and 30, out of which only a scattered point is present. However, the cumulative data is still a narrow spread, indicating that the process is reasonably well controlled for this sort of instrument.

ID 2 Nork-V has got its range from 10 to 40 with a little more spread than the first graph but the number in between and additional scattered points are still not very out of range to suggest that there is a special cause. The degree of range variation is not alternated suddenly and does not appear to be related to some tool.

Roved Cube (ID 3) has a range from 10 to 70 and though there is fluctuation it has been established that it is normal in the sense that measurement distribution is normal and does not exhibit a rise in variation that is abrupt or due to an identifiable cause.

It suggests that no special cause of variation exists for any of the tool types, because no specific tool type shows any Drastic or Rapid fluctuation which would directly indicate the presence of some special cause of variation in tool range difference. Range variation, depicted in the above table, can therefore be assumed to be in some ways due to process variation say in material and a reflection of a severe fundamental tool type issue.

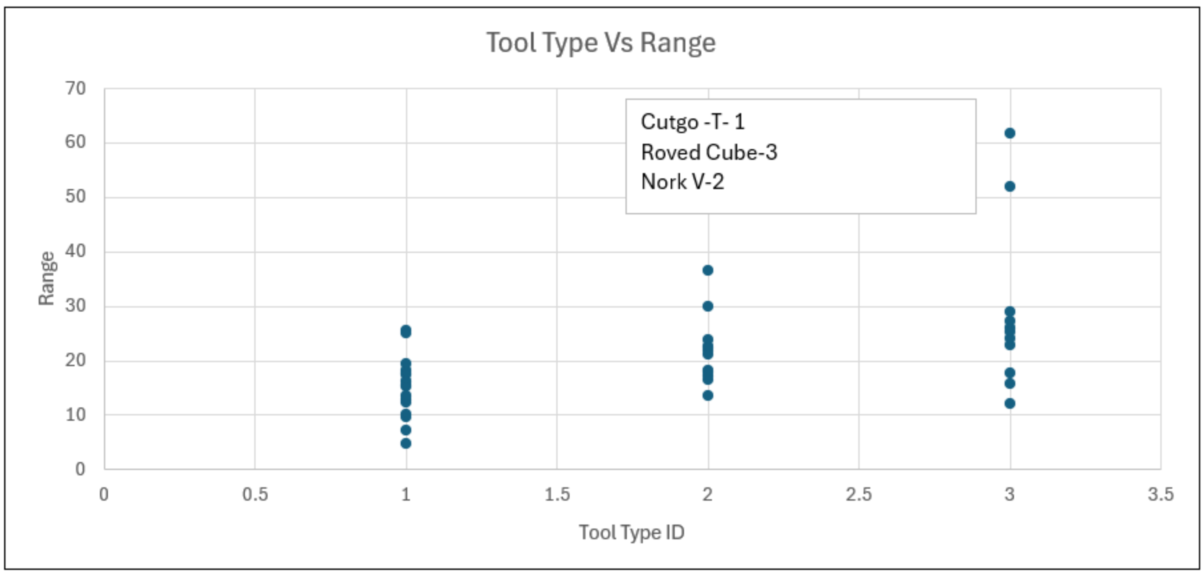


Fig 1.7: Tool type ID Vs Range (Surface Roughness) µin

Sixth Case: Set Up Person

The Scatter plot of Setup person ID vs Range which is Surface Roughness shows distinct patterns of each setup person. For setup person 1 (Mr. Richard), the range is between 0-70 , with the large scattering observed especially in the last three points which can be visualized from the plot . As well as a crowd of points is scattered between the 10-20 range, showing irregularities in the performance. In other hand the setup person (Mr. Samuel) the range of the scattering is between 10-30 with scattering and more of a consistent pattern. therefore, we can say that Samuel's setup is more controlled and hence less variolation n. from the pattern seen, it indicated that there is no special causes related for the variation based on the setup person since such changes are because of their own processes and not due to external causes, so this particular parameter <u>can not be a potential special cause</u>.

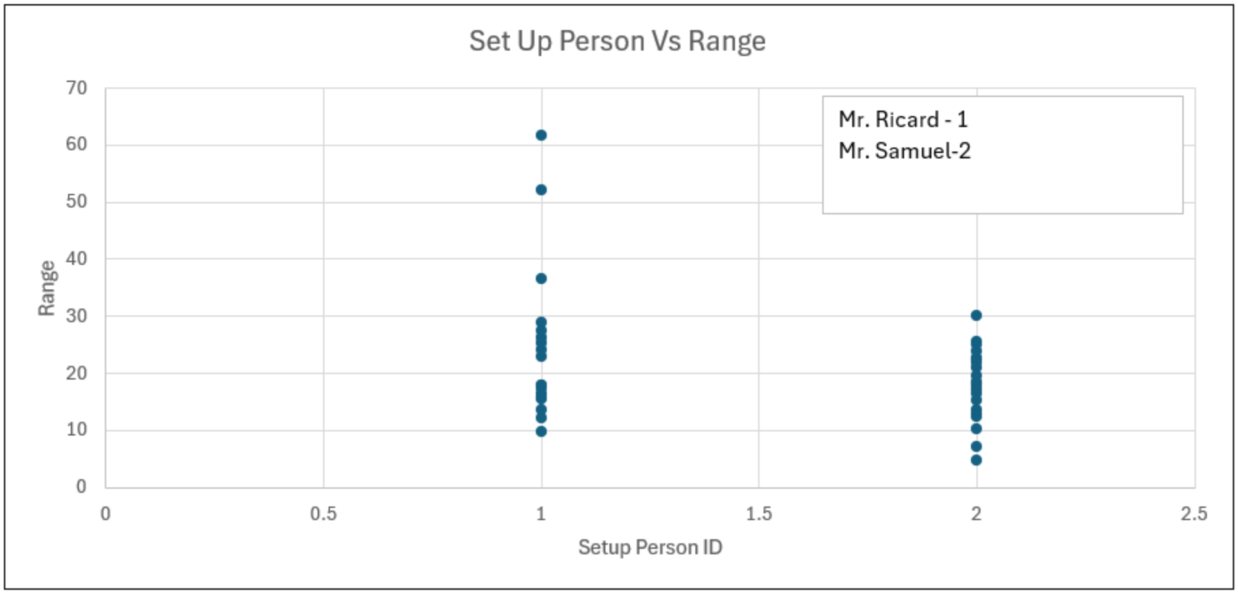


Fig 1.8: Setup Person ID Vs Range (Surface Roughness) µin

Seventh Case: Operator

Now in the case of the Operator vs the Range scatter plots is illustrated and in that we can visualize that there are two operator that is 1) Regular and 2) Substitute based on this we can see the operator 1 does not have much variation in the range between 10-30 , but the operator 2 has too much variation and the scattering of points is from 15-50 , which can be seen in the plots that the Substitute Operator there is one sample point which is so different from the other , so there can be a cause for a Potential Special Cause .<u>The inconsistency of data for operator 2 suggests potential issues such a lack of familiarity with the equipment , variation in the skill levels, deviations</u>. These factors can be a reason to consider Operator 2 as a Potential Special cause contributing to the variability in the process.

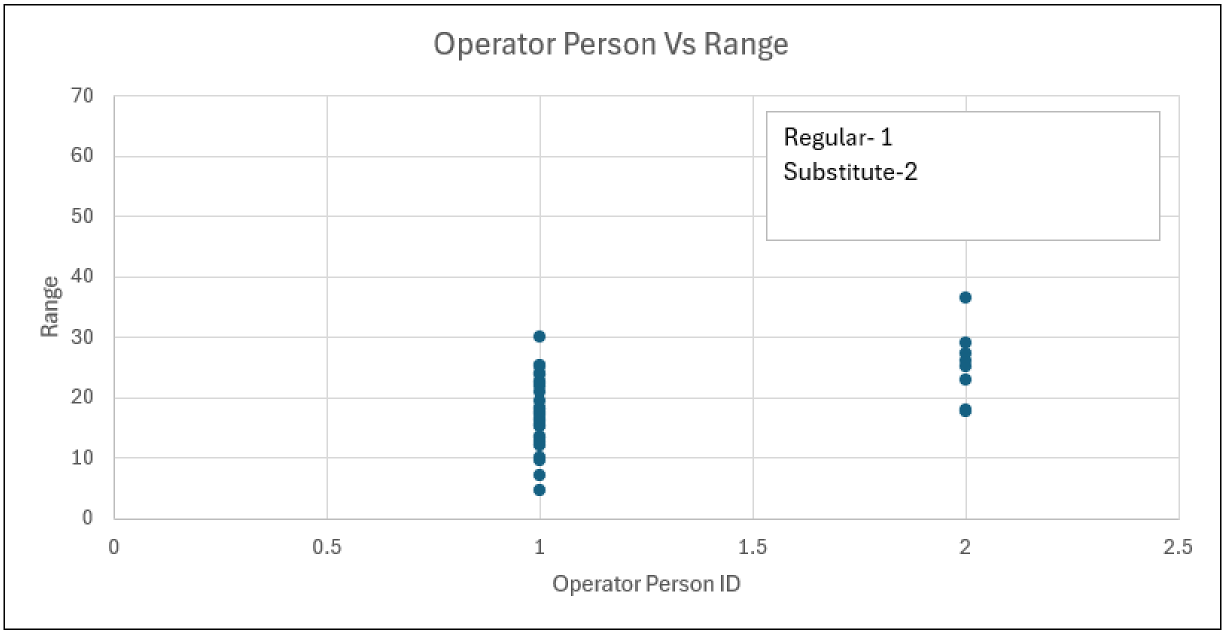
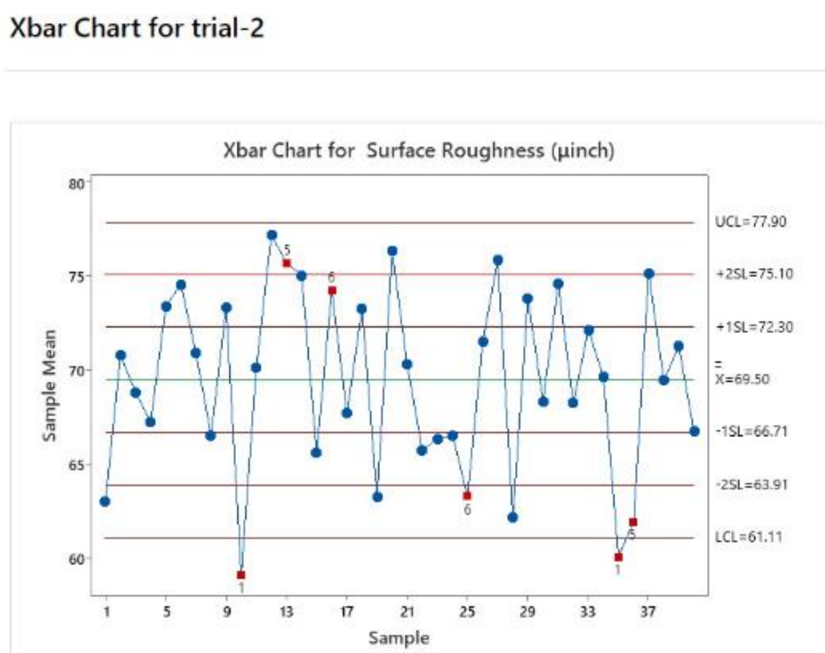
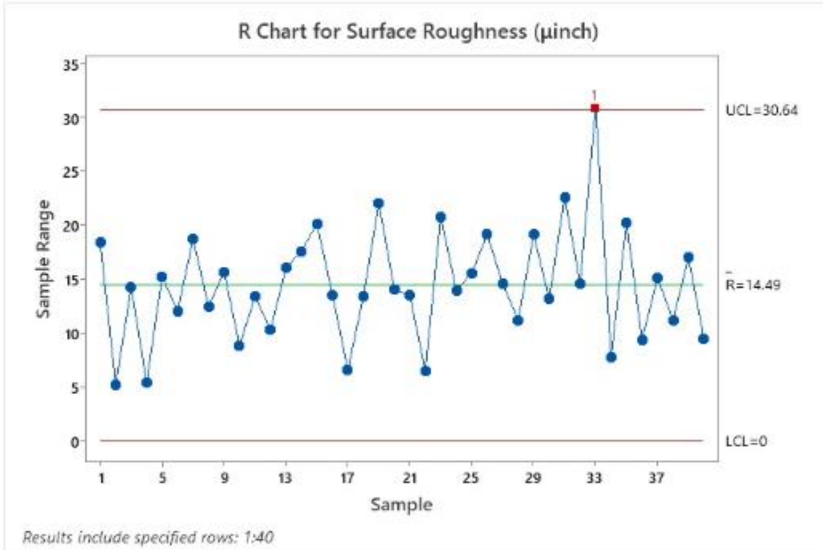


Fig 1.9: Operator Person ID Vs Range (Surface Roughness) µin

Trial 2:

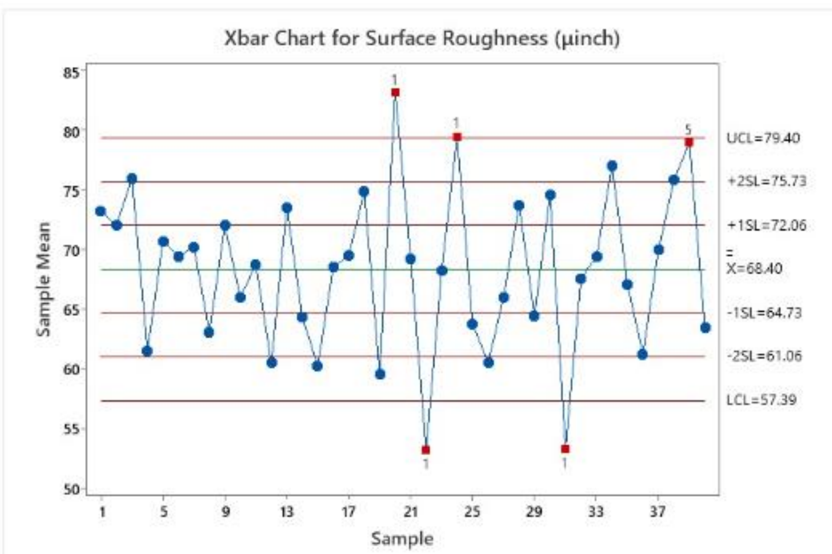


R Chart for trial-2

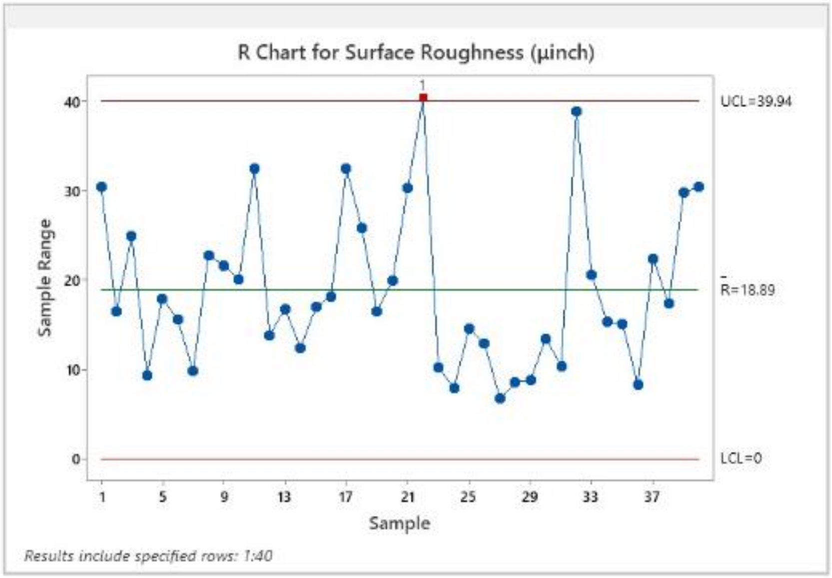


Trial 3:

Xbar Chart for trial-3

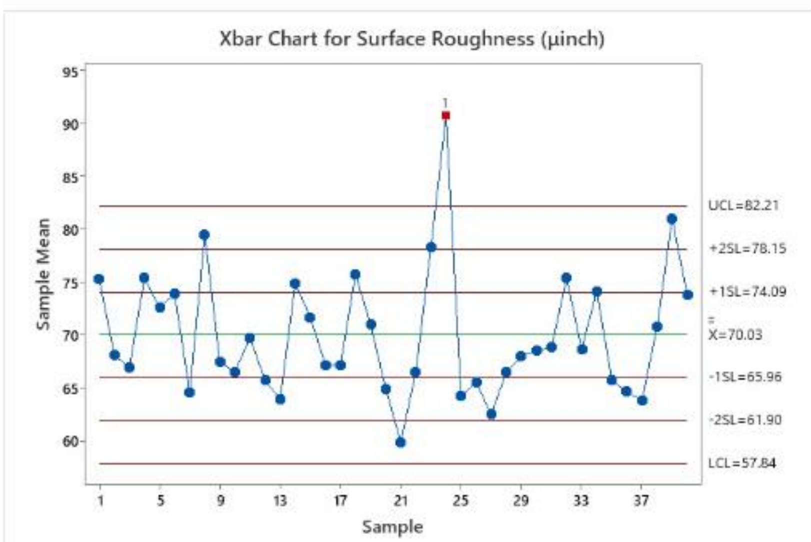


R Chart for trial-3

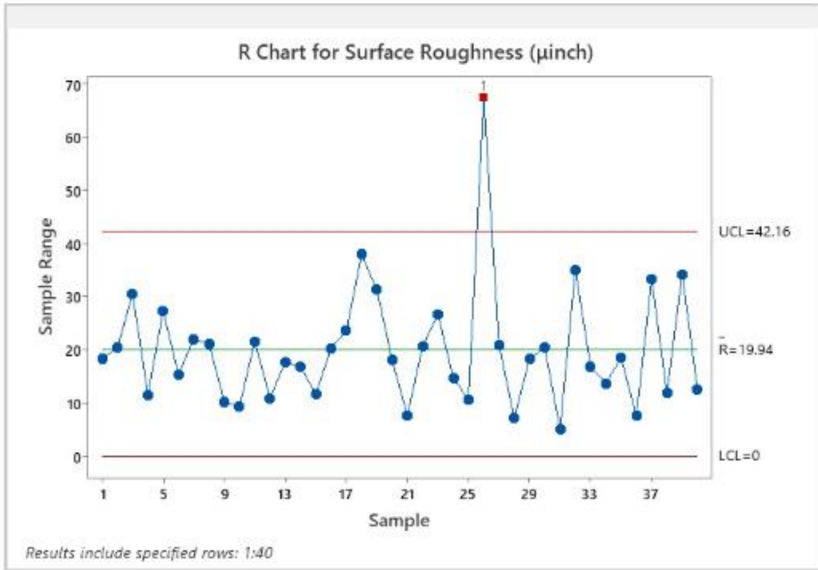


Trial 4:

Xbar Chart for trial-4

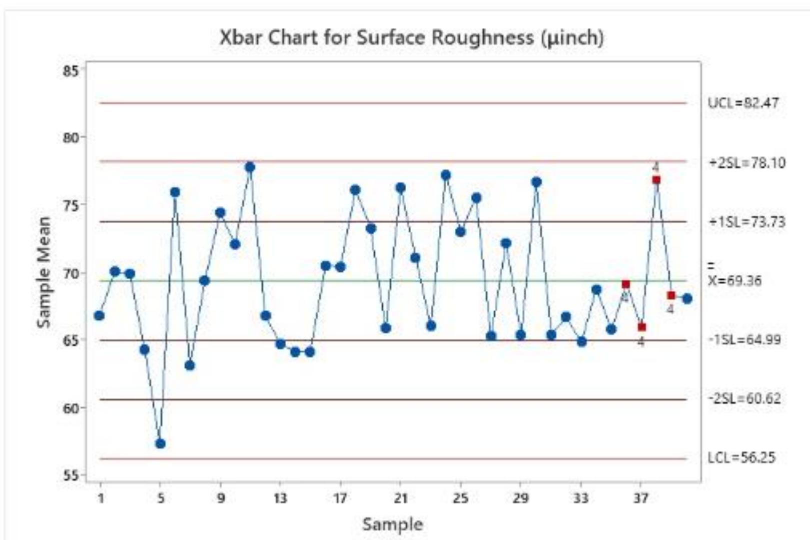


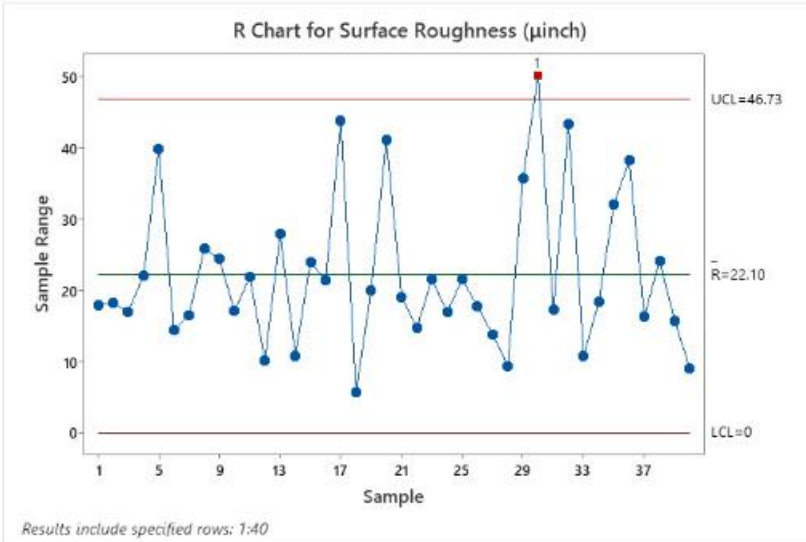
R Chart for trial-4



Trial 5:

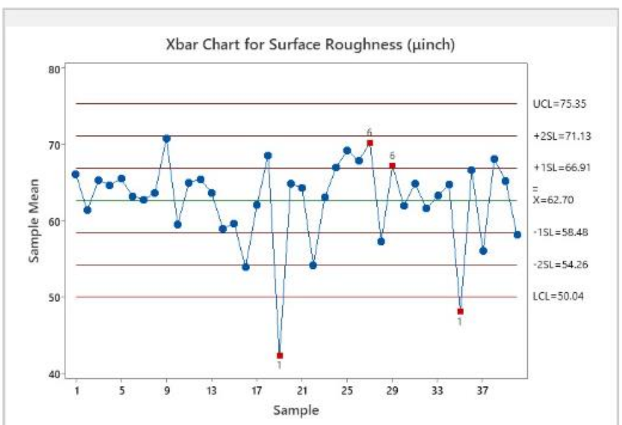
Xbar Chart for trial-5



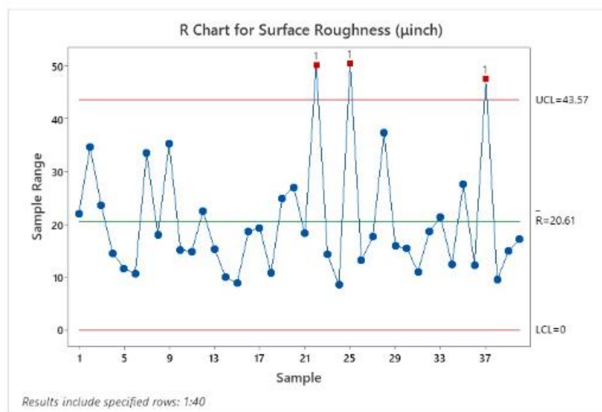


Trail-6 machines 1

Xbar Chart for trial-6 machine1

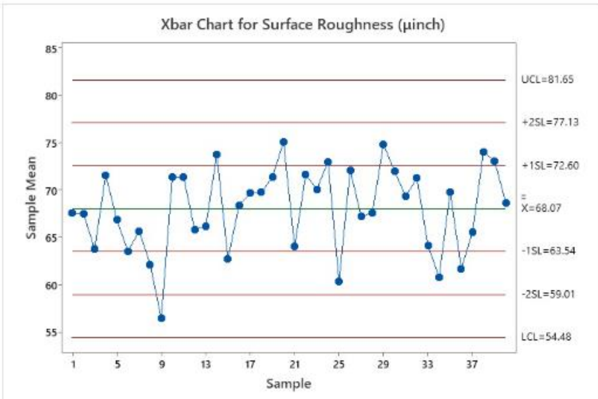


R Chart for trial-6 machine1

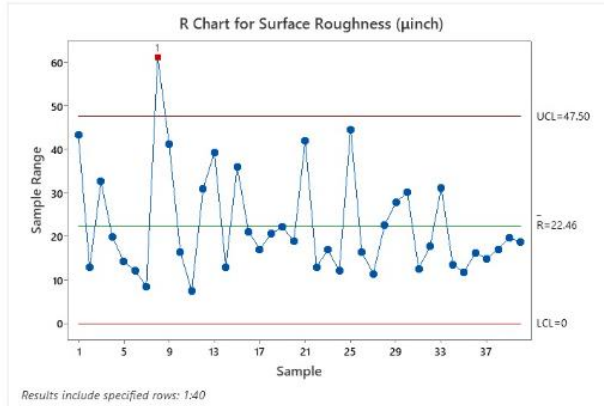


Trail-6 machines 2

Xbar Chart for trial-6 machine2

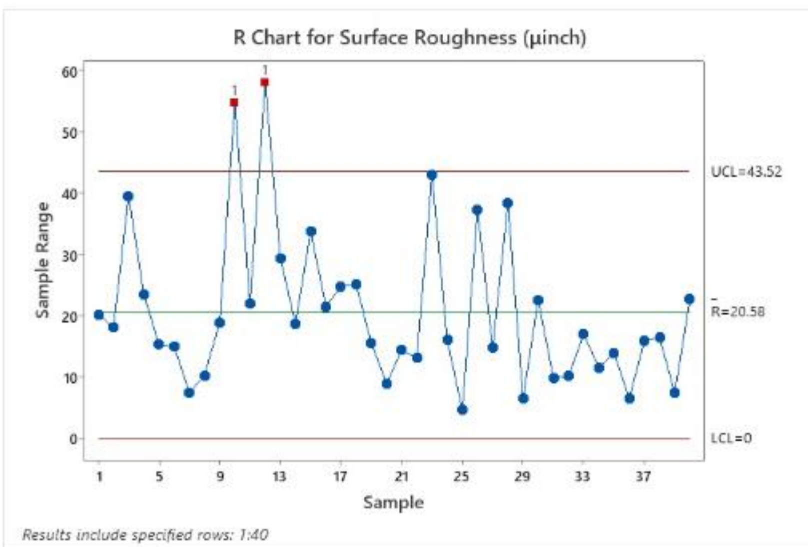


R Chart for trial-6 machine2

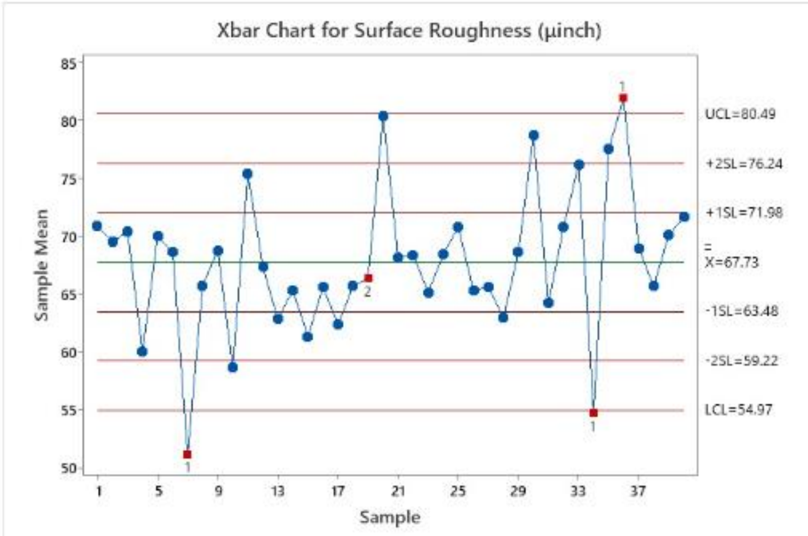


Trail-6 machines 2

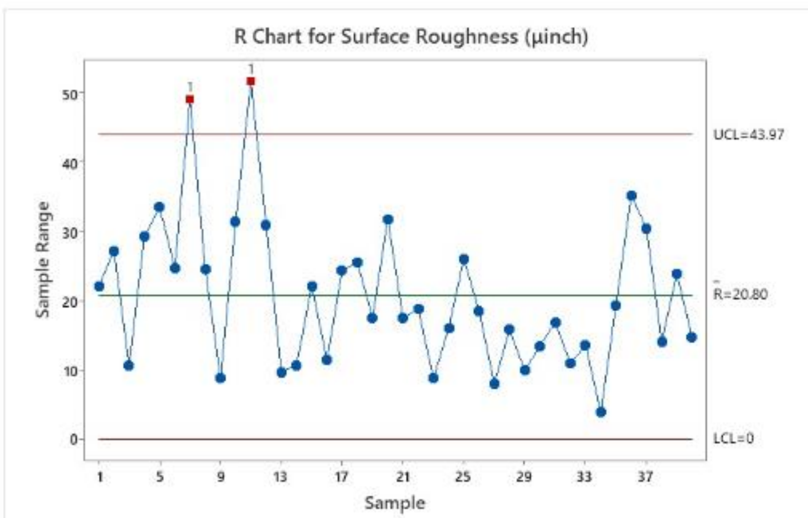
R Chart for trial-6 machine3



Xbar Chart for trial-7



R Chart of for trial-7



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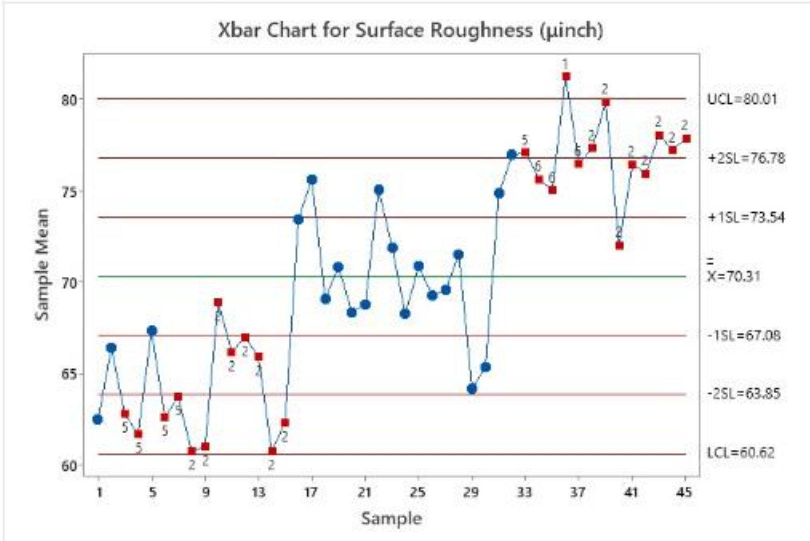
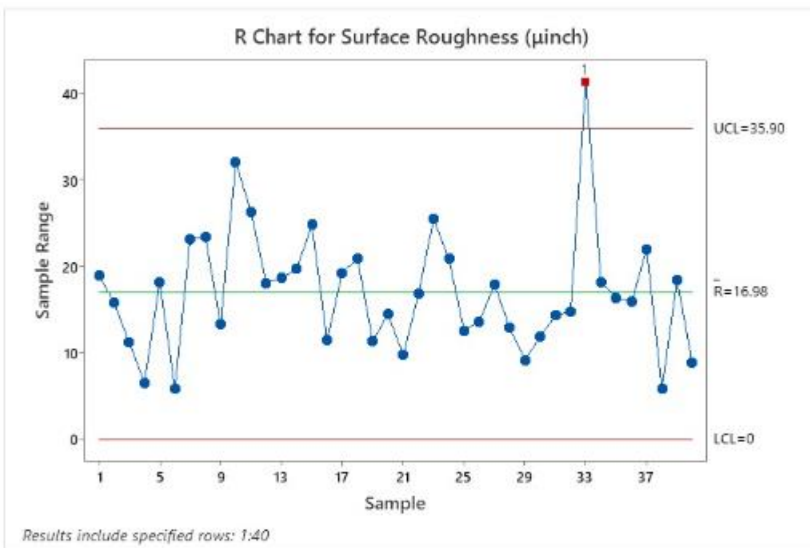
Xbar Chart for trial-9 (3 machine combine)

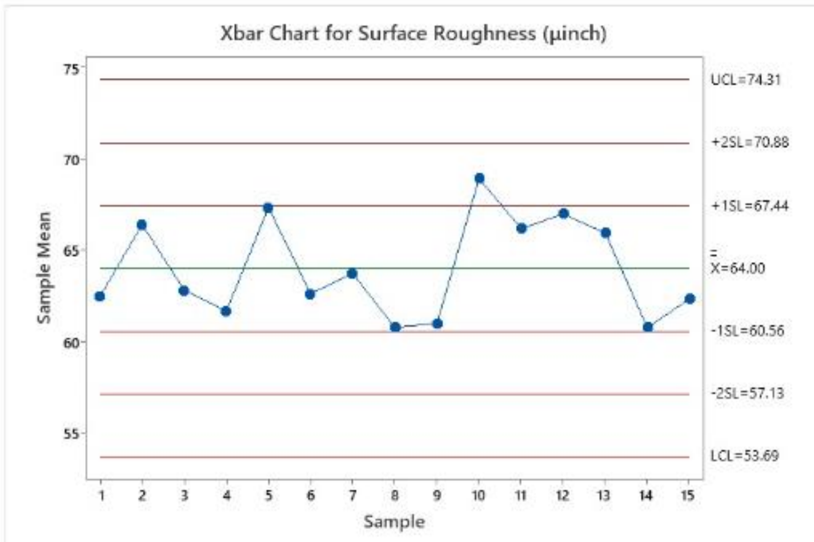


R Chart for trial-9 (3 machine combine)

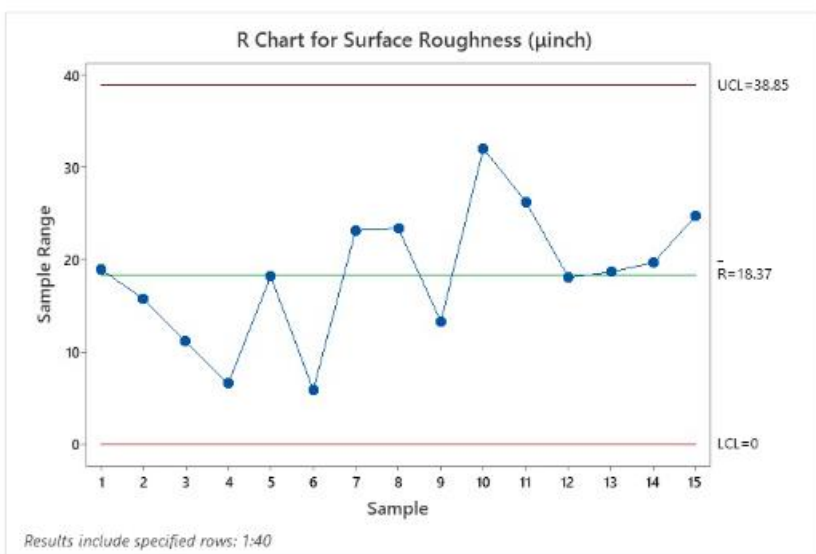


Machine 1

Xbar Chart for trial-9 (machine1)

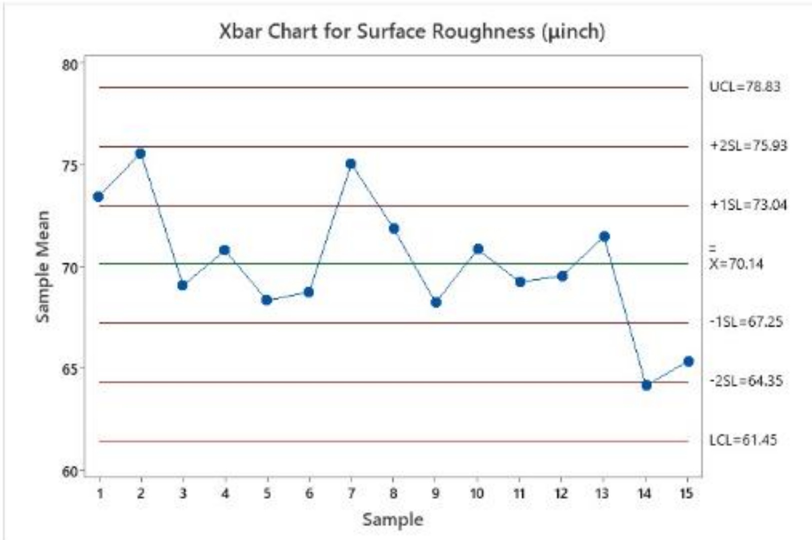


R Chart for trial-9 (machine1)

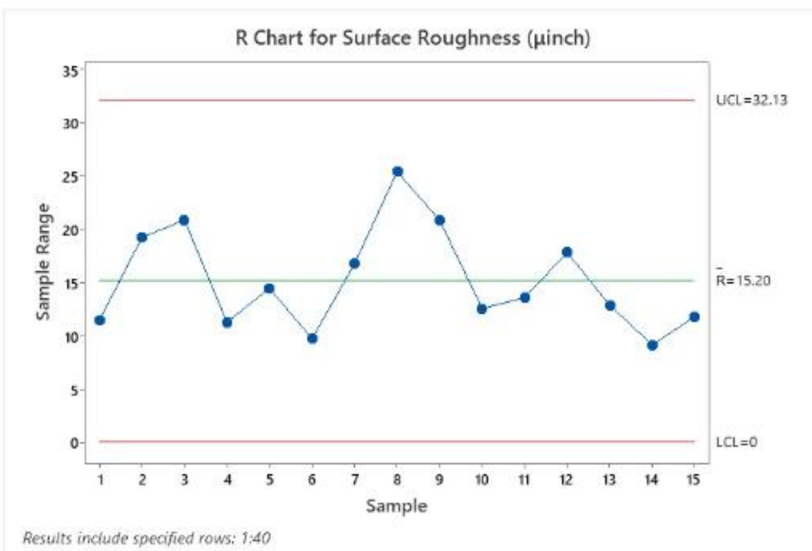


Machine 2

Xbar Chart for trail-9 (machine2)

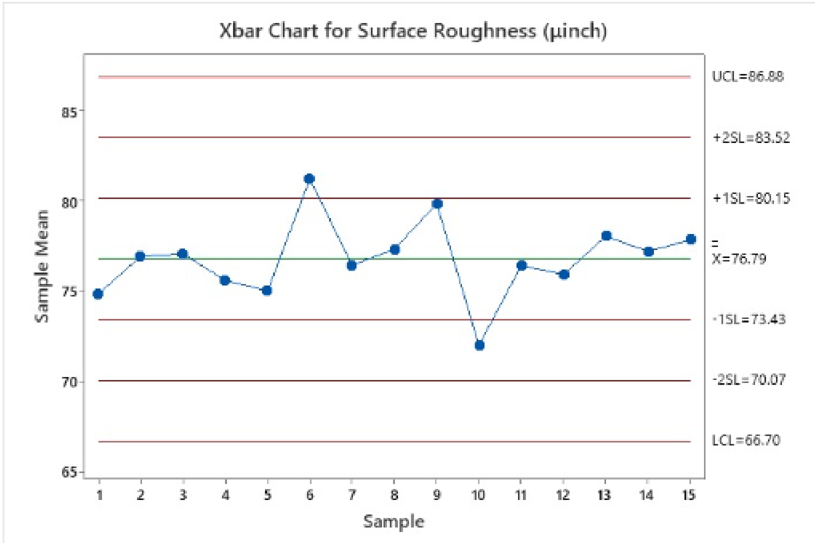


R Chart for for trial-9 (machine2)

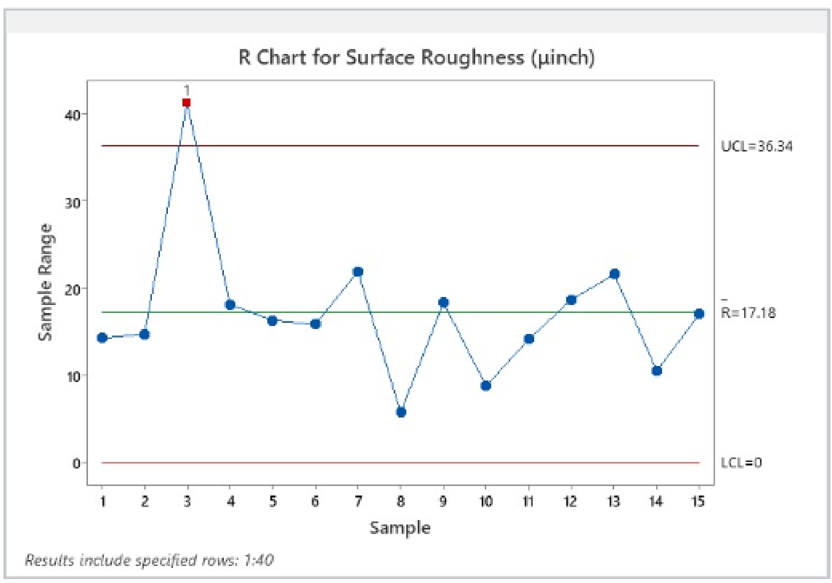


Machine 3

Xbar Chart for trial-9 (machine3)

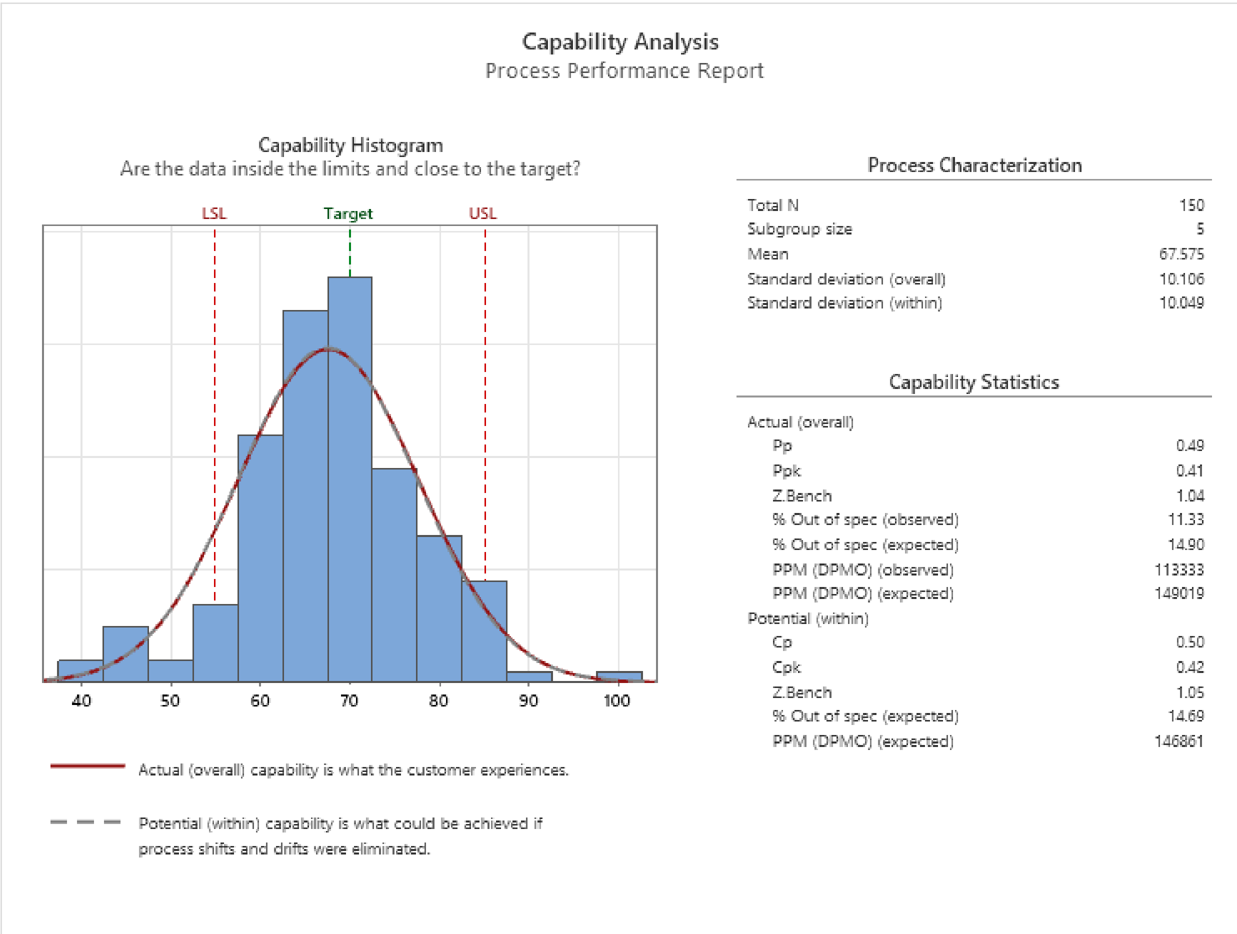


R Chart for trial-9 (machine3)



Capability Analysis

After eliminating special causes, the data was in statistical control and further capability studies were performed using Minitab.



USL=85 µin

LSL=55 µin

Target=70 µin

Observation:

1. Cp= 0.5<1. This indicates process spread is more and parts aren't able to meet specifications even when the process is centered. Hence this indicates the process capability is poor.
2. Cpk=0.42<1. This indicates produced parts are out of specification limit and the reason might be process not being centered and high variations.
3. Out of specification %= 14.69

Solution:

1. After eliminating special causes, process has been brought under statistical control which could be further refined to improve process capability using root cause analysis (RCA).
2. SPC tools like fishbone, pareto. etc. and some more tools like fault tree analysis (FTA), p-diagram and FMEAs can be used to identify root causes and resolve them as per there severity levels.
3. The best possible solution for this would be to use pareto analysis and rank parameters as per there impact and one by one resolving them to increase process capability and eventually increase percentage of parts under specifications.

Conclusions

In this Workshop, we identified and established the three exact variables affecting the turning process:

Operator Variability: Proposed with out-of-control limits highlighted at the X-bar chart and further confirmed with the help of scatter plots that detect no systematic trends in measurements.

Tool Condition: it is depicted as a gradual change in the process mean and was observed in both the X-bar and R charts. This relationship was depicted by scatter plots especially over the Surface Roughness vs the Tool Condition.

Machine instability was easily detected from the R chart since sometimes it had sharp high points that illustrates a higher variation. Additionally, scatter plots provided consistent evidence with the pattern of the variable measurements. X-bar and R charts with the help of scatter diagrams have been used to contribute towards confirming these causes and strong proofs were established regarding the impacts of those causes. While the process capability can be regarded as promising ($Cp > 1.33$), Seventh improvement still must be made to guarantee stability ($Cpk < 1.0$).

Lessons Learned:

Understanding Process Variations: When it comes to control charts and scatter plots, the learning was more grounded because these charts enabled the linking of statistical signals to real-world causes which include operator action, tool condition, and equipment status.

Data Collection is Key: Recurrent collection and analysis of information made a quality identification and confirmation of the causes possible.

Practical Application of SPC: Through the assignment, we learned how Statistical Process Control tools are applied to diagnose and manage a manufacturing process efficiently.

Executing turning enhanced our knowledge of the level of control over conditions and identified weaknesses in the turning process.

Appendix:

Trial	1
Subgroups	30
Special Cause	

	Candidate Special Causes of Variation and Their Levels										Sample Roughness (microinches)				
Test No.	Cutting Speed (fpm)	Feed Rate (ipr)	Set up Person	Operator	Tool Type	Tool Condition	Depth-to-Shoulder	Machine	Measuring Device	Rake Angle (deg.)	1	2	3	4	5
1	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1003	Rex	Surfchek 3	10	75.864	83.737	71.512	65.926	79.556
2	1050	0.0089	Mr. Ricard	Substitute	Nork-V	Dull	0.1003	Rex	Surfchek 3	10	77.605	59.907	59.63	67.935	70.222
3	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0998	Le-Lathe	Talymeas 5	5	72.996	56.508	58.455	60.851	59.39
4	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0999	Le-Lathe	Talymeas 5	5	68.051	58.513	79.851	64.568	56.723
5	1000	0.0086	Mr. Ricard	Regular	Cutgo-T	Sharp	0.1002	Nacirema	Surfchek 3	10	63.108	68.174	76.346	74.924	77.97
6	1050	0.0089	Mr. Ricard	Substitute	Roved Cube	Dull	0.0997	Rex	Surfchek 3	10	67.109	69.269	64.956	81.165	82.782
7	1050	0.0089	Mr. Ricard	Substitute	Roved Cube	Dull	0.0997	Rex	Surfchek 3	10	72.343	68.759	90.603	58.489	64.662
8	1050	0.0089	Mr. Ricard	Substitute	Roved Cube	Dull	0.0997	Rex	Surfchek 3	10	39.735	58.122	68.215	63.743	69.902
9	1000	0.0086	Mr. Ricard	Regular	Cutgo-T	Sharp	0.1002	Nacirema	Surfchek 3	10	69.192	62.552	77.415	63.836	71.66
10	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0999	Le-Lathe	Talymeas 5	5	61.27	65.757	64.041	69.319	62.644
11	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0999	Le-Lathe	Talymeas 5	5	47.84	60.388	67.494	66.717	60.382
12	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0998	Le-Lathe	Talymeas 5	5	59.453	53.791	66.309	58.693	62.642
13	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0998	Le-Lathe	Talymeas 5	5	63.57	67.644	69.026	60.065	57.742
14	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0998	Le-Lathe	Talymeas 5	5	62.596	53.346	71.819	71.642	74.962
15	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0997	Le-Lathe	Talymeas 5	5	63.404	75.372	51.191	61.974	73.938
16	1000	0.0086	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1	Nacirema	Talymeas 5	5	79.188	72.574	82.271	78.418	68.901
17	1050	0.0089	Mr. Ricard	Substitute	Roved Cube	Dull	0.0997	Rex	Surfchek 3	10	65.86	82.618	64.849	71.277	44.666
18	1000	0.0086	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1001	Nacirema	Talymeas 5	5	61.309	62.54	67.545	74.722	77.384
19	1050	0.0089	Mr. Ricard	Substitute	Roved Cube	Dull	0.0997	Rex	Surfchek 3	10	99.863	83.314	42.897	44.578	80.387
20	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0999	Le-Lathe	Talymeas 5	5	68.595	54.082	58.526	62.118	73.356
21	1050	0.0089	Mr. Ricard	Substitute	Roved Cube	Dull	0.1	Rex	Surfchek 3	10	79.674	83.674	68.541	70.059	43.348
22	1000	0.0086	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1	Nacirema	Talymeas 5	5	71.393	65.777	74.11	75.098	63.096
23	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1003	Rex	Surfchek 3	10	64.355	72.63	71.244	76.19	63.346
24	1050	0.0089	Mr. Ricard	Substitute	Roved Cube	Dull	0.0997	Rex	Surfchek 3	10	83.151	66.104	71.925	66.081	66.419
25	1050	0.0089	Mr. Ricard	Substitute	Roved Cube	Dull	0.0997	Rex	Surfchek 3	10	53.596	62.588	75.099	79.067	67.815
26	1000	0.0086	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1	Nacirema	Talymeas 5	5	77.04	69.311	80.57	82.765	67.981
27	1000	0.0086	Mr. Ricard	Regular	Cutgo-T	Sharp	0.1002	Nacirema	Surfchek 3	10	68.99	67.637	59.176	84.611	74.391
28	1050	0.0089	Mr. Ricard	Substitute	Roved Cube	Dull	0.1	Rex	Surfchek 3	10	64.751	71.179	82.027	62.038	54.464
29	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0999	Le-Lathe	Talymeas 5	5	68.731	71.95	67.886	71.779	59.438
30	1050	0.0089	Mr. Ricard	Substitute	Roved Cube	Dull	0.1	Rex	Surfchek 3	10	86.31	63.873	62.682	43.751	38.895

Date	12/11/2024
Trial	2
Subgroups	30
Special Cause	Operator,

	Candidate Special Causes of Variation and Their Levels										Sample Roughness (microinches)				
Test No.	Cutting Speed (fpm)	Feed Rate (ipr)	Set up Person	Operator	Tool Type	Tool Condition	Depth-to-Shoulder	Machine	Measuring Device	Rake Angle (deg.)	1	2	3	4	5
31	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Dull	0.0997	Rex	Surfchek 3	10	64.006	64.91	78.225	65.032	60.988
32	1000	0.0086	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1001	Nacirema	Talymeas 5	5	68.603	60.606	60.311	68.783	63.265
33	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1003	Rex	Surfchek 3	10	71.187	75.78	81.003	84.049	70.357
34	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Dull	0.1	Rex	Surfchek 3	10	71.149	61.364	72.503	71.483	69.29
35	1000	0.0086	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1001	Nacirema	Talymeas 5	5	87.122	68.778	61.666	75.712	79.223
36	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Dull	0.0997	Rex	Surfchek 3	10	81.98	63.098	68.46	78.81	75.059
37	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0997	Le-Lathe	Talymeas 5	5	68.629	77.544	64.696	55.296	63.428
38	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Dull	0.1	Rex	Surfchek 3	10	58.322	66.994	63.054	75.217	70.059
39	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1003	Rex	Surfchek 3	10	74.064	75.776	76.469	74.079	76.54
40	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0998	Le-Lathe	Talymeas 5	5	57.057	68.49	52.428	55.77	66.549
41	1000	0.0086	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1001	Nacirema	Talymeas 5	5	56.265	79.419	75.123	69.335	71.459
42	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1003	Rex	Surfchek 3	10	84.301	74.782	81.514	73.852	77.385
43	1050	0.0089	Mr. Ricard	Regular	Nork-V	Dull	0.1003	Rex	Surfchek 3	10	73.214	68.459	75.641	65.969	74.294
44	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0999	Le-Lathe	Talymeas 5	5	71.677	55.051	62.867	62.769	67.921
45	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0999	Le-Lathe	Talymeas 5	5	66.467	52.949	74.866	65.017	64.006
46	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Dull	0.1	Rex	Surfchek 3	10	62.545	71.481	73.991	72.272	79.757
47	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Dull	0.1	Rex	Surfchek 3	10	66.658	66.765	61.916	75.042	64.29
48	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0999	Le-Lathe	Talymeas 5	5	62.583	63.224	54.259	74.767	51.921
49	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Dull	0.0997	Rex	Surfchek 3	10	77.688	68.45	71.654	61.557	60.643
50	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0999	Le-Lathe	Talymeas 5	5	61.2	67.246	70.34	67.011	59.016
51	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0999	Le-Lathe	Talymeas 5	5	53.368	62.239	63.193	66.171	61.641
52	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1003	Rex	Surfchek 3	10	73.8	65.717	91.812	70.98	78.357
53	1000	0.0086	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1001	Nacirema	Talymeas 5	5	63.856	69.245	77.538	70.494	75.574
54	1000	0.0086	Mr. Ricard	Regular	Cutgo-T	Sharp	0.1002	Nacirema	Surfchek 3	10	62.357	80.148	60.644	72.891	69.411
55	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Dull	0.1	Rex	Surfchek 3	10	64.413	73.115	65.816	58.105	69.499
56	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Dull	0.0997	Rex	Surfchek 3	10	65.1	80.048	70.404	57.787	62.766
57	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Dull	0.0997	Rex	Surfchek 3	10	78.766	64.96	74.459	67.698	73.106
58	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Dull	0.1	Rex	Surfchek 3	10	68.624	72.02	61.386	70.996	62.869
59	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Dull	0.0997	Rex	Surfchek 3	10	71.486	74.205	73.302	78.423	72.265
60	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Dull	0.0997	Rex	Surfchek 3	10	65.681	65.878	65.281	77.552	79.745

Date	12/11/2024
Trial	3
Subgroups	30
Special Cause	Operator,Tool Condition,

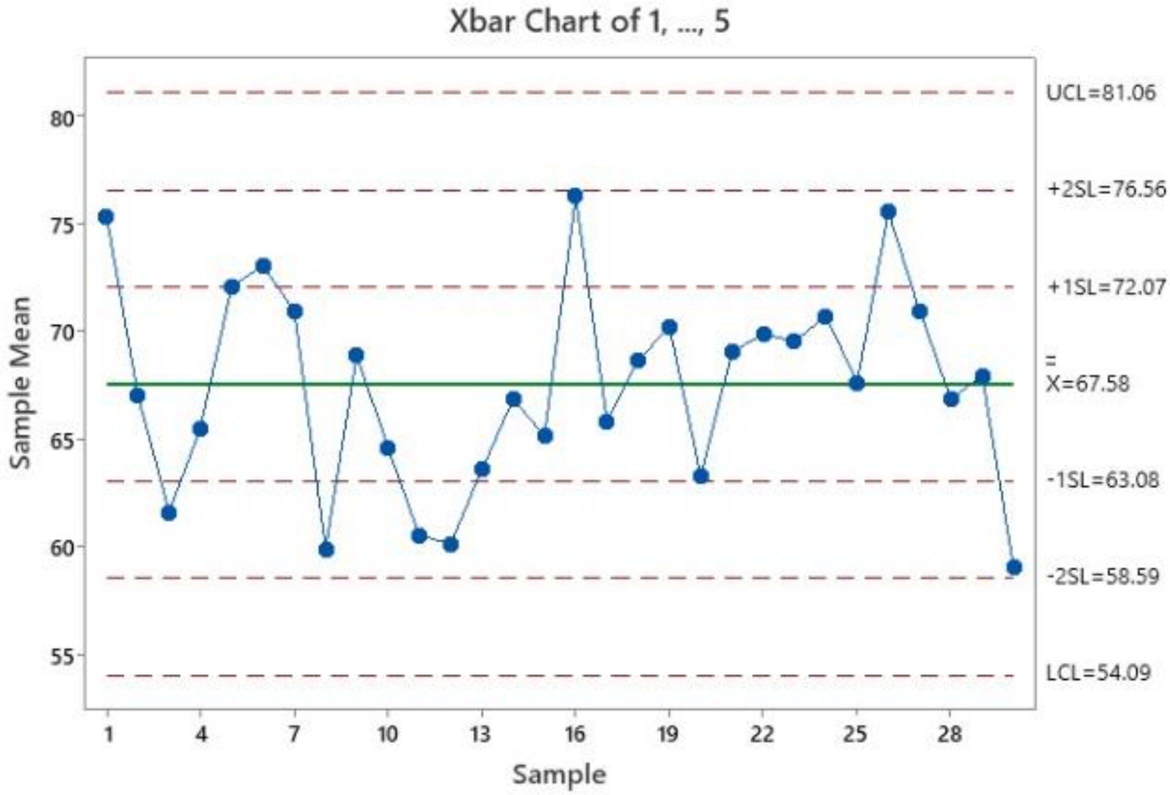
	Candidate Special Causes of Variation and Their Levels											Sample Roughness (microinches)				
Test No.	Cutting Speed (fpm)	Feed Rate (ipr)	Set up Person	Operator	Tool Type	Tool Condition	Depth-to-Shoulder	Machine	Measuring Device	Rake Angle (deg.)		1	2	3	4	5
61	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1003	Rex	Surfchek 3	10		81.117	76.833	87.037	80.875	85.27
62	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0999	Le-Lathe	Talymeas 5	5		73.149	65.293	65.175	73.58	66.725
63	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1	Rex	Surfchek 3	10		80.275	89.263	71.191	73.46	74.729
64	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0998	Le-Lathe	Talymeas 5	5		66.247	55.909	66.322	65.424	63.352
65	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0999	Le-Lathe	Talymeas 5	5		78.155	56.768	65.259	52.055	68.741
66	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1003	Rex	Surfchek 3	10		74.794	73.343	73.694	76.313	76.806
67	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.0997	Rex	Surfchek 3	10		72.476	70.285	76.135	82.128	69.319
68	1000	0.0086	Mr. Ricard	Regular	Cutgo-T	Sharp	0.1002	Nacirema	Surfchek 3	10		71.46	81.007	69.535	60.275	61.595
69	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0998	Le-Lathe	Talymeas 5	5		72.597	63.214	50.39	66.24	69.044
70	1000	0.0086	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1	Nacirema	Talymeas 5	5		62.072	61.56	68.654	76.471	78.078
71	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1003	Rex	Surfchek 3	10		83.315	68.576	75.48	69.172	82.307
72	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1	Rex	Surfchek 3	10		85.761	75.424	62.167	72.149	75.825
73	1000	0.0086	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1001	Nacirema	Talymeas 5	5		76.095	56.957	75.131	66.159	66.627
74	1000	0.0086	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1	Nacirema	Talymeas 5	5		60.919	74.519	59.967	68.196	69.598
75	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1003	Rex	Surfchek 3	10		60.269	70.794	89.174	64.936	99.195
76	1000	0.0086	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1001	Nacirema	Talymeas 5	5		68.031	74.098	71.212	64.791	69.168
77	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0999	Le-Lathe	Talymeas 5	5		63.197	71.782	54.954	59.914	68.395
78	1000	0.0086	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1	Nacirema	Talymeas 5	5		71.613	72.271	85.75	67.768	64.441
79	1000	0.0086	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1	Nacirema	Talymeas 5	5		70.899	63.038	59.557	60.096	79.197
80	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0997	Le-Lathe	Talymeas 5	5		59.156	55.401	78.828	62.683	67.179
81	1000	0.0086	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1001	Nacirema	Talymeas 5	5		70.023	71.271	67.488	64.1	73.28
82	1050	0.0089	Mr. Ricard	Regular	Nork-V	Sharp	0.1003	Rex	Surfchek 3	10		87.829	78.674	69.021	70.225	73.004
83	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1	Rex	Surfchek 3	10		76.041	78.293	72.251	79.66	88.126
84	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0999	Le-Lathe	Talymeas 5	5		55.245	61.553	59.54	64.064	69.376
85	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0998	Le-Lathe	Talymeas 5	5		67.25	65.973	75.894	57.796	67.547
86	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1	Rex	Surfchek 3	10		79.954	76.619	70.408	78.7	65.709
87	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0999	Le-Lathe	Talymeas 5	5		69.579	67.925	67.103	84.509	56.491
88	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0997	Le-Lathe	Talymeas 5	5		71.19	69.03	58.573	67.922	59.888
89	1000	0.0086	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1	Nacirema	Talymeas 5	5		69.506	69.164	76.469	73.933	65.153
90	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1	Rex	Surfchek 3	10		77.018	77.208	68.113	88.296	74.345

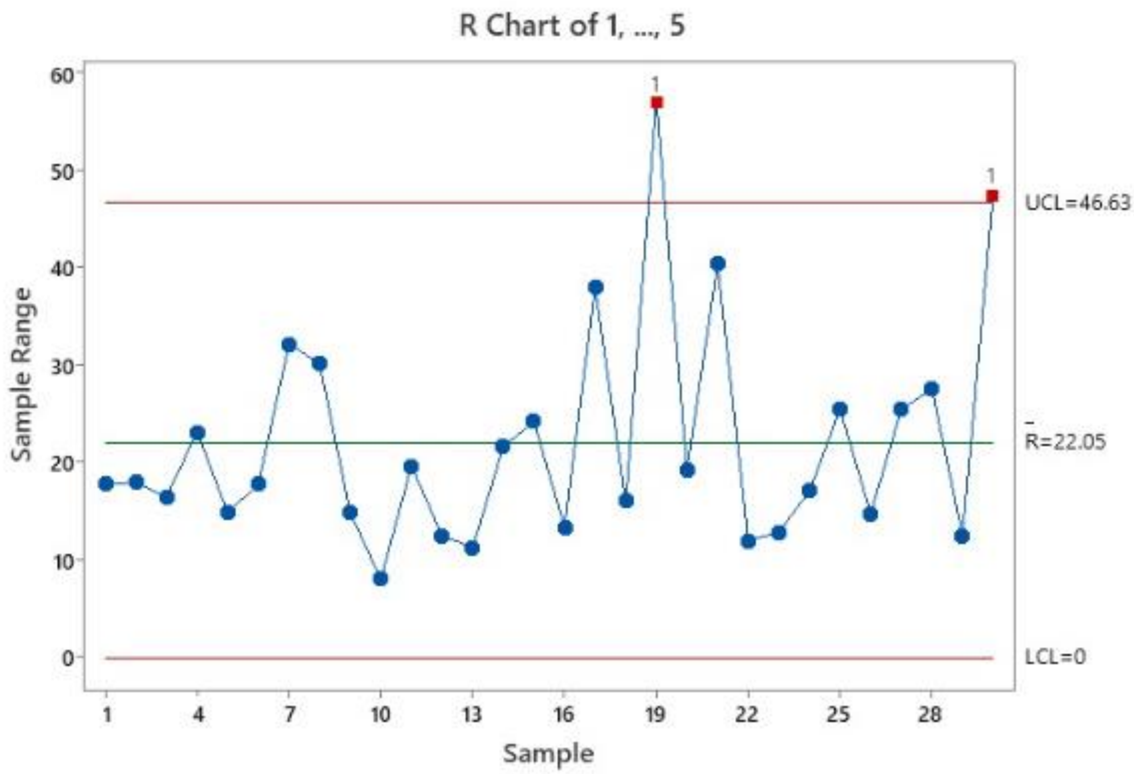
Date	12/11/2024
Trial	4
Subgroups	30
Special Cause	Operator,Tool Condition,Rake Angle,

	Candidate Special Causes of Variation and Their Levels											Sample Roughness (microinches)				
Test No.	Cutting Speed (fpm)	Feed Rate (ipr)	Set up Person	Operator	Tool Type	Tool Condition	Depth-to-Shoulder	Machine	Measuring Device	Rake Angle (deg.)		1	2	3	4	5
91	1000	0.0086	Mr. Ricard	Regular	Cutgo-T	Sharp	0.1002	Nacirema	Surfchek 3	10		84.003	74.877	72.158	68.862	65.451
92	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0998	Le-Lathe	Talymeas 5	5		68.186	62.117	61.996	65.964	61.256
93	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1	Rex	Surfchek 3	10		74.683	79.022	87.01	69.568	76.25
94	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0999	Le-Lathe	Talymeas 5	5		65.549	54.419	63.132	62.25	59.999
95	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1003	Rex	Surfchek 3	10		67.414	68.482	77.093	76.06	78.081
96	1000	0.0086	Mr. Ricard	Regular	Cutgo-T	Sharp	0.1002	Nacirema	Surfchek 3	10		62.941	64.55	70.044	70.149	70.641
97	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1003	Rex	Surfchek 3	10		74.924	73.088	70.891	76.604	84.774
98	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.0997	Rex	Surfchek 3	10		69.673	79.137	75.474	66.111	71.33
99	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.0997	Rex	Surfchek 3	10		80.993	75.152	69.135	62.683	75.918
100	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0998	Le-Lathe	Talymeas 5	5		71.55	71.103	56.883	70.377	71.96
101	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1003	Rex	Surfchek 3	10		80.16	61.039	83.998	84.797	76.829
102	1000	0.0086	Mr. Ricard	Regular	Cutgo-T	Sharp	0.1002	Nacirema	Surfchek 3	10		70.33	59.543	74.702	55.017	64.477
103	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1003	Rex	Surfchek 3	10		71.658	75.837	70.775	73.2	81.274
104	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.0997	Rex	Surfchek 3	10		74.511	65.073	83.666	77.632	79.099
105	1000	0.0086	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1001	Nacirema	Talymeas 5	5		70.496	76.062	70.85	72.42	66.573
106	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.0997	Rex	Surfchek 3	10		72.236	81.125	73.308	68.264	73.469
107	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1003	Rex	Surfchek 3	10		70.962	78.667	71.707	75.146	73.779
108	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0999	Le-Lathe	Talymeas 5	5		58.867	59.663	72.734	68.719	71.379
109	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1	Rex	Surfchek 3	10		70.047	76.717	79.962	80.184	72.053
110	1000	0.0086	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1	Nacirema	Talymeas 5	5		64.566	67.294	69.796	70.715	70.436
111	1000	0.0086	Mr. Ricard	Regular	Cutgo-T	Sharp	0.1002	Nacirema	Surfchek 3	10		74.657	66.057	59.897	79.571	85.886
112	1000	0.0086	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1	Nacirema	Talymeas 5	5		65.551	82.006	60.033	61.864	70.312
113	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1003	Rex	Surfchek 3	10		71.904	76.814	73.087	58.981	54.116
114	1000	0.0086	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1001	Nacirema	Talymeas 5	5		78.311	68.332	71.236	65.932	76.441
115	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0999	Le-Lathe	Talymeas 5	5		63.221	73.79	59.57	58.834	68.424
116	1050	0.0089	Mr. Ricard	Regular	Nork-V	Sharp	0.1003	Rex	Surfchek 3	10		75.839	83.057	92.062	74.713	67.534
117	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1	Rex	Surfchek 3	10		82.512	70.547	74.984	81.157	78.644
118	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.0997	Rex	Surfchek 3	10		73.693	76.923	59.042	76.018	81.93
119	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1	Rex	Surfchek 3	10		67.76	79.873	66.153	70.964	78.257
120	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0999	Le-Lathe	Talymeas 5	5		62.385	48.404	78.509	64.807	59.442

Date	12/11/2024															
Trial	5															
Subgroups	30															
Special Cause	Operator,Tool Condition,Machine,															
	Candidate Special Causes of Variation and Their Levels											Sample Roughness (microinches)				
Test No.	Cutting Speed (fpm)	Feed Rate (ipr)	Set up Person	Operator	Tool Type	Tool Condition	Depth-to-Shoulder	Machine	Measuring Device	Rake Angle (deg.)		1	2	3	4	5
121	1100	0.008	Mr. Ricard	Regular	Roved Cube	Sharp	0.0997	Le-Lathe	Surfchek 3	10		57.63	76.35	75.92	69.174	65.638
122	1100	0.008	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1	Le-Lathe	Talymeas 5	5		65.586	65.528	65.409	61	64.702
123	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0998	Le-Lathe	Talymeas 5	5		64.977	62.056	66.997	60.513	55.532
124	1100	0.008	Mr. Ricard	Regular	Roved Cube	Sharp	0.1	Le-Lathe	Surfchek 3	10		65.355	53.909	71.146	69.816	56.695
125	1100	0.008	Mr. Ricard	Regular	Cutgo-T	Sharp	0.1002	Le-Lathe	Surfchek 3	10		70.779	71.721	49.628	63.87	61.122
126	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0999	Le-Lathe	Talymeas 5	5		72.233	62.417	67.569	67.689	68.267
127	1100	0.008	Mr. Ricard	Regular	Roved Cube	Sharp	0.1	Le-Lathe	Surfchek 3	10		58.707	55.935	67.486	80.994	70.456
128	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0999	Le-Lathe	Talymeas 5	5		79.487	72.125	67.16	72.103	52.485
129	1100	0.008	Mr. Samuel	Regular	Nork-V	Sharp	0.0998	Le-Lathe	Talymeas 5	5		65.053	66.809	61.631	70.574	76.687
130	1100	0.008	Mr. Ricard	Regular	Cutgo-T	Sharp	0.1002	Le-Lathe	Surfchek 3	10		60.908	60.62	66.219	60.097	61.15
131	1000	0.0086	Mr. Ricard	Regular	Roved Cube	Sharp	0.1003	Nacirema	Surfchek 3	10		70.377	76.247	62.433	76.795	69.749
132	1000	0.0086	Mr. Samuel	Regular	Nork-V	Sharp	0.0998	Nacirema	Talymeas 5	5		72.59	63.935	74.722	55.167	76.13
133	1000	0.0086	Mr. Ricard	Regular	Nork-V	Sharp	0.1003	Nacirema	Surfchek 3	10		66.934	73.245	68.507	68.367	76.893
134	1000	0.0086	Mr. Ricard	Regular	Roved Cube	Sharp	0.0997	Nacirema	Surfchek 3	10		69.734	62.059	69.358	75.545	77.712
135	1000	0.0086	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1	Nacirema	Talymeas 5	5		62.257	67.313	60.704	63.566	61.829
136	1000	0.0086	Mr. Ricard	Regular	Cutgo-T	Sharp	0.1002	Nacirema	Surfchek 3	10		70.198	84.981	76.726	67.31	71.319
137	1000	0.0086	Mr. Ricard	Regular	Roved Cube	Sharp	0.1	Nacirema	Surfchek 3	10		74.024	74.149	69.749	73.027	71.618
138	1000	0.0086	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1001	Nacirema	Talymeas 5	5		69.077	69.713	61.406	60.631	63.973
139	1000	0.0086	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1	Nacirema	Talymeas 5	5		73.254	66.082	69.32	75.889	70.04
140	1000	0.0086	Mr. Ricard	Regular	Cutgo-T	Sharp	0.1002	Nacirema	Surfchek 3	10		76.995	83.37	73.757	66.079	70.657
141	1050	0.0089	Mr. Ricard	Regular	Cutgo-T	Sharp	0.1002	Rex	Surfchek 3	10		74.588	75.838	68.364	90.025	75.264
142	1050	0.0089	Mr. Samuel	Regular	Nork-V	Sharp	0.0999	Rex	Talymeas 5	5		75.415	69.067	82.211	83.495	83.152
143	1050	0.0089	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1001	Rex	Talymeas 5	5		60.723	84.054	82.103	87.256	70.234
144	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1003	Rex	Surfchek 3	10		76.976	66.108	82.863	66.078	66.516
145	1050	0.0089	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1001	Rex	Talymeas 5	5		64.489	76.235	83.493	82.531	72.934
146	1050	0.0089	Mr. Samuel	Regular	Nork-V	Sharp	0.0998	Rex	Talymeas 5	5		76.951	85.237	69.511	78.045	72.351
147	1050	0.0089	Mr. Ricard	Regular	Cutgo-T	Sharp	0.1002	Rex	Surfchek 3	10		75.762	74.437	67.218	74.799	72.524
148	1050	0.0089	Mr. Samuel	Regular	Cutgo-T	Sharp	0.1001	Rex	Talymeas 5	5		77.943	81.667	79.976	78.043	76.155
149	1050	0.0089	Mr. Ricard	Regular	Cutgo-T	Sharp	0.1002	Rex	Surfchek 3	10		82.592	74.537	81.573	76.644	72.993
150	1050	0.0089	Mr. Ricard	Regular	Roved Cube	Sharp	0.1	Rex	Surfchek 3	10		89.734	75.202	74.633	83.154	77.025

X bar an R bar Charts :


Xbar Chart of 1, ..., 5
Sample Mean
Sample
UCL=81.06
+2SL=76.56
+1SL=72.07
X=67.58
-1SL=63.08
-2SL=58.59
LCL=54.09
80
75
70
65
60
55
1
4
7
10
13
16
19
22
25
28


R Chart of 1, ..., 5
Sample Range
Sample
UCL=46.63
R=22.05
LCL=0
60
50
40
30
20
10
0
1
4
7
10
13
16
19
22
25
28
1
1