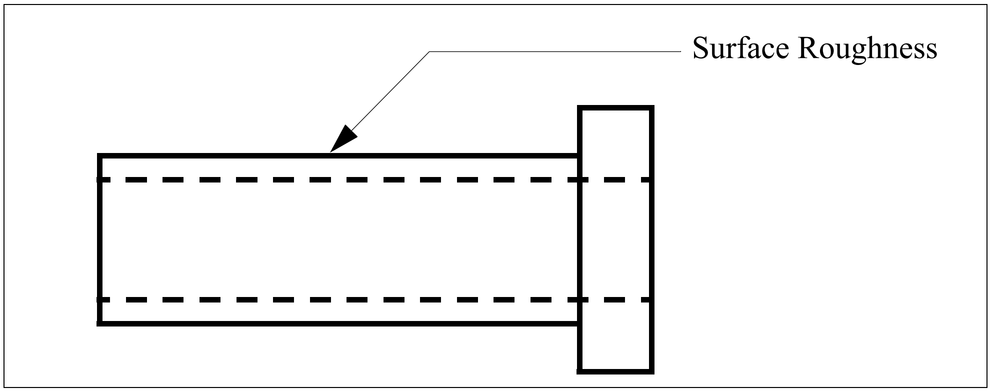
TURN5DOE Workshop

Assigned: April 12, 2005 **Due: April 19, 2005**

Background

In previous studies via Computer Simulation, a turning process producing the outside diameter of a certain bushing was studied, with the finish of the outside surface serving as the quality characteristic of interest. These studies revealed that initially many parts were outside the specifications (70± 15 μ inches). The part is shown below:



$\overline{X}$ and R control charts were used to study the process. Diagnostic work revealed that three special causes were leading to an unstable and erratic behavior of the process. These were

1. The inexperience of a substitute operator which at times led to excessive variation in surface roughness,
2. A poor tool change policy which often led to badly worn tools going undetected, causing parts at times to have unexpectedly smooth surfaces,
3. A poor chart sampling technique. Three different machines were being used and samples drawn from all three (at different times) were being plotted on the same chart.

Corrective actions were formulated and implemented for each special cause. A training program was initiated for all substitute operators. A tool change policy requiring more frequent surveillance of tool condition was put in place. The sampling and charting method was changed so that separate $\overline{X}$ and R charts were maintained for each machine. After the above actions were put in place the $\overline{X}$ and R charts for <u>each</u> machine showed good statistical control - a stable, predictable process was attained.

Process Capability Analysis

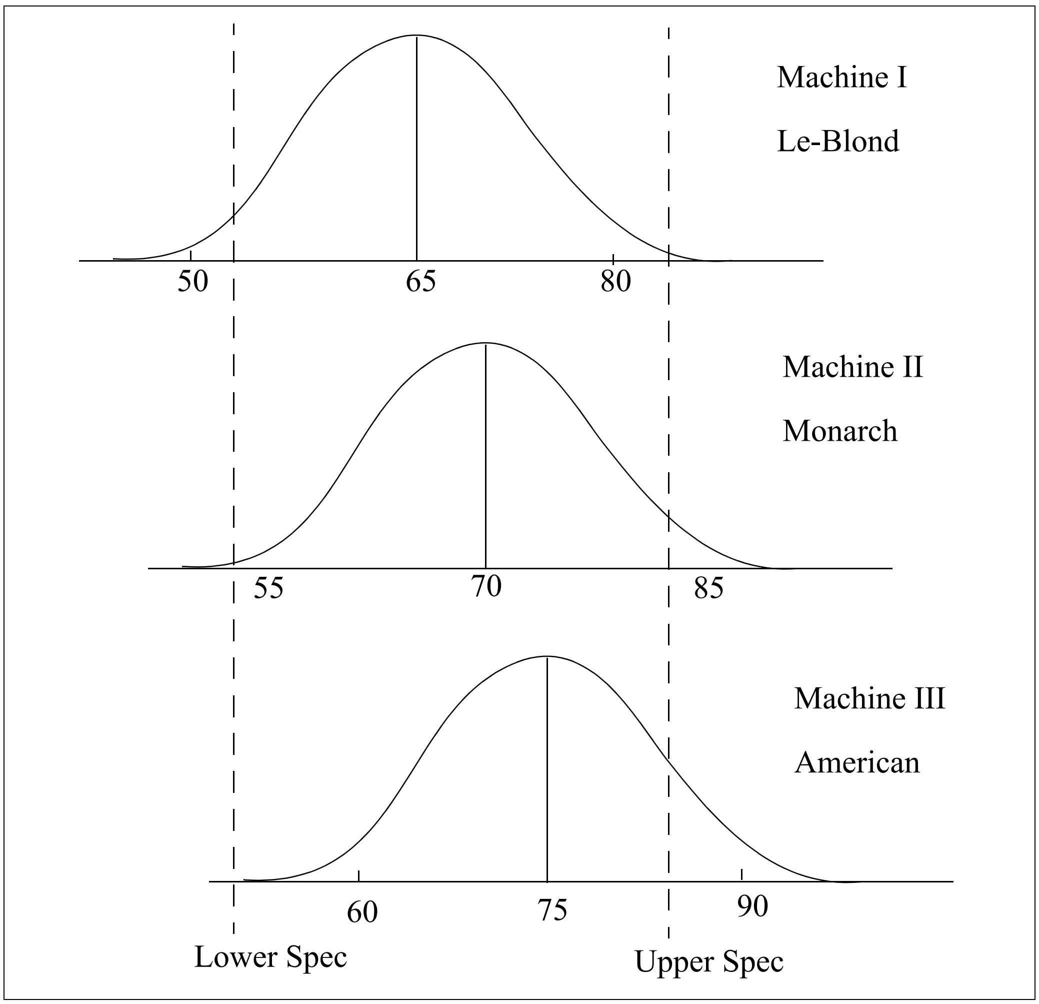
Each of the three stable processes/machines was examined in terms of their process capability. It was determined that two of the three machines were not well centered at the process target - nominal surface roughness value. The current state of affairs is as depicted in the figure on the next page.

An Initial Solution Proves Unsuccessful

In assessing the current state of affairs, it appears that two problems still seem to be present in this process:

1. Two of the three machines are not running at/near the part nominal requirement of 70 μ inches.
2. All three of the machines appear to still exhibit excessive variability in the output surface roughness values.

Since being on target is important to improving the quality and since process centering will somewhat reduce scrap it was decided to initially attack the centering problem.



From the diagnostic work done using $\overline{X}$ and R charts it was observed that all three machines were using somewhat different cutting speeds and feed rates. In fact, there appeared to be a strong correlation between the machine output surface roughness and feed rate which makes sense mechanistically:

Machine 1 (Le-Blond) - lower average roughness and a feedrate of 0.0080 ipr

Machine 2 (Monarch) - “on the nominal” average roughness and a feedrate of 0.0085 ipr

Machine 3 (American) - higher average roughness and a feedrate of 0.0089 ipr

To achieve better centering for machines 1 and 3 it was decided to use a feedrate of 0.0085 ipr. on all machines. $\overline{X}$ and R charts were continued after the changes were made in feedrate but no noticeable change occurred in the process average for either machines 1 or 3. Being somewhat perplexed by this result the foreman and process engineer got together and decided that cutting speed could be the problem as well. Since the Monarch (Machine 2) used a cutting speed of 1100 surface feet per minute it was decided to run the other two machines in a similar fashion. Still no noticeable change occurred in the surface roughness for machines 1 and 3. The foreman called for the feeds on machines 1 and 3 to be returned to the original settings but the speeds were continued at 1100 sfpm. The condition for machine 3 got slightly worse! Finally, the process engineer called for the company sorcerer who was left alone with the machines for several hours. The processes were than continued but no noticeable improvement was seen!

A New Approach to Finding the Problem

The process engineer working on this problem had recently become acquainted with the techniques of statistical design of experiments. He decided to try to apply these techniques in an attempt to learn more clearly what factors might influence surface roughness, either independently, or in concert with each other, or both. He met with several individuals associated with the process and they developed a list of potentially important factors together with the feasible ranges of variation for these factors. The table on the next page provides this list of factors. The table also provides the current state of affairs with respect to each of these factors.

Your Job

The process engineer needs guidance in designing the tests and analyzing the data. He calls on you for help. Use the general classes of 2^k and/or 2^{k-p} factorial and fractional factorial designs to discover what changes might be initiated to improve the two off-target machines. The following guidance may be useful:

1. You should be concerned only with process centering at this point, i.e., we will work only with location effects.
2. You may experiment with all (5) factors or with any subset that you choose - it’s all up to you.
3. You should run no more than about 30-40 experiments in the entire study.
4. You are free to choose the high and low levels for the experiments anywhere within the feasible range - again, it’s all up to you.

Once you have completed your experiments (using TURN5DOE), fully analyzed the results (using FACT or FFD), and come to some conclusion about how to improve the process, i.e., recommended new operating conditions for the poorly centered machines, you should then run a few validation/confirmatory tests to see if your recommendations can be reproduced at the process.

It will be useful for you to use the mathematical models developed from the results of your experiments as a means to determine the conditions required to improve the two poorly centered machines. Describe in detail the results of your investigation. Be sure to list all experiments you conducted, the data obtained, and the associated analysis. Don't forget to indicate the logic used in your design of experiments strategy. Include graphs of the relevant response surface(s). Carefully explain your recommendations and the logic associated with them. Show the results of confirmatory tests.

Potentially Important Process Factors

Factor	Feasible Range for Experiments
1. Machine Used	Only the American or Leblond lathes can be used for experimentation
2. Use of Cutting Fluid	Either present or absent
3. Cutting speed	8 90 - 1150 sfpm
4. Feedrate	0.0071 - 0.0095 ipr
5. Tool Nose Radius	0.0156" to 0.0625" in 0.0156" increments

Computer Software

A computer simulation program called TURN5DOE has been developed to simulate the act of running experiments with the five (5) process variables in the table. The program simply "produces" a surface roughness value as a test result for any given combination of process settings for the five variables. Test results are obtained one-by-one, given the user selected processing conditions and are displayed as they are generated. If you are experimenting with only a subset of the full set of five variables, default values will be used for the process conditions you do not specifically set. Once a set of test results has been obtained from TURN5DOE, analyze the data as appropriate. Once you have established a model for the response, use suitable plotting software to characterize the response surfaces.