Managing Six Sigma: Understanding the Importance of Self Study

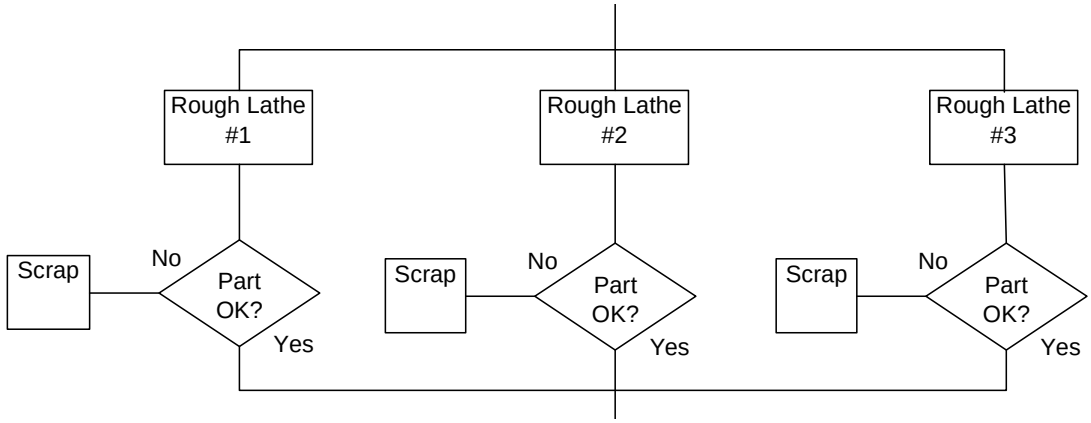
By Dean Christolear

Chapter Four – Improve and Control

After the Operations meeting, your supervisor notifies you that you have full management support for further investigation of Rougher 2. Anxious to improve the financial performance of the company, the plant manager has asked for weekly updates on your project. He would like the project closed by the end of the quarter, which is fast approaching. He has set a project due date for you that is four weeks away.

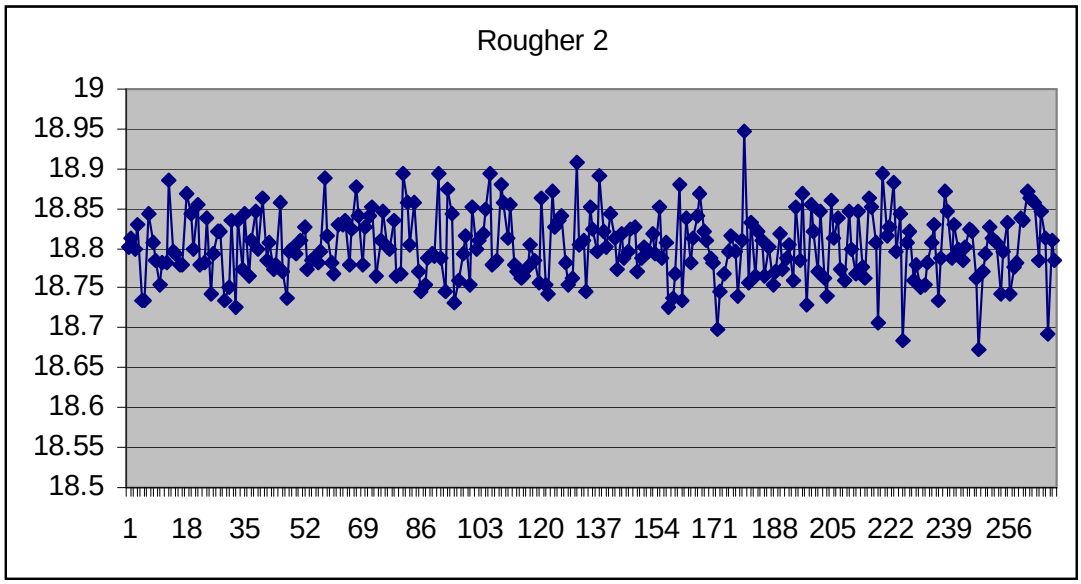
The pressure is extremely high for you to perform. Your work to this point has been exceptional, but you don't have many clues as to what is causing the variation in Rougher 2. You have scheduled a meeting with key personnel in the department to organize a problem solving team. Unfortunately, it was difficult finding a time when everyone was available, and the meeting had to be scheduled a week from today! You know that the plant manager is expecting an update next week, and you need to be able to report progress.

You take some time to review your training materials and some interesting ideas begin to form. Your training indicates that most projects will require a study of the measurement system. Variation in the measurement system can directly influence the data it collects. You review the process flowchart and realize that each rougher has a dedicated gage.



Your investigation of the historical data has resulted in identifying problems with the mastering of the gages on Rougher 2 and Rougher 3. Could there be other issues as well?

A traditional Gage Repeatability and Reproducibility (GR&R) study can be used to fully characterize the measurement system by quantifying the effect of the gage (repeatability) and the operator (reproducibility) on the measured values. You re-examine the Run chart you created and realize it included data from first and second shifts. It did not display any cycles, trends or shifts that could be attributed to the operator.



You decide to investigate only the repeatability of the gage using a scatter diagram. A scatter diagram is a simple, powerful chart that can show clear statistical relationships. You can find an excellent reference on scatter diagrams at http://www.itl.nist.gov/div898/handbook/eda/section3/scatterp.htm. You are expected to have a thorough understanding of this tool.

You develop a data sheet that will allow you to measure 30 shafts each on Rougher 1 and Rougher 2. It is set up to record two measurements for each of the 30 shafts.

	Rougher 1	
	First Meas.	Second Meas.
Part 1		
Part 2		
Part 3		
Part 4		
Part 5		
Part 6		
Part 7		
Part 8		
Part 9		
Part 10		
Part 11		
Part 12		
Part 13		
Part 14		
Part 15		
Part 16		
Part 17		
Part 18		
Part 19		
Part 20		
Part 21		
Part 22		
Part 23		
Part 24		
Part 25		
Part 26		
Part 27		
Part 28		
Part 29		
Part 30		

	Rougher 2	
	First Meas.	Second Meas.
Part 1		
Part 2		
Part 3		
Part 4		
Part 5		
Part 6		
Part 7		
Part 8		
Part 9		
Part 10		
Part 11		
Part 12		
Part 13		
Part 14		
Part 15		
Part 16		
Part 17		
Part 18		
Part 19		
Part 20		
Part 21		
Part 22		
Part 23		
Part 24		
Part 25		
Part 26		
Part 27		
Part 28		
Part 29		
Part 30		

You desire to collect a sample of parts from the full range of variation of the process. First, you ask the operator on Rougher 2 to save you 10 “good ones” that are near the specification nominal of 18.85 mm. You also ask the scrap person to save you 20 “rejects” from Rougher 2--10 out of specification at the high limit and 10 out of specification at the low limit.

Once you have collected all 30 shafts, you mix them up and randomly assign a number to each one, marking the number on the end of the shaft where it is difficult to see.

Next, you get permission from the supervisor to bring in the first shift operator two hours early to help you with the measurement study. You hand the parts to the operator in

serial number order and ask him for the measured value. Once all 30 shafts have been measured, you re-submit the shafts to the operator for a second measurement. You pass the shafts to the operator in random order instead of serial number order. This randomization is performed to reduce the chance of any bias the operator may introduce having checked the parts once before.

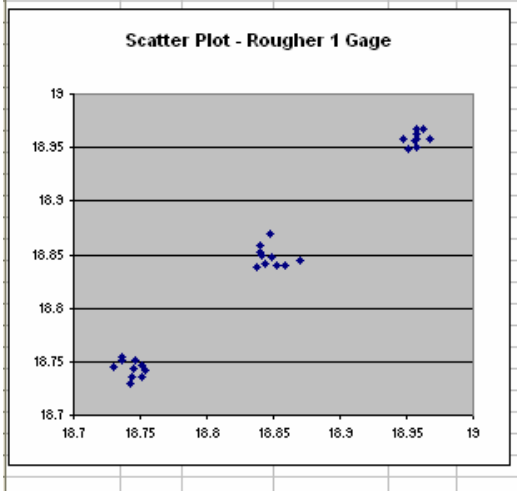
After you have collected the second set of measurements, the operator and you repeat the process on the gage for Rougher 1.

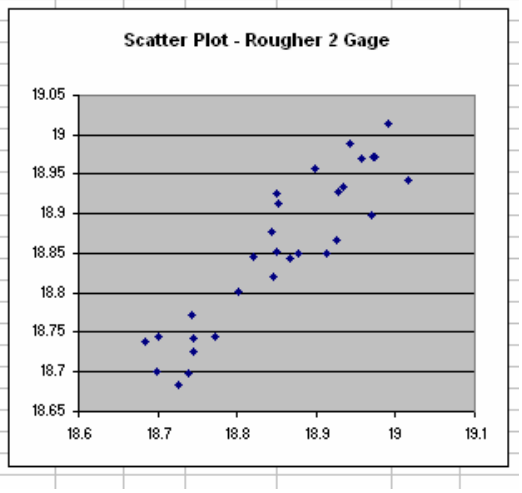
Open the file `Rougher 2 scatter diagram.xls`. On Sheet 1 you will find the results of the study. Paint the data for Rougher 1, Measurements 1 and 2. Do not include any headers or labels for the part number or the measurement number. Insert a chart as you did before by selecting the XY (scatter) option. The default of scatter with no lines is the correct chart type. Select Next twice, since the chart source data is already displayed correctly. In Step 3 of 4, go to the Titles tab and enter the title of the chart as "Scatter Plot - Rougher 1 Gage". Go to the Legend Tab and uncheck the Legend box. Click Finish.

Repeat the procedure for Rougher 2. Size the charts so that they are square. You may need to adjust the font size so that they are legible. Your spreadsheet should look generally as shown.

	Rougher 1	
	First Meas.	Second Meas.
Part 1	18.73	18.745
Part 2	18.754	18.742
Part 3	18.751	18.736
Part 4	18.745	18.744
Part 5	18.736	18.754
Part 6	18.744	18.736
Part 7	18.742	18.73
Part 8	18.746	18.751
Part 9	18.751	18.746
Part 10	18.736	18.751
Part 11	18.852	18.84
Part 12	18.84	18.852
Part 13	18.841	18.849
Part 14	18.844	18.841
Part 15	18.84	18.859
Part 16	18.838	18.838
Part 17	18.859	18.84
Part 18	18.87	18.844
Part 19	18.849	18.847
Part 20	18.847	18.87
Part 21	18.958	18.967
Part 22	18.958	18.962
Part 23	18.956	18.956
Part 24	18.958	18.951
Part 25	18.951	18.948
Part 26	18.967	18.958
Part 27	18.948	18.958
Part 28	18.958	18.958
Part 29	18.967	18.958
Part 30	18.962	18.967

	Rougher 2	
	First Meas.	Second Meas.
Part 1	18.744	18.743
Part 2	18.802	18.802
Part 3	18.725	18.684
Part 4	18.745	18.725
Part 5	18.699	18.7
Part 6	18.7	18.745
Part 7	18.738	18.699
Part 8	18.743	18.773
Part 9	18.684	18.738
Part 10	18.773	18.744
Part 11	18.867	18.844
Part 12	18.85	18.852
Part 13	18.845	18.82
Part 14	18.914	18.85
Part 15	18.849	18.926
Part 16	18.844	18.877
Part 17	18.877	18.849
Part 18	18.82	18.845
Part 19	18.852	18.914
Part 20	18.926	18.867
Part 21	18.934	18.934
Part 22	18.969	18.899
Part 23	18.899	18.957
Part 24	18.972	18.973
Part 25	18.928	18.928
Part 26	18.942	18.99
Part 27	18.957	18.969
Part 28	19.015	18.942
Part 29	18.99	19.015
Part 30	18.973	18.972





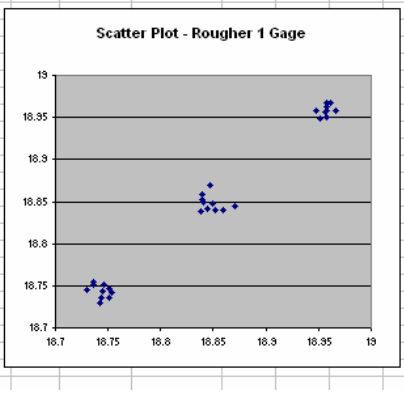
There appears to be a clear difference between the gages. Go to the data table for Rougher 1. At the end of the row for the two measurements taken for Part 1, insert the function MAX to find the maximum value of the two measurements taken. Move one cell to the right and use the MIN function to find the minimum value. Move again to the right

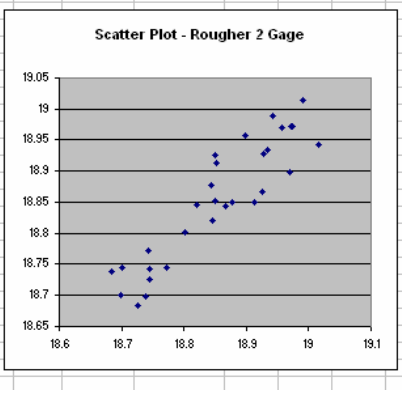
to the next cell and subtract the minimum from the maximum to find the range of the two measurements. Label the column headings “Max”, “Min” and “Range.” Using the MAX and MIN functions maintains a positive value for the range of the two measures.

Go to the bottom of the Range column and insert the AVERAGE function to find the average of all the ranges. Repeat this procedure for Rougher 2. Your spreadsheet should look generally as shown.

	Rougher 1				
	First Meas.	Second Meas.	Max	Min	Range
Part 1	18.73	18.745	18.745	18.73	0.015
Part 2	18.754	18.742	18.754	18.742	0.012
Part 3	18.751	18.736	18.751	18.736	0.015
Part 4	18.745	18.744	18.745	18.744	0.001
Part 5	18.736	18.754	18.754	18.736	0.018
Part 6	18.744	18.736	18.744	18.736	0.008
Part 7	18.742	18.73	18.742	18.73	0.012
Part 8	18.746	18.751	18.751	18.746	0.005
Part 9	18.751	18.746	18.751	18.746	0.005
Part 10	18.736	18.751	18.751	18.736	0.015
Part 11	18.852	18.84	18.852	18.84	0.012
Part 12	18.84	18.852	18.852	18.84	0.012
Part 13	18.841	18.849	18.849	18.841	0.008
Part 14	18.844	18.841	18.844	18.841	0.003
Part 15	18.84	18.859	18.859	18.84	0.019
Part 16	18.838	18.838	18.838	18.838	0
Part 17	18.859	18.84	18.859	18.84	0.019
Part 18	18.87	18.844	18.87	18.844	0.026
Part 19	18.849	18.847	18.849	18.847	0.002
Part 20	18.847	18.87	18.87	18.847	0.023
Part 21	18.958	18.967	18.967	18.958	0.009
Part 22	18.958	18.962	18.962	18.958	0.004
Part 23	18.956	18.956	18.956	18.956	0
Part 24	18.958	18.951	18.958	18.951	0.007
Part 25	18.951	18.948	18.951	18.948	0.003
Part 26	18.967	18.958	18.967	18.958	0.009
Part 27	18.948	18.958	18.958	18.948	0.01
Part 28	18.958	18.958	18.958	18.958	0
Part 29	18.967	18.958	18.967	18.958	0.009
Part 30	18.962	18.967	18.967	18.962	0.005
				Average	0.00953

	Rougher 2				
	First Meas.	Second Meas.	Max	Min	Range
Part 1	18.744	18.743	18.744	18.743	0.001
Part 2	18.802	18.802	18.802	18.802	0
Part 3	18.725	18.684	18.725	18.684	0.041
Part 4	18.745	18.725	18.745	18.725	0.02
Part 5	18.699	18.7	18.7	18.699	0.001
Part 6	18.7	18.745	18.745	18.7	0.045
Part 7	18.738	18.699	18.738	18.699	0.039
Part 8	18.743	18.773	18.773	18.743	0.03
Part 9	18.684	18.738	18.738	18.684	0.054
Part 10	18.773	18.744	18.773	18.744	0.029
Part 11	18.867	18.844	18.867	18.844	0.023
Part 12	18.85	18.852	18.852	18.85	0.002
Part 13	18.845	18.82	18.845	18.82	0.025
Part 14	18.914	18.85	18.914	18.85	0.064
Part 15	18.849	18.926	18.926	18.849	0.077
Part 16	18.844	18.877	18.877	18.844	0.033
Part 17	18.877	18.849	18.877	18.849	0.028
Part 18	18.82	18.845	18.845	18.82	0.025
Part 19	18.852	18.914	18.914	18.852	0.062
Part 20	18.926	18.867	18.926	18.867	0.059
Part 21	18.934	18.934	18.934	18.934	0
Part 22	18.969	18.899	18.969	18.899	0.07
Part 23	18.899	18.957	18.957	18.899	0.058
Part 24	18.972	18.973	18.973	18.972	0.001
Part 25	18.928	18.928	18.928	18.928	0
Part 26	18.942	18.99	18.99	18.942	0.048
Part 27	18.957	18.969	18.969	18.957	0.012
Part 28	19.015	18.942	19.015	18.942	0.073
Part 29	18.99	19.015	19.015	18.99	0.025
Part 30	18.973	18.972	18.973	18.972	0.001
				Average	0.03153





Look at the average range values for both gages. The range of variation for Rougher 1 averages around 0.01 mm, or one-tenth of the tolerance. The range of variation for Rougher 2 averages around .03 mm, or about 30% of the tolerance and three times greater than rougher 1. You can easily see the excessive variation in the gage at Rougher 2 by reviewing the scatter diagram. Repeated measurements should be tightly grouped, as they are in the scatter diagram for Rougher 1. This is not a formal GR&R study, but it is more than sufficient for problem solving.

Save the file to your computer. Ensure that the file is kept in a safe place—backup copies are encouraged.

You are now convinced that the variation in Rougher 2 is the result of the gage and not the machine. You contact the gage man and ask for his help determining what might be wrong with the gage on Rougher 2. The gage man is perplexed and agrees to examine both gages closely on the next break.

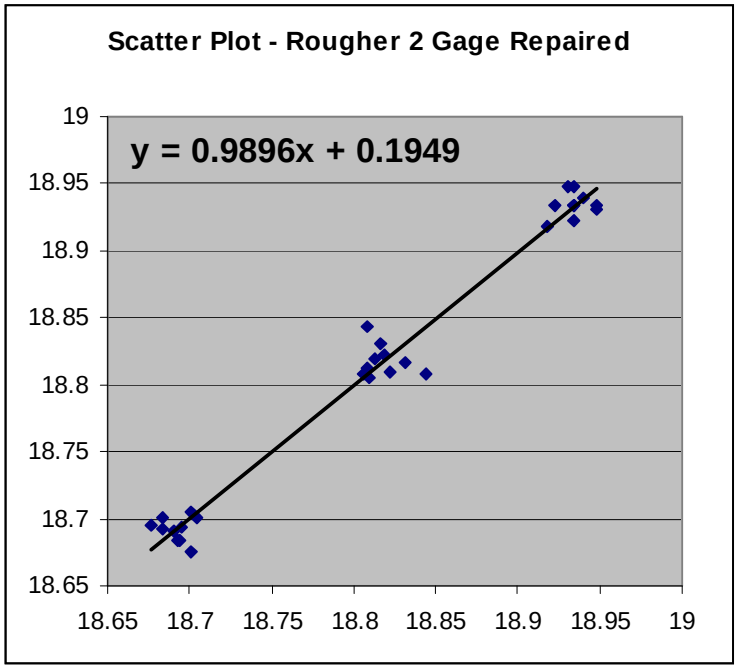
At the end of the shift, you receive a call from the gage man informing you that he has discovered the source of the problem. There is a mechanism that brings the dial indicator in contact with the shaft after it is loaded in the gage. This mechanism slides on bronze bushings, which were severely worn on the Rougher 2 gage. He also examined the gage at Rougher 3 and found the bushings were worn as well, but not to the extent of Rougher 2. Replacement bushings were available in the tool crib, and the gage man has already repaired the gages. The gage at Rougher 1 was fine.

The gage man tells you that the worn bushings are difficult to see as they are on the underside of the mechanism. They are not indicated as a wear item in the Metrology Lab calibration files and, therefore, were never examined during annual calibrations. He has updated the files for these gages to include replacement of the bushings each year when the gage is calibrated.

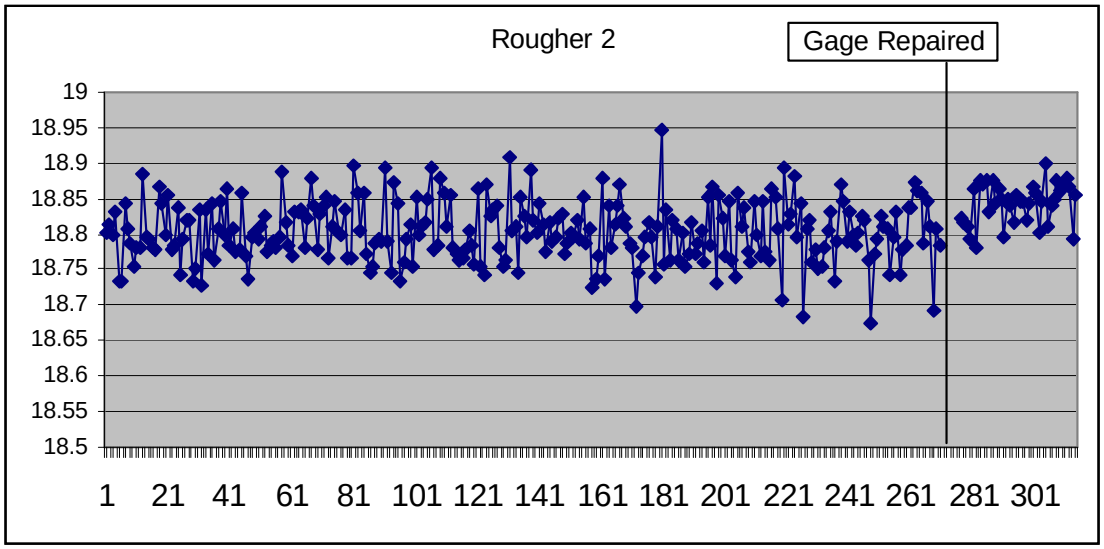
It is the opinion of the gage man that the bushings were also at the root of the mastering problem you had discovered earlier in your investigation. The worn bushings were influencing the readings of the gage master as well. Re-mastering the gages only gave the illusion of improvement.

You follow up with the Metrology Lab supervisor and ask for a review of all gages in the plant that may be susceptible to worn bushings. Additionally, you request that each affected calibration file be updated to require bushing replacement during annual calibration. He is reluctant to take on such a large task, but he understands the importance and assigns a person to the job.

Two days before your scheduled review with the plant manager, you return to Rougher 2 with the 30 shafts used in the prior study. You collect repeated measures in the same fashion as before and generate the scatter diagram shown.



Now that the gage is repaired, you need to confirm that the variation in the parts coming from Rougher 2 is reduced. You know from your previous analysis that the variation came and went hour to hour, not shift to shift or day to day. While you were developing your process flowchart, you learned that every shaft is measured while only one per hour is recorded. You elect to stand on the platform and record the part measurements as they are taken. You quickly collect a large sample of data. Adding this new data to the historical data, you are able create a new Run chart.



You are able to put the information together in time for your review with the plant manager. He is extremely pleased with the results of the project and asks a lot of questions about your Green Belt training. He is very interested in forming a group of Green Belts and Black Belts to attack some of the tough, nagging projects in the plant. He would like for you to continue with Black Belt training so that you can lead the team.

After the meeting, your supervisor is both pleased and impressed. He had fully suspected that Rougher 2 would need to be rebuilt. Rebuilding would have caused numerous issues with production, which would have required a considerable amount of overtime to support assembly requirements. Correctly diagnosing the measurement issue has saved money without impacting production schedules. He tells you to take the afternoon off but to be ready to select your next project when you come in tomorrow!