Process Trial Charts

The third of six uses

Donald J. Wheeler

Having described the report-card chart and the process monitor chart in previous columns, we now turn to a third way that people use process behavior charts—the process trial chart. Here the emphasis shifts from the detection of unknown changes or upsets to the evaluation of deliberate changes introduced by the user.

A process trial occurs when the engineers go out to the production line, get in the way of the operators, fiddle with the process inputs while they collect some data, and then go back to their office to argue about how to interpret those data. In short, they are generally simple, *ad hoc* experiments. Thus, like all experiments, a process trial chart involves the one-time analysis of a finite amount of data. Since the earlier uses involved the sequential analysis of a continuing stream of process data, process trial charts are interpreted slightly differently than report card charts and process monitor charts. While we will still be alert for any unplanned process upsets, the main job of a process trial chart is to evaluate the effects of planned changes in the process inputs.

Of course, in determining what changes to evaluate there may well be some preliminary charts created along the way. I tend to include these in with the actual process trial chart as part of the overall investigative process. Our example will involve a problem with the production of motor mounts.

Motor mounts are a sandwich of two metal plates around a rubber filler. This sandwich is produced in a transfer press where the rubber is extruded into the cavity between the metal plates and cured. If the rubber slug is too small there will be a void in the finished motor mount, and the assembly will be scrapped.

If rubber slug is too large the extra rubber will result in flash around the motor mount. Since one of the few places for this flash to go is the thread spaces on the bolts, flash requires rework to get the threads clear of the excess rubber. (Ten men and two robots are employed in the job of deflashing the motor mounts.)

Finally, if a rubber slug is grossly overweight it will cause the transfer press to stop before it completes a full stroke. Since the press makes 30 motor mounts with each stroke, one grossly overweight slug can result in voids in 29 other motor mounts. So, variation in the weights of the rubber slugs creates scrap and rework in subsequent steps.

The process of producing rubber slugs begins with an extruder that bulks up rubber strips into a tuber, a conveyer belt that carries the tuber to the cutter, and a guillotine-style cutter that produces the slugs. This process is shown schematically in Figure 1.

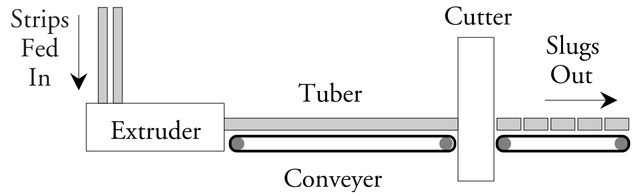

Figure 1: The Slug Line

The conventional wisdom in this department was that the slug line cutter, which was over 40 years old, was a hunk of junk. So Terry, the process engineer, decided to see if the conventional wisdom was correct. He took a paint pen and went out to the slug line cutter. As 100 successive slugs came off the line he used his paint pen to number them so he could keep them in time-order sequence, and then he measured their weights. He arranged these 100 weights into 20 subgroups of size five and created the average chart in Figure 2. Since the line produced 20 slugs per minute, this average chart shows a five-minute window on production and each subgroup represents fifteen-seconds elapsed time.

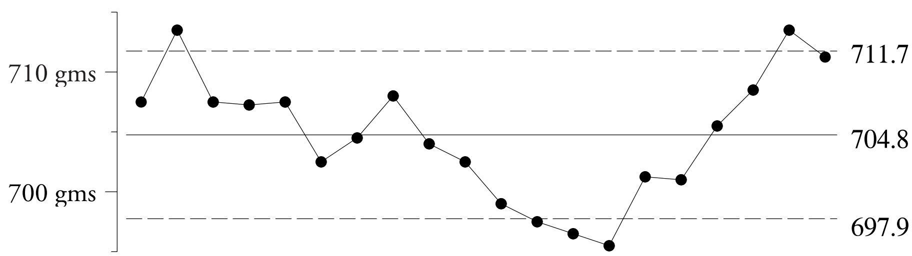

Figure 2: Average Chart for Slug Weights

Terry wanted to show that the variation in the weights was due to a variation in the lengths of these slugs. To do this he got a special caliper designed to measure these soft, uncured rubber slugs, and obtained the lengths shown in Figure 3. Once again, subgroup one was pieces 1 to 5, etc., for the same 100 slugs shown in Figure 2.

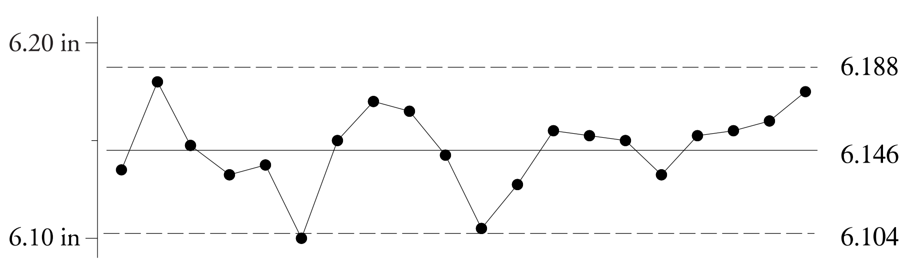

Figure 3: Average Chart for Slug Lengths

If the cutter was the culprit Terry expected to see the weights and lengths track each other: the average weights and average lengths should go up and down together. This more or less happens for the first eleven subgroups, but the last nine subgroups tell a completely different story. There the changes in weight do not track with the changes in length. So Terry measured the volume of each slug and created a third average chart.

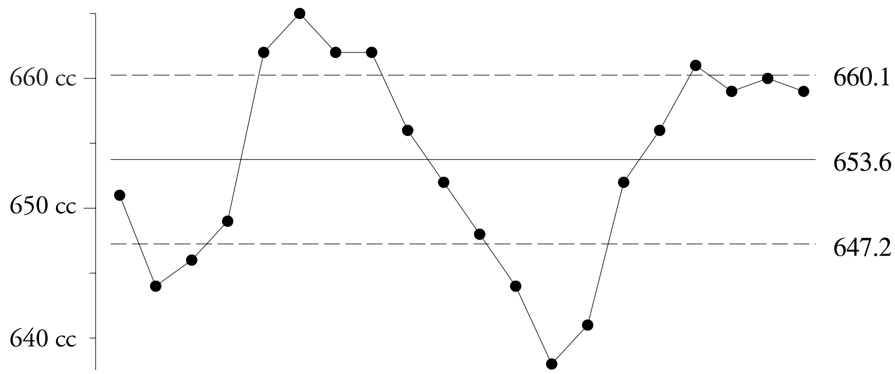

Figure 4: Average Chart for Slug Volumes

The parallelism between the last ten subgroups of Figures 2 and 4 suggested that the weight changes in the slugs depended upon more than just the lengths. The variation in the weights also depended upon the cross-sections, and the cutter had no impact upon the cross sections.

Of the three average charts above, it is the volumes that show the greatest degree of exceptional variation, thus Terry was convinced that the extruder, rather than the cutter, was the source of the problem. When he had the motor speed of the extruder checked he discovered that it varied by plus or minus two percent. When he dug out the specifications for that extruder he discovered that plus or minus two percent was exactly what they had ordered. In response to this Terry ordered a new motor speed controller that would hold the speed within plus or minus two-tenths of a percent. Since variation in the motor speeds for the conveyer and cutter could affect the lengths, he also put the new motor speed controllers on the conveyer belt and the cutter as well as the extruder.

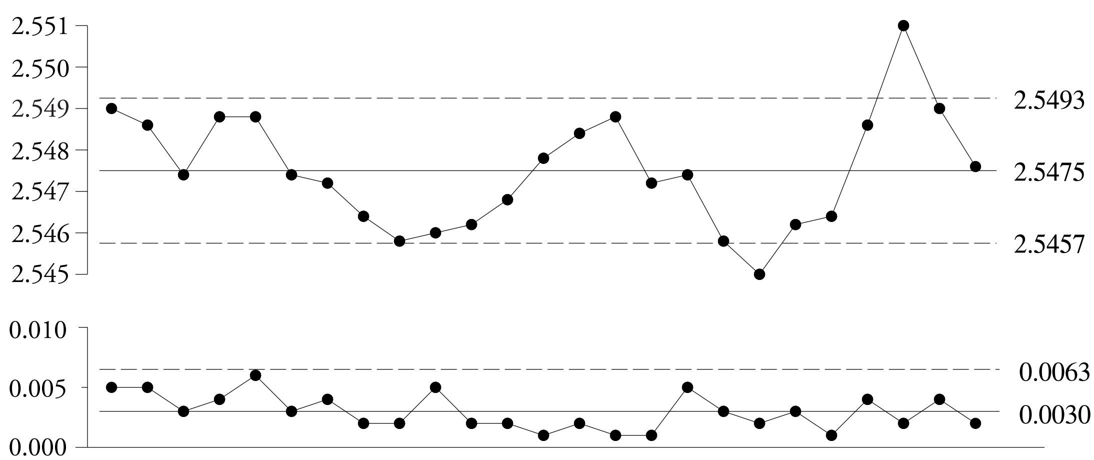

Figure 5: Average and Range Chart for Time Between Cycles, Old Controller

Since they had already installed a timer on the cutter he used the time between successive cycles of the cutter to compare the old and new controllers. The average and range chart in

Figure 5 shows the times between successive cycles of the cutter (in seconds) for 125 successive cycles with the old controller, and Figure 6 does the same for the new controller. Once again, each chart represents about 5 minutes of production.

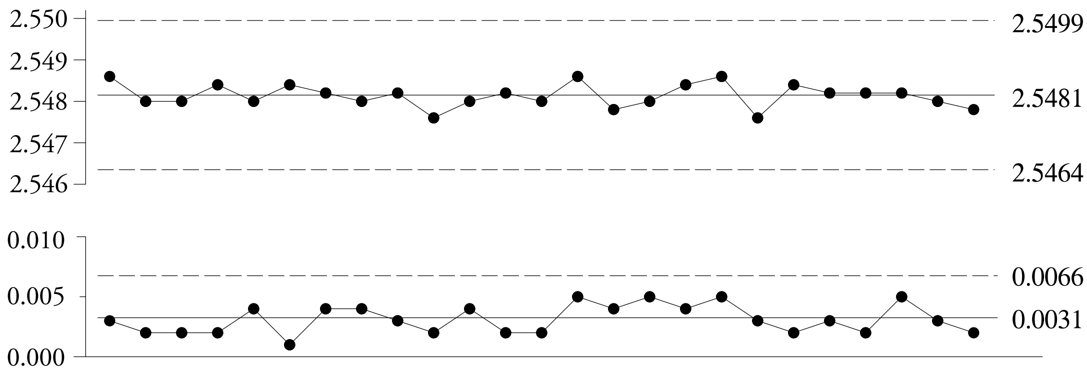

Figure 6: Average and Range Chart for Time Between Cycles, New Controller

Clearly, the new controllers dramatically improved the consistency of the motor speeds for the slug line. It is instructive to stop and note how Terry got to this point. He had set out to confirm the conventional wisdom, but the data did not support the idea that the cutter was the culprit. The variation in weight was found to be a function of both length and cross-section. As Terry tackled the problem of the variation in the cross-sections he found and fixed a problem with the motor speeds.

Having greatly reduced the variation in the motor speeds, Terry wanted to know what impact these improvements had had upon the slug weights. So he took his paint pen back out to the slug line and collected, numbered, and weighed another 100 consecutive slugs. These weights were used to create the average chart in Figure 7.

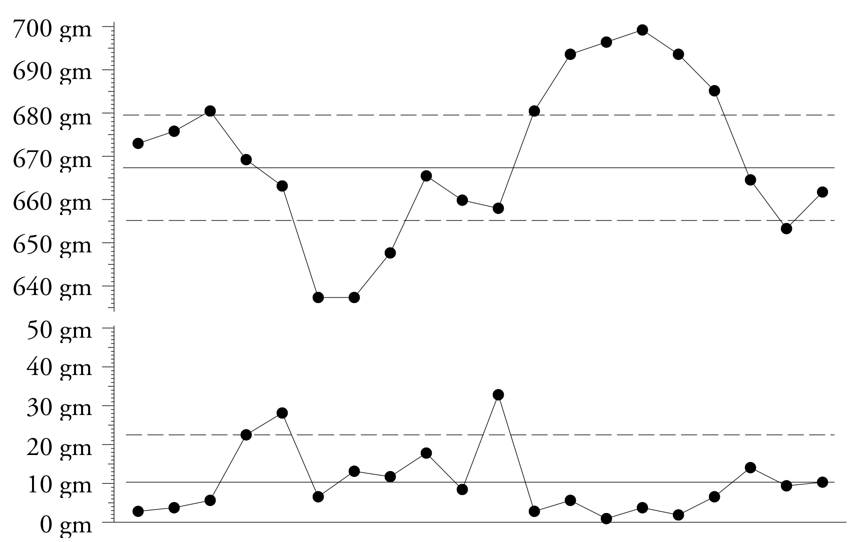

Figure 7: 100 Consecutive Slug Weights with New Motor Speed Controllers

Clearly, the new motor speed controllers did not make the problem go away. If anything, they may have made things worse since the limits of Figure 7 are almost twice as wide as those of Figure 2. Either way, there was still too much variation in the slug weights, and the slug weight process remained unpredictable on time spans as short as five minutes. As is so often the case, Terry was working within the set of known process inputs. He was adjusting these known control factors when he needed to be looking outside the set of known process inputs. Here it is the fact that the motor mount slug weights kept changing in spite of the increased consistency of the motor speeds that is the clue that Terry needed to find an input that either was uncontrolled or was controlled at the wrong level. He needed to find an assignable cause of exceptional variation, and so he went out to talk with the operator, John.

At first John was reluctant to offer any suggestions, but when Terry convinced him that he would listen to any idea, John said that he thought they might be starving the screw of the extruder. So Terry decided to conduct another simple process trial. They were currently feeding two strips of rubber into the extruder. This was the standard operating procedure. It is what was done while the data of Figure 7 were collected.

So Terry had John feed three strands of rubber into the extruder while Terry collected, numbered, and weighed 100 consecutive slugs. Then Terry and John repeated this exercise while feeding four strands of rubber into the extruder. Terry then produced average and range charts for each of these conditions, placed them side by side, attached a cover sheet, and produced one of the most powerful memos of his career. Terry's three charts are in Figure 8.

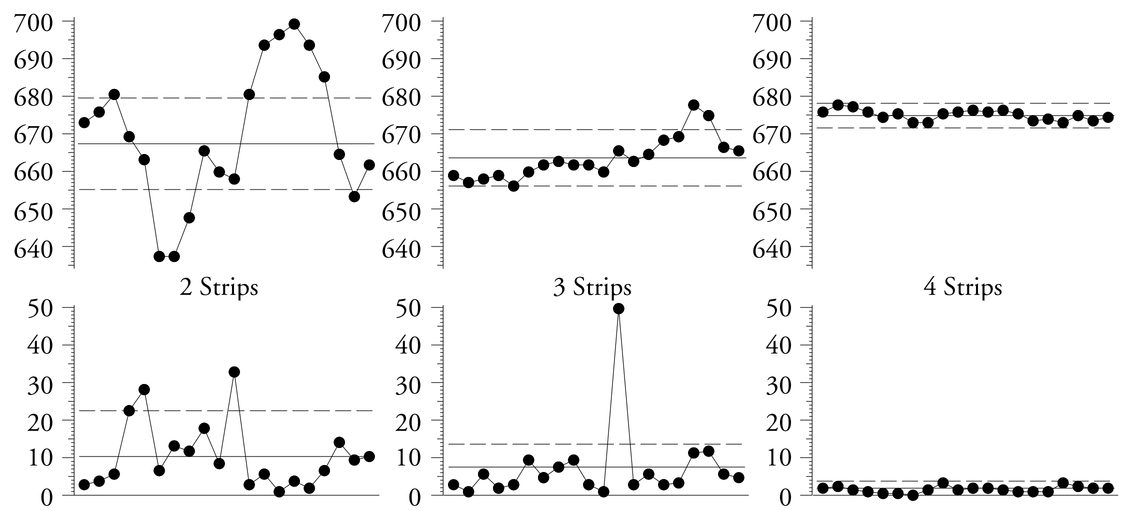

Figure 8: Average and Range Charts for Three Operating Procedures

In Terry's words: "I got no arguments. Everyone agreed. We clearly needed to feed four strands of rubber into the extruder." And so the standard operating procedure was changed. Subsequently, the ten men who had been routinely injuring themselves while deflashing the motor mounts were moved to other jobs in the plant, and when I next visited this department the two robots were sitting idle. You cannot stop scraping the toast until you learn how to quit burning it.

SUMMARY

When you carry out a process trial there are generally two sticking points. The first is discovering what the data are telling you about your process, and the second is communicating these discoveries to others. The process trial chart helps with both discovery and communication, so that you no longer have to have an argument about what the data mean. It becomes clear to all so that effort can be spent on fixing the things that need to be fixed, as they need fixing. Additionally, as happened here in Figure 7, the charts will nag you when you have not yet fixed the right thing.

While designed experiments are needed when working with multiple factors, when we are operating in a problem solving mode we are often challenged to come up with even one factor to investigate. The simplicity of the process trial chart provides the needed feedback to allow you to work your way through a problem with a minimum of effort.

For more formal experiments involving two or more factors the Analysis of Means (ANOM) combines the simplicity of the average and range chart with the more traditional structure of choosing the risk of a false alarm for your analysis. For more on this technique see "The Analysis of Experimental Data," ***QDD*** January 6, 2014.

Finally, why did Terry use average and range charts instead of *XmR* charts? This was Terry's first project; the piece of paper in front of him was set up for subgroups of size five; and I had not yet taught him how to create an *XmR* chart. The point is not whether or not you can create the best possible chart, but rather if you can learn from the chart you have created. As long as you can use your chart to tell the story contained in your data you are using the right chart. The two reasons for using a process trial chart are discovery and communication. When this happens the process trial chart has fulfilled its purpose.