Roll Variability Analysis
Six Sigma for Roll Goods Processing

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In terms of understanding and quantifying outgoing product variability, there are significant differences between piece part and roll goods (continuous process) manufacturing operations.

These differences impact the entire evaluation process beginning with sampling strategy and sample size calculations and extending through both the statistical methodology and the graphic selections used to create a realistic understanding of what, exactly, is being sent to our customers.

Because the preponderance of literature dealing with sampling, statistical analysis and graphic analysis deals with piece part systems, the majority of roll product manufacturers have, by default, adopted these systems to analyze their own product variability.

This has resulted not only in a lack of real and quantitative understanding of outgoing product variability, but has also negatively impacted product quality and consistency, scrap and customer satisfaction over time, usually without the roll manufacturer's knowledge.

Ultimately, the roll goods producer needs to define, in both statistical and graphic terms, both its significant *levels* of performance and its significant normal and abnormal *patterns of variability*. Patterns of variability examples include cross directional profiles, machine direction harmonics and trending over time.

The ultimate key to success revolves around sampling. Sample strategy must always consider the objective of the study or sampling system while sample size must consider both the specific cross web locations of the test values along with the machine direction quantities. Both of these considerations will ultimately provide a realistic sample size.

A major consideration in the analysis process must be our recognition of correlation effects. Because roll goods variability is integrated (as compared with piece parts having units of production with individual, unique values), sample values may well be correlated in the cross direction and/or the machine direction (autocorrelation). These effects prohibit the use of normal statistical methods, particularly in the cross direction. This means that we must utilize graphic and statistical methods that define our process in a correct manner.

Today we will demonstrate a number of graphic techniques from actual data that will provide a real life picture of the benefits of this approach. We will also discuss future steps and objectives that will maximize the benefits of these techniques.

As a manufacturer of highly engineered adhesive and specialty coatings and laminates, Adhesives Research has found that its customers are demanding tighter tolerances relative to their critical performance parameters. These include, but are not limited to coat weight, thickness, peel adhesion, release, conductivity, optical transmission, and contact angle.

Roll variability analysis (RVA) tools add value to the whole supply chain when applied effectively. These include our raw materials (films, release liners, foils, paper, nonwovens, foams, etc) and our coating processes. They can positively impact our slitting processes, our customers' fabricating processes, and the performance of our customers' final assemblies.

Application of RVA to Liner Release for an Unsupported Transfer Adhesive

The following illustrations show the application of some RVA tools in understanding the liner release performance of one of our unsupported transfer adhesives. Liner release is a critical customer parameter for this particular product as it impacts their processing speeds. For these studies, we looked at five process streams: left edge, left center, center, right center, and right edge.

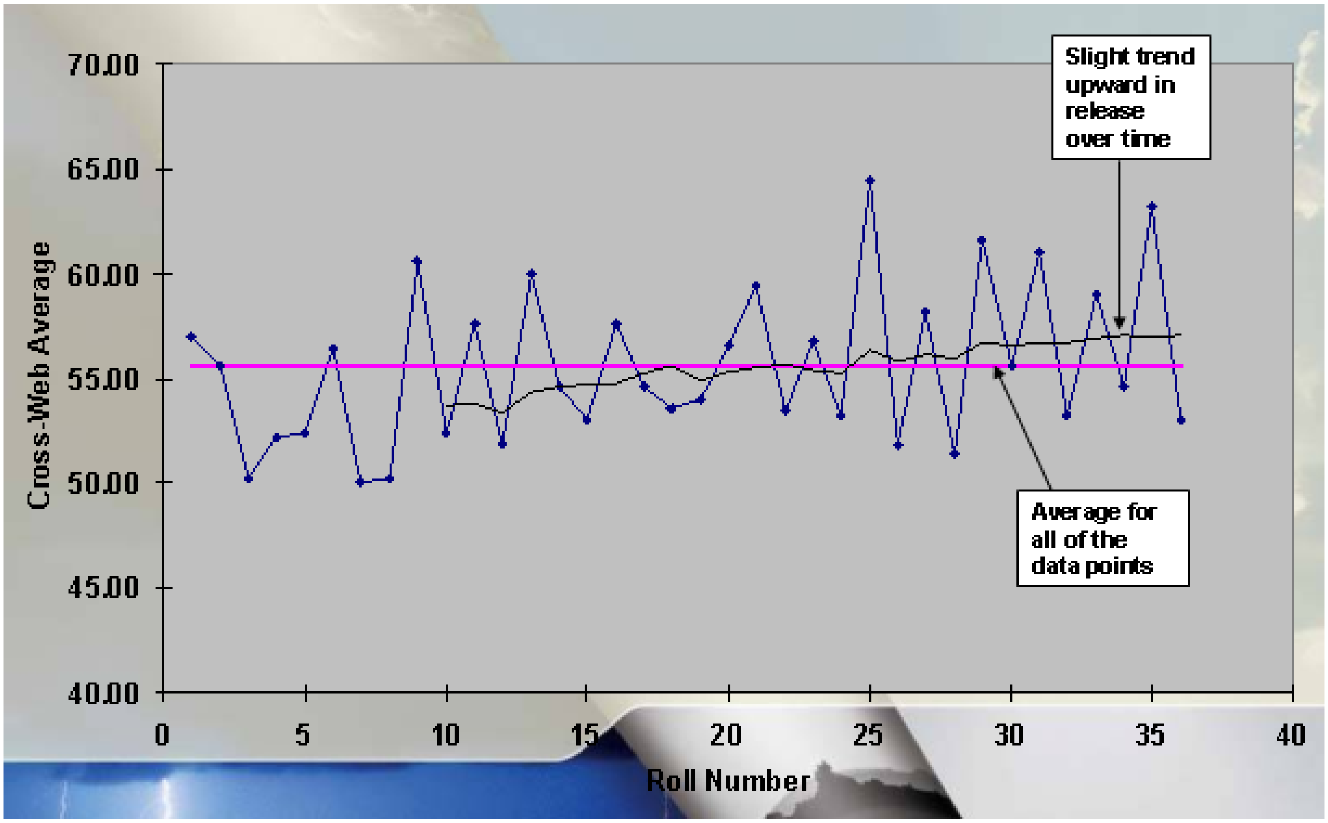
We first evaluated cross correlation and found that it is significant, as shown by the following table. Note the very high Pearson correlation values across the web, with the correlation highest with the closest process streams. These data reinforce why it is statistically incorrect to use cross-web subgroups for Shewhart X-Bar-R control charts:

Correlations: L, LC, C, RC, R

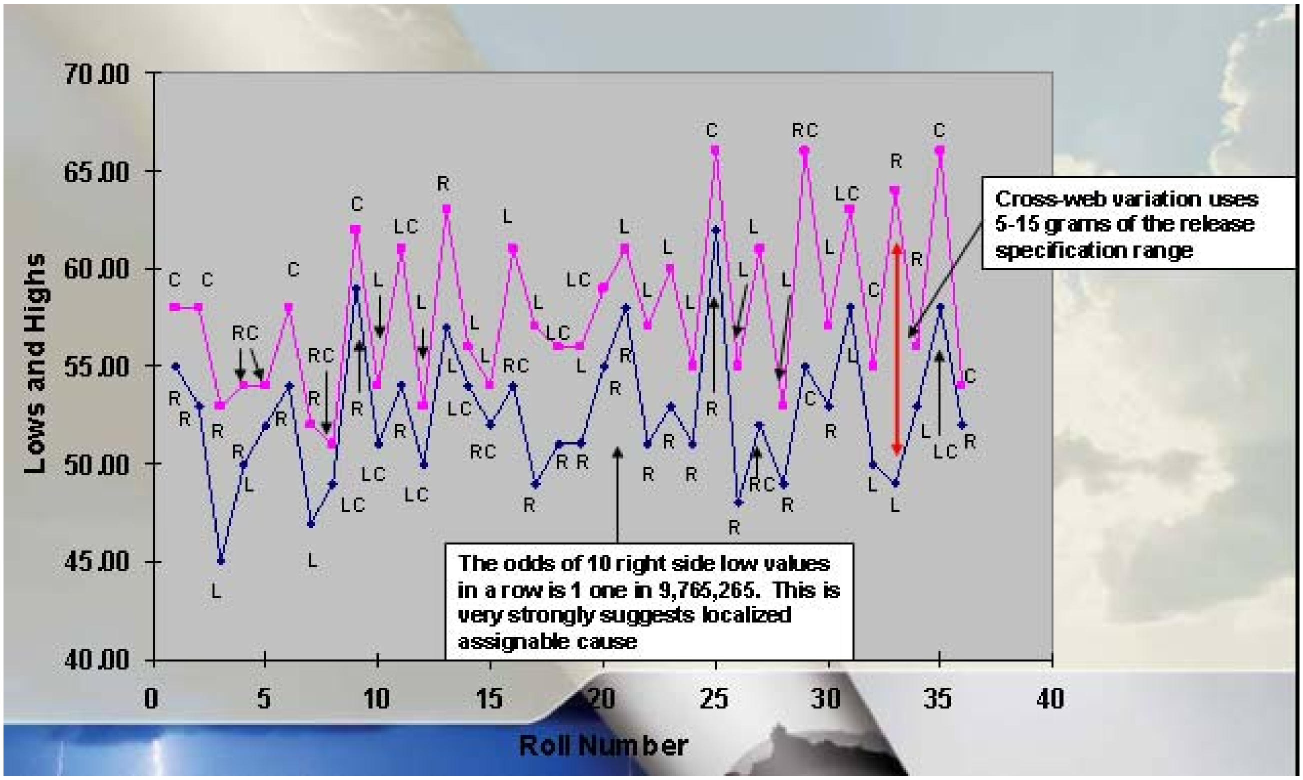
	L	LC	C	RC
LC	0.809			
	0.000			
C	0.734	0.880		
	0.000	0.000		
RC	0.632	0.876	0.869	
	0.000	0.000	0.000	
R	0.337	0.583	0.725	0.749
	0.038	0.000	0.000	0.000

Cell Contents: Pearson correlation
P-Value

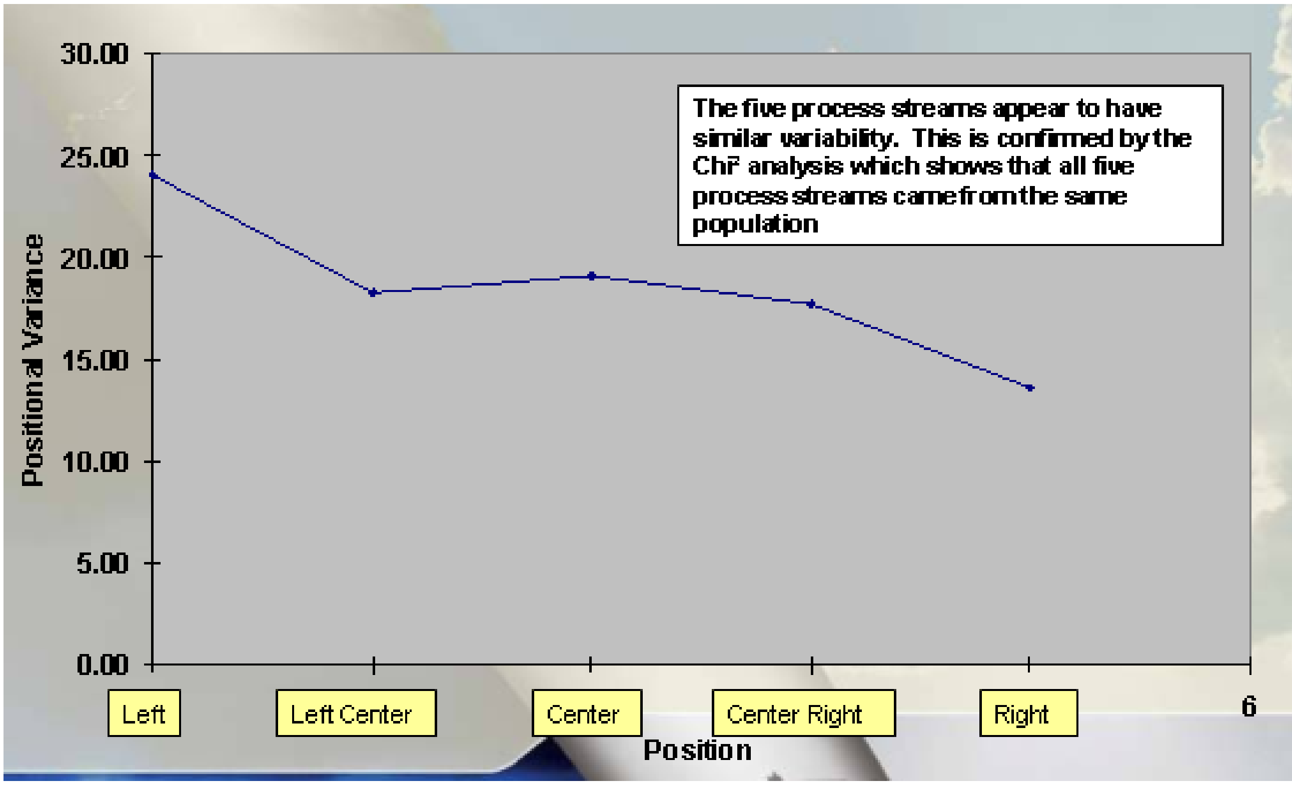
We then started applying RVA tools to better understand liner release variability in the cross and machine directions. The first example is a chart that shows cross web liner release averages over time:



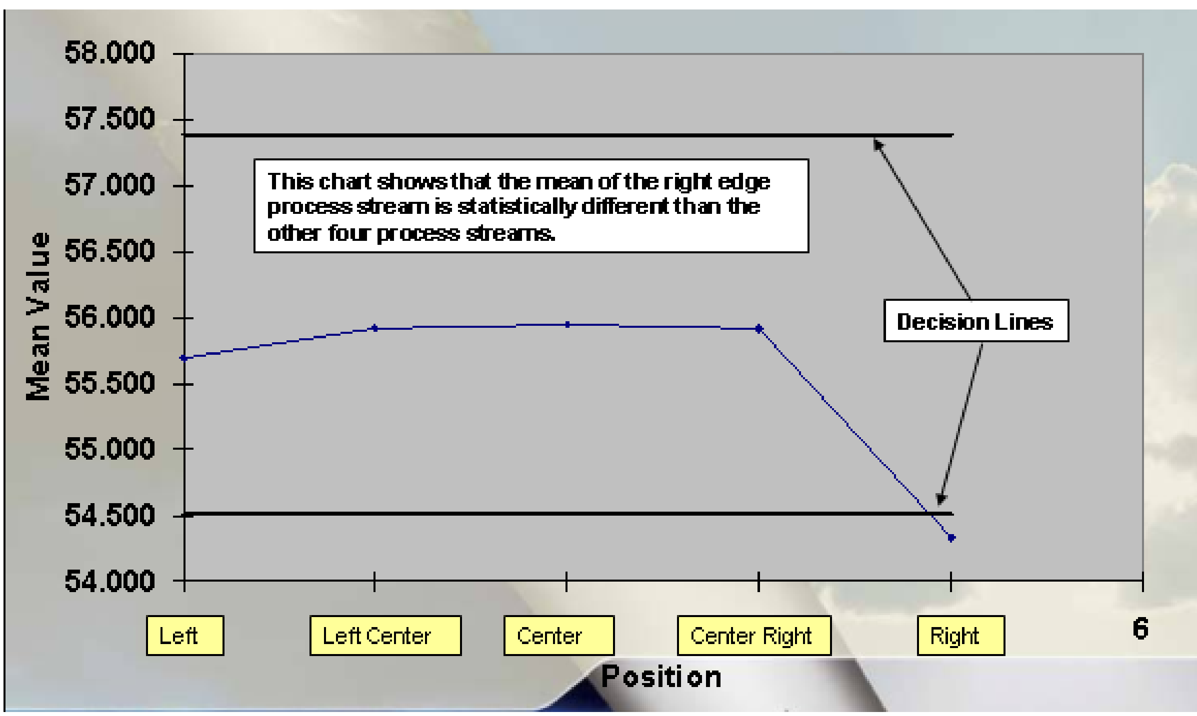
The next example illustrates the impact of cross web variation. The cross web variation tool shows the lowest and highest of five cross web values for each machine direction location. In this example, cross web variation uses up 5 – 15 grams of the release specification range. Please also note that the right edge process stream is the lowest value for ten consecutive machine direction locations. The odds of this occurring randomly are 1 in 9,765,265, strongly suggesting a localized assignable cause:



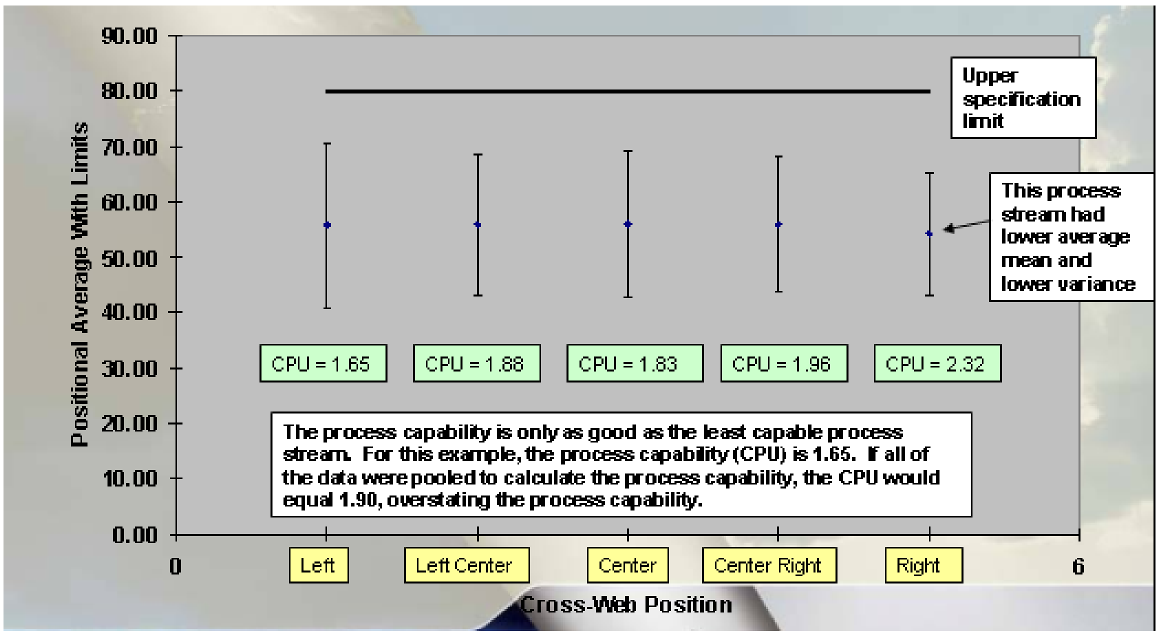
In the next example, we look at the positional variance RVA tool. The variances of the five process streams are compared graphically and statistically. The graph suggests that the five process streams appear to have similar variability. This is confirmed by the Chi-Squared analysis, which shows that all five process streams came from the same population:



Analysis of Means is an excellent tool to determine if there are any statistical differences in the machine directional averages of each of the five process streams. In this example, the right edge process stream average is statistically different from the other four process streams, suggesting assignable cause:

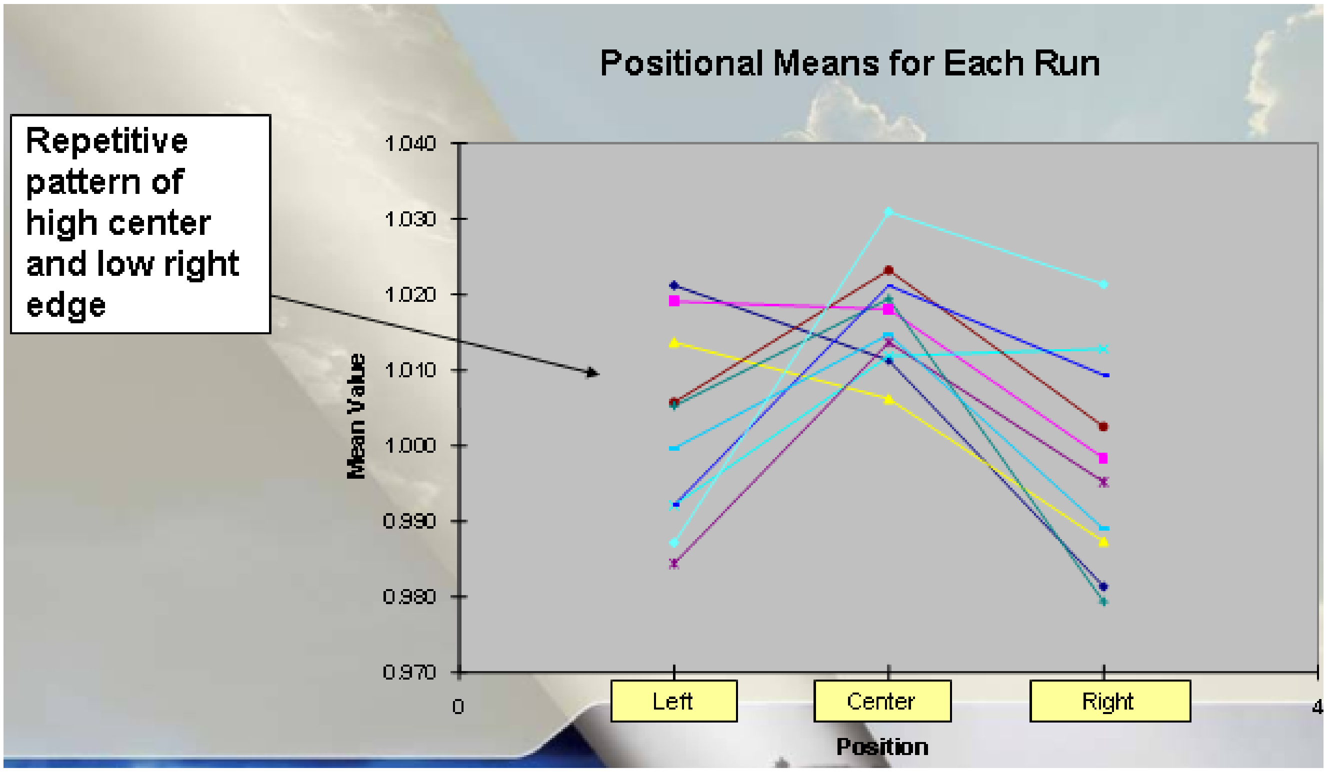


This last example for liner release of this unsupported transfer adhesive is an excellent method for graphically illustrating process capability. In addition, it demonstrates the trap we can fall into by pooling all data in calculating process capability (e.g. CPK, CPU, or CPL). When using process streams, the capability of a given process is only as good as the least capable process stream. Many of our customers purchase rolls slit from our master rolls; our process capability is only as good as the least capable process stream. This is what our customers experience. In this example, the least capable process stream has a CPU of 1.65 and reflects the actual capability of this process. If the data were all pooled to calculate CPU, the value would be 1.90, and would overstate actual process capability:

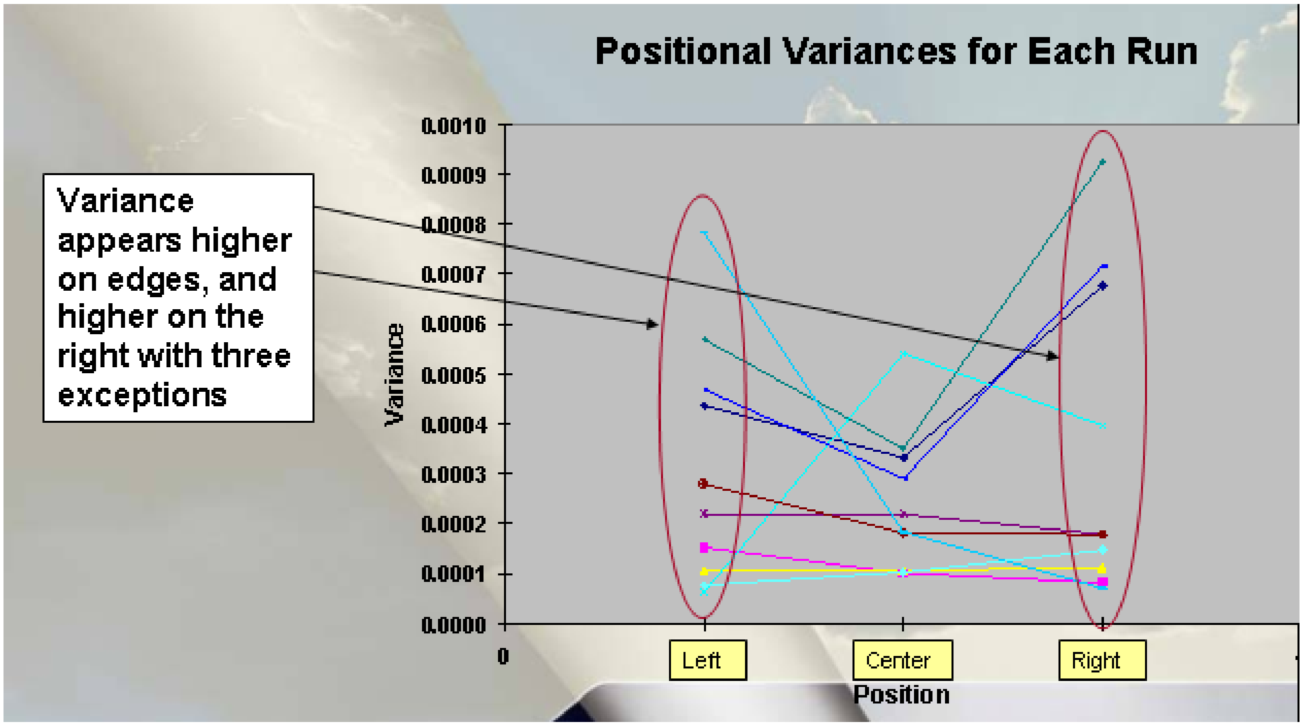


Application of RVA for Analyzing Thickness Variation for Several Developmental Unsupported Transfer Adhesives.

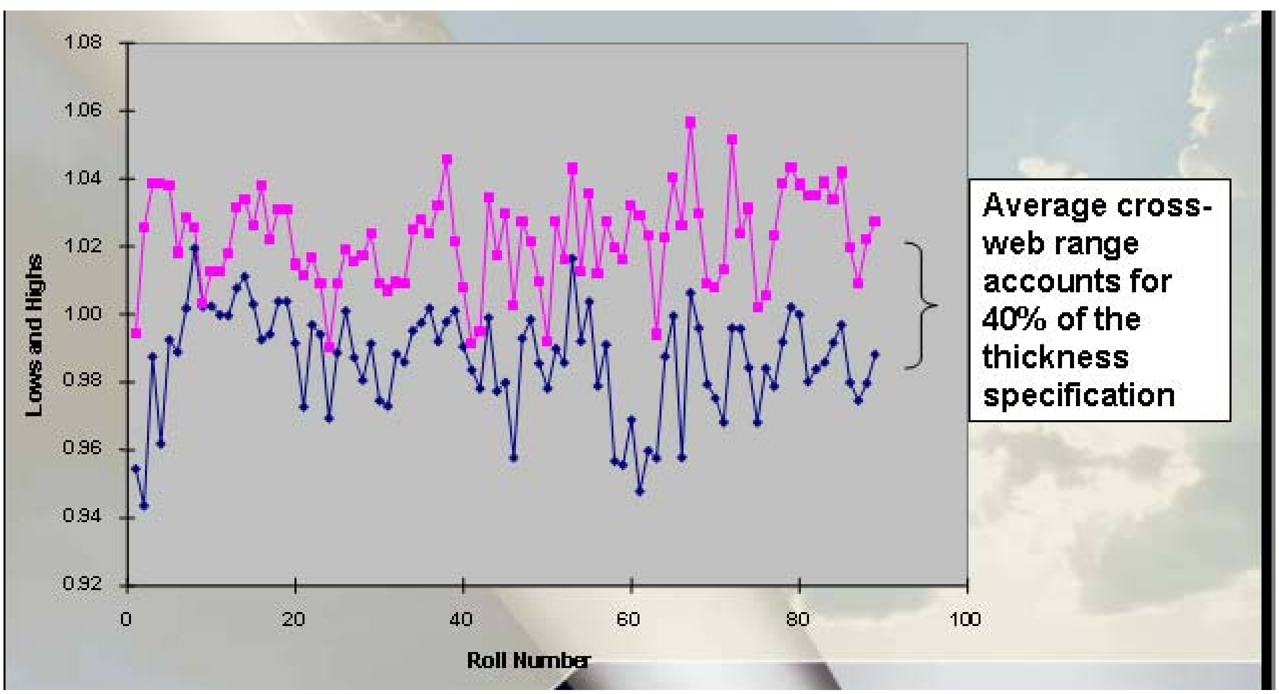
The following example looks at positional means of product thickness from lot to lot. The graph suggests a cross directional frown profile with a repetitive pattern of high centers and low right edges. Through better understanding of cross directional profiles, we are in a stronger position to address those root causes and reduce our process variability:



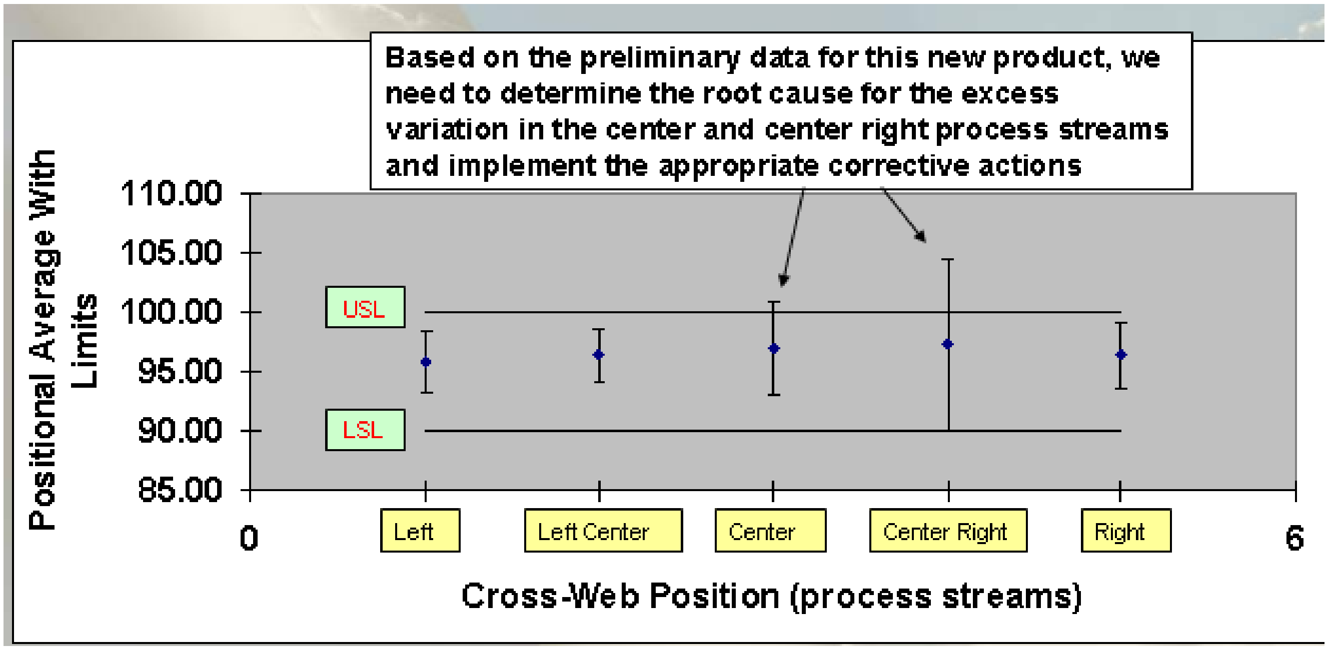
This graph illustrates positional lot to lot variance data for the same developmental transfer adhesive. It suggests higher variance on the right edges with just three exceptions:



The following example shows how much cross web thickness variation impacts process capability. If we can reduce cross direction variability (typically a cross directional profile), we can improve our process capability:



In this example, the process stream variability graph of thickness for a developmental transfer adhesive shows assignable causes that need to be addressed for the center and center right process streams. The data strongly suggest a cross directional frown that needs a root cause investigation to determine assignable cause…to address a critical customer requirement:



Where Do We Go From Here?

At Adhesives Research, we are actively using RVA for our new product development and process improvement projects. We have modified our sampling SOP to take into account RVA principles. Longer term, we plan to implement RVA where practical to other key existing products where our customers are demanding increased roll consistency to meet their processing requirements and end product performance needs.

Our next area of focus will be with our key vendors. Our roll variability consistency is very much dependent on the roll variability consistency of our key raw materials. We will be asking our key vendors for help in understanding their roll process variability where it impacts the performance of our processes and products.

Conclusions

- A well thought out sampling plan with consistent machine direction process streams is key to performing robust roll variability analyses.
- Cross web averaging can mislead you into believing your process is more capable than it actually is.
- Roll variability analysis is an excellent tool for showing opportunities for improvement in your roll processes.

- Piece part statistics do not all apply to roll goods. Control charting should be for each process stream rather than using cross web subgroups.