MONTE CARLO SIMULATION AND DESIGN OF EXPERIMENTS FOR IMPROVED PIN-PAD ALIGNMENT

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Johnstech is known for providing high performance and lowest cost of test contactors to back end test users. Cost of test is lowest when retest is a minimum. One source of retest is inadequate control of pin-pad alignment. Monte Carlo Simulation is a tool for maintaining pin-pad alignment. DOE extends the capability of Monte Carlo Simulation by ranking the factors and interactions.

Process control is required to maintain pin to pad alignment. This applied to the handler, packages and contactor. Above, you will see a BGA package presented by a pick and place handler. The contactor and alignment plate have been replaced with an acrylic plate that is engraved with contact locations and the alignment plate window. This acrylic component will reveal the behavior of the package as it approaches the alignment plate. When a large number (100 packages) are cycled to this acrylic plate we can determine what changes are necessary. Every insertion must be on target. The balls must be aligned to the contact locations. Consistent but offset behavior indicates adjustment is needed. Inconsistent behavior can mean worn or dirty parts need attention.

As presented at the prestigious Burn-In Test Socket (BiTS) Workshop
March 2011

History

Monte Carlo was conceived before the computer. In the 1940's there were some physicists working on radiation shielding. They were assigned to a secret program and gained access to the computer. Secret work needs a code name, so they chose Monte Carlo after the casino where an uncle would gamble. In 2006 and 2007, Monte Carlo was mentioned at BiTS as a method to address pin-pad alignment for fine pitch packages. This paper adds to what has already been done. Monte Carlo is coupled with DOE to identify significant factors and interactions.

- 1946: Scientists working on radiation shielding gained access to a computer and code named their work Monte Carlo
- 2006: Ultra Fine Pitch Socket Development Challenges, Wei-ming Chi, Ken Kassa, Chak Fung Kong
- 2007: Monte Carlo Based Package to Socket Alignment Assessment Methodology, David Shia, Wei-ming Chi
- New: This presentation couples DOE with Monte Carlo for pin-pad alignment

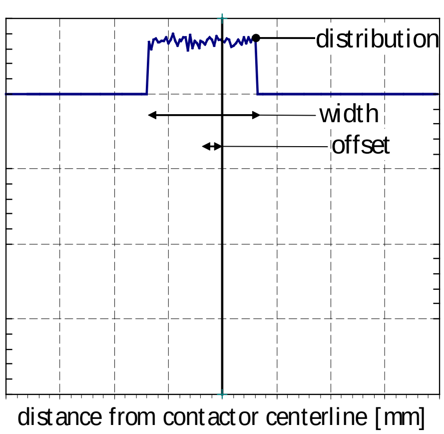
Alternatives

Monte Carlo is not the only solution analysis of pin-pad alignment. Worst case is another common method. The inputs are the min and max values from the individual component specifications. Because this method relies on the extremes only, the result is biased. It predicts a low process capability index. If we relied on WC analysis, vision systems would be a lot more common.

Root sum squared is another common method for tolerance analysis. For this analysis, parts are measured and the variations are assumed to be normal distributions. The result is limited to a linear result. Relative to the WC model, this is method gives a high process capability and leaves little margin for error. Root sum squared users may see intermittently high scrap rates when a process shift exceeds the margin for error.

Monte Carlo is the preferred tool for analysis of pin to pad alignment because it will accommodate any distribution type (it will deal with normal distributions too). The inputs are still measured process variation. Another benefit is that boundary conditions can be more complicated. The output need not be linear. A good example is the radiation transmitted through a particular shield material.

The model developed by Johnstech follows the same process that the package travels through the handler. In this next plot, the blue line represents the packages as they are retrieved from a shuttle/track/or precisor. A good way to characterize this is to measure the boat pocket, track width or precisor features. A better way to go is to measure an alignment plate that has exceeded its useful life. The opening width and offset are a witness of the presentation. Video of the packages presented to the contactor is best. This provides the width, offset, and distribution that we need.



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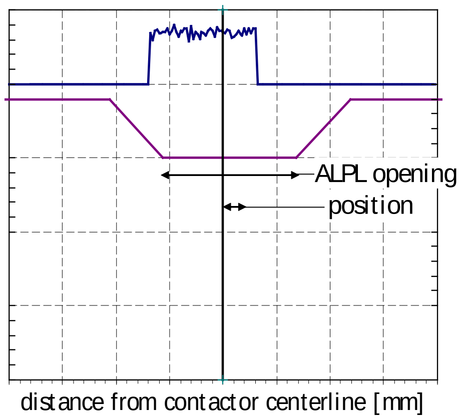
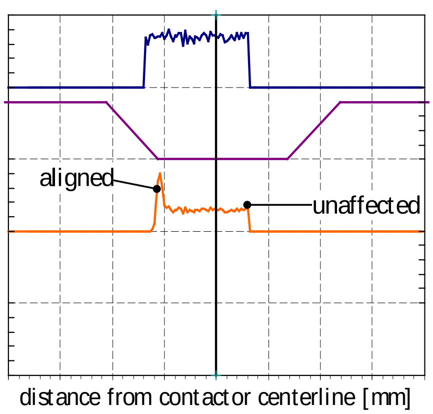
Worst case analysis would use the extreme values only. Root sum squared relies on a normal distribution. Monte Carlo accommodates this non-normal distribution.

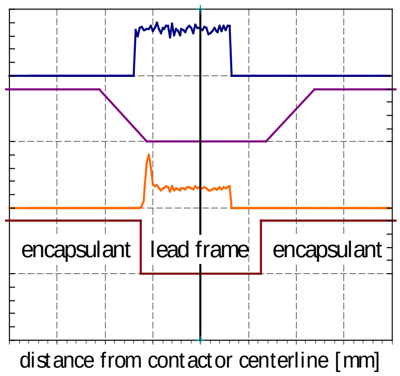
The next event is the alignment plate. The window can be measured with a caliper but that will only give the size and not the location. A better measure is the use optical equipment. This will provide the location and size. Alignment plates wear, so the best solution is to consider a range of window sizes and locations. See the purple line in the figure below for the alignment plate features.



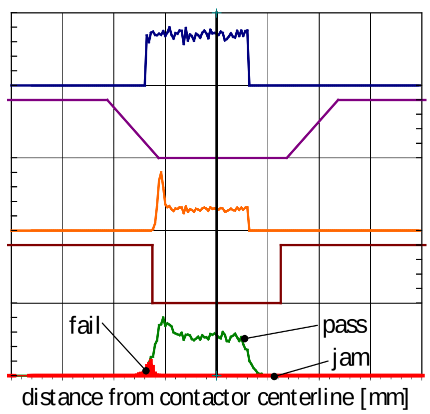
After the alignment plate, some packages are aligned. Other packages pass through untouched. See orange line in the plot below. Again, only Monte Carlo allows for complicated boundary conditions. This is also the stage where package body size is considered. The good method of measuring parts is to sample virgins. Rejects may be biased. It is better to have statistics from 100% visual inspection. The best data comes from visual inspection of consecutive lots through the service life of the package assembly and singulation tools.



The aligned package has pads and they interact with the contacts. This interaction limits the process capability. Contactor data is unique for each technology. It is sufficient to measure just one contactor, but better to know all of the potential combinations of contact and housing. Data for the pads/leads/balls can be collected the same as the body size. See the brown line in the plot below. The pin-pad limits are shown here as binary and that is appropriate for the binning strategy.



On the test floor, parts are binned. The orange distribution in the figure below is compared to the brown process limits. See the bottom of the following plot for the final yield. Good parts are shown as green. Failed parts are red. Jams are black.



Monte Carlo is very nice, but the result is narrow. To this point, the model is capable of predicting the effect of any one change. This can be done on the test floor any day of the week. Design of Experiments opens things up to other possibilities. Commercially available software can be used create a discrete matrix of all of the factors and to randomize the order. At each test point, the Monte Carlo model is repeated for the prescribed conditions. See the matrix below.

< - factors ->

test points	A	B	C	D	E	F	G	H	J	K	L	M	N	O
1	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2	+	+	+	+	+	+	+	+	+	+	+	+	+	-
3	+	+	+	+	+	+	+	+	+	+	+	+	-	-
4	+	+	+	+	+	+	+	+	+	+	+	-	-	-
5	+	+	+	+	+	+	+	+	+	+	-	-	-	-
6	+	+	+	+	+	+	+	+	+	-	-	-	-	-
7	+	+	+	+	+	+	+	+	-	-	-	-	-	-
8	+	+	+	+	+	+	+	-	-	-	-	-	-	-
9	+	+	+	+	+	+	-	-	-	-	-	-	-	-
10	+	+	+	+	+	-	-	-	-	-	-	-	-	-
11	+	+	+	+	-	-	-	-	-	-	-	-	-	-
12	+	+	+	-	-	-	-	-	-	-	-	-	-	-
13	+	+	-	-	-	-	-	-	-	-	-	-	-	-
14	+	-	-	-	-	-	-	-	-	-	-	-	-	-
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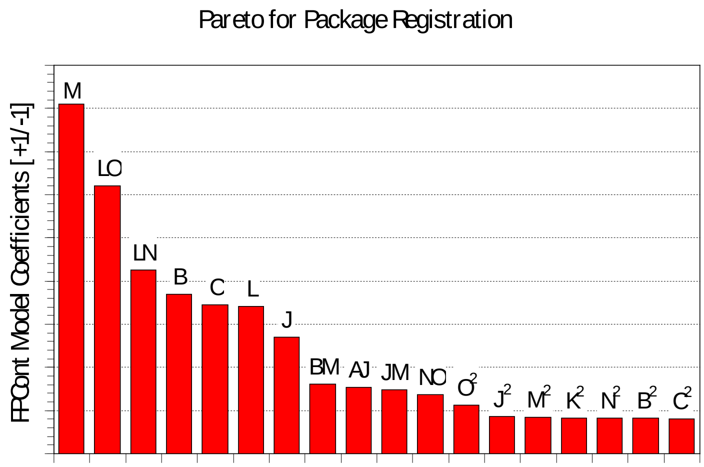
The relative differences between the responses can be assessed to understand the strength of the individual factors and their interactions. A quadratic polynomial is fit to the data set. Analysis of variance identifies which factors are significant and which are just noise. See the pareto below.

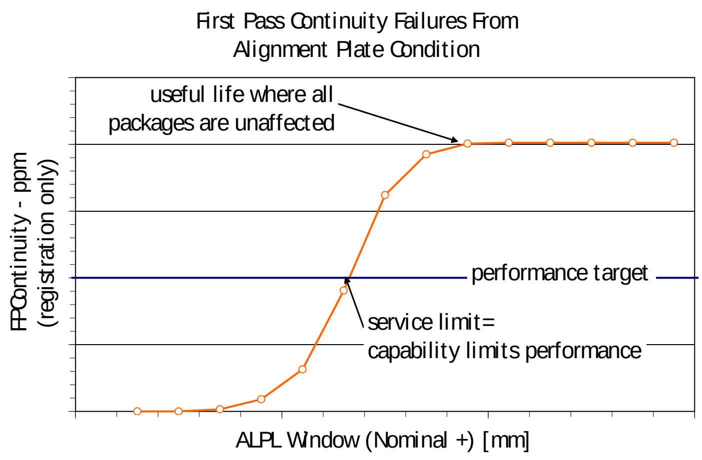


This pareto ranks the individual factors and interactions. The potential benefit of improving any factor by X% will generate this relative improvement. If it is possible to reduce M by 10%, the effect on first pass continuity would be 2x that of changing LN by 10%.

<u>Case Study 1</u>

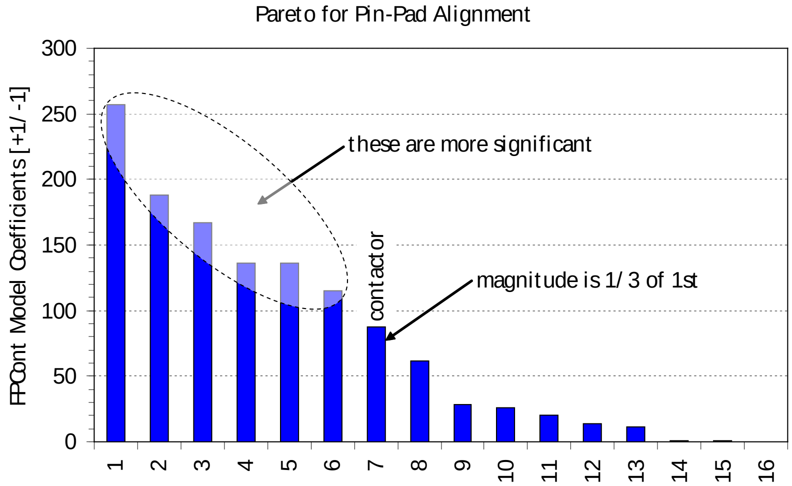
A valued customer was concerned with retest rate and alignment plate life. We measured packages and characterized the handler presentation. Johnstech performed Monte Carlo analysis for this particular handler and package.

The resulting Pareto chart confirmed that the alignment plate clearance was critical. Johnstech recommended changing the alignment plate material to ceramic with smaller window size and smaller service limits. In the following figure, first pass continuity increases with alignment plate window size until it reaches a plateau. This plateau describes the condition where no package is aligned. Useful life is achieved when no packages are aligned. The other significant event occurs where this curve crosses the performance target. That intersection, of performance and capability, defines the service limit.



Case Study 2

In this 2nd case, a valued customer was concerned with the contactor contribution to retest. Johnstech developed a collaborative relationship with this customer and gained access to statistical data for package assembly over several weeks time. Johnstech used the acrylic plate (interface analyzer) to characterize the package presentation. Contactor data was retrieved as well. MC was performed for all of the package, handler and contactor combinations. The resulting pareto indicated that the contactor contribution was 7th and 1/3 the magnitude of the 1st factor.



In the preceding figure, it is possible to see that the contactor was 7th and 1/3 the magnitude of the 1st. The focus of attention shifted to the first 6 factors.

Monte Carlo is appropriate statistical tool for pin-pad alignment. It can identify critical issues and predict yield. Design of experiments makes the Monte Carlo capable of doing what can not be done on the test floor. It exposes the importance of the factors and the interactions. As lead density increases, this analysis will become more complex and number of significant factors will increase. Johnstech has the products and services to maintain lowest cost of test.

John DeBauche is Engineering Manager at Johnstech International, where he also designs and develops innovative test socket products for back end test. He holds a M.S. in mechanical engineering from the University of Minnesota.