Innovations in Process Management

Fabtech International & AWS Welding Show

November 17, 2009

Murray Desnoyer
CEO, Origin International Inc., Richmond Hill, ON

Al McCallum
Tooling Engineer
Pridgeon and Clay Inc, Grand Rapids, Mi

Contents

Overview

This session introduces engineers to 'root cause analysis' software, demonstrating how it shortens the launch period of new parts and accelerates die modifications of worn dies, to produce one hundred percent 'buy off' acceptable parts after the first iteration. A case study to launch a stamped part will walk you through the complete analysis and corrective action that was taken to successfully fix the stamping with just the additions of a few shims vs. sending the die back to the tool shop for re-work.

- Case study on how using a 'root cause analysis' software can eliminate costly die-rework of a stamped part
- 'Best Fix' simulation cuts launch iterations to only one
- Eliminate scrap and sorting from stamped part manufacturing
- How to use multi-part data to correct a stamping process

Context

Metal forming is a global industry where competition is stiff and margins are slim. In these circumstances responding to customers' demands for higher quality at lower prices is a constant challenge. Adding to the challenge is the uncertain outlook for major sectors such as automotive. Even optimistic industry analysts believe that there will be some contraction over the next 5 to 10 years.

Some companies can compensate by off shoring production. Others may be unable to. Whichever position you are in, now is a good time to evaluate your options. The question is, **how**?

Perhaps the best place to begin is the beginning. That is, the methodology metal formers use to launch new parts. Inefficiencies during launch are multiplied at each subsequent step. So improvements during launch will have the biggest benefit. Let's look at the current process.

Current Best Practice: The Manual Method

In the manual method you produce the first run of parts. You select a few parts at random and measure them. The parts are almost always out of tolerance in some dimensions. Engineers make adjustments. The tool is pulled out of the press and sent out for modification. Typically only one or two parts are measured and changes are based solely on the part dimensions. This leads to 'KNEE JERK" corrections. Another run is scheduled for the projected return date of the tool. The process is repeated until you achieve compliance and get buy off from the customer.
There are several advantages to the manual method. It is time tested and is relied on the world over to produce acceptable results. There is a talent pool of experienced tooling engineers and tool makers who know the methodology. It can be transported offshore.

Introducing total quality processes and CAM tools has not eliminated the manual method from the part launch process. It is still common to hear tooling engineers complain of having:

- to re – measure for multiple alignment
- to make repeated hard tool changes chasing a dimensional issue
- to interpret multiple text reports
- to "trust the data"
- CMM reports not matching the data
- to work without a gage
- to move a Datum
- to consider capability before making changes or use only one part layout
- moved something in the wrong direction
- to guess about what, and how much, to move a feature

Singly or in combination these problems have serious consequences for schedule, quality and profitability:

- Even a simple part can take several iterations that eat up weeks of time.
- Complex parts need many iterations, often half a dozen or more, that take months.
- There is scrap during both setup and production. Compliant parts must be sorted from scrap.
- Even in compliant parts process variations in complex parts can combine to produce assembly process instability that is very difficult to predict

These costs of time, labor and materials have been accepted as a cost of doing business for years. As an industry we are rapidly approaching the point where these become unacceptable costs to our customers. On the other hand, these are opportunities for substantial productivity and quality gains.

Exploiting these gains will also lower risk. Any time an assembly process fails because of part variability it is a major customer satisfaction problem. Customer demand for higher quality will continue to rise. Process instability may become a legal issue for suppliers as well as a customer satisfaction headache. New processes are needed to protect you against this risk.

Process Control Overview

The starting point to any tool adjustment is statistical process control.

The dimensions of different parts will be spread about some average. And, in turn, this average will be well or poorly centered around nominal. There are two numbers used to describe this: Cp and Cpk.

The Cp is a measure of the ratio of the tolerance zone width to the 6-sigma process spread – the bigger the number the smaller the spread. Processes that are stable or in control will have a large Cp. An unstable or out of control process will have a small Cp.

But you can have a very stable process making all bad parts if the average is off nominal. Cpk is not only a measure of the spread but a measure of how well centered that spread is. Again, the bigger the Cpk value the better.

Given a distribution curve for a set of samples with a low Cp and Cpk we would see something like Figure 1.

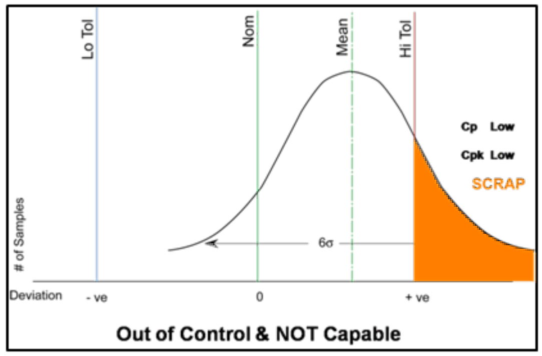


Figure 1

The wide distribution curve is indicating the process is out of control (the variation of features from part to part is unacceptable) and because it so far off nominal it is considered incapable. Even if we were to adjust our tool to center that distribution at nominal we would still make parts high and low.

The first step is to get the process under control. In figure 2 the process has been significantly improved resulting in a tight distribution curve and could be considered as in control. However it is still incapable as it is still producing scrap.

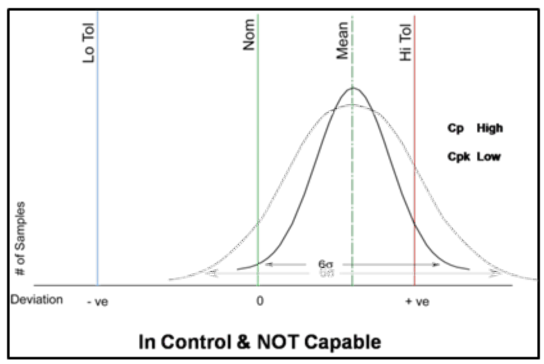


Figure 2

Once a stable process is achieved the tool can be adjusted to move the feature to the center of the tolerance zone. Figure 3 displays the results after modifications to the die to correct dimensional and/or form related issues. As you can see the distribution curve is tight and centered on the nominal. The process is now considered both in control and capable.

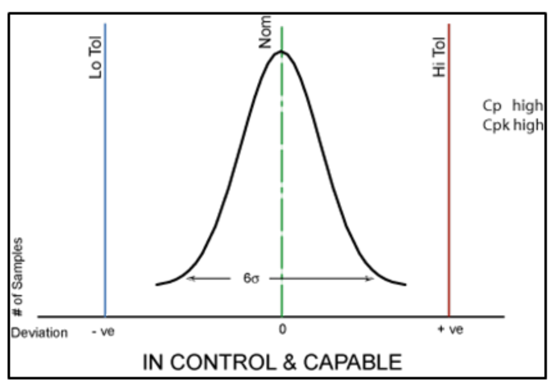


Figure 3

The concept of "robust tooling" also comes in to play here. When a tool is producing parts this capable it ensures that fabrication shops have the greatest possible range of presses, material temperature and wear available to them while satisfying press utilization targets and production quality standards.

The prerequisite to tool adjustment (centering the distribution) is process control (narrowing the distribution). Origin's software tools provide statistical process control (SPC) information like many other SPC software packages. These are numbers like the average, Cp and Cpk.

In addition, the software has further analysis capabilities that can be used to determine which features are causing part variation. Imagine that a part is aligned to a few surface areas, a hole and a slot. If it is the slot that is being located and it is unstable, with large variations with respect to the rest of the part this will not be obvious in regular SPC analysis. The slot will appear completely stable, (after all, it's a datum) and the rest of the part will appear out of control. The software allows for "whole part" alignments which is very useful for detecting the features that are unstable with respect to the rest of the part.

A common mistake often made in the name of expediency or the lack of the proper tools is to base corrective action tooling decisions on too few samples.

The example here shows what can go wrong with a sample of one, an extreme case no doubt, but one that clearly illustrates what can go wrong when decisions are made based on two few samples.

Figure 4 is reflective of our starting point. The process is considered in control as shown by the relatively tight distribution curve but not yet capable as we see by the fact that it is not centered or near enough to nominal to avoid producing scrap. There are three features plotted on the graph and we will have a look at what happens when corrective action decisions are made on either of sample 1 (S1) or sample 3 (S3).

In figure 5 modifications have been made to bring S1 to the nominal for that feature. This results in the distribution moving in a positive direction and the end result is overshoot on the high side.

Modification to the tooling based on results from sample 3(S3) results in the distribution curve being driven in the negative direction and now the tool would produce scrap at the low end. Figure 6

Knee jerk decisions such as these made on single as well as too few samples will most often result in multiple iterations of tooling modifications adding considerable cost and turnaround time to the process.

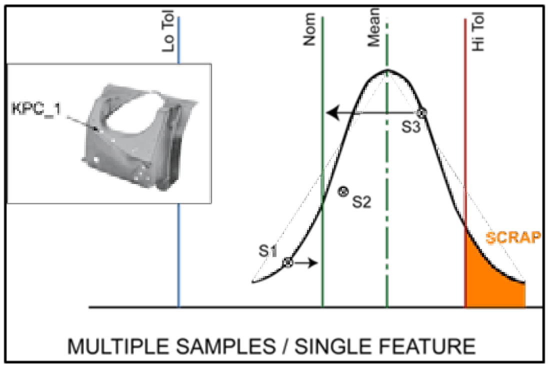


Figure 4

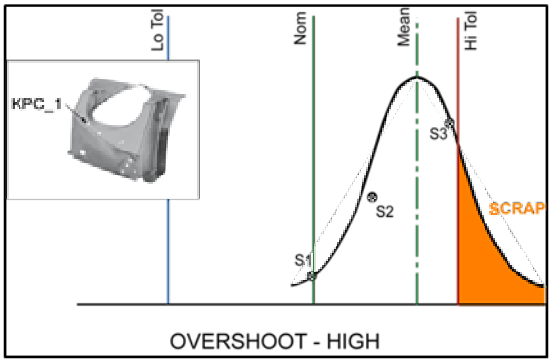


Figure 5

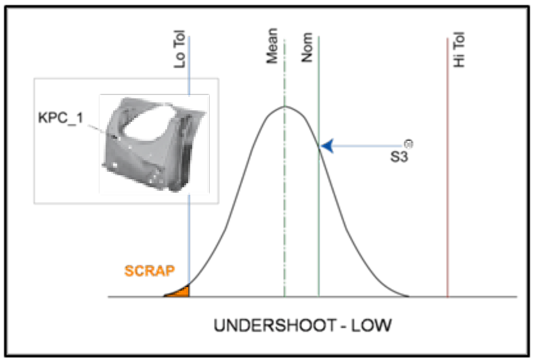


Figure 6

When corrective action decisions for die modifications are made based on data from multiple samples that are in control as in Figure 7, single die change iterations become realistic.

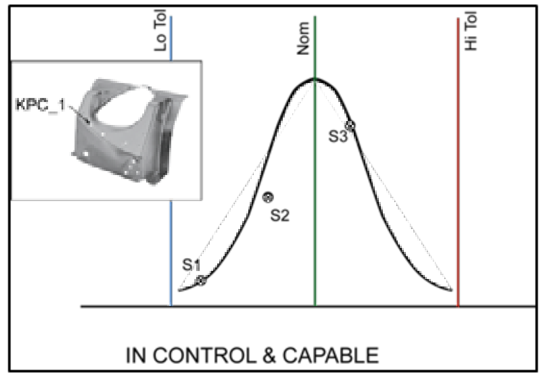


Figure 7

Keep in mind we also have to make decisions correcting multiple features based on data from multiple parts simultaneously evaluating the effect corrections have on each other as well as on the entire part.

In Figure 8 we have highlighted three features but realistically there would be many such features on any given part that need to be considered simultaneously using data from many parts.

Being able to fix all the features simultaneously from the average part will result in a stable process that is capable of producing in-tolerance parts.

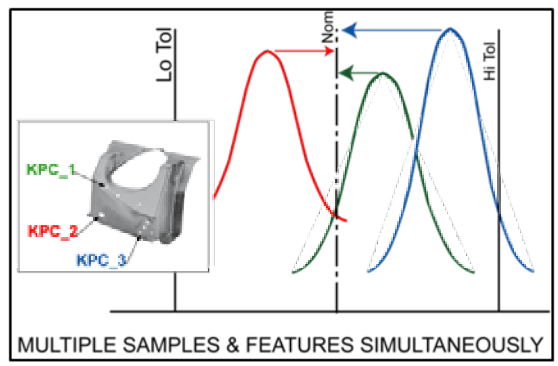


Figure 8

But how can you fix multiple features simultaneously? Some features may be to the right and some to the left. It's true that sometimes you can only fix features individually. But often with today's CAD-based and numerically controlled machining a bad part is a part – or an area of a part – that is just out of location with respect to the alignment features of other areas of the part. Otherwise, its shape is good. For example, rotating a part can cause the upper features to move back to the right and the lower features to move back to the left. The analysis software lets you find these kinds of easy fixes by examining many features with several samples of each simultaneously.

It is almost never necessary to have a part come out of a tool in a particular orientation as long as the part is the correct shape. But think of the effort poured into tool rework if adjustments are always made with respect to the axes of the tool.

Current Implementation

With conventional methods currently being used at most shops these corrective action decisions are being made by;

- Gleaning data from stacks of reports from dimensional measuring equipment (DME) such as coordinate measuring machines (CMM), articulating arms, laser point taking devices and point cloud scanning equipment.
- Evaluating data using any number of statistical process control (SPC) packages and custom built methods with spread sheets.
- Trial and Error
-

All of which are formidable tools, but are islands unto themselves and lack the ability to simulate proposed modifications before making changes to the tooling. Even with highly experienced and qualified tooling engineers the these methods lead to;

- Multiple tooling iterations cost and turnaround time implications
- Possible containment issues.
- Customer anxiety and general dissatisfaction
- Overall lower competitive capability

The Solution

What follows is a case study focusing on the implementation of a single piece of software to;

Evaluate data from any number of DME's
Perform what-if calculations to determine best-fix scenarios
Simultaneously simulate the effect of various corrective action scenarios on the process.

And how this systematic approach to die modification and process simulation results in the reduced turnaround time and lower costs that build competitive advantage and result in satisfied customers.

Case Study

P&C History Introduction

This case study describes the process of launching a “take over tool”. In this case, the OEM required a sample submittal and process capability of critical features of 1.67. The expectation was that parts would be to print and process capable prior to movement to our facility.

The previous Tier 1 was in process of a shut down and lacked the resources to repair the tool to an acceptable level, which P&C then quoted to the previous Tier 1 for costs of repair. This was a tool and part currently in production; so time was of the essence in order to maintain the OEM production. The first parts run did not pass the gage checks.

We needed to identify the root cause. And we needed to make the changes needed to achieve customer buy off. The parts were measured on a CMM .The results were analyzed with “Root Cause Analysis software” from Origin International Inc. to determine a corrective action plan for tool modifications.

Overview

Problem solving with a software tool should at least be able to achieve the same result as the manual method. In fact the process is basically the same.

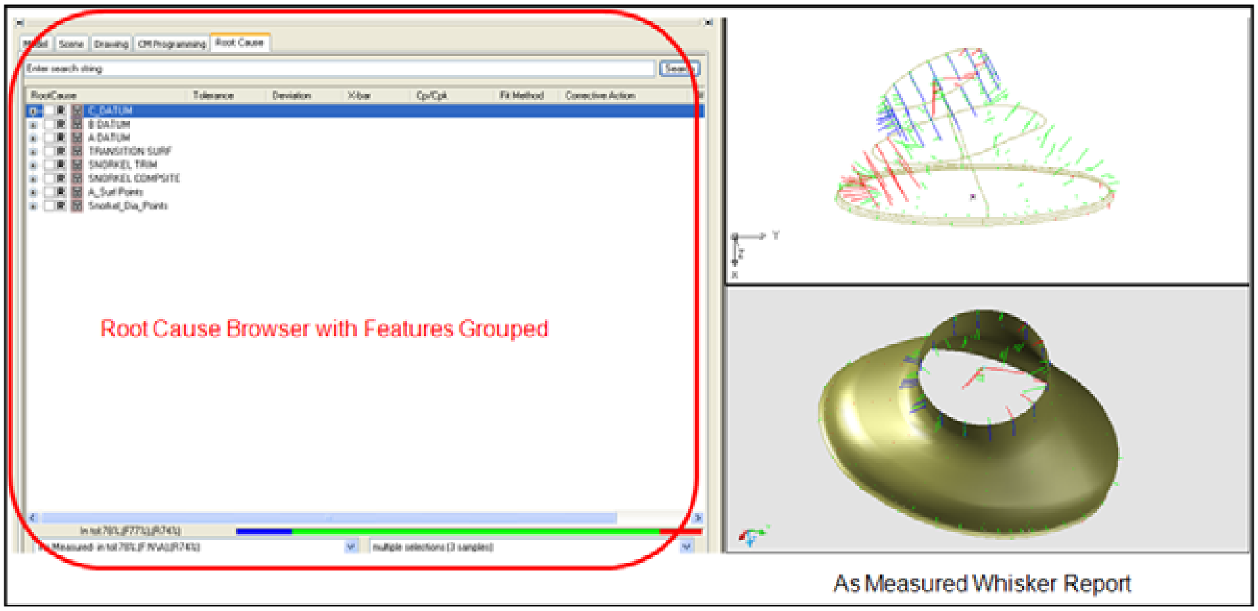
- Define the problem
- Verify that the data matches the symptoms of the problem
- Make a change based on the available information.

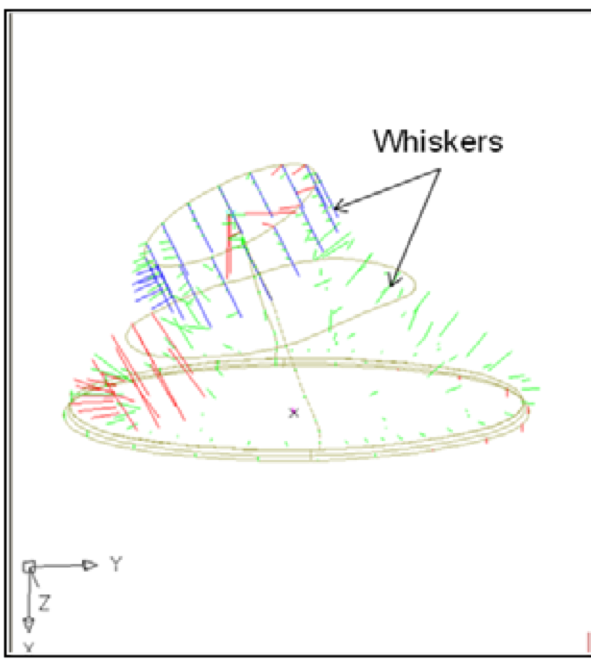
Here is where a simulation tool varies from the manual process. We could simulate changes in the software and see new / modified results of the process without running more parts.

- If the simulated part does pass then using the software to make further MODs to simulate the effect that change would make and re-analyze.
- It should be noted that determining what changes to make in the forming process needs to be taken into account. That is, the obvious fix might require an expensive change so we might not be able to make it. We may need to simulate second or third fixes to accommodate time and cost restraints.

After this software or simulated iteration process we now have the exact corrective action to do to fix the tool and process.

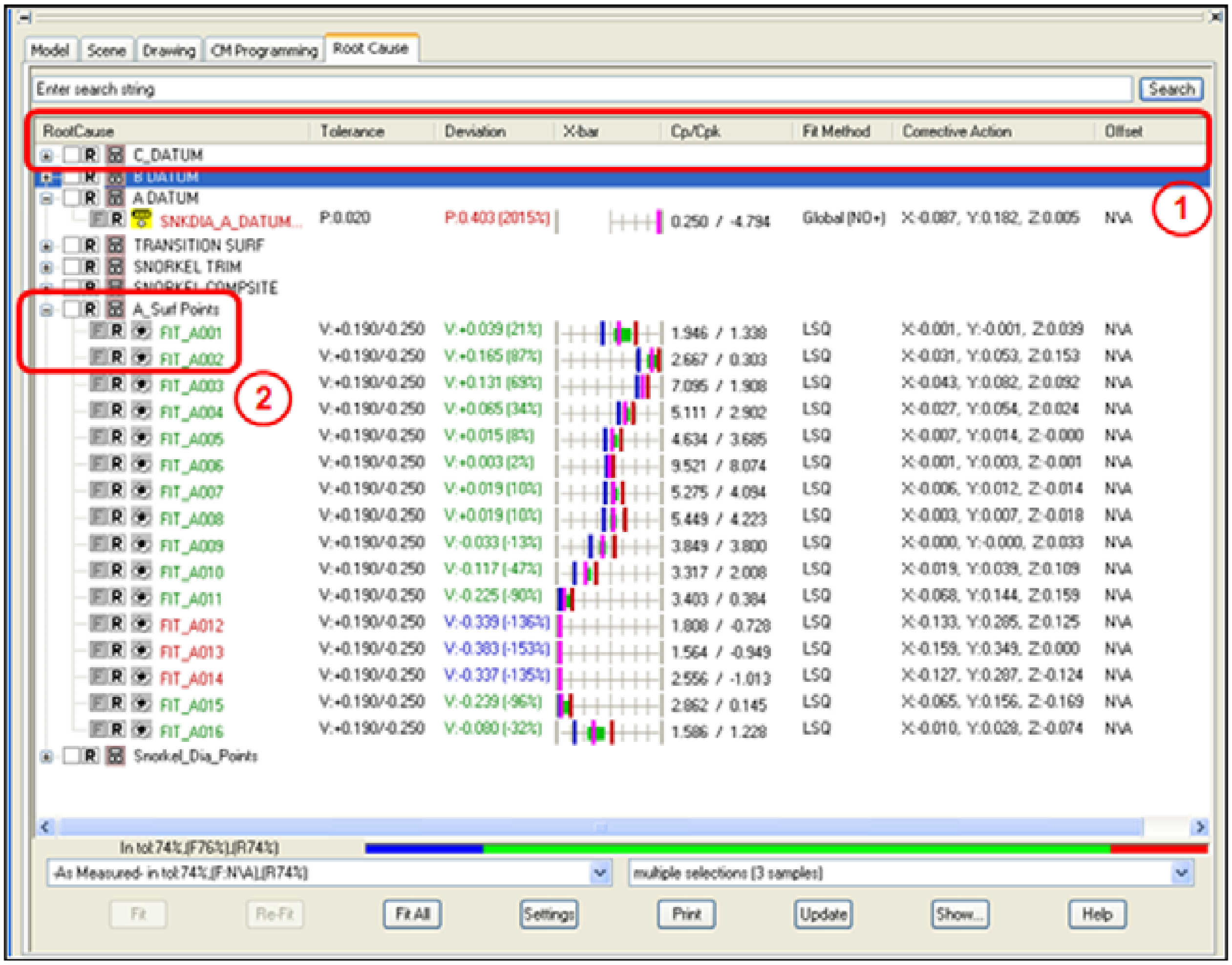
What you are looking at in the pictures



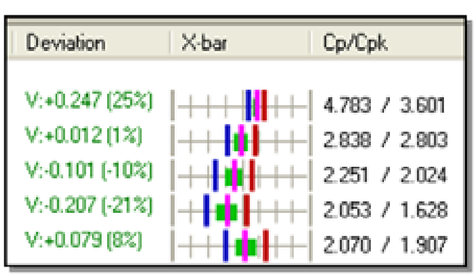


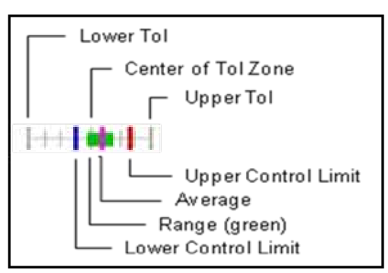
- Features were measured on the inside of the cone.
- Coloured whiskers indicate direction and magnitude of deviation.
- Green whiskers are features that are within tolerance.
- Red whiskers are features that are out of tolerance on the High side.
- Blue whiskers are features that are out of tolerance on the Low side.

Root Cause Browser



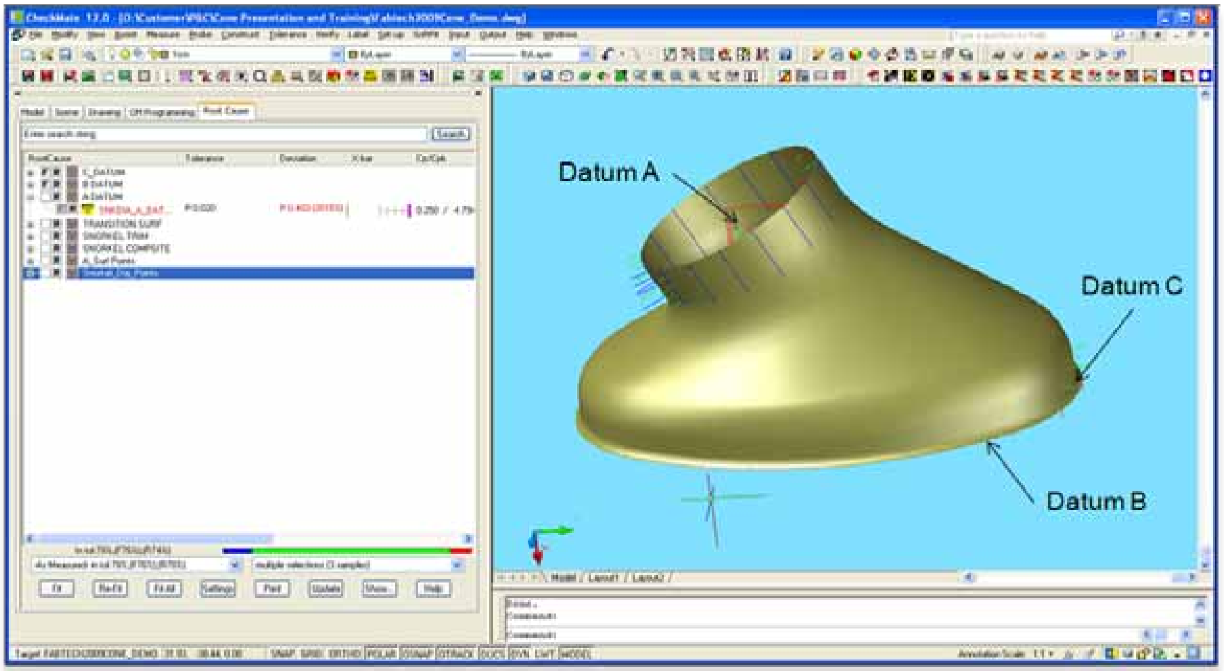
1. Browser Columns
    a. Group and Features – group name is defined by user. Each has an F and an R box to control that group or feature's inclusion in a fit (F) or reports (R), such as a whisker report.
    b. Tolerance – feature tolerance setting. The tolerance defines how tightly a feature will be held to nominal during a fit and also defines how a feature may move during a fit.
    c. Deviation – deviation from nominal. Number in parentheses is the percent of tolerance used. The color coding of text in this column is the same as the whisker reports.
    d. X-Bar – graphic of sample distribution. See Figures 9 & 10, below, for color code.
    e. Cp/Cpk – capability ratios
    f. Fit Method – algorithms used to fit the features.
    g. Corrective Action – corrections in Cartesian coordinates to put that feature at nominal.
    h. Offset – user defined correction to the feature's actual location to simulate a shim or movement.





Verifying what we see

The parts are manufactured and measured on a CMM and then the results are displayed to verify the gage results.

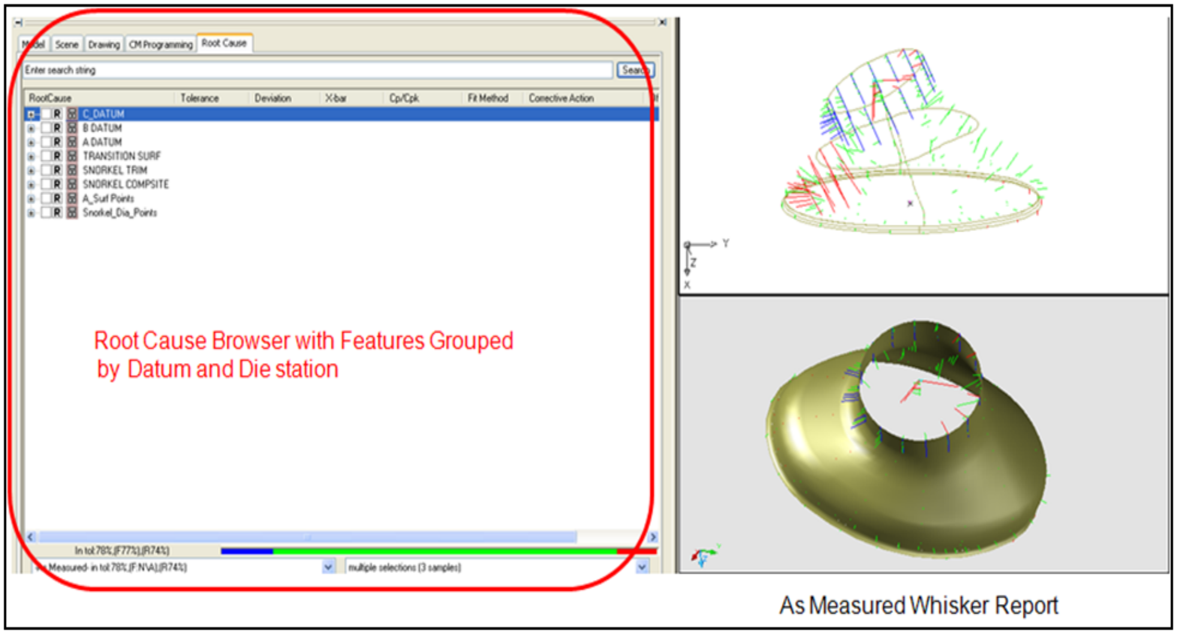


For this part the print callout has:

- Datum A is the position of the circle at the top.
- Datum B is the oval at the bottom.
- Datum C is the plane of the Oval.

As Measured

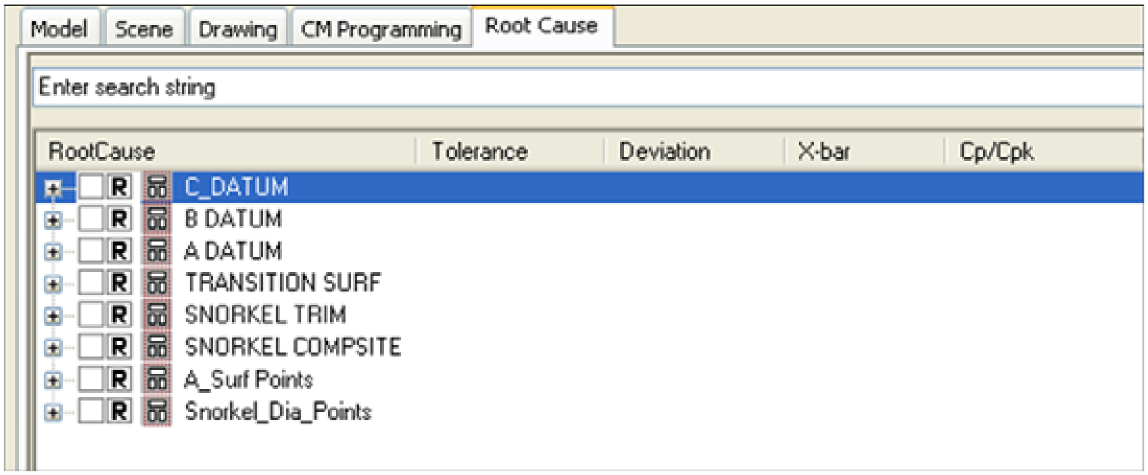
The CMM data reported errors for some features in Datum B and C, on the Snorkel, and the transition area.



Data Organization in Preparation of Analysis

If this part were a part produced as a single draw between one cavity and one core then corrections to the shape would almost certainly require rework to the die shapes. The fact that this part is produced by a progressive die in several operations at different stations allows for a more creative approach to adjusting the tool.

By breaking down all the measurements into groups corresponding to stations in the die we can perform “what-if” fits of the data on individual groups to determine at what stations the problems occur and how best to fix them.



- Datum's A, B, C
- A_surf_ Points – surface points around the neck of the Snorkel which would make up Datum A features.
- Snorkel Trim – point on the edge of the Snorkel.
- Snorkel Dia Points – points that measure the diameter of the rest of the Snorkel.
- Snorkel Composite – surface points on the Snorkel throat.
- Transition Surf – surface points in the transition area between the two openings.

Example, a fit only on the transition points would show that they are good. This is a good thing because the stage of the die that forms that shape is expensive to fix. These deviations are the large red whiskers in Fig.1. However looking at initial measurement results it is easy to see how someone could mistakenly go in that direction for corrective action.

Similarly the hits on the end (edge) of Snorkel are showing a deviation in blue (late hit) indicating it is too short.
A correction needs to be made at the oval end, a best-fix scenario that is not evident without the what-if evaluation and process simulation capabilities.

Adding confusion to the evaluation was the fact that initial measurement results do not match what we see at the gage at the Snorkel trim. Given the datum scheme conventional CMM measurement technology is not capable of properly aligning the part prior to measuring.

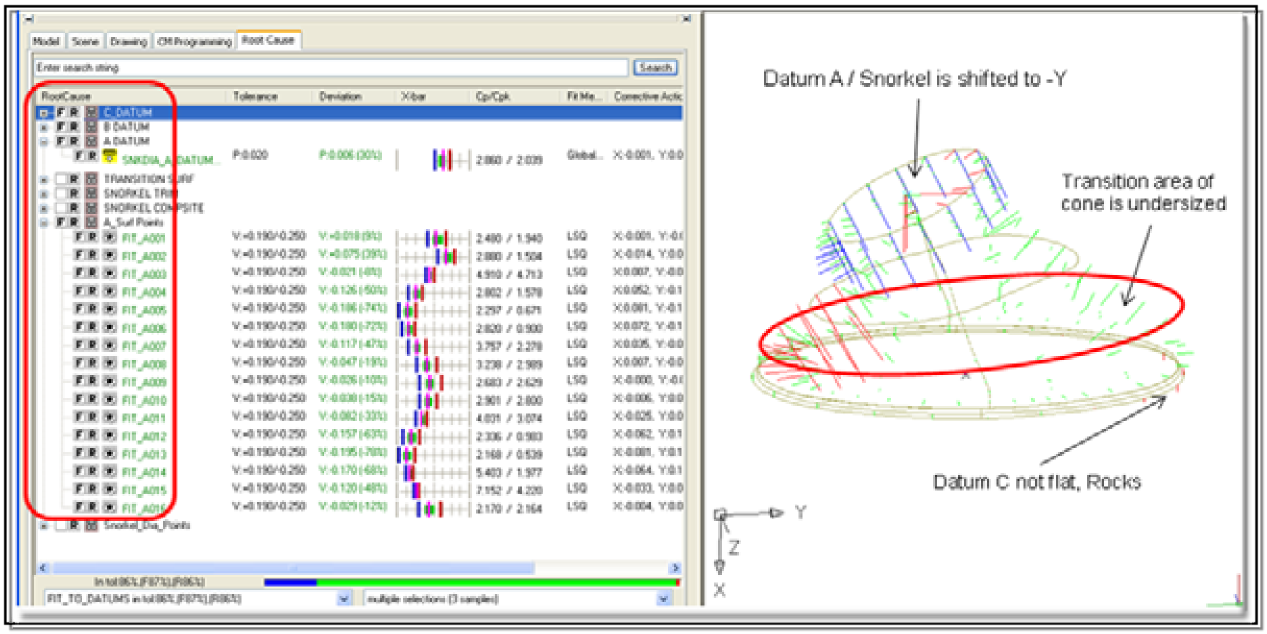
In new product launch cases ages are rarely available when the first buy off samples are run. Simulation of the gage with software (soft gauging) reduces turnaround time and reduces gagging costs by deferring the build until after the process has been stabilized and corrective action on the die has been implemented.

Simulate Gage Results.

A gage measures the part with respect to the Datum structure. To simulate the Gage we fit the results to the Datum's. If the measurement alignment was off we will at least remove that error in the data.
It is unsafe to assume that just because it is a datum that it is correct and that adjustments can be made relative to the datum.

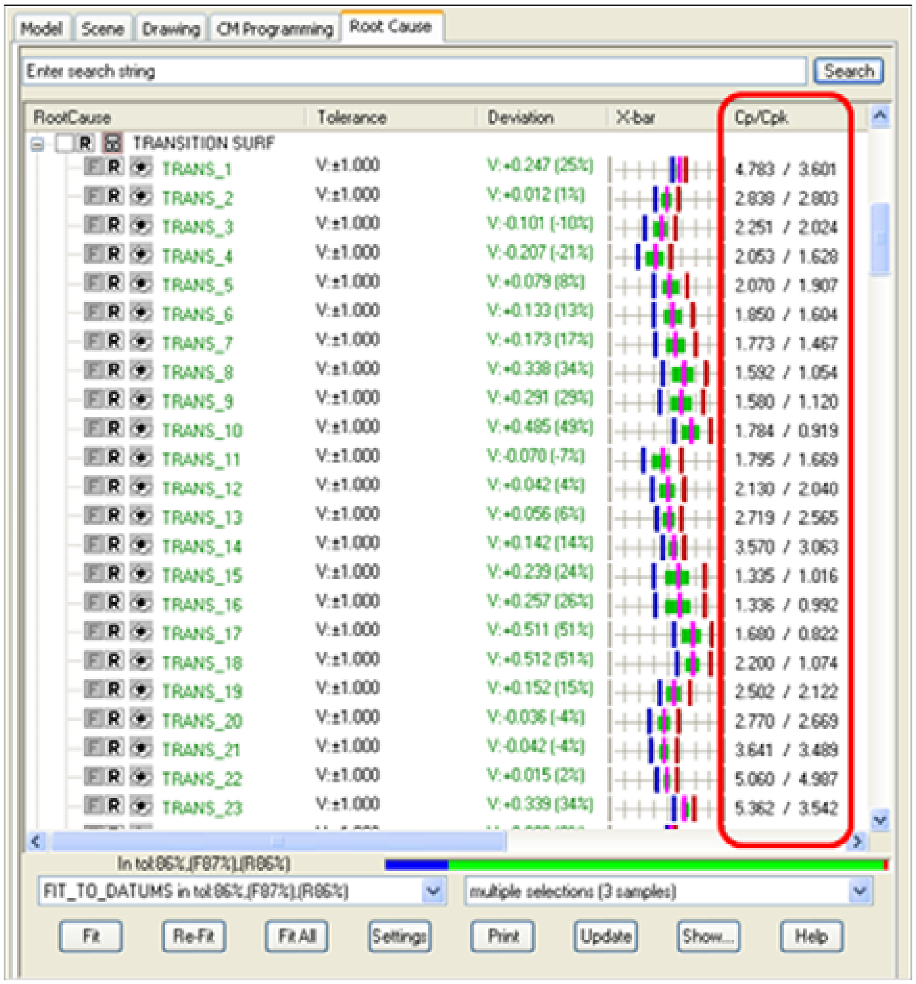
In fact the opposite is true in this case. We will show that adjustments to the C datum will correct transition features in the form portion of the part.

Many arguments can be made for how to fix this part (die) but ultimately the right one is the one that is most expedient, costs less and produces the best parts.



In the above figure we enabled fitting on the datum features and A_surf_points around the diameter of the Snorkel (small F's in the red outline). The results now simulate what the gage was telling us. First the oval plane is canted and that all the internal measurements of the cone transition area are undersized. There are also some problems with datum A, but what is indicated is that Transition area datum C hasn't completely formed. The easiest method to fix this is to raise the steel at that die station. This will cause the cone draw further over the steel. This will have the effect of extending datum C lower and flattening it to the DIE plane.

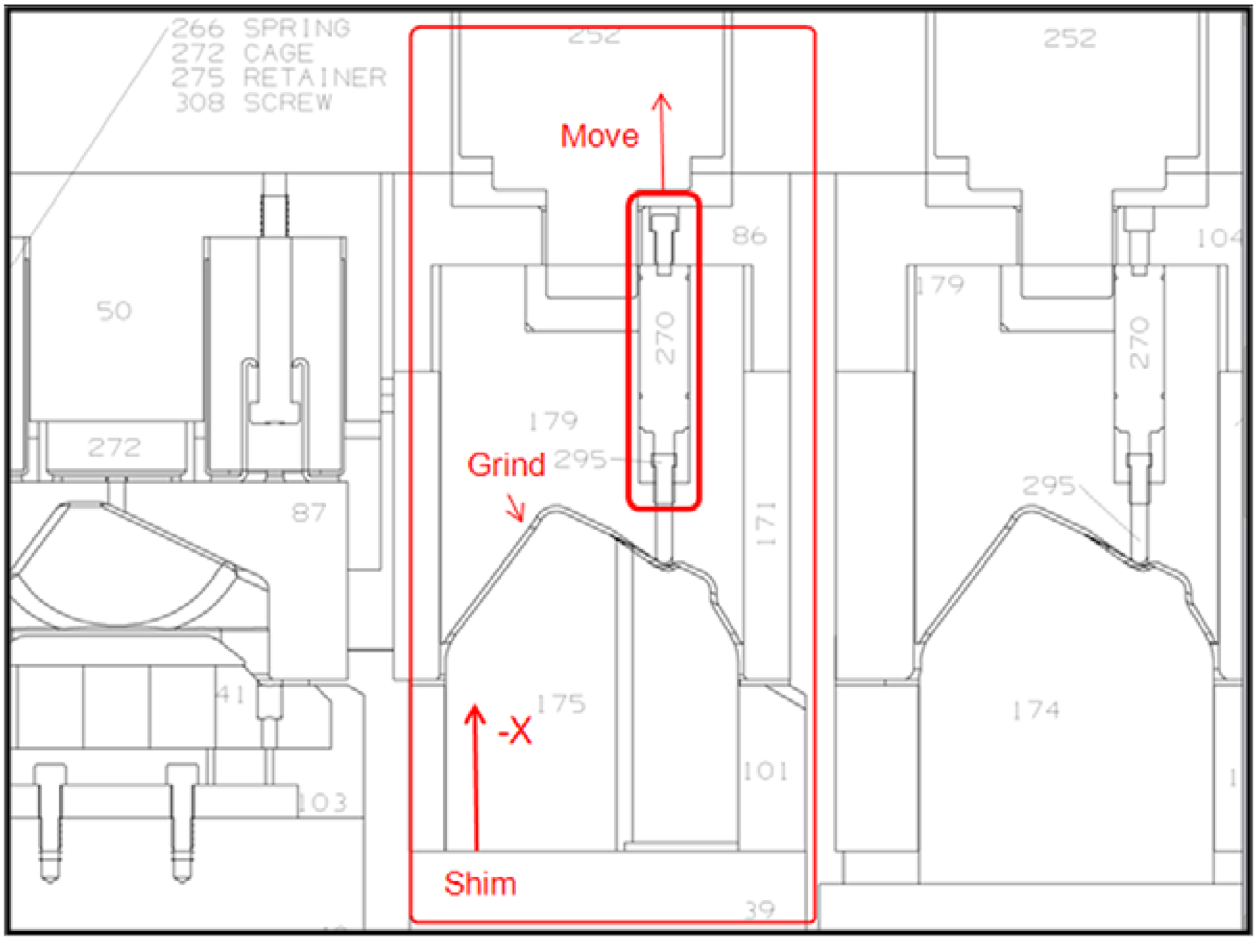
However, before simulating any fix we need to check for process capability. Any feature that we Fit and apply offsets to must be stable to effect meaningful changes.



In the transition area and datum C, we are achieving acceptable Cp's 1.33 and above. So if we use these futures in the fits we can feel comfortable that using the average part we will only require one change or iteration.

Begin simulation to correct the AVARAGE part

The first simulation is to correct for the draw in the transition area. The results in the transition area are all pointing toward the inside of the part. This indicates that it is not being completely formed. To correct this we shim the die station where the transition is formed.

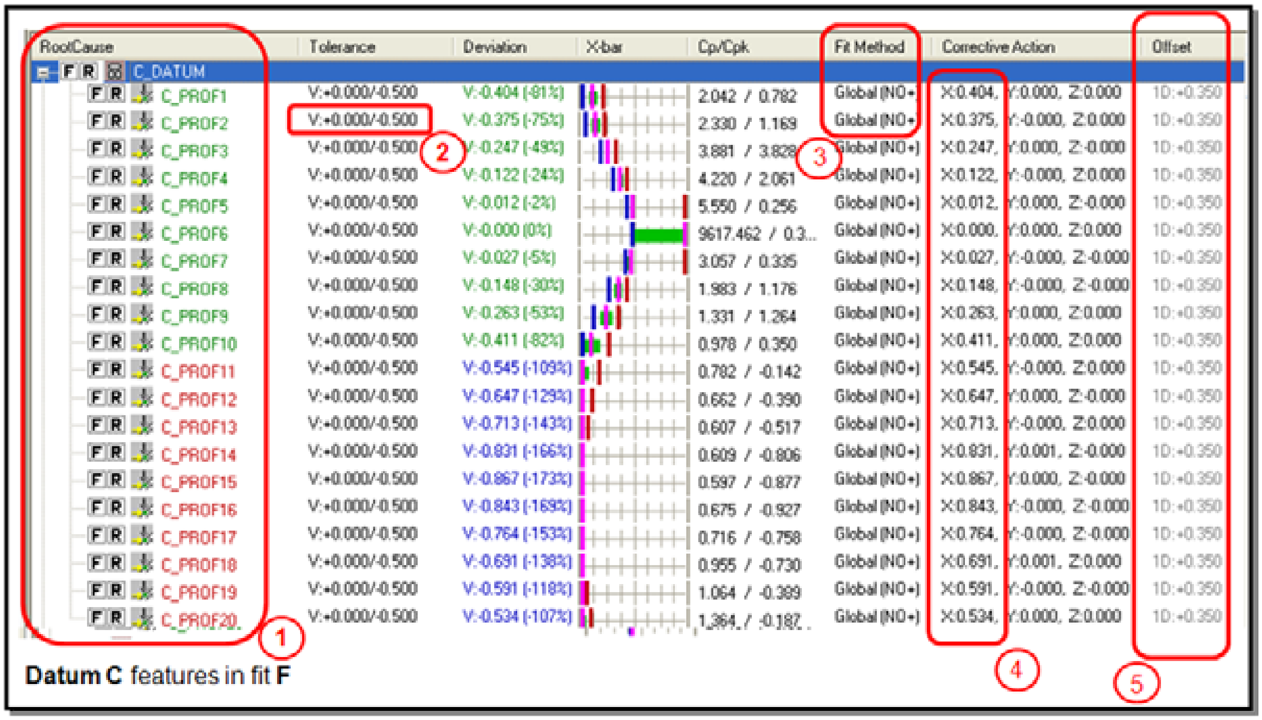


We simulate this action by "shimming" datum C. In the middle diagram of Figure 11 shims are placed between die components #39 and #175 of the core and between #171 and #86 of the cavity. Also #179 needs grinding and punch #270 needs to move the shim amount. The net result is to cause a deeper draw of datum C.

Setting up the simulation software:

1^St Simulation

For the 1^st simulation we want to emulate shimming of the above DIE station. This is accomplished by Fitting and shimming datum B and datum C with the following settings.



RootCause	Tolerance	Deviation	X-bar	Cp/Cpk	Fit Method	Corrective Action	Offset
F R C_DATUM							
F R C_PROF1	V:+0.000/-0.500	V:-0.404 (-81%)		2.042 / 0.782	Global (NO+	X:0.404, Y:0.000, Z:0.000	1D:+0.350
F R C_PROF2	V:+0.000/-0.500	V:-0.375 (-75%)		2.330 / 1.169	Global (NO+	X:0.375, Y:-0.000, Z:0.000	1D:+0.350
F R C_PROF3	V:+0.000/-0.500	V:-0.247 (-49%)		3.881 / 3.828	Global (NO+)	X:0.247, Y:0.000, Z:-0.000	1D:+0.350
F R C_PROF4	V:+0.000/-0.500	V:-0.122 (-24%)		4.220 / 2.061	Global (NO+)	X:0.122, Y:-0.000, Z:0.000	1D:+0.350
F R C_PROF5	V:+0.000/-0.500	V:-0.012 (-2%)		5.550 / 0.256	Global (NO+)	X:0.012, Y:0.000, Z:-0.000	1D:+0.350
F R C_PROF6	V:+0.000/-0.500	V:-0.000 (0%)		9617.462 / 0.3...	Global (NO+)	X:0.000, Y:0.000, Z:0.000	1D:+0.350
F R C_PROF7	V:+0.000/-0.500	V:-0.027 (-5%)		3.057 / 0.335	Global (NO+)	X:0.027, Y:-0.000, Z:-0.000	1D:+0.350
F R C_PROF8	V:+0.000/-0.500	V:-0.148 (-30%)		1.983 / 1.176	Global (NO+)	X:0.148, Y:-0.000, Z:-0.000	1D:+0.350
F R C_PROF9	V:+0.000/-0.500	V:-0.263 (-53%)		1.331 / 1.264	Global (NO+)	X:0.263, Y:0.000, Z:0.000	1D:+0.350
F R C_PROF10	V:+0.000/-0.500	V:-0.411 (-82%)		0.978 / 0.350	Global (NO+)	X:0.411, Y:0.000, Z:0.000	1D:+0.350
F R C_PROF11	V:+0.000/-0.500	V:-0.545 (-109%)		0.782 / -0.142	Global (NO+)	X:0.545, Y:-0.000, Z:0.000	1D:+0.350
F R C_PROF12	V:+0.000/-0.500	V:-0.647 (-129%)		0.662 / -0.390	Global (NO+)	X:0.647, Y:0.000, Z:-0.000	1D:+0.350
F R C_PROF13	V:+0.000/-0.500	V:-0.713 (-143%)		0.607 / -0.517	Global (NO+)	X:0.713, Y:-0.000, Z:0.000	1D:+0.350
F R C_PROF14	V:+0.000/-0.500	V:-0.831 (-166%)		0.609 / -0.806	Global (NO+)	X:0.831, Y:0.001, Z:-0.000	1D:+0.350
F R C_PROF15	V:+0.000/-0.500	V:-0.867 (-173%)		0.597 / -0.877	Global (NO+)	X:0.867, Y:0.000, Z:-0.000	1D:+0.350
F R C_PROF16	V:+0.000/-0.500	V:-0.843 (-169%)		0.675 / -0.927	Global (NO+)	X:0.843, Y:-0.000, Z:-0.000	1D:+0.350
F R C_PROF17	V:+0.000/-0.500	V:-0.764 (-153%)		0.716 / -0.758	Global (NO+)	X:0.764, Y:-0.000, Z:-0.000	1D:+0.350
F R C_PROF18	V:+0.000/-0.500	V:-0.691 (-138%)		0.955 / -0.730	Global (NO+)	X:0.691, Y:0.001, Z:0.000	1D:+0.350
F R C_PROF19	V:+0.000/-0.500	V:-0.591 (-118%)		1.064 / -0.389	Global (NO+)	X:0.591, Y:-0.000, Z:-0.000	1D:+0.350
F R C_PROF20	V:+0.000/-0.500	V:-0.534 (-107%)		1.364 / -0.187	Global (NO+)	X:0.534, Y:0.000, Z:0.000	1D:+0.350

Datum C features in fit **F**

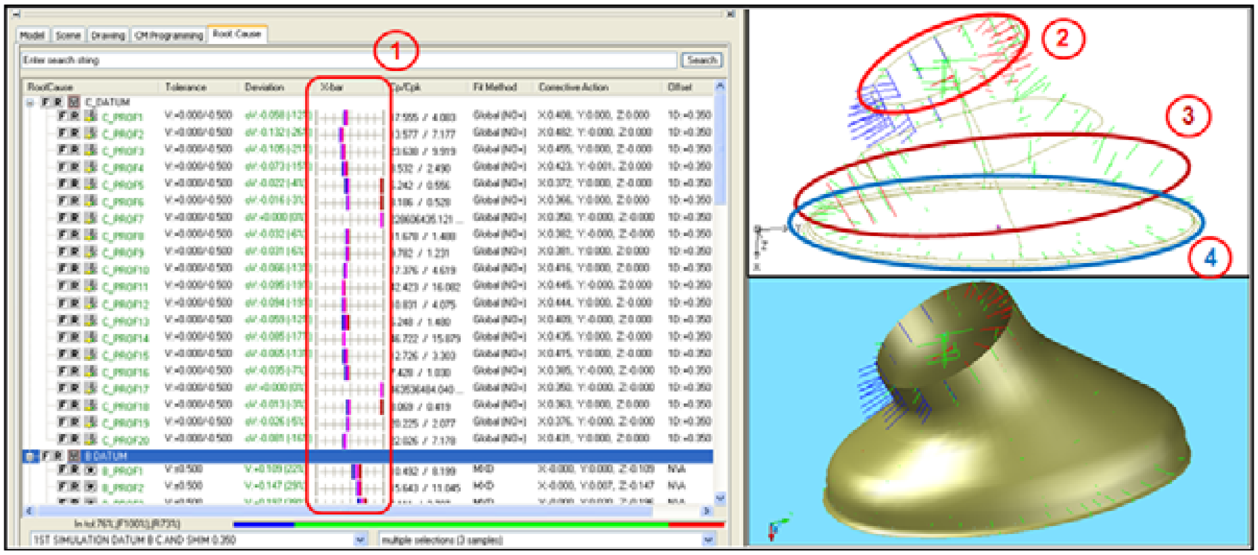
Datum C - the Plane of the Oval - Setup

1. Datum C features are selected to be in the Fit via the F in the box.
2. Tolerance is set to unilateral of + 0.0 and -0.500 to allow freedom of movement along the vector in the negative direction only. In the same way that the top of the Snorkel will only touch a physical plane (nominal) at its highest point(s) and all other points are lower, in the fit no point will be allowed to have a positive deviation from nominal.
3. Fit method is set to Global fit method: NO+. This means that no positive directions out of tolerance deviations are allowed.
4. Suggested correct action along the X ranges from 0.000 to 0.867. For the 1^st simulation a shim of 0.350mm was chosen.
5. Set Offset to simulate a shim in X of 0.350

Datum B – the Oval - Setup

1. Datum B features are selected for the Fit with the F in the box.
2. Tolerance is left set to bilateral, allowing freedom of movement along the vector.
3. Fit method set to Maximum in Tolerance (MXD). This allows freedom of movement within the tolerance zone but does not allow the feature to go out of tolerance.
4. No offset or shimming to this feature

Results of 1st Simulation

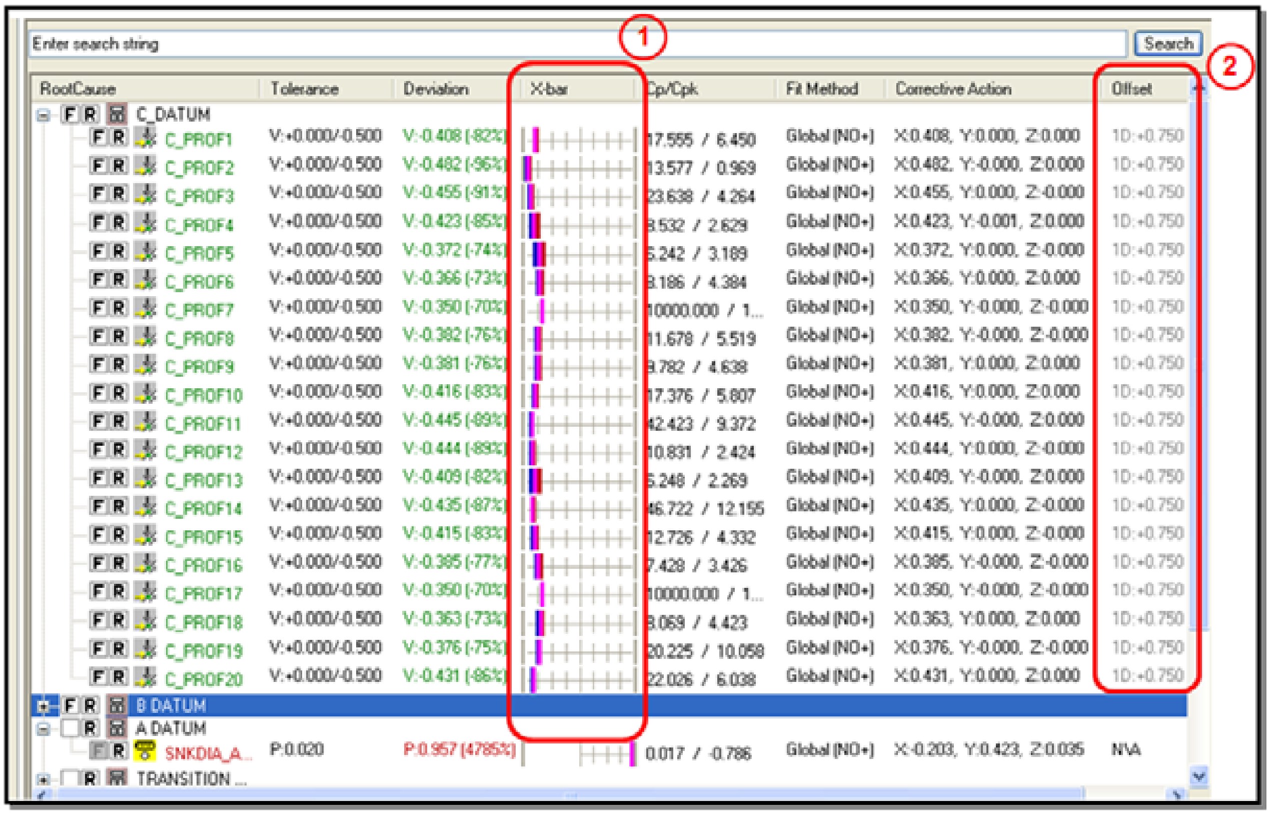


1. Datum C is now flat to the die plane and in tolerance.
2. Datum A deviation in the negative Y direction is increased.
3. Transition area still has all the vectors inward, could still be shimmed more.
4. Datum B is within tolerance.

2nd Simulation

For this simulation we need to increase the die station shimming

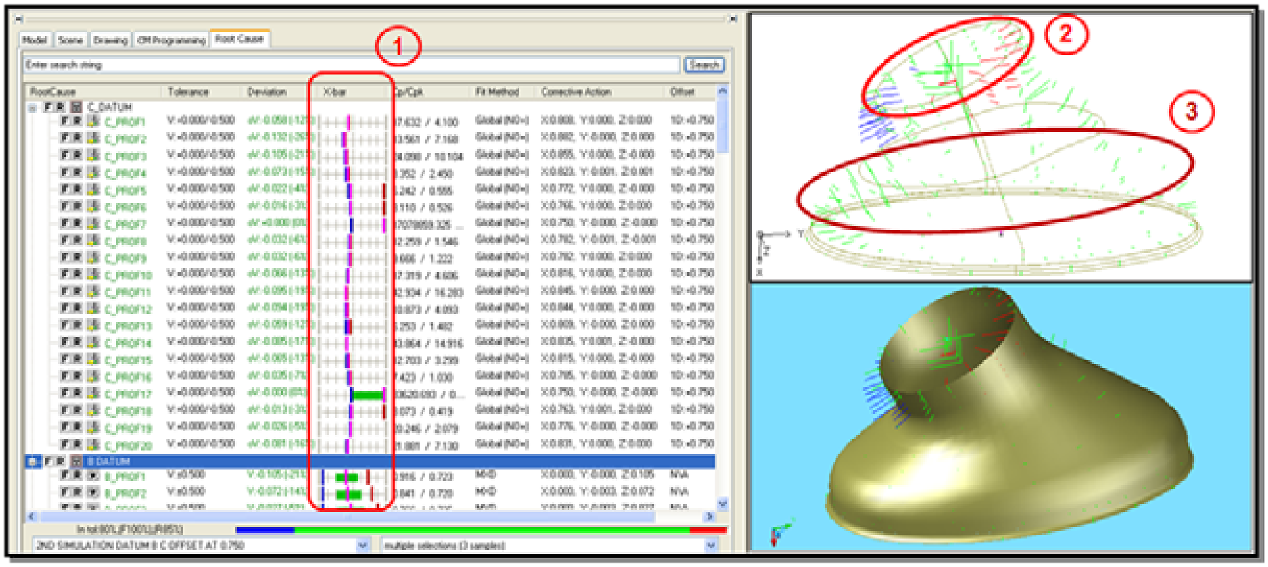
Setup Datum C



1. Before fit with Shim added the X-bar shows effect of shim (offset) on the features.
2. Offset is set to 0.750 mm

Setup for datum B is the same as above.

Results after 2nd Simulation Fit.



1. Datum C is locked in and flat to the die plane.
2. Datum A needs to be shifted in the Y-Axis
3. Transition area is now all within tolerance and well centered. Therefore we will not have to adjust form steels.

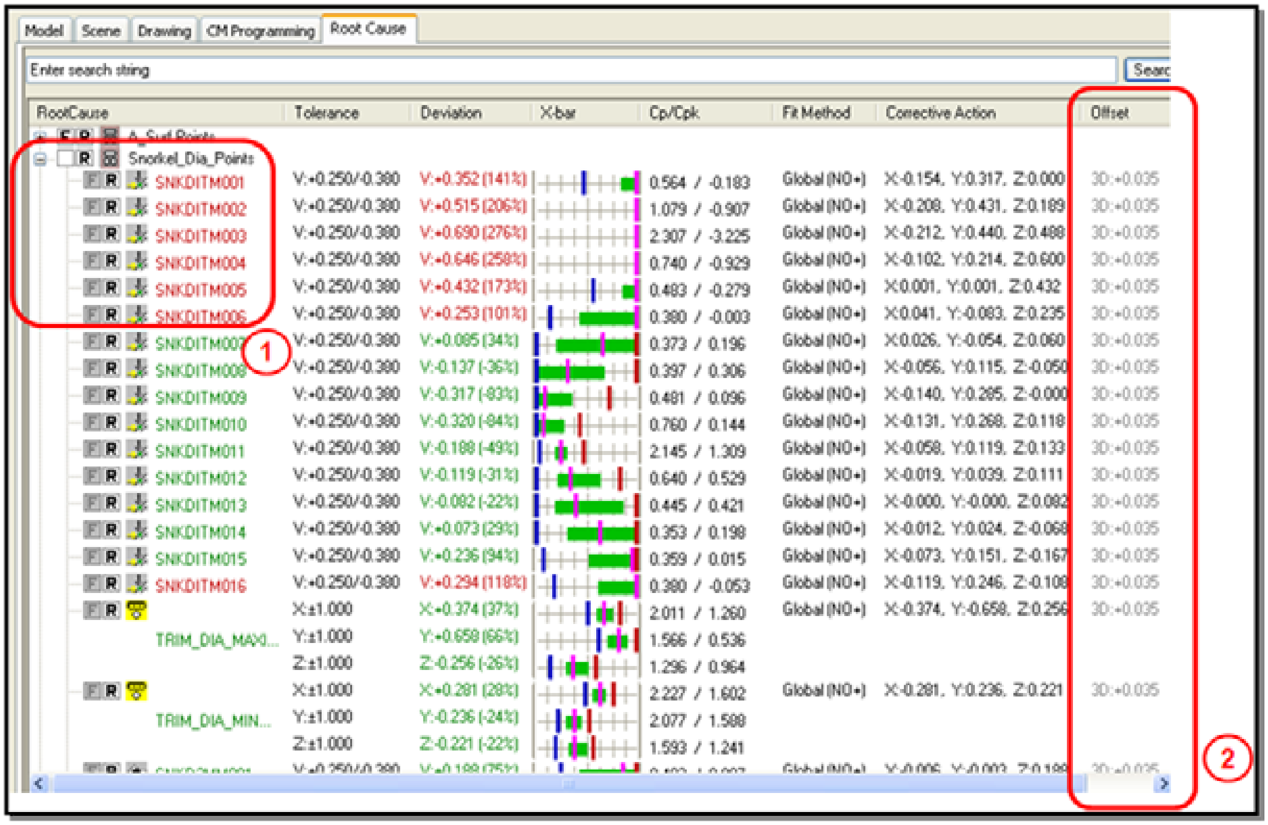
3rd Simulation

Now that we have datum B and C and the transition area corrected we can fix the Snorkel and Datum A. This can be accomplished be trying to offset datum A in the Y axis.

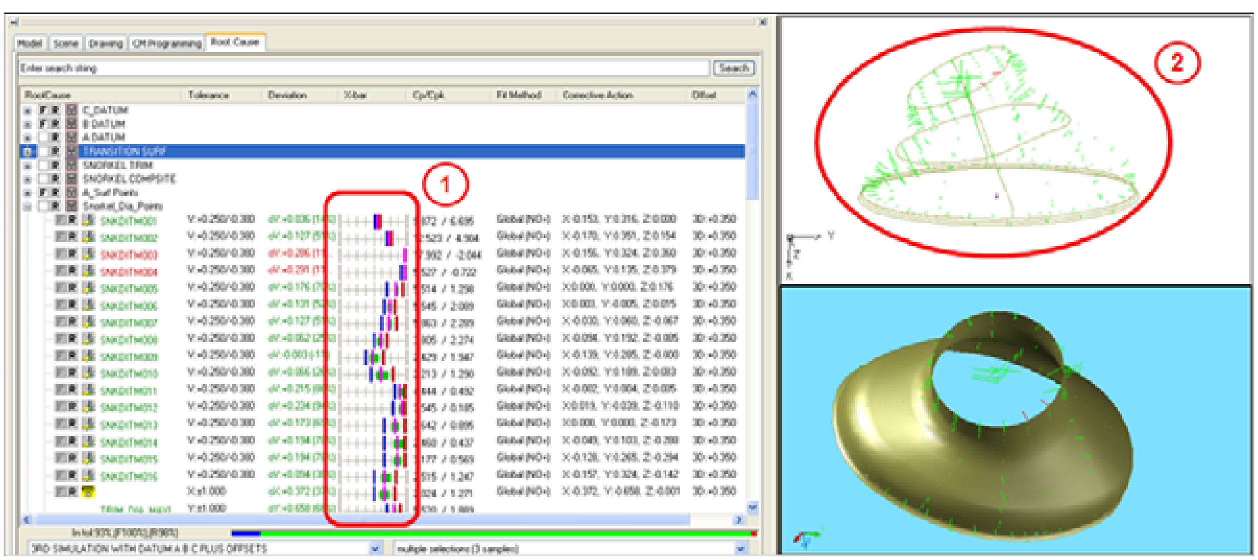
Setup for the 3rd Fit (simulation) is to offset datum A and leave the rest as set.

1. Datum A use surface points around the Snorkel for datum A
2. Fit method for datum A features is leas squares (LSQ).
3. Set offset to 0.350 along the Y-Axis

To simulate shifting the Snorkel, offset all the features on the Snorkel



1. Note that the Snorkel_dia_Points are **not** included in the fit, only in the report. They are updated by the fit without affecting it.
2. Set to simulate a shift at a die station along the Y axis 0.350mm, the same as datum A



Result of 3rd Simulation

1. Snorkel points are capable and in tolerance if we shift that die station.

Summary of corrective action

1. Datum C was fixed by shimming die station 0.750 mm in along the –X-Axis.

2. Datum B was then forced to the die plane. The die plane is a fixed parameter. By forcing datum B on to it we will force the errors (corrections) elsewhere.

3. Using the new Datum's B and C we then fix datum A and the Snorkel by moving the die stations that form the Snorkel feature 0.350 mm in the Y-Axis.

4. Overall corrective action simulation took five hours. P&C avoided die changes. We did not have to run and measure more parts, or analyze results. Using the manual process launching this part would have taken a minimum of 5 days.

5. By basing changes on stable or capable features we avoid knee jerk corrections that lead to multiple iterations.

6. All the changes or corrective action are based on the **average part.** Doing it this way we have now built a "***Robust Tool"*** that will withstand process variations, such as variation in steel, lubrication, press speed etc.

All the screen grabs in this section are actual P&C data, displayed on LaunchRite software from Origin International Inc.

Summary

1. Tooling engineers are experiencing increasing pressure to meet PPAP targets and buy off schedules.

2. Companies moving to Lean are seeking improvements in all areas of process, labor and materials efficiency.

3. Part launches are now candidates for Lean due to new software tools that automate the manual part launch process. Tooling engineers can analyze root-causes of problems, simulate tool changes, and select the optimal correction.

4. The case study shows a typical example of the efficiencies tooling engineers are achieving. A part launch that took a minimum of 5 days took 5 hours. On more complex parts the savings are greater.

5. Root cause methodology and tools apply to any situation where process variability is a factor.

Bibliography

A.I.A.G Statistical Process Control Second Printing March 1995.

Authors Biographies

Murray J. Desnoyer

C.E.O. Origin International Inc.
Murray graduated from Ryerson University with a diploma in Physics and Electrical Technology in 1971. While at Ryerson he earned the Gold Medal for overall academic achievement. On graduation Murray worked for Questor Surveys where he participated in the development of airborne geophysics (ore locating) survey equipment. In 1972 he founded Trintronics and undertook the manufacture of airborne geophysics equipment. In 1976, Murray opened “The Computer Place” the first computer store in Canada. In 1980 he and Stephen Pumple formed AZCAR Technologies which incorporated The Computer Place and IMMAD Broadcast Services Limited. In 1992 he left AZCAR and started Origin International. Origin develops and manufacturers software used for checking manufacturing tolerances in the aerospace, nuclear and automotive sectors. Murray was active in several software development groups, co-chairing the DMIS enhancement committee for 5 years. Murray is a member of the Board of AZCAR Technologies, a public company, chairing the Operations Committee

Al McCallum

Tooling Engineer, Pridgeon and Clay Inc.
Al has made his career in the Tool and Die trade for the past 30 years. He began in 1979 as an automatic punch press operator. He was responsible for inspecting his parts on layout table for production. After 3 years he began a 2-year tool and die apprenticeship at Ranger Tool and Die in Grand Rapids, Mi. He began as die repairman, and finished as journeyman diemaker as certified by Michigan Dept of Labor. He moved Enterprise Tool and Die, Grandville, Mi., and for the next 17 years took on roles of increasing scope and responsibility. This included Diemaker, Lead Diemaker, CMM programmer, CADCAM Modeler/Programmer and CNC Department Leader. For the past 8 years Al has been one of four Tooling Engineers at Pridgeon and Clay Inc, Grand Rapids, Mi. He is responsible for sourcing and developing outside tool sources, including Asia and Eastern Europe, for global manufacturing sites.

Contributors

David Schlitt	Marketing, Origin International Inc.
Bob Stone	Lead Developer, Origin International Inc.
Geoff Foulds	Principal, DG & Company