AN ANALYSIS OF THE MANUFACTURING PROCESS AS RELATED TO THE CAMBER REQUIREMENT FOR BRAKE PADS

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Morehead State University, 2010

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This thesis started as a case study to answer the question, "What is the root cause of why an automotive manufacture[1] in Central Kentucky is not meeting the camber[2] specification during normal production?" To you understand camber scheme image taking a paperclip and try pulling it apart one millimeter with a tolerance of plus or minus a half a millimeter. Repeat this process several thousand times and see if the process is stable. With this example in mind, imagine placing a bend of forty micrometer into a brake pad with a tolerance of plus sixty micrometers minus forty micrometers and repeat this process sixty thousand times throughout a production run with an unstable process.

There were many theories as to why the camber specification was not being met, ranging from operator error to process error. Also, there were a lot of variables that needed to be examined in order to answer the question. When the first study was complete, many questions had been answered;

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1. The name of the manufacturing company is confidential.
2. Slight bend purposely placed in the part.

however, more questions were asked. To answer the additional questions that were asked after the completion of the first study, a second study was conducted which led to the answering of the original question. The next step in the process was to take the answers from the first two studies and find a stable manufacturing process which would benefit the automotive manufacture by easing the camber specification and to benefit the customer by giving a cost reduction. The automotive manufacture has an advantage over other manufactures however, finding a stable manufacturing process could remove this advantage, which could lead to a loss of business.

Accepted by:
Chair

Ahmad Zargari,

Acknowledgements

Completing the Masters Program at Morehead State University has not been an easy task. Watching my girlfriend, Carolyn, die of cancer when I started back to school full time was very painful, and I sometimes felt as if I did not have the emotional strength to continue my education. However, having the support of my family, friends from past projects, and the friends that I made while I was at MSU made it possible for me to continue. There are several people that I would like to single out and say thank you for their support and help.

To Kathi York, Horst Griesbaum and the team at the automotive manufacture in Central Kentucky- thank you for giving me the opportunity to be an intern inside the Quality Department. The experience gave me insight into the world of automotive manufacturing. The work I completed there gave me the material that I needed to complete this thesis. I gained valuable experience which should help in the future.

I want to thank my family for their unending support. I would especially like to thank my aunt, Ann Hamon, who spent countless hours with me proof-reading my papers. I would also like to thank my father, for providing me with a home and necessities when I decided to return to school.

Finally, I want to thank all the faculty and staff at Morehead State University for all of the assistance that they provided. I especially want to thank my department chair, Ahamd Zargari, who has been a mentor, teacher, and supporter during this process. I would also like to thank Dr. Nilesh Joshi and Dr. Steven Hunt for serving on my thesis committee and giving suggestion to improve my thesis.

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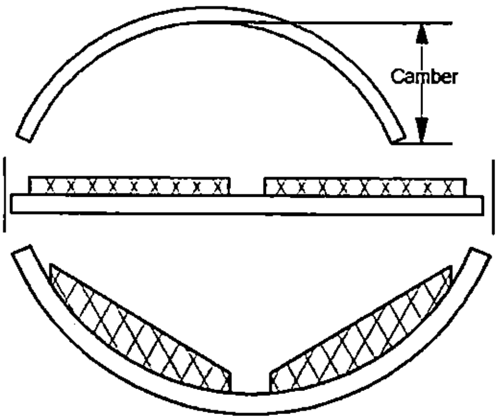
Chapter I-Introduction

1.1 General Area of Concern

Automotive engineers have found a way to increase the quality and life of disc brake pads by having a slight bend placed inside the part known as camber when the blank pad is manufactured. The idea is to apply braking material to the blank pad, causing the pad to contract to a flat surface. The flatness causes even wear to the brake pad and rotor of the car, making the life of brake pad and rotor longer; thus, better quality. However, if there is no camber in the blank pad when the braking material is added, the part will shrink into a “u” shape which does not give even wear. This lowers the life of the brake pad and rotor, which lowers quality.



Example of camber added to brake pad

Example of brake pad after braking material is added

Example of brake pad when no camber is added and braking material added

Figure 1-1: Shows camber and how a brake pad reacts when camber is or is not applied.

1.2 Statement of the Problem

In the past, manufacturing of the 7011 brake pad was made to customer’s specification as set forth in PPAP. However, the customer has been rejecting parts because the camber of the part has not been meeting customer’s tolerances, which in the past has required rework. Since the rejection rate is higher than average, the manager has decided to make the rework process a secondary operation to the manufacturing process. This is an extra step in the manufacturing process, increasing the cost of production. With the manufacturing process having detailed steps, many questions need to be answered:

1. Is camber being placed in the blank brake pad at the fineblanking stage of the manufacturing process as stated in PAPP?
2. Has there been a change in the tool?
3. What type of part is being produced at the fineblanking stage of the manufacturing process; correct camber, most flat part, or camber in the opposite direction?
4. Can changes be made to the tool to have camber placed inside the part during the fineblanking process, or does the secondary step to add camber become a permanent part of the manufacturing process?

1.3 Significance of the Study

To find any and all changes to the manufacturing process for the 7011 brake pad so customer's tolerances of .04mm (+.06 -.04mm) are met thereby reducing the cost of manufacturing and passing the savings on to the customer.

1.4 Limitations

1) The study was limited by scheduling of production of the part.

2) Sample sizes varied in size due to the needs of the company.

1.5 Definitions of Terms

Camber: A bend in a part that allows for shrinkages after the manufacturing process is complete.

PPAP: Production Parts Approval Process

Tool: A two sided part used in the manufacturing process that forms the component

Fineblanking: Producing a part inside of a press in one stroke of the press which leaves a small burr in the part

Burr Up: The burr left after a roll of steel is cut to width facing in the up direction

Burr Down: The burr left after a roll of steel is cut to width facing in the down direction

Blank pad: The metal part of the brake pad before the braking material is added

630 Ton Press: Fineblanking press that uses 630 ton of pressure to produce the part

800 Ton Press: Fineblanking press that uses 800 ton of pressure to produce the part

Strip of metal: A piece of metal that is taken off the coil to be measured

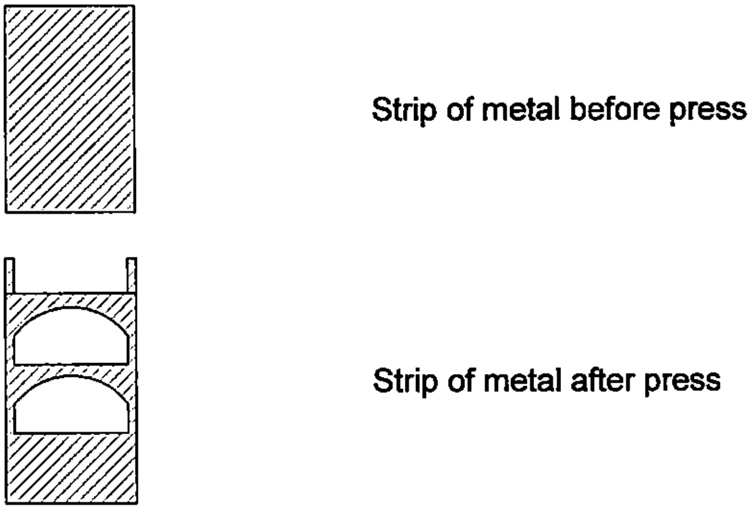


Figure 1-2: Shows strips of metal

CMM: Coordinated Measuring Machine

Surface plate: A machine material that is designed to be as flat as possible

Mini-jacks: Tools used to support samples for measuring

Height gage: A tool used to measure flatness of material and camber of brake pad

kN: (kiloNewton)-the international system of measurement for force.

Heat lot: A tracking system for steel

Z reference: Depth reference in a coordinate plane system

Chapter II-Literature Review

There are three common terms that are the backbone of this thesis; camber, fineblanking, and measuring. Camber is a bend in a part that is either wanted or unwanted. Since camber is wanted or unwanted it must be controlled to where it is consistent thought out production and over time. The reason why camber is wanted is to increase the surface area, which increases contact with another surface, which decreases braking times and uses less energy to move forward. When camber is wanted there must be some type of action to force the bend in place. This action must be strong enough to break the memory of the metal (yield strength) yet not too strong that there is a permanent bend in the metal.

To bend the metal to where the camber is wanted a V-die bending process is needed which is based on the idea of deforming the metal. There are two variables- displacement and rotation of the surface nodes, which means the metal, can be deformed into a shape (Chen, 2004). This method uses a punch and a die. The punch is in the shape of an arrow and the die is in a v shape. Force is applied to shape the metal; the greater the force the greater the bend, which also reduces the memory of the metal to where it will no longer bounce back. This method of producing camber however would not be acceptable because of the small amount of camber that is needed. This method causes a permanent bend in the metal. Another type of camber that is wanted is the angle of the wheels in relation to the road surface. As the angle of the tire increases; the tire makes less contact with the road which makes the car less stable (Pacejka, 2005). Camber that is not wanted is when there is a bend in steel as it is being produced. This type of camber is unwanted because it decreases the quality of the products, because it looks bent and would not be used in other process (Montague, 2005).

Fineblanking is a manufacturing process that uses hydraulic presses to produce a part in one stroke of the machine instead of a multistep process. Since the parts are made in one step, there is little secondary process needed to complete the manufacturing process. This makes the producing of the parts fast, complete, with low cost, and with good quality (Vasilash, 1998). The idea behind fineblanking produces a flat part however; there are limitations-geometrical shape of the part, thickness, and strength of the material. These three rate how difficult it is to produce a part. For example, a part that has straight lines with a thin material is easier to produce than a part that has gearing or is thick. There are several standards that are used to cover the forming process shown in table 2-1 (Atanu Mikhoty, 1997).

Forming under compressive stresses (upsetting, flat coining, punch marking, hobbing)	DIN 8583
Forming under combined compressive and tensile stress (deep drawing, flange forming)	DIN 8584
Forming under tensile stresses	DIN 8585
Forming by bending (free bending and die bending	DIN 8586
Forming under shear stresses	DIN 8587

(embossing)

Table 2-1: Different fineblanking standards

An automotive manufacturer in central Kentucky is a global leader in fineblanking technology, having serviced its customers for more than fifty years. As a dynamic and growing company, they provide critical component solutions for manufacturers throughout the world. This automotive manufacturer combines the inherent value of fineblanking with a broad array of in-house secondary finishing capabilities that enable them to provide complete ready-to-assemble components to their customers. This automotive manufacturer has twelve strategically located facilities in North America, all TS/QS 16949 certified, with more than one hundred fineblanking presses in operation – more than any other company in the world. They can produce components large and small, simple to intricate, on presses ranging in size from forty to fourteen hundred tons. The Kentucky Division maintains the largest fineblanking presses in the world, ranging in size from six hundred thirty tons to fourteen hundred tons. The Kentucky Division makes parts primarily for the automotive and off-road industries and is strategically located in order to service the automotive market (Precision Resource, 2010).

Measuring and the collecting of data is an important part of any process. The method and accuracy of the tool being used is what makes the difference between a good or bad part. There are two different methods of measuring being used in this thesis. The first method is the use of a coordinate measuring machine and the second is a combination of a height gauge and an indicator. Each of these methods is accurate as long as correct procedure, indicator and program are being used.

The use of a coordinate measuring machine is a fast, accurate, and efficient way of measuring parts. The software of the coordinate measuring machine can be connected to statistical process control software for the use of data collection and quality control, making the process of collecting data easier and requiring less time for an analysis (Jordan, 1997). However, there are some limits to the use of the machine because the correct measuring points need to be programmed into the machine. Small and delicate parts are often difficult to measure because of their size which means they can be easily damaged by the probe. The use of multi-sensor coordinate measuring machine can be used to reduce these factors, which allows the measuring of smaller pieces with a greater accuracy (Danford, 2009).

The ideas behind producing and measuring camber are simple but complex. Many issues related to part defects occur during the design and manufacturing start of a product. This maybe because many engineers do not understand the tolerances they are working, which in today's manufacturing tolerances are becoming more and more complex (Ceglarek, 2008). It is simple to bend a piece of material, however; the bend that is required for brake pads is .05 millimeter, which is very small. To produce quality parts one questions needs to be answered, "What has changed in the process?" To help find the answer two quality tools were used Statistical Process Control (SPC) and Design of Experiment. SPC measured the inputs of a process in order to detect changes and remove the need of final inspections. If the inputs of a process are controlled you would then have control over the outputs as well. This would reduce the time and money wasted in detecting problems and rework (AIAG, 1995). Through SPC process capability is proven which is a measure of what percentage of parts are meeting specifications. However, if no change has occurred, "What can be done to produce a stable manufacturing process?" This is when Design of Experiment (DOE) is conducted which helps reduce the variability of tolerances by ensuring closer conformance to normal tolerances (Caplan, 1997). By changing key inputs the output will change and measurement can be taken to see what input affects the output and how that affect process capability. Camber had many inputs to answer, "What has changed in the process?"

Review of historical data and collection of current measurement information shown in figure 3-1 shows that the camber of the brake pad has changed starting in December 2009.

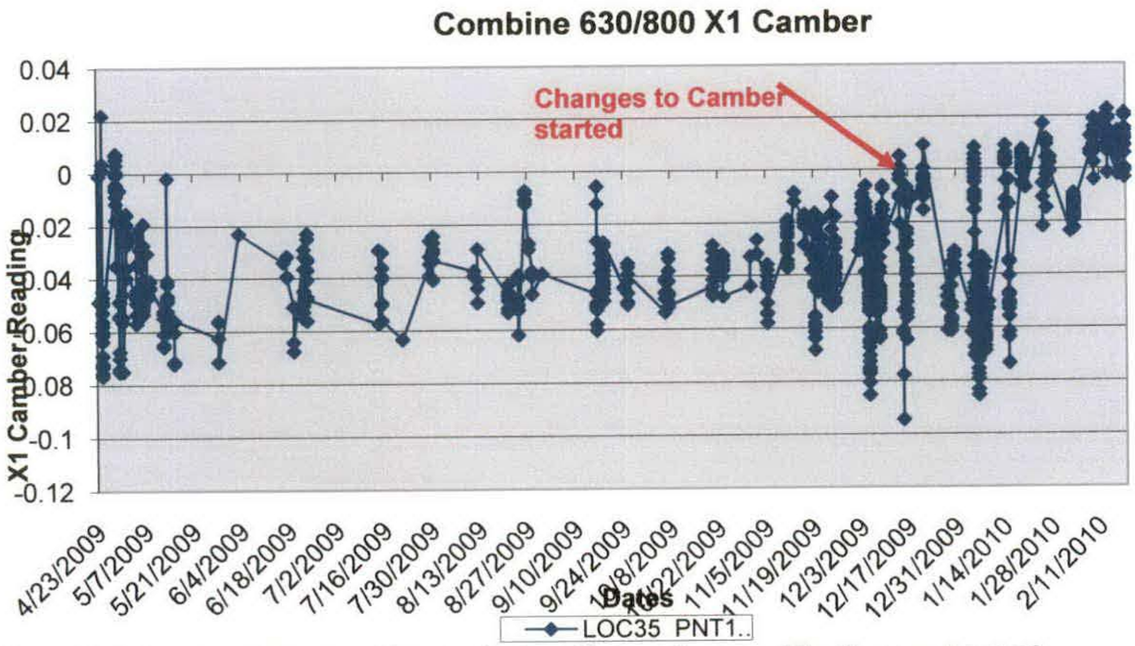


Figure 2-1 Shows camber over time and when the camber specification went out of control.

CHAPTER III - METHODOLOGY

Chapter Three desires the procedures that were used in measuring and collecting of data.

Research Instrument and Procedure

1. Procedure for measuring strips of metal for flatness:
    1. Scope
        a. This standard covers the methods for measuring the flatness of a strip of metal. The measurements are taken before and after the metal enter the press.
    2. Measurement devices and tools
        a. Surface plate
        b. 3 Mini-jacks
        c. Height gauge with 0.01mm resolution
    3. Measurement methods
        a. Insure the sample strip of metal is clean and free of stains and dirt
        b. Place the sample strip of metal on mini jacks on points A, B, and C (Figure 3-2)

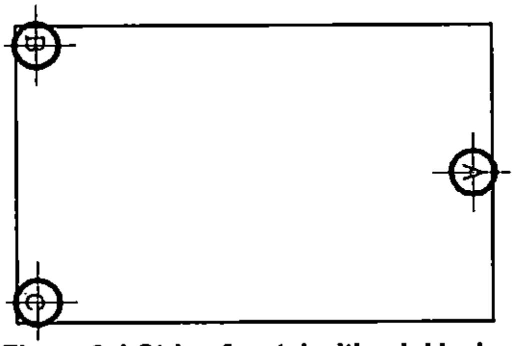


Figure 3-1 Strip of metal with mini jack points

c. Using the height gauge, adjust the mini jackets at points A, B, and C until they are all set to zero

d. Move the height gauge slowly across the sample strip in the Y direction

e. Measure the height along the lines of Y_0, Y_1, and Y_2 as shown in figure 3-3. Record the maximum and minimum along each line, then calculate the difference. The calculated differences is the flatness of the sample strip of metal

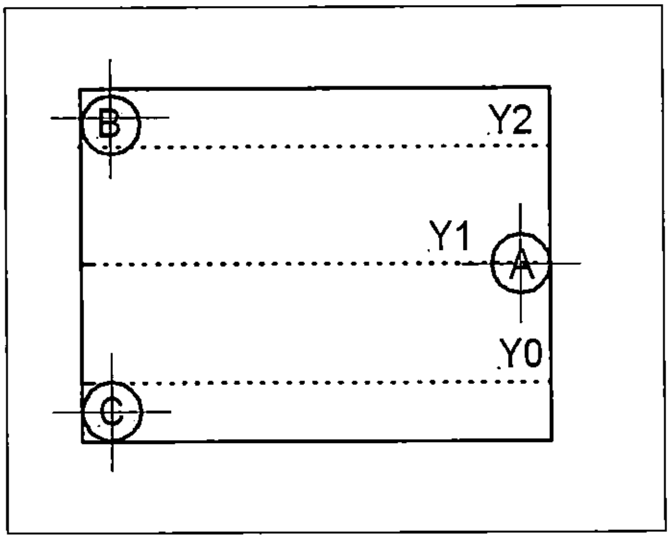


Figure 3-2: Strip of metal with measuring points

	Maximum	Minimum	Difference
Line Y_0	0.02	-0.03	0.05
Line Y_1	0.02	0.01	0.01
Line Y_2	0.04	0.02	0.02
	Flatness		0.05

Table: 3-3: An example of flatness measurements

2. There are two different methods for measuring camber. Method one is the preferred method. It is used by the customer to check the quality. Method two is the use of a CMM machine. The machine's measuring program will record data and analyze data inside SPC quality control database.
   - Method one
     1. Scope
        a. This standard covers the methods for measuring the camber of the blank brake pad
     2. Measurement devices and tools
        a. Surface plate
        b. 3 Mini-jacks
        c. Height gauge with 0.01mm resolution
     3. Measurement method
        a. Remove oil and stains from blank brake pad using rags, and keep the measurement surface clean

b. Set the blank brake pad on mini jacks at the back sides of point A, B, C as shown in figure 3-5

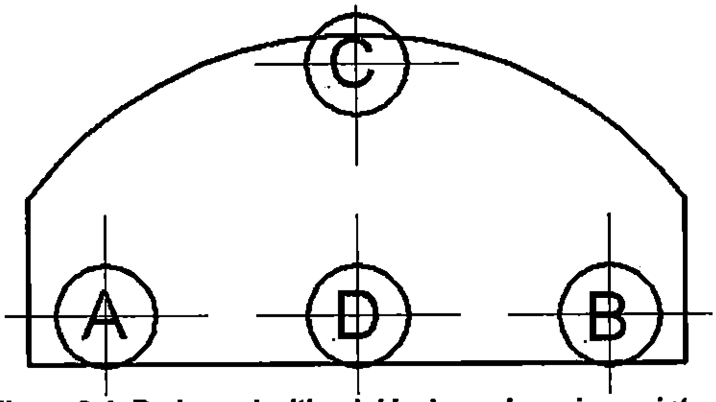


Figure 3-4: Brake pad with mini jacks and zeroing points

c. Adjust the mini jacks at the back side of point A and B in order to set zero for both point A and B measured by height gage

d. Adjust the mini jacks at the back side of point C in order to have the same value for both point C and D measured by height gage.

e. Repeat steps C and D until setting zero for both A and B and both C and D having the same value

f. Measure the height along the X_0, X_1, and X_2 within the specified area of flatness, then calculate the difference of maximum and minimum values.

g. The calculated average of the three shall be the average camber, and maximum of the three shall be the maximum camber.

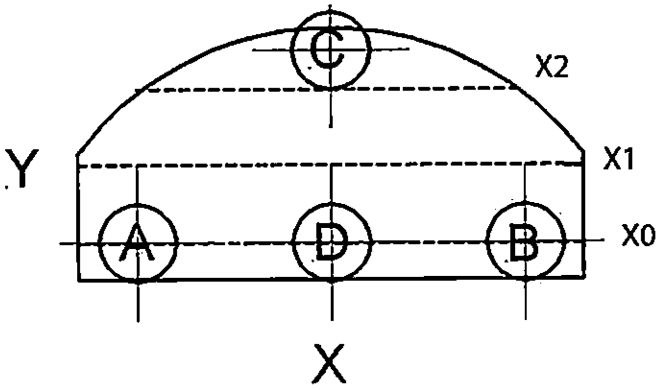


Figure 3-5: Brake pad with measuring points

	Maximum	Minimum	Difference
Line X_0	0.11	-0.01	0.12
Line X_1	0.10	0	0.10
Line X_2	0.12	0.01	0.11
	Average camber		0.11
	Max camber		0.12

Table 3-6: An example of camber measurements

Data Collection Methods

1. Examine straighter settings for the past six months
2. Examine press settings for the past six months
3. Examine changes to camber over the past six months
4. Examine changes to the tool for the past six months
5. Examine the changes to the camber measuring program
6. Measure a strip of metal for flatness before it enters the press
    a. Burr Up
    b. Burr Down
7. Measure a strip of metal for flatness after parts have been formed
    a. Burr Up

    b. Burr Down

8. Measure the camber of the parts in groups of thirty (total 90 parts) from the beginning, middle, and end of coil Compare the measurement between the different heat-lots of the raw material.
    a. Burr Up
    b. Burr Down
9. Analyze data
10. Adjust machines as needed
11. Make changes in tooling if needed
12. Repeat process as needed

Data Analysis

The data that was collected will be analyzed in the following methods:

1. All measuring data collected from the CMM will be placed into statistical processing control (SPC) software and Excel. The SPC software will be used for process control charts and calculating mean and standard deviations, while Excel will be used to create run time charts.
2. All machine settings will be placed in Excel and charted to see if there are any differences in settings.

Chapter IV-Findings

Chapter 4.1

All the data collected came from different databases that were used to document changes to the process. Below are charts 4-1 – 4-4 illustrate the changes to the process that have been documented for the period from April '09 to present. Changes that occurred have been highlighted in red with an explanation for the change; also there is a list of changes for items that could not be charted.

Results:

1. Straighter settings

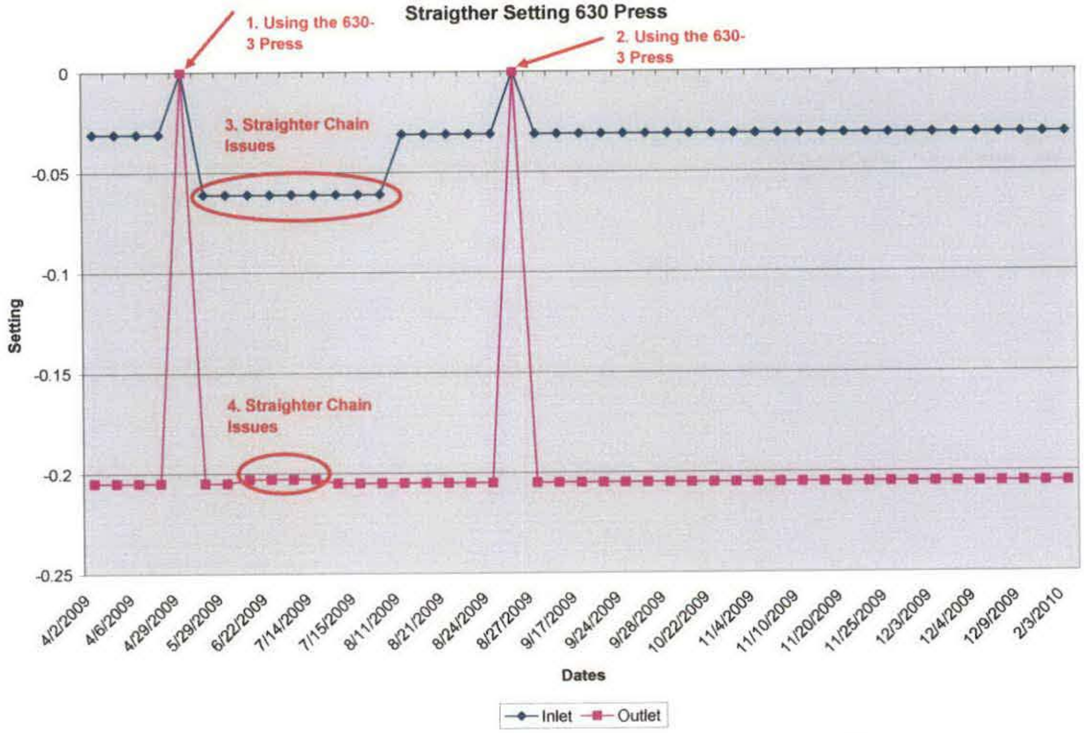


Chart 4-1: Shows the straighter setting for the 630 ton presses over time.

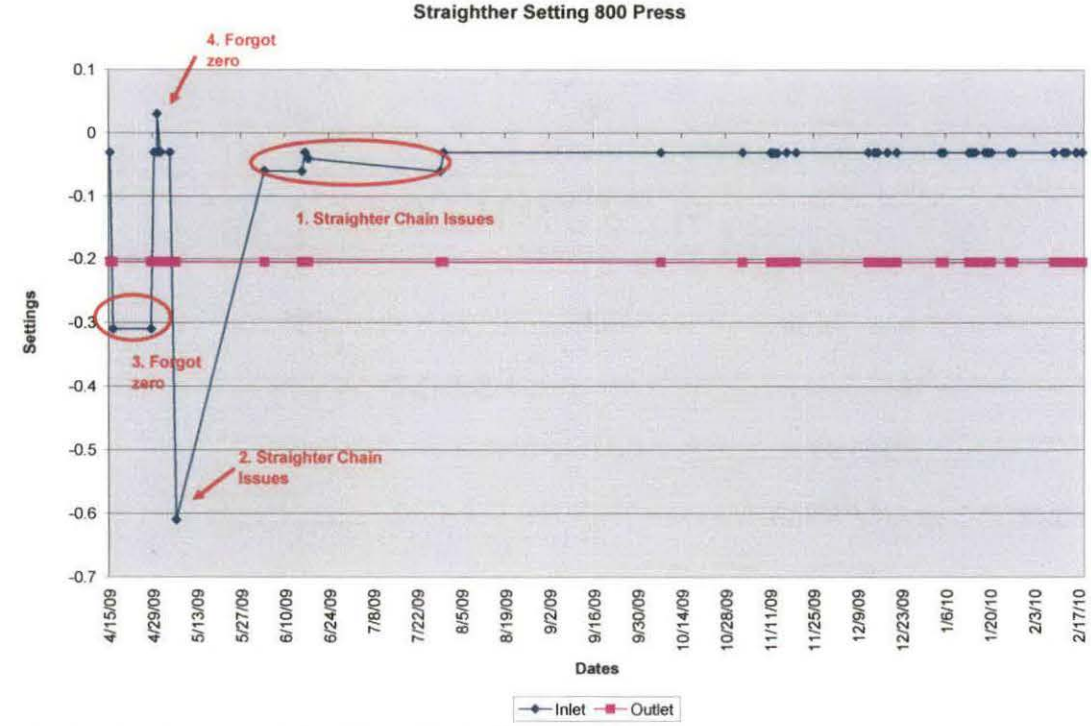
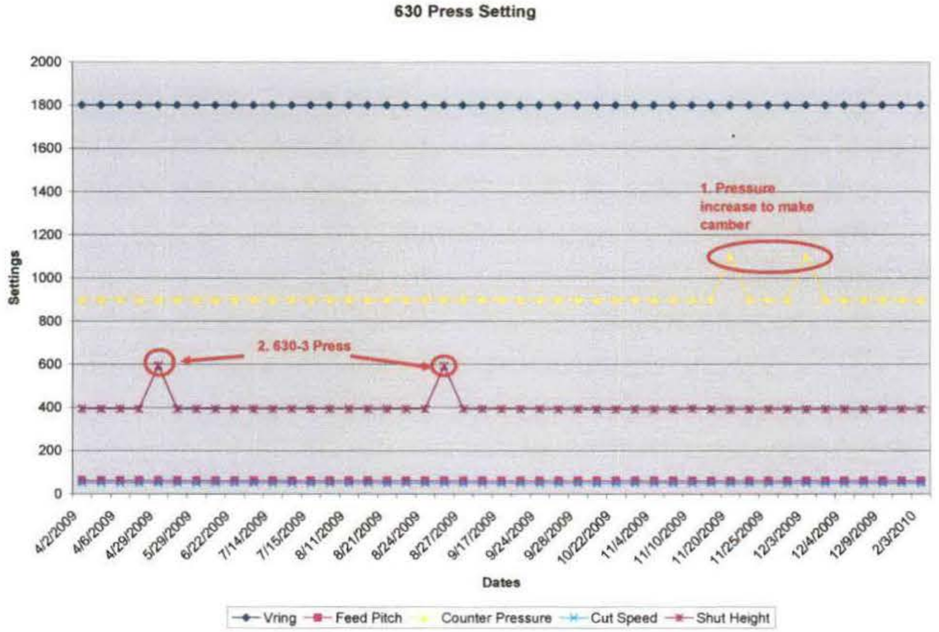
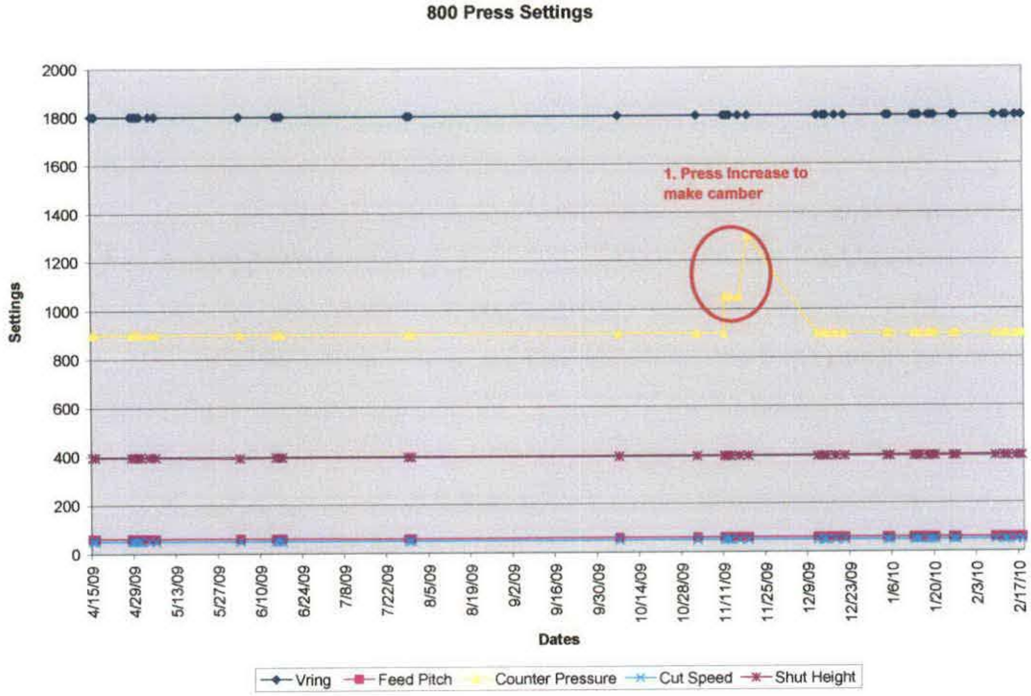


Chart 4-2: Shows the straighter setting for the 800 ton presses over time.

2. Press settings



Chapter 4-3: Shows the press setting for the 630 ton presses over time.



Chapter 4-4: Shows the press setting for the 800 ton presses over time.

3. Changes to camber

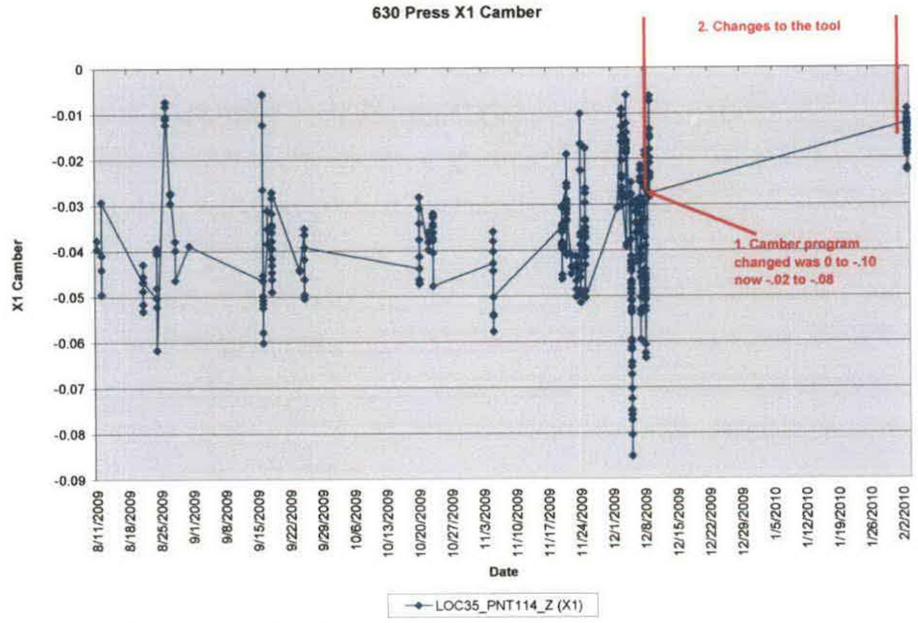


Chart 4-5: Shows camber from the 630 ton presses.

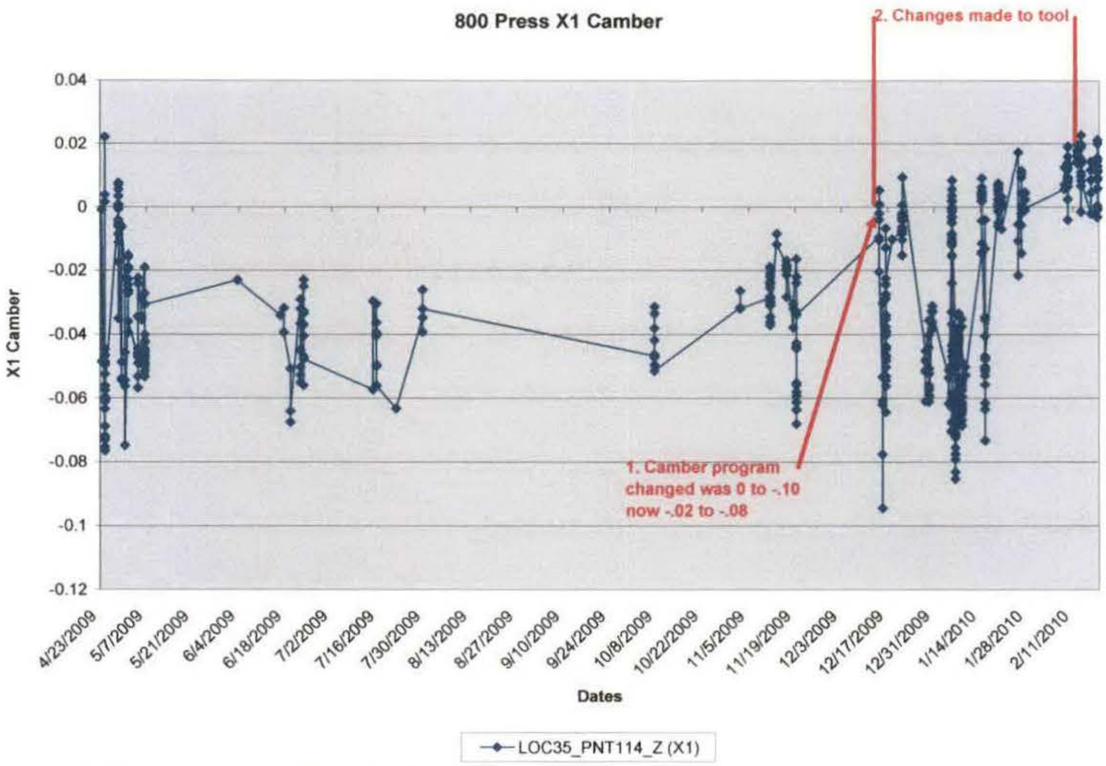


Chart 4-6 Shows camber from the 800 ton press.

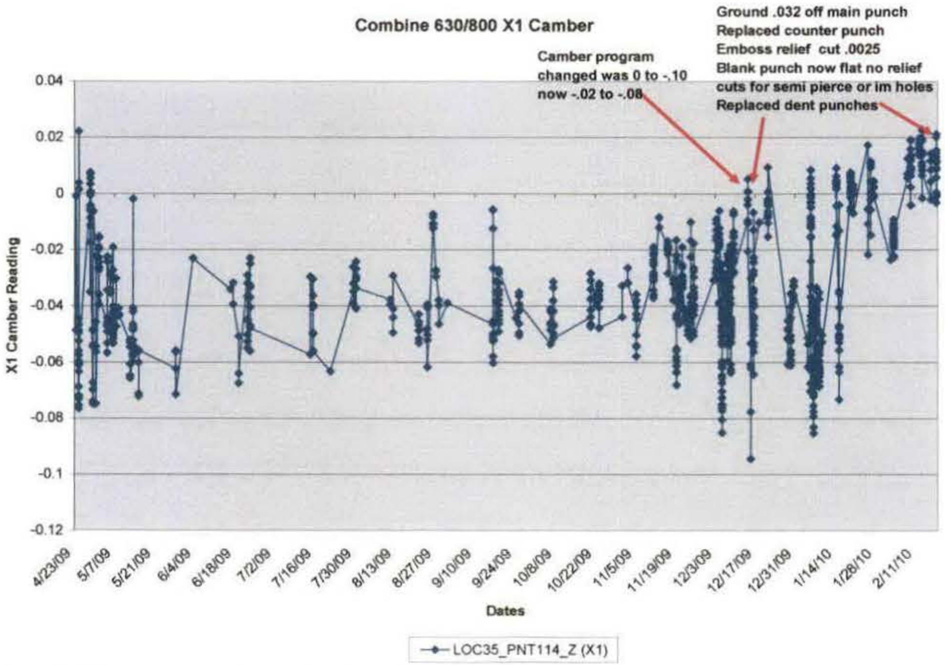


Chart 4-7 Shows camber between the 630 and 800 ton press.

4. Changes to the tool:

   a. 12/02/09 - .032 ground off the main punch
   b. 12/03/09 - Counter punch replaced
   c. 12/30/09 - Tool modified in the trim station
   d. 01/21/10 - Blank punch now flat, no relief cuts
   e. 02/03/10 - Dent punches replaced

5. Measure the camber of the parts in groups of thirty (total ninety parts) from the beginning, middle, and end of coil Compare the measurement between the different heat-lots of the raw material.
   a. Burr Up

Start of Coil

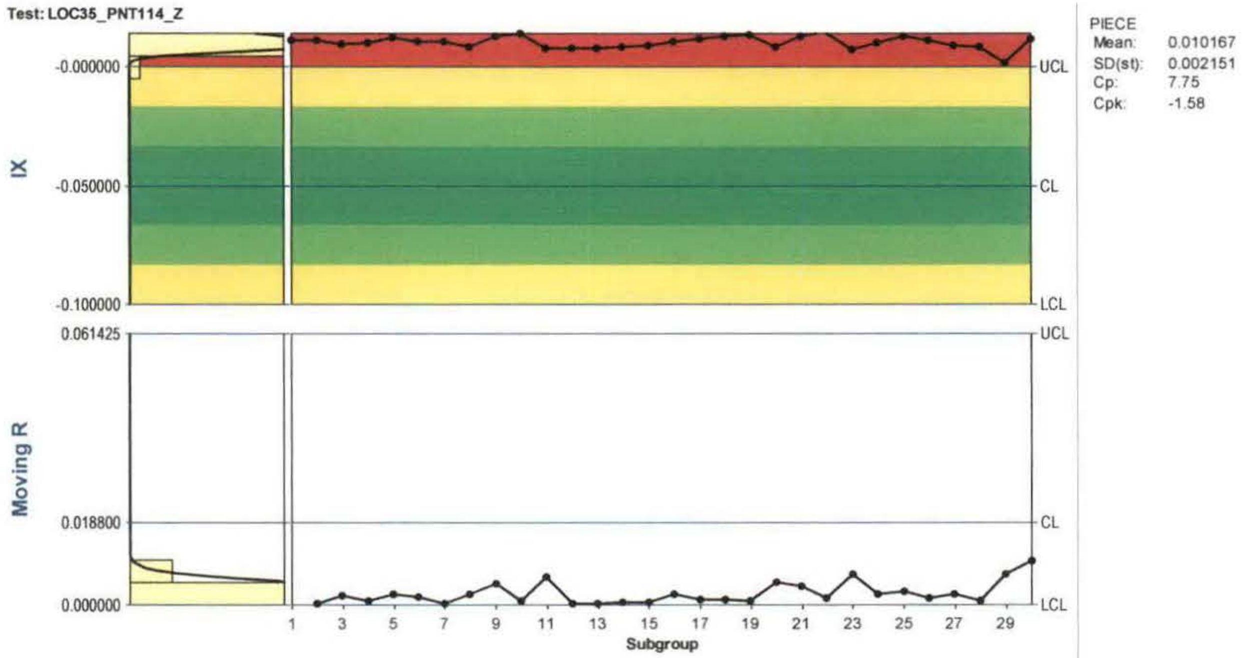


Chart 4-8: Shows the camber at the start of the coil.

Middle of coil

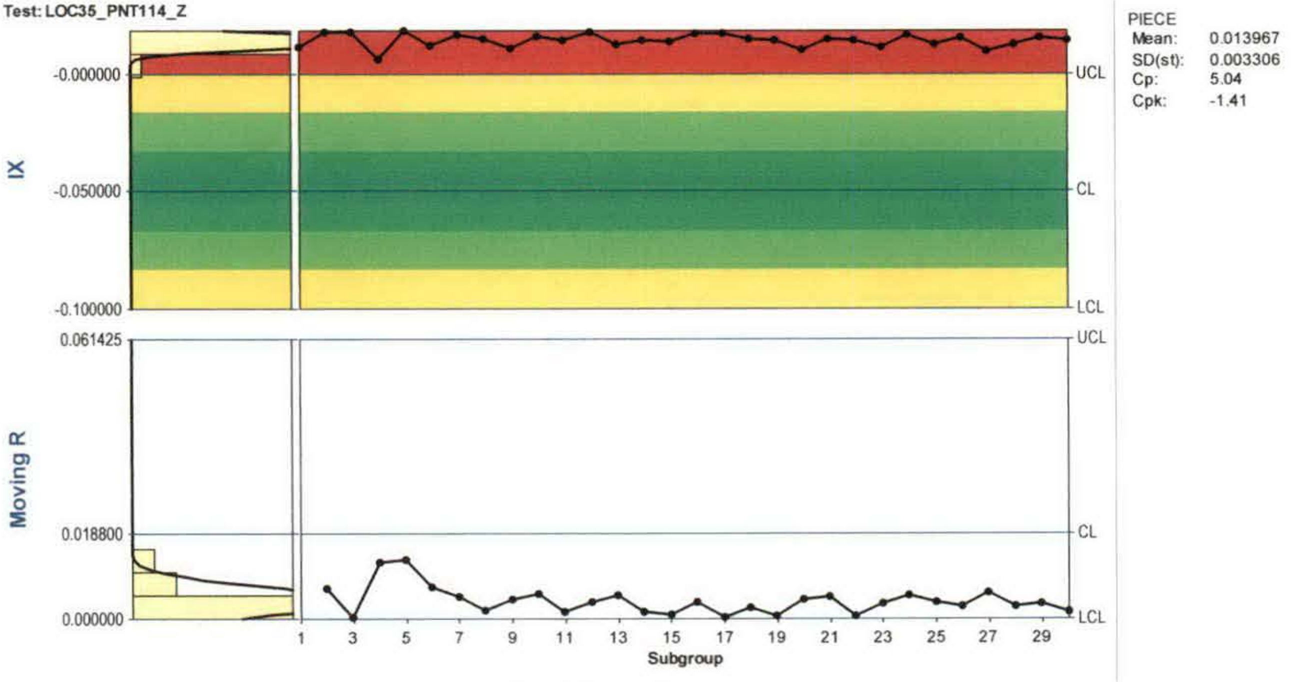


Chart 4-9: Shows the camber at the middle of the coil.

End of Coil

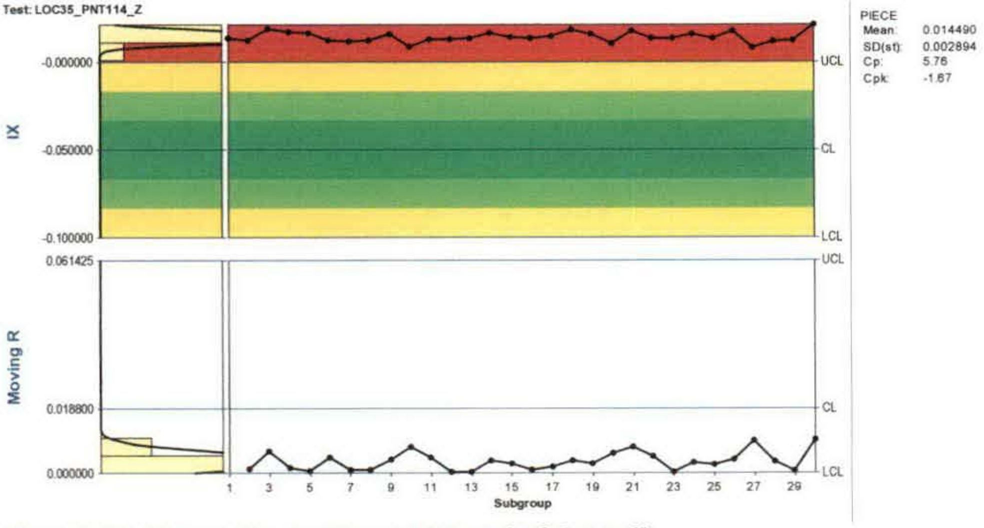


Chart 4-10: Shows the camber at the end of the coil.

Camber Bur Up Coil

	Mean	Standard Deviation
Beginning of Coil	.010167	.002151
Middle of Coil	.013967	.003306
End of Coil	.014490	.002894
Minimum	.001608	
Maximum	.021766	

Table: 4-1: Summary of the camber results burr up coil.

b. Burr Down

Start of Coil

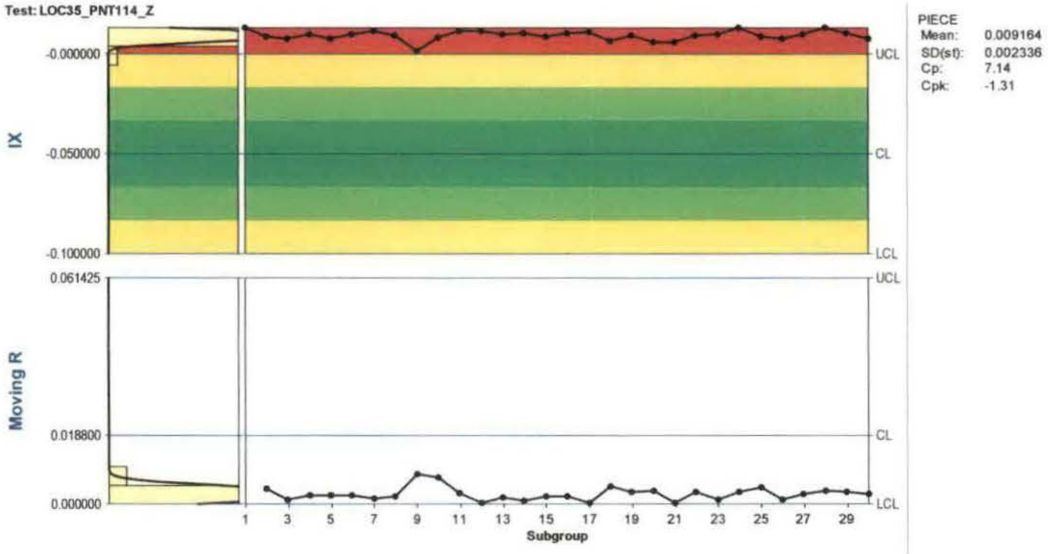


Chart 4-11: Shows the camber at the start of the coil.

Middle of Coil

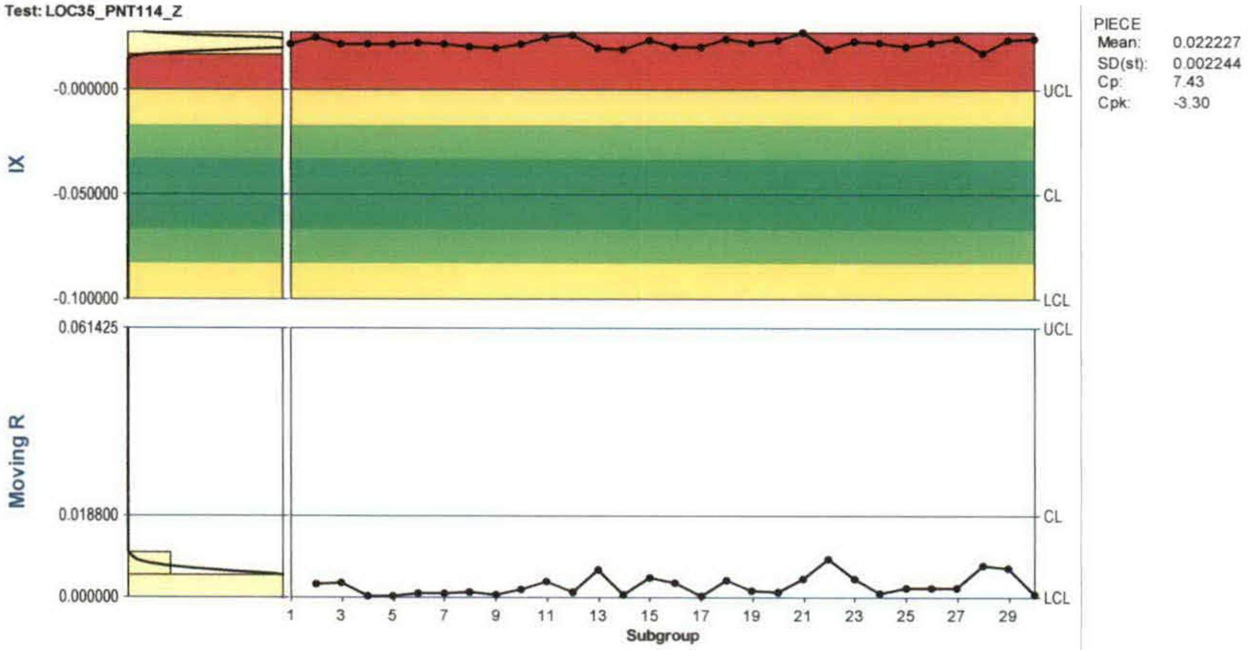


Chart 4-12: Shows the camber at the middle of the coil.

End

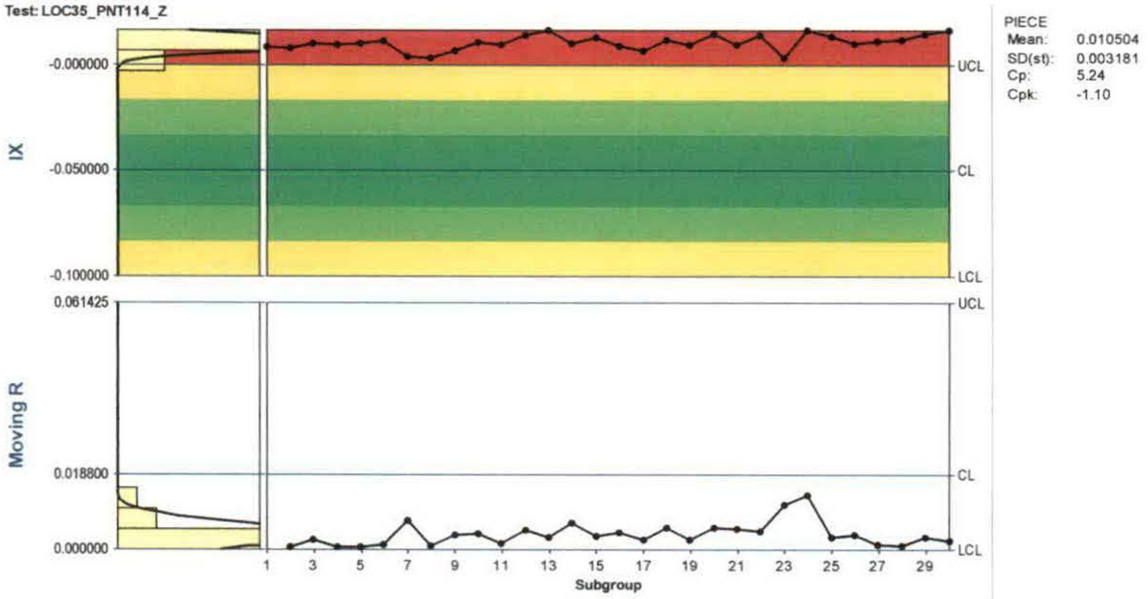


Chart 4-13: Shows the camber at the end of the coil

Camber Burr Down Coil	Mean	Standard Deviation
Beginning of coil	.009164	.002336
Middle of coil	.022227	.002244
End of coil	.010504	.003181
Minimum	.001123	
Maximum	.027627	

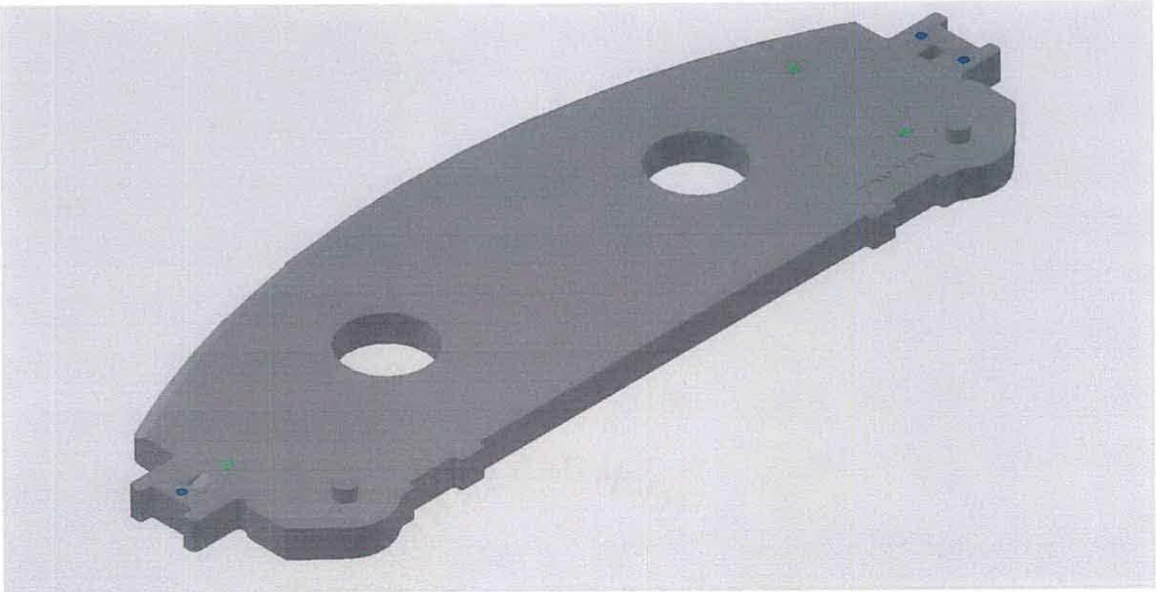
Table 4-2: Summary of the camber results burr down coil.

Study 1 Conclusion:

The results of this study show that the changes in the press setup during the production run had little effect on camber. The results of the short term study to determine the effect of camber between the beginning, middle, and end of a coil and the burr direction (up or down) show that there is a difference in camber, however, not the same between the two coils. In the burr up coil, the camber that was produced was in the opposite direction which does not conform to customer's specifications. At the beginning of the coil, the amount of camber is less than at the middle or end of coil and the standard deviation is higher at the middle of the coil than at the end. Just as with the burr up coil the burr down coil produced camber in the opposite direction with slightly better results. The standard deviation between the beginning and middle of the coil are similar as shown in charts and tables 4-8 – 4-15. Overall, a burr down coil produces a more consistent part, however; the burr direction or the location of the material from where the part is procedure does not affect camber.

Chapter 4.2

A short study was conducted to see if the changing of the "Z" reference plane in the CMM program had been the cause of the camber going in the opposite direction. The reference plane was changed to make more consistent readings when comparing the readings from the CMM and the height gage (customer preferred measuring method).



New reference points
Old reference points

Figure 4-16: Showing Z references points

A comparison was made between an older version of the CMM program, the current CMM program and the customer preferred measuring method. Thirty sample parts of the KY 7011 brake pad where used in this comparison. Below are the results.

Camber with the older version of the CMM program:

Average	Standard Deviation
.0067263mm	.001539mm

Camber with the current version of the CMM program:

Average	Standard Deviation
.01692363mm	.001705mm

Camber using the customer's preferred method:

Average	Standard Deviation
.01667mm	.00479mm

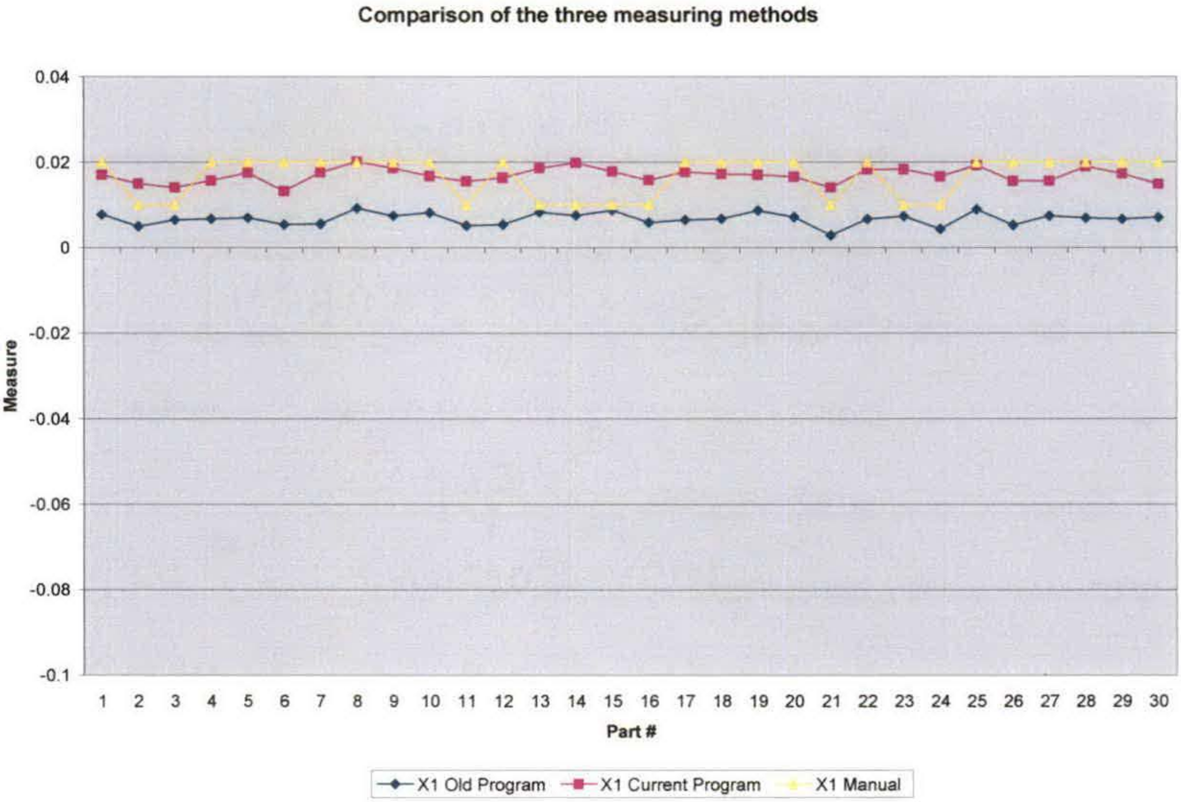


Chart 4-14: Shows all three camber measurements.

Study 2 Conclusion:

There is a difference of .010197mm between the two versions of CMM program which show an increase of camber. However, when comparing the readings from the CMM programs to the preferred customer method, the newer version of the CMM program is more consistent. The changing of the program is not the cause of the current camber issues.

Chapter 4.3

After completing studies one and two it was determined that the tool was the source of the camber specification issues with the brake pads. The customer requested a price reduction. A third study was conducted to see if a new specification for camber could be found. If the customer approves the new standard when presented with this data, a price reduction could be offered. A total of five hundred forty parts were measured for the study.

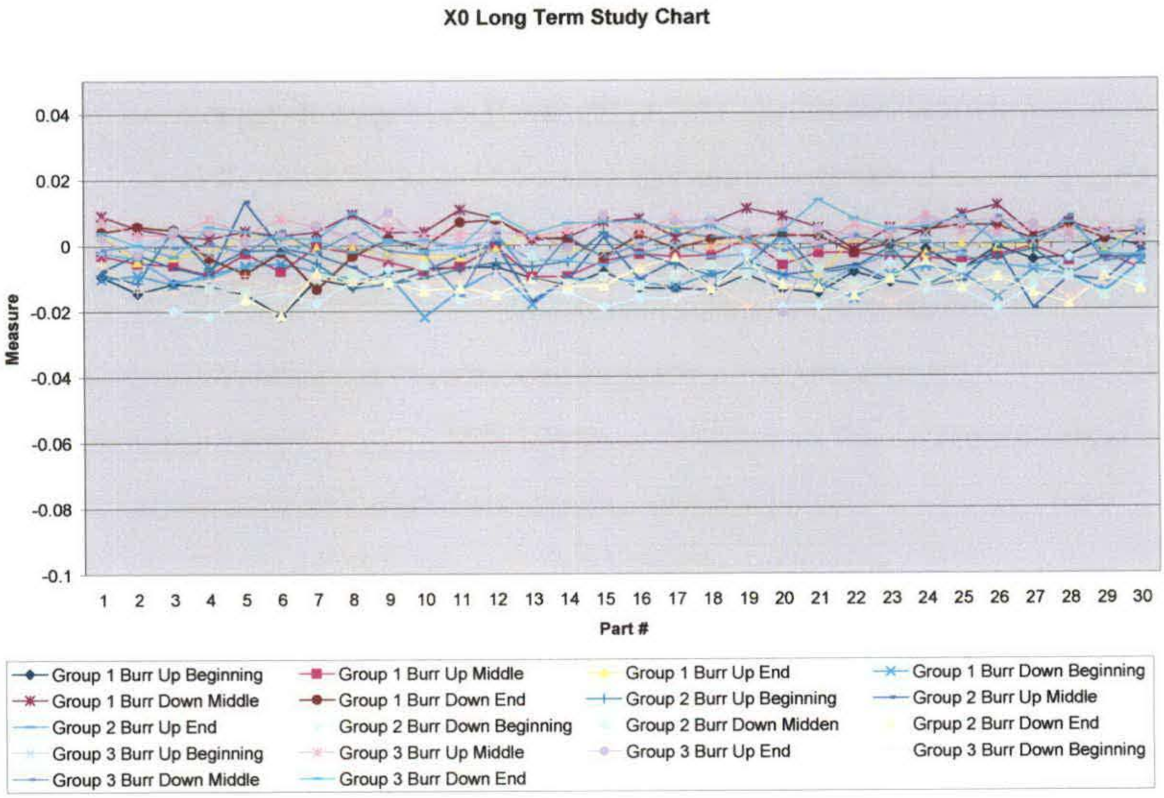


Chart 4-15: Shows camber measurements.

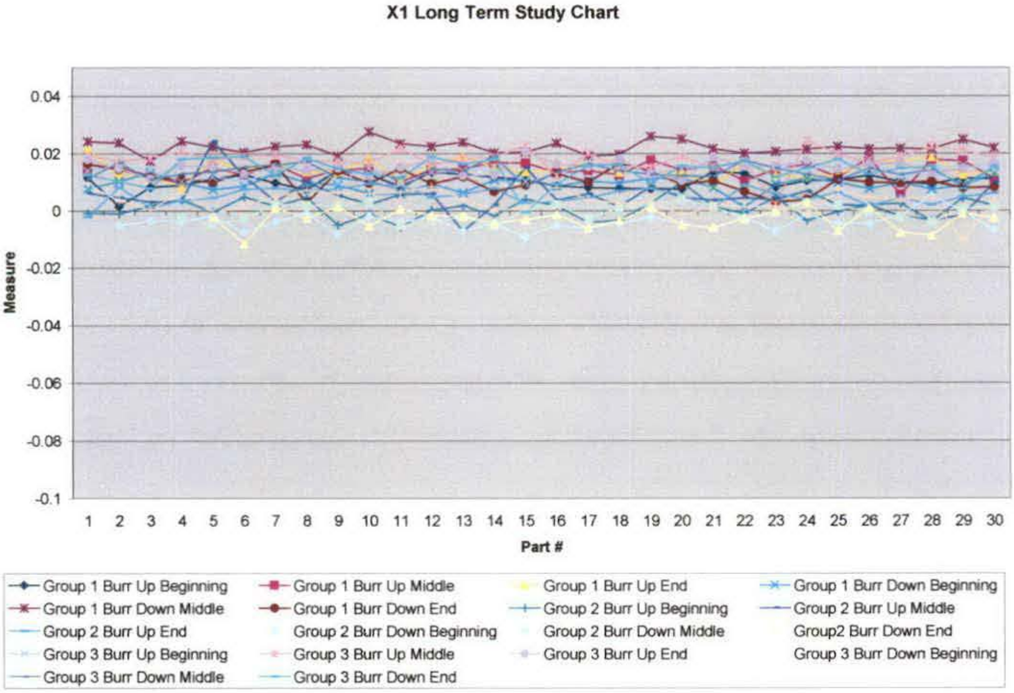


Chart 4-16: Shows camber measurements.

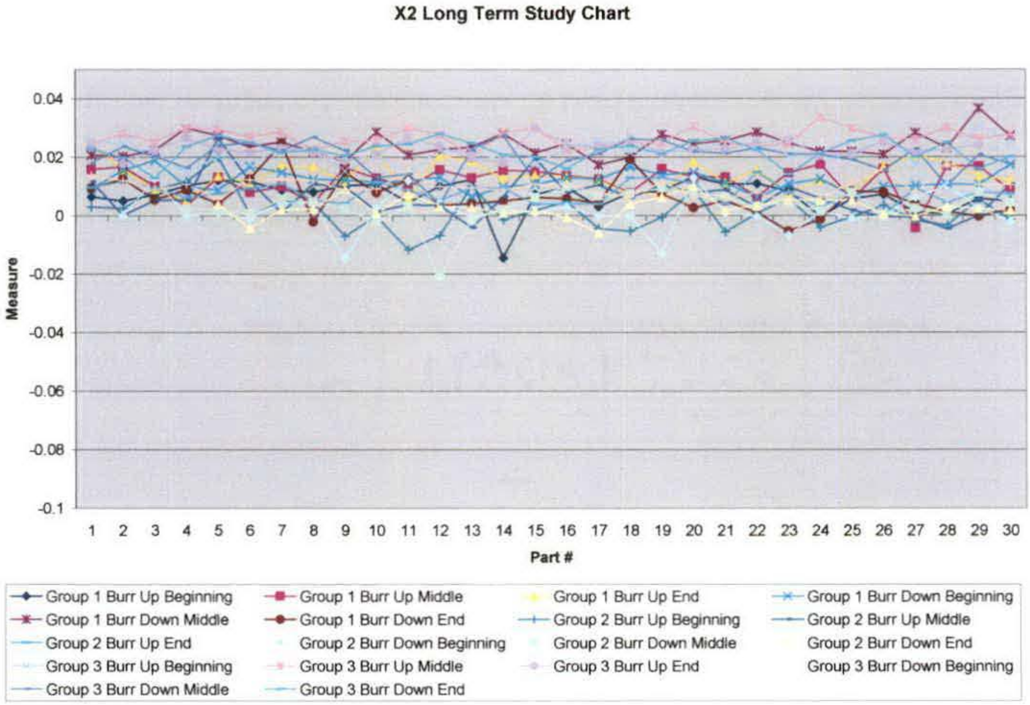


Chart 4-17: Shows camber measurements.

Average	0.005922347
Standard Deviation	0.010877038
Minimum	-0.0218
Maximum	0.036704

The following equation was used to calculate the proposed new standard:

Proposed New Standard = Average + (4 * Standard Deviation)
Proposed New Standard = 0.005922347 + (4 * 0.010877038)
Proposed New Standard = 0.005922347 + 0.043508152
Proposed New Standard = 0.049430499

The following equation was used to calculate the capability index (CP).

CP = 0.1 / (6 * Standard Deviation)

A 99.73% spread is represented by a multiplier of six which is plus or minus three sigma which represents the full spread of the curve.

CP = 0.1 / (6 * 0.010877038)
CP = 0.1 / (0.06526228)
CP = 1.532279897

The following equation was used to calculate the process performance (CPK).

$$CPK = \frac{(\text{Proposed new Standard} - \text{Average})}{(3 * \text{Standard Deviation})}$$

A 95.45% spread is represented by a multiplier of six which is plus or minus two sigma which represents the full spread of the curve.

$$CPK = \frac{(0.049430499 - 0.005922347)}{(3 * 0.010877038)}$$

$$CPK = \frac{0.043508152}{0.032631114}$$

CPK= 1.33

At 0.049 micrometers the process would be capable.

Chapter V Results

In conclusion, the automotive manufacturer in central Kentucky is producing a consistent part; however, the camber is in the wrong direction. There are three possible solutions for correcting camber in the part-changing the tool, changing the specification, or continuing using the current solution. Each of these solutions would help in correcting the camber but would also have significant drawbacks as well.

The first solution would be to change the tool inside of the press to make the camber as the part is being produced. This solution is possible; the tool would have to be cut so that the camber would be produced in the correct direction. However, this raises other issues. If the tool was to chip or break, production on the part would have to stop while the tool is removed from the machine, ground to remove the chip / break, and then cut to the correct shape. This process is very costly to the manufacturing process because of the time it takes to grind and cut the tool. It slows down production which makes it difficult to meet orders and delivery dates. The second drawback to this solution is that every time a tool is cut, the same shape is not being produced. The same part is being produced, but the camber specification is not being met. For example, production has stated the camber of the part is forty micrometers. The tool breaks and is repaired and production starts again. However, camber is one hundred micrometer; which is too high. Production is stopped again, and the tool is repaired, when production starts again, the camber is now ten micrometers and is too low. Basically, there would be a lot of down time while adjustments are made to the tool, trying to get the correct camber specification. This is costing time and money to the company.

The second option is to find a new specification where it does not matter in what direction camber is going. This is what study three is showing; if specification for camber is changed to forty micrometers in the opposite direction, the camber specification would be capable. This would allow increased production of the part and a cost reduction to the customer. If the customer were to accept the new specification, the automotive manufacturer could lose its competitive edge over other manufacturers who are trying to achieve the same process, which could lead to loss of business.

The third option is to continue producing the part with the extra step that places the camber into the part. The drawback to this option is that it adds a step to the manufacturing process which adds time and cost to the product. The original intent of the study was to find out why the camber specification was not being met and to remove the extra step in the process. Just as in solution one, the tool used needs to be adjusted every time it is used, because the amount of camber that is needed is different from lot to lot. This adds time to the manufacturing process and cost more.

All three solutions point out that the tool needs to be changed in order to meet the camber specification. However, each solution can be very costly to the automotive manufacturer.

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Appendix I Chapter 4.1 Data

Burr Up
Beginning

Bin	X2	X1	X0
33562B30	0.006393	0.011504	-0.009395
33562B29	0.004994	0.001608	-0.014489
33562B28	0.00715	0.008256	-0.01165
33562B27	0.010272	0.008865	-0.012497
33562B26	0.012043	0.011167	-0.014747
33562B25	0.011693	0.012561	-0.021368
33562B24	0.008838	0.009724	-0.010186
33562B23.	0.008062	0.007396	-0.012438
33562B22	0.010258	0.01417	-0.008239
33562B21	0.010721	0.012675	-0.006934
33562B20	0.004563	0.008508	-0.006879
33562B19	0.010023	0.013529	-0.006605
33562B18	0.012363	0.012818	-0.01003
33562B17	-0.014484	0.011702	-0.012353
33562B16	0.00724	0.010798	-0.008202
33562B15	0.009519	0.008642	-0.013113
33562B14	0.003092	0.008121	-0.013436
33562B13	0.00787	0.007764	-0.013837
33562B12	0.008321	0.007631	-0.009313
33562B11	0.01329	0.007566	-0.013846
33562B10	0.010669	0.013678	-0.014792
33562B9	0.010896	0.01303	-0.00855
33562B8	0.008379	0.008228	-0.011677
33562B7	-0.000229	0.010467	-0.001654
33562B6	0.005796	0.010598	-0.008057
33562B5	0.007232	0.012342	-0.000945
33562B4	0.001163	0.01003	-0.004889
33562B3	0.000653	0.009274	-0.003873
33562B2	0.005814	0.011279	0.001593
33562B1	0.004978	0.01109	-0.000949

Middle

Bin	X2	X1	X0
33562M30	0.015799	0.01418	-0.003058
33562M29	0.016617	0.015415	-0.005369
33562M28	0.010077	0.012117	-0.006042
33562M27	0.003334	0.009644	-0.009046
33562M26	0.013132	0.015188	-0.002439
33562M25	0.007956	0.012588	-0.007875
33562M24	0.00989	0.016178	-0.000382
33562M23	0.004257	0.011268	-0.002204
33562M22	0.016341	0.014337	-0.005012
33562M21	0.012817	0.014793	-0.007872
33562M20	0.009715	0.010156	-0.00639
33562M19	0.015731	0.014288	-0.000373
33562M18	0.012934	0.014669	-0.009713
33562M17	0.01546	0.016821	-0.009556
33562M16	0.015215	0.016683	-0.004926
33562M15	0.013696	0.013355	-0.00283
33562M14	0.012487	0.014038	-0.003679
33562M13	0.007716	0.012555	-0.003332
33562M12	0.015991	0.017658	0.001509
33562M11	0.013222	0.014309	-0.006305
33562M10	0.013167	0.015768	-0.002692
33562M9	0.006361	0.010435	-0.002748
33562M8	0.01464	0.01444	-0.004107
33562M7	0.017523	0.01621	-0.004145
33562M6	0.005497	0.011567	-0.005526
33562M5	0.016032	0.01842	-0.003506
33562M4	-0.00424	0.00568	-0.000855
33562M3	0.016932	0.017748	-0.005233
33562M2	0.016875	0.017466	-0.003218
33562M1	0.00858	0.01104	-0.007832

End

Bin	X2	X1	X0
33526E30	0.024422	0.021766	0.003345
33526E29	0.015596	0.012421	-0.004755
33256E28	0.00905	0.011864	-0.003337
33562E27	0.005114	0.008622	-0.002065
33562E26	0.013593	0.017738	0.003292
33526E25	0.011145	0.01399	0.002724
33526E24	0.01693	0.016371	-0.000724
33526E23	0.016653	0.013595	-0.000925
33526E22	0.011701	0.013562	-0.002602
33526E21	0.022728	0.018085	-0.003613
33526E20	0.006122	0.010575	-0.003355
33526E19	0.020449	0.016236	-0.001172
33526E18	0.018476	0.01875	0.003758
33526E17	0.012754	0.015185	-0.001321
33526E16	0.01398	0.013605	-0.002506
33526E15	0.01343	0.014361	0.00119
33526E14	0.012357	0.016948	0.005415
33526E13	0.007329	0.013411	-0.000146
33526E12	0.007548	0.013234	0.001411
33526E11	0.018346	0.013371	-0.001734
33526E10	0.011254	0.008898	-0.01042
33526E9	0.015616	0.016226	0.001827
33526E8	0.007604	0.012532	0.000328
33526E7	0.012083	0.011658	-0.002883
33526E6	0.008119	0.012521	-0.000311
33526E5	0.016609	0.016913	-0.000906
33526E4	0.020641	0.017348	-0.000653
33526E3	0.018092	0.018788	0.002228
33526E2	0.013461	0.012497	-0.001548
33526E1	0.012096	0.013633	0.004727

Burr Down Beginning

Bin	X2	X1	X0
34925-30B	0.009175	0.007618	-0.01018
34925-29B	0.015514	0.010251	-0.009032
34925-28B	0.018814	0.01334	-0.011787
34925-27B	0.009851	0.00991	-0.008682
34925-26B	0.008776	0.007369	-0.006196
34925-25B	0.016787	0.008555	-0.005457
34925-24B	0.014823	0.01305	-0.00791
34925-23B	0.012491	0.009946	-0.010276
34925-22B	0.012262	0.009	-0.00911
34925-21B	0.011499	0.005954	-0.0218
34925-20B	0.011945	0.005879	-0.013672
34925-19B	0.013103	0.009402	-0.007456
34925-18B	0.006506	0.006209	-0.017985
34925-17B	0.009824	0.010796	-0.010333
34925-16B	0.010599	0.010497	-0.010366
34925-15B	0.013046	0.008565	-0.011407
34925-14B	0.012404	0.010391	-0.012982
34925-13B	0.016651	0.009615	-0.008956
34925-12B	0.013965	0.011409	-0.007296
34925-11B	0.014709	0.01112	-0.009506
34925-10B	0.011254	0.008131	-0.011628
34925-9B	0.006134	0.001123	-0.01664
34925-8B	0.010799	0.0092	-0.009403
34925-7B	0.012468	0.011294	-0.006988
34925-6B	0.006755	0.009921	-0.00898
34925-5B	0.009845	0.007621	-0.016071
34925-4B	0.010165	0.009766	-0.007823
34925-3B	0.010704	0.007484	-0.009663
34925-2B	0.010593	0.008646	-0.014477
34925-1B	0.017467	0.012855	-0.006072

Middle

Bin	X2	X1	X0
34925-30M	0.020685	0.02419	0.009025
34925-29M	0.020214	0.023715	0.005124
34925-28M	0.022334	0.017313	0.00313
34925-27M	0.029946	0.024288	0.002137
34925-26M	0.027369	0.022283	0.004377
34925-25M	0.023546	0.020427	0.002943
34925-24M	0.025176	0.022418	0.004132
34925-23M	0.021799	0.023139	0.009484
34925-22M	0.018494	0.019118	0.003935
34925-21M	0.028593	0.027627	0.004031
34925-20M	0.02074	0.023546	0.010753
34925-19M	0.022541	0.02249	0.008165
34925-18M	0.02339	0.023971	0.001473
34925-17M	0.028039	0.020331	0.002316
34925-16M	0.021487	0.020511	0.007022
34925-15M	0.024568	0.023591	0.008004
34925-14M	0.0174	0.019122	0.002109
34925-13M	0.019907	0.019673	0.006319
34925-12M	0.027709	0.025984	0.010877
34925-11M	0.024586	0.025063	0.008551
34925-10M	0.0256	0.021635	0.004977
34925-9M	0.028482	0.020044	-0.00164
34925-8M	0.024832	0.020602	0.004881
34925-7M	0.021899	0.021539	0.003619
34925-6M	0.021828	0.022384	0.00898
34925-5M	0.02089	0.021615	0.011716
34925-4M	0.028318	0.021749	0.002451
34925-3M	0.023054	0.021628	0.00624
34925-2M	0.036704	0.02491	0.002951
34925-1M	0.027124	0.021901	0.003502

End

Bin	X2	X1	X0
35914(E30)	0.009344	0.016335	0.004078
35914(E29)	0.012521	0.014526	0.005711
35914(E28)	0.005458	0.011747	0.004667
35914(E27)	0.008686	0.011007	-0.003813
35914(E26)	0.004065	0.010001	-0.008589
35914(E25)	0.01257	0.013515	-0.002066
35914(E24)	0.02473	0.016285	-0.013376
35914(E23)	-0.002066	0.00285	-0.003334
35914(E22)	0.014813	0.013987	0.001839
35914(E21)	0.007859	0.009633	-0.00042
35914(E20)	0.012234	0.014713	0.006971
35914(E19)	0.003576	0.009497	-0.049021
35914(E18)	0.004121	0.011884	0.007715
35914(E17)	0.004926	0.00673	0.00226
35914(E16)	0.006243	0.008998	0.001807
35914(E15)	0.005793	0.013045	-0.003633
35914(E14)	0.004248	0.009967	0.002974
35914(E13)	0.019225	0.016508	-0.001167
35914(E12)	0.007452	0.013744	0.001494
35914(E11)	0.002668	0.009121	0.002386
35914(E10)	0.005075	0.010503	0.002647
35914(E9)	0.001027	0.006669	0.002418
35914(E8)	-0.005303	0.003061	-0.002627
35914(E7)	-0.00124	0.003923	-0.000086
35914(E6)	0.008399	0.011018	0.004204
35914(E5)	0.007972	0.00993	0.005683
35914(E4)	0.00398	0.009611	0.005511
35914(E3)	0.001415	0.010165	0.001224
35914(E2)	-0.000281	0.007904	0.005526
35914(E1)	0.002158	0.008248	0.001347

Appendix II Chapter 4.2 Data

Bin	Date	X1 Old Program	X1 Current Program	X1 Manual	Difference
30	3/8/2010	0.007725	0.01704	0.02	-0.009315
29	3/8/2010	0.004922	0.01498	0.01	-0.010058
28	3/8/2010	0.006443	0.014062	0.01	-0.007619
27	3/8/2010	0.006693	0.015713	0.02	-0.009020
26	3/8/2010	0.006941	0.017559	0.02	-0.010618
25	3/8/2010	0.005393	0.013227	0.02	-0.007834
24	3/8/2010	0.005566	0.017639	0.02	-0.012073
23	3/8/2010	0.009213	0.020132	0.02	-0.010919
22	3/8/2010	0.007407	0.018576	0.02	-0.011169
21	3/8/2010	0.008198	0.01678	0.02	-0.008582
20	3/8/2010	0.005142	0.01558	0.01	-0.010438
19	3/8/2010	0.005407	0.016357	0.02	-0.010950
18	3/8/2010	0.008264	0.01858	0.01	-0.010316
17	3/8/2010	0.007537	0.019858	0.01	-0.012321
16	3/8/2010	0.008755	0.017855	0.01	-0.009100
15	3/8/2010	0.005835	0.015799	0.01	-0.009964
14	3/8/2010	0.006452	0.01772	0.02	-0.011268
13	3/8/2010	0.006731	0.01722	0.02	-0.010489
12	3/8/2010	0.008662	0.017083	0.02	-0.008421
11	3/8/2010	0.007115	0.016603	0.02	-0.009488
10	3/8/2010	0.002866	0.014113	0.01	-0.011247
9	3/8/2010	0.006653	0.018287	0.02	-0.011634
8	3/8/2010	0.007295	0.018369	0.01	-0.011074
7	3/8/2010	0.004349	0.016699	0.01	-0.012350
6	3/8/2010	0.00894	0.01931	0.02	-0.010370
5	3/8/2010	0.005259	0.015634	0.02	-0.010375
4	3/8/2010	0.00741	0.015657	0.02	-0.008247
3	3/8/2010	0.006929	0.019002	0.02	-0.012073
2	3/8/2010	0.006641	0.017346	0.02	-0.010705
1	3/8/2010	0.007046	0.014929	0.02	-0.007883
	Average	0.0067263	0.016923633	0.016666667	-0.010197
	SD	0.001539	0.001705	0.004794633	

Appendix III Chapter 4.3 Data

X0	Group 1 Burr Up Beginning	Group 1 Burr Up Middle	Group 1 Burr Up End
30	-0.009395	-0.003058	0.003345
29	-0.014489	-0.005369	-0.004755
28	-0.01165	-0.006042	-0.003337
27	-0.012497	-0.009046	-0.002065
26	-0.014747	-0.002439	0.003292
25	-0.021368	-0.007875	0.002724
24	-0.010186	-0.000382	-0.000724
23	-0.012438	-0.002204	-0.000925
22	-0.008239	-0.005012	-0.002602
21	-0.006934	-0.007872	-0.003613
20	-0.006879	-0.00639	-0.003355
19	-0.006605	-0.000373	-0.001172
18	-0.01003	-0.009713	0.003758
17	-0.012353	-0.009556	-0.001321
16	-0.008202	-0.004926	-0.002506
15	-0.013113	-0.00283	0.00119
14	-0.013436	-0.003679	0.005415
13	-0.013837	-0.003332	-0.000146
12	-0.009313	0.001509	0.001411
11	-0.013846	-0.006305	-0.001734
10	-0.014792	-0.002692	-0.01042
9	-0.00855	-0.002748	0.001827
8	-0.011677	-0.004107	0.000328
7	-0.001654	-0.004145	-0.002883
6	-0.008057	-0.005526	-0.000311
5	-0.000945	-0.003506	-0.000906
4	-0.004889	-0.000855	-0.000653
3	-0.003873	-0.005233	0.002228
2	0.001593	-0.003218	-0.001548
1	-0.000949	-0.007832	0.004727

X1	Group 1 Burr Up Beginning	Group 1 Burr Up Middle	Group 1 Burr Up End
30	0.011504	0.01418	0.021766
29	0.001608	0.015415	0.012421
28	0.008256	0.012117	0.011864
27	0.008865	0.009644	0.008622

26	0.011167	0.015188	0.017738
25	0.012561	0.012588	0.01399
24	0.009724	0.016178	0.016371
23	0.007396	0.011268	0.013595
22	0.01417	0.014337	0.013562
21	0.012675	0.014793	0.018085
20	0.008508	0.010156	0.010575
19	0.013529	0.014288	0.016236
18	0.012818	0.014669	0.01875
17	0.011702	0.016821	0.015185
16	0.010798	0.016683	0.013605
15	0.008642	0.013355	0.014361
14	0.008121	0.014038	0.016948
13	0.007764	0.012555	0.013411
12	0.007631	0.017658	0.013234
11	0.007566	0.014309	0.013371
10	0.013678	0.015768	0.008898
9	0.01303	0.010435	0.016226
8	0.008228	0.01444	0.012532
7	0.010467	0.01621	0.011658
6	0.010598	0.011567	0.012521
5	0.012342	0.01842	0.016913
4	0.01003	0.00568	0.017348
3	0.009274	0.017748	0.018788
2	0.011279	0.017466	0.012497
1	0.01109	0.01104	0.013633

X2	**Group 1 Burr Up Beginning**	**Group 1 Burr Up Middle**	**Group 1 Burr Up End**
30	0.006393	0.015799	0.024422
29	0.004994	0.016617	0.015596
28	0.00715	0.010077	0.00905
27	0.010272	0.003334	0.005114
26	0.012043	0.013132	0.013593
25	0.011693	0.007956	0.011145
24	0.008838	0.00989	0.01693
23	0.008062	0.004257	0.016653
22	0.010258	0.016341	0.011701
21	0.010721	0.012817	0.022728
20	0.004563	0.009715	0.006122
19	0.010023	0.015731	0.020449

18	0.012363	0.012934	0.018476
17	-0.014484	0.01546	0.012754
16	0.00724	0.015215	0.01398
15	0.009519	0.013696	0.01343
14	0.003092	0.012487	0.012357
13	0.00787	0.007716	0.007329
12	0.008321	0.015991	0.007548
11	0.01329	0.013222	0.018346
10	0.010669	0.013167	0.011254
9	0.010896	0.006361	0.015616
8	0.008379	0.01464	0.007604
7	-0.000229	0.017523	0.012083
6	0.005796	0.005497	0.008119
5	0.007232	0.016032	0.016609
4	0.001163	-0.00424	0.020641
3	0.000653	0.016932	0.018092
2	0.005814	0.016875	0.013461
1	0.004978	0.00858	0.012096

X0	**Group 1 Burr Down Beginning**	**Group 1 Burr Down Middle**	**Group 1 Burr Down End**
30	-0.01018	0.009025	
29	-0.009032	0.005124	0.004078
28	-0.011787	0.00313	0.005711
27	-0.008682	0.002137	0.004667
26	-0.006196	0.004377	-0.003813
25	-0.005457	0.002943	-0.008589
24	-0.00791	0.004132	-0.002066
23	-0.010276	0.009484	-0.013376
22	-0.00911	0.003935	-0.003334
21	-0.0218	0.004031	0.001839
20	-0.013672	0.010753	-0.00042
19	-0.007456	0.008165	0.006971
18	-0.017985	0.001473	0.007715
17	-0.010333	0.002316	0.00226
16	-0.010366	0.007022	0.001807
15	-0.011407	0.008004	-0.003633
14	-0.012982	0.002109	0.002974
13	-0.008956	0.006319	-0.001167

12	-0.007296	0.010877	0.001494
11	-0.009506	0.008551	0.002386
10	-0.011628	0.004977	0.002647
9	-0.01664	-0.00164	0.002418
8	-0.009403	0.004881	-0.002627
7	-0.006988	0.003619	-0.000086
6	-0.00898	0.00898	0.004204
5	-0.016071	0.011716	0.005683
4	-0.007823	0.002451	0.005511
3	-0.009663	0.00624	0.001224
2	-0.014477	0.002951	0.005526
1	-0.006072	0.003502	0.001347

X1	**Group 1 Burr Down Beginning**	**Group 1 Burr Down Middle**	**Group 1 Burr Down End**
30	0.007618	0.02419	0.016335
29	0.010251	0.023715	0.014526
28	0.01334	0.017313	0.011747
27	0.00991	0.024288	0.011007
26	0.007369	0.022283	0.010001
25	0.008555	0.020427	0.013515
24	0.01305	0.022418	0.016285
23	0.009946	0.023139	0.00285
22	0.009	0.019118	0.013987
21	0.005954	0.027627	0.009633
20	0.005879	0.023546	0.014713
19	0.009402	0.02249	0.009497
18	0.006209	0.023971	0.011884
17	0.010796	0.020331	0.00673
16	0.010497	0.020511	0.008998
15	0.008565	0.023591	0.013045
14	0.010391	0.019122	0.009967
13	0.009615	0.019673	0.016508
12	0.011409	0.025984	0.013744
11	0.01112	0.025063	0.009121
10	0.008131	0.021635	0.010503
9	0.001123	0.020044	0.006669
8	0.0092	0.020602	0.003061
7	0.011294	0.021539	0.003923
6	0.009921	0.022384	0.011018

5	0.007621	0.021615	0.00993
4	0.009766	0.021749	0.009611
3	0.007484	0.021628	0.010165
2	0.008646	0.02491	0.007904
1	0.012855	0.021901	0.008248

X2	Group 1 Burr Down Beginning	Group 1 Burr Down Middle	Group 1 Burr Down End
30	0.009175	0.020685	0.009344
29	0.015514	0.020214	0.012521
28	0.018814	0.022334	0.005458
27	0.009851	0.029946	0.008686
26	0.008776	0.027369	0.004065
25	0.016787	0.023546	0.01257
24	0.014823	0.025176	0.02473
23	0.012491	0.021799	-0.002066
22	0.012262	0.018494	0.014813
21	0.011499	0.028593	0.007859
20	0.011945	0.02074	0.012234
19	0.013103	0.022541	0.003576
18	0.006506	0.02339	0.004121
17	0.009824	0.028039	0.004926
16	0.010599	0.021487	0.006243
15	0.013046	0.024568	0.005793
14	0.012404	0.0174	0.004248
13	0.016651	0.019907	0.019225
12	0.013965	0.027709	0.007452
11	0.014709	0.024586	0.002668
10	0.011254	0.0256	0.005075
9	0.006134	0.028482	0.001027
8	0.010799	0.024832	-0.005303
7	0.012468	0.021899	-0.00124
6	0.006755	0.021828	0.008399
5	0.009845	0.02089	0.007972
4	0.010165	0.028318	0.00398
3	0.010704	0.023054	0.001415
2	0.010593	0.036704	-0.000281
1	0.017467	0.027124	0.002158

X0	Group 2 Burr Up	Group 2 Burr Up	Group 2 Burr Up End

	Beginning	Middle	
30	-0.008781	-0.007791	-0.002192
29	-0.011399	-0.002701	-0.00401
28	0.005062	-0.006755	-0.010927
27	-0.0069	-0.009155	-0.009857
26	-0.001583	0.013368	-0.006072
25	-0.001193	-0.000684	-0.002235
24	-0.005497	-0.002874	0.001465
23	-0.013019	-0.006571	-0.002036
22	-0.011745	-0.012228	0.001717
21	-0.010026	-0.007791	-0.00173
20	-0.007097	-0.003277	-0.000682
19	-0.005284	0.000434	0.001509
18	-0.006632	-0.01694	-0.004543
17	-0.005049	-0.010493	-0.004776
16	0.003718	0.002277	-0.006224
15	-0.002472	-0.01041	-0.002631
14	-0.006069	-0.005	-0.000281
13	-0.009441	-0.012577	-0.003887
12	-0.006566	-0.005103	-0.003115
11	0.003066	-0.009434	0.001454
10	-0.008962	-0.008216	-0.012849
9	-0.007392	-0.006423	-0.007334
8	-0.000963	-0.011257	-0.003268
7	-0.012918	-0.01283	0.000685
6	-0.007465	-0.01124	-0.003779
5	-0.004101	-0.00141	-0.006378
4	-0.001797	-0.019493	-0.007557
3	-0.009498	-0.010074	-0.005263
2	-0.004346	-0.011377	-0.003382
1	-0.004192	-0.002245	-0.003599

X1	Group 2 Burr Up Beginning	Group 2 Burr Up Middle	Group 2 Burr Up End
30	-0.00086	0.006183	-0.00218
29	-0.00099	0.004645	0.008209
28	0.001808	0.003085	0.001237
27	0.003907	0.003326	0.003669
26	-0.000439	0.024344	0.004516
25	0.004837	0.012047	0.007464
24	0.001744	0.003291	0.008006

23	0.004692	0.009964	0.007069
22	-0.005077	0.005462	0.00766
21	-0.001127	0.002375	0.009412
20	-0.005645	0.005699	0.008885
19	0.000257	0.006061	0.004742
18	0.001831	-0.007147	0.005849
17	-0.00165	0.00208	0.00772
16	0.004042	0.015079	0.002719
15	0.001779	0.003791	0.003316
14	-0.004127	0.005947	0.004602
13	-0.003296	0.001516	0.006803
12	0.002739	0.008347	0.007778
11	0.009838	0.00478	0.00547
10	0.001537	0.003733	0.000989
9	-0.001011	0.004517	0.009032
8	0.004831	0.003933	0.005913
7	-0.003399	0.006802	0.003978
6	-0.000336	0.001963	0.006393
5	0.002012	0.001891	0.001634
4	0.002563	-0.002022	0.004503
3	-0.003606	-0.003173	0.002156
2	0.0045	-0.001652	0.004882
1	0.001748	0.009943	0.006039

X2	**Group 2 Burr Up Beginning**	**Group 2 Burr Up Middle**	**Group 2 Burr Up End**
30	0.002946	0.011592	0.009593
29	0.002578	0.000162	0.011736
28	0.008776	0.005284	0.009413
27	0.011693	0.005304	0.006216
26	0.019905	0.026417	0.007573
25	0.00075	0.011774	0.009202
24	0.005102	0.001203	0.010817
23	0.004644	0.010769	0.005287
22	-0.006998	0.009864	0.00423
21	-0.000167	0.001563	0.011322
20	-0.01169	0.003786	0.008782
19	-0.00671	0.003526	0.005189
18	0.010164	-0.004041	0.00952
17	-0.001362	0.006451	0.009339
16	0.001851	0.019601	0.003984

15	0.004794	0.007947	0.004192
14	-0.004423	0.010459	0.004063
13	-0.005245	0.006158	0.012955
12	-0.000518	0.010439	0.012945
11	0.008671	0.007948	0.011075
10	-0.005601	0.008759	0.004128
9	0.000819	0.002797	0.014799
8	0.005971	0.00974	0.007844
7	-0.003928	0.005865	0.002999
6	-0.000435	0.001879	0.007573
5	0.003511	-0.00037	0.000169
4	-0.001619	-0.000527	0.009378
3	-0.003337	-0.004445	0.00448
2	0.005441	0.000128	0.008007
1	-0.001355	0.010609	0.007466

X0	**Group 2 Burr Down Beginning**	**Group 2 Burr Down Midden**	**Group 2 Burr Down End**
30			
29			
28	-0.019763		
27	-0.021674	-0.012915	
26	-0.016751	-0.014162	-0.016143
25	-0.014125	-0.013222	-0.021199
24	-0.017379	-0.009914	-0.008195
23	-0.010675	-0.008892	-0.010801
22	-0.007127	-0.011302	-0.011059
21	-0.012402	-0.006061	-0.013864
20	-0.016929	-0.015377	-0.012736
19	-0.014994	0.008973	-0.015042
18	-0.014636	-0.003243	-0.010201
17	-0.01445	-0.011806	-0.012732
16	-0.019024	-0.009852	-0.012422
15	-0.016244	-0.012398	-0.007127
14	-0.016258	-0.009477	-0.003794
13	-0.013454	-0.006289	-0.013421
12	-0.002499	-0.009189	-0.005645
11	-0.01913	-0.003294	-0.012387
10	-0.018598	-0.007869	-0.013276

9	-0.014368	-0.012356	-0.01565
8	-0.005514	-0.010655	-0.010575
7	-0.014002	-0.012015	-0.005126
6	-0.01398	-0.007579	-0.01322
5	-0.019543	-0.010176	-0.009935
4	-0.013004	-0.01084	-0.014746
3	-0.004101	-0.010026	-0.018299
2	-0.008622	-0.015929	-0.009946
1	-0.011769	-0.008353	-0.013681

X1	**Group 2 Burr Down Beginning**	**Group 2 Burr Down Middle**	**Group2 Burr Down End**
30			
29	-0.005082		
28	-0.003641		
27	-0.003567	-0.002808	
26	-0.001714	-0.004497	-0.001992
25	-0.007532	-0.00286	-0.011686
24	-0.003982	0.002339	0.001067
23	-0.000818	0.001981	-0.002577
22	-0.008374	0.001714	0.001433
21	-0.001915	0.003258	-0.005316
20	-0.004023	-0.005175	0.000655
19	-0.002187	-0.003588	-0.00157
18	-0.007144	-0.002291	-0.001815
17	-0.004208	-0.005236	-0.004307
16	-0.009303	0.000762	-0.00313
15	-0.005183	0.002253	-0.001306
14	-0.00603	-0.003061	-0.005967
13	-0.004342	0.001192	-0.003305
12	-0.002214	0.001667	0.001183
11	-0.004547	0.004022	-0.004934
10	-0.006331	0.001443	-0.005804
9	-0.002195	-0.00287	-0.002883
8	-0.007246	-0.000993	-0.000001
7	-0.001272	0.002535	0.00309
6	-0.004484	0.001753	-0.007054
5	-0.004478	-0.000472	0.001066
4	-0.001638	-0.00194	-0.007639
3	0.005309	-0.003956	-0.00868
2	-0.000265	0.000732	-0.000879

1	-0.00667	0.001536	-0.00251

X2	Group 2 Burr Down Beginning	Group 2 Burr Down Middle	Group 2 Burr Down End
30			
29	0.000029		
28	0.012625		
27	-0.000163	0.00235	
26	0.000946	0.001906	0.003971
25	-0.00099	0.000686	-0.004266
24	0.004358	0.005512	0.002018
23	0.004455	0.004582	0.002392
22	-0.014654	0.002512	0.008986
21	0.002738	-0.002364	0.000875
20	0.012007	0.003168	0.007353
19	0.004182	-0.020944	0.003269
18	-0.000528	-0.001464	0.00294
17	0.00216	0.002248	0.000891
16	0.001069	0.00625	0.001884
15	0.002979	0.009913	-0.000695
14	-0.00015	0.006711	-0.005915
13	-0.00006	0.007613	0.004023
12	-0.012971	0.009409	0.006444
11	0.012796	0.007906	0.010146
10	0.000919	0.006341	0.001872
9	-0.000211	0.003042	0.003592
8	-0.006608	0.004613	0.005429
7	0.001308	0.001464	0.005142
6	-0.000936	0.00792	0.005243
5	0.000051	-0.000168	0.000472
4	0.006236	0.002479	-0.000187
3	0.010065	0.000552	0.003112
2	0.002602	0.007933	0.002381
1	-0.002081	0.004435	0.00176

X0	Group 3 Burr Up Beginning	Group 3 Burr Up Middle	Group 3 Burr Up End
30	-0.002293	0.007417	0.002096
29	0.001409	0.003358	-0.002679
28	0.000634	0.003142	0.004322
27	-0.002406	0.007969	0.004428

26	0.00029	0.003462	0.001201
25	0.00024	0.008035	0.003151
24	-0.002583	0.005802	0.006052
23	0.001878	0.001547	0.002532
22	-0.003549	0.005498	0.010029
21	0.000622	0.002792	0.000634
20	-0.002396	0.003204	0.000141
19	-0.002575	0.004089	0.003996
18	-0.000876	0.002431	0.003308
17	-0.002276	0.004367	-0.000879
16	-0.002457	0.008266	0.009094
15	0.00012	0.004047	0.000302
14	-0.000951	0.008116	0.006974
13	0.008196	-0.000822	0.007218
12	-0.005918	0.001023	0.003414
11	-0.001073	0.005051	-0.020721
10	0.002002	-0.000586	0.004559
9	0.002201	0.005946	0.002393
8	0.00092	0.00271	0.004384
7	0.003045	0.0089	0.006596
6	-0.00215	0.003725	0.006377
5	0.002001	0.00338	0.007483
4	0.000361	0.004913	0.005731
3	0.001691	0.003703	0.000973
2	-0.001236	0.004611	0.003168
1	0.002484	-0.00018	0.005443

X1	**Group 3 Burr Up Beginning**	**Group 3 Burr Up Middle**	**Group 3 Burr Up End**
30	0.013994	0.019246	0.017844
29	0.015784	0.017373	0.01475
28	0.014283	0.01829	0.011259
27	0.010183	0.020919	0.015764
26	0.01188	0.017742	0.015293
25	0.01048	0.019011	0.013098
24	0.01339	0.019569	0.015217
23	0.017849	0.017354	0.014262
22	0.010136	0.017319	0.01483
21	0.015	0.016847	0.012127
20	0.009704	0.021801	0.015129
19	0.013452	0.016201	0.017661

18	0.013844	0.018028	0.012235
17	0.015294	0.018763	0.012469
16	0.010212	0.022754	0.020634
15	0.012248	0.01231	0.016293
14	0.017147	0.020202	0.015453
13	0.01427	0.015566	0.018048
12	0.013007	0.015064	0.012754
11	0.014601	0.019113	0.010513
10	0.015832	0.014905	0.018761
9	0.016118	0.016796	0.015384
8	0.015176	0.002245	0.015308
7	0.014437	0.024575	0.017456
6	0.015684	0.019751	0.014523
5	0.017915	0.016659	0.016141
4	0.011357	0.018791	0.016663
3	0.014351	0.02237	0.013173
2	0.015692	0.021144	0.014538
1	0.014302	0.018369	0.016721

X2	**Group 3 Burr Up Beginning**	**Group 3 Burr Up Middle**	**Group 3 Burr Up End**
30	0.025704	0.024586	
29	0.024417	0.028071	0.023869
28	0.021721	0.025216	0.017831
27	0.014855	0.030043	0.02247
26	0.02027	0.029426	0.026431
25	0.017759	0.027005	0.022656
24	0.022909	0.028488	0.021636
23	0.022769	0.022332	0.023099
22	0.015228	0.025407	0.021534
21	0.020509	0.025678	0.018738
20	0.014599	0.029847	0.020955
19	0.022414	0.027717	0.026507
18	0.021946	0.020038	0.023947
17	0.018958	0.028361	0.019551
16	0.017515	0.029958	0.01803
15	0.023212	0.022363	0.030085
14	0.025359	0.023031	0.024441
13	0.021692	0.024988	0.023315
12	0.021639	0.024968	0.026326
11	0.022381	0.030461	0.021399

10	0.02485	0.02471	0.022374
9	0.024112	0.023607	0.022672
8	0.02025	0.024718	0.02484
7	0.020127	0.033696	0.025853
6	0.019162	0.029744	0.020568
5	0.027917	0.026647	0.02123
4	0.017655	0.025911	0.025099
3	0.017529	0.030022	0.021848
2	0.030549	0.026003	0.022723
1	0.025399	0.027842	0.023985

X0	**Group 3 Burr Down Beginning**	**Group 3 Burr Down Middle**	**Group 3 Burr Down End**
30		-0.001201	0.003916
29	-0.005527	0.000015	0.000009
28	-0.013981	-0.0006	-0.003436
27	-0.014254	0.000623	0.005629
26	-0.010424	-0.002234	0.004242
25	-0.009159	0.004564	0.002264
24	-0.013788	-0.001797	0.002093
23	-0.010011	0.00369	0.009708
22	-0.011348	-0.001639	0.00082
21	-0.00899	-0.002724	0.001592
20	-0.010968	-0.015323	-0.000628
19	-0.010981	0.003644	0.009444
18	-0.007982	-0.010246	0.003551
17	-0.014372	0.002505	0.006603
16	-0.012339	-0.003878	0.00694
15	-0.011685	0.00009	0.007098
14	-0.006692	0.003452	0.00457
13	-0.015649	0.002319	0.00546
12	-0.011855	0.001922	0.000767
11	-0.018962	-0.002055	0.004039
10	-0.014993	-0.000753	0.013405
9	-0.010266	0.002374	0.007779
8	-0.013474	-0.000045	0.00447
7	-0.017986	-0.003529	0.00514
6	-0.012771	-0.002505	0.008325
5	-0.01054	0.008138	0.000126
4	-0.01512	-0.001103	0.001241

3	-0.010364	0.008386	0.006387
2	-0.016342	-0.005453	-0.003164
1	-0.010883	-0.004428	0.003799

X1	**Group 3 Burr Down Beginning**	**Group 3 Burr Down Middle**	**Group 3 Burr Down End**
30	0.009099	0.011239	0.012528
29	0.00366	0.016827	0.010216
28	0.000501	0.010978	0.007806
27	0.00675	0.012917	0.017974
26	-0.000821	0.013597	0.01854
25	0.00183	0.015346	0.018944
24	0.004971	0.016064	0.012512
23	0.007293	0.017209	0.018301
22	0.006158	0.011587	0.014798
21	0.005964	0.010224	0.012858
20	0.006431	0.007566	0.011573
19	0.008495	0.014645	0.018809
18	0.004245	0.013952	0.016344
17	0.000168	0.018991	0.017902
16	0.001083	0.0086	-0.000356
15	0.007957	0.013515	0.00923
14	0.00407	0.016278	0.015794
13	0.002622	0.014145	0.016156
12	0.003176	0.012666	0.009621
11	-0.001461	0.012161	0.015526
10	0.001607	0.011978	0.01507
9	0.001491	0.017627	0.017407
8	0.001467	0.014898	0.011746
7	-0.000727	0.012779	0.01498
6	0.007012	0.010687	0.01785
5	0.004705	0.014789	0.012851
4	0.00406	0.01264	0.01474
3	0.004387	0.014321	0.015433
2	-0.010651	0.008868	0.00764
1	0.0033	0.015118	0.015404

X2	**Group 3 Burr Down Beginning**	**Group 3 Burr Down Middle**	**Group 3 Burr Down End**
30	0.013631	0.018064	0.022895
29	0.011992	0.023608	0.019735
28	0.008865	0.020309	0.012959

27	0.010704	0.016368	0.023606
26	0.005752	0.023977	0.027327
25	0.012167	0.024941	0.024907
24	0.012426	0.022323	0.021533
23	0.01213	0.026856	0.022639
22	0.008658	0.022301	0.020493
21	0.009157	0.012986	0.023815
20	0.015262	0.014247	0.024459
19	0.009919	0.003968	0.027939
18	0.009535	0.022572	0.024757
17	0.008761	0.027481	0.020879
16	0.010761	0.011972	0.020117
15	0.010572	0.018831	0.016099
14	0.007785	0.021177	0.02257
13	0.006612	0.026197	0.023814
12	0.011306	0.025844	0.02109
11	0.006575	0.021917	0.02557
10	0.005959	0.021371	0.026351
9	0.00773	0.023087	0.022525
8	0.005043	0.021098	0.014188
7	0.006054	0.020799	0.021188
6	0.011365	0.019123	0.025556
5	0.015365	0.015557	0.027448
4	0.008124	0.022854	0.0201
3	0.017155	0.010182	0.024889
2	0.010593	0.020806	0.015964
1	0.010456	0.01755	0.02003

Average	0.005922347	
Standard Deviation	0.010877038	
Min	-0.0218	
Max	0.036704	
Standard	**0.0494305**	Spec needed to be 1.33 CPK capable
CPK	1.333333333	
Cp	1.532279844	CP based on 0.1 overall tolerance