Profile Gage

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by

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ABSTRACT

Design and validate a part specific profile gage that is accurate and more efficient to the comparator and chart method that is used now. When designing a gage there are different factors to look at, like the gage department's goal, the program teams' goal and the goal of the end customer. The goals of each department have characteristics that over lap like accuracy and efficiency. The difference is the approach each group takes. This design project has shown that there are many different considerations that have an impact on the design and approval of something. Listening to one group or person will provoke redesigns and changes when the other departments look at the drawings.

INTRODUCTION:

Currently to inspect a part both the customer and supplier are using a comparator and chart. A comparator is a large magnifying glass; the chart is a transparency of the part's drawing. There is some error that can occur in this process with the human eye looking at the screen. The supplier is unable to verify the part on a coordinate measuring machine since their machine is not capable of defining the profile. Currently the supplier is sending the customer parts where the profile is not the same as the drawing. Therefore the solution proposed is a functional gage to remedy the incorrect parts making it to the customer.

RESEARCH:

COORDINATE MEASURING MACHINE (CMM)

The Coordinate Measuring Machine (CMM) (1) is the ideal method of checking the profile of a part. A Nikon CMM requires an operator with knowledge of Geometric dimensioning and tolerance along with programming skills. The CMM provides variable data to validate if the part is conforming to the drawing. A CMM is not part specific and can be used to check other parts and assemblies. The CMM is repeatable in validation of a part.

A CMM requires electricity and money at the beginning of the project for the actual machine, a program, a programmer, and maintenance. The CMM is a machine that is calibrated then used in one location. The CMM is not made for portability between the supplier and customer.

Figure 1 Nexon CMM

COMPARATOR AND CHART

A comparator (2) is a large microscope, and a chart is a template of what the part should be. There are two common types of comparators: ones that require physical chart and one where the chart is a step file that the program hooked to the comparator can read. The comparator is multi functional with different parts being able to be checked. The Chart is part specific and cannot check more than the intended part. The chart is placed on the comparator and a part is placed in front of the light and the part is projected on the screen where the chart is attached. The operator then looks at the screen to determine if the part shadow matches the chart.

Since a chart is like a template, there cannot be any variable data retrieved from the inspection. The chart is like a pass fail check to determine quickly if a part meets the drawing. The comparator is not portable but the chart can be shipped from the supplier to the customer easily for a small fee.

Figure 2 15-541-6 SPI Optical Comparator
From Great Gages

Based on the above research and seeing that the supplier does not have CMM capability, the supplier is a small shop, and the comparator and chart are being used now with disagreements on conforming, passing, or non conforming, failing, parts. The solution is a functional gage that is not subjective to human error.

SURVEY

The survey evaluated the desirable features for a profile gage that is part specific. The features chosen for the survey were determined through the interviews of gage designers (3) (4) and quality engineers (5) (6). The survey was given to operators who inspect the parts, Quality Engineers, the supplier and program manager. The tables below show the customer responses from the survey questions.

Table 1 Survey Question 1 Answers

Jennifer Hardwick Profile Gage	Customer importance	Current Satisfaction	Relative weight %
Low cost	4.00	3.27	7.8%
Low maintenance	4.54	3.50	8.3%
Resistance to tempature change	4.46	3.50	8.1%
Portable	4.69	3.00	10.0%
Durable	4.77	3.58	8.5%
Minimal fatigue for operator	4.85	2.83	10.9%
Repeatable	4.85	2.85	10.8%
One person Operation	4.85	3.50	8.8%
Accurate	4.92	2.08	18.8%
Safe	4.92	3.92	8.0%

Customer Importance

The customer importance level for each feature was calculated to determine which Product Features were most important to the potential customer base. Customer importance was calculated by averaging the selected importance of each feature from the surveys collected. Based upon the survey results, the Product Feature most important to customers is a two way tie between having the profile gage is accurate and safe; the least important customer feature is the cost of the gage.

Current Satisfaction

The customer satisfaction level for each feature was calculated. This determined which Product Features were important to the customer that the existing product lacked. Customer satisfaction was calculated by averaging the selected current satisfaction for each feature from the surveys collected. Based upon the survey results, customers are most satisfied with the safety of the comparator and chart; they are dissatisfied with the accuracy of the chart.

Relative Weight Percentage

The Relative weight percentage is calculated from the modified importance divided by the total importance and multiplied by 100. The relative weight percentage shows that the customer puts high importance on the accuracy of the gage and the cost is not of high importance on the scale.

PRODUCT FEATURES

Design a functional profile gage that is part specific. Accepting the conforming product

1. Accuracy 19%
   a. Solid Edge validation of gage
   b. Rapid Prototype validation of gage
   c. CMM validation of gage

2. Minimal fatigue for operator 11%
   a. Part physical fits gage
   b. No math calculations required to validate gage results
   c. Movable parts weight less than 10lb

3. Repeatability 11%
   a. Hardness of material
   b. Certificate of conformance
   c. Hardness test

4. Portability 10%
   a. Gage weight is less than 20lb

5. One person Operation 9%
   a. Gage can be used in 10 steps or less

6. Durability 9%
   a. Material
   b. Validation of not changing parts
   c. Oxidation
   d. Design factor consistent with loading conditions in expected use

7. Low maintenance 8%
   a. Minimal cleaning
   b. No adjustable parts
   c. No removable parts

8. Resistance to temperature change 8%
   a. Material can go through thermal cycle and still be conforming. (Specific temperatures to come)

9. Safety 8%
   a. Gage does not change the profile (CMM validation)
   b. No Sharp edges
   c. No physical harm or a warning label

10. Cost 8%
    a. Reasonable for a gage

DESIGN

When starting to design for this project, the rules for Geometric Dimensioning and Tolerance, GD&T, that were taught freshman year needed to be refreshed. Once the GD&T had been refreshed, there was a section about gages and how to design for them (7). This with the advice of the Gage designers at the company, allowed for preliminary sketches of a design.

ALTERNATIVES

The first possible design was a plate with both the inside profile and outside profile machined in the plate. This allowed the part to be placed upside-down to verify if the profiles were correct. This was positive in the view of portability and that it is only one gage. The negative about this design was the violation of GD&T rules to check the profile. Figure 3 describes how the reading the feature control frame is read. The feature control frame calls out datum “A” to be the primary, “B” to be the Secondary and “C”to be the tertiary in that order. When looking at the figure this means the part must be sitting on datum “A” first since the part is sitting on the datum it locks the part in the X-axis direction to locate the part. Then with the part still on datum “A, the second datum “B” to be located and placed locking the part in the Y-axis to locate the part. Datum “C” then locks the part in the Z-axis. Once all three datum’s have been located then the part can be gauged. For the plate design the part would not be located on any of the three datum’s that are called out in the feature control frame.

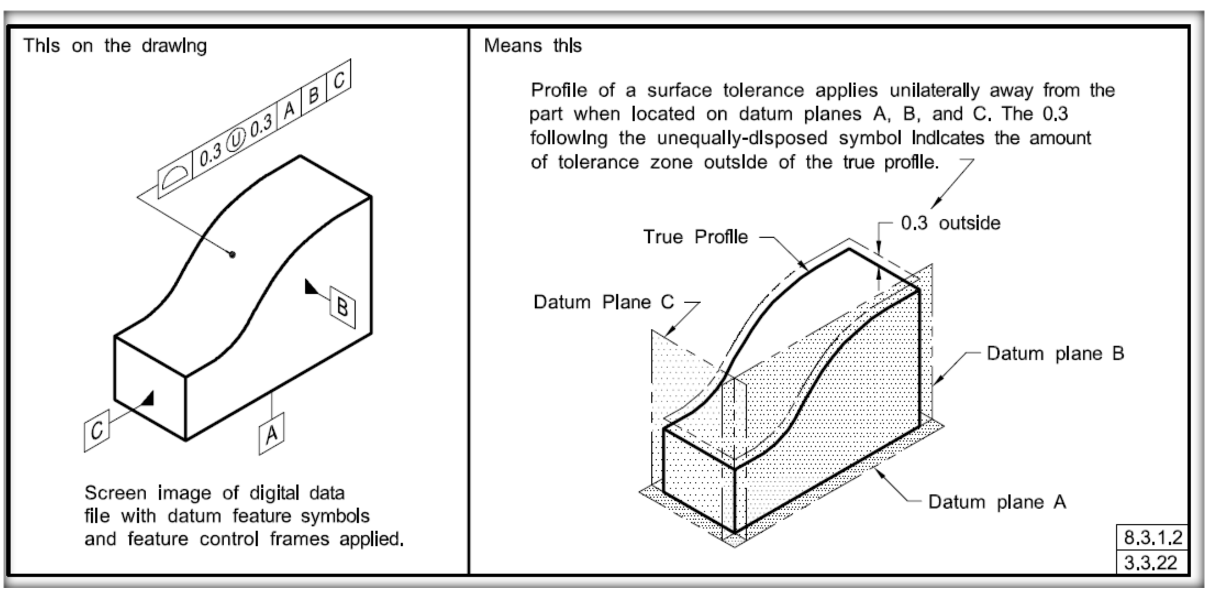

Figure 3 Profile of a Surface Application (8)

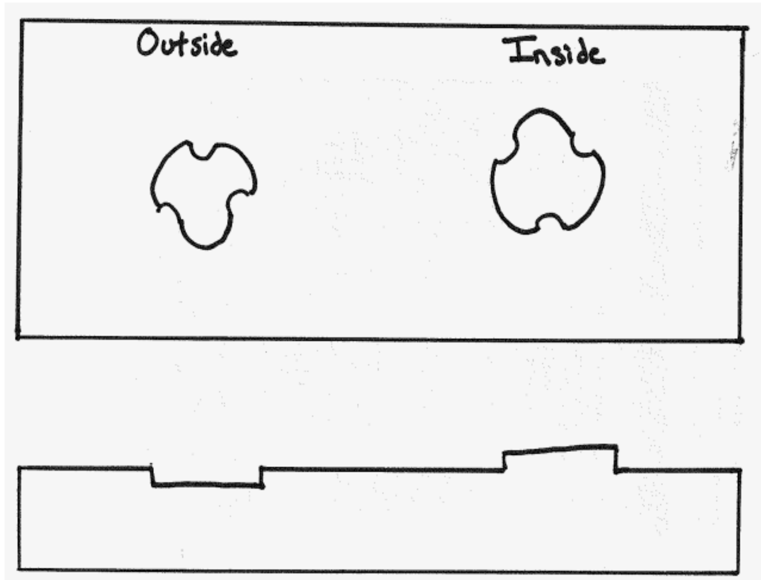

Figure 4 Alternative Design I Plate

The second possible design was flush gages. The flush gage would be a cylinder that has an inside diameter to locate off datum B and a center insert that was a check for the inside profile. This insert would be flush with the cylinder when the profile is conforming. The inset would not be allied with the cylinder when the part is nonconforming. There would be a separate gage for the inside and outside profiles. This would allow one of the profiles to be conforming and the other would be out and the program team could determine if that is the critical profile that is out of tolerance. The rotational orientation of the part to the gage is left to the insert and could provide false data for a conforming part or nonconforming part.

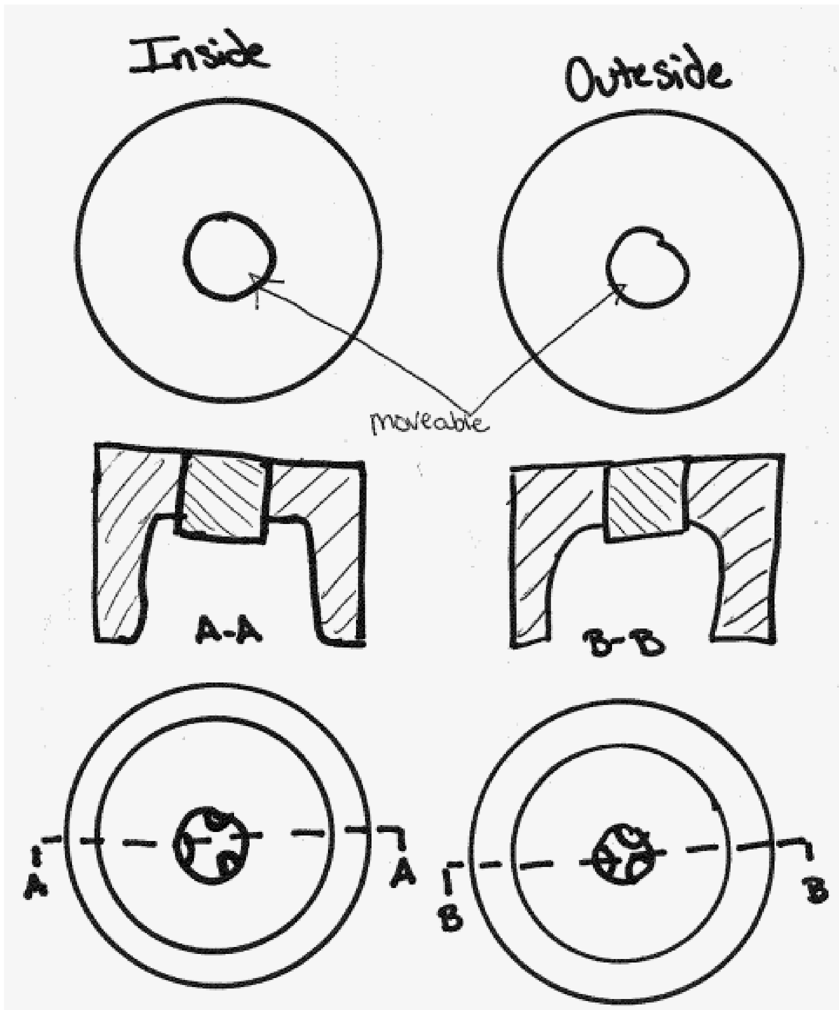

Figure 5 Alternative Design II Flush Gages

The third possible design was position gages. The position gage would located off datum A and would be a cylinder that has an inside diameter to locate off datum B. This locks the part in the x and y axis but leaves the rotational orientation of the part to the gage to be free to move. The rotational orientation can be locked with a pin to show where datum C is located. The insert for this position gage would be fixed and there would be holes in the side of the gage to verify the insert is seated in the part correctly. There would be two separate gages, one for the inside diameter and one for the outside diameter.

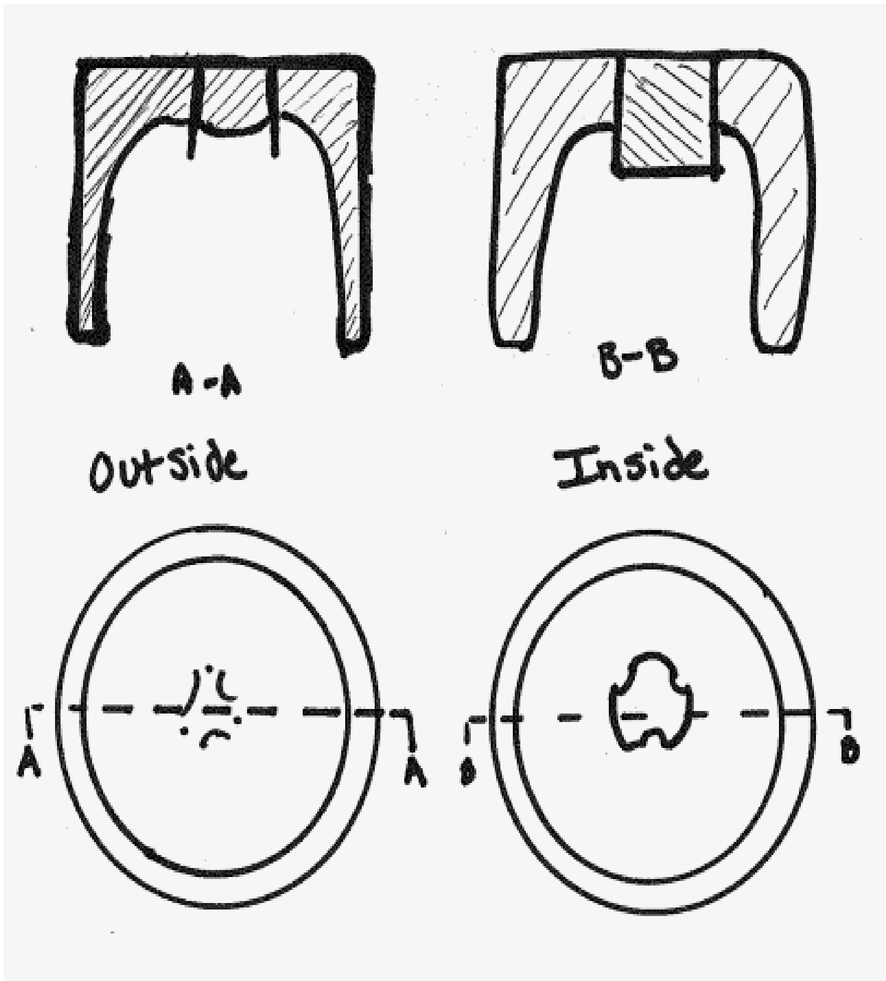

Figure 6 Alternative Design III Position Gages

SELECTION

Since only the flush gages and position gages follow the rules of GD&T these will be evaluated to determine which design is needed. There are several systematic ways to determine which design is best suited for the application needed. There is the Pugh's, Modified Pugh's and the weighted analysis (9). The Pugh's method used what is already in place or used to calculate which alternative design is best for the application. Pugh has you take the existing gauging and set that as the datum to look at the designs and compare them if they are better or worse. The criteria chosen to compare the designs came from the proof of design.

Table 2 Pugh's Method

Pugh's Method				
Profile Gage				
Jennifer Hardwick				
Criteria		Flush Gages	Comparator and Chart	Position
Accuracy		+	D	+
Minimal Fatigue		S	A	S
Repeatablility		-	T	+
Portability		+	U	+
One person Operation		+	M	+
Safe		-		-
Resistance to tempature changes		-		-
	∑ +	3	NA	4
	∑ -	3	NA	2
	∑ S	1	NA	1

Pugh's method shows that the position gage would be the best solution for the application.

CALCULATIONS

The calculations for designing the inside profile gage takes the minimum diameter or distance of the part and subtracts the gage tolerance. The dimensions for the outside profile take the maximum diameter or distance of the part and add the gage tolerance. This is called pessimistic tolerance, meaning there is the potential to fail a good part before passing a bad part (10).

LOADING CONDITIONS

For this application the loading conditions that the customer desires are the forces between the part and the gage. Ideally the dimensions of the gage include tolerances that the part and gage never touch. In the actual application the datum B and C will touch between the part and gage. The insert may also touch the part depending on the actual part being gauged. If the part is bad or nonconforming there will be interference with the gage and could potentially damage the part.

Component Selection

Component selection was applicable to the raw materials that would need to be purchased. The material needed to be durable enough to withstand repeated usage. Consulting with gage designers at the company the material chosen was tool steel for all the components of each gage that are machined and standard off the shelf parts for the screws and gage pins. The profile defined on the customer drawing is hard to machine with the tight tolerance the inside profile will be wire burned on the insert and the outside profile will be wire burned on the housing. The inside profile is hard to verify, which is why there are windows cut out of the housing to allow visualization.

BILL OF MATERIALS

The outside profile gage has four components, the housing and insert are machined and the screw and gage pin are bought. The housing is machined from tool steel and the insert is machined from tool steel. The gage pin is a class x and is pressed in to the housing to help locate the part relative to the insert.

The inside profile gage has two components: the cylinder to be machined and the Class X gage pin to locate the part. The pin gets pressed in the cylinder and the gage is ready for use. The inside profile gages uses the gage pin to locate the part relative to the gage.

PROJECT MANAGMENT

Schedule

Once the proof of design statement (Appendix G) was agreed upon the design phase was complete and the production of the gages could begin. The production of the gages also depended on the validation from the gage department that this is how they would design the gage. Once the gage department had verified my design with limited changes the drawings were sent out to Alpine Gage. Alpine gage then provided a quote to produce the gages and once the quote was accepted Alpine gage started work. When the quote was sent back the turn around time was to be four weeks. This affected my schedule by putting me behind where I wanted to be but the four weeks was a practical turn around time opposed to five weeks (11). The needs of my customer were to have the gages produced, validated, and sent to the supplier by the end of February. This was not met since the gages were not ordered till the middle of January and Alpine gage took about five weeks to produce the gages and were shipped over night.

BUDGET

The budget listed for the design and fabrication of the gage. The Machining of the product will be the most expensive part of the design due to the tight tolerances required for a position profile gage. The validation of the gage is important and required by the customer. The quote for producing the gages was sent to three companies. Only two of the three companies sent quotes back. They quoted each gage separately calculating the machining and material both being over the forecasted amount. Alpine gage quoted four weeks to produce the gages with about $1000 more than the other company who quoted five weeks to produce the gages.

Table 3 Budget

Materials, components	Forcasted Amount	Actual Amount	
	Both Gages	Inside	Outside
Gage material	$ 500.00		
Machining	$ 600.00	$ 2,064.00	$ 1,152.00
Validation	$ 500.00	$ 300.00	
Total	$ 1,600.00	$ 3,516.00	

In discussing the quotes with the gage department and program team, alpine gage was selected to produce the gages. Alpine gage is a smaller gage production shop with few operators. The other company was larger and would have many operators to touch the gages during production allowing for more variability. The gage department at my company determined the extra $1000 was worth having only one operator produce the gages. The program team was accepting to the extra money since the gages would be in a week earlier.

VALIDATION

Once the gages were received from Alpine gage, I worked with a CMM operator to validate that the profile dimensions met those of the drawing. The experience of validation of a profile on a part is all about how the program is set up to look at the part. The experience needed takes years to develop, other wise the program could be set to anything and the validation could mean nothing if the calculations and starting points were incorrect.

Then the sample parts were also sent through the CMM there was a program already set up to determine the profile of the surface. Once the data from the parts was collected, the inside profile gage and outside profile gage were used to measure the part. Both profile gages produce variable data of pass or fail. The gages passed the parts. To verify the loading conditions assumption of the gages never touching the part. The parts were run through the CMM again with the same part specific profile program. The data came back that the parts were the same and the dimensions were not affected by the gage.

The gages were then taken to the scale to determine the weight of each gage was less than 10lbs. The inside profile gage weight was 2.94 lbs and the outside profile gage was 1.30 lbs. Both gages passed the criteria set forth in Appendix G. When the gages came in from

Alpine gage there was a sharp corner that was not meeting the drawing specifications of outside radiuses to be rounded. This sharp corner was located on the inside of the housing for the inside profile gage. This was remedied with some sandpaper to remove the burrs.

The gages were then taken to the people that were involved with the survey, mainly focusing on the inspectors who would be using the gage on a daily basis. The responce from the group was positive. They commented how the new gages had less variation than the old method. The team pointed out that since our company is a lean manufacturing plant, there is always room for improvement on how to make a process better. The team suggested taking the existing gages and placing them in a press to help with the flow of the gauging process since the gages are used 100% on this specific part.

CONCLUSION

The customer was satisfied with the profile gages designed and produced by Alpine gage. The customer uses other gages on this part before the profile gages are used, this helps verify that the datum's called out in the feature control frame are located correctly to allow the profile gages to check only the profile. The customer had one suggestion since the profile gages are use on 100% of all incoming parts. The gages were to be mounted in a press. This improved the inspection time and reduced the amount of work the inspector had to do on every part. This is an internal improvement that does not violate any of the requirements that were set forth in the proof of design. The customer plant is a lean manufacturing plant and the improvement is listed under continuous improvement allowing the project to be complete.

This project improved the design skills required by the engineers. Two dimensional drawings are the communication between the customer, designer and manufacture. The common language between the different people is the two dimensional drawing of the part.

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APPENDIX A – RESEARCH

Interview with industry expert: Gage Designer Date:9/3/13
Industry experience: 37 years
Important features to include:
Design a functional fixed go gage that is similar to the mating part.
Functional movable go gage would not be recommended due to the complexity and confusion that the supplier would have.
Fixed go gage like a plug gage.
Gages should be separate easier to machine and validate the supplier's parts.

Interview with industry expert: Program Quality Engineer Date:9/3/13
Industry experience: 13 years
Important features to include:
Both inside and outside profile are needed to be checked by this gage.
This gage is to help the supplier produce conforming product. Supplier is having difficulty with current measurement methods (CMM & comparator charts) and recent shipments have been non-conforming to the profile requirements.
May require Separate gages to check inside and outside profiles.
.

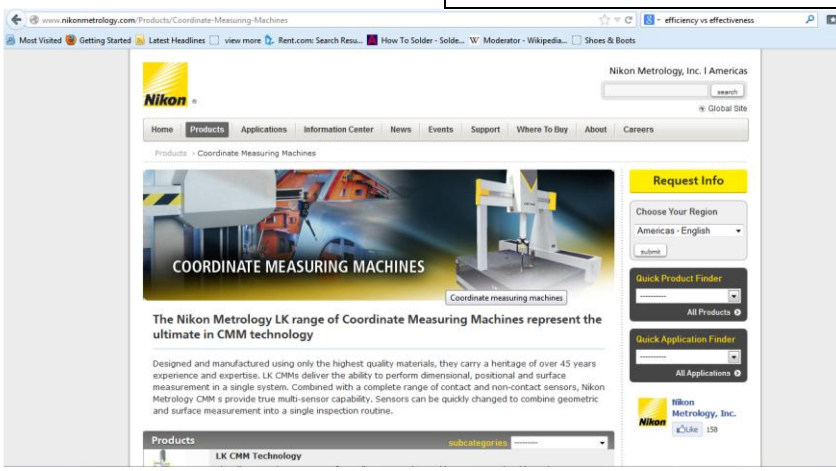
Interview with industry expert: Supplier Quality Engineer
Industry experience: 43 years
Important features to include:
Fixed functional gage incorporating all datum's.
Multi part gage.
Separate gages to check the two profiles.

Interview with industry expert: Gage Designer Date:9/3/13
Industry experience: ~40 years tool and gage designing
Important features to include:
Only able to produce a go gage at max material conditions.
Comparator and chart or CMM would be better methods of measuring the profiles.

Coordinate Measuring Machine (CMM)

Machine=$50000-$100000
Program=$1795 (MeasureLink)
Training operator=$100/1hr
Minimum 3 hr
Total Cost=$70000-$120000

http://www.nikonmetrology.com/Products/Coordinate-Measuring-Machines
9/11/13



Ideal Qualities:
Provides Variable data
Can be used on other parts
Repeatable with or without programming

Dislikes:
High Cost
Not able to travel

Comparator and Chart

Visually verify that the shape matches the chart.

Comparator=$10699
Chart design=$300
Chart produced=$500
Total Cost= $11400

http://store.greatgages.com/servlet/-strse-1989/15-dsh-541-dsh-6-SPI-Optical-Comparator/Detail?gclid=CP-Xod6Sx7kCFbF9Ogod5zoAkQ
9/12/13

Ideal Qualities:
Medium Cost
Repeatable
Visual check
Faster than CMM

Dislikes:
No variable data
Not able to travel

APPENDIX B – SURVEY

PROFILE GAGE
CUSTOMER SURVEY

A comparator and chart can be used to check and verify a profile. The accuracy and repeatability of this inspection method is unreliable. I will design and validate a functional profile gage.

How important is each feature to you for the design of a new Profile Gage?
Please circle the appropriate answer. 1 = low importance 5 = high importance

							Average
Repeatable	1	2	3	4(2)	5(11)	N/A	4.85
One person operation	1	2	3	4(2)	5(11)	N/A	4.85
Portable	1	2	3	4(4)	5(9)	N/A	4.69
Minimal fatigue for operator	1	2	3	4(2)	5(11)	N/A	4.85
Safe	1	2	3	4(1)	5(12)	N/A	4.92
Low Cost	1	2(1)	3(5)	4	5(7)	N/A	4.00
Durable	1	2	3(1)	4(1)	5(11)	N/A	4.77
Resistance to Temperature Change	1	2	3(3)	4(1)	5(9)	N/A	4.46
Low Maintenance	1	2	3(1)	4(4)	5(8)	N/A	4.54
Accurate	1	2	3	4(1)	5(12)	N/A	4.92

How satisfied are you with the current Comparator and Chart to check the Profile?
Please circle the appropriate answer. 1 = very UNsatisfied 5 = very satisfied

							Average
Repeatable	1(3)	2(1)	3(5)	4(3)	5(1)	N/A	2.85
One person operation	1(3)	2(1)	3(1)	4(1)	5(6)	N/A	3.50
Portable	1(4)	2(1)	3(2)	4(1)	5(4)	N/A	3.00
Minimal fatigue for operator	1(4)	2(1)	3(2)	4(3)	5(2)	N/A	2.83
Safe	1(2)	2	3	4(5)	5(5)	N/A	3.92
Low Cost	1(3)	2	3(3)	4(1)	5(4)	N/A	3.27
Durable	1(2)	2	3(3)	4(3)	5(4)	N/A	3.58
Resistance to Temperature Change	1(2)	2	3(1)	4(5)	5(2)	N/A	3.50
Low Maintenance	1(2)	2	3(2)	4(6)	5(2)	N/A	3.50
Accurate	1(2)	2(2)	3(3)	4(3)	5(2)	N/A	3.08

APPENDIX C – QUALITY FUNCTION DEPLOYMENT (QFD)

Jennifer Hardwick Profile Gage 9 = Strong 3 = Moderate 1 = Weak	Solid Edge Validation of gage	CMM validation of gage	Gage does not damage profile	No sharp edges	Hardness test	Parts physically fit gage	No calculations required to verify parts are good	Movable Parts less than 10 lb	Gage can be used in 10 steps or less	minimal maintanence and cleaning required	Material can with stand different tempature enviorments	Customer importance	Current Satisfaction	Planned Satisfaction	Improvement ratio	Modified Importance	Relative weight	Relative weight %
Low cost									9			4.00	3.27	4	1.2	4.9	0.08	7.8%
Low maintenance								3		9		4.54	3.50	4	1.1	5.2	0.08	8.3%
Resistance to tempature change		9									9	4.46	3.50	4	1.1	5.1	0.08	8.1%
Portable								9				4.69	3.00	4	1.3	6.3	0.10	10.0%
Durable					9							4.77	3.58	4	1.1	5.3	0.08	8.5%
Minimal fatigue for operator							3		3			4.85	2.83	4	1.4	6.9	0.11	10.9%
Repeatable	9	9								3		4.85	2.85	4	1.4	6.8	0.11	10.8%
One person Operation			3	1			9		9			4.85	3.50	4	1.1	5.5	0.09	8.8%
Accurate	9	9				9				3		4.92	2.08	5	2.4	11.8	0.19	18.8%
Safe	3			9								4.92	3.92	4	1.0	5.0	0.08	8.0%
Abs. importance	2.91	3.40	0.26	0.81	0.76	1.69	1.12	1.14	1.82	1.63	0.73	46.85				62.81	1.0	1.0
Rel. importance	0.06	0.07	0.01	0.02	0.02	0.04	0.02	0.02	0.04	0.03	0.02	0.3						

APPENDIX D- PROJECT OBJECTIVES

Design a functional profile gage that is part specific. Accepting the conforming product

Accuracy **19%**

Solid Edge validation of gage
Rapid Prototype validation of gage
CMM validation of gage

Minimal fatigue for operator **11%**

Part physical fits gage
No math calculations required to validate gage results
Movable parts weight less than 10lb

Repeatability **11%**

Hardness of material
Certificate of conformance
Hardness test

Portability **10%**

Gage weight is less than 20lb

One person Operation **9%**

Gage can be used in 10 steps or less

Durability **9%**

Material
Validation of not changing parts
Oxidation
Design factor consistent with loading conditions in expected use

Low maintenance **9%**

Minimal cleaning
No adjustable parts
No removable parts

Resistance to temperature change **8%**

Material can go through thermal cycle and still be conforming. (Specific temperatures to come)

Safety **8%**

Gage does not change the profile (CMM validation)
No Sharp edges
No physical harm or a warning label

Cost **8%**

Reasonable for a gage

APPENDIX E- SCHEDULE

Jennifer Hardwick
Profile Gage

Yellow is planned
Blue is actual

Tasks	Sep. 29 - Oct 5	Oct. 6 - Oct. 12	Oct. 13 - Oct. 19	Oct. 20 - Oct. 26	Oct. 27 - Nov. 2	Nov. 3 - Nov. 9	Nov. 10 - Nov. 16	Nov. 17 - Nov. 23	Nov. 24 - Nov. 30	Dec. 1 - Dec. 7
Content Review		9								
		9								
Proof of Design Agreement (Dr.Dave)			16							
			16							
Concepts/Selection (Dr. Dave)			16							
			16							
3D Model - Solid Edge				23						
						6				
3D Model - Rapid Prototype						6				
Design Calculations					2					
							15			
Bill of Materials							15			
								23		
Quote for Purchase									30	
Order Gage										
Fabrication										
Oral Presentation to UC Faculty										
Report Due (Dr. Dave)										
Validation CMM										
Gage R&R										
Demonstration (Dr. Dave)										
Tech Expo										
Final Presentation to UC Faculty										
Report										
Contracts review of Report										
Submitted (Dr. Dave)										
Report Corrections										
Report PDF to UC Library										

Tasks	Dec. 8 - Dec. 14	Dec. 15 - Dec. 21	Dec. 22 - Dec. 28	Dec. 29 - Jan. 4	Jan. 5 - Jan. 11	Jan. 12 - Jan. 18	Jan. 19 - Jan. 25	Jan. 26- Feb. 1	Feb. 2 - Feb. 8	Feb. 9 - Feb. 15
Content Review										
Proof of Design Agreement (Dr.Dave)										
Concepts/Selection (Dr. Dave)										
3D Model - Solid Edge										
3D Model - Rapid Prototype										
Design Calculations										
Bill of Materials										
Quote for Purchase										
		20								
Order Gage	14									
					8					
Fabrication								29		
									4	
Oral Presentation to UC Faculty								27		
							16			
Report Due (Dr. Dave)									3	
									3	
Validation CMM							25			
Gage R&R									6	
Demonstration (Dr. Dave)										
Tech Expo										
Final Presentation to UC Faculty										
Report										
Contracts review of Report										
						15		1		
Submitted (Dr. Dave)										
Report Corrections										
Report PDF to UC Library										

Tasks	Feb. 16 - Feb. 22	Feb. 23 - Mar. 1	Mar. 2 - Mar. 8	Mar. 9 - Mar. 15	Mar. 16 - Mar. 22	Mar. 23 - Mar. 29	Mar. 30 - Apr. 5	Apr. 6 - Apr. 12	Apr. 13 - Apr. 19	Apr. 20 - Apr. 26
Content Review										
Proof of Design Agreement (Dr.Dave)										
Concepts/Selection (Dr. Dave)										
3D Model - Solid Edge										
3D Model - Rapid Prototype										
Design Calculations										
Bill of Materials										
Quote for Purchase										
Order Gage										
Fabrication										
Oral Presentation to UC Faculty										
Report Due (Dr. Dave)										
Validation CMM										
				14						
Gage R&R										
					16					
Demonstration (Dr. Dave)	20									
Tech Expo							3			
							3			
Final Presentation to UC Faculty								9		
								8		
Report						29				
Contracts review of Report							2			
								7	16	
Submitted (Dr. Dave)								12		
										22
Report Corrections									19	
										22
Report PDF to UC Library										23
										23

APPENDIX F- BUDGET

Materials, components	Forcasted Amount	Actual Amount	
	Both Gages	Inside	Outside
Gage material	$ 500.00		
Machining	$ 600.00	$ 2,064.00	$ 1,152.00
Validation	$ 500.00	$ 300.00	
Total	$ 1,600.00	$ 3,516.00	

APPENDIX G- PROOF OF DESIGN

Profile Gage

Proof of Design Agreement

The following criteria will be met upon Proof of Design

Accuracy

1) Solid Edge and CMM validation of gage
2) Profile gage will be portable

Safety

1) Gage does not change the part physically
2) No Sharp edges
3) Profile gage will weigh less than 10lb

Temperature change

1) Resistant to temperature change (specific temperatures to come)

Cost

1) Profile gage will cost less than the initial method of inspection

Dr. Janak Dave

Jennifer Hardwick

APPENDIX H- DRAWINGS

SPECIFIC PART

Customer reviewed and asked me to take the detailed drawings out.

INSIDE GAGE

Customer reviewed and asked me to take the detailed drawings out.

OUTSIDE GAGE

Customer reviewed and asked me to take the detailed drawings out.