INTRODUCTION TO QUICK RELEASE PINS

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Part 1

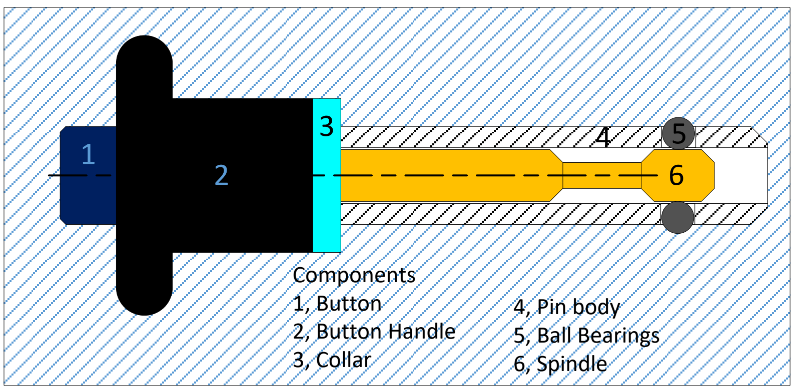
Quick Release Pins

Contents

a) Introduction:

2.1 Project

This project was done five years ago for a Manufacturing company located at Cleveland, Ohio, United States of America. The Quick release pins and Lifting pins are very precision pins, which are being used in all quick fastening applications in various industries that include, entertainment industry for mounting speakers on the overhead fixtures in musical concerts podium, Military application for loading Missiles in fighter planes, Aerospace applications for quick locking mechanisms. Amusement parks as a quick fastening safety pins in roller coasters, Automobile engine assembly for lifting engines, Skyscrapers Construction Industry as a secondary safety application, used for lifting scientific equipment's. These pins reached NASA's International Space Station as a fastening member of a 3D printer.



Any failure in functioning of these pins may cause a major disaster. This project is one of the best examples for the design and development of a new concept that exceeds the US Military and National Aerospace Specifications NAS 1332 and gave an assurance in attaining manufacturing excellence.

b) Background:

2.2 Nature of the overall engineering project

This engineering project was started with exploring the other ways of manufacturing pins to overcome the present manufacturing issues.

1. ID hole with step marks on Pin body due to drilling from both ends,
2. Discoloration during vacuum heat treatment process,
3. Collet marks, nicks and scratch parts due to material handling,
4. Pin cross holes Sizing
5. Poor stacking process
6. Missing balls from the pin after assembly,
7. Internal and external burrs on the cross holes.

These issues resulted in non-conforming products in assembling process which highly demanded the first pass yield to be improved very much to minimize the product cost. All these issues were addressed concurrently and the most challenging one is Pin cross hole sizing were the ball bearings are assembled for functioning of the pins.

The sizing of cross holes, missing balls from the pin after assembly and internal & external cross hole burr issues were initially addressed by unconventional machining process EDM-Drilling using Electrical discharge drilling Machine. Carried out EDM Drilling process trials, the results were satisfactory, it is so time consuming, expensive and it is not suitable for mass production

On the other hand, we had a huge product recall about 5K pins about $35K from one of the premium customer for missing balls issue. It was necessary to prove the customer; we make products that exceed their expectations. Lately these issues were turned to be the key influencers that gave the thought for evolution of this new conceptual design. DMAIC Six sigma methods and tools were used for this new conceptual reality.

2.3 Objective of the project

Objective of the project is a to prove the new conceptual design of making cross holes in quick release Pins and lifting pins meeting the National Aerospace Standard Specifications NAS 1332, Design of cutting tools, gauges, develop CNC programs, inspection methods, prototypes, perform destructive testing and the process capability by identifying the key product features - variables and attributes.

2.4 Nature of particular work zone

- Design and develop the Positive Ball Retention conception for all 20 different diameter Pins.
- Design and develop cutting tools a special key way end mill cutter with special geometry, fixtures, gauges, CNC programs, Inspection methods.
- Study the cutting tool life with different cutting parameters, effects of water soluble/Oil coolant.
- Develop prototypes.
- Perform destructive testing both internally and with certified third party outside.
- Process capability study to make consistent products.
- Define the acceptable specification for the new features attributes and variables.
- Design the required tools by selecting the suitable material for long life as a CAD model using Solid works & AutoCAD.
- Geometric dimensioning and tolerance for each of the 20 different diameter pins.

2.5 duties performed

- Collected the missing ball RMA details from Syteline ERP system, hole sizing and Burr issues from the QA portal.
- Studied the missing balls product recalls and component cross hole failures are impacting the business.
- Gathered all dimensional details from the current design prints for all the 20 different pins.
- Chosen the peak failure design pin supplied to prime customer and analyzed how the cross holes issues can be addressed.
- Conducted brain storming sessions with the respective CNC machine operators, technicians, assembly operators and supervisors to address the issues.
- Inspected and corrected all the drill and reamer sizes being used in the process.
- Worked with maintenance personals and replaced the power tool with new bearings on hydromat and swiss machine were cross holes are being made. Even after bearing replacement it is not meeting the cross hole size consistently.
- Designed the new concept Positive Ball Retention PBR, now a new premium product line in pin family.

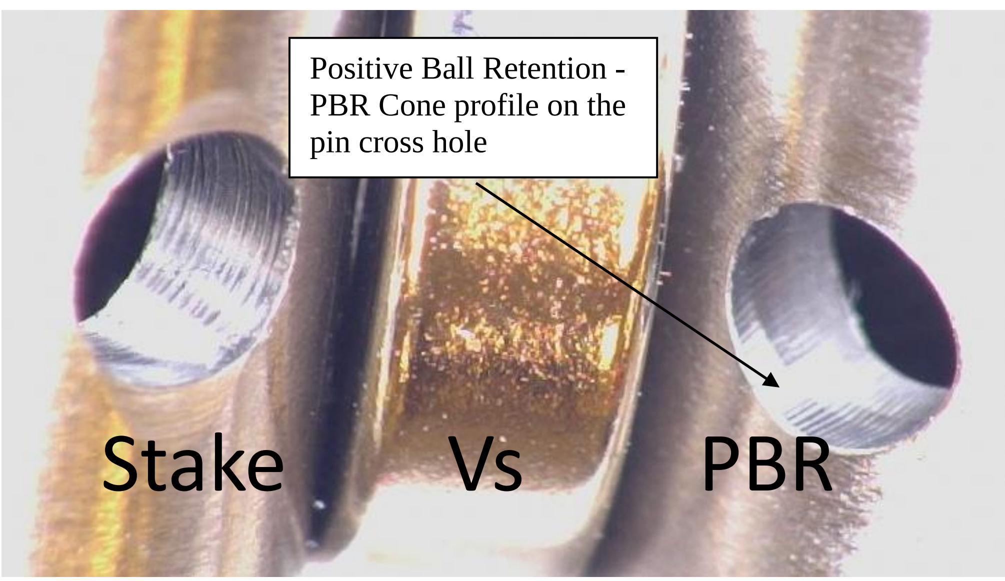
- Prepared the Six Sigma Project charter a single page report, which is a brief summary about the project scope, problem statements, benefits to the customer, Business, Objectives, Team members, Schedule, Risks.
- Processed a customer order with the new conceptual design. Performed destructive testing in-house and also tested with approved third party labs. After successful testing the pins, supplied to Truck manufacturing company for lifting Engine blocks in their assembly section.
- Designed and developed the fixtures for holding the lift pins bodies to make the new PBR feature in the cross holes.
- Designed and developed a special form key way end mill cutter, special gauges.
- Developed the CNC programs in Hass VF4 Milling and swiss machine.
- Identified the key attributes and variables in the component during machining process and developed the new inspection methods and procedures.
- Mechanical Engineering skills and Minitab statistical tools to do the hypothesis testing, process normality testing and Process capability.
- Improvement decisions were made with statistically supported data.

c) Personal Workplace Activity:

2.6 Technical details of the work

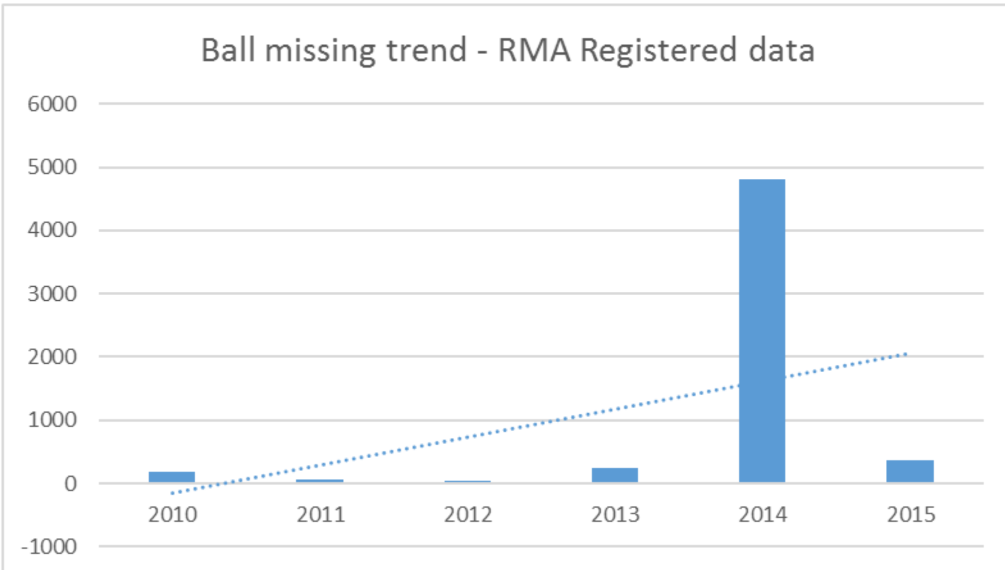
2.6a Design conception of conical profile - Pin cross hole.

Picture - 1 Stake Vs PBR



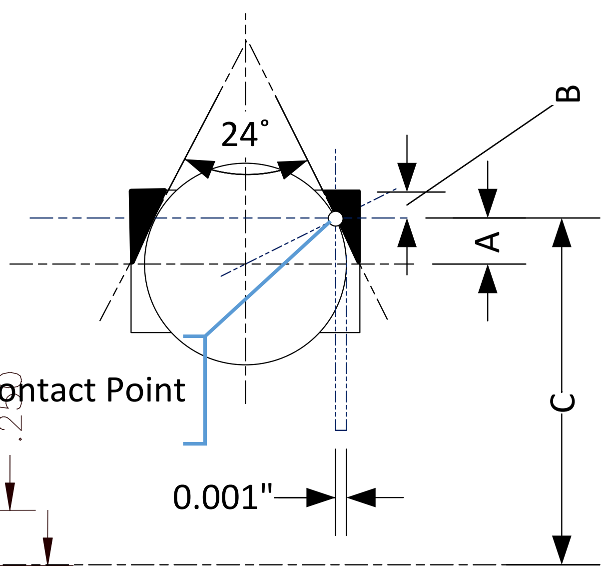
Customer return and product recall of Missing balls on the pins - RMA Details

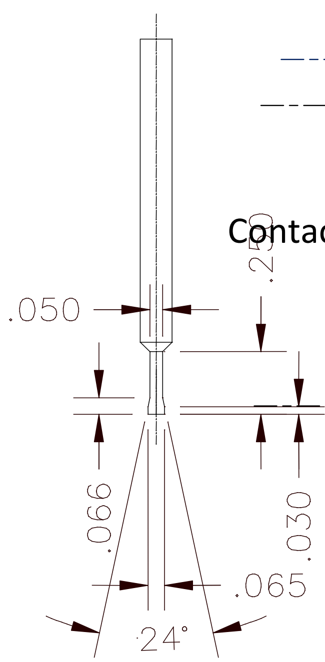
Graph - 1 Ball missing pins



1/4” Oversize ball Pin - PBR Profile angle.
Explained in next section about how this angle is arrived.

Fig - 1 ¼” Oversize ball PBR Geometry





2.6b Design of cutting tools

Manufacturer recommendations

1, Surface footage – 150 Surface Feet Per Minute
2, Speed – 11,500 RPM
3, Feed – 0.27 Inch Per minute – Circular feed
4, Feed – 10 Inch Per minute – Linear.

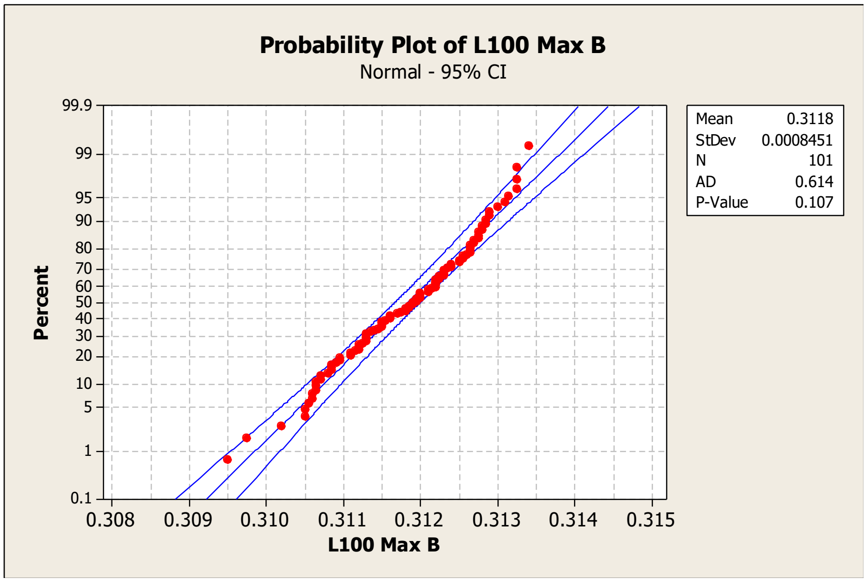
Raw material - SOLID CARBIDE, AlTiN COATED

Number of Flutes – 4

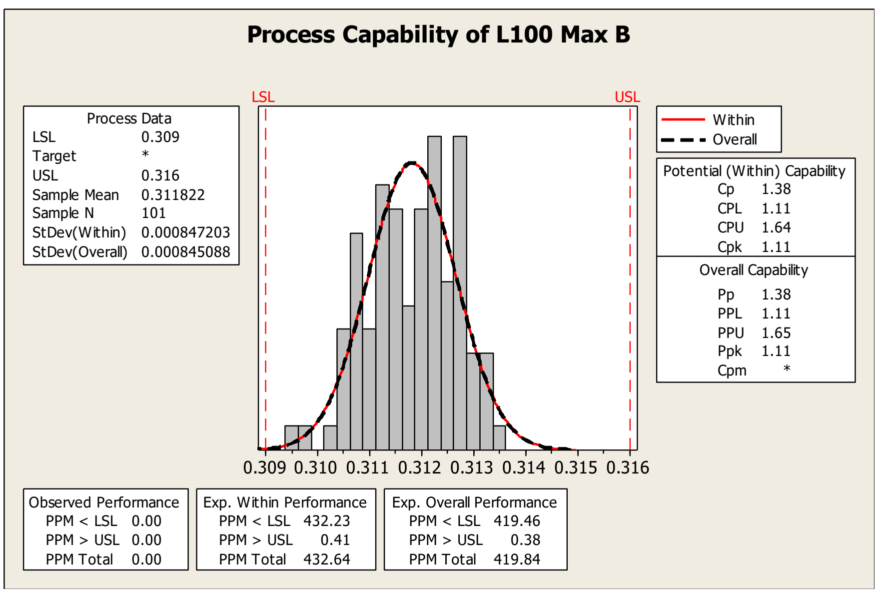
Fig - 2 Conical form end mill cutting tool

2.6c Normality and Process capability statistical charts

Machining Process Normality testing proved with High Probability P Value on ¼” oversize ball Max B – Dim as a Variable.



Graph - 2 Normality Plot



Graph - Bell

3 Process Capability curve

Process SL 35 machine

capability on HANWHA HPII -Swiss Style

- Used a precise 0.00005” Pitch Micrometer with conical spot profile anvils for process capability study of Max B dimensions.
- Can able to shift the mean from 0.3110 to 0.3135 and process them with the limits 0.3110 to 0.3160 for future runs.
- Over all the Max B Dim on the components are within the limits.

Attribute data as follows,

Stem-and-Leaf Display: L 100 Cross Hole ID, PIN OD – 0.24800 to 0.24808

Stem-and-leaf of L 100 Cross Hole ID N = 202

Leaf Unit = 0.00010

PBR Design – 0.094/ 0.096

(157) 96 00000000000000000000000000000000000000000000000000000000000000000+
45   97 000000000000000000000000000000000000000000000

Stem-and-Leaf Display: L 100 Cross Hole OD, PIN OD – 0.24800 to 0.24808

Stem-and-leaf of L 100 Cross Hole OD N = 202
Leaf Unit = 0.00010

PBR Design – 0.089/ 0.090

(126) 90 00000000000000000000000000000000000000000000000000000000000000000+
76   91 00000000000000000000000000000000000000000000000000000000000000000+

2.6d Cutting Tool Life study

The study of cutting tool life estimation has been performed on 3/8" diameter Pin, with 6 flute cutter, 20˚ Included angle.

The below Table1 & Table2 showing the variable feature, "Max B dimension" drop on every 6th pin collected orderly while making a 1000 pcs sample order on a CNC Milling Machine Haas VF4 with Midaco Pallet changer.

The Life of the tool comes down with the number of holes. Designed the experiments to estimate the cutting tool life using statistical analysis. The process needs Z correction after couple of 100 pcs is made. To maintain the Max B dimensions, Did 3 Z corrections to use up the first tool to produced 1200 holes. After 1200 holes, it was rubbing. We changed the tool to complete the order.

The water soluble coolant (cheap) was used for the Tool life estimation which always gives worst results than coolant Oil (expensive).

It was estimated that 500 pcs per tool with 2 to 3 Z corrections can be made in a worst condition being a cheaper process and can be increased to 800 pcs with 3 Z corrections by tweaking the cutting parameters and with coolant oil.

2.6e Destructive test using tensile testing machine

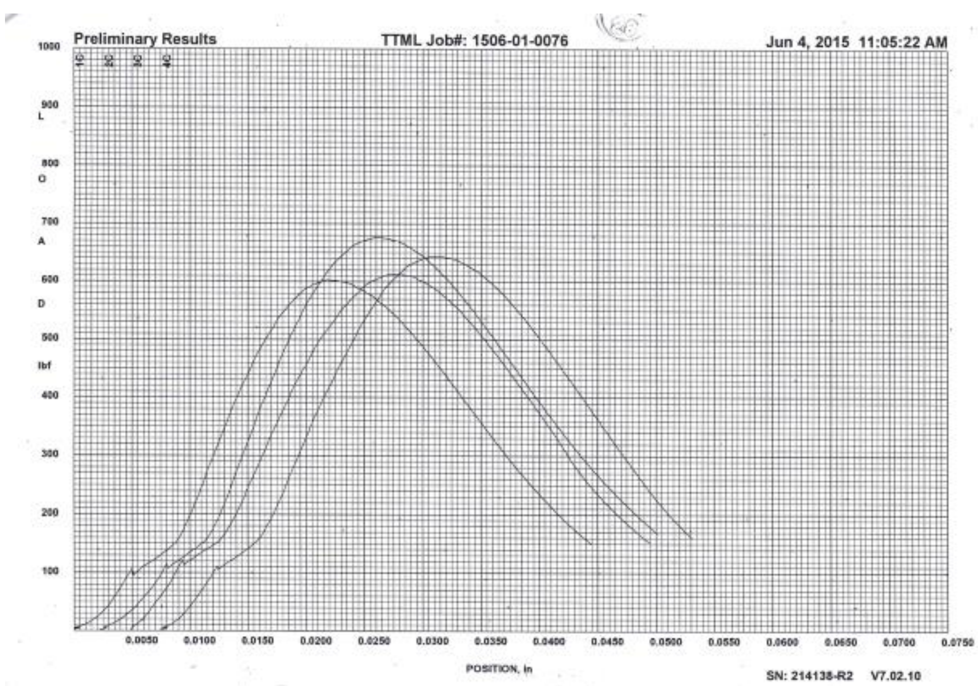
Tensile Testing
4520 Willow Pkwy
Cleveland OH 44125
216.641.3290

Preliminary Results

Item Ref 1	Item Ref 2	Sample No.	Break Location	Area in²	Ult Load lbf	Ultimate N	Max Stress psi
ITEM#77845 8-TEST 1	PIN DIA .5965	1A		0.0373	701	3120	18790
ITEM#77845 8-TEST 1	PIN DIA .5965	2A		0.0373	770	3430	20600
ITEM#77845 8-TEST 1	PIN DIA .5965	3A		0.0373	678	3020	18170
ITEM#77845 8-TEST 1	PIN DIA .5965	4A		0.0373	657	2920	17610
ITEM#77845 8-TEST 1	PIN DIA .5965	1B		0.0373	547	2430	14660
ITEM#77845 8-TEST 1	PIN DIA .5965	2B		0.0373	553	2460	14820
ITEM#77845 8-TEST 1	PIN DIA .5965	3B		0.0373	570	2530	15260
ITEM#77845 8-TEST 1	PIN DIA .5965	4B		0.0373	581	2590	15570
ITEM#77845 8-TEST 1	PIN DIA .5965	1C		0.0373	603	2680	16160
ITEM#77845 8-TEST 1	PIN DIA .5965	2C		0.0373	677	3010	18140
ITEM#77845 8-TEST 1	PIN DIA .5965	3C		0.0373	613	2730	16430

NAS 1332 Standard calls for 30 Lbs Push out to failure, Graph shows 600 Lbs.
These Pins exceeds National Aerospace Standard NAS 1332 specs by 20 times.
Ensured the Tensile testing machine calibration certificate No EKBYJR0Y are valid to accept the destructive test results

Graph - 4 Destructive test results



2.7 How engineering knowledge and skills applied;

2.7a Conceptual visibility, Issues and constraints

As a mechanical engineer, picking up concepts while seeing any mechanisms and realizing it once the right application is found. This particular knowledge and skills will always help to design and developing new things. When inventing new things conceptually, It will be so excited to see how my conception is being converted to reality.

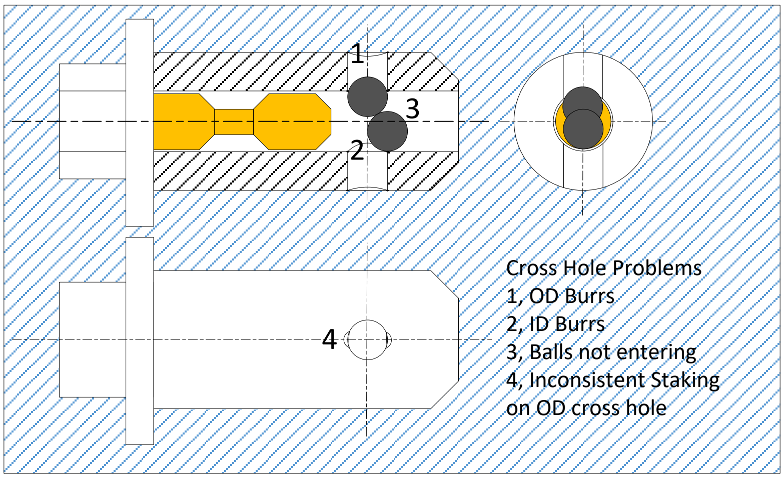
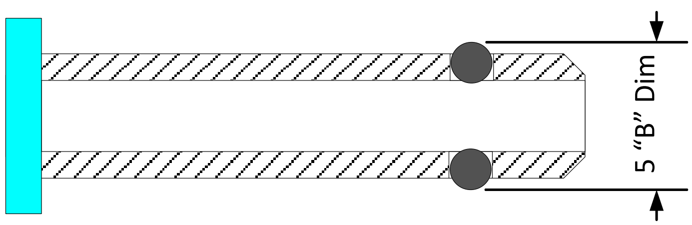


Fig - 4 Cross Hole issues of Pin

2.7b Conceptual Design Evolution

STEP 1

Fig - 5 MAX B Dimension



Collected Pin Body Component Dimensional Details and focused on unknown feature.

- Outer diameter – 0.2470" to 0.2485"
- Inner diameter – 0.140" to 0.150"
- Cross hole diameter – 0.094" to 0.096"
- Ball GR100 diameter – 0.09370" to 0.09375"
- "B" Dimension – 0.306" to 0.316"
- Stake depth - unknown – "Big?" (measured by the amount of pound force used)

STEP 2

Concept Required:

- To have a positive stop, for missing balls on Pin OD cross holes.
- Positive stop can vary B dim between 0.311" to 0.316"
- Spindle Diameter tolerance is 0.005" can use B dim between 0.306" to 0.311"
- Need to get away from the Unknown feature.

STEP 3

- Positive stop in a form of a cone has been created on the Pin OD cross hole as shown in the black transparent circles.
- Introducing this positive stop, we can eliminate staking process from regular Pins.
- The Cross Hole stake depth - unknown – “Big ?” has been removed from Pins.
- This Positive ball retention cone also eliminates the OD burr.
- It is achieved by circular and helical interpolation using a CNC programing with the conical form end mill key way cutter.

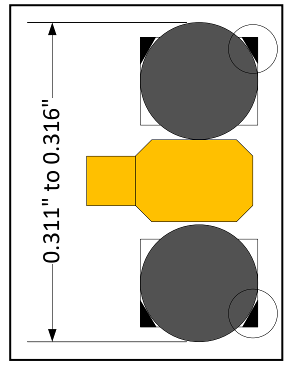


Fig - 6 With cone

STEP 4

- Bottom chamfer as shown in the ovals has been introduced.
- By doing this Bottom chamfer the ID burrs in the Pin ID cross holes has been removed.
- Now there is a clear passage for the ball bearings to enter the cross holes.
- This can be achieved by circular and helical interpolation using CNC programing with the conical form end mill key way cutter.

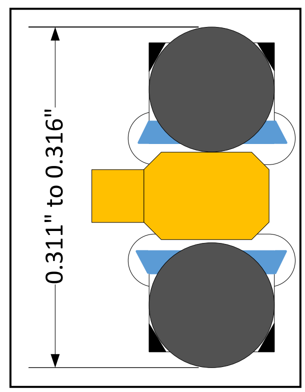


Fig - 7 With ID & OD cone

PBR Concept is great, but need to find the Cone Angle through study and investigation of possibility of the design.

2.7c Mechanical Design Engineering application

The following conditions, geometry dimensioning and tolerance determine the Positive Ball Retention cone angle.

S.no	Feature	Max	Min	Critical Condition	Considered
1	Pin outer diameter	0.2485”	0.2470”	Min	0.2470”
2	Pin inner diameter	0.150”	0.140”	Max	0.150”
3	Pin cross hole diameter	0.0960”	0.0940”	Mean	0.095”
4	Ball bearing diameter	0.09375”	0.09370”	Min	0.09370”
5	B – Dimension	0.316”	0.311”	Min	0.311”
6	Spindle diameter	0.119”	0.116”	Max	0.119”

Construct the Geometry using AutoCAD,

- Draw all elements with its critical dimensions as shown.
- The critical diameter ball contact point should be above its equator and cone contact point should be below the Pin critical outer diameter to have PBR cone.

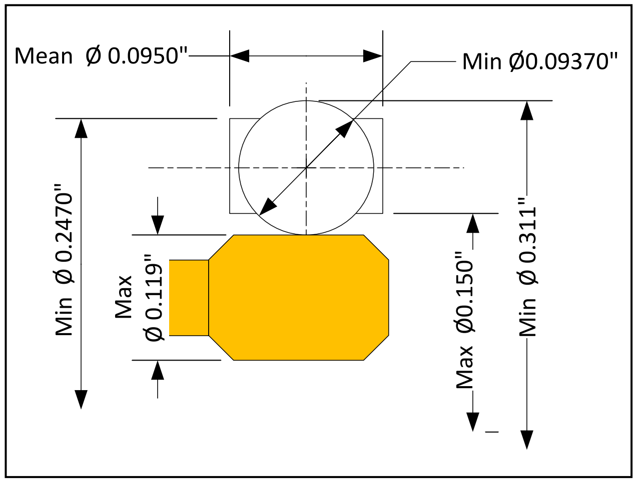


Fig - 8 Critical Dimension

Refer Fig - 1 ¼" Oversize ball PBR Geometry

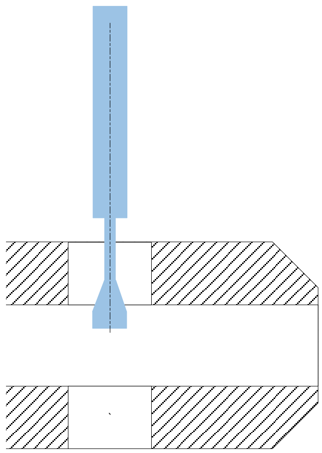
- Drawn a horizontal line to the left of length 0.001" from the ball bearing extreme point on the X axis and cut the ball diameter above the equator on the first quadrant to get the ball contact point.
- A tangent line drawn through the contact point to touch the Y axis and repeat the same on the second quadrant.
- The tangent lines shall cut the cross hole diameter to form a conical profile as shown in black triangles in the above construction.
- Now it measures the included angle is 24˚,
  The linear dimensions,
  Center of ball bearing to the contact point - A is 0.009",
  Pin outer diameter to the contact point - B is 0.011" and
  Pin center to the contact point - C is 0.118".
  Now the contact point is well within the specifications as stated above.
- The above geometry with critical boundary conditions confirms that if this conical profile can able to machine then the ball bearings will have a positive ball retention feature, will eliminate the missing balls issues and is better than inconsistent staking process.

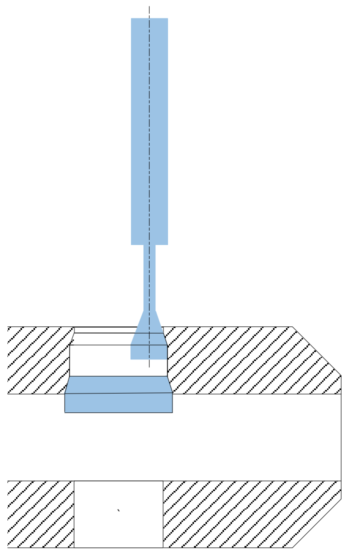
2.7d Cutting tool design based on the machining process

A cutting tool is required to make the above constructed cone in the Pin cross holes. The tool should follow the path as shown below.

Cutting Tool generated two conical profiles - Top cone is PBR feature with no OD burr & Bottom cone is to remove ID burr

Fig - 9 Cutting Tool Entry in the cross hole





2.7e Geometry and Dimensioning the cutting tool.

Refer fig -2

- Overall length - 2”
- Neck diameter – 0.050” ± 0.001”
- Cutting edge diameter – 0.065” ± 0.001”
- Straight Cutting edge length – 0.030” ± 0.001”
- Cone length – 0.066” ± 0.001”
- Cutting base to neck length – 0.250” ± 0.001”
- Cone angle - 24˚ ± 1˚

This cutting tool geometry profile can be able to make two cones and sizing with no burrs left inside for easy ball bearing entering the cross holes.

In old process we used straight reamers for sizing after drilling the cross holes.
Failure Mode Effective Analysis FMEA was done to identify the key risk element that affects the formation of the cone profile on the cross hole. Developed Form cutting tool inspection methods and procedures to its tolerance to validate the retention profile, which ensures product safety feature while lifting heavy objects.
Enquired and made these cutting tools with Harvey and Fullerton tools. As the diameter of the tools is too small, needs higher surface footage to cut the profile. The best suited material is Solid carbide with Tin Aluminum Coating.

2.7f Fixture design, Process capability and Cutting Tool Life study

Work holding fixtures were made to hold 12 pc in a run, based on the available table space with 6 pins facing each other. When I run the machine, the first 6 pins will have the first cross hole and the second 6 pins will have the second cross hole. CNC programs were made to follow the path as explained in above layout. Once the CNC program has been proved, the next step is to study the cutting tool life to estimate the number of holes can be made per cutting tool.

Set aggressive cutting parameters for the cutting tool to break initially and then dropped down to optimal parameters. Both tool life and process capability study performed together to reduce the project time frame.

Based on experience, drafted a sample plan to make 1000 pc order. The life of the tool was initially expected to 400 to 500 pcs. The results were shown above in the previous section. Each sample represents every sixth pc of a run. All the samples were collected in an order to see how the Max B Dimension is varying and also to see how the cutting tool is behaving in the process.

Initially I started with Max B- Dimension, after machining some pins, I have witnessed the Max B Dimensions were dropping. Analyzed it was due to tool wear happened in the process. Then I did Z correction to make the Max B Dimension to the same as started. I repeated the same till the tool is not cutting the metal. I made 3 Z corrections for making 600 pins before I change the tool. Then I completed the balance pins with new tool.

2.7g New Inspection methods:

For Variable feature – Max B Dimension

Picture - 3 Measuring Max B Dimension

- Inserted the balls in to cross holes of the pin.
- Designed a ball nose plunger and adopted to a load meter of capacity 100 Lbs.

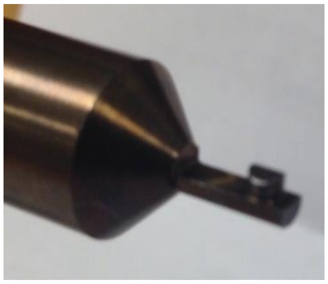
Picture - 2 Inspection set up

- Pushed the balls against the PBR profile using the plunger and maintained the load 11 to 13 Lbs. for each pin to get its Max B dimension.
- Used a pitch Micrometer - 0.00005" resolution to get Max B dimensions as shown.
- Inspected all the pins and got the dimensions and used Minitab to check the process normality and Process Capability **Refer Graph 2 & 3**

For Attribute features

1, Cross hole diameter measure through ID of pin.

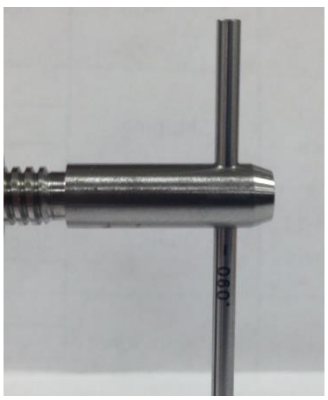
There are no standard instruments available to get the cross hole diameter after the top cone has been machined due to its inaccessibility. Developed a new break through tooth brush form gauge as shown below. It has a sizing cylinder made on stem diameter which is lower than the internal diameter of the pin. It can enter through the nose of the pin and get inserted in to the cross holes to check its size. These gauges were made with increments of 0.001” on the sizing cylinder diameter.



Picture – 4 Tooth Brush form Gauge

These gauges can answer Yes or No type. The stem and Leaf Plot display shows 157 cross holes has 0.096” and 45 cross hole has 0.097”. These cross hole sizes 0.096” and 0.097” can allow the ball bearings to enter freely during the assembly.

2, OD Cross hole diameter of the pin (Cone minor diameter).



Used regular Pin gauges to check the OD cross hole of the pin.

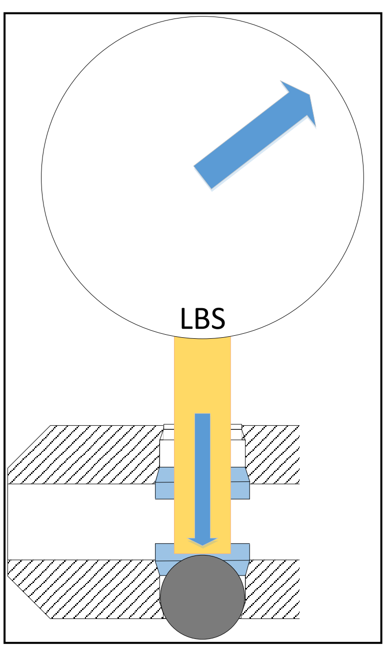
126 Holes are with 0.090” and 76 Holes are with 0.091”

This confirms that the contact point circle diameter is 0.093” is on the cone formed in the pin cross hole.

Now, PBR is realized.

Picture – 5 pin gauge

2.7h Destructive testing and Customer Specification



Cross hole Ball push out destructive testing was carried out per NAS 1332 Specification. The push out values should be at least 10 lbs. for 3/16”, 15 lbs. for up to 3/8” pins and 30 lbs up to 1” Pins.

Ball push out test performed for the PBR feature. Insert the ball in to the cross hole, insert the hardened pin from the top hole and apply load on the pin and measure the load when the ball is popping out.

		Push out Values lbs		
S.no	Pin	NAS 1332	Stake	**PBR**
1	¼”	15	20	**45**
2	3/8”	15	35	**175**
3	½”	30	45	**600**

This PBR feature shown superior results than NAS 1332 specification and stake design, the ball will not get missed after the pin assembly.

Fig - 10 Push out Testing

The high ball pushes out values has provided opportunity for a higher Max B dimensions by increasing its tolerance range. This ensures additional product safety while lifting heavy objects.

2.8 The tasks delegated and how it was accomplished;

Initially it was started as an improvement project with the Warner Swasey multi spindle machine leads to "The Other way of manufacturing Quick release Pins". Mapped the overall project process layout and solved the important issues as stated above in the background of this project. The fourth and fifth one was totally a new conceptual thing. Eliminating the cross hole issues and staking process from the regular pin's, implementing the new concept PBR for addressing missing ball issues and make them a reality is one of the benchmark conceptual reality project, that was accomplished.

This huge task was achieved by taking positive steps applying Mechanical and Industrial engineering knowledge and conceptual skills gained through earlier work experience by asking right questions at each difficult situation. Solid works and AutoCAD skills helped to spec out the concept in a visual and dimensional format by eliminating the unknowns in the processes. Team work thought process begins with the team members and higher ups in the organization and gained their support to move forward to make the concept a reality. Designed and developed the concept, tools, gauges, inspection methods and identified the product variables and attributes. Once the destructive test has proved that PBR concept is working and is the best than the current staking process. True objective was achieved when we presented the concept to our premium customer and reinstated their satisfaction on the products.

2.9 Any particular technical difficulties/problems faced and how it was solved ;

When it was planning to machine the PBR cross holes in the pins, it was not knowing that how to measure the ID cross hole diameter. There was no standard instrument is available to check the diameter at the machine due to it accessibility. We were trying using the correct ball size bearings in to the holes, but it was not the right method to measure the ID cross hole diameter. Questions were raised in the meeting that how measuring this diameter can be achieved.

Applied thought process, which resulted a new form gauge that can enter through the nose side of the pin. The tooth brush form gauge as shown in the previous section under inspection. The form gauge was presented to the Team with the PBR Pin samples everybody was so satisfied. This custom tooth brush form gauge has solved the problem of not having a standard gauge and can measure the product attribute feature.

2.10 Strategies devised including any original or creative design work:

- History data collection from ERP system and Quality portal to see how bad the Quick Release Pin cross hole issues are affecting the business.
- Performed close observation at each process of manufacturing pin.

- Prepared the project details and shared with all its metrics to the higher ups, to start the project and as the project getting progressed, immediately sharing the details on regular intervals with the team members.
- Studied and Reviewed the geometrical dimensioning and tolerance requirements stated in the products (stake design). Documented the tolerance range for each dimension and captured the critical boundary conditions. Asked the right questions to the features that doesn't get answered, which is a huge variable that always lead to inconsistency in the products.
- Resulted a new creative design using solid works and AutoCAD,that led to the introduction of the new concept Positive ball retention – PBR. A new premium product line in the Pin Family.
- Constructed geometry of the new PBR concept for 20 different pins with critical boundary conditions and arrived its cone angle.
- Design the cutting tools with its dimensional constraints and purchased the cutting tools from the suppliers.
- Creatively designed the tooth brush gauges with it accessibility constraints to check an important attribute "ID cross hole diameter"

d) Summary

2.11 My view of the overall project

In over all this Positive Ball Retention PBR is a high level project for the conceptual reality. Design and developing the complete new concept, its tools, gauges, process development, new inspection methods, identifying the attributes and variables in the component manufacturing is a remarkable challenge. Always so thankful to all the team members in this project who physically worked, actively participated and helped in achieving this new conception. Again this PBR project has eliminated the current cross hole issues and regained the customer confidence with products. Now, this PBR is a new product line in the Pin Family.

2.12 How the project fared in meeting the goals/requirements;

The project has truly met the goal that was defined in the objective. This project has proved the conceptual reality with all its parameters. I have presented the details, that how the concepts came to reality, supported with all the documentary evidences such as test results, process capability results, cutting tools designs, development of new inspection systems and new custom gauges. I have proven the product being supplied to the truck company for their engine block assembly section. The conceptual reality got presented to the customer who rejected the pins for missing balls issue a year ago, this concept regained the confidence and also supported with new business for this premium pins.