Senior Design Fall 2007-Spring 2008

GT Technologies™

Group 10:

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Fall Semester Final Report

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1.0 <u>Abstract</u>

This project examines the hydraulic lash adjuster assembled by GenTek Technologies of Tallahassee, Florida. The subject of interest is the valve seat surface and the polishing process performed by GT Technologies to improve the performance of the hydraulic lash adjuster. The purpose was to develop a quality control system capable of developing quantitative data on the quality of the valve and valve seat surface and relating this quantity to oil leakage through the valve.

The desired end state was to posses a system capable of determining the predicted leak rate of the hydraulic lash adjuster and to have determined whether the polishing process needs to be applied after the supply of plungers had changed. In addition, the sponsor of the project, GenTek Technologies, desired to improve the polishing process such that the finished surface has a better quality than the products currently produced.

Research began with a close inspection of the current polishing process and an identification of what variables could be changed with the present setup without requiring the purchase of new machinery. Different grades of polishing stones and different materials were identified as test subjects. The visual inspection and air leak quality control systems currently used were determined to be insufficient to give quantitative data on the valve seat. Therefore, a suitable replacement was identified.

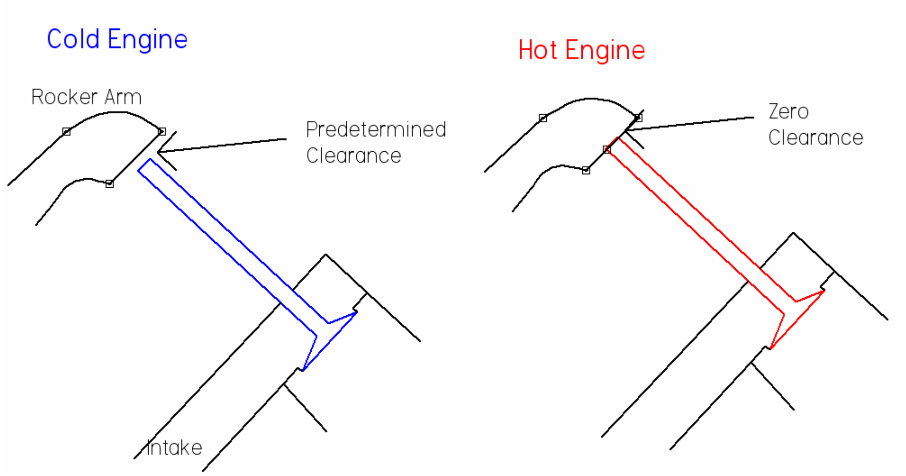
It was found that by cutting the plunger along its long axis and exposing the inside of the valve, the surface of the valve seat could be viewed underneath a high powered scanning electron microscope and the pits and grooves could be measured easily. A large number of polishing processes were found which, for different reasons, were not suitable for this application and it was concluded that mechanical polishing could produce a better result than other commonly used methods.

2.0 Introduction

2.1 *What the hydraulic lash adjuster is and how does it work and effect of HLA on automobile performance*

Our design project revolves around improving the plunger seat polish of GT Technologies' hydraulic valve lash adjuster. To understand the importance of a good plunger seat polish, we must first understand what a lash adjuster's function is. Hydraulic valve lash adjusters are used in most present day internal combustion engines. There are few different designs out on the market, but they all serve the same purpose; and that is to keep the rocker arm in contact with the valve stem. Zero clearance is desirable to the everyday driver because it prevents the annoying valve train rattling noise that may occur upon engine startup. Additionally, zero clearance is also crucial to the life of the valves themselves because without it, they will burn rapidly from the high temperature gasses exiting from the combustion chamber, especially the exhaust valve. That will lead to expensive maintenance that could have been avoided by use of lash adjusters.

Lash adjusters have the ability to keep the valve at zero clearance before and after thermal expansion of the valves takes place. In most cases, the valve stem is manufactured to a certain length during engine assembly. This valve is designed to be shorter than necessary when cold. Thermal expansion allows the valves to fit the engine perfectly and run with minimal clearance at normal engine operating temperatures. However, the deliberate shortness of the valve stem means that there is a gap, about 0.010" – 0.025", between the rocker arm and valve stem when the engine is cold.



Hydraulic lash adjusters compensate for valve stem shortness before thermal expansion occurs. Once the engine heats up, the lash adjuster will yield to the force of the expanded valve stem pushing on the rocker arm. The amount of force created by a lash adjuster is only enough to keep the rocker arm in contact with the valve stem; only the cam can overcome the valve spring force and push the valves open. A functioning lash adjuster will not be able to push a valve open. Only under extremely rare circumstances will an adjuster "pump up" and prevent the valve from closing.

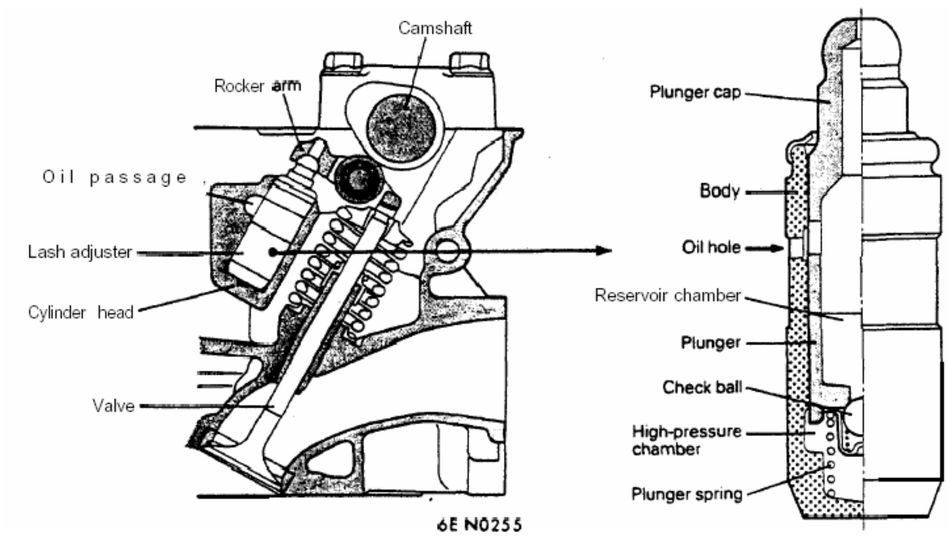
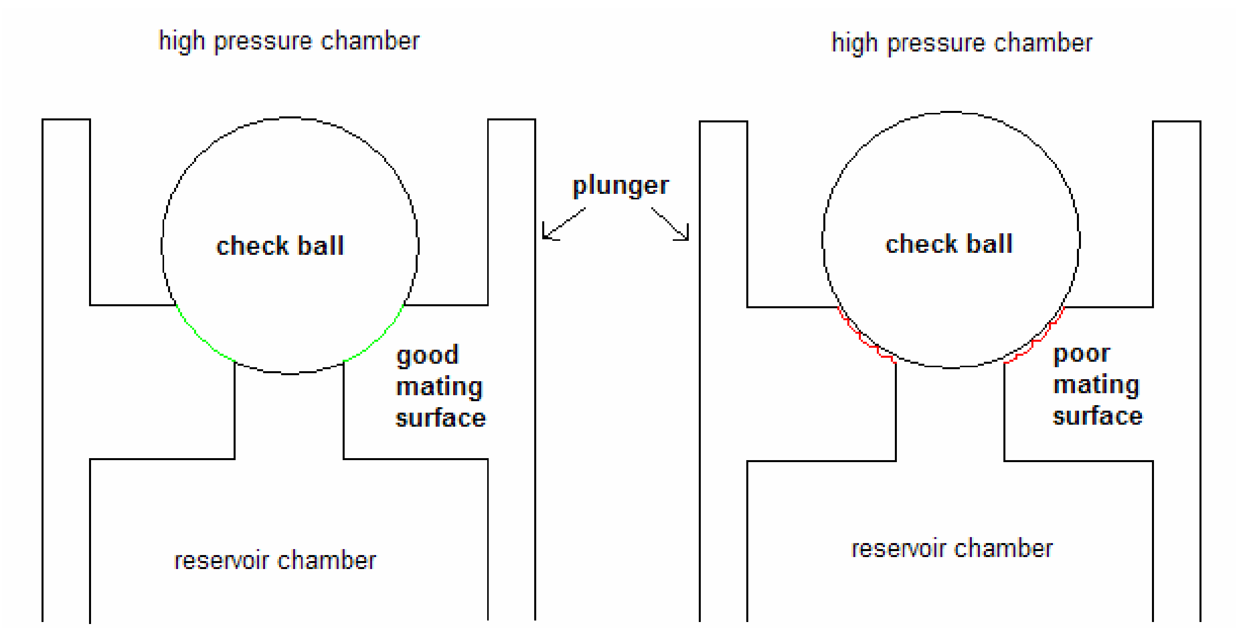


Figure 01

Referring to **Figure 01**, here is a walkthrough on how lash adjusters function. First, pressurized oil is brought to the adjuster via the oil passage. It then enters the lash adjuster through oil holes in the body and the plunger. Once inside the plunger's reservoir chamber (RC), the oil is forced down past the check ball (which works as a one way valve) and is trapped in the high pressure chamber (HPC). When this trapped oil builds up enough pressure, it pushes up on the entire plunger, which then pushes on the rocker arm, which in turn forces the rocker arm to a zero clearance position with the valve stem. Notice that once a certain amount of oil is in the HPC, no more can enter due to the plunger oil hole and the body oil hole being out of alignment. This leaves virtually no possibility of the lash adjuster expanding so much as to force the valve open. Once the engine is turned off and the car sits parked for a while, the oil in the HPC slowly leaks out through an extremely small clearance between the plunger and the body (roughly 35 millionths of an inch). The lash adjuster is no longer in effect, which is why there may be a noticeable rattling noise at engine startup. However, the noise should end within a couple of minutes, usually a few seconds with good lash adjusters.

2.2 *Effect of the seat polish on valve performance*

The focus of our project is on the plunger seat where the check ball contacts the plunger. This area is quite crucial to the overall quality of the assembled hydraulic lash adjuster. As stated in the previous explanation, the check ball is purposed to work as a one way valve between the RC and the HPC. Ideally, oil inside the RC will be forced into the HPC and trapped there by the check ball. If the geometry of the plunger seat prevents the check ball surface from mating perfectly, there will undoubtedly be some amount of backflow. **Figure 02** illustrates a good and a bad plunger seat mating surface.



(Not drawn to scale)
Figure 02

If the mass flow rate of oil leaking back into the RC is too large, the pressure in the HPC will not build up enough for the lash adjuster to function as it should. The importance of attaining a good mating surface is such a high priority that GT has designed a test specifically for the plunger seat / check ball seal. **Figure 03** demonstrates this test. They place a check ball on top of the plunger seat; then they clamp an air jet on top of the plunger, symbolizing the high pressure chamber. Most of the air flow is blocked, but a small portion makes it through to the reservoir chamber. The testing device is able to get a measure of the flow being blocked. The results are displayed on an LED scale. Good plungers with a low amount of leakage produce a reading in the "green" region on the scale. Failing plungers with too much leakage produce a reading in the "red" region.

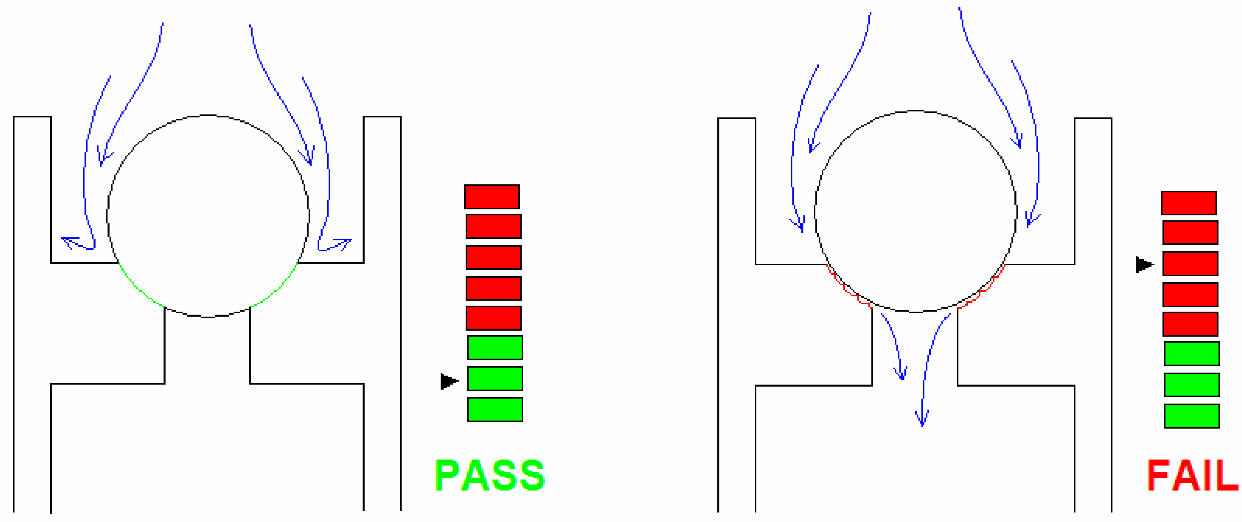
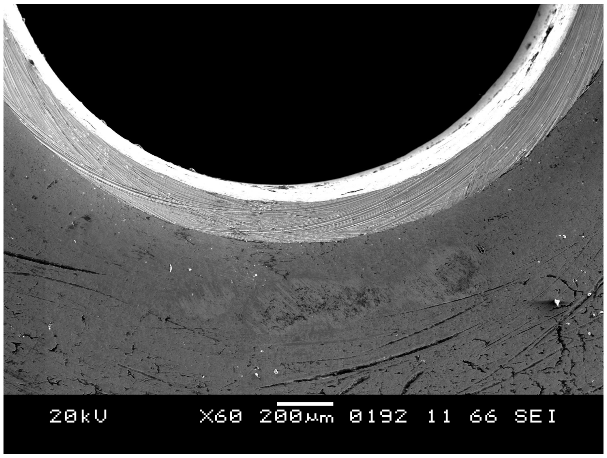


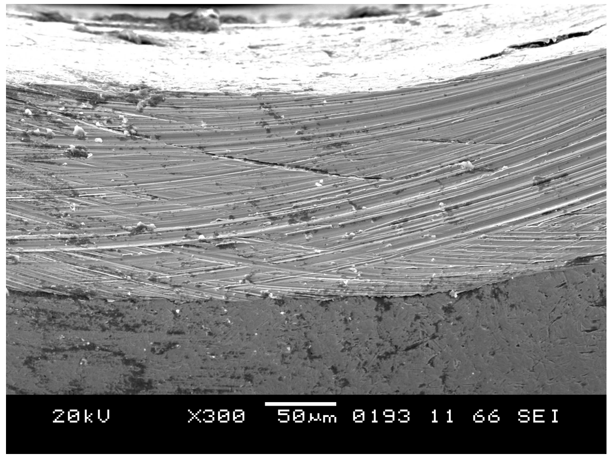
Figure 03

If a failing plunger is found, production stops immediately and the bad plungers are weeded out. It would be a devastating blow to the company if a large quantity of poor quality products hit the market. They would have to do a recall on the parts, they would lose credibility as a reliable manufacturer, and they might even face a lawsuit. Looking at money the company could potentially lose due to producing malfunctioning lash adjusters, it is very much worth discarding a batch of faulty plungers at one dollar a piece.

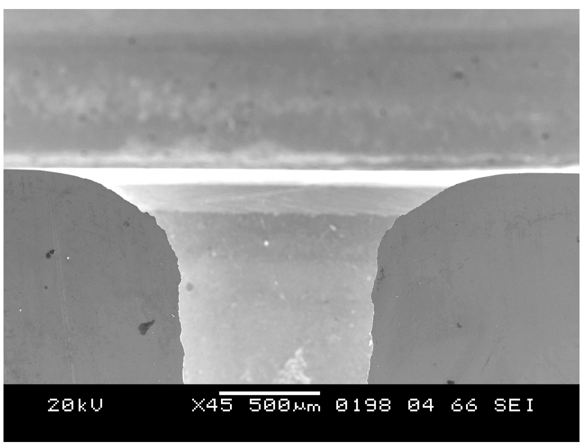
<u>2.3</u> *Polishing Process*

The polishing process used by GT technologies has been standardized over the past 12 years of operation. The plungers used in the hydraulic lash adjuster were tempered at 400 °F to help increase its strength, the side effect being the scales produces at the plunger seat. The process was original introduced to rid the seat of the plunger of scale and other imperfections.





A side effect of polishing the plunger seat is that the radius of the check ball is imposed onto the seat, which provides more surface area for the check ball to sit. Once, the manufacturer heat treated the plungers. This was a necessary step to remove carbide scale that would adversely affect product performance.

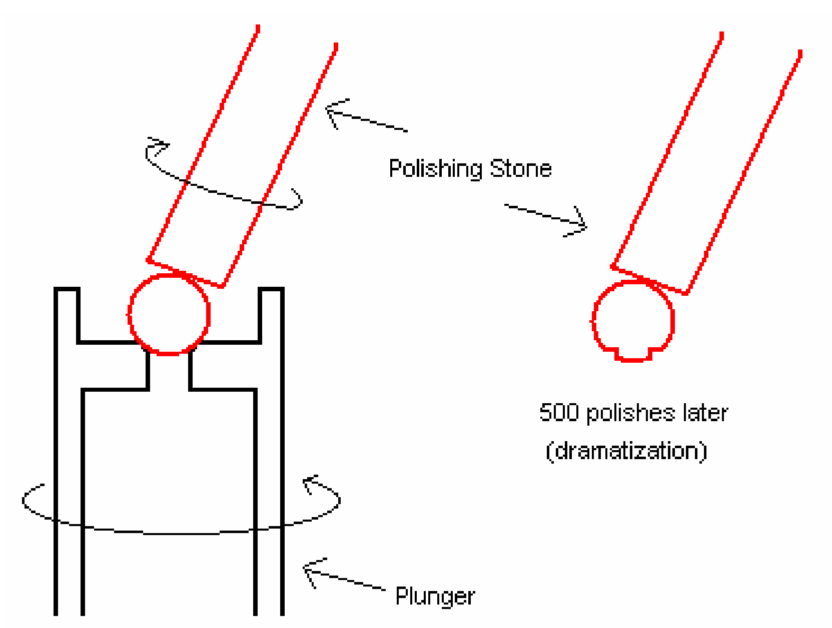


See Appendix H for more microscopy pictures

GT Technologies wishes to utilize the advancement in technology to stay competitive. The manufacturer supplying the plungers has changed the way produces the parts. The plungers have moved changed from being heat treated the plungers to cold formed. The plungers retain their strength without the side effects of scale deposits on the plunger seat. However, GT Technologies has not updated the processing of the plungers. The polishing process continues, but now instead of removing the heat scale the machines are actually grinding grooves into the seat. The grooves actually degrade surface finish. This could allow oil to leak faster than intended causing engine noise that is not destructive but affects customer perception. The goal is to reduce this side effect and determine if the process is even necessary.

The polishing process is autonomous. Three machines perform the polishing:

1. A hopper that stockpiles raw parts, orients in plungers with the valve in the proper direction, and feeds them to the spindle
2. A spindle that holds the plunger during polishing and ejects them when finished
3. A drill arm, offset at a previously optimized angled, adapted to hold a polishing stone and geared to polish for a set time



The polishing process repeats a five step cycle:

1. A plunger is fed to the spindle which rotates the plunger counter clockwise
2. The drill arm translates forward coming into contact with the plunger valve seat
3. The drill continues to translate forward a preset distance, depressing a spring in the drill head and applying a fixed amount of force from the polishing stone to the seat
4. The drill head finishes its cycle and retracts, removing contact of the polishing stone with the valve seat
5. The spindle finishes its timed cycle and ejects the plunger

In order to protect GenTek Technologies proprietary process, the specific details have been deliberately omitted.

Mechanical polishing has many variables that affect the surface finish. Eight of these variables were identified and are listed below:

1. Polishing stone material
2. Drill/polishing arm pressure
3. Drill head rotational speed
4. Plunger holding rotational speed
5. Lubricant
6. Time duration of polishing
7. Angle of drill head offset from plunger
8. Longevity of polishing stone use

This process repeats for another 499 parts. Once the 500 part capacity of the stone has been reached the machine stops and the operator must change the stone and restart the machine. This 500 part cycle takes about 30 minutes.

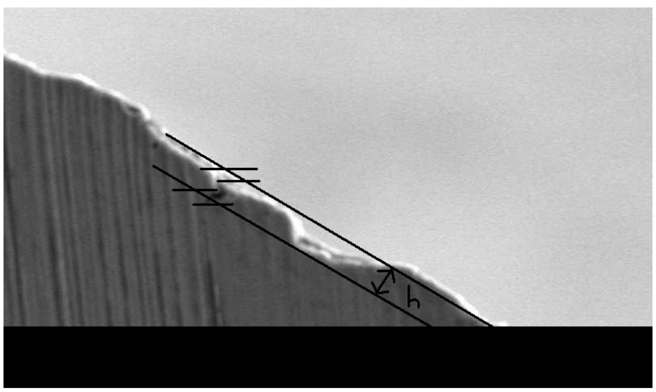
The stone currently used is course grit ¼” x 4” round ruby stone. This single stone is cut into four polishing stones with the 1/8” diameter of the check ball cut into the head. The stone used is manufactured by a company called *Gesswein*. They produce multiple grits of this same material as well as other finishing stones of the same dimensions and different materials.

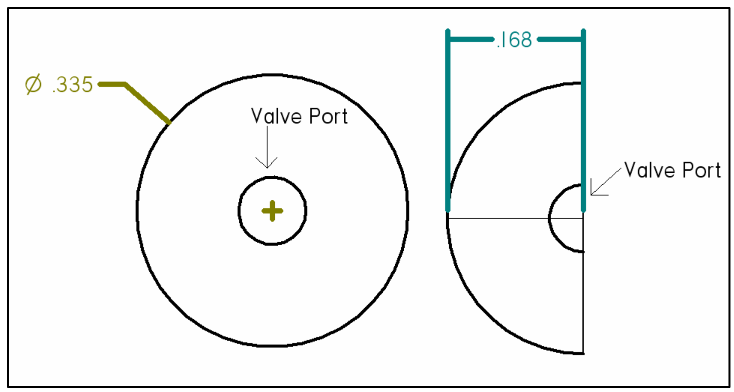
See Appendix D for Screenshots of www.gesswein.com

3.0 Technical Investigation

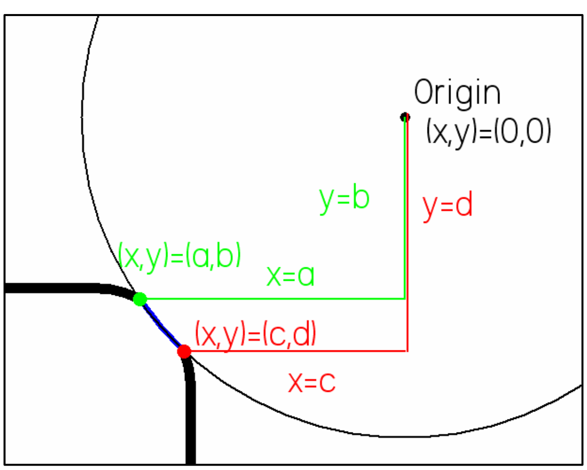
3.1 *Calculation of Valve Contact Surface*

Calculation of the surface finish is reasonably simple. Once a high resolution side view picture is obtained that contains the full check ball, the peaks and valleys of the grooves can be measured normal to the surface. The picture shown below and left is a 400x magnification of a plunger that has been cut along its long axis. For future testing, the accuracy of the surface calculations requires that the plungers be cut exactly in half. This will be done by measuring the sectioned plunger with precision calipers to verify that the piece is exactly half the diameter of a standard plunger.





Measuring the contact surface is also relatively simple. The ends of the contact band can be plotted on a coordinate system with the center of the check ball as the origin. Then a multi-variable calculus formula can be applied that finds the area of a surface of revolution. The contact surface can be viewed as a two dimensional surface revolved around a central axis that passes through the center of the valve hole and the check ball. Once coordinates are established, the "height" of the band is found by simple algebra.



$$y_2 - y_1 = h$$

Surface area = S

See Appendix E for proof

<u>3.2</u> *Plunger-Plunger Body Leakage*

In order to find the mass flow rate around the cylinder, we used Bernoulli's equation   First, the flow areas were calculated simply by taking the inner diameter and adding 35 millionths of an inch to the value. This tolerance was specified by GT technologies. The operating pressure was also presented and the density of oil was known. The velocities and areas give rise to the mass flow rates. The volumetric flow rate was also presented in order to better show the relationship between a pressure and the flow around the plunger body.

See Appendix F for calculations

The calculations are a rough estimate of the amount of flow through an enclosed space, but have few implications on the actual leakage of the plunger. Bernoulli’s equation applies only to incompressible, non-viscous flow. Yet considering that the clearance between the plunger and plunger is only 0.000035” of an inch, surface tension between the metal and the oil cannot be ignored. Lubrication theory must be applied here. The theory deals with fluids in small spaces where surface tension, viscosity, and even intermolecular forces are considered. This is not a subject typically covered in undergraduate engineering but is necessary to developing an accurate model of oil leakage through the valve and around the plunger.

<u>3.3</u> *Theory of cause of leaks*

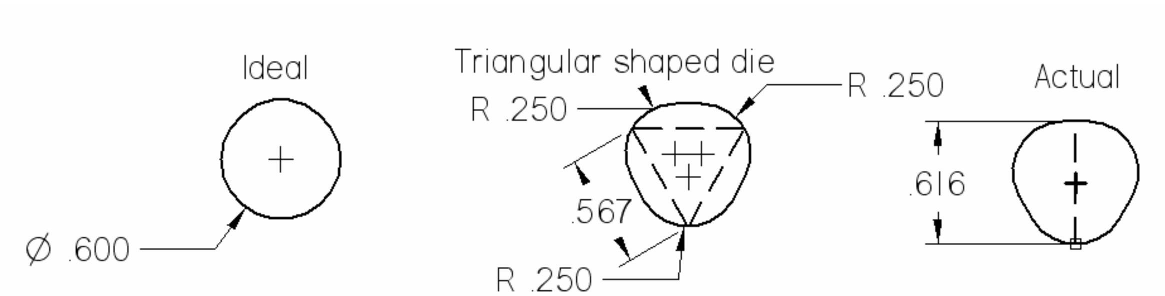
The main characteristics of the hole can be divided into two categories: geometry of the valve hole and surface finish of the seat. Valve geometry is determined solely during the manufacturing of the plunger, which takes place at the suppliers manufacturing plant and is beyond the scope of this experiment. Surface finish is determined by many factors, some of which can be easily changed and some require retooling and new machinery.

The specifications for the valve are as follows:

- Valve port is 0.086” ±0.006” diameter
- Ideal port is countersunk at 86° angle
- Tapered valve contact surface is a minimum of 0.006” wide after polishing
- Check ball used is a 0.125” ±0.00012” diameter grade 24 ball bearing

See Appendix I for Pro Engineer model and live picture of plunger

According to Ken Bunne, an engineer employed by GT Technologies, the manufacturer uses a triangular shaped tool to tap the hole in the plunger. The resulting hole therefore slightly takes on the shape of the tool. Even after rounding out the hole in a milling machine, the valve will retain some triangular characteristics.



These dimensions are not accurate to the design specifications and are exaggerated to demonstrate the concept.

This leads to deviation of the hole from the defined roundness tolerance. Clearly, a sphere will not share as much contact surface with a non circular hole as with a circular hole. Less contact surface results in more leakage. The engineer stated that the roundness of the hole has a larger impact on the amount of backflow fluid leakage than any other factor including surface finish. Consequently, the new quality check method would need to measure the roundness as well as surface finish.

Technicians began to notice horizontal grooves in the valve seats after changing the supply of plungers from heat treated to cold formed parts. Different manufacturing process will give the stainless steel plungers different properties, particularly surface hardness. Though little is known about what cooling method the manufacturer used when forming the plungers, it is accurate to state that the heat treated plungers for which the polishing process was designed have different material properties than the cold formed plungers now in use. The original purpose was to remove carbide scale from the steel. Carbides materials are alloys of metals and nonmetals and carbon. Materials such as aluminum carbide, silicon carbide, and boron carbide are known for their hardness and strength. Boron carbide is among the hardest known materials. Therefore, heat treated plungers likely had a harder surface than the current cold formed plungers. Softer metals should respond better to a softer grit polishing stone and lighter pressure from the polishing arm.

In conclusion, the two primary causes of leaks are roundness of the hole and change in surface hardness of the valve seat. Roundness has a larger effect on leakage but is determined by the manufacturer of the plungers. Surface finish will affect the clearance between the check ball and the valve seat but the polishing process in its current form may be degrading the surface quality rather than helping it.

3.4 *Cost analysis*

The money spent on the polishing process is a significant cost to GT Technologies. The polishing machines are run during the first and second operating shift. Each shift is 8 hours long and the polishing machines run continuously for those 16 hours. GT Technologies operates 24 hours a day 7 days a week 365 days a year. The operating cost for each machine is approximately $9.12/hr. That amounts to operating cost of $53,260.80 per year for one machine. Multiply that by three and the total cost is (not including operator's cost) $159,782.40 per year. One worker is in charge of operating all three polishing machines used by GT Technologies. Depending on the labor grade of the operator determines the amount of money they are paid for operating the machines. In other words if they make $9.00/hr divided by three machines that means $3.00 more dollars is added to the operating cost of each machine. GT Technologies even includes a 41% fringe benefit plan for its workers, which would increase the hourly pay of the worker to $12.69/hr. The labor grade of the operator is usually a 5 whom gets paid 12.38/hr plus fringe benefits. In total, the operator makes $17.46/hr. Their hourly rate is divided by the 3 machines and is added to its operating cost, which now totals $14.94/hr. This now bring the total cost of running all three machines for the year to $261,724.27 per year. Now this is for a perfect scenario with no needed machine repairs. Since these are man made machines with multiple moving parts, break downs are inevitable. Clearly, running these machines greatly cuts into GT Technologies profits.

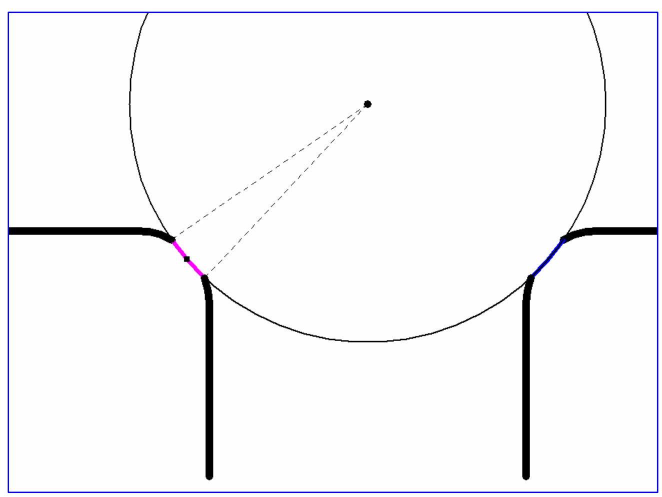
See Appendix G for Tabulated Cost Data

<u>3.5</u> *Proposed Improvements*

The purpose behind changing a manufacturing process is typically one of the following:

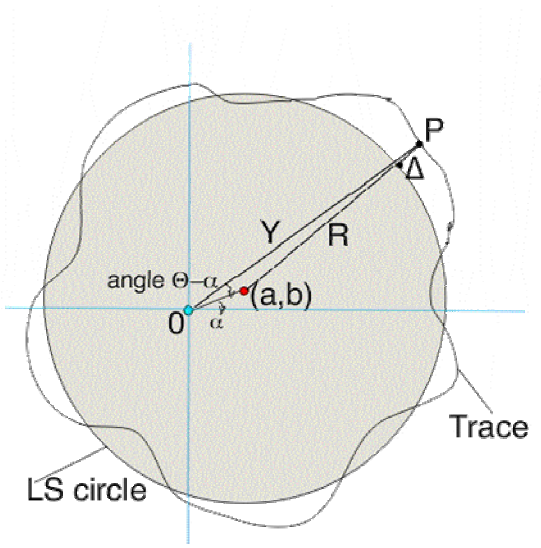
- Decrease costs to produce the product
- Decrease production time
- Improve quality by decreasing failure rate
- Improve the safety of workers and the environment

GT Technologies has already improved workplace safety by changing to a more environmentally friendly lubricant. The task for this team was to improve upon one of the first three goals. The highest priority was to improve the quality of the plungers that are sent to the plunger assembly station. A secondary priority was to determine whether the polishing process could be eliminated, decreasing costs significantly as discussed in the Cost Evaluation. The current process operates at a very fast pace that could only be improved by employing another method of polishing. Therefore, this team only focused on not increasing production time and did not concern themselves with decreasing production time.



Quality is defined as having a surface geometry that permits the least amount leakage. This is accomplished through valve port roundness and surface finish. Therefore, standards need to be established on what constitutes acceptable roundness and surface finish. The shape of the surface seat is a spherical impression that permits greater surface area contact, a desirable characteristic that should be maintained.

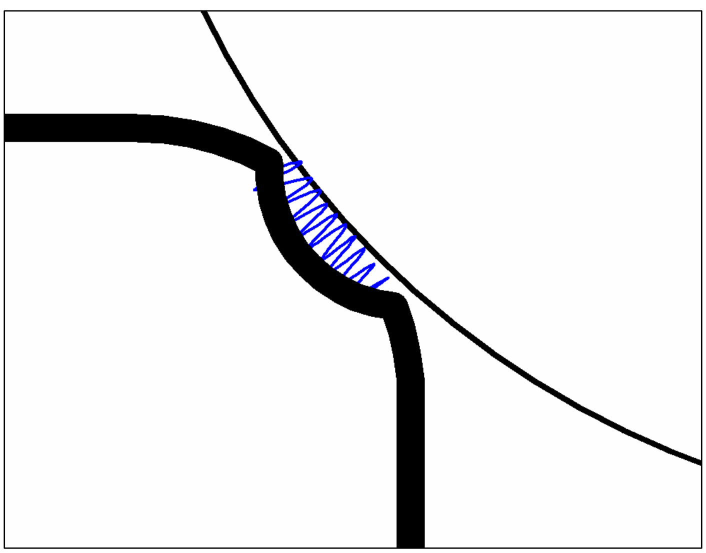
While roundness has a greater impact on the quality of the valve seal, it is mostly determined when the plunger is manufactured, before they arrive at the plant floor.



Improvements to the quality here will be the addition of a measurement system that quantifies the roundness of the hole to see that they are within the specified limit. Calculating the roundness can be done by tracing the circular surface, in this case the valve seat. This can be done by a mechanical stylus or an optical laser. Lasers provide higher speed, precision, and accuracy and could simultaneously measure the surface finish.

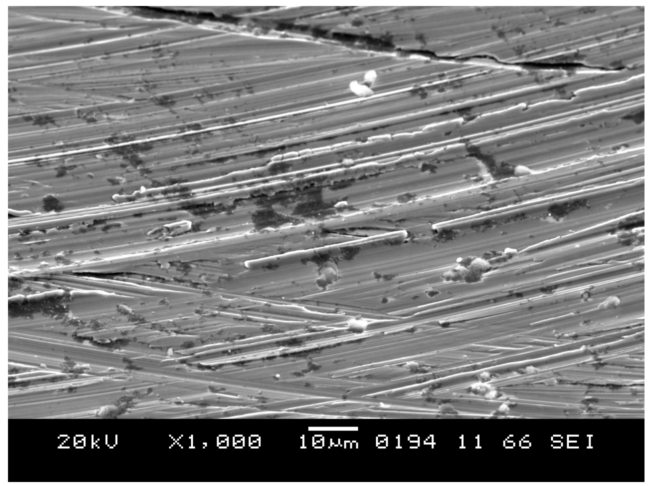
http://www.itl.nist.gov/div898/handbook/mpc/section3/mpc344.htm

The same system that measures the roundness should be able to measure the variation in peaks and valleys in the valve seat. The peaks reduce surface contact area by keeping the check ball from seating all the way into the valve. Valleys can trap debris in the oil and lodge the valve open, increasing leak down rate.



If a polish of good finish can be obtained once, the image can be captured and used for computerized comparison during the quality control process, much like fingerprinting. During the testing process, plungers will be cut in half in order to measure the surface variation. However, the online quality control machine will need to measure surface variation from directly above as cutting parts will add to production time and lost product.

The majority of the effort will focus on improving the seat polish. As discussed in the technical investigation the polishing process in its current form cuts grooves into the seat. What is desired is to maintain the spherical shaped seat while reducing or eliminating the peaks and valleys of the grooves. Testing will include three variables:



1. Polishing material
2. Time
3. Pressure

The other 5 of 8 variables were excluded due to previous optimization and inability to change with significant retooling. Removing the grooves will be accomplished through use of finer grit materials, increasing polishing time, and decreasing pressure. A two stage polish of course grit then fine grit may also be successful. Stone longevity will be increased by using harder polishing stones such as diamond that require less frequent replacement, decreasing machine down time. Increasing pressure will increase pressure on the polisher will cut a deeper seat, but may increase the depth of grooves.

Improvements to the plunger seat polishing station will include the addition of a roundness measuring system, a non destructive polish quality measuring system, and decreasing the surface grooves.

4.0 Test Procedure

4.1 *Test Procedure*

Testing will be done in multiple stages.

1. Preliminary high resolution photography at NHMFL (National High Magnetic Field Laboratory)
2. Measure and calculate the pre-polish surface area and finish.
3. Perform polishing at College of Engineering machine shop
4. High resolution photography at NHMFL
5. Measuring and calculating contact surface area and surface finish

The first set of polishing tests will include five different variables: stone material, rotational speed, polishing time, pressure, and direction.

				# of Tests
Material	Fine Grit Ruby 5/16” x 4” round	Fine Grit Diamond	Course Grit Diamond	3
Speed	Low	Medium	High	3
Time	2 Seconds	5 Seconds	10 Seconds	3
Pressure	10 lbs	20 lbs	30 lbs	3
Direction	one direction	two directions		2
				14

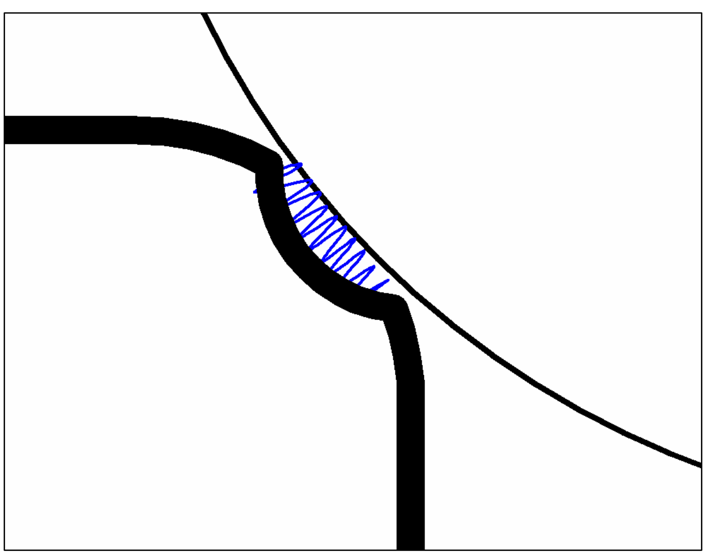
Test 1: Material: The material used is a fine grit Ruby as discussed earlier. Two other materials that have been found potentially offer a better polish in a shorter amount of time. The Fine Grit Diamond and the Course Grit Diamond can offer a longer length of operation with potentially better results. These three materials will be used for three polishes each. The surface finish quality and the roundness of the seat will be analyzed by the high resolution photography at NHMFL. The test will also analyze how the material lasts in a run of 500 parts, a typical cycle of one polishing stone. If the results of the surface finish and the material last longer, this test will be determined to be a success.

Test 2: Rotational speed. The speed of the polishing machine can be programmed into the controls of the machine. Testing the change in speed will look at how many rotations are done by the machine to remove material. In addition, to consider on the rotational speed is the heat generated by the polishing stone, and how this affects the wear of the stone and the effect on the part. Also in this test, the polishing stone will be analyzed after the testing procedure is completed and a run of 500 parts is completed. The test will also be a success if the polish quality is improved and the material at least lasts the 500 part duration.

Test 3: Time of Polish: This test essentially provides the same result as the rotational speed, more or fewer polishing stone rotations. The one difference is the amount of heat generated by the increase in speed of the first test. One drawback to altering the time of the polish is this changes the amount of parts that can be polished per hour. The amount of parts completed is vital to the success of an improvement for the company. The test will have three different lengths of polish: 2 seconds, 5 sec. and 10 sec. This test will only be a success if the parts have a significant improvement in the seat quality or roundness. The sponsor does not want the process of polishing the parts lengthened.

Test 4: Pressure of Polishing Stone: The pressure of the polishing stone is altered by the spring loaded in the polishing machine. This test will have three different spring pressures: 10 pounds, 20 pounds, and 30 pounds. The pressures could allow more material to be taken off in a shorter amount of time. If the test does prove to remove enough material to make a more round seat and make a smooth surface, the polishing process could be changed to be a shorter process. This test will be a success if the seat quality is improved and the polishing process can be shortened.

Test 5: Rotational Direction: This test will run with 3 plungers and will test if the polishing process should rotate the polishing machine in two separate directions: clockwise and counter-clockwise. The test will be a success if the roundness of the seat is improved or if the surface quality is improved.



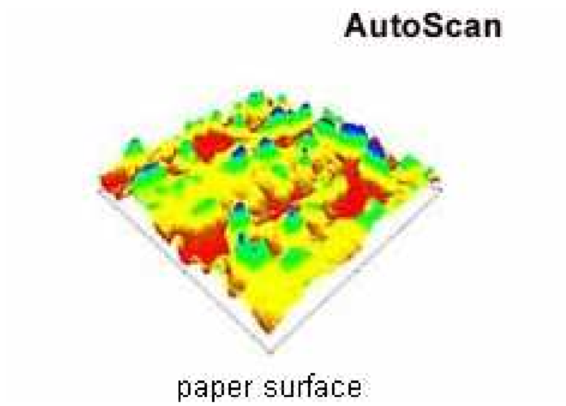
With each test variable 3 plungers will be polished. One of these will be taken to the NHMFL, cut in half, sealed with a check-ball spring-cap retainer assembly from the GT Technologies assembly line, and photographed under the JEOL JSM-6380 scanning electron microscope. The purpose of sealing with a check ball is to see the actual contact surface between the valve seat and the ball bearing. The seat geometry calculation process described in the Technical Investigation section will be used evaluate the performance of each polish. Once all test samples have been measured, the variables producing the best result will be run through a second set of trials, perhaps combining multiple variables. Once the best combination of variables is identified that obtains the best seat polish a recommendation will be submitted to GT Technologies for approval.

4.2 *Selected Quality Control Method*

The chosen method for quality control is an optical scanning, measurement and comparison computer. Optical scanners have an advantage in precision, accuracy, and speed over mechanical stylus measurement machines. Optical machines have the capability to measure both valve port roundness and surface polish quality simultaneously. By visual detecting the geometry of the port and modeling in a computer program, a polished plunger can be compared to a digital master stored in the computer. The standard of comparison will be an image of a previously polished plunger seat that has been determined to be of passing quality or a computer generated ideal model. The chosen standard will depend on what the software is capable of performing.

Since the surface of any polished valve will be less than perfect, upper and lower tolerance limits will need to be established. An acceptable amount of leakage through the valve is that which is minimal compared to the flow rate around the plunger. Using lubrication theory as a model for the fluid flow a flow rate for the outside of the plunger will be found. When the acceptable fluid flow is found around the plunger, an acceptable flow rate at the valve seat of the plunger and ball bearing will be found. The clearances at this valve will be based on the valve seat geometry. The amount of contact surface area will need to be sufficient to allow the fluid to be closed off in a single direction. The surface of the plunger seat is the area of interest because the ball bearing comes at a near perfect 0.125 inch radius.

As discussed before, the plunger seat is a triangular shape and the major problem in the contact area is in the roundness of the plunger seat. The polishing process that is currently being used is performed to create a new surface with better roundness. A new process of measuring the roundness of the plunger seat should be used to see if the polishing process is needed. An optical scanner should be used to measure the seat of the plunger using a distribution of the centers of radii. With an optical detection system, computer software would be required because calculations of this magnitude are difficult and time consuming to perform. The size of this part and the changes in the curvature of the seat are so minute that a computer would be more adept for the measurement of these parts. Also by using a machine, the process would be much faster and more accurate.



UBM Corporation has a machine that is capable of producing a picture as shown above that shows the surface quality by displaying peaks and grooves of the surface in a color-coded height. The ability to analyze the actual surface heights would be vital to the analysis of the quality of the seat of the plunger.

4.3 *Suitable Quality Control Machines*

An idea we had for testing the polished plunger seat surface was a 3D surface comparison. We would start by creating digital master of a geometrically perfect polished plunger seat, and program that into the computer. Then we would require hardware capable of taking a 3D scan of the plunger seat. Next, we would need some software that could compare the scanned image to the digital master. Based on how close the scanned image and the digital master match up, the part will either pass or fail. This seems to be the most logical approach because what the problem on hand is a geometry problem. If the plunger seat has the correct geometry, the check ball will create a good seal no matter what. Theoretically, there would be no need for the air test, which they are currently using, and is not necessarily accurate.

In our research, we were able to find a few machines capable of doing a 3D scan of the polished plunger surface. The first is the Wyko NT1100 by Veeco (see **Figure 04**). This machine produces fast and repeatable high resolution 3D surface measurements. In addition, the precision is more than suitable for our needs. This device can measure roughness on the sub-nanometer scale, and it can measure millimeter-high steps. The machine's advanced optics ensures high sub-nanometer vertical resolution at all magnifications.

Wyko NT1100

Figure 04

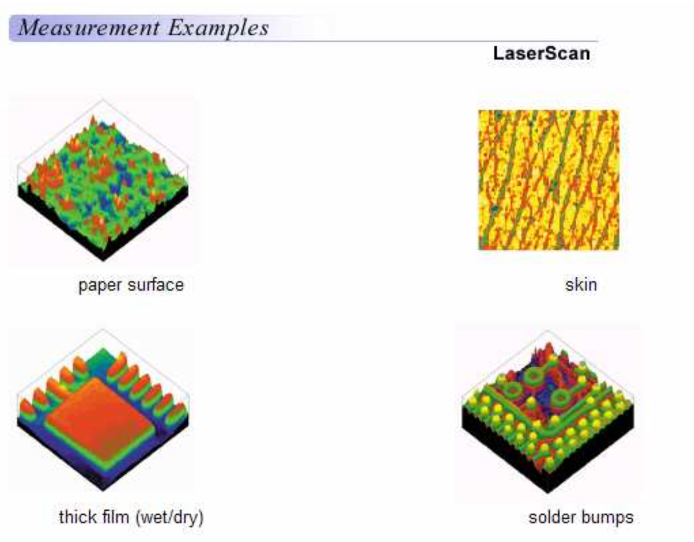
The next machine is also from Veeco. It is the Wyko NT9800 (**Figure 05**). This optical profiler delivers rapid, non-contact, 3D measurements from 0.1 nanometers up to 10millimeters. The measurements we would need are well within that range. The machine's speedy non-contact repeatability is also a feature we are interested in. The more parts we can test, the better. It will give us a better idea of the consistency of the polishing process; more specifically, when do the polishing stones wear down to the point of producing a bad polish?

Wyko NT9800

Figure 05

Last but not least we came across the UBM LaserScan (**Figure 06-a**) which sounds perfect for our application. The product description tells us this device can conduct nondestructive laser measuring of touch-sensitive surfaces, the accuracy range encompasses vertical resolutions down to .01 micrometers, and it has a fast sensor cycle time. This non-contact surface profile scanning laser is one of the more affordable solutions, yet the accuracy is not sacrificed. In order to be applicable for a wide range of customer-specific scenarios, the LaserScan’s sensor and staging configurations can be adjusted and tweaked to fit virtually any customer need. On the UBM LaserScan webpage they include a short list of customer applications, which include: thick film and hybrid fabrication for height measurement, paper printability and surface texture, and most importantly for us, automotive component measurement of wear, radius of curvature and surface finish. Refer to **Figure 06-b** for examples of the UBM’s scanning capabilities.

Figure 06



UBM LaserScan Setup

UBM LaserScan Samples

(a)

(b)

5.0 Conclusion

The project in nature is an analysis and improvement on an existing procedure. The lash adjuster seat polishing machine is already designed and implemented in an everyday process. Therefore, the project at hand is to analyze the problem and prevent it from happening. Also included in this analysis, GT Technologies has asked us to analyze the parts as they have come from the supplier to see if any process to improve the seat quality and roundness is needed.

The quality of the part from the manufacturer as mentioned before is now cold formed, without scale from a heat treated process. This has questioned the process at hand because the original reason for the process to take place was to remove that scaling. Analysis run by the sponsor in the past has shown that the scale was not the only issue in the leakage in the valve, but the shape is a large factor.

The shape of the seat is being analyzed by high resolution photography at the National High Magnetic Field Laboratory. After the preliminary tests have been completed this semester, it has been found that a better device designed entirely for this analysis should be used. The size in which the analysis is being run makes the analysis difficult to do by hand. One product of the testing this semester has led us to see that the surface quality is also very poor. The polishing process, although improving the roundness of the seat, is also destroying the surface of the part, making it rough and uneven.

The surface of the polished material is not of a very high quality because the materials and processes being used are old and outdated. We have taken the notion to prevent the problem of a leak in the surface contact to mean that the surface polished needs to be analyzed and improved before the leak should be tested. Also completed this semester is a preliminary analysis of the surface to identify the problems inherent in the quality of the polish. This preliminary analysis has shown that the material is in fact a problem and that something in the process of the polishing needs to be changed to improve the quality.

The test procedure discussed above is our plan to analyze the current process and materials in a hope to improve the seat finish and roundness. All of the factors in the process have been looked at and either eliminated or included in this test. The testing will occur next semester and will provide for some answers on how to improve the lash adjuster seat quality, the roundness of that seat, and the process that goes into improving the seat.

6.0 References

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Hydraulic Lash Adjuster image
http://www.idmoc.com/Images/News/hla1.gif

Troy Johnson

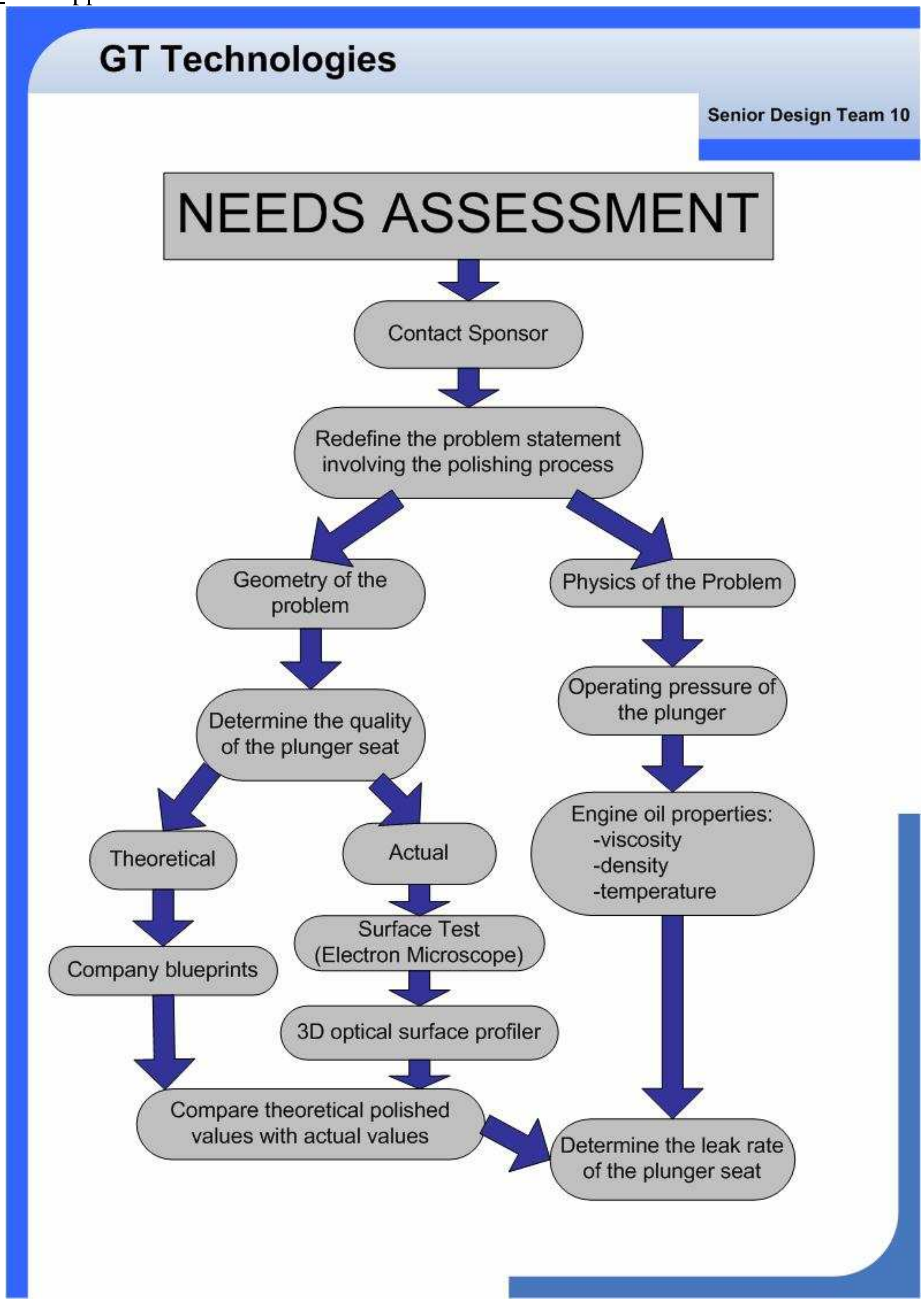
Al Petrovosky

Ken Bonne

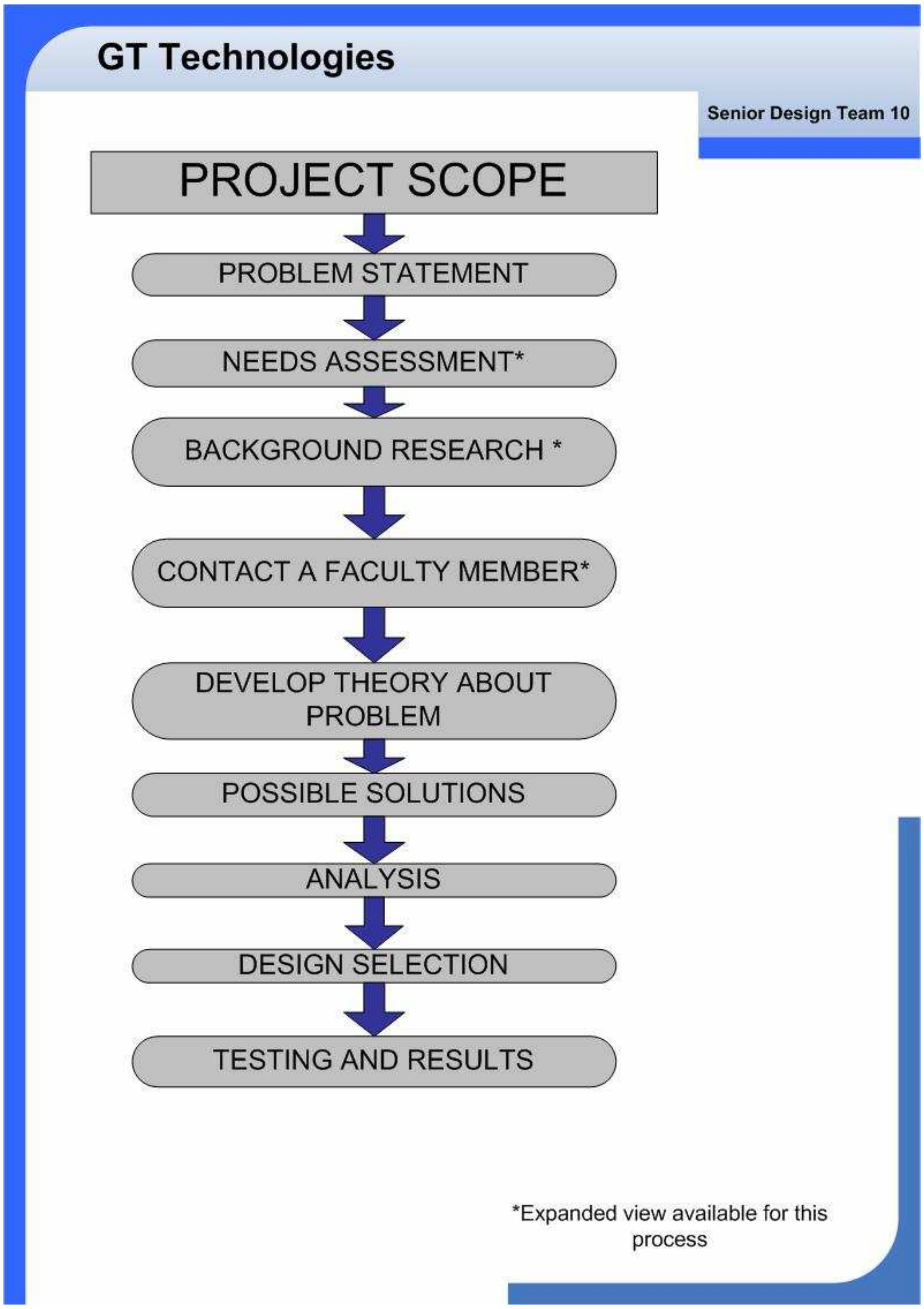
Shiva Vekatamaran

7.0 Appendices

7.1 Appendix A – Needs Assessment



7.2 Appendix B – Project Scope



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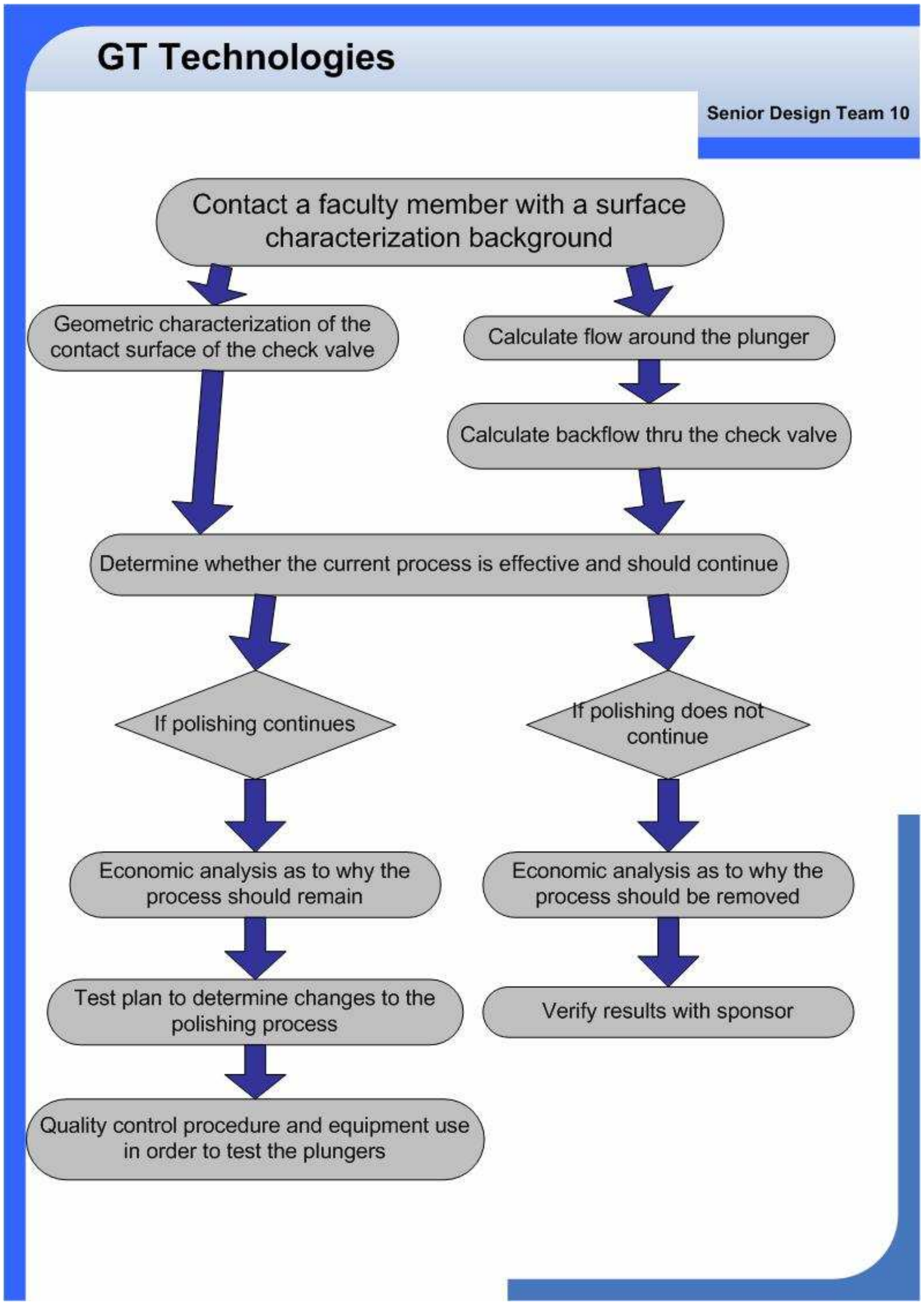

GT Technologies
Senior Design Team 10
Contact a faculty member with a surface characterization background
Geometric characterization of the contact surface of the check valve
Calculate flow around the plunger
Calculate backflow thru the check valve
Determine whether the current process is effective and should continue
If polishing continues
If polishing does not continue
Economic analysis as to why the process should remain
Economic analysis as to why the process should be removed
Test plan to determine changes to the polishing process
Verify results with sponsor
Quality control procedure and equipment use in order to test the plungers

7.3 Appendix C – Product Specifications

GT Technologies has asked us to design a test apparatus that could effectively test the clearances/seal quality between a ball and plunger set that is being used in a hydraulic lash adjustor assembly. The product itself has to follow a set of guidelines:

1. Test clearances between the ball and plunger close to 35 millionths of an inch
2. Determine the eccentricity of a circle, representative of the spherical shaped ball seat, to within 1 ten-thousandth of an inch
3. The tester should be able to perform two tests in less than five minutes in order to keep up with the production line.
4. It cannot contain any known carcinogens or materials that are harmful to human health
5. Provide operation conditions/scenarios that are similar to those in a working internal combustion engine.
6. The design should be able to accurately tell the amount of test fluid that is leaking in between the test object and plunger. An experiment will then be set to find out whether the grinding of the plunger seat is even necessary to the production of the hydraulic lash adjuster.
7. Display quantitative data on the quality of the seal between the seat and plunger.
8. Set an effective “pass” or “fail” system for the leak tolerances of each plunger.
9. The machine has to able to fit on top of a standard 18’’ X 4’ work bench
10. Has to meet the ISO/TS 169 49:200 Quality Assurance Systems standards.
11. The systems must be user-friendly, which means that its operation can be taught to an employee within minutes.

7.4 Appendix D - Gesswein™ Website

Finishing Stones » Arkansas Stones

Arkansas Bench Stones
For precision sharpening or for finishing a very sharp edge. Measures 6"L x...

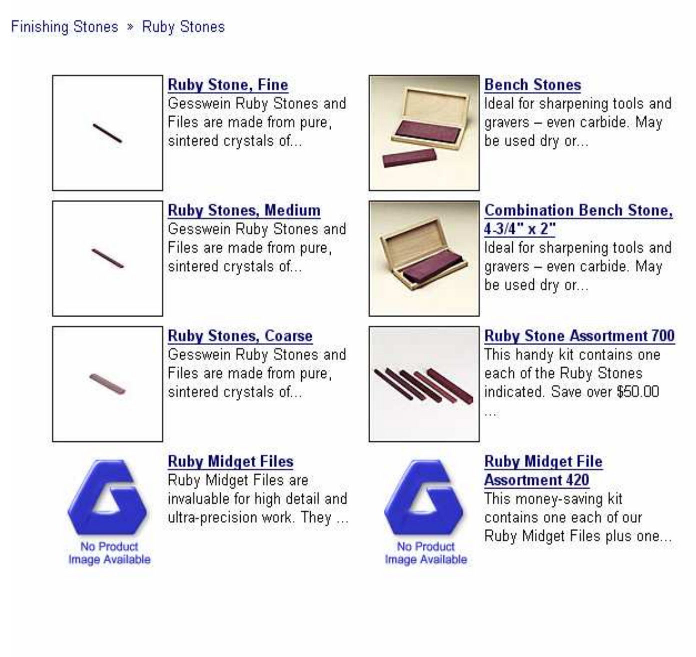
Quad-Hone Stone
Four different stones mounted on a rectangular block for a wide range of...

Norton® Hard Arkansas Files
Natural Arkansas Stones have gained a reputation over the years as the finest...

Norton® Arkansas Engravers Points
For stoning and cleaning tight corners and recesses. Measure 1"L x 1/8" dia....

Hard Black Arkansas Files
These natural hard Arkansas stones are the finest grade abrasive stones...

Norton® Arkansas Penknife Stones
Natural Arkansas Stones have gained a reputation over the years as the finest...



Finishing Stones » Ruby Stones

Ruby Stone, Fine
Gesswein Ruby Stones and Files are made from pure, sintered crystals of...

Bench Stones
Ideal for sharpening tools and gravers – even carbide. May be used dry or...

Ruby Stones, Medium
Gesswein Ruby Stones and Files are made from pure, sintered crystals of...

Combination Bench Stone, 4-3/4" x 2"
Ideal for sharpening tools and gravers – even carbide. May be used dry or...

Ruby Stones, Coarse
Gesswein Ruby Stones and Files are made from pure, sintered crystals of...

Ruby Stone Assortment 700
This handy kit contains one each of the Ruby Stones indicated. Save over $50.00 ...

No Product Image Available

Ruby Midget Files
Ruby Midget Files are invaluable for high detail and ultra-precision work. They ...

No Product Image Available

Ruby Midget File Assortment 420
This money-saving kit contains one each of our Ruby Midget Files plus one...

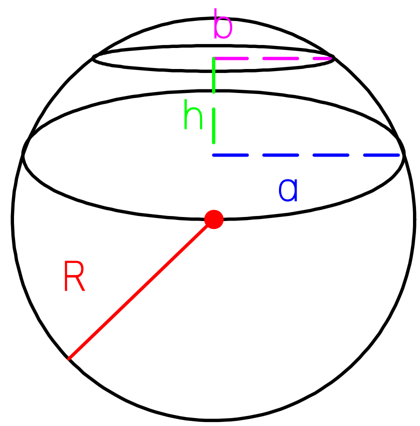
7.5 Appendix E - Evaluation of Valve Seat Geometry

Area of a Surface of Revolution: $S_{revolution} = \int_a^b 2\pi y \cdot \sqrt{1 + \left(\frac{dy}{dx}\right)^2}\, dx$

$S_{zone} = 2\pi r \cdot h$

Proof

Area of a Zone:



$$S = 2 \cdot \pi \cdot \int x \cdot \sqrt{1 \cdot \left(\frac{dx}{dz}\right)^2}\, dz$$

$$x = \sqrt{R^2 - z^2}$$

$$\frac{dx}{dz} = -z \cdot \left(R^2 - z^2\right)^{\frac{-1}{2}}$$

$$\left(\frac{dx}{dz}\right)^2 = \frac{z^2}{R^2 - z^2}$$

$$S = 2 \cdot \pi \cdot \int_{\sqrt{R^2 - a^2}}^{\sqrt{R^2 - b^2}} \sqrt{R^2 - z^2} \cdot \sqrt{1 + \frac{z^2}{R^2 - z^2}}\, dz$$

$$S = 2 \cdot \pi R \cdot \int_{\sqrt{R^2 - a^2}}^{\sqrt{R^2 - b^2}} 1\, dz$$

$$S = 2 \cdot \pi \cdot R \cdot \left(\sqrt{R^2 - b^2} - \sqrt{R^2 - a^2}\right)$$

$$\sqrt{R^2 - b^2} = y_2 \qquad \sqrt{R^2 - a^2} = y_1$$

$$y_2 - y_1 = h$$

$$S = 2 \cdot \pi \cdot R \cdot h$$

Thanks to Wolfram MathWorld
http://mathworld.wolfram.com/Zone.html

7.6 Appendix F - Calculation of Oil Leakage between Plunger and Plunger Body

$P := 10psi .. 60psi$ Range of Operating Pressures

$\rho := 880 \frac{kg}{m^3}$ Average Density of Motor Oil

$\rho = 0.032 \frac{lb}{in^3}$

$V(P) := \sqrt{\frac{2 \cdot P}{\rho}}$ Velocity of the fluid as derived by Bernoulli's Equation

$D_i := .355in$ Outside Diameter of the Plunger

$D_o := .35507in$ Inside Diameter of the Body

$A_{leak} := \frac{\pi D_o^2}{4} - \frac{\pi \cdot D_i^2}{4}$ Area of the Leak

$A_{leak} = 3.904 \times 10^{-5} in^2$

$m(P) := \rho \cdot V(P) \cdot A_{leak}$ Mass flow rate of oil

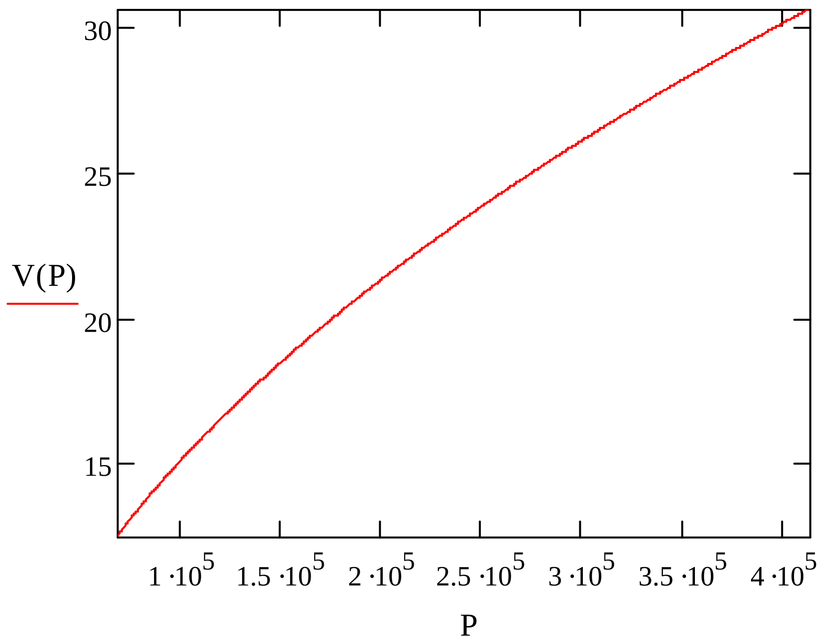
$v(P) := \frac{m(P)}{\rho}$ Volumetric flow rate of oil

Continued on next page

The Ford Mustang 2.3L engine has a rocker arm pressure of 15 psi

$$v(15psi) = 0.386\frac{cm^3}{s} \qquad m(15psi) = 3.398\times 10^{-4}\ \frac{kg}{s}$$

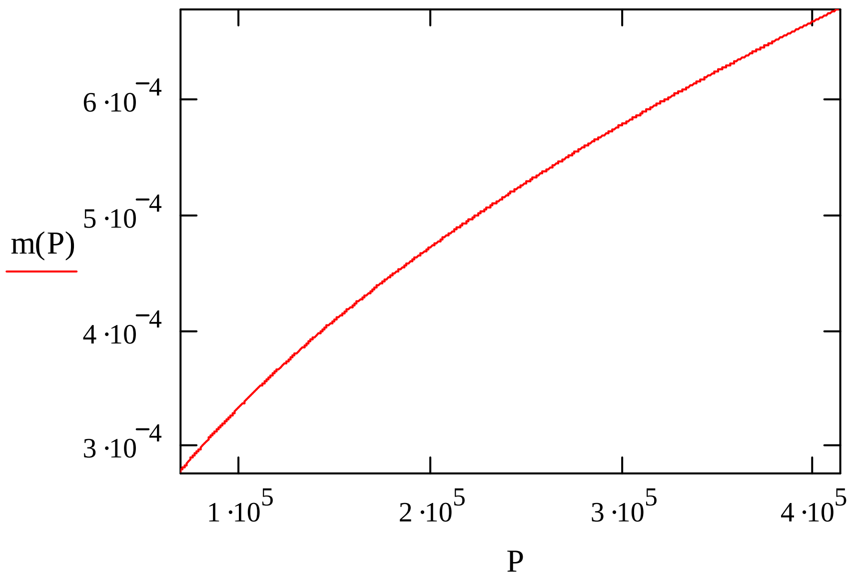
Here we have shown the values for a typical Ford engine. The volumetric flow rate and the mass flow rate are calculated in order to show the leakag that occurs on the outside of the plunger and body combination



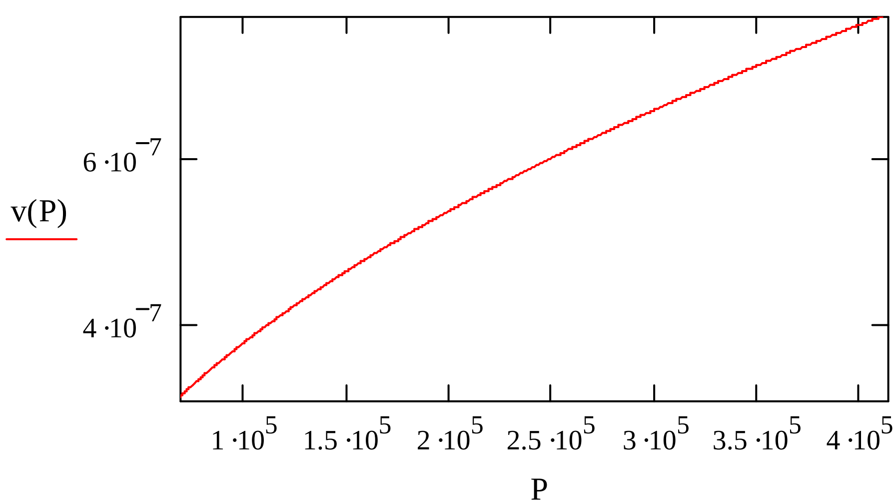
-The graph above show the relationship that was attained between velocity and pressure with the help of Bernoulli's Equation

Continued on next page

-The mass flow rate at various engine pressures is shown below. This also shows that as the operating pressure in the engine is increased, th mass flow rate of the oil escaping the plunger body increases as well.



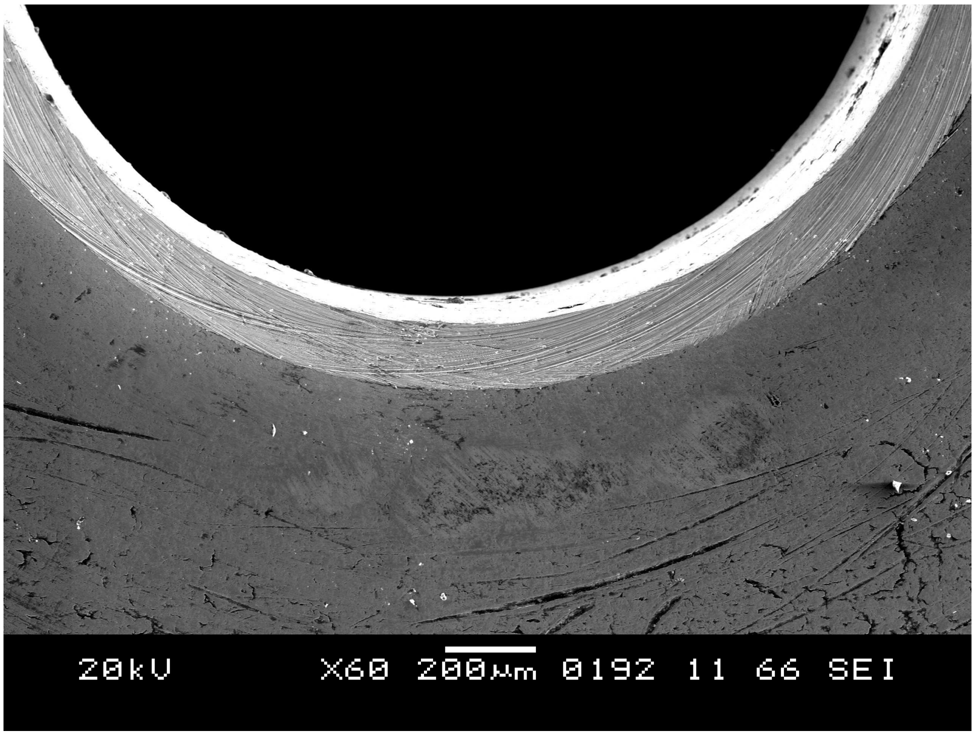
-We can clearly see that the pressure relationship that affects the mass flow rate, also affects the volumetric flow rate. An increase in the pressure will bring about an increase in oil's volumetric flow rate.



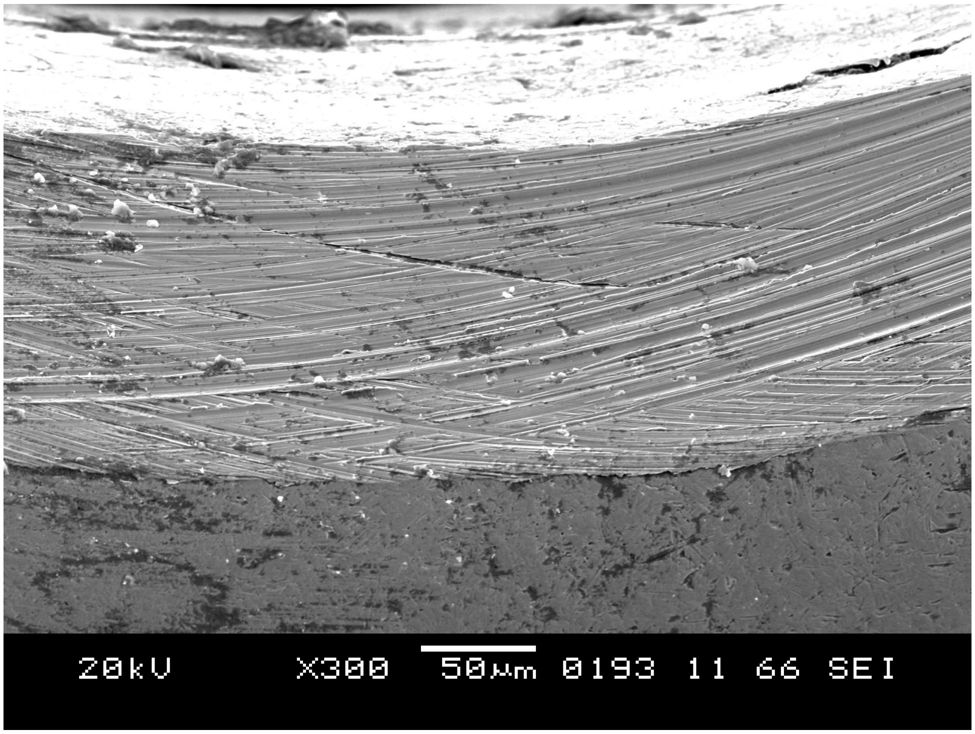
7.7 Appendix G – Economic Cost of Polishing

Labor Grade	3	4	5	5.2	6	6.2	7	7.2	8	8.2	9
Employee Cost	$9.49	$10.80	$12.38	$12.95	$13.88	$14.54	$15.88	$16.42	$17.45	$18.27	$18.83
Employee Fringe Benefits	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
Overall Employee Cost	$13.38	$15.23	$17.46	$18.26	$19.57	$20.50	$22.39	$23.15	$24.60	$25.76	$26.55
Employee cost per machine	$4.46	$5.08	$5.82	$6.09	$6.52	$6.83	$7.46	$7.72	$8.20	$8.59	$8.85
Machine Cost per Hour	$9.17	$9.17	$9.17	$9.17	$9.17	$9.17	$9.17	$9.17	$9.17	$9.17	$9.17
Number of shifts	2	2	2	2	2	2	2	2	2	2	2
Hours per shift	8	8	8	8	8	8	8	8	8	8	8
Operating Cost per Day	$146.72	$146.72	$146.72	$146.72	$146.72	$146.72	$146.72	$146.72	$146.72	$146.72	$146.72
Total Machine and Employee Cost per Hour	$13.63	$14.25	$14.99	$15.26	$15.69	$16.00	$16.63	$16.89	$17.37	$17.76	$18.02
Daily Operating Cost per Machine	$218.08	$227.94	$239.82	$244.10	$251.10	$256.06	$266.14	$270.20	$277.94	$284.11	$288.32
Yearly Cost per Machine	$79,600.95	$83,196.64	$87,533.42	$89,097.96	$91,650.62	$93,462.19	$97,140.22	$98,622.42	$101,449.56	$103,700.30	$105,237.38
Total Daily Cost	$654.25	$683.81	$719.45	$732.31	$753.29	$768.18	$798.41	$810.60	$833.83	$852.33	$864.96
Total Yearly cost	$238,802.86	$249,589.92	$262,600.27	$267,293.88	$274,951.87	$280,386.58	$291,420.67	$295,867.25	$304,348.68	$311,100.89	$315,712.15

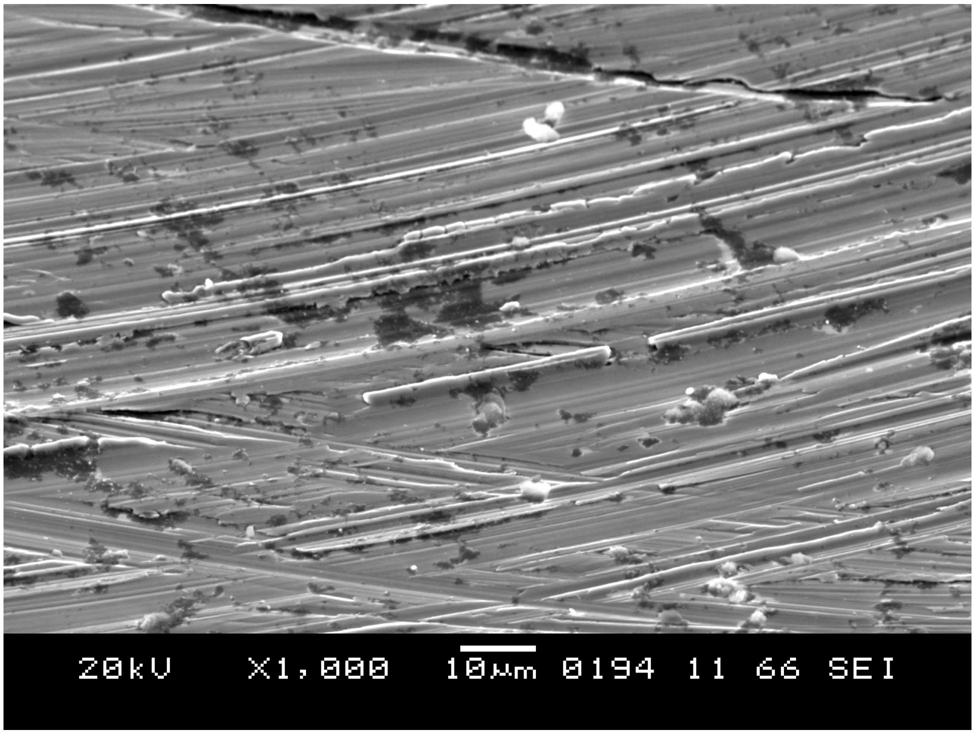
7.8 Appendix H – Microscopy Pictures of Plungers



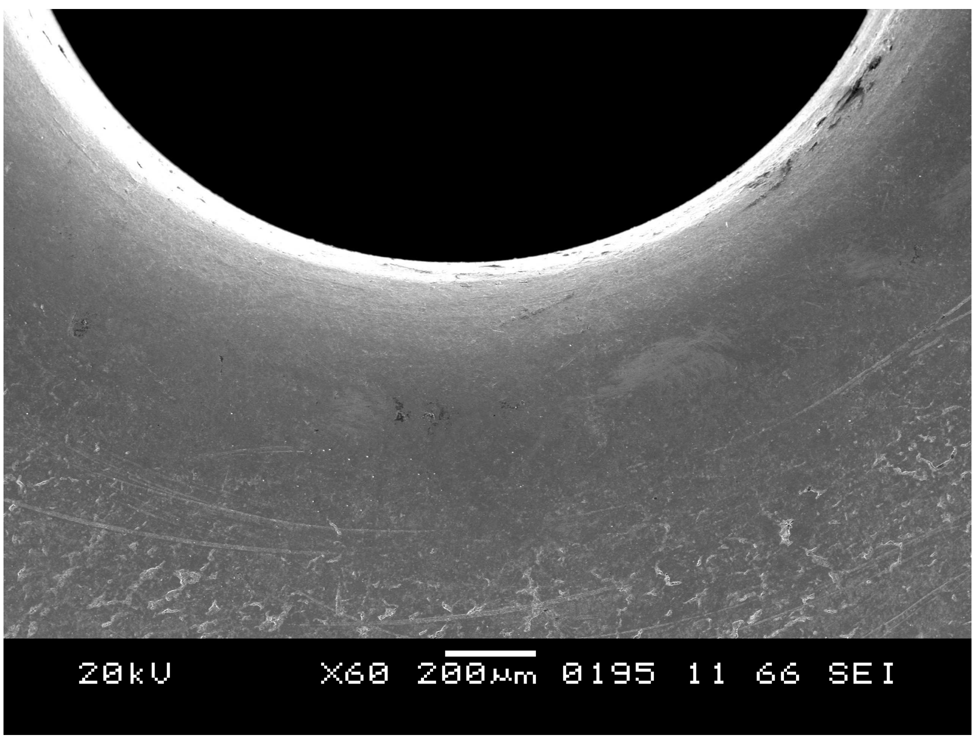
Scanning Electron Microscope (SEM) overhead pictures of Polished Plunger at 60x



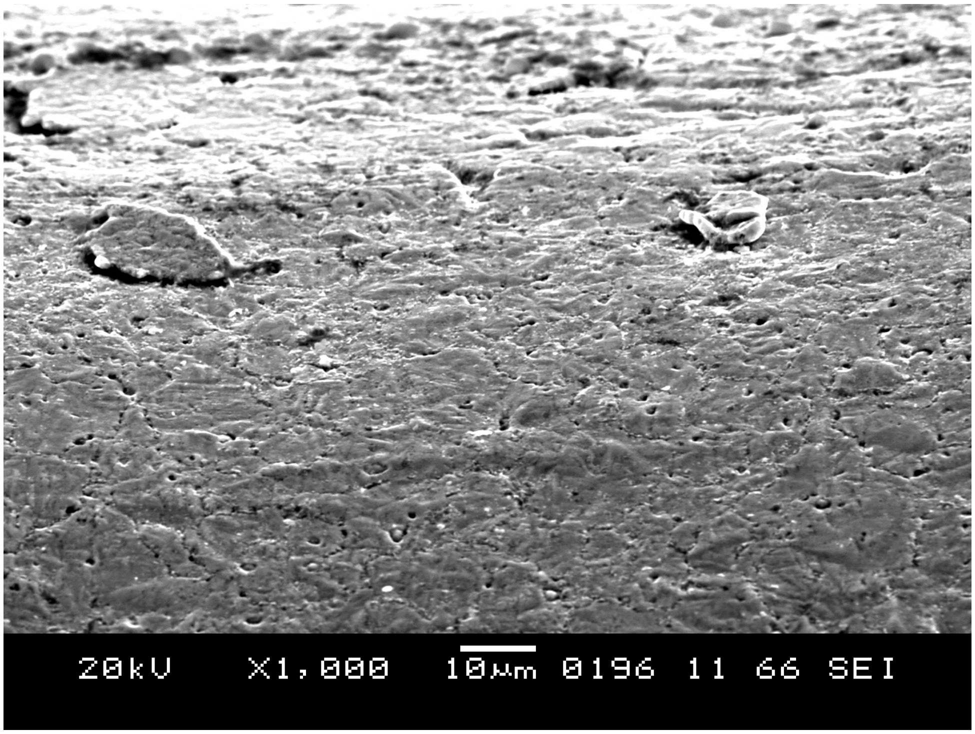
SEM overhead picture of Polished Plunger at 300x



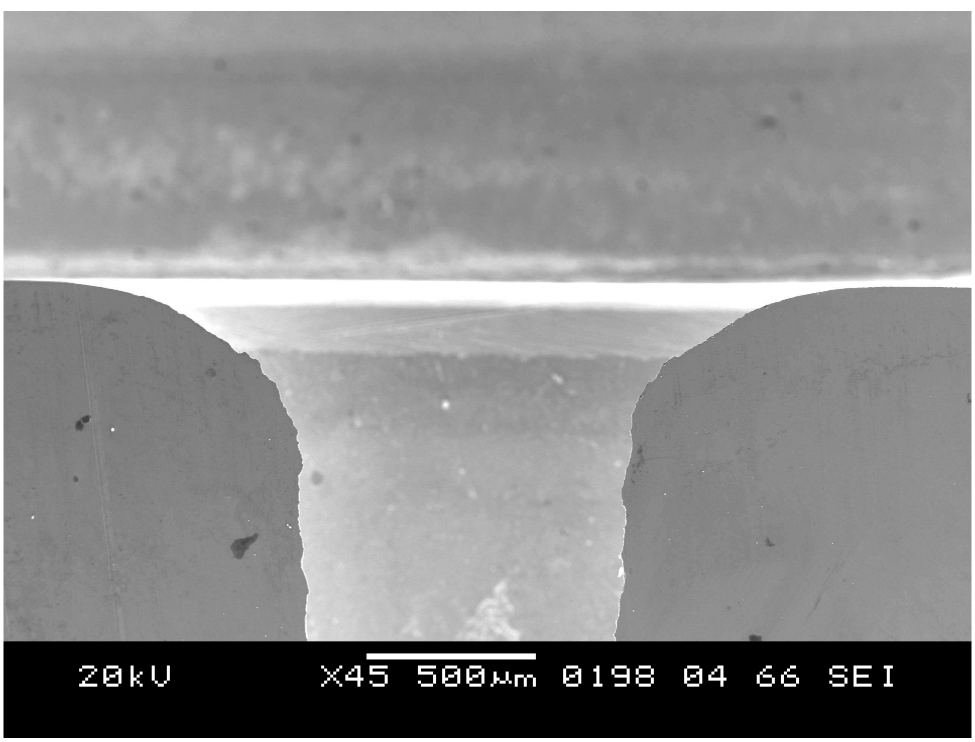
SEM overhead picture of Polished Plunger at 1000x



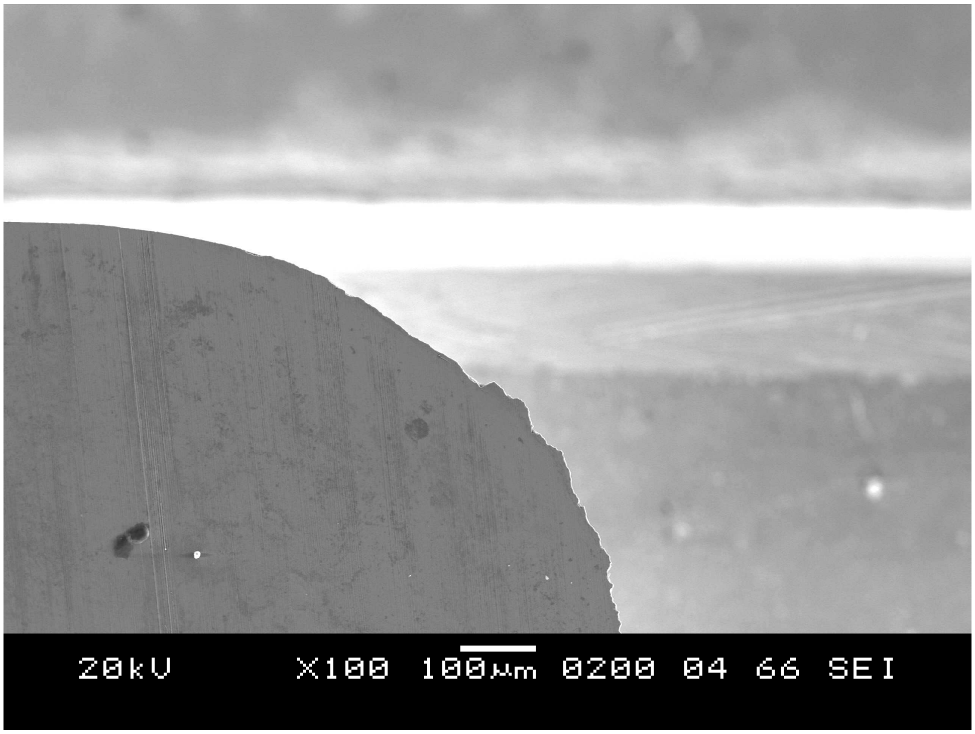
SEM overhead picture of unpolished plunger at 60x



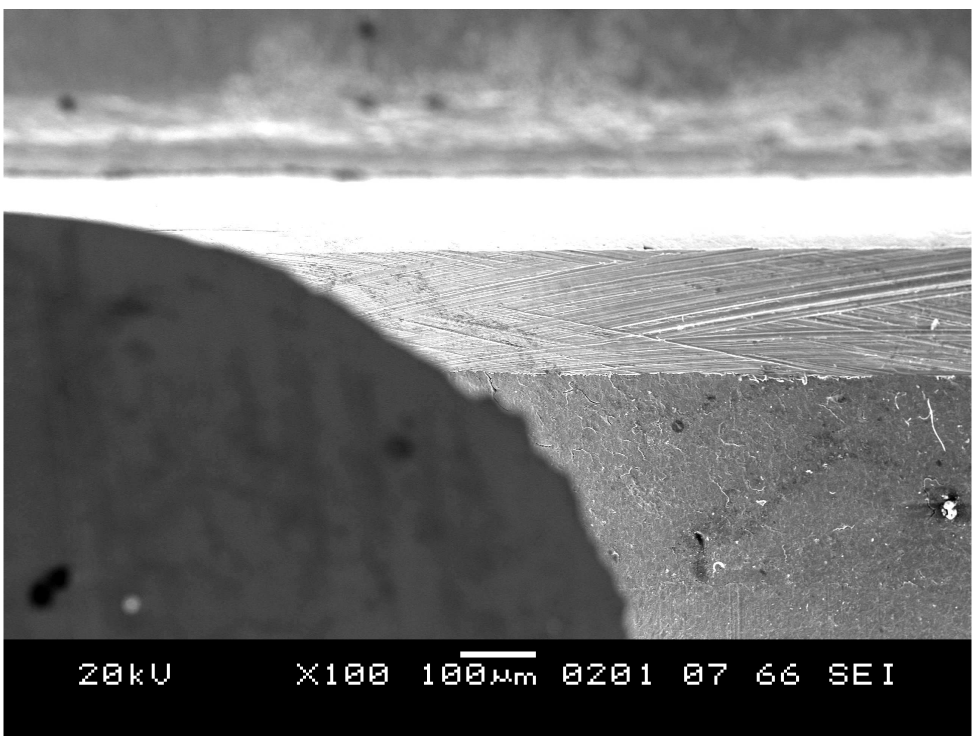
SEM overhead picture of unpolished plunger at 1000x



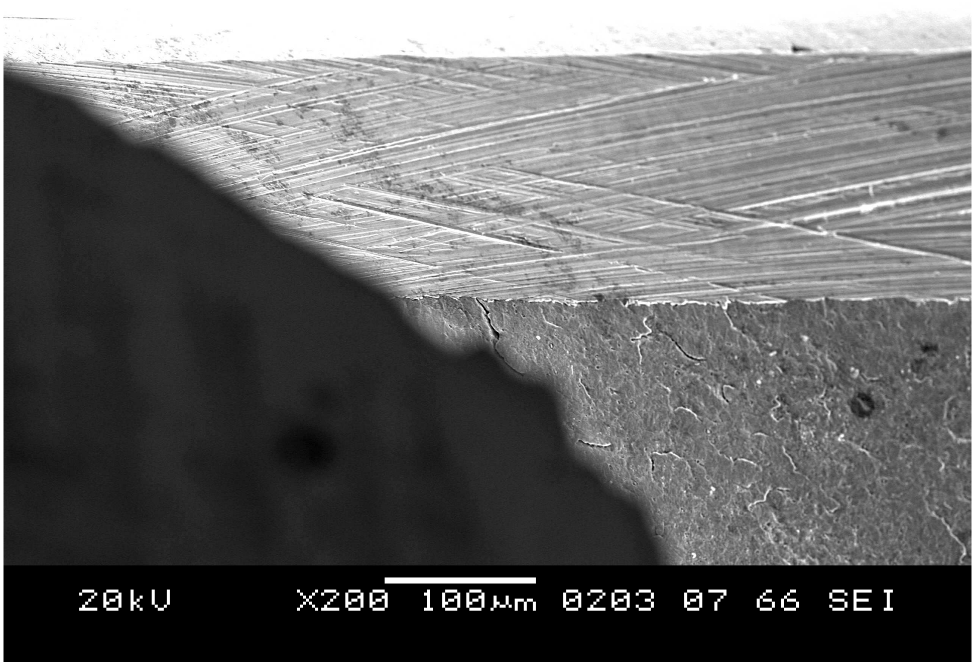
SEM vertical cross section picture of polished plunger at 45x

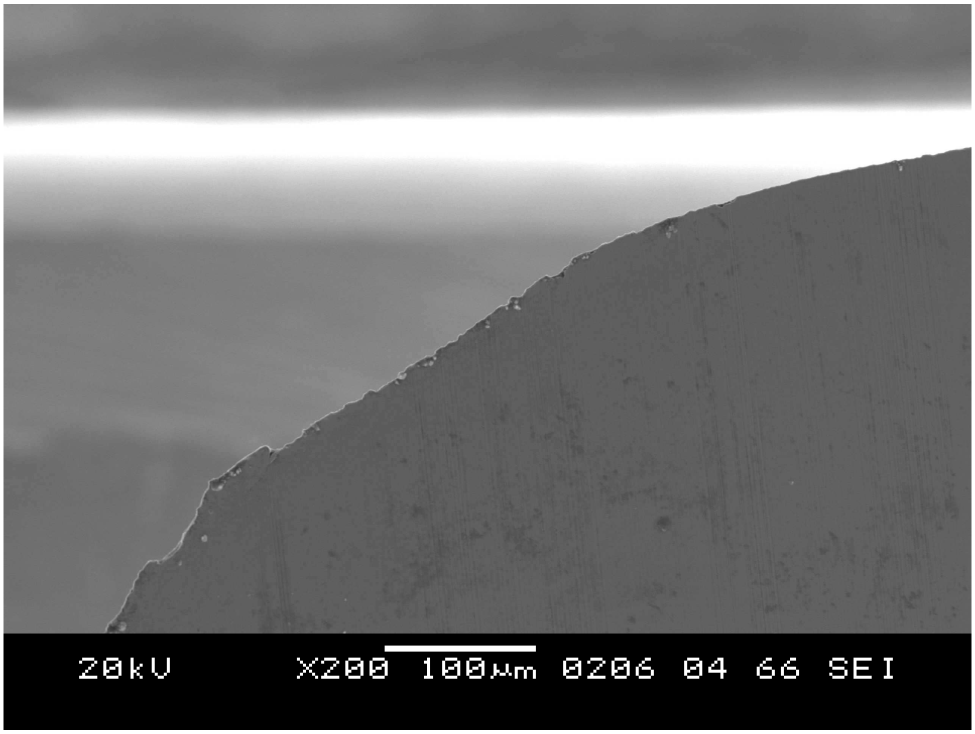


SEM vertical cross section picture of polished plunger at 100x

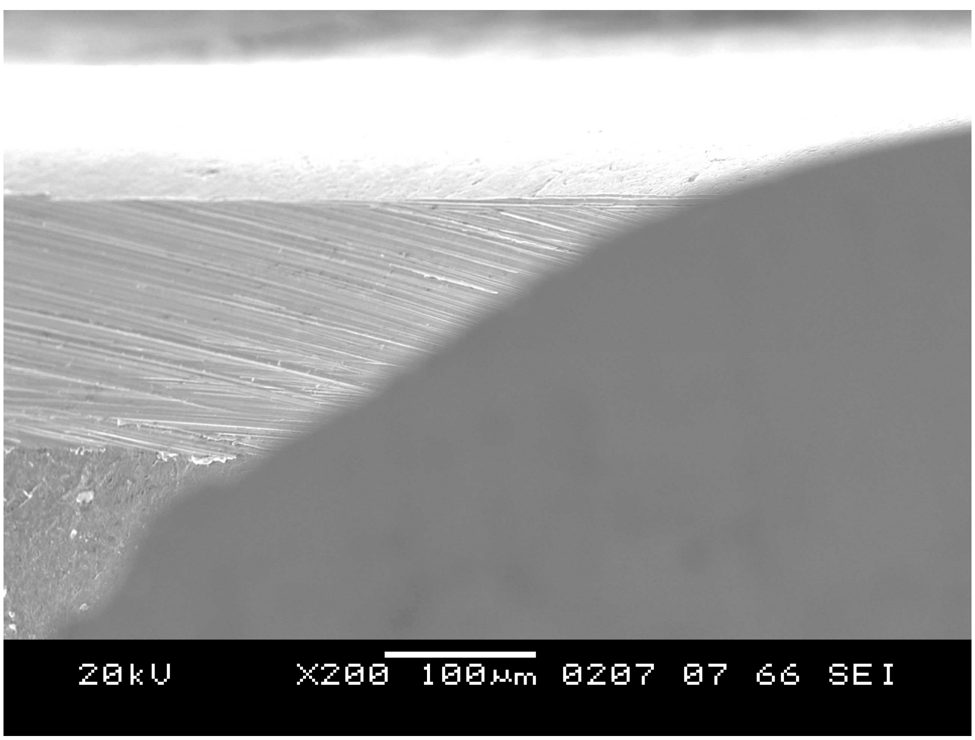


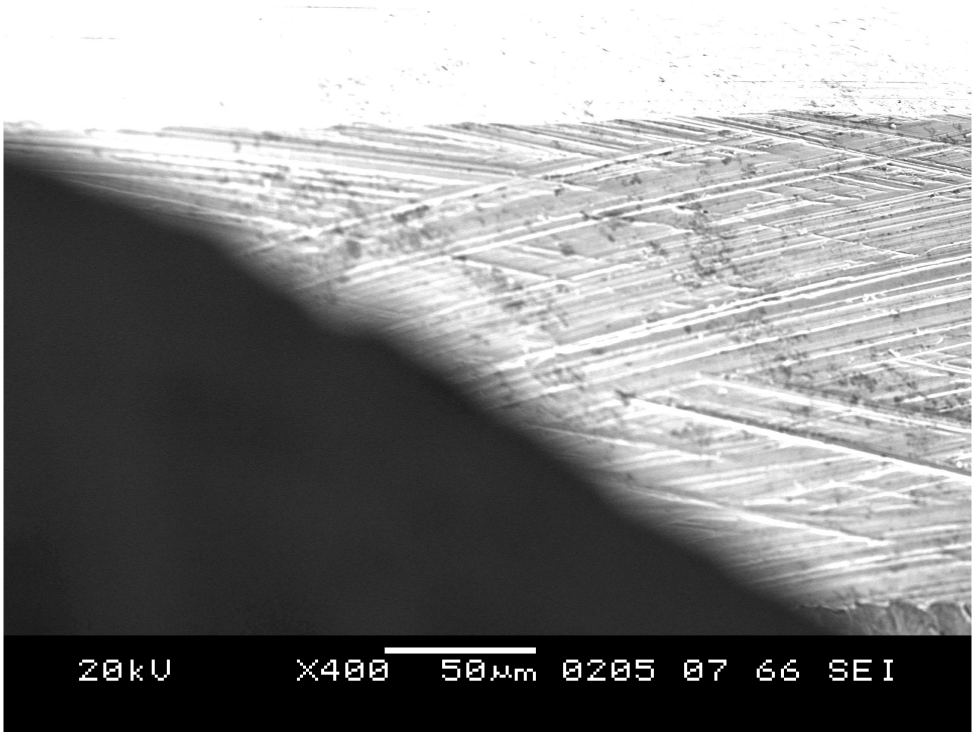
SEM vertical cross section picture of polished plunger at 200x



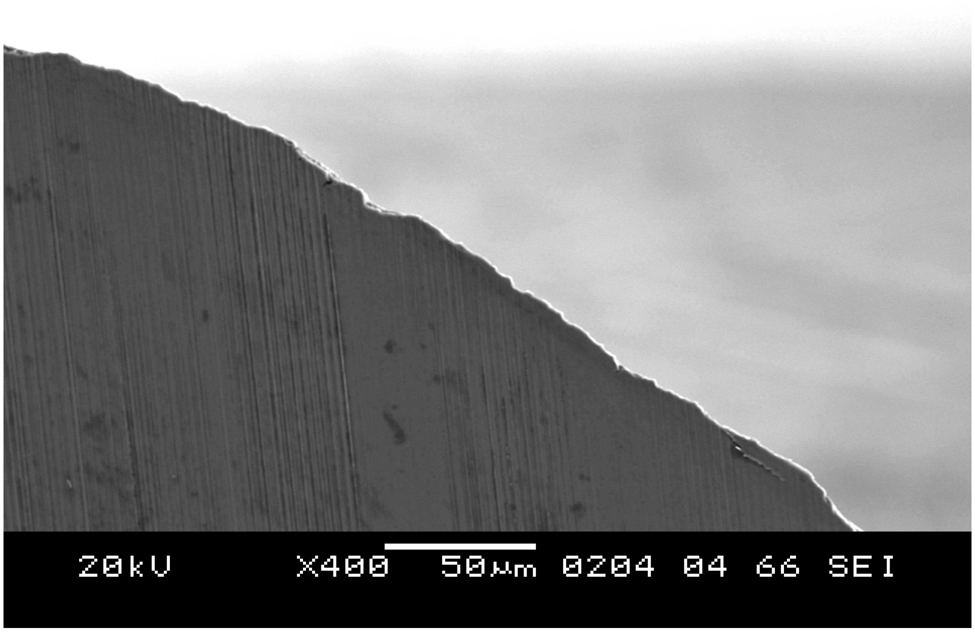


SEM vertical cross section picture of polished plunger at 200x

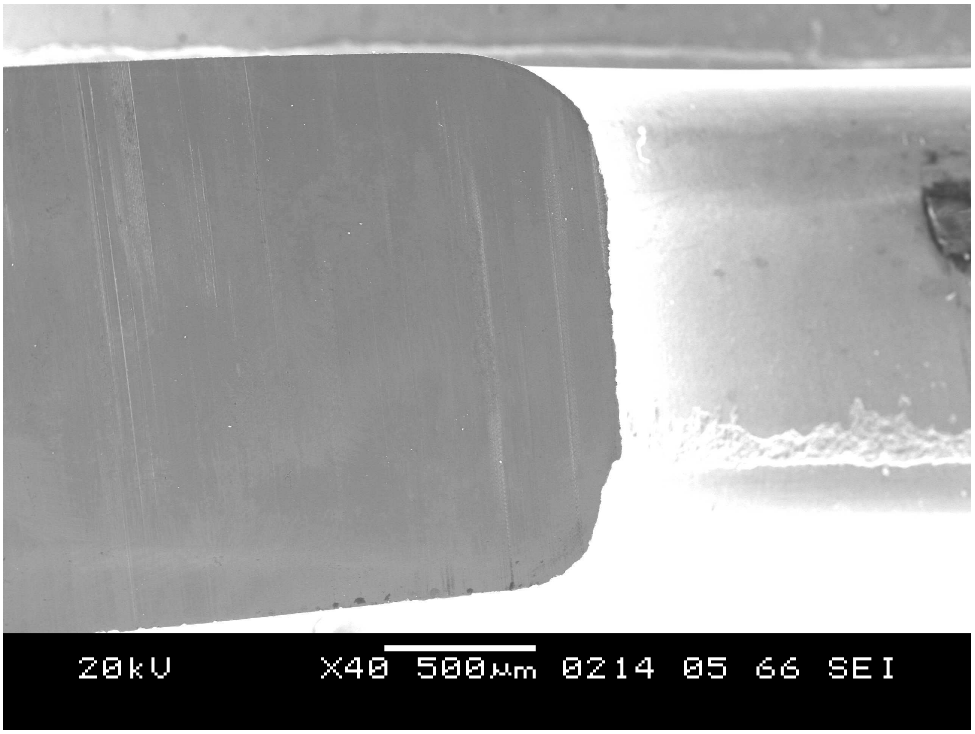




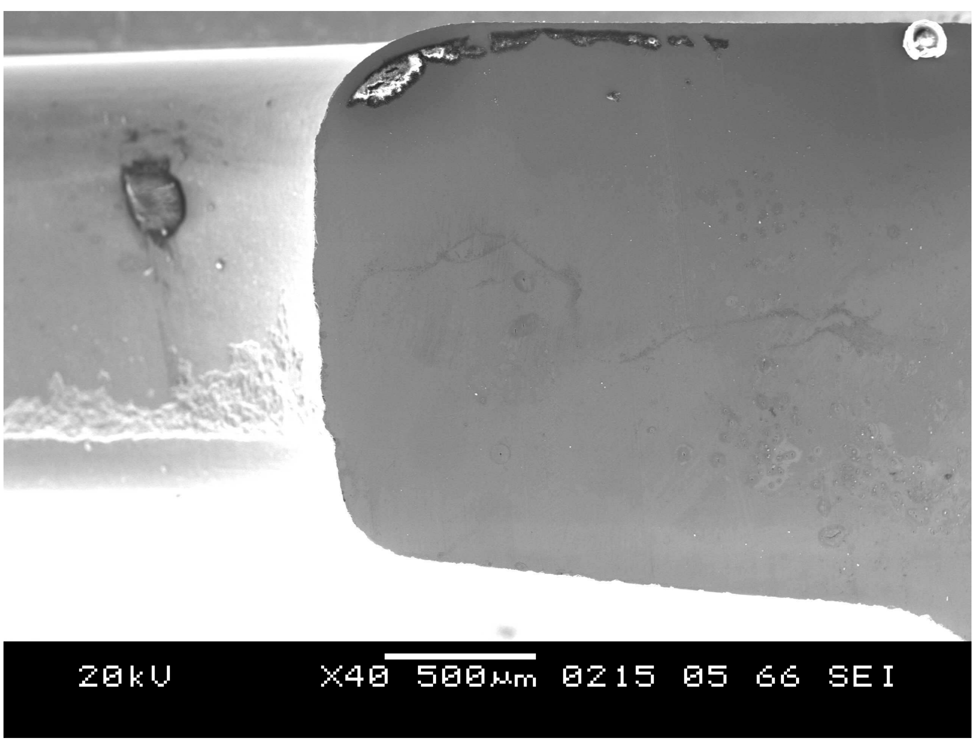
SEM vertical cross section picture of polished plunger at 400x

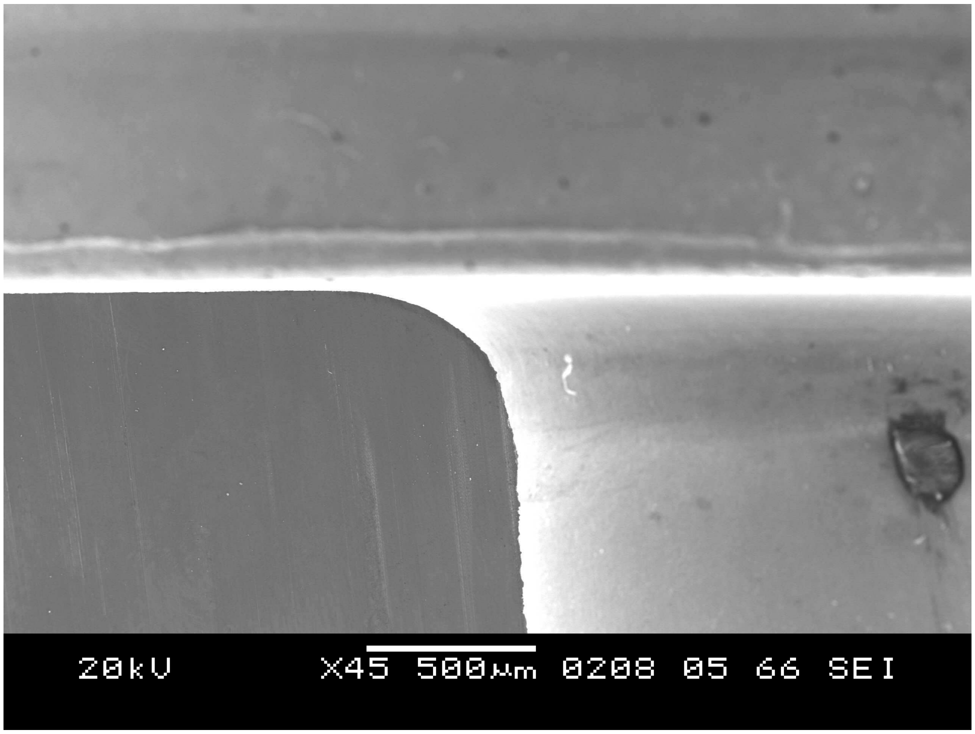


SEM vertical cross section picture of unpolished plunger at 40x

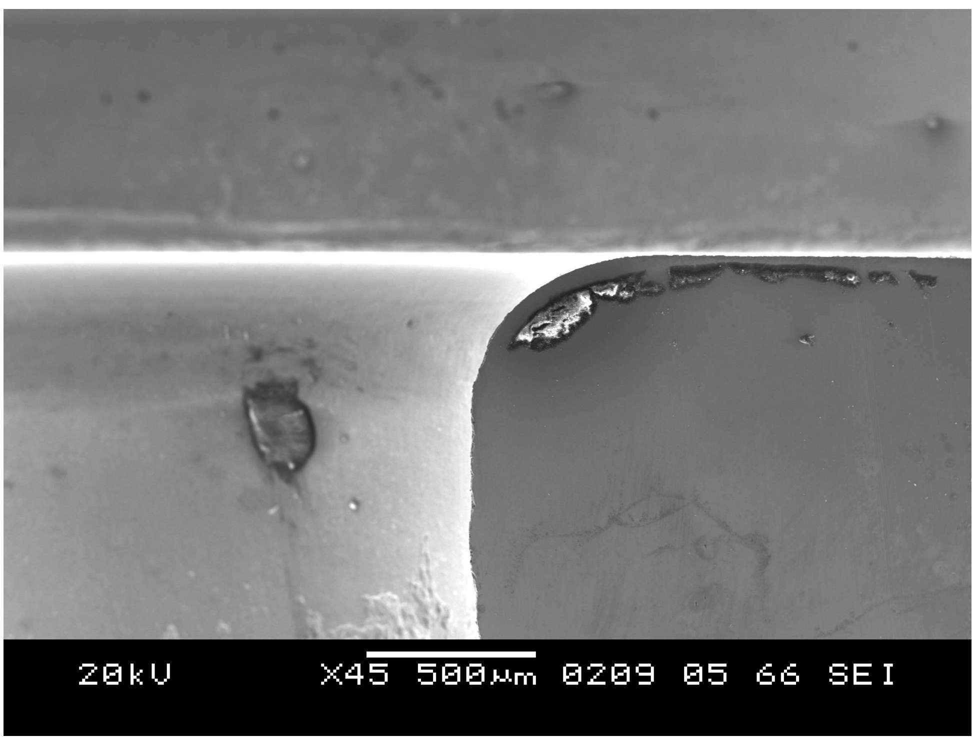


SEM vertical cross section picture of unpolished plunger at 40x

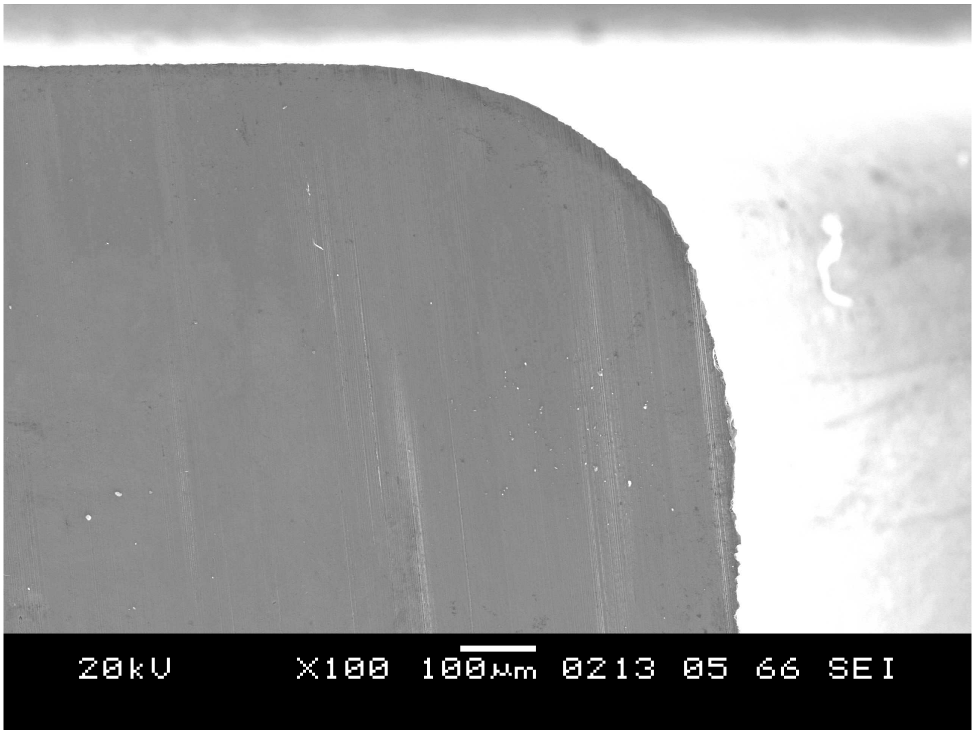




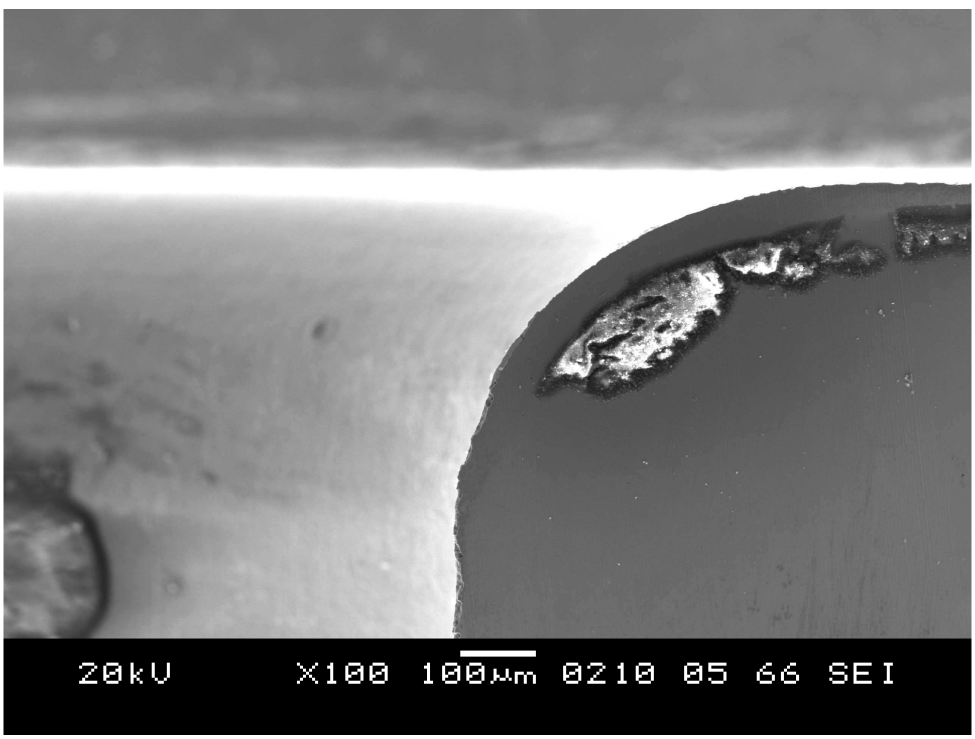
SEM vertical cross section picture of unpolished plunger at 45x



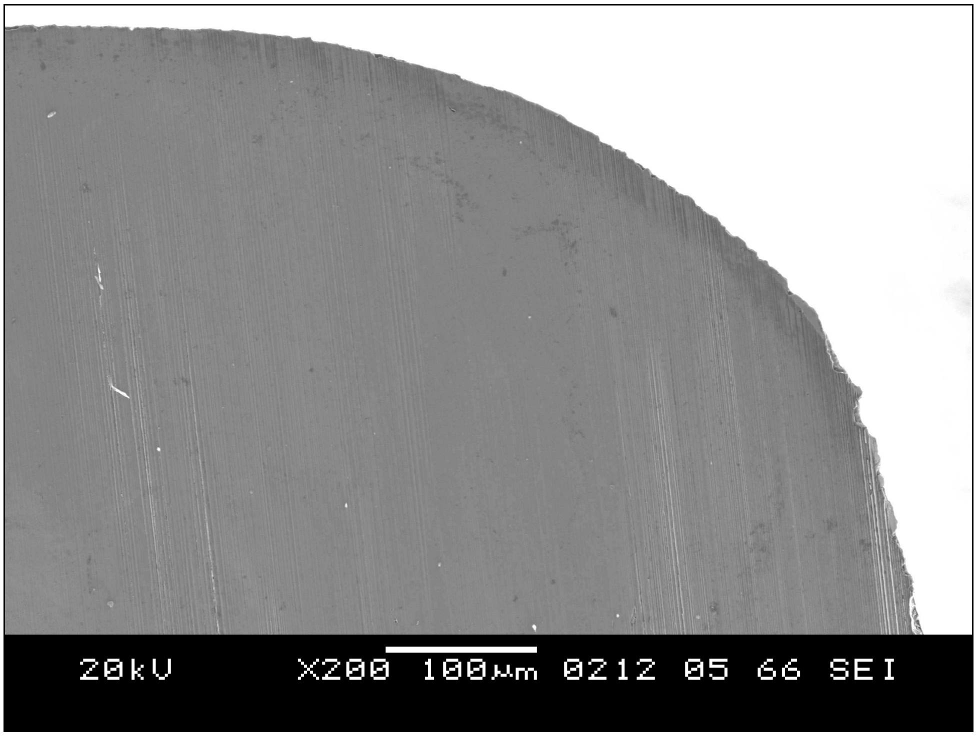
SEM vertical cross section picture of unpolished plunger at 45x



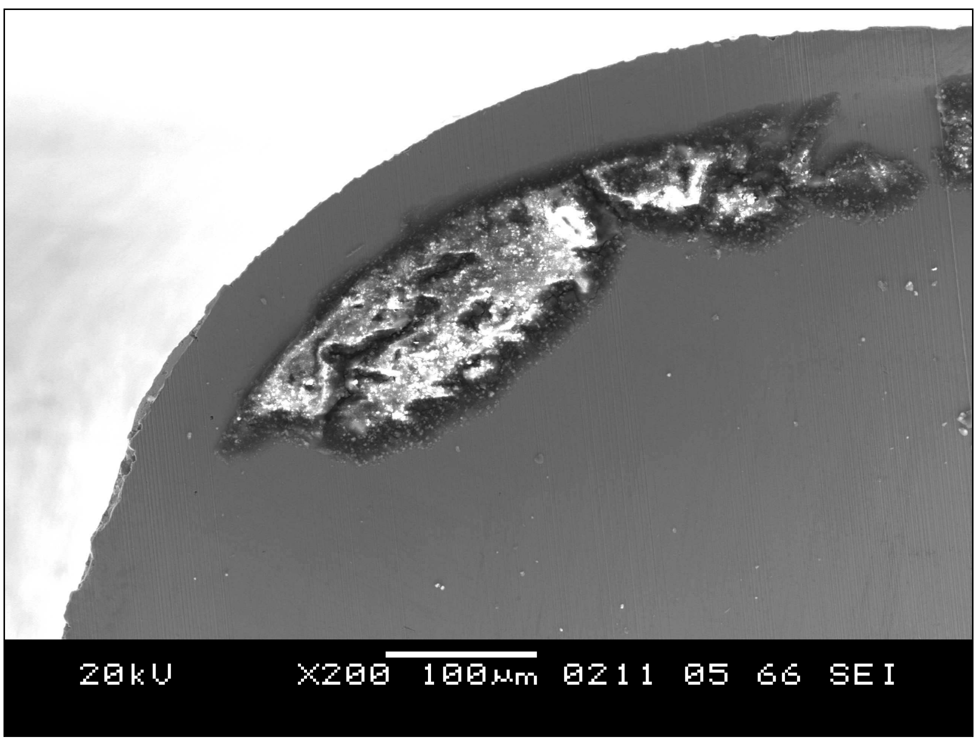
SEM vertical cross section picture of unpolished plunger at 100x



SEM vertical cross section picture of unpolished plunger at 100x



SEM vertical cross section picture of unpolished plunger at 200x



SEM vertical cross section picture of unpolished plunger at 200x

7.9 Appendix I – PRO-ENGINEER model and live picture of Plunger