1. MAZDA OEM

a. Mazda Hard Chrome

For wear protection, Mazda OEM rotor housings are hard chrome plated and the cast iron end housings are soft gas nitrided. Mazda chose these processes in the mid 1960's as the best option available to them ***at the time***. There are several criteria that would have influenced Mazda's choices at the time, including:

<u>Performance</u>: Specifically, that the coating or treatment must result in a motor that will meet minimum performance criterion such as engine life and sealing ability. Lets say for instance that Mazda's engineers were required to produce block components that could be operated within their allowed dimensional and wear margins for 80,000 km, the chosen coating or treatments would have to meet this minimum criterion in order to be considered.

<u>Availability / Resources</u>**:** Now remember, we are in the mid 1960's! A major consideration when choosing what kind of surface treatment to use is its availability on the market now and in the future. Both Chrome and Soft Nitriding were widely available and they were very commonly used in many industries. These were hence safe choices as there was no sign that these well established, refined processes would soon be replaced by others.

<u>Cost</u>**:** Cost is always the bottom line. This is true for Mazda in the 1960's as well (just as in any manufacturing facility). Recall, back then Mazda was a small manufacturer taking a big chance on a new engine design. They could not afford to spend huge sums of money on new technologies to develop this engine. They needed to focus the monies spent on the real problem areas, not on re-inventing the wheel. Hence, where possible they would rely on economical, proven technologies such as chrome plating and gas nitriding.

Ironically, these types of decisions are not always the best and may have become an Achilles heel for Mazda in the end. It is the *opinion* of the engineers at JHB Performance that the cause of problems such as wear, chatter marks and poor compression are due to the use of chrome plating. Mazda spend lots of time and effort trying to alleviate these problems with alternative seal designs and material compositions rather than attacking the root cause of the problem that we feel is the chrome plating itself. Nonetheless, Mazda stuck with their huge capital investment into hard chrome plating and invested over 30 years of development time into trying to make this type of wear coating work in the rotary engine with little success. This is not to say that Mazda did not achieve an engine with moderate reliability, but to point out that their success would have been compounded many times had they not stuck with chrome plating.

Hard Chrome Plating on Rotor Housings

Hard Chrome plating in the 1960's was a cheap and easy surface treatment with very low friction that was easily adapted to the rotary engine. However, this type of coating has many problems and disadvantages when used in a rotary engine application. The effects of these inherent problems are notoriously associated with the rotary engine today…

Oil Retention / Lubrication**:** Hard Chrome is a dry coating; this meaning that hard chrome will not naturally retain any oil or lubricants. In a piston engine or a hydraulic cylinder type of application this not an issue because there is ample lubrication applied to the chrome during operation (oil splashing on the cylinder walls of a piston engine during operation OR hydraulic oil that fills a hydraulic cylinder during operation). However, Rotary engines are sealed from the oil pan and there is not oil or lubrication for the trochoid surface. Hard Chrome will not naturally retain or absorb oil. Through special honing and etching variations of chrome plating such as channel chrome or porous chrome can be achieved whereby micro-channels or pores are created to try and retain lubrication.

Mazda found that neither channel chrome nor porous chrome were able to meet the high lubrication demands of the rotary engine. To somewhat alleviate this problem they developed micro channel pinpoint porous chrome plating for the rotary engine, a combination of channel and porous chrome. The principle behind this development is that porous chrome is applied to the part and then etched to produce channels connecting the pores. This network of pores and channels is devised to aid in the "spreadability" of the oil over the entire surface.

As demonstrated in the figures below, the ratio of pores versus channels is highly critical. If this ratio is wrong the resultant coating will suffer from very poor oil spreadability and chatter marks OR scratching of the surface. This process that Mazda devised is very difficult and not easily replicated (especially cost effectively), these figures show the ***obvious*** shortcomings of simply trying hard chrome plate a rotor housing cheaply. The effects of improper plating are excessive apex seal temperature and wear on both the seal and the chrome. This eventually results in ***apex seal failure***.

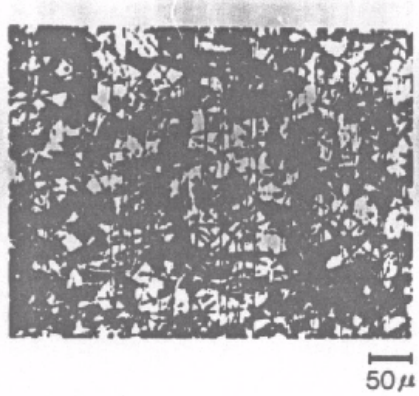


Fig.1 Micro-channel porous Cr plating

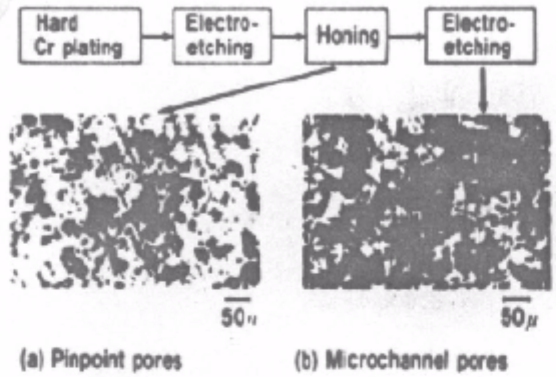


Fig.6 Porous chromium plating process and the surface structures

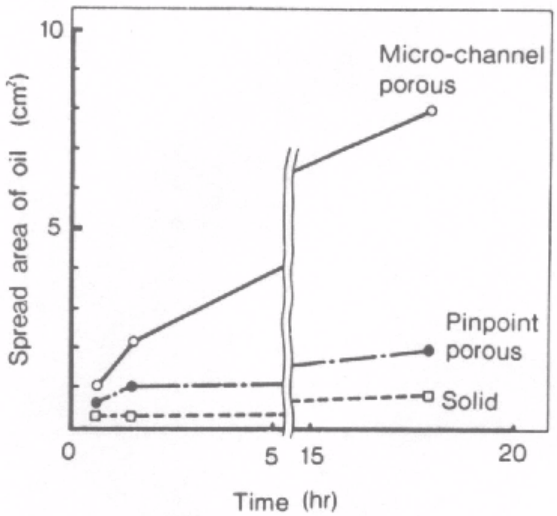


Fig.2 Spreadability of oil with regard to Cr plate

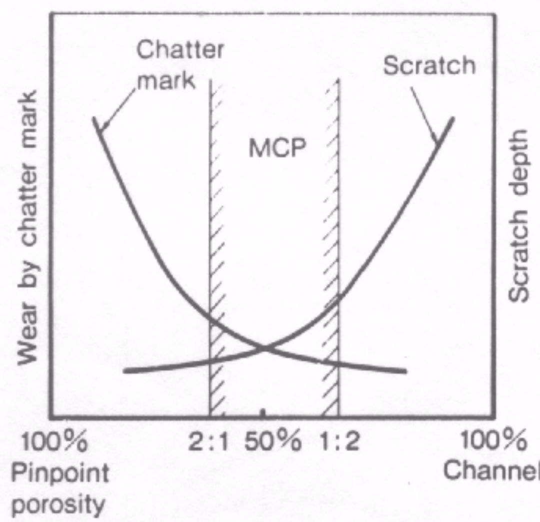


Fig.3 Oil spreadability as a function of Cr plating pattern

In attempts to further reduce the overall friction and increase the performance of the chrome plating Mazda attempted to apply various coatings on top of the chrome surface. In the mid 1980's, along with the higher output rotary engines, coatings such as the UMC were developed to ease the wear on the apex seal tips during break in as well as to try and extend the optimum life of the chrome on the rotor housing. The coated portion of the rotor housing does not last very long at all and is intended to reduce friction and increase sealing ability of the engine when new. Hence providing more impressive output ratings for horsepower and emissions. Below is a graphical view of the effects of these coatings while they remain on the rotor housing surface.

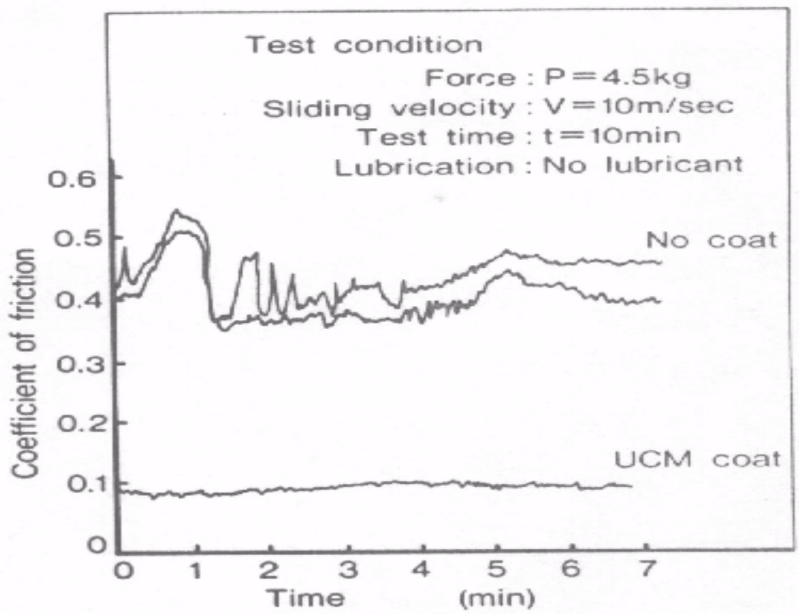


Fig.4 Coefficient of friction between apex seal and trochoid

Fig. 4 shows the coefficient of friction between Cr-plated surface and apex seal. The UCM-coated surface shows a markedly low friction co-efficient compared to the uncoated surface.

The dry nature of the chrome plating also required that a large amount of oil be injected into the engine to provide adequate lubrication for the apex seals and rotor housing surface. If too little lubrication is used the result is excessive wear on the apex seal and the chrome surface, finally resulting in apex seal failure. If to great an amount of oil is used emissions levels are compromised and maintenance requirements of the engine become much greater as oil needs to be added very frequently. Under fully operational and optimal conditions, Mazda found that about 300 cc/hour was the minimum amount of oil injection that resulted in somewhat reliable operation. This rate of oil injection is controlled by the oil metering pumps and injectors to provide maximum lubrication at high engine loads and minimal amounts under low loads. The figure below shows the correlation between oil injection volumes and apex seal temperatures. Note that apex seal temperature is directly related to higher friction and wear.

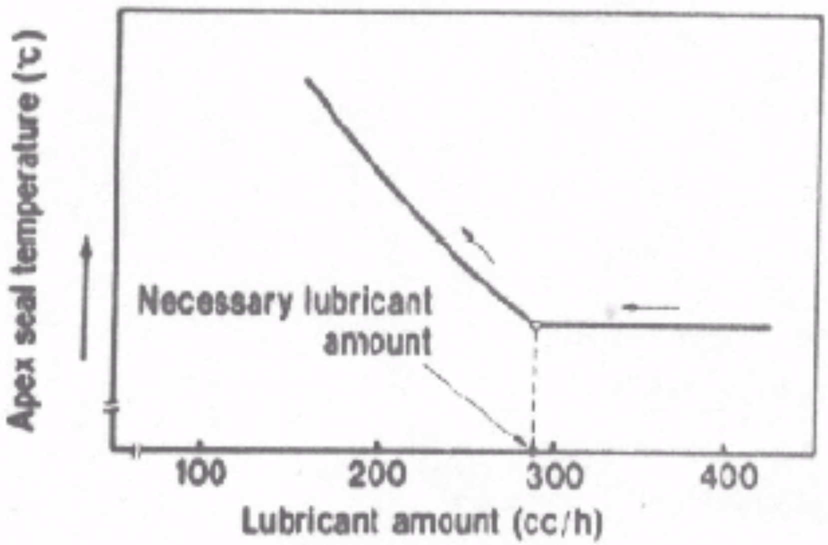


Fig.9 The relation between lubricant amount and apex seal temperatura.

In order for this delicate system to operate properly it is essential that several conditions be met:

1- That the oil being injected into the motor be clean and have optimum viscosity (spreadability) and lubricating properties (as motor oil would when new).
2- That the oil metering pump be properly adjusted and be in perfect operation.
3- That the oil lines that feed the oil injectors and the injectors themselves be in perfect working order.

In real life operation these conditions are rarely ever met. Reality is that the oil metering system is very problematic at best. The oil lines are very fragile and frequently cracked, the oil is almost never in its optimum lubricating state (as the system relies on used motor oil from the engine’s oil pan) and the oil metering pumps are also prone to seizure and malfunction.

All of these factors contribute to accelerated wear and failure due to the very difficult operating conditions under which the chrome plated trochoid surface needs to operate.

Durability: Hard Chrome can be applied in many applications to provide a very hard, durable long lasting wear surface. However, if this coating is not applied properly or not used in a favorable environment then I can be subject to many problems.

As shown in the figures above, the lack of pores and channels in the chrome plating applied to a rotor housing surface will result in chatter marks, scratches and poor overall lubrication resulting in accelerated wear. The positive effect of the pores and channels is that is *somewhat* alleviates the lubrication issue. The down side of the resultant “fix” is that the corrosion barrier provided by the chrome has now been compromised by creating all of these channels and pores. These channels and pores are very susceptible to corrosion. The results of corrosion on rotor housings are ***flaking and peeling of the chrome plating*** due to the formation of corrosion in all of the channels and pores. This corrosion leads to the pre mature failure of rotor housings and subsequently to the engine.

This problem lead to the reputation of the rotary engine burning oil, losing compression and having short engine life. Anyone who has disassembled a rotary engine has seen the effects of this problem first hand.

In addition to corrosion, there are also issues with cyclic failure of the bond between the chrome plating and the rotor housing surface. Chrome does not bond well to aluminum; especially back in the 1960’s with the technology available then. Also, the aluminum casting material used for the rotor housings is subject to fatigue from the cyclic loading of the apex seals as well and thermal cycling. The effects of this can easily be seen on rotor housings where the chrome was deposited directly on the Ni-Al surface such as on the Mazda Factory Racing Peripheral Port housings or the old NSU rotor housings. On these rotor housings you will notice a type of scale pattern formed in the chrome surface where it has been cracked from the cyclic loading. Eventually the chrome will fail from this type of loading and flake off.

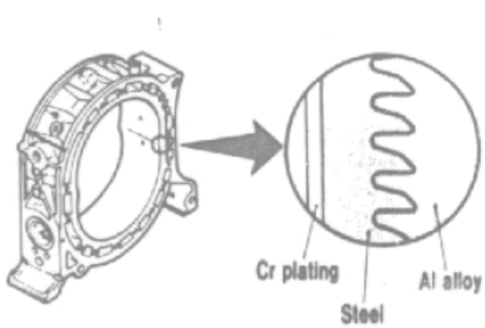
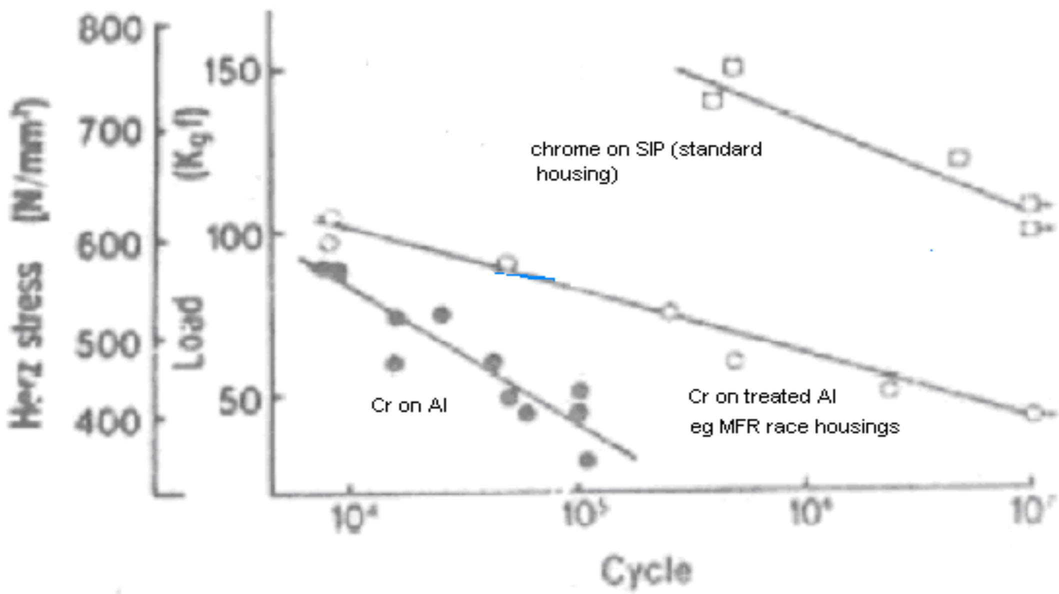


Fig.3 Cross section of trochoid surface

In order to increase the life of the rotor housing, Mazda developed the Sheet Metal Insert Process (SIP) where a thin layer of serrated sheet metal is shaped to form the inside of the trochoid profile and provide a metal substrate for the chrome to bond to. The aluminum housing is cast around the serrated side of the sheet metal and this provides a good bond between the metal and the aluminum casting. By implementing this method Mazda was able to significantly increase the adhesion life of the chrome plating against cyclic failure. The lack of this type of SIP is evident in the many failures of racing Peripheral Port rotor housings as well as the NSU rotor housings. Unfortunately, the steel provides a highly corrosive substrate that effectively promotes flaking of the chrome by corrosion and the formation of rust. Mazda in effect solved the problem of cyclic failure by implementing a very costly process that in the end highly contributed to the very common failure mode that is seen in all rotor housings; ***chrome flaking***. Separately, the micro-channel porous chrome and the SIP are very clever ideas but together result in a product that is highly susceptible to failure and accelerated wear.

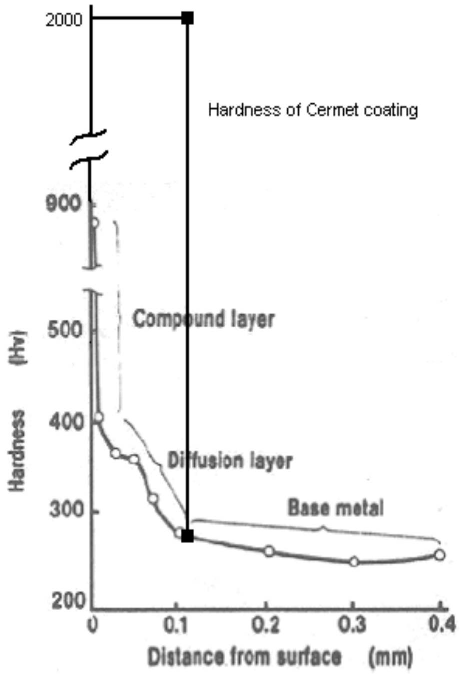


Adhesion life of Chrome of various housings by contact rolling method

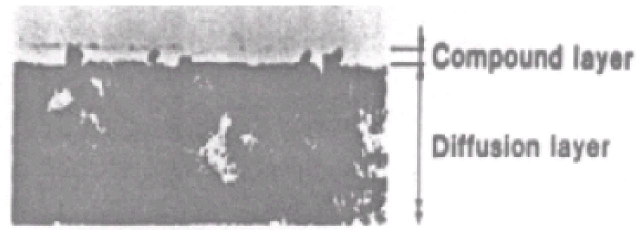
b) Mazda Soft Nitriding

Again, for wear resistance and overall durability, the cast iron end housings of the rotary engine are treated by a soft gas nitriding process. This is a good method for high production manufacturing that is also cost effective and repeatable. Soft gas nitriding is a method of case hardening the surface of the part making it much harder and wear resistant and also enhancing corrosion resistance and frictional properties. This is a very good and effective method.

The faces of the cast iron parts are nitrided and surface ground on a cylindrical surface grinder. Mazda still uses this method today on the Renisis engines. The resultant parts have a hard surface that is about 0.0004” deep and rapidly drops off in hardness the deeper you go.



Hardness of soft nitrided side housings vs. Cermet coated



Cross section of soft nitride layer

These above graphs shows that the surface of the part has a hardness of just under 900 Hv and that the hardness drops very sharply to about 360 Hv as you move further from the surface of the part. What are referred to as the Compound and diffusion layers are what gives the part its enhanced properties. The optimum effects of the soft nitrided part are limited to the Compound layer of the part (the first 0.0004” below the surface). As you move further below the surface the frictional, corrosion resistant and wear resistant effects of the soft nitriding process drop off very rapidly.

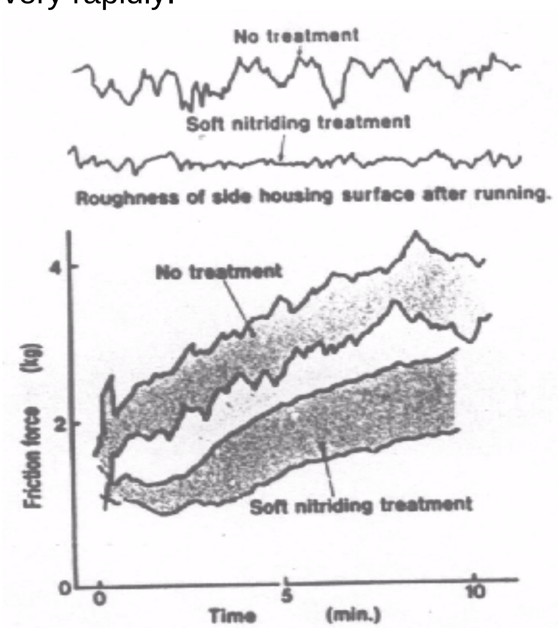


Fig.17 Characteristics of friction force

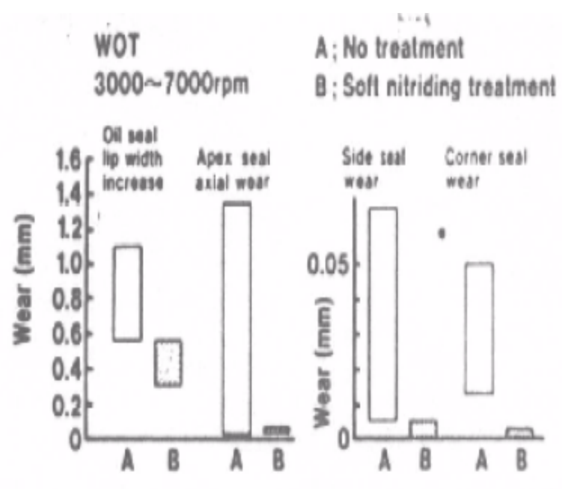


Fig.18 Effect of soft nitriding treatment for wear after 150 hr test running

The above graphs also clearly show the effects of the soft nitriding process on surface roughness, friction and seal wear.

These factors are a clear indication of why side housings should NEVER be lapped or ground.

Even the slightest grinding or lapping of one of these faces will ultimately remove THE ENTIRE compound layer created by the Soft Nitriding Process. Lack of this compound layer will result in greater friction and greatly accelerated wear on the corner seals, side seals, apex seals and oil seals. Unless the parts are being nitrided or otherwise hardened after lapping or grinding the performance of the parts is being GREATLY compromised when the compound layer is removed.

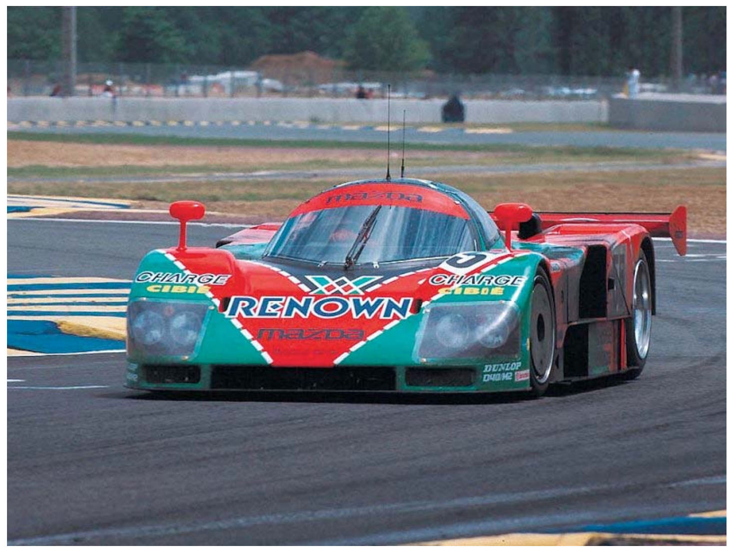
Having made this statement, the depth of the compound layer can vary from part to part and will sometimes exceed 0.0004” and can be as much as 0.002” on some parts. This is why some parts that are lapped or ground very minimal amounts can sometimes be used with moderate success while others produce poor results. If you want to know how much of the soft nitriding is remaining on your parts after you have ground of lapped them, test the hardness!

Overall, if the compound layer of soft nitriding infused into the part by Mazda is not replaced by a comparable hardening process, the part should then be replaced. Unless the step wear on the face of the part exceeds the allowable limit expressed by Mazda it is smarter to leave it alone than to remove all of the surface hardness by lapping or grinding.

2. INTRODUCTION TO CERMET COATINGS

a. Cermet coatings

The name CERMET is derived from CERamic-METallic and these are composite coatings that have ceramic particles in a metal matrix, analogous to re-bar in a cement matrix or carbon fiber in a resin matrix etc… These coatings are used in many industries for their superior wear (and high temperature wear) resistance, corrosion resistance and frictional properties.



There are many different types of cermet and also many different grades within the different types. The cermet A coating that we use on our rotor housings and cast iron plates is today’s evolution of the exact coating that was used in the 1991 LeMans winning 787B racecar. Although cermet coatings have been around since the mid 1960’s, the coatings have evolved greatly over the past 15 years. Today’s coatings are superior in all aspects including cost, bond strength, reduced friction as well as corrosion and wear resistance. The coating and process we use is widely used in aerospace applications but we modify the coating ingredients and application process. The resulting coating has greatly reduced internal stresses, higher bond strength and reduced friction to the coatings that were used in highly successful racing rotary engines 15 years ago.

A new application for thermally sprayed cermet coatings is as replacements for hard chrome plating. Hard chrome plating can produce a wear resistant coating with good surface finish at cost effective price. However, there are growing environmental concerns associated with the disposal of the effluents from the used plating solution and these concerns have caused the cost of the process to increase.

Cermet coatings have a wear resistance which is between two and a half and five times better than hard chrome plating and do not suffer from effluent disposal problems. They are therefore finding increasing use at the expense of hard chrome plating, particularly if wear resistance is important or if a thick coating is required on a large part.

Some technical specifications and comparisons:

application chart				
	re-ground chrome	Cermet B	Cermet A	Cermet X
stock engine	good	better	best	Ultimate
performance street	good	better	best	Ultimate
novice racing	good	better	best	Ultimate
professional racing	not recommended	good	better	Ultimate
aviation	not recommended	good	better	best
power generation	not recommended	good	better	best
alternative fuels	not recommended	good	better	best
apex seal compatibility				
Cermamic	X	X	X	X
Carbon	X	X	not recommended	
Hard ferrous >60 Rc	X	X	X	X
Soft ferrous <60Rc	not recommended	X	not recommended	
Mazda OEM	X	X	X	X
attributes				
oil retention	poor	oleophilic	oleophilic	oleophilic
Hardness- Macro	68-72 Rc	47	50	58
Hardness- Micro	1000 Hv	2800 Hv	1800 Hv	2400 Hv
friction	0.4	0.2-0.3	0.2	0.1
wear resistance	fair	very good	excellent	ultimate
bond strength	>12000 psi	>12000 psi	>12000 psi	>12000 psi

3. OUR PROCESS

a. Rotor housings

Our process for remanufacturing used housings involves several steps and although we will not divulge some of the details of our process we will give a general outline of what is involved.

The housings are first inspected for any obvious flaws or damage that make repairing that specific housing unfeasible, damage such as extreme corrosion of the water passages, large cracks in the casting and severe warping or shrinking of the housing.

The housings are then cleaned and degreased as well as media blasted before being inspected again for dimensional conformity.

We now take the good core and strip the chrome off of the trochoid surface. We DO NOT grind the chrome off or cut the chrome out, we use a non-destructive method that strictly removes 100% of the chrome and does not touch the aluminum or the sheet metal insert. Although this method is more expensive, it is the best (in our opinion the ONLY way) to properly remove and dispose of the chrome for both functional and environmental reasons. Once the chrome is removed we perform a chemical test on the trochoid surface to ensure that there is absolutely no chrome left.

After the chrome is removed we inspect the sheet metal insert for signs of wear or damage and also for any cracks that may be present and we then make any necessary repairs or alterations (mostly for racing) to the trochoid surface.

The housings next gets prepped for coating, this involves a grit blast to the trochoid surface and as well a pre treatment in a special solution that etches the sheet metal and results in an increase in bond strength of the cermet coating.

Depending on the geometry of the housing we are coating, we then apply between 0.007” to 0.018” of cermet A or B coating to the trochoid surface. During each batch we also coat a test coupon for quality assurance. The test coupon permits us to test the coating’s bond to the substrate without sacrificing a housing.

The freshly coated housing gets glass beaded for a nice finish and then goes through a 7 step finishing process (not including inspections). The process begins with rough lapping the sides of the rotor housings to remove any excess coating that is protruding from the edges of the trochoid surface. The cermet coating then undergoes a 6 step grinding and polishing process in our finishing machine. This involves a roughing diamond tool to start and the diamond tools get finer as the process moves on towards final polish. In between the roughing stages and the final stages the rotor to housing clearances and checked in several key areas to ensure that they are within our parameters. In the last step we induce a special finish that is the rotary equivalent to a crosshatch pattern in a reciprocating engine. This proprietary finish promotes break-in and oil dispersion, hence increasing longevity.

The finished housing gets a final inspection for surface finish and all dimensional parameters before being packaged for shipping.

b. End and intermediate housings

The process is very similar for the cast iron plates. We first inspect the plates and then grind off the required amount of material necessary to flatten the part (typically 0.005”). The part is then prepped for coating in a similar fashion as the rotor housings and then coated and finished using our diamond grinding and lapping equipment. The final coating thickness on the plates is about 0.005”.

c. Rotors

Our thermal barrier ceramic coated rotors are inspected to ensure that they are dimensionally correct and have proper step clearance on both rotor side faces as well as proper apex seal groove dimensions.

The good core is then cleaned & degreased to remove and oil or impurities. The rotor then gets grit blasted on the rotor faces before having the ceramic coating applied in a controlled environment. The coating is then air dried for 30 min before being cured at 650F for 1 hour. The finished rotor gets inspected for flaws in the coating before packaging and shipping.

4. QUALITY CONTROL

a. Tolerances and specifications

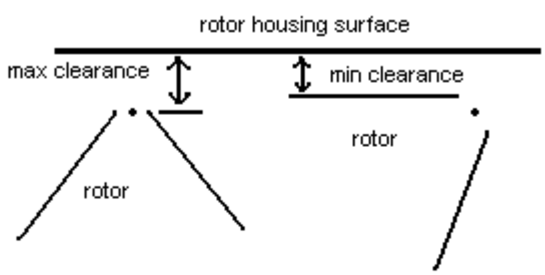
I would be quite easy to just list out all of the theoretical tolerances and specifications for a rotor housing, yet this would be of no practical use unless you first understand what is currently being manufactured.

Contrary to popular belief, the inner surface of a Mazda rotor housings is NOT a perfect trochoid as described by the following set of parametric equations;

$$\left.\begin{aligned} x &= e\cos\alpha + R\cos\alpha/3 \\ y &= e\sin\alpha + R\sin\alpha/3 \end{aligned}\right\}$$

It is rather a parallel trochoid curve offset by a constant amount α, this value of α is added to the generating radius R and this provides clearance for the apex seal, in the case of the Mazda engines, the value of α is 3mm. We will get to the tolerances and variations in these values shortly.

Another common misconception is that the clearance between the tip of the rotor and the rotor housings should remain constant along the entire trochoid surface. This is absolutely not true nor is it possible. This would be true only if the maximum angle of oscillation was to be 0° and this is not possible. The actual max angle of oscillation of the Mazda engines is in fact 26.2° and varies as the rotor spins. As the angle of oscillation varies between the max and min values the clearance between the rotor and the rotor housing also varies between the set max and min clearances. The following diagram illustrates the basic mechanism of “how” this happens:



Although this sketch is not technically correct it helps to illustrate how the clearance changes as the angle of oscillation changes.

The general Mazda guidelines for clearance are 0.017” to 0.030”. The minimum practical clearance at TBC at the minor axis for a performance naturally aspirated engine (up to 300 hp) is about 0.010” to avoid rotor to housing contact, for forced induction motors this value is slightly higher; 0.014”.

A good new Mazda Renisis rotor housing will generally have a min clearance of 0.015” – 0.026”.

There are several ways to measure these clearance values and each method may yield slightly different results. We have constructed a fixture that permits consistent and repeatable clearance measurements for every housing that we measure. To do this we have a half engine on our test rig using zero tolerance bearings and an optical clearance sensor for dynamic clearance measurement while the engine operates at 800RPM, we also perform a static clearance measurement of each housing using traditional calibrated feeler gauges. The rotor that we use in our test fixture has also been measured on a CMM (digital coordinate measuring machine) to assure that the rotor dimensions are exact as variances in rotor shape and size will consequently affect clearance measurements.

JHB cermet housings are manufactured with the following clearances unless otherwise requested by the customer:

> Minimum clearance of 0.015” to 0.032”. For race engines we can modify the clearances to accommodate high RPM operation (see Racing Modifications section).

Rotor housing width is also measured in accordance with Mazda specifications. Our standard process can occasionally restore slightly warped or shrunk housings up to about 0.002”. If so desired, we can also fix housings that are warped or shrunk beyond this amount for an extra charge.

Here are some other parameters that we measure:

Trochoid profile:
e = 15mm +/- 0.05mm
R = 102mm +/- 0.05mm
alpha = 3mm +/- 0.25mm
Waviness = +/- 0.01mm
Coating thickness = 0.152mm +/- 0.038mm
Bond strength: 11500 psi+

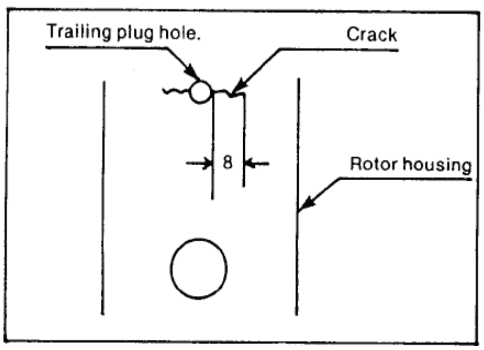
b. Core guidelines

All cores being sent to JHB Performance must be clean and free from oil and debris. Parts that are excessively dirty will result in a cleaning surcharge. If you do not have access to a parts washer or do not own a pressure washer we recommend you take your parts to the car wash and spray them down.

You should also be very aware of the state of your parts before you send them to JHB Performance. If we receive parts that are out of specification we will not be able to remanufacture or alter these parts and you will be wasting your money on shipping these to us. In accordance with Mazda specifications, the parts should meet all of the following criteria in order to be considered cores;

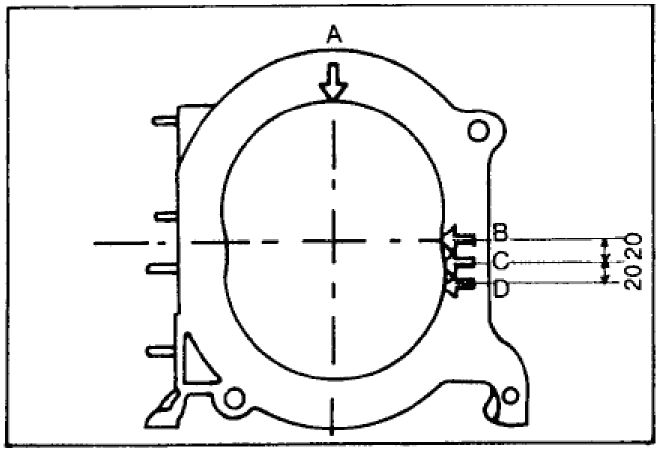
i) Rotor Housing Inspection

Cracking by trailing plughole: The maximum allowable projection of these cracks by Mazda is 8mm as indicated in the diagram below. We can repair housing that do not meet these inspection criteria at an additional charge and recommend that this repair be done only to “special” housings that have been extensively modified and have a higher replacement value.



Rotor housings width: The rotor housing must be inspected to ensure the width is within the allowable limits. Measure the width or thickness of the rotor housing at points A, B, C and D as shown in the figure below. Points C and D are each 20mm steps, individually beginning at point B. Compare the dimension at point A with the smallest of the other three, whichever it is. If the difference is more than 0.06 mm the housing will not qualify as an acceptable core. We can repair housing that do not meet these inspection criteria at an additional charge and recommend that this repair be done only to “special” housings that have been extensively modified and have a higher replacement value.

Rotor housing width should be:
13B Engine 80mm (3.149”)
12A Engine 70mm (2.756”)



Visual inspection after cleaning: Once the part is clean, carefully inspect the rotor housing o-ring grooves to ensure that no groves have been compromised due to excessive corrosion. Also inspect the water passages for corrosion.

ii) Trochoid Surface Inspection

Chrome housing honing service: For this service, we remove a maximum of 0.003” of chrome. This removal amount will take out imperfections such as chatter marks, tapers, wear and slight grooves that are often found by the trailing plug. Grooves or imperfections that are deeper than 0.003” will not be 100% remedied by this service. The customer should inspect the housings to ensure that they are aware of which imperfections exceed the 0.003” limit.

Cermet B coating service: For this service, we can repair trochoid surface damage such as chrome flaking, chatter, tapers, wear and all such imperfections that do not penetrate into the steel liner more than 0.015”. Damage and imperfections that penetrate into the steel liner more than this amount are at risk of showing up in the final ground surface.

Cermet A & X coating service: For this coating service we can repair all of the same trochoid surface damages as in cermet B coating as well as deeper grooves and damage that can be caused by apex seal failure to a maximum depth of 0.030” into the steel liner. These damaged areas should be photographed and e-mailed to us for inspection before sending us your housings and we only recommend fixing this sort of damage on “special” housings that have been extensively modified and have a higher replacement value.

iii) End Housing Inspection

The customer should inspect the end housings for any damage to the o-ring grooves or any cracks in the cast iron material prior to sending these parts fro cermet coating.

c. Warranty

JHB Performance cermet coatings are harder, more wear resistant and longer lasting than any other coating available. We are very proud to stand behind our cutting edge cermet coatings and back them with a limited 1-year warranty, the same as a brand new Mazda rotor housing.

JHB Performance shall not, under any circumstances, be liable for any special, incidental or consequential damages, including, but not limited to, damage, or loss of equipment, loss of profits or revenue, cost of purchased or replacement goods, or claims of customers of the purchase, which may arise and/or result from sale, installation or use of our product. In the unlikely event of any warranty concerns, you must contact us to obtain a Returned Goods Authorization (RGA) number. Please be sure to call us BEFORE returning any items, as we will not give any warranties without the proper RGA number.

5. PERFORMANCE AND ADVANTAGES

a. Benefits

The benefits to the cermet A, B & X coating process are gains in Power/Friction/Sealing as well as gains in Wear resistance/Durability and Corrosion resistance.

Performance gains are achieved through a reduction in the friction between the apex seals and the trochoid surface. The friction is reduced due to several factors including and not limited to the olephelic nature of the cermet coatings (meaning the coatings attract oil, retain oil and in the case of cermet A & X has self lubricating properties), the superior finishing process that we use on our housings and our proprietary sin-wave patter that we induce into the finish. Power gains using our cermet A, B & X coatings on the rotor housings alone are in the 2.5-5% range over chrome housings. When using our coatings on the end and intermediate plates additional gains of 2.5-6% can be realized.

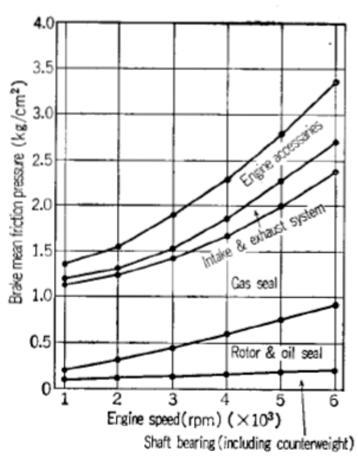


Fig. 4.2 Analysis of friction loss

In a rotary engine, around 25% of the losses are due to friction. By reducing seal friction between the seals and the rotor housing and the end housings we can reduce the losses and achieve a performance gain measured in horsepower and torque. See diagram to left to see how the various components cause power losses.

The extremely high micro-hardness of coatings as well as the olephelic nature of the coatings also dramatically increases the wear resistance of the rotor housings as well as its resistance to chatter marks and grooving. We have also found our coatings to be more resistant and robust to failure caused by rotor to housing contact and apex seal chipping and damage caused by foreign debris.

> *In one test we actually let a running motor ingest ½ cup of ground aluminum oxide grinding wheel with particle sizes up to 3mm. The rotor housings were untouched whereas the apex/side and oil seals and side plates had severe damage and wear caused by the highly abrasive material.*

In addition, the very dense (99.5% density) cermet material has a far greater corrosion resistance than pinpoint porous channel chrome as there is no exposed steel liner via any channels or pits with the cermet coating that may promote corrosion and flaking.

Cermet coated rotor housings have superior sealing ability and are also not subject to the same degradation of sealing ability over time as seen in the Chrome plated Mazda housings.

Over time, the Mazda chrome will experience wear. In the intake portion of the trochoid this is often manifested as chatter. In the vicinity of the trailing and leading plug there is also a large amount of uneven wear and distortion, seen as grooves and scratches. The cause of the wear by the spark plugs is thermal distortion of the rotor housing.

ALL used Mazda chrome rotor housings have a worn surface that greatly compromises sealing ability and performance. These effects are not always clearly shown with a compression test.

Dealing with the affects of thermal distortion in this area of the rotor housing has been very difficult for Mazda. Due to the high thermal loads and the asymmetric distribution of these thermal loads the trochoid wall tends to expand at different rates. These differences in thermal expansion cause the trochoid surface to warp during operation. The warped and deformed chrome plated trochoid surface does not form a good seal against the apex seal and thus allows unacceptable amounts of blow-by.

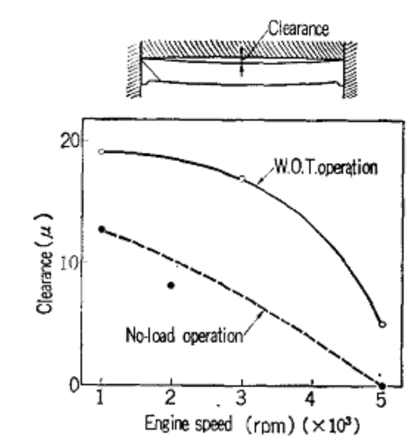


Fig. 4.42 Clearance between apex seal and rotor housing

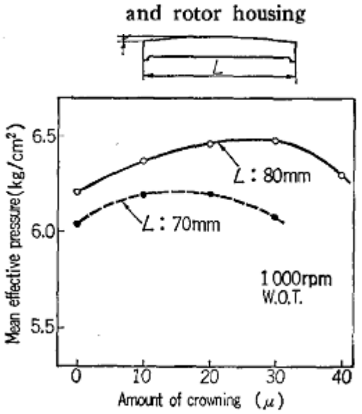


Fig. 4.43 Effect of crowning

To combat this issue Mazda has taken two approaches: the first is to compensate for the deformation by altering the apex seal geometry. The second is to alter the trochoid wall thickness in the vicinity of the spark plugs to aid in heat transfer.

Since 1985, Mazda has tried to manufacture an apex seal that will yield superior sealing at high loads. Several alterations have been made to the apex seal design to aid its sealing function. One alteration in particular was made to compensate for the thermal distortion of the trochoid surface. This alteration is the crowning of the apex seal along its beam. This slight crowning effectively compensates for the distortion of the rotor housings and provides a better seal… That is until the apex seal wears away the crowning effect.

The second method used by Mazda to compensate for the uneven thermal loads and expansion of the trochoid walls was to remove material in select areas of the trochoid wall to accelerate heat transfer around the spark plugs and reduce thermal distortion. These methods can be seen clearly on the renisis rotor housings and the earlier FD RX-7 rotor housings. Similar techniques have long been used by racers, such as the grinding of small channels in the vicinity of the spark plugs to aid with cooling efficiencies. The effectiveness of these methods is poor and there is room for further improvements in this area.

The cermet coated housings attack the root cause of this problem and have shown to alleviate the distortion problems of the trochoid surface through greater heat dissipation and lesser heat generation by friction. In addition to this, the honing method used by JHB applies a “reverse crown” on the trochoid surface ONLY in the areas greatly affected by this problem. This way the engine does not suffer the same problems associated with blow-by along the entire trochoid surface (around the entire rotor housing) when using a crowned apex seal. This honing method coupled with a true flat apex seal (such as a ceramic apex seal) have shown superior sealing ability and greater power yields than a chrome housing with a crowned apex seal.

In a head to head comparison, cermet coated parts are superior in every aspect and deliver greater power without any comprise of durability.

b) Housing comparisons

Models of housings and differences.

There are many differences between different model years of rotor housings ranging from the casting design itself to the porting and plug timing as well as the grade and quality of the materials used. The chrome plating has evolved over the last 35 years of rotary engine production and the underlying steel liner has also been upgraded accordingly.

The most visible difference is the exhaust port timing; the port timing and location have changed considerably from generation to generation.

The spark plug location and timing has also changed slightly between different years of rotor housings. The change was made for the S4 (1986-1988) model rotor housings that have different plug locations that the rest of the model years. The locations of the plugs on the S4 rotor housings match that of the Mazda Factory Racing Peripheral Port rotor housing.

The trochoid profile has also changed a very slight amount from generation to generation; these changes were seen in conjunction with a change of apex seal design, i.e. a change from 6mm to 3mm and from 3mm to 2mm and again from

2mm to shorter height 2mm Renisis. These changes are very minimal and intended to provide a better match between the apex seal radius and the trochoid surface.

There have also been some slight alterations in the casting moulds from generation to generation. Most of these are attempts at reducing the thermal distortion of the rotor housing in efforts to provide a better seal at operating temperatures. Other modifications have been made to make the rotor housing stronger in high stress areas that may have been prone to failure.

However, most of the differences in the molds have no functional value at all and are just the result of the rotor housings being manufactured at different foundries.

For racing we feel the best rotor housing to start with is the 1984-1985 13B rotor housing. This rotor housing has a trochoid profile that matches 3mm apex seal tip radius. It has greater water jacket volume, the water jacket o-rings are in the rotor housing rather than the cast iron plates (more reliable). The oil injection holes are larger and the spark plug positioning matches the latest generation rotor housings. Also, the exhaust port is slightly smaller and narrower than the later models allowing greater flexibility in exhaust porting. This rotor housing lends itself very well to the most common racing modifications such as turbulence grooving in the water passages, peripheral porting, doweling, addition of a far trailing plug hole and a floating combustion wall.

Another rotor housings that are excellent for modifying are the S4 naturally aspirated rotor housings. We use these as a base for our Peripheral Port rotor housings as the have the same spark plug placement as the Mazda Factory Racing peripheral port race housings.

6. RACING MODIFICATIONS

a) Water jackets

i) PP housings

JHB Performance offers custom made Peripheral Port rotor housings with intake and exhaust ports with custom shape and timing configurations. Because we use our cermet process, we are able to make further alterations to the ports than other peripheral port manufacturers. We can actually change the location of the exhaust or intake port by inserting a solid sleeve and milling the port orifice. This also enables us to seamlessly remove the trailing plug for certain applications or even add a far-trailing plug for others. For additional questions regarding these services, please contact us.

ii) Porting

Contrary to popular belief, in most cases exhaust porting is NOT necessary. Nearly all performance gains can be had with intake porting and alterations to the intake and fuel injection system. The stock exhaust ports are quite big and the opening and closing timing will be suitable for most applications. Under no circumstances should the exhaust be ported to advance the opening timing of the exhaust port more than about 10 degrees. The only real benefit of doing so would be to give the opening portion of the port a more preferable shape as the stock port opens the exhaust very abruptly. The disadvantage of opening the exhaust port earlier is that you are shortening the power stroke. This reduces the amount of time that pressure can be applied to the rotor face to generate torque!

The width of the exhaust port is another part that should never be touched. The stock exhaust ports are plenty wide for any application, making them wider only reduces the bearing area for the apex seals.

The closing time of the port can be modified to suit the application of the engine. For naturally aspirated engines this is determined by the type of intake porting that was done and by how much overlap will be desired. In effect, for a bridge port or peripheral port a very late closing exhaust port with a rounded top is desirable whereas for a street port you would only want to round the closing of the exhaust port and alter the closing timing very little.

In turbocharged engines however, overlap is not desirable and should be kept to a minimum. Shaping the opening and closing of the ports is all that is required and in extreme cases small changes in port timing can be made.

Making changes to the exhaust port sleeve can also be of benefit. Replacing the insert with one that does not open as rapidly has been shown to increase performance. In theory, an orifice should not expand at a rate greater then 10 degrees (included angle) for optimum performance. Rapid expansion causes turbulence and decreases velocity abruptly resulting in poor flow.