

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:

Performance: 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.

Availability / Resources: 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.

Cost: 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**.

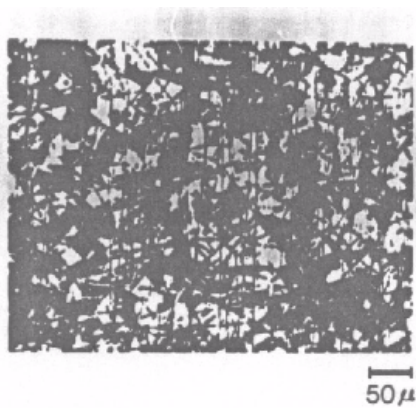


Fig.1 Micro-channel porous Cr plating

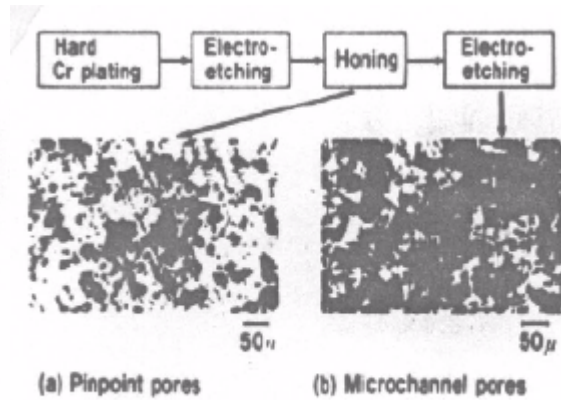


Fig.6 Porous chromium plating process and the surface structures

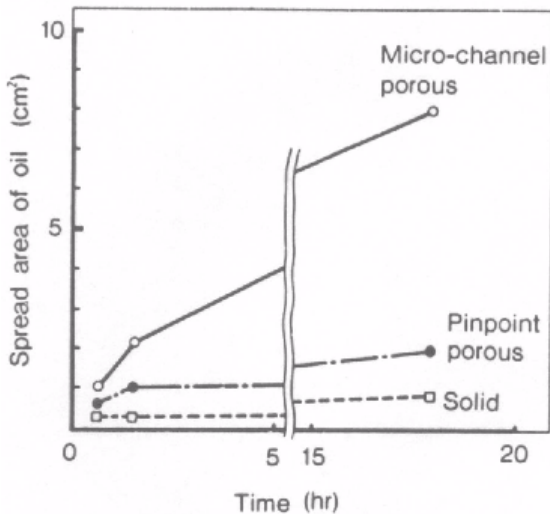


Fig.2 Spreadability of oil with regard to Cr plate

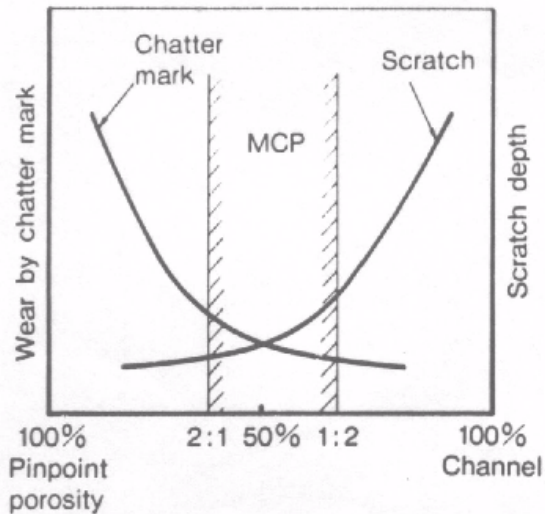


Fig.3 Oil spreadability as a function of Cr plating pattern

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.

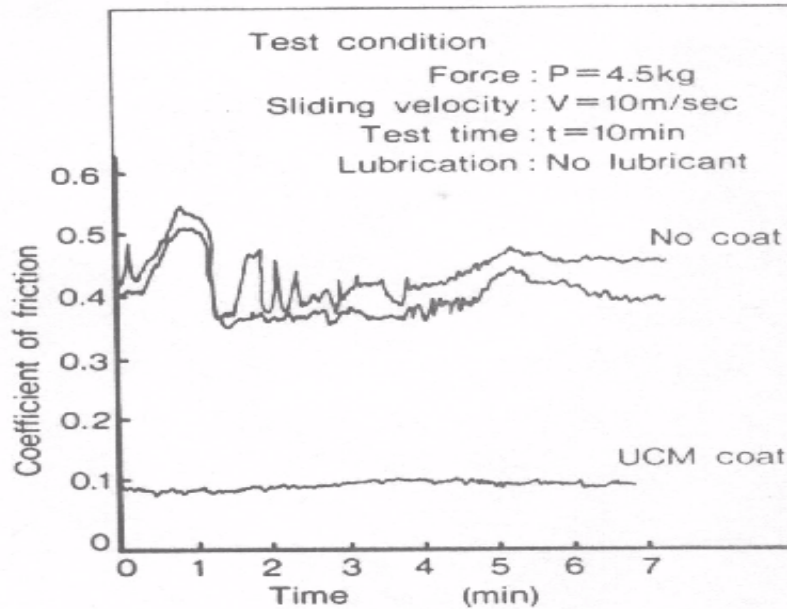


Fig.4 Coefficient of friction between apex seal and trochoid

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 too 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.

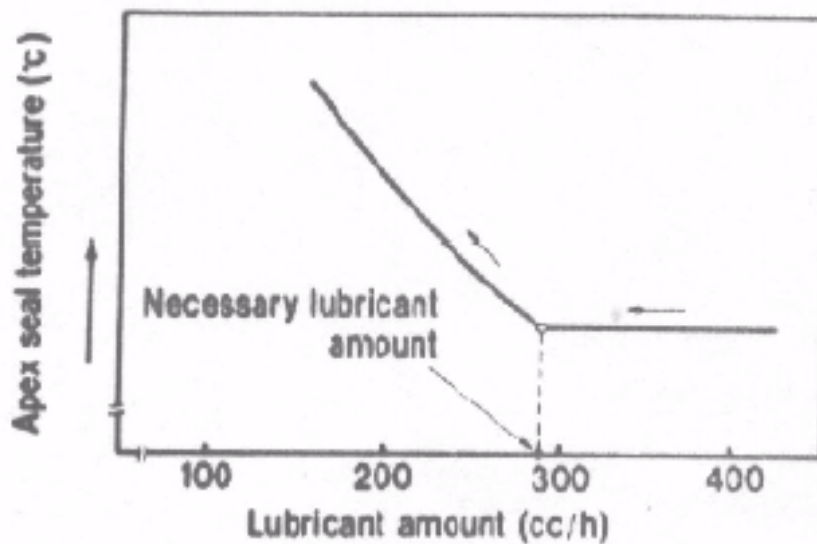


Fig.9 The relation between lubricant amount and apex seal temperature.

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 it 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 it *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 led 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 as 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.

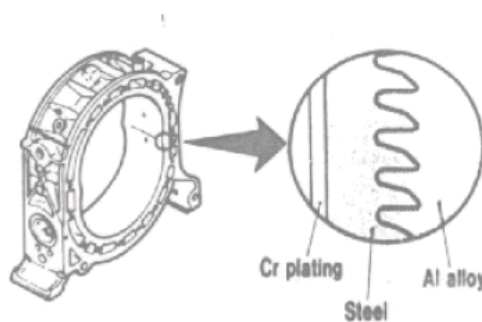
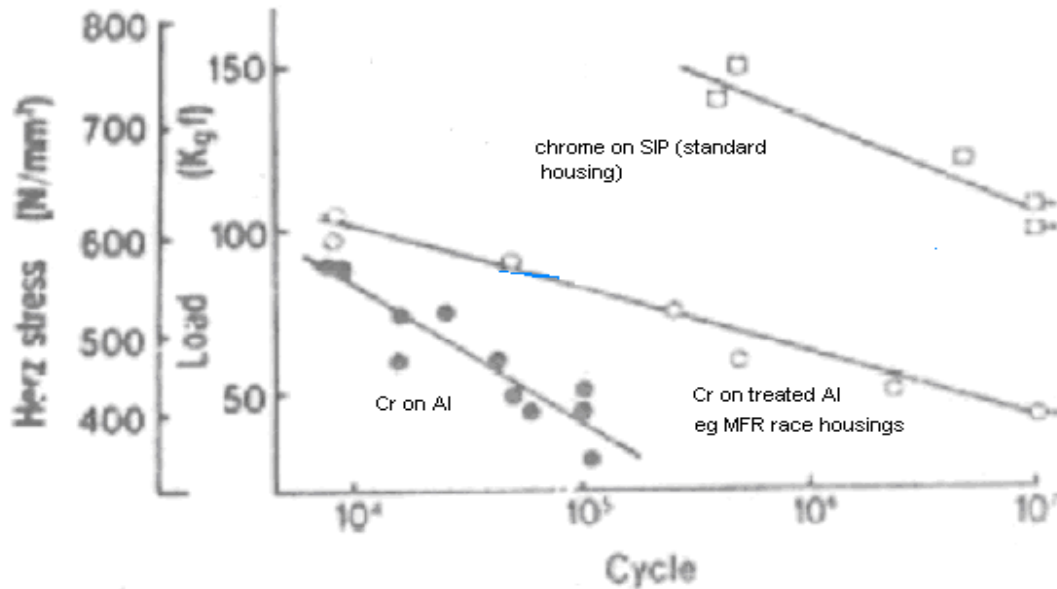


Fig.3 Cross section of trochoid surface

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.

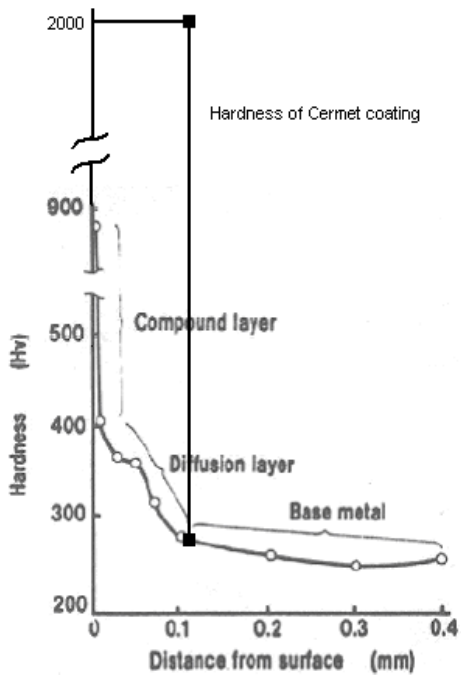


Adhesion life of Chrome of various housings by contact rolling method

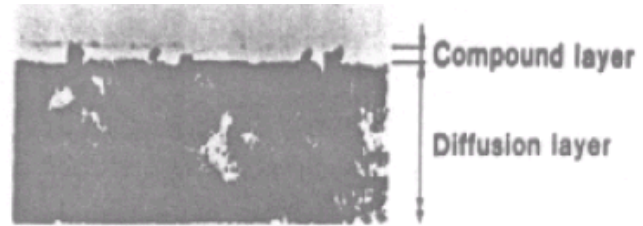
b) Mazda Soft Nitriding

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 Renesis 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.

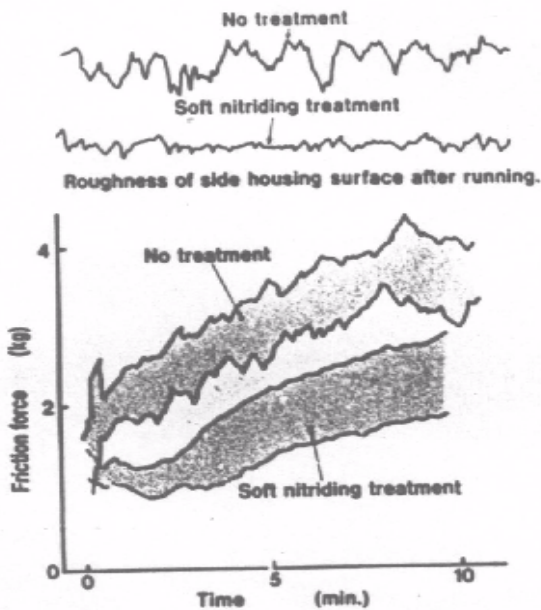


Fig.17 Characteristics of friction force

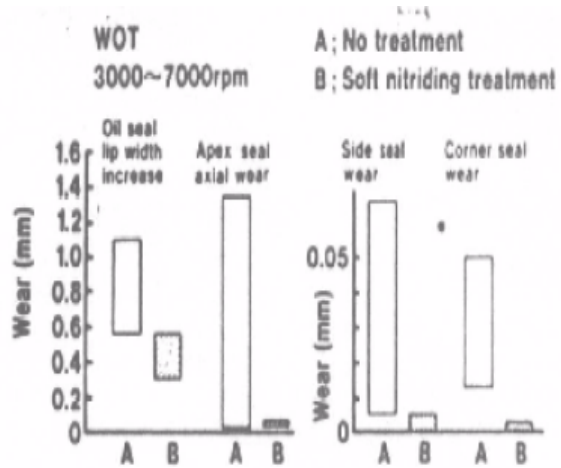


Fig.18 Effect of soft nitriding treatment for wear after 150 hr test running

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 or 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.