The Myth of Magnetic Oil Filters

Bill Smith, Vintage Auto P/L
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The fitting of magnets into the sump plugs of gearboxes and rear axles has long been thought beneficial to the health of gears and bearings. However, as a by-product of some R&D work done in the 1980s by Borg Warner, my previous employer, it was found that the humble magnet did not contribute *in any way* to improving gear or bearing life *unless the magnets were cleaned very frequently*.

For a newly assembled rear axle, we found that this meant dropping the oil and cleaning the magnet at 100, 500 and then 1000km. After this initial period we found that the frequency could drop to every 1000 km until about 10000 km.

If this cleaning was not carried out in the first 1000km, the damage that was already done to the gears and bearings would ensure that these parts would wear at a faster rate for the remainder of their (shortened) life.

The test methods need to be explained to help understand what is happening inside a rear axle. I will extend this later in the report to explain the similarities and differences with manual transmissions. These test results where found using precision made gears, the recommendations I have included at the end of the report are even more critical than these tests suggest as the average replacement gears for our type of cars are on average simply appalling.

Test methods and results

Parts for test axles were assembled in laboratory conditions of cleanliness. Prior to assembly every wearing part was weighed to high degree of accuracy, right down to each taper roller bearing being weighed as 4 separate components, that is, the outer cup, inner cone, rollers and cage. In this way the contribution to debris mass could be allocated to each part. After a standardised test run, the axles were torn down with great care so that the ***position, particle size and mass*** of each pocket of debris could be recorded, as well as the weight loss by component. The axles were then reassembled and the debris placed back into the positions where they were found. This included placing the debris found on the magnet back onto the magnet.

The results in the following graph show the problem of installing magnets and leaving them undisturbed. Simply put, the particle size and mass collected by a magnet at 100km has by 500km increased in mass and ***decreased in particle size***.

This process continues until the magnet is saturated and cannot hold any further metal.

The only conclusion that can be reached here is that the metal on the magnet is constantly being stripped off and sent back around the axle to be further ground up which results in further debris generation and further damage to the wearing parts. At the time of tear down the super magnets employed during the trials held approx 70% of the total mass of debris.

Other trials using an oil pump and paper oil filter suggest a far lower wear rate in the initial running-in period (up to 1000kms), then the wear rate slows right down for the remainder of the rear axle's life, typically well beyond 300,000 km.

The best protection is found with a dry sump system with full pressure oil distribution via an inline filter. This avoids the gears from dipping in the used, dirty oil and recontaminating the oil available in the gear mesh. Such systems are found in racing cars.

Rear Axle and Manual Transmission oil filtration

The stripping of the debris from the magnet in rear axles is a direct result of the very high surface speed of the ring gear or crown wheel. The bigger the diameter of the gear and the smaller the tyre size the higher the oil speed across the magnet. The ring gear usually runs in a confined housing which turns the gear into a very efficient oil pump.

To reduce the stripping effect of oil speed across a magnet, the magnet needs to be placed where the oil flow is quite slow. If such a position can be found in a rear axle the percentage of total oil flow that reaches the magnet would be very low. In filtration terms a magnet in such a position would be classified as a 'low by-pass filter' and, whilst it would contribute to better gear and bearing wear, the effect would be minimal.

Rear Axle bearing preload

The bearings in modern rear axles typically comprise 2 pairs of taper roller bearings. This type of bearing can be set in one of three different ways; end float between the bearings, zero end float and, thirdly, negative end float (preload).

The common modern practice is to have preload as this allows the bearing to run with the rollers in constant contact and with the most precise positioning of the rollers to the raceway. Preloading of bearings in rear axles is like tightening critical bolts in an engine. The tension in a bolt stops it from flogging and predisposes the joint to accept load with minimal deflection.

By way of example the typical Ford or GM Holden rear axle used for the above tests has the drive pinion bearings preloaded to approx 1 tonne. A 1 tonne force is roughly equivalent to the removal of a 0.025-0.030mm shim from a spacer between the two bearings that gave zero end float. This preload reduces slightly during the run in period, but will reduce dramatically with excess debris in the oil. As the preload reduces the gear tooth contact area moves more freely under the varying loads that are applied.

If your car has a 'rigid' rear axle suspended on simple cart springs for instance, hitting a bump in the road causes the contact point on the drive gears to oscillate. This also happens when you apply the brakes. As the tyres are being pulled backwards and the mass of the car is pulling forward this bends the axle housings and moves the gear contact position. This adds to metal removal from the gears as it is like a lapping movement. Therefore the whole system will self-destruct. As the bearings wear and lose preload the gears wear faster and the metal debris goes through the bearings further reducing the preload.

Vintage and Veteran Rear Axles

As a generalisation, rear axle housing and bearing systems in these car groups are not stiff enough to resist the forces of drive or overrun torque or braking forces. If the gears were made to a good standard as originally supplied (many examples I have seen suggest this is true), then the parts made today are generally appalling. In particular, the quality of surface finish and geometric accuracy of the tooth flanks, are the key factors governing the quantity of debris that will be generated in service.

Bearings in this period were generally not preloaded. In the case of the Citroen B12, where they used 'chevron' or herringbone spiral bevel gears, the bearings had to be set with an alarming degree of end float to allow the gears to function.

Fitting modern bearings and assembling them with preload is often limited in this group of cars by the lack of oil flow provided in the housings to cool the preloaded pinion bearings. In stark contrast to the quality of gear spare parts, modern replacement bearings are significantly better than those of the 'old days'.

Classic cars are generally much better designed, but spare parts can still be a problem. The use of limited slip differentials adds a large amount of debris to the system. The advent of transaxles in this group (Bugatti had one pre WW1) has an additional complication that I will cover in the next section under transmissions.

Manual Transmissions

Whilst the same stripping of debris collected on a magnet happens with transmissions, the surface speeds of the gears are much lower than rear axle crown wheel gear. But the effect is still significant enough to warrant our attention. For this discussion it is best to split transmissions into two groups, Vintage/pre-WW2 and modern/classic.

Vintage and Pre WW2 Transmissions

These transmissions generate very high levels of debris, particularly the 'crash box' design that is the most common during this period.

The advent of the 'dog box' (as used in current motorcycles, as well as many post vintage cars (including Lancia models from Dialambda to Ardea) and early synchronised 'constant mesh' designs that became ever more popular during the later stages of this period reduced the debris generation towards modern levels. But even modern designs can benefit from the fitment of some type of filtering if the owner is interested in the ***long-term*** preservation of the vehicle.

The reason for this high level of debris generation in this period is as follows, in order of importance:

1. The chipping of gear teeth during gear change.

2. The bruising of gear teeth during gear change and the teeth running on bruised areas during operation.

3. The common use of gearshift fork detents to hold the gearbox in gear against the forces of drive torque leading to the gearshift fork rubbing constantly on the gear whilst that gear is in operation.

4. The manufacturing technology that was available in the period is naturally less favourable than is available today. There were variations in the technology manufactures employed; some employed the worst available and some the best. This also applies to current production. The surface finish and geometric accuracy of the gears varies the amount of debris generated.

5. Replacement gears typically rank with the worst of those manufactured during the 1920's period. As with the rear axle gears, some I have seen are

simply appalling.

6. The very heavy gear oils (typically SAE 140 and heavier) that were specified during the period help keep the ground up debris in suspension, effectively acting as a lapping paste.

7. Lubrication of the 'pocket bearing' in the input gear is prone to poor lubrication making the bearing both generate and be susceptible to debris. (Also related to point 6 above).

Modern and Classic Transmissions and Transaxles

It is impossible to generalise with this group of vehicles, as the diversity is enormous. Owners should look to their repair manuals for any clues as to how they function. Some features of the vintage period persisted up into 1960s, such as items 3, 6 & 7 above.

The advent of synchronisers leads to many of the gears being supported on bearings on their respective shafts, some with plain bronze bearings and some with needle bearings. These both generate debris and are susceptible to damage from it. Transaxles introduce the bevel gear issue into the transmission so this doubles up the debris generation. Most types of limited slip differentials are a significant source of debris.

Summary

Whenever metals rub together debris will be generated. Lubrication is vital in minimising the amount of debris but it does not eliminate the problem. Piston engines today run full flow oil filtering for this very reason.

Transmissions and rear axles do not generate the levels of debris of a piston engine but, if the conditions are poor, they will self-destruct in less than a thousand miles. Do not let this happen to your new, expensive and rare gear sets.

The use of magnets as a filtering means is a good simple filtering mechanism, but ***only*** if they are regularly cleaned and the oil changed frequently. Many replacement gears are so poor in quality that they cannot reasonably be called gears. The best description is a cog that is best suited to 16^{th} century corn mill or the like. The recommendations below will help poorly made gears but it is not a universal fix.

Recommendations

Newly rebuilt axles or transmissions:

1. Fit magnetic drain plugs wherever possible, employing so called super magnets.

2. When draining the oil do so when the oil is hot and as soon as possible after bringing the car to a halt.

3. Manufacture new drain plugs with deeper internal recesses to tuck the magnets out of any turbulent oil flow if possible. Ensure the fixing of the magnets is such that the oil flow cannot dislodge them and that they can be cleaned when required. Some axles will require the magnet to be housed in a brass mesh cage to ensure the magnet is secure. If you can dislodge your magnet with compressed air, some axles will achieve the same movement with the oil stream at high road speeds.

4. Some designs of rear axles (Lambda) do not allow for the complete volume of oil to drain. Use an oil sucker to improve the drainage and manufacture a magnet on a stick to trawl to bottom surface of the axle for debris after draining.

5. Establish an oil and magnet cleaning routine, starting at 50 km intervals until at least 200 km then, depending of the amount of debris being collected the next check could be at 500 km, then at 1000km and from there on at 2000km intervals up to 10,000 km. With Lambda I recommend trawling the bottom of the axle housing with a "magnet on a stick" at each magnet cleaning period. I have found it best to have a bench-mounted oil filtering system to clean the oil before returning oil to service.

6. Use Full Synthetic oil to improve the settling rate of debris in the oil and improve the lubrication of hard to reach areas, such as pinion bearings and manual transmission bearings. Ensure the oil company tech reps advise the use of their diff oil in units with copper based alloys present.

Existing gearboxes and rear axles:

1. Fit magnets and start a routine of magnet cleaning ASAP.

2. Monitor the debris generation rate over a 1000Km period to ensure the process of debris generation slows down as much as possible.

3. Fill with a suitable synthetic oil to improve gear life and improve debris settling times.