

The Evaluation of Mechanical Design and Comparison of Automotive Oil Filters

2010-01-1542

Published
05/05/2010

Daniel Lamon
General Services Administration

Daming Zhang
California State Univ.

Copyright © 2010 SAE International

ABSTRACT

Approximately 500 million oil filters are sold in the United States of America each year, and are not required by law to meet any Government or industry testing procedures prior to being sold in the US market. The lack of required testing has resulted in no uniform testing procedure which in many cases leads to misleading claims by the manufacturer and/or inferior filtration designs and construction materials. Due to the lack of mandatory testing, the majority of oil filter manufacturers use in-house labs with different filtering methods to highlight the filter's unique strengths while not disclosing all relevant filtering data and in turn the filters inherent weaknesses. Instead of manufacturers offering full disclosure of the relevant performance specifications and internal design characteristics of the oil filter, they state that the specifications are proprietary information. This unfortunate trend results in consumers not being able to properly identify a superior oil filter that meets their individual performance needs. Due to the lack of mandatory standardized testing some consumers have had catastrophic engine damage from using an inferior oil filter.

The idea for this research came through the desire to find the best designed and manufactured automotive engine oil filters. An analysis protocol was developed and applied to the sample of 15 oil filters on 29 characteristics in order to accurately determine and compare filter design, construction and manufacturer specific claims. Our research determined inaccurate and misleading statements from the oil filter manufacturers as well as inherent design flaws and use of potentially dangerous internal materials and oil additives. Our conclusion determined the need for a mandatory standard testing procedure in order for consumers to properly identify

and determine the filtering specifications and the materials used in the construction of the filter.

INTRODUCTION

An oil filter with superior filtering ability and holding capacity has the ability to improve engine longevity, increase maintenance intervals and results in substantial financial savings over the life of the vehicle. Extending an engine's oil drain interval while maintaining the same engine wear primarily revolves around the durability of the engine oil additive package and the holding capacity and the micron filtering ability of the oil filter.

Unfortunately, all automotive oil filters sold in the United States are not required to pass any form of Government or industry testing from the Society of Automotive Engineers (SAE), International Standards Organization (ISO), American National Standards Institute (ANSI) and/or the National Fluid Power Association (NFPA) in order for them to be sold in the US market. Due to the lack of oil filter testing and misleading advertising statements, many consumers cannot determine which manufacturer produces a superior automotive oil filter to suit their individual needs. To confound the problem even more, manufacturers often test their own filters using separate tests designed from different agencies that do not directly correlate to one another. This is due to the fact that some tests are more difficult to pass than others. Some oil filter companies will often only test the largest physical oil filter they manufacture and state that oil filters data on their entire oil filter's line. An oil filter that fits a large 16 liter Cummins diesel engine will not have the same holding capacity as the company's smaller oil filter that corresponds to a 1.0 liter stationary generator engine. These simple issues make it very

difficult for a consumer to determine the quality of an oil filter and compare them against one another.

This research developed an analysis protocol that measured 29 characteristics that related to the performance of the oil filter in order to accurately determine filter design, construction and manufacturer specific claims. The testing protocol was applied to a sample population of 15 oil filters and the results were in turn compiled and analyzed against the manufacturers published data on the respective oil filter. Our research identified that there was not a direct correlation between the cost of the oil filter and seven distinct characteristics that relate to the performance of the oil filter. For instance, the most expensive oil filter in the test sample with a 35,000 mile drain interval had almost three times less filtering media than the original equipment oil filter. The research determined inaccurate and misleading statements from the oil filter manufacturers as well as inherent design flaws and use of potentially dangerous internal materials and oil additives. Another interesting observation was that the sample of 15 different oil filters were manufactured from only six different companies with some competing filters being identical in construction and filtering ability.

In conclusion, our research determined a need for a mandatory standard testing procedure in order for consumers to properly identify and determine the filtering specifications and the materials used in the construction of the filter, so that they can make an informed and accurate oil filter purchase for their unique performance needs.

HYPOTHESES

Due to the lack of standardized testing and proprietary information the comparison of micron-filtering values, holding capacity, flow rates, by-pass pressures and other relevant data could not be compared based on the available published data from the respective manufactures. Thus the hypotheses and research questions revolved solely around the physical construction of the oil filters and advertisement statements from the oil filter manufactures. The research and testing methods tested the following hypothesizes and research questions:

1. Multiple oil filters sold under different brands are in fact made by the same manufacturer.
2. There is not a direct correlation between the cost of the oil filter and the total surface area of the filtering element.
3. There is not a direct correlation between the cost of the oil filter and the thickness of the filtering media.
4. There is not a direct correlation between the total surface area of the filtering media and the number of pleats in the filtering media.
5. There is not a direct correlation between the total surface area and the thickness of the filtering media.

6. There is not a direct correlation between the weight of the oil filter and the total surface area of the filtering element.

7. There is not a direct correlation between the cost and the weight of the oil filter.

8. There is not a direct correlation between the thickness of the filter housing and the cost of the oil filter.

9. There is not a direct correlation between the cost of the oil filter and the oil inlet surface area.

The limitations of the research are that all measurements were taken off their actual value. No means of synergism was calculated regarding filtering media material, thickness of the material, total surface area of the filtering element, number of pleats per filtering element and the porosity of the filtering element in the evaluation process.

METHODOLOGY

The 15 aftermarket oil filter test samples corresponded to being compatible with an OEM filter that corresponds to the world's most commonly produced filter model.

The analysis and measuring sequence were conducted in the same manner for each oil filter. First the dry weight of the oil filter was determined. The external measurements that were taken are the filter housing length and width along with the base gasket width and height. The number and diameter of the inlet holes were the last external measurements recorded. After the external measurements were taken, each oil filter has the metal case cut open using a pneumatic cut off wheel in order to access the internal parts of the oil filter for measurements. The inside diameter of the housing was then determined using the dial caliper. The outside diameter minus the inside diameter determines the wall thickness of the oil filter. The filter end cap material was determined and any differences in design or construction of the end cap were also mentioned. The filter anti-drain back valve and by-pass valve material and design were then reported. The backplate thickness was measured using the dial caliper. The number of pleats in the filter was counted and the depth of each pleat was measured using the depth gauge feature of the dial caliper. The length, width, thickness and total surface area of the oil filter were measured.

Once the oil filter data is gathered, it is compared against the other oil filters in the sample in order to determine the advantages and disadvantages of each oil filter design. The weight of the oil filter in grams was determined using a digital scale to establish if there is a correlation between the weight of an oil filter and its total filtering media surface area. In the past, many consumers have guessed the efficiency of an oil filter from its weight. Their thinking was that a heavier oil filter must have more filtering material inside and thus it is a superior filter as some forms of advertisement have lead consumers to believe. However, this

is a common misconception as the research will show. Following the weighing of the oil filter, the outside dimensions of the oil filters were measured and recorded. In order to understand the relationship and purpose of the measurements it is important to understand the basic construction of an oil filter. [Figure 1](#) contains the five main components of an oil filter. The casing components include the housing, top cap and bottom cap. These three parts make up the external case of the oil filter and are what holds the internal parts stationary by spring pressure. The cartridge components are made up of the filtering element and the inner core support and the end caps which are not shown. The filtering element collects foreign particles in the oil while the inner support sleeve gives support to the filtering element and stops it from distorting and compressing due to the oil pressure being applied to the filtering media as oil is being pushed through it.

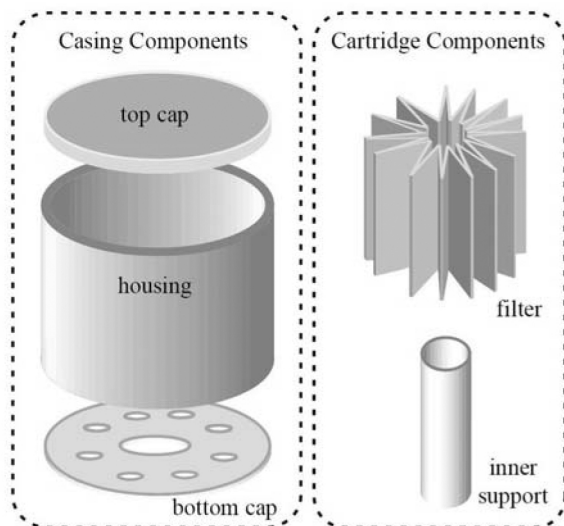


Figure 1. Oil Filter Components [1] “©2006 by Dr. Aughenbaugh. All rights reserved. Used by permission.”

The physical size of each oil filter is important information, in that some engine filter locations have very tight clearances and an increase of a quarter of an inch in width or length can result in the filter not being able to fit due to interference problems.

The base gasket seal is then measured for its height and width. Generally the base gasket is a square cut seal, but some manufacturers use a conventional O-ring or round seal while others use a lip seal design. A visual comparison of the three primary seals can be seen in [Figure 2](#).

See [Figure 2](#) after last section of paper

O-ring seals must be tightened more after the base gasket seal touches its mating surface in order to obtain the given seal compression or crush. The advantages of the lip seal is that

there is a small lip on one side of the seal that is compressed between another steel lip of the oil filter canister. By applying pressure to the lip of the seal it helps to hold it in place during the installation and removal of the oil filter. The lip also reduces the likely hood of the seal sticking to its mating surface on the engine, as it is already firmly compressed and firmly held to the oil filter. When measuring the width of a lip seal, the lip portion is not included in the measurement as it does not make contact with the oil filters mating surface and does not increase the sealing ability of the gasket. The base gasket seal material is determined from the manufacturer specific information, as various forms of rubber have been shown to last longer under pressure and during repeated heating and cooling cycles. In the event of a base gasket seal failure the engine would most likely be operating on an insufficient supply of oil which will result in engine damage to internal rotating and reciprocating parts. Nitrile is the most common base seal material as it has sufficient sealing properties and is fairly inexpensive. Nitrile has a maximum service temperature of 100 degrees Celsius which can be problematic in medium and heavy duty vehicles where air flow around the filter is minimal and the engine naturally runs hot like in a Hummer H1 with a 6.5L diesel engine [2]. Hydrogenated Nitrile (NABR) provides superior thermal and chemical resistance to standard nitrile and has a maximum service temperature of 150 degrees Celsius [2]. Some oil filter companies use a pre oiled nitrile base gasket seal in order to reduce the likely hood of the oil seal sticking to the oil filter sealing surface and provide stronger initial sealing ability. Viton is used as a base gasket seal due to its incredible heat resistance of over 205 degrees Celsius [3]. Viton is also impervious to automotive fuel and highly acidic and alkaline solutions. Viton is commonly referred to as mil-spec due to its common requirement on military vehicles. Texolon (PTPE) is used as a base gasket seal since the material has the ability to withstand distortion in both extreme cold and heat with a maximum service temperature of 260 degrees Celsius [2]. Both Viton and Texolon are not used as often due to the higher cost for the material which is why the majority of oil filters on the market use nitrile. The base gasket seal material is very important to customers who operate their vehicles in extreme operating conditions present in Alaska and the Mojave Desert or are focusing on extended drain intervals.

The oil inlet passage's total surface area is measured to determine the total volume of oil that can enter the oil filter at a given flow rate. Engine oil leaves the main oil gallery discharge port and enters the oil filter through the small holes located on the top of the oil filter. Since the number and size of the oil inlet passages determine the total volume of oil that can enter the oil filter, the total surface area of the inlet holes is calculated.

After all external measurements and calculations are determined, the oil filter is then cut open and the contents are

taken out (as shown in [Appendix](#)). Once the contents have been removed, the thickness of the oil filter cartridge is determined. In some automotive engine designs the oil filter is not always placed in the safest possible place due to engineering or space requirements. In vehicles where the oil filter is located in the vicinity to where it can be easily damaged by rocks or other debris, the thickness of the filter is very important, as a pierced filter housing will result in an oil leak and possibly engine damage.

The next step is to determine the oil filter's anti-drainback valve material from the manufacturer's data. The purpose of the anti-drainback valve is to stop engine oil from draining out of the filter and reentering the engine crankcase when the engine is off. When the anti-drainback valve is faulty, the engine oil drains out of the filter when the vehicle is off and is partially filled with air. When the vehicle is started the oil pump must refill the oil filter again before the oil can travel to reciprocating and rotating parts. In the time it takes the oil pump to refill the filter, the engine will have run with minimal lubrication, which results in increased engine wear. The majority of oil filters have built in anti-drainback valves which are usually rubber diaphragms. Most companies use nitrile rubber diaphragms due to the fact that they are inexpensive. However, in extremely cold climates or during prolonged oil drain intervals nitrile rubber diaphragms can become stiff from repeated heat cycles and not seal properly. Silicone rubber diaphragm seals hold their shape and sealing ability better in high heat, extreme cold and during prolonged usage due to the material's superior temperature characteristics and memory properties. Unfortunately, many oil filter manufacturers do not use silicone rubber diaphragms because of their inherent greater cost. The anti-drainback valve is never used for its intended purpose if the oil filter is mounted vertically with the filter screwed up onto the engine, and if the car is always parked on level ground when it is turned off. The Anti-drainback valve is functional when an oil filter is mounted at an angle or vertically downward with the oil filter inlet is facing down. When an oil filter is mounted vertically with the base gasket facing upwards, gravity keeps the oil inside the oil filter when the engine is off, but when the oil filter is placed at an angle or vertically down, an anti-drainback valve is needed to stop the oil from flowing out of the filter and back into the engine sump.

The oil filter bypass valve is designed into almost every OEM oil filter or placed either end of the filtering media. An oil bypass valve is used in order to prevent the engine from being starved of oil. A bypass valve is a safety feature that allows the engine oil to bypass the filtering element inside the oil filter. The bypass valve is normally closed, but can open during high RPM, cold start conditions and if the filtering element becomes clogged and the oil flow rate is reduced as under these conditions it is likely that the oil filter cannot filter the new higher oil volume requirement in such an abrupt period of time. This results in the oil bypass valve

opening to allow non filtered oil to enter the engine and lubricate the moving parts. Engineers have designed this feature due to the fact that non-filtered oil entering the engine will likely result in less damage than starving the engine of oil. The oil filter bypass valve also opens if the oil filter has been on the vehicle for a longer period of time than it was originally designed for and becomes clogged. When an oil filter reaches its maximum filtering capacity a pressure difference occurs on either side of the oil filter. When the differential pressure between the upstream, or non filtered side, and downstream, or filtered side, of the oil filter reaches between 0.4-2.1 BAR, the bypass valve opens and allows the unfiltered oil to enter the oil circuit [4]. If an oil bypass valve was not designed into the filter or lubricant circuit, or if the oil bypass valve was stuck closed the oil filter inner support sleeve would collapse due to the pressure differential as seen in [Figure 3](#).

See [Figure 3](#) after last section of paper

Therefore, a collapsed oil filter inner support sleeve is generally attributed to a stuck closed oil bypass valve or a greater than specified oil pressure.

Inside the oil filter there are two main spots to place a bypass valve. The most common place is at the rear of the oil filter due to ease of construction and the greater space that it provides within the oil filter. The second and less common place for an oil bypass valve is at the front of the oil filter due to the increased costs of the design. [Figure 4](#) shows the difference in oil flow between the two designs.

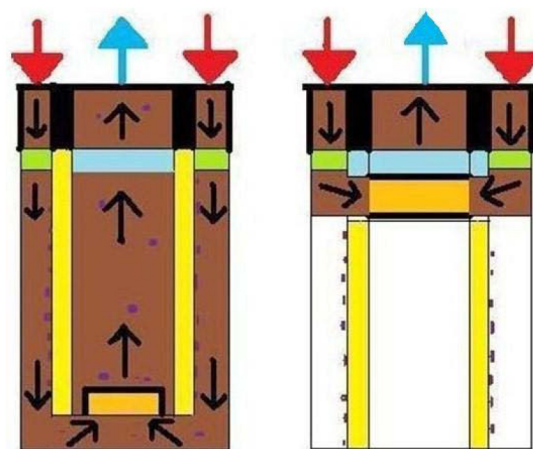


Figure 4. Oil Filter Bypass Valve Placement and Operation

Researches have found that when the bypass valve is placed at the rear of the oil filter, the likely hood of additional foreign material entering the engine is increased dramatically due to the fact that the oil must pass the contaminated side of the filtering element before leaving the oil filter and entering

the engine oil galleries, which can be seen in the figure above. Since placing the bypass valve at the front of the oil filter results in the likely hood of less foreign particles entering the engine when the filter is in bypass mode it is considered to be a superior design.

Oil filter bypass valves are either manufactured out of steel or plastic. Steel bypass valves are generally considered superior as they are less likely to deform under heat and pressure. The majority of bypass valves are compressed closed by a steel coil spring while a few manufacturers use a leaf spring design. There are no major filtering advantages or disadvantages to using either a leaf or coil spring, as both designs serve the same function given the spring pressure and flow rate is correct for the design and that the spring does sag over time.

The oil filter baseplate or bottom cap is the strongest and thickest part of the oil filter because it is threaded onto the engine block and supports the weight of the oil filter. Baseplates are generally manufactured out of medium grade austenite steel. The baseplate must be flat and not warped as upstream and downstream oil travel through the passages in the baseplate and the oil is only sealed by a single square, round cut or lip base seal gasket. In extreme situations and through misuse some baseplates have warped due to excessive heat, over tightening and extended periods of use. The thickness of the backplate is important to consumers, as it is the foundation of the oil filter.

The oil filter end caps are what seals and holds the filtering element and core together. The majority of all end caps are manufactured out of stamped steel, but some companies use cardboard, aluminum and stainless steel. Stamped steel end caps are the most common method since the material is fairly inexpensive, stiff and will not disintegrate or wear out under normal use. Cardboard is not a superior material for an end cap due to possible durability issues. A comparison of cardboard and steel end caps can be seen in [Figure 5](#).



Figure 5. Comparison of Cardboard and Steel End Caps.

When an engine reaches normal operating temperature the engine oil is generally between 80 and 105 degrees Celsius and can even go higher [5]. Engine oil is also under a variable

pressure and flow rate which over time can lead to porosity issues with cardboard end caps or total failure. Aluminum and stainless steel end caps are generally only used in expensive reusable and cleanable oil filters due to the inability to rust and react with many cleaning solvents.

The remaining steps of the research revolve around the filtering media. First the number of pleats are counted and recorded. A common misunderstanding is that many tend to correlate a larger number of pleats in an oil filter with a greater filtering element total surface area and thus the total holding capacity. While the number of pleats is directly related to the total surface area of the filtering media, it is not the only variable. The depth and length of the pleats are also two variables that determine the total surface area of the filtering media. The thickness of the filtering media is determined next, as it relates to the micron filtering ability and holding capacity, as the engine oil travels through the filtering media in order to be filtered under normal operation. The width and length of the filtering media is calculated lastly to determine the total surface area of the filtering element. It is important to note that any part of the filtering element, which is covered in glue from the manufacturing process, is not counted in the total surface area of the filtering media, due to the fact that the glue that is imbedded into the filtering element does not allow that portion of the filtering element to actually filter the engine oil.

The above parameters are important since they are relevant information that consumers cannot determine from the published manufacturer's data on the oil filter. The evaluation parameters discussed directly relate to the filtering efficiency and total value and durability parameters that influence a customer's decision on which oil filter to purchase.

RESULTS

The results of the research determined that out of the test sample many brands of oil filters were almost identical to one another in design and construction and were simply labeled differently. Out of the 15 different oil filters in the sample, there are only 6 different manufacturers. While knowing which manufacturer produces each oil filter does not pertain to the filtering efficiency or longevity of the oil filter, it does provide greater insight within the automotive oil filter industry and results in perspective buyers knowing the internal design differences among various brands.

The goal of the research was to determine if there was a direct correlation between the cost of the oil filter and the total surface area of the filtering element. The research determined that there was no correlation between the cost of the oil filter and the total surface area of the filtering element, [Figure 6](#).

See [Figure 6](#) after last section of paper