Testing the Quality and Efficiency of Oil Filters used in Vehicles

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ABSTRACT

Oil filters are being used to remove metal particles, which are harmful to the smooth functioning of engines of vehicles. This study was carried out to find the quality of filter materials, filtering process and filter efficiency of commonly used filter types. In this connection used and brand new oil filters of Toyota Hiace vans were analyzed.

Used oil filters were analyzed to check the filter materials. The Toyota Genuine and VIC filter elements have equal gaps between pleats and they are well structured. Nevertheless, in other filters, gaps between pleats of filter elements are not equal and components in inside the filter are weakly structured.

Similarly, the efficiency of filters was studied using brand new VIC (Japan) and Prime Auto (Korea) filters. Apparatus constructed for the study was utilized with pure engine oil mixed with iron dust to check the efficiency of filters. Prime Auto filter did not filter metal particles with sizes less than 307 microns, whereas the VIC filter was able to filter these sizes successfully.

The overall results of the investigation indicate that the prices directly correlate with the efficiency and the quality of oil filters.

1. INTRODUCTION

When oil is used in an engine for a long period, undesired metal particles build up in the oil. Rubbing of metal engine parts automatically produces some microscopic metallic particles. Such particles could circulate in the oil and grind against the moving parts, causing erosion and wear. Therefore, to remove those harmful particles, oil filters are used. Oil filter systems can be divided into two parts: Full flow filter system and By-pass filter system.

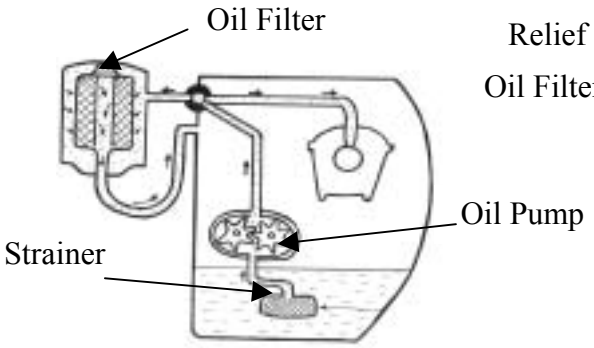

Figure 1: By-Pass filter system

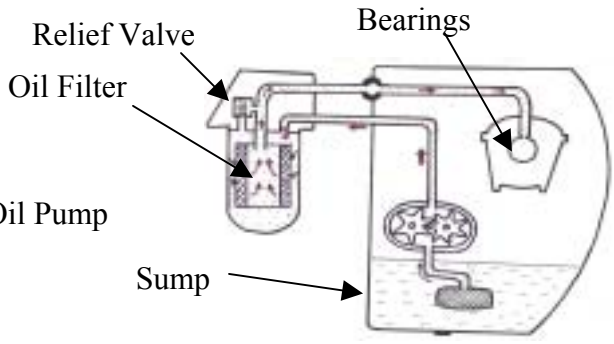

Figure 2: Full flow filter system

2. INSTRUMENTATION

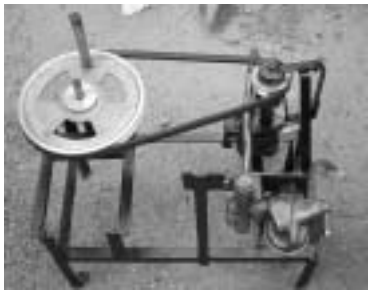

Figure 3: Manually Designed Oil Filter System

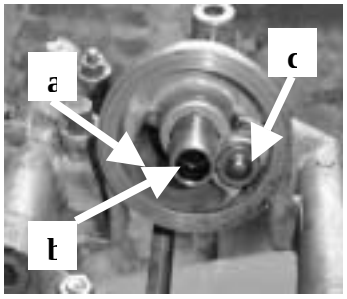

Figure 4: Filter Head

Figure 5: Oil Pump

Table 1: Component description of the oil filter head

(a) Input	Oil comes into the filter, through this hole
(b) Outlet	Filtered oil goes back to the engine, through this hole.
(c) Relief Valve	If there is a blockage in the oil filter, this iron ball goes inside and allows oil to come into it. Then oil goes to the engine without filtering.

3. METHODOLOGY

3.1 Investigating the Filter Materials

Different brands (VIC – Japan, Toyota Genuine – Japan, Prime Auto – Korea) of **used** Toyota Hiace oil filters were taken into consideration. Firstly, used oil was removed inside the oil filters, by rinsing them with kerosene oil. Then, oil filter housing was removed using a hacksaw. Generally filter housing could be removed by the following methods.

1) Electric cutting machine
2) Hacksaw

If a cutting machine was used, it could damage the filter element. Therefore, a hacksaw was used carefully to remove the filter housing without damaging the filter papers. Kerosene oil was used to clean the filter element and other parts inside the filter. Subsequently, a micrometer screw gauge was used to measure the thickness of the filter elements and a microscope was used to measure the sizes of the metal particles.

3.2 Testing the Oil Filter Efficiency

Designed apparatus was used to check the efficiency of oil filters. The oil pump generates the required pressure to filter the oil. Procedure that was used to test the filter efficiency is given below. Toyota genuine filter is much expensive than the other filters. Therefore, only VIC and Prime Auto filters were used.

Procedure

Firstly, iron dust sample was separated into two different sizes, using 0.5 mm and 2.5 mm strainers. Brand new VIC (made in Japan) and Prime Auto (made in Korea) oil filters were used in this connection. The VIC oil filter was connected to the filter head.

Filter was tightened until the o-ring fits to the filter head. Then one container was filled with pure oil (SAE 40).

Iron dust was not mixed with the oil at the first instance, because a brand new oil filter takes some time to fill its volume from oil. Time spent to fill the 0.5 liter output container was measured without the iron dust in the oil. Then 20 mg of iron dust (particle sizes ≤ 0.5 mm) was mixed with oil and measured the time required to fill 0.5 liters. The filtered oil was kept until the iron dust comes down totally, on to the bottom of the container. Then unfiltered particles were separated, in the filtered oil, using a blotting paper. After that, particles were kept until they become dry.

After cleaning the oil, another 20 mg of iron dust (particle size ≤ 0.5 mm) was mixed with the oil and the Korean filter was fixed to the filter head. Then, the above steps were repeated. The two steps mentioned above were performed again with the other sample of iron dust (0.5 mm < particle size < 2.5 mm). The investigations were carried out three times. Dried unfiltered particle sizes were measured using a stereo microscope.

Each measured particle did not have an identical shape. According to their shapes, the parameters which are required in order to calculate the areas were measured. By using the measurements, areas were calculated and by equating the calculated area of a particle, to that of an area of a circle, radii were determined.

4. DATA ANALYSIS & RESULTS

4.1 Results & Analysis of used oil filters

Four different, used oil filters were taken to investigate the filter materials, namely KLJ, Prime Auto, VIC and Toyota Genuine filter.

Table 2: Specifications of filters

Oil filter name	KLJ (a)	Prime Auto (b)	VIC (c)	Genuine (d)
Number of pleats	68	45	60	6
Height of the full flow filter element (cm) $\times 10^{-1}$	(107.0± 0.5)	(100.0± 0.5)	(107.0 ± 0.5)	(42.0 ± 0.5)
Height of the by-pass filter element (cm)	-	-	-	(65.0 ± 0.5)
Diameter of the filter (cm) $\times 10^{-1}$	(80.0 ± 0.5)	(80.0 ± 0.5)	(85.0 ± 0.5)	(80 ± 0.5)
Thickness of the filter element (mm) $\times 10^{-2}$	(51.0 ± 0.5)	(54.0 ± 0.5)	(63.0 ± 0.5)	(100.0 ± 0.5)
Length of one pleat (cm) $\times 10^{-1}$	(30.0 ± 0.5)	(26.0 ± 0.5)	(34.0 ± 0.5)	-
Element Length (m)$\times 10^{-1}$	(20.4 ± 0.3)	(11.7 ± 0.2)	(20.4 ± 0.3)	(36.0 ± 0.6)
Surface area of the element paper (m^2) $\times 10^{-2}$	(22.0 ± 0.3)	(11.7 ± 0.6)	(22.0 ± 0.3)	(15.1 ± 0.3)
Anti-Drainback valve	Yes	Yes	Yes	Yes

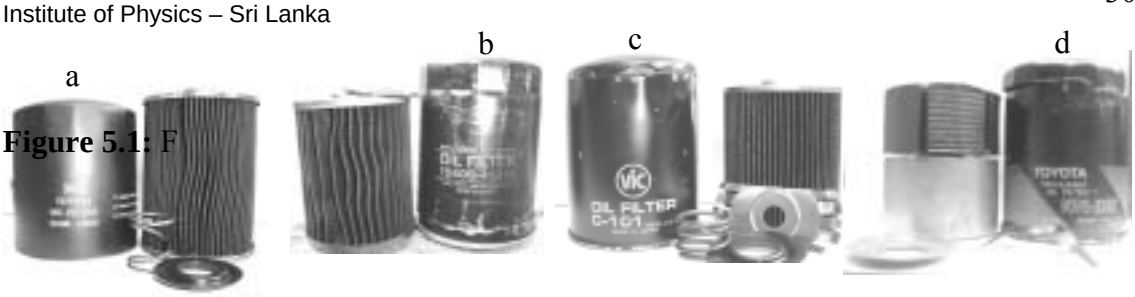

Figure 5.1: F

Figure 6: Filter materials of (a) KLJ (b) Prime Auto (c) VIC (d) Toyota Genuine

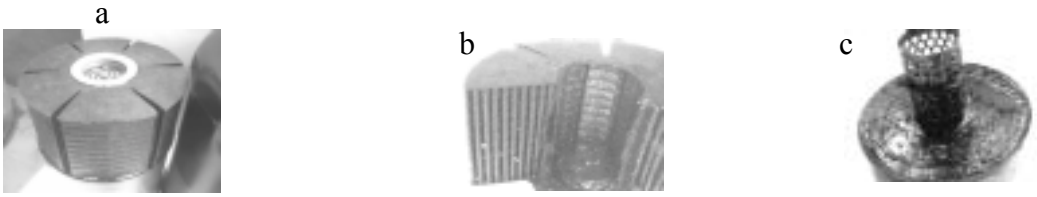

Figure 7:(a) Full flow filter (b) no. of Layers (c) By-pass filter in Toyota Genuine filter

The KLJ, Prime Auto and VIC oil filter elements have 68, 45, and 60 pleats respectively. KLJ filter has more pleats and Prime Auto filters have fewer pleats than the VIC oil filter. Nevertheless, only the VIC filter element has the, equal gaps between pleats, as shown in the figure 6. Therefore, it is clear that, the number of pleats has no effect on the quality of an oil filter.

Heights of all the filters, which are used in this investigation, were between 10 cm and 11 cm. In addition, all the filters have the same diameter. Most of the filter heads are different from vehicle to vehicle. There is a limited space to fix an oil filter in a given vehicle and therefore, height and diameter cannot be changed considerably.

By considering the above factors alone, oil filter quality cannot be determined. Thickness of Toyota Genuine and VIC filter elements were 1 mm and 0.63 mm respectively. Thickness of the other filter elements were less than 0.6 mm. Filter elements other than genuine and the VIC, have low thicknesses. Therefore, they cannot bear the oil pressure which is produced by the oil pump. Because of this reason, gaps between pleats of KLJ and Prime Auto oil filters were not equal.

KLJ, Prime Auto and VIC filters have only one filter element. Therefore, filtering process is done through this single filter element alone. But Toyota Genuine oil filter has two filter elements. Therefore, its filtering process is more efficient to that of the other filters.

When oil filters are being used for a long time, they can get blocked from dirty oil. If it happens, usually, the relief valve is opened in the filter head and oil flows through it without filtering. It can badly damage the engine. Because of this reason, Toyota Company has made oil filters with two filter elements, which are named as full flow filter element and the by-pass filter element. Oil filters normally through the full flow filter element (see figure 7) but, when the full flow element is blocked, then the by-pass filter element opens. Therefore, it reduces the flow of particles to the engine. When the number of filter elements and its processes are considered, it can be clearly seen that the Toyota genuine filters have better quality than the other filters.

4.2 Results & Analysis of Filtering Time

Table 4: Time taken to fill oil filters first time

VIC	10.14 ± 0.01 s
Prime Auto	8.72 ± 0.01 s

Table 5: Time to fill 0.5 liters of the container

Filter Name	*Before mixing iron dust*	*After mixing iron dust*
VIC	(16.38 ± 0.01) s	(16.14 ± 0.01) s
Prime Auto	(13.22 ± 0.01) s	(13.47 ± 0.01) s

Calculations

Oil Flow Rate = Volume of oil collected / Time

Table 6: Calculated oil flow rate

Filter Name	*Oil flow rate (milliliters per second)*	
	Before mixing iron dust	*After mixing iron dust*
VIC	(30.53 ± 0.02)	(30.98 ± 0.02)
Prime Auto	(37.82 ± 0.03)	(37.12 ± 0.03)

Analysis

When brand new oil filters are used, VIC oil filter has taken roughly 10.14 s and Prime Auto oil filter has taken roughly 8.72 s to fill the filter completely for the first time. During this period, the engine runs without oil. Therefore, this can cause damages to the engine. Because of this reason, when a brand new oil filter is used, it should be filled by oil, up to ¾ of the filter, roughly.

There is no appreciable time difference between the time taken to fill the filter with and without the iron dust. Variations of the oil flow rate could occur due to the following reasons.

(1) Thickness of the filter element :
According to the earlier analysis of the used oil filters, thickness of the Prime Auto filter element and the VIC filter element are 0.54 mm and 0.63 mm respectively. VIC filter has higher element thickness than the Prime Auto filter.

(2) Rotation speed of the oil pump:
Oil pump has to be manually rotated by using the lever in my apparatus.

4.3 Analysis of unfiltered particles in the filtered oil

Results

Experiment was repeated three times. In each situation particles left unfiltered only in Prime Auto filter with particle size ≤ 0.5 mm.

Prime Auto Filter

Limited numbers of particles were found. Ten large particles were selected randomly. Particle dimensions were measured according to their shape, using the microscope.

Table 7: Initial readings of case 1 and actual dimensions of objects

Particle Number	Shape of the Particle	Readings	Actual Values (mm) $\pm (5 \times 10^{-3})$ mm
1	Triangle	Base(30), Height(42)	Base(0.29), Height(0.41)
2	Rectangle	Length(33), Width(29)	Length(0.32), Width(0.28)
3	Rectangle	Length(28), Width(17)	Length(0.27), Width(0.16)
4	Triangle	Base(22), Height(63)	Base(0.21), Height(0.61)
5	Rectangle	Length(34), Width(13)	Length(0.33), Width(0.12)
6	Semi-Circle	Diameter(29)	Diameter(0.28)
7	Rectangle	Length(20), Width(12)	Length(0.19), Width(0.11)
8	Rectangle	Length(26), Width(18)	Length(0.25), Width(0.17)
9	Rectangle	Length(54), Width(20)	Length(0.53), Width(0.19)
10	Rectangle	Length(36), Width(16)	Length(0.35), Width(0.15)

Calculations

Depending on the shapes of the particles, areas were calculated.
By assuming,

$$Area\_of\_the\_circle = Area\_of\_the\_particle$$

$$\text{The radius of the particle} = \sqrt{\frac{Area\_of\_the\_Circle}{\pi}}$$

Table 8: Calculated area from the actual values and radii for case 1

Particle Number	Area (mm^2)	Radius (μm)
1	$(5.9 \pm 0.2) \times 10^{-2}$	$(13.7 \pm 0.1) \times 10^{1}$
2	$(9.0 \pm 0.2) \times 10^{-2}$	$(16.9 \pm 0.2) \times 10^{1}$
3	$(4.3 \pm 0.2) \times 10^{-2}$	$(11.7 \pm 0.3) \times 10^{1}$
4	$(6.4 \pm 0.2) \times 10^{-2}$	$(14.3 \pm 0.2) \times 10^{1}$
5	$(4.0 \pm 0.2) \times 10^{-2}$	$(11.2 \pm 0.3) \times 10^{1}$
6	$(6.2 \pm 0.4) \times 10^{-2}$	$(14.0 \pm 0.2) \times 10^{1}$
7	$(2.1 \pm 0.1) \times 10^{-2}$	$(8.2 \pm 0.2) \times 10^{1}$
8	$(4.3 \pm 0.2) \times 10^{-2}$	$(11.6 \pm 0.3) \times 10^{1}$
9	$(10.1 \pm 0.3) \times 10^{-2}$	$(17.9 \pm 0.3) \times 10^{1}$
10	$(5.3 \pm 0.2) \times 10^{-2}$	$(12.9 \pm 0.2) \times 10^{1}$

Similarly,

Table 9: Initial readings and calculated radii for case 2 & case 3

Particle Number	Case 2		Case 3	
	Readings	Radius (μm)	Readings	Radius (μm)
1	Diameter(16)	$(7.5 \pm 0.5) \times 10^{1}$	Length(45), Width(22)	$(17.0 \pm 0.2) \times 10^{1}$
2	Base(20), Height(28)	$(9.0 \pm 0.2) \times 10^{1}$	Length(54), Width(35)	$(23.0 \pm 0.3) \times 10^{1}$
3	Length(46), Width(27)	$(19.3 \pm 0.3) \times 10^{1}$	Length(38), Width(18)	$(14.1 \pm 0.2) \times 10^{1}$
4	Base(54), Height(35)	$(16.9 \pm 0.2) \times 10^{1}$	Base(62), Height(50)	$(21.4 \pm 0.2) \times 10^{1}$
5	Length(61), Width(20)	$(18.9 \pm 0.3) \times 10^{1}$	Length(32), Width(17)	$(12.6 \pm 0.2) \times 10^{1}$
6	Base(75), Height(46)	$(22.8 \pm 0.2) \times 10^{1}$	Base(26), Height(22)	$(9.1 \pm 0.2) \times 10^{1}$
7	Length(60), Width(18)	$(17.7 \pm 0.3) \times 10^{1}$	Length(31), Width(27)	$(14.7 \pm 0.3) \times 10^{1}$
8	Diameter(24)	$(11.5 \pm 0.5) \times 10^{1}$	Base(75), Height(23)	$(11.5 \pm 0.5) \times 10^{1}$
9	Length(68), Width(47)	$(30.7 \pm 0.2) \times 10^{1}$	Length(64), Width(46)	$(29.5 \pm 0.2) \times 10^{1}$
10	Length(65), Width(27)	$(22.8 \pm 0.2) \times 10^{1}$	Length(40), Width(38)	$(20.9 \pm 0.2) \times 10^{1}$

Analysis

Iron dust of sizes between 0.5 mm to 2.5 mm filter from both types of filters. But, by considering the above-calculated results, one can clearly conclude that Prime Auto oil filter (Korean oil filter) cannot filter the particles of radii ≤ 307 microns.

According to the SAE tests [1, 2], particles less than 10 microns are considered as harmless particles. But, obtained results are very much higher than the recommended value. This proves that, VIC filter is better than Prime Auto filter.

5. MARKET RESEARCH

Table 10: Prices of oil filters

Name of the Oil Filter	Manufactured Country	Price (Rs.)
Toyota Genuine	Japan	1322.50
VIC	Japan	515.00
Prime Auto	Korea	250.00

6. DISCUSSION

6.1 Limitations and suggestions

The unfiltered particles, which come through the prime auto filter, can be observed clearly. In contrast, there were no unfiltered particles observed after filtering from the VIC filter. Even though, there are no unfiltered particles, it cannot be concluded that VIC filter has been filtered all the particles. There may be some microscopic particles in the filtered oil which cannot be detected. Therefore, by considering the observations as stated above, it can conclude that the VIC filter has high performance than the prime auto filter.

Rotation speed of the oil pump is not uniform during the filtering process, because oil pump has to be manually rotated by using the lever, which is connected to the oil pump. Even though filter efficiency is affected by the rotating speed, time taken, to fill the 0.5 liters of oil has no significant difference. Oil flow rates may vary from the calculated value, if the rotating speed was remained as constant, during the filtering process. Electric motor can be used to avoid above problem.

Toyota genuine filter is much expensive than the other filters. Therefore, it was unable to purchase a genuine filter. However, when comparing the internal structure of oil filters, (number of filter elements and thickness of the filter paper) it can be realized that the genuine filters are better than the other filters, because of both, number of filter elements and thickness of the filter elements are higher than that of other filters.

7. CONCLUSION

Prime Auto filter has not filtered the particles less than 307 microns. However, the oil filtered through the VIC filter, does not contain iron particles of these sizes. Therefore, it is clear that, VIC filter is better than the Prime Auto filter.

Toyota Hiace oil filter has the highest filter element thickness. VIC filter element has the next highest thickness. Thickness of the filter elements of other filters is considerably less. Analysis of used oil filters confirms that the VIC and the Toyota genuine filters are better than the other filters.

When compared with the number of filter elements in oil filters, Toyota genuine filter has two filter elements. However, other filters have only one filter element. As explained earlier, filtering process of a genuine filter is different from that of the others.

REFERENCES

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