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Influence of engine and vehicle construction to fuel consumption and air pollution

Thesis by

Radovan Marin

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Abstract

This dissertation analyses and explains influence of engine and vehicles constructions to fuel consumption and emission of harmful gases. In following text, it is clearly stated how new innovations, on mostly, personal vehicles contributes to increased air pollution and some clever innovations which contribute to reduction of air pollutions are ignored just in interest of car's manufacturers and the profit they make keeping technology as it is. It is quite explicit, that most of innovations made on recent manufactured cars are done just to attract buyers, as such modifications improve the vehicle's performances but do not contribute to green environment as it is put out every time when new model comes out from factory. On bellow written chapters several examples are stated where is clearly explained how some existing technologies can be used to reduce emission of harmful gases as well as some suggestions of modified technologies which would also contribute to reduction of air pollutions.

When we calculate the possibility of reduced fuel consumption and thus reduction of air pollution which is roughly stated in below written chapters, we will come to the conclusion that emission of harmful gases can be reduced up to 50% on personal motorcars which make the majority of vehicles worldwide.

Introduction

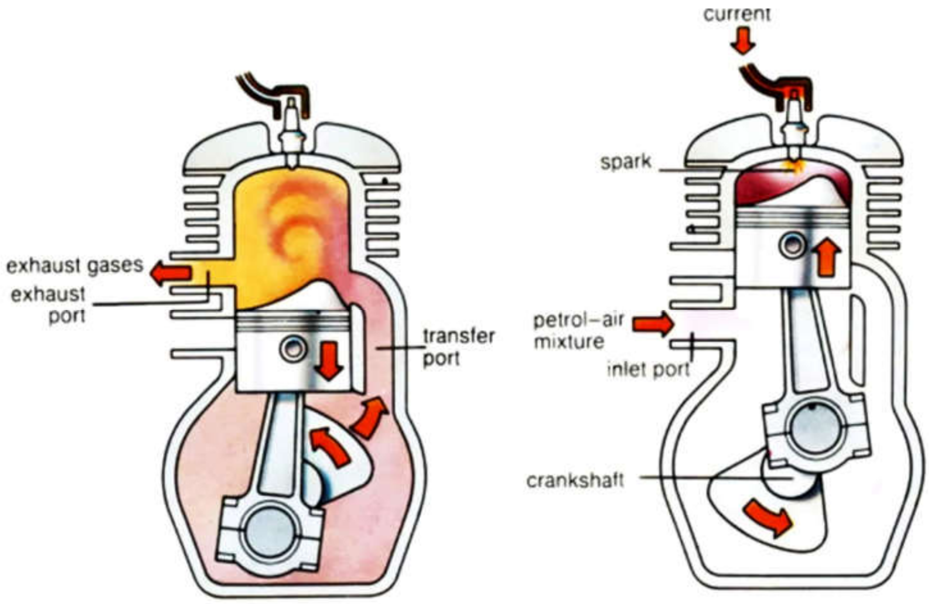
When first introduced in commercial market, the goal of internal combustion engines was to replace the horse's physical strength used to pull carriages. As the early engines were very unreliable and inefficient as well as transmissions, vehicle steering and suspensions, innovations in large specter of new ideas and solutions are implemented in the industry of motor vehicle technology, but without paying much attention to air pollution. The first serious attempt to reduce air pollution was proclamation of Clean Air Act in 1970 by EPA (Environmental Protection Agency). EPA and the state of California took the lead in the control of vehicle pollution. Since than, great results are achieved in this field, but among thousands of innovation implemented in the automotive industry during last several decades great number of them are rejected just for the reason as they were unprofitable. In other words, very bright innovations were never implemented in vehicle's industries regardless of possible improvements in vehicle performance, safety and particularly air pollution, just for the reason as such technological improvements increase the cost of productions and thus reduced the profit. The new demands of the market, competitions and new laws related to the emission of harmful gases forced the manufacturers to improve motor vehicle technology day after day. This dissertation, trough researches, describes and discusses development of motor vehicle technology, achieved improvements during the time as well as possibilities of greater improvements in case of implementations of new ideas which are, in most cases, unacceptable for manufacturers because of higher production cost, or sometimes reduced performances, but would have a great influence in reducing emissions of harmful gasses.

1. Historical context of motor vehicle technology and development of innovations

1.1 Engines

Just for introduction, first automobiles were powered by external combustion engines or steam engines which operation principle will not be discussed in this dissertation. Rapid development of internal combustion engines technology in the 1900s replaced steam engines in automobiles almost over the night.

Basic principle of internal combustion engines operation did not change since invented. From the very beginning of automotive industry many imperfections of internal combustion engines are noticed which challenged engineers to bring up numerous innovations to improve efficiency, power, fuel consumption, emission of harmful gasses etc. Internal combustion engines are divided in two groups, Otto and Diesel engines, or Petrol and Diesel engines, and further divided in subgroups as two and four stroke engines. Four stroke Otto and Diesel engines are generally used in automotive industry. The third type of internal combustion engine is rotary or Wankel engine. This type of engine is rarely used in automotive industry and will be not discussed in this dissertation.



Two stroke engines

Above sketches show simplified working principle of two stroke engines. This engine has many advantages compare to four stroke engines, but also many disadvantages. Advantages are: simplicity, lightness and twice the power produced in each engine revolution compared with four stroke engines. Beside that, such constructed engine does not use inlet and exhaust valves and therefore no resistance exists by resistance of valve springs or friction caused by valve train.

On the other hand, this type of engine has more disadvantages than advantages. Therefore they are rarely used in automobiles. First disadvantage to mention is durability. This type of engine has not oil lubrications under the pressure distributed all around the moving parts in the engine. Engine moving parts are lubricated by around 2-4 percent of oil mixed with petrol which powers the engine. Such lubrication drastically reduces engine durability.

Working principle of two stroke engines is quite simple and produces power in every engine cycle, contrary to the four stroke engines which produce power on every other crankshaft cycle. In first engine stroke when piston moves from TDC or top dead center towards the BDC or bottom dead center, inlet port closes and air fuel mixture is pressed into the engine cylinder. In the same time, gases from previously power stroke are leaving combustion chamber additionally pressed out by pressurized air fuel mixture formed in the crankcase. On, let's say, second stroke, when piston is traveling towards TDC, exhaust port closes and air-fuel-oil mixture is compressed and power stroke occurs.

In such combustion we can see many disadvantages of two stroke engine. Firstly, fuel is mixed with 2-4% of oil to enable lubrication of crankshaft bearings and piston. Secondly, emission of burned, or partly burned, gases is highly polluted. The third disadvantage is air-fuel-oil mixture which unburned leaves the combustion chamber during the inlet-exhaust cycle. This part of two stroke engine can be compared with four stroke engine valve overlap discussed in further text.

Almost the same principle of two stroke engines applies to Diesel engines. The only difference is that instead of air fuel mixture the only air is sucked into the crankcase and fuel is injected additionally at TDC.

Working principle of four stroke engines is explained in chapter 1.1.1.4 Engine head and valve train.

1.1.1 Otto engines

Otto, or better known as Petrol, engines are invented, or one may say designed, by Nikolaus August Otto in the second half of 19th century. Why the word design is more

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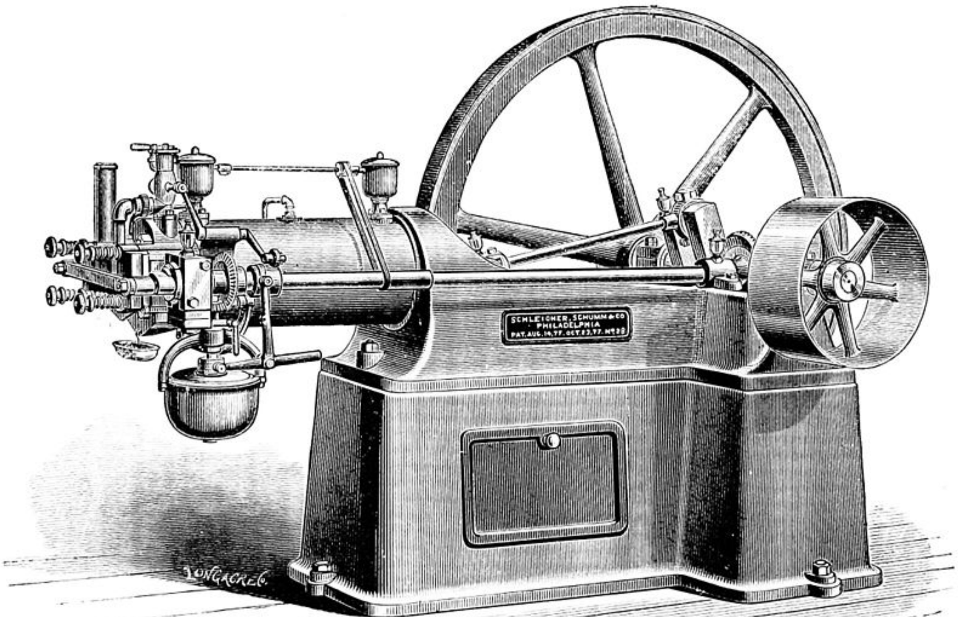
commonly used in such situations rather than invention? Invention is by its definition something entirely new while innovation is a composition of, more or less, known technologies and materials which finally make something new. Therefore, in this dissertation, expressions as design and innovations will be used for new ideas and improvements achieved in automotive industry. Most of ideas and innovations commonly occur accidentally when ordinary people or engineers encounter problem in some already developed projects. This is the case with Nikolaus Otto. He was a salesman who traveled almost all over the world. It happened that he has seen one of the first internal engines build in Paris by Belgian emigrant Jean Joseph Etienne Lenoir. Aware of poor efficiency of such designed engine, Otto tested the replica of Lenoir's engine and come up with idea of using compressed air-fuel mixture and drastically improves the engine efficiency. So, this is how it started with, let's say, efficient internal combustion engines powered by Gasoline fuel and air mixture. The following drawing (Public domain) shows the first Otto one cylinder stationary engine.



In early days of internal combustion engines, the numbers of different fuels were used to power the engines. In all cases the large amount of fuel was wasted. Otto engines have had difficulties to fully ignite most of used fuels, thus efficiency was very low. A later development of Diesel engines improved burn the heavy fuels and oils.

Here, we shell leave the long history and list of people who contributed in early days of automotive industry as Gottlieb Daimler, Wilhelm Maybach and many others and focus to the innovations which made today's automobiles modern and efficient as they are.

In the beginning of development of gasoline engines, it was very obvious that more power is obtained if air-fuel mixture is progressively burned rather than obtaining the power from sudden air-fuel mixture explosion. From then on, innovations made a rapid rise in engine modifications.

First serious innovations on four stroke Otto engines were related to electrically ignited air-fuel mixture and fuels which will resist self-ignition when mixed with air and compressed. Early engines were powered by, so called, straight run gasoline which was a byproduct of crude oil distillation. Despite of very low engine compression ratio, result of using such fuel was abnormal engine knocking and pre-ignition. That means that compressed air-fuel mixture detonated in the engine cylinder before piston reached the top dead center. Thus, instead of forcing the engine piston down after it passed the top dead center, detonation partly pushed piston in its opposite way. It is not difficult to conclude how much power was wasted and how enormous fuel consumption was. Even worse, emission of harmful gases from unburned air-fuel mixture was extremely high. To overcome such big problem some fuel additives had to be found to resist auto-ignition caused by pressure and temperature during the compression cycle of four stroke engine. In early 20th century every automotive manufacturer was searching for chemical which will resist self-ignition of the air-fuel mixture. Finally, it was discovered that lead mixed with fuel would reduce engine knocking caused by pre-ignition. Here, we shall see very clear example where the bright innovation where not accepted in automotive industry just for the reason of losing the great profit, even if such decision is deadly dangerous for billions of people. Namely, in the same time some more chemicals, benzene and ethanol, are discovered which can provide octane in fuel. Despite the critics and the resistance of the whole world against the leaded fuel, it dominated worldwide until late 1970s when unleaded fuels started to be sold and used by law.

References:

The History of Leaded Gasoline

https://articles.mercola.com/sites/articles/archive/2015/10/10/leaded-gasoline.aspx

The U.S. Experience with the Phasedown of Lead in Gasoline Richard G. Newell and Kristian Rogers*

http://web.mit.edu/ckolstad/www/Newell.pdf

1.1.1.2 Octane in Gasoline or Petrol fuel

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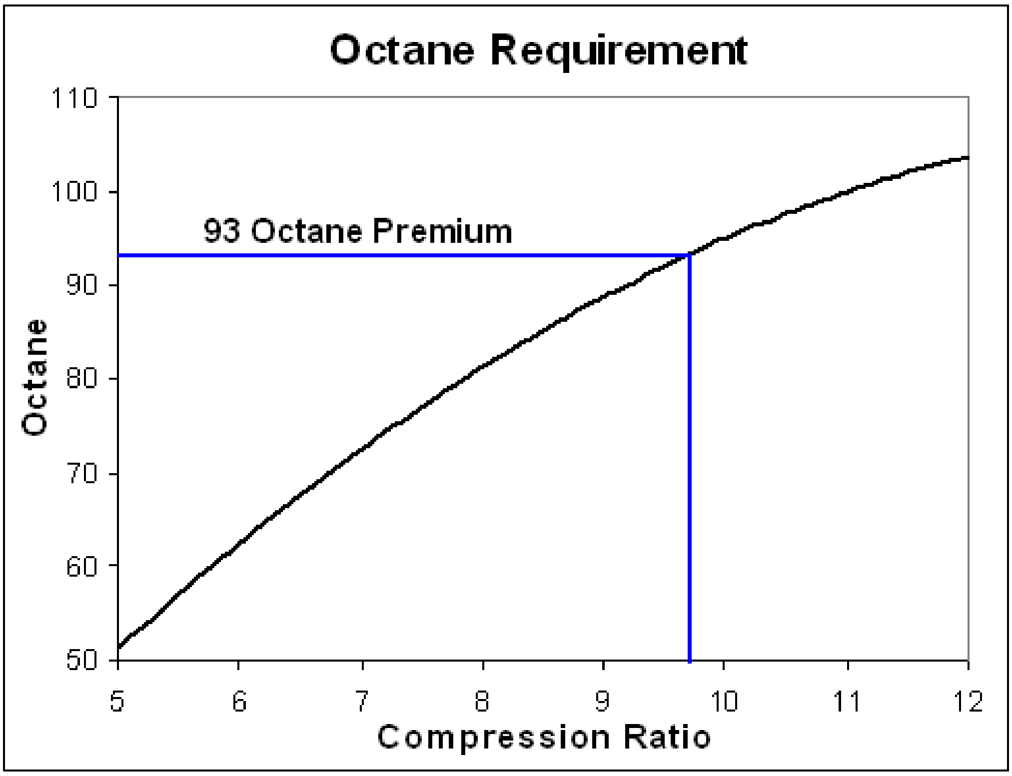
When octane value was implemented in Gasoline or Petrol fuel, many things changed in sense of modifications in internal combustion engines. Day after day, so many ideas and innovations were brought up that gasoline engines with very low revolutions per minute and low output power, rapidly turned to very efficient and powerful engines.

Fuels with added octane resisted auto-ignition of fuel and thus reduced engine knocking or pinging, which is also common expression for engine noise caused by early ignition, or auto-ignition of air-fuel mixture. With new octane fuels, realization of many innovating ideas became possible. The one of the first ideas were to increase the engine compression ratio. It was quite obvious that air-fuel mixture compressed in higher stage, when ignited, could produce more power than the same amount of air-fuel mixture compressed at lower stage. Certainly, until then, implementation of such idea in action was impossible because of problem with self-ignition of air-fuel mixture in even very low engine compression ratio. Octane fuel ratings are expressed in numbers. Most usual octane grade fuels were Regular fuel octane graded by number 87 or 89 (earlier fuels even with number 85) and Premium fuel octane graded with number 92 or 93. Of course, today's fuels with much higher octane value are offered on market. The use of the specific octane grade fuels are determined by vehicle manufacturer and mostly depend of engine compression ratio of particular automobile model. The following table and chart of engine compression ratio and octane value in the fuel shows approximately how the compression ratio is related to octane value in the fuel.

Engine compression ratio	Minimum octane value	Maximum octane value
8:1	87	92
9:1	89	96
10:1	92	100
11.1	96	102
12:1	100	108



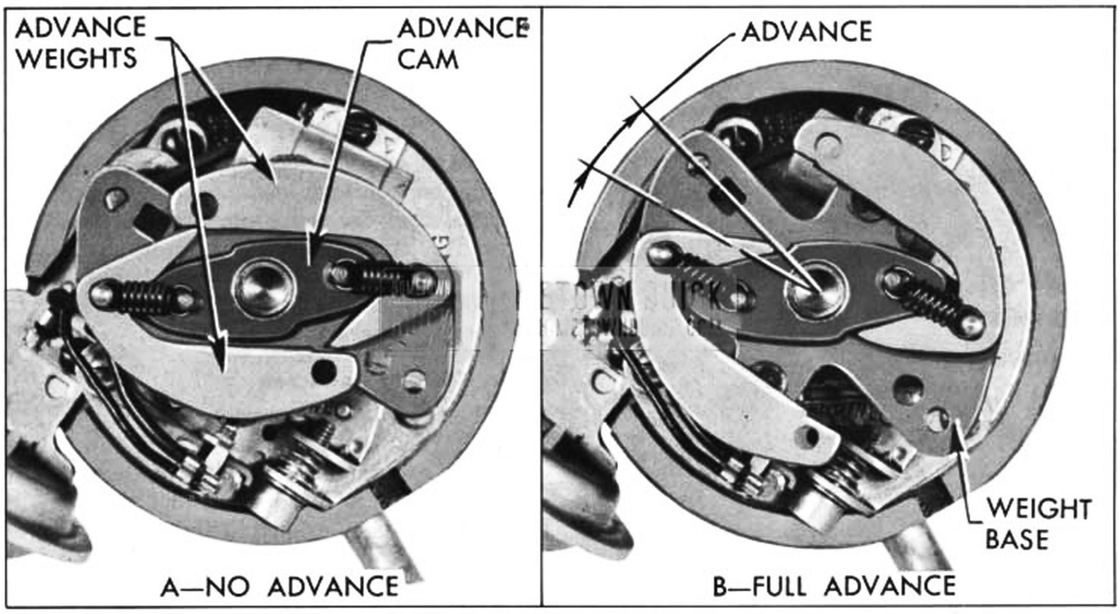
That is to say, that octane implemented in petrol fuels enabled engineers to start increasing engine compression ratio to obtain more power from engine using the same amount of air-fuel mixture. Further more, with such modification when air-fuel mixture is maximally compressed, and thus more efficient burn of fuel is obtained, emission of harmful gases were considerably reduced. As octane values in fuels were increased during the time, the possibility of increasing engine compression ratio was further allowed resulting with increased engine power, more efficient burn of air-fuel mixture and reduced emission of harmful gases. From all this we can conclude that octane made great improvement in air-fuel mixture in internal combustion engines. As almost all advantages of octane fuels are exploited at that time in sense of obtaining maximum power from engines, engineers focused on ignition timing of air-fuel mixture in the compression cycle of four stroke engines. Namely, when compressed air-fuel mixture is ignited by electrical spark, flame in compressed air-fuel area needs some time to spread over and fully ignite its volume just in time when piston passes the top dead center in order to push the piston down in its power stroke with all its strength.

1.1.1.3 Ignition timing

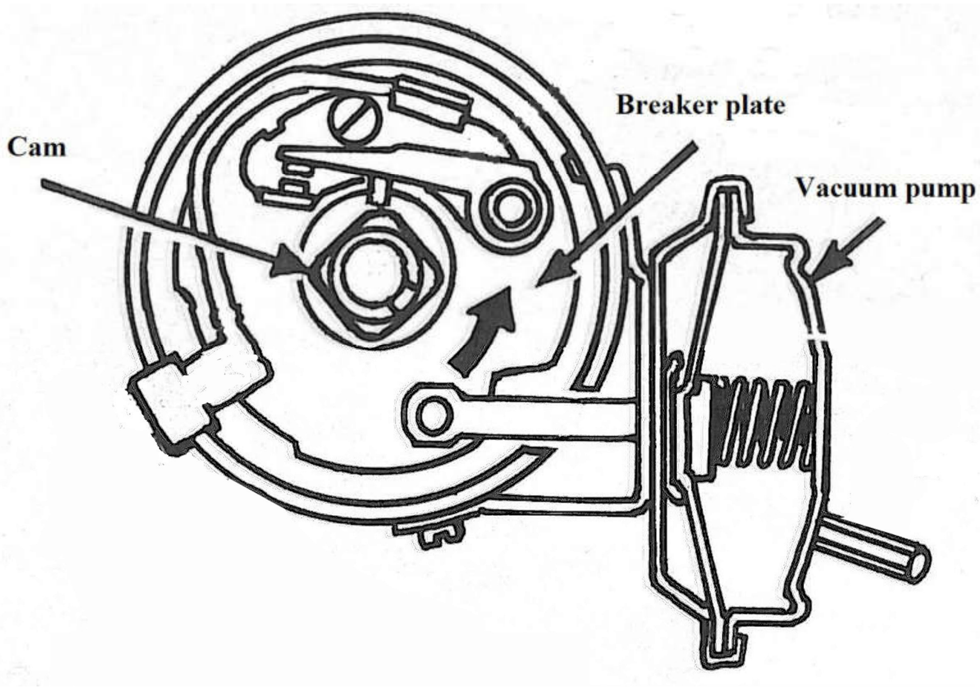
As said previously, air-fuel mixture needs some time to ignite. Here will be explained basic system of air-fuel ignition and modification which have been made during the time to improve proper and full ignition of mixture. All this is important to understand researches, questions and hypotheses in this work.

The spark timing on very early engines was fixed. Spark timing was set at calculated time before TDC (top dead centre) of engine piston. Such ignition timing was fairly good when engine was running at constant speed RPM (revolutions per minute). When RPM was increased, timing was too late. As mentioned, air-fuel mixture needs some time to ignite completely just at the moment when piston passes TDC and pushes the piston down with all its power. This was achieved by setting the timing for particular RPM. When RPM was increased and piston moved much faster toward the TDC, time of air-fuel ignition was shortened. That means, mixture did not have enough time to ignite completely and ignition was prolonged during the time when piston passes TDC. In such case, air-fuel mixture reaches full ignition quite late and considerable loss of power occurred. To overcome this problem, engineers made several modifications to enable spark to occur in the specific time related to RPM. In fact, mechanical or electronic device was needed to distribute sparks on each engine cylinder at specific time, late ignition at low RPM and advanced ignition at high RPM.

First modification was made by installing movable breaker points plate in the distributor. As most readers would know, the breaker points are placed on breaker points plate where the points are opened and closed by distributor spindle cams. Cams will lift one part of the points at the desired time in which spark occurs. By installing movable breaker plate connected with linkages to the dashboard, or more often to the center of steering wheel, driver was enabled to adjust ignition timing during the driving. We can assume that motorcars drivers at that time had to be well educated to drive. They had to have a basic knowledge of engine technology to properly advance or retard ignition timing. Thus, when engine was idling, breaker points plate had to be retarded to its basic position as calculated by engineers when basically tuned the engine. As vehicle accelerated the engine RPM increased and ignition timing had to be advanced. That was done by moving the linkage lever forward and opposite when vehicle decelerated. By moving the breaker plate left or right distributor cam will open the points earlier or later and spark will occur at the right time, certainly, if driver was well educated to make right adjustment at the right time. This improvement was certainly great and improved engine efficiency as well as fuel consumption and automatically reduced pollution. But, such vehicles were definitely unsuitable for ordinary people who did not want to be drivers and mechanics to own a motorcar.



Centrifugal advance



Vacuum advance

As advanced timing problem was solved, engineers focused on automation of timing advance to enable automotive uneducated people to own and drive personal vehicles. To achieve automatic advance timing, the centrifugal weights and springs are added underneath the brake points plate. Instead of adjusting ignition timing manually, the centrifugal weights and springs took over that task. As distributor shaft is turning faster or slower the centrifugal weights are expanding or contracting and accordingly adjusting breaker plate position. As expanding of centrifugal timing advance takes some time, system was further improved by adding small vacuum pump to distributor linked to breaker plate. Vacuum pump linked by tube to carburetor reacted on depression in carburetor and proportionally promptly advanced breaker plate. This vacuum pump overcomes the problem with delay of centrifugal advance. In general, knowing that air-fuel mixture is proportionally sucked into the engine trough the carburetor and timely ignited by spark, we can conclude that such engines were ready for mass production with more or less acceptable pollution. Why more or les? During the time so many innovations are implemented to reduce pollution that such concept of engine would have minimum pollution if engine performance did not take priority as well as ignorance of innovation which are to expensive to be used in automotive mass production.

In order to improve engine RPM and achieve the spark occurrence at the precise time, engineers attention was focused to elimination of mechanical breaker points which limited RPM at high engine speed as well as they limited accuracy of air fuel ignition. On seventies, when electronics replaced most of electromechanically operated systems in industries, automotive engineers were able to improve the function of timing distributor and modify the breaker points with, so called, transistor assisted ignition. This was the first step in modifying accuracy of air fuel mixture ignition by use of electronics.

In electromechanical breaker points system, a breaker points, or simpler said switch, break the electrical circuit at determined time for each cylinder when high voltage is induced in the ignition coil. Certainly, accuracy of ignition timing as well as value of high voltage depends of, so called, dwell angle and cleanliness of breaker points contacts. Determined dwell angle, the time when breaker points are closed, allows enough time for high voltage to be formed in the ignition coil. Cleanliness of breaker contacts will allow sufficient current to flow between the battery and ignition coil. Lack of time caused by irregular dwell angle or partly burned breakers contacts will result with drop of high voltage on spark plugs and thus poor ignition of air fuel mixture. To partly overcome the duration of closed points and avoid burned surfaces of breakers contacts, a transistor is used to solve this problem.

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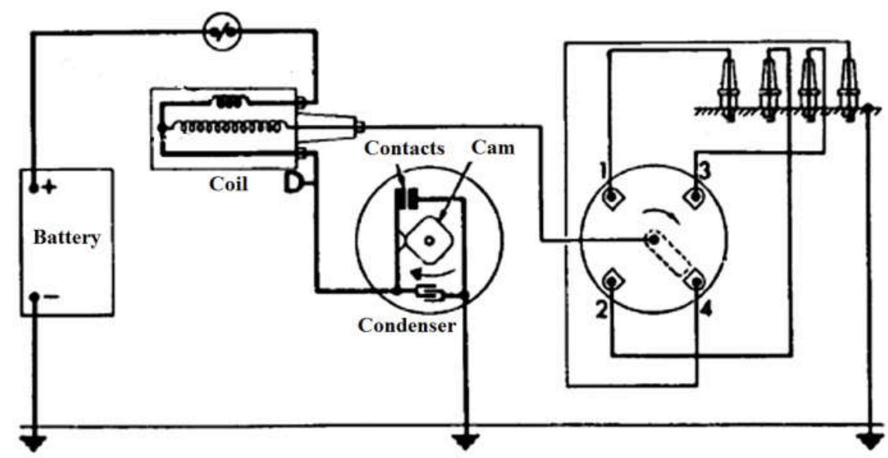

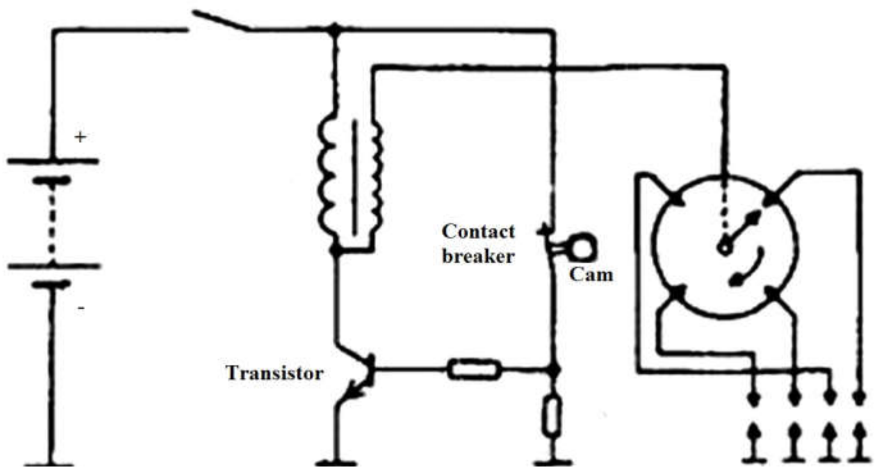

On the first drawing shown above, the electromechanical ignition system is sketched. In simple words, current flows from battery to the ignition coil. To make circuit closed, breaker contacts are connected and coil is charged. When contacts open on the cam lobe, electrical circuit is open and coil is discharged trough the distributor cup to determined spark plug. Shown condenser is used to absorb sparking between contact points when they start to open. But, even condenser can not absorb sparking between contacts absolutely. Some small sparking will still occur between the contacts and by the time will make the contacts surfaces partly burned and reduce the current flow trough the ignition coil.

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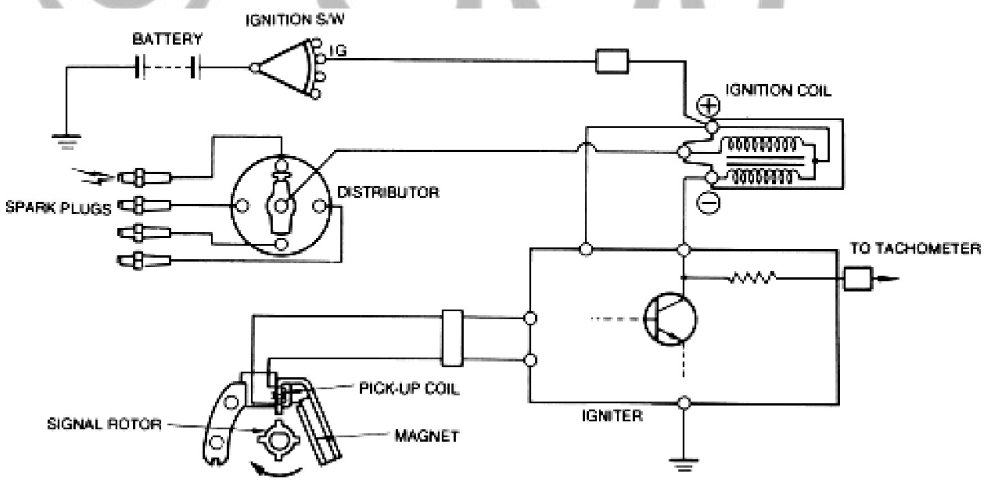
The second drawing shows the same electromechanical ignition system where transistor is implemented and capacitor removed. So, where is the advantage? Unlike the situation in previous case where current flows over the breaker points, in this case current flows directly trough the transistor to the minus pole of the battery without any obstructions and drop voltage. Voltage of very small value flows from the transistor over the resistor to the breaker points which does his job as previously described. Transistor, as a switch, is very fast and dwell angel accuracy can oscillate a bit. As current is very low between the breaker points, there is not any burn deposits on the contacts ad current can flow freely.

Finally, before computerized ignition system was implemented, fully transistorized ignition system was developed and all imperfections of two previously described ignition system are solved.



Here, we have almost identical ignition system as previously described, but fully transistorized. This is contactless system which consists of transistorized module, rotor with lobes, pick-up coil and magnet. Simple said, whenever one of the rotor lobes approaches the pick-up, signal is sent to the module which opens and closes electrical circuit in the ignition coil. As we can assume, this electronically operated ignition system is very accurate and spark occurs at determined time on the spark plug.

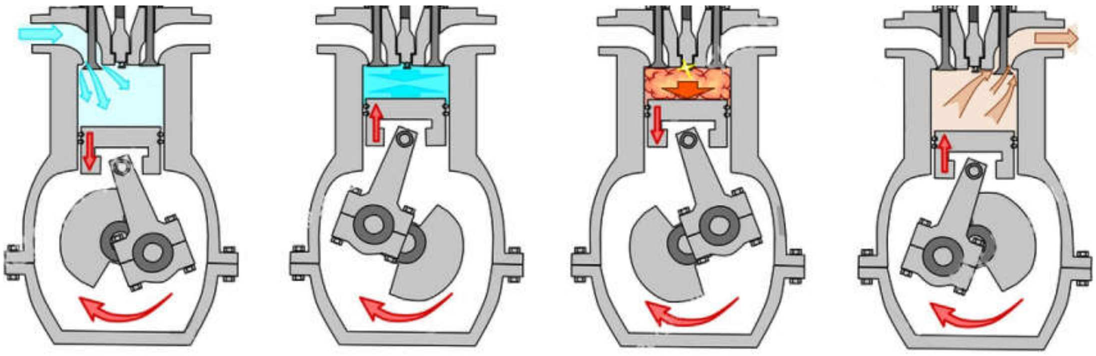
1.1.1.4 Engine head and valve train

In this chapter we shall discuss about innovations which have been made on engines to increase its performances but not paying much attention to pollution. As previously explained, engines design reached satisfactory level. Such designed engines with today known modifications which can further reduce emission of harmful gases would produce enough power to drive the personal vehicles sufficiently well. Knowing that, all over the world, vehicle's speed is restricted to 80 Miles even on highways, it is absolutely senseless to manufacture powerful high performance cars. As driving such vehicles with drastically limited speed does not make sense, these cars should be highly taxed. Namely, most of today's cars could be perfectly run by engines with a half of power then they have. Reducing power and using today's technology means cutting fuel consumption by almost fifty percent and thus pollution also. How owning the personal vehicle is in most cases a prestige, demand for performance cars on world's market is great, regardless of limited use of their performances. Therefore, where demand exists there is a profit. Where the profit is high, law is tolerant. Until eighties law was quite tolerant regarding high fuel consumption and emission of harmful gases. Thus, car manufacturer used all efforts to design powerful engines and compete with competition.

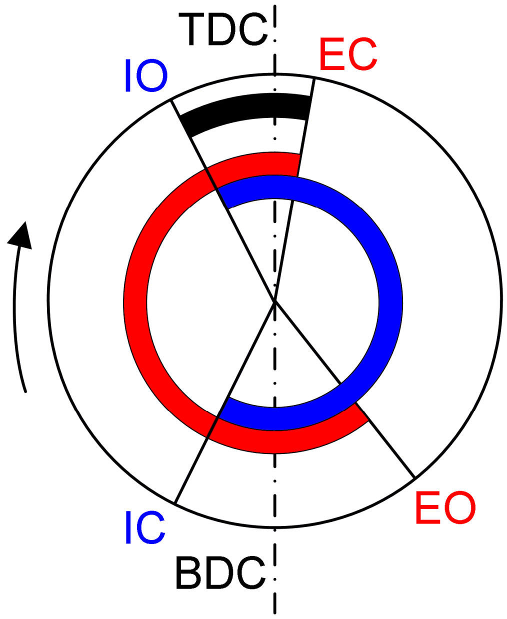
To compete on market, manufacturers worked very hard to attract potential buyers with new designed exteriors and rich looking interior. Along with these novelties, engine power increscent was inevitable. Regardless of engine capacities, engine power could be increased by improving air-fuel intake and exit of burned gases. With such improvements, engine of the same capacity would produce much more power. Widening the inlet ports and valve heads to its maximum, much larger volume of air-fuel mixture entered engine cylinder and thus produced much more power on combustion stroke. As the inlet valves were widened to its maximum, the same thing was done with exhaust valves. To speed up exit of exhaust gases even more, exhaust manifold was separated in tubes for each cylinder and joined in one or two tubes quite far from engine. Concerning maximum power which can be obtained from an engine, excluding electronically controlled engines and supercharged and turbocharged engines, these innovations would be a final step for design of powerful enough engine whose harmful gases could be successfully controlled.

Now we are encountering first problem when increasing the engine power which will have the negative effect to the environment. It is not surprising, as people always want to achieve more and more even when some ideas could be harmful. The goal of new improvement was to bring more air-fuel mixture into the engine cylinder. The idea was quite simple and used even today, but causes increased fuel consumption and thus pollution too. This innovation is called engine valve overlap. Before we come to the point, let’s see standard valve opening during the engine’s four cycles:

Intake – Compression – Power – Exhaust.



On above drawing a typical four strokes of engine are shown. In the first stroke of intake, piston is on its way down to BDC (bottom dead centre). In this stroke inlet valve is open and air-fuel mixture is sucked into the engine cylinder. Soon as piston passes BDC inlet valve closes and stay closed together with exhaust valve during the compression stroke. When piston passes TDC, power stroke takes action where compressed air-fuel mixture is ignited. During this stroke both valves are closed until piston reaches BDC. As piston passes BDC after power stroke is completed, exhaust valve opens and burned gasses are let out trough exhaust manifold. In this valves opening timing only a limited amount of air-fuel mixture enters the cylinder as some exhaust gasses are left in the cylinder after exhaust stroke is completed. Trying to solve this problem, engineers came to bright idea. If the exhaust valve stays slightly open for a while after its stroke is completed and inlet valve opens before intake stroke, the air fuel mixture will be additionally sucked into the cylinder by gasses flow inertia. In such situation there will not be any burned gasses left in the cylinder and it will be completely charged with fresh air-fuel mixture. Now, it is easy to conclude that cylinder filled with fresh mixture will produce more power in power stroke than when filled with smaller volume of air-fuel mixture which will be mixed with burned gasses left in the cylinder after exhaust stroke. This flow of air-fuel mixture from inlet to exhaust port is known as valve overlap. Diagram of valve overlap is shown below.



- TDC top dead centre
- BDC bottom dead centre
- IO inlet valve opens
- IC inlet valve closes
- EO exhaust valve opens
- EC exhaust valve closes

On upper diagram intake valve is shown in blue color and exhaust valve in red color.

Contrary to previously described valve opening during the engine strokes, this diagram shows valves opening and closing before and after TDC and BDC. Overlap is expressed in degrees which would be the black mark drawn below TDC. The overlap value in degrees may vary from engine to engine. Higher value in degrees means higher engine performance. On upper drawing we can see that exhaust valve opens before BDC on power stroke. This means that some power at the end of this stroke will be lost trough partly open exhaust port. But, inertia of gasses flow will increase the gasses flow during the exhaust stroke. Exhaust valve stays open during its stroke and few degrees after the piston reaches TDC. In the same time, inlet valve opens also several degrees before its intake stroke which begins when piston passes TDC. This particular moment when both valves are open between exhaust and intake strokes is called valve overlap, when air-fuel mixture is sucked by exhaust gasses into the cylinder. Here we can see evident problem. If we want to fill complete volume of engine cylinder with fresh mixture, we have to let some volume of mixture out trough partly open exhaust port. This wasted volume of air-fuel mixture will depend of overlap degrees. The wasted mixture does not just rapidly increases fuel consumption, but unburned fuel also increases emission of harmful gasses. To prove how this innovation in engine deigns is more harmful than useful, some tests are done comparing the fuel consumption, which concern pollution automatically, on two vehicles of the same production year and engine capacities.

1.1.1.5 Test methodology

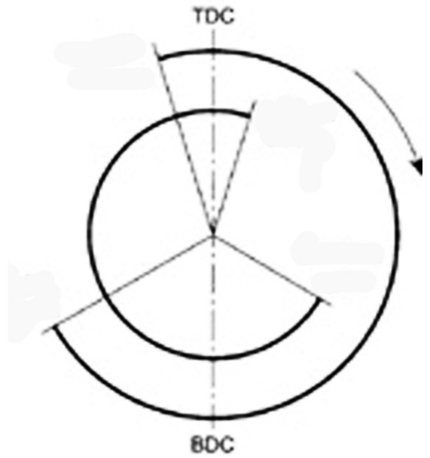
The next test was done theoretically comparing vehicle’s size, weight, speed, engine capacity and output power.

1. Alfa Romeo Giulia 1.3 Super 1972.

- Four door Sedan car
- Weight 1010 kg
- Calculated fuel consumption: 14 Liters / 100 km

This particular car has quite a high valve overlap value in degrees. With such modification manufacturer managed to obtain 103 bhp from the 1300 cc engine and the maximum speed of 165 km/h.

High performance valve overlap

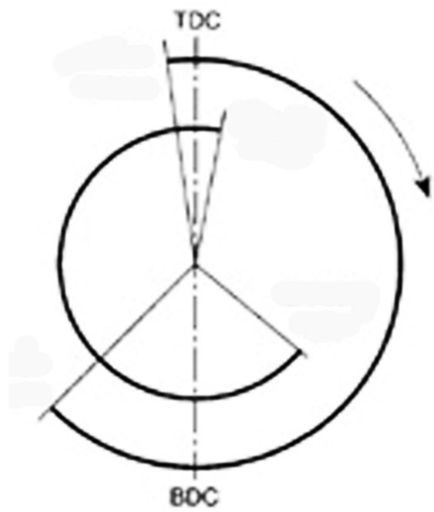


2. Opel Kadett 1.3 SR 1979.

- Four door Hatchback car
- Weight 1010 kg
- Calculated fuel consumption 7.8 Liters / 100 km

This compared personal vehicle has output of 75 bhp from the engine of the same cylinders capacity 1300 cc and maximum speed obtained by this car is 167 km/h.

Medium performance valve overlap

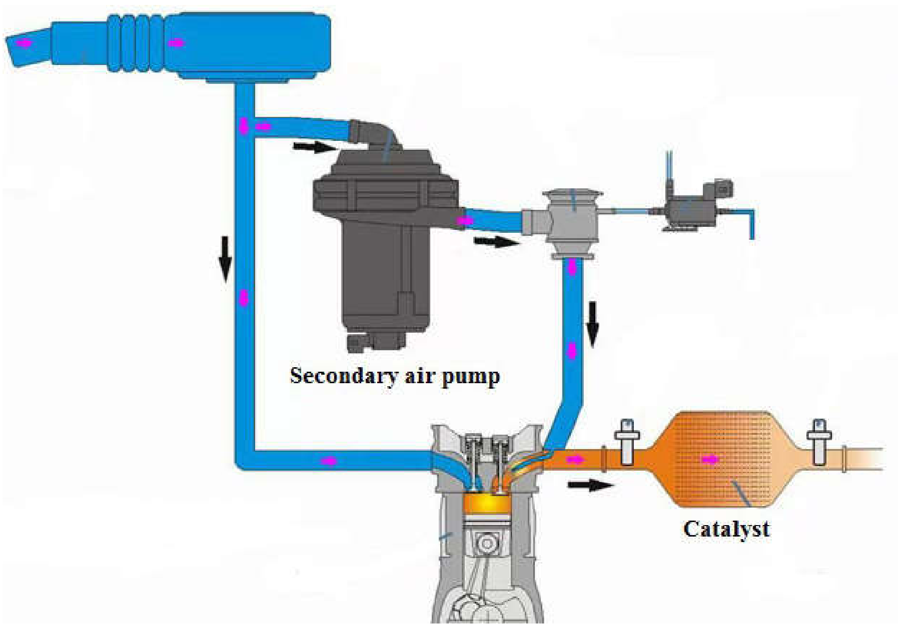


1.1.1.6 Conclusion of chapter 1.1.1.4

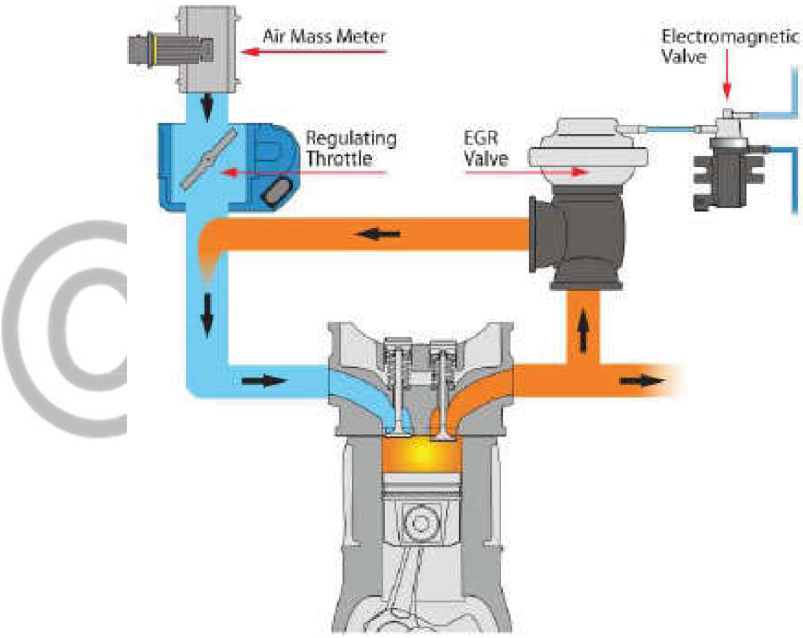
Comparing data of these two vehicles it can be seen that greater power is obtained by increasing valve overlap, which is also known as high performance overlap. Certainly, there are some more modifications used in Alfa Romeo Giulia to increase power for 40% compare to Opel Kadett. Such modifications are double overhead camshafts and two twin carburetors. But, these modifications would not help much in engine power increase if valve overlap was not increased. As in this chapter we are focused on valve overlap, it is quite clear that with such overlap great amount of air-fuel mixture is wasted trough the exhaust port. Consequence of increasing power in such way is almost 60% increased fuel consumption compares to the Opel Kadet with same engine capacity and thus increased emission of harmful gases. The worrying fact is that such increase in engine power did not increase maximum speed of Alfa Romeo compare to Opel Kadett. It reflects only in vehicle performances such as fast acceleration. That is to say, at the expense of enormous air pollution car manufacturers are using very harmful modifications to satisfy some demanding customers just to be competitive on market and make profit. Knowing what is valve overlap used for and how it affect environment, we can definitely conclude that it is the one of most harmful modification in car engines.

How this problem is serious can be seen from serial attempts to burn these unburned gasses which exit from exhaust port. One of them is the installation of secondary air pump which injects air into exhaust manifold to help burn these gases. The other is the catalytic converter whose purpose is also to burn unburned gases. It really does not matter how efficient are these devices. The fact is, engine with high performance overlap have much higher fuel consumption than low performance engines and thus emit much higher quantity of harmful gases, burned or unburned. Until now, manufacturers made such effort to overcome this problem of unburned air-fuel mixture that tests of exhaust gases are almost perfect. But nobody is dealing with the question about the quantity of such gases. Burned gases simply have to come out from the engine. With high performance overlap, greater amount of air-fuel mixture is entering into the engine and thus greater amount of gases have to come out regardless of the degree of their harmfulness. Beside that, wasted mixture is not used to produce any power, it is just wasted. Now, it does not really matter are these gases are burned in exhaust manifold or catalyst, they are harmful and simply should not exist.

On below drawing we can see mentioned air pump and catalytic converter in function. It is very obvious that air is pushed into the exhaust manifold to help burn unburned gases which would be additionally burned in catalytic converter.



To further reduce emission of harmful gases, more devices are implemented in today's engines. One of them is EGR valve (Engine Gases Recirculation valve). Even this device does not help much as it is activated only at constant higher speed of vehicle. That means vehicles will still emit harmful gases in towns. Even the variable camshaft system used lately does not solve the problem. This system is able to change the valve overlap which depends of engine speed. But, the overlap still exists when needed.



Is the EGR system questionable as contribution to reduction of air pollution? Above drawing shows the simplified recirculation of exhaust gases. First to know is, inert exhaust gases recalculating trough combustion chamber do not produce any power. This is the reason that EGR valve opens only at certain constant speed of vehicle when power is no needed. We all know that such situations during the driving are very rare as car does not drive by inertia. Soon as we accelerate the vehicle, EGR valve closes. Valve is also closed when engine is idling to prevent rough engine idling caused by poor combustion. Recirculation of engine exhaust gases would be welcome during the valve overlap. But of course, this would not make any sense. With engine valve overlap, intention is to bring as much fresh air fuel mixture in the combustion chamber as possible. Any amount of inert gases would make valve overlap senseless Also, it is very well known that emission of harmful gases is at highest level when vehicle accelerates or is under the load of any kind. In these crucial situations, EGR valve is closed as engine needs fresh air to produce power. So, where is the point of EGR system?

Problem of very high emission of harmful gasses would be not present if cars manufacturers are not forcing to get out as much power as possible from engines just to compete on market and make profit. Very decent power can be obtained from any engine using known modifications and eliminating valve overlap. As known, more power can be obtained by allowing entrance of as much air-fuel mixture into the cylinder as possible. This is done by maximally widening the inlet and exhaust valves. Modifying exhaust manifold to let out burned gases as fast as possible and even using turbo chargers. With today's electronically controlled fuel injection and ignition timing, almost perfect combustion can be achieved. Certainly, in such case considerably les power can be obtained from engine but environment would bread much easier.

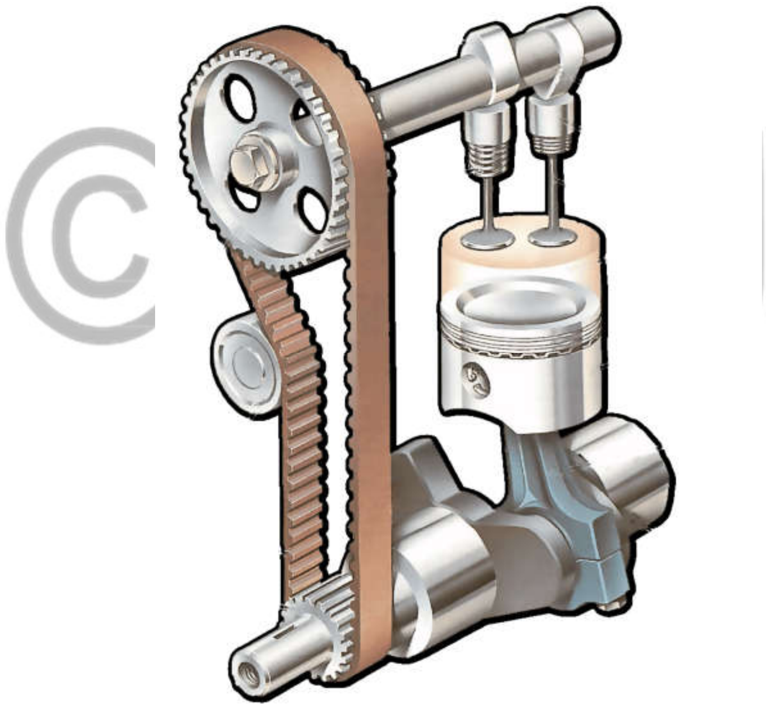
Emission of harmful gases can further be reduced if some loads of engine elements are eliminated. Such modifications are also known but not in use because of production expense. In next chapters we will discus this problem and some others related to vehicle wheels geometry and vehicle's drag coefficient.

1.1.1.7 Engine wasted power by valve train load

Internal combustion engines have relatively poor efficiency. The efficiency is generally lost by friction of engine moving parts as pistons, bearings etc. Friction of these parts is maximally reduced by lubrication and not much more can be done for further reduction of friction. Beside the reduced efficiency caused by mentioned frictions, great loss of efficiency is caused by valve train resistance. Inlet and exhaust valves are constructed to be closed by springs. That means, to open these two valves in certain time considerable pressure is required. This pressure is provided by engine. Thus, instead of using this power to drive the vehicle it is wasted to compress valves spring.

This problem is known since the internal combustion engines are constructed. Here again we are coming across the problem of production cost and profit. During the time, many innovations were offered to overcome this problem, but no one was accepted as all of them increase the cost of production. It is sad to be aware that profit is more important than saving the environment. Namely, by solving this problem, power created by engine partly used to compress valves springs could be used to drive the vehicle. This additional power which could be obtained by eliminating valves springs could reach the value between 10 and 30 percents. These calculations are made all over the world and opinions differ. Certainly, car manufacturer's calculations are quite different from calculations made by independent institutions whose researches are done on the base of physics laws. Very unacceptable interpretation of car manufacturers is that there is no loss of power on valves train as depressed spring bounces back and provides enough power to depress next valve spring. Beside this explanation, they claim that there is inertia from rotating camshafts which additionally provide power for valves spring depressions. Certainly, these interpretations are against the laws of physics.

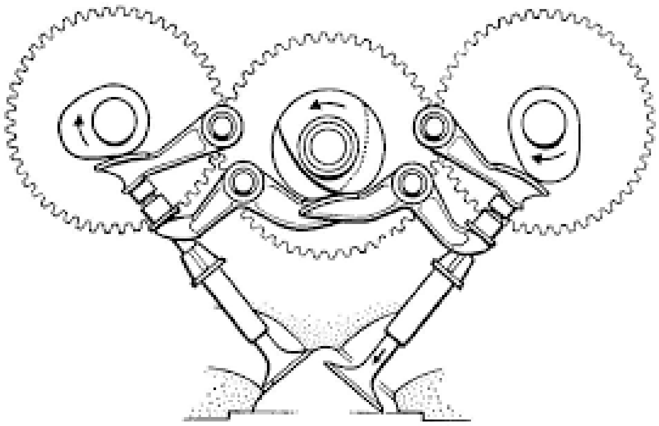
Bounced spring can not provide enough power to depress the other spring with the same strength as used to depress the bounced spring. If that would be the case we could easily make perpetuum mobile just by use of two springs which would endlessly propel each other. Camshaft's inertia is questionable too as it has small mass. Inertia is provided by crankshaft and flywheel and instead to be fully used to power the vehicle it is partly used for valves train.



Above drawing of four strokes single cylinder engine clearly shows how cam lobes open the valves by depressing valves springs. When the cam lobe on the right side of the drawing passes depressed valve spring it will react opposite way pushing the cam lobe up. But this force will last only one fourth of the cycle when spring cup will lean on the almost flat surface of the cam lobe. In the same time the left lobe on the drawing will turn also for one fourth of the cycle and lean on the flat surface of the cam lobe. Now, it is very obvious that extra force is needed to depress the valve spring on the left side of the drawing. This extra force is provided by engine in which moment loss or waste of power occurs. Of course, this waste of power is reflected on higher fuel consumption and emission of harmful gases. Beside the resistance of valves springs in consideration have to be taken frictions between spring cups and cam lobes and frictions of camshaft bearings. Now, we can conclude that consumption of engine power by valve train exists and thus have influence on fuel consumption and pollution.

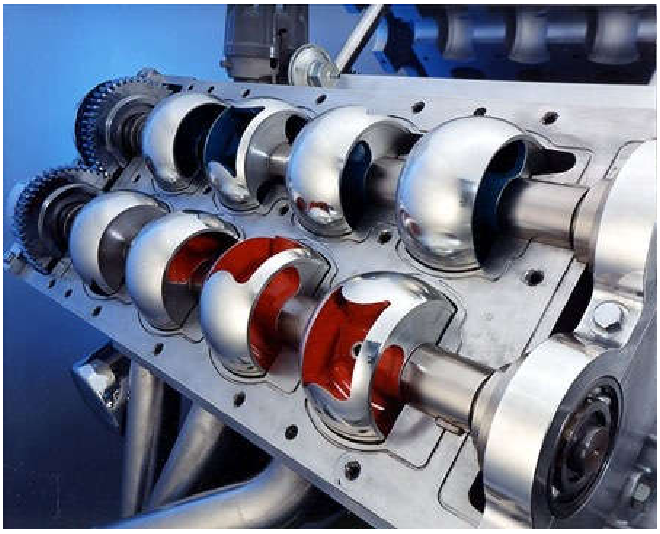
As previously said, several innovations are offered during the time to overcome this problem. One of them, very successful solution, unfortunately rarely used by car manufacturer will be described.

Valve train without springs which uses return cam lobes and rocker arms is known for decades. On the drawing below we can see single cylinder engine with valves train which does not use valves springs. Instead return camshaft is used. At first glance on the drawing it is very obvious that this solution of the valve train is more complex than one which uses valve springs and thus more expensive in production.



Just by looking at above drawing it is easy to conclude how this system does not need any engine power to operate. From the left to right we can see inlet cam lobe, return cam lobe and exhaust cam lobe. Inlet cam lobe opens the inlet valve encountering not any resistance. Return cam lobe closes the inlet valve in specific time very accurately and faster than spring at higher RPM. The same procedure goes for exhaust valve. Even today this system is used by some manufacturers of high performance engines where the price is almost no object. But, do we have to sacrifice our environment just because of the increased production cost?

How this subject of wasted engine energy is taken very seriously all over the world, can be seen trough so many attempts to overcome this problem. But until now, no one offered project was accepted by car manufacturers. Below is shown another project which uses rotary valves. Obviously, this project also does not use any engine power to operate. So, it is quite obvious that people have and offer better solutions than are used in today's vehicles which can drastically reduce emission of harmful gases but they are rejected. The reason is more than obvious. Mass production of existing engine elements is established and cheaper day after day. Any complex changes in engine parts production on serial manufactured vehicles would require considerable investments and thus loss of profit.



1.1.1.8 Test methodology

Test was done theoretically and practically. Theoretically test was related to known law of physics which clearly say from any aspect of view that engine power has to be used to operate valve train which uses valves springs. Practically test was done by use of electromotor to operate the camshaft. In simple words, quite powerful electromotor was used to operate the valve train and when disconnected by electromagnetic coupling valve train instantly stopped and no inertia was noticed. Such test was sufficient to prove that considerable power is needed to drive the valve train.

1.1.1.9 Conclusion of chapter 1.1.1.7

Conclusion of this chapter supposes to be quite simple as this paper is related to influence of engine constructions to fuel consumption and pollution. Mathematical calculation and formulas are avoided as they are absolutely irrelevant. Any unnecessary percentage of pollution is more than important. Therefore, calculations which would show more or less pollution produced would not matter as even 1% of pollution which we can reduce is significant step in saving word's environment. Facts in this chapter show that conventional valve train used in 99% of today's vehicles consumes considerable amount of engine power which affect fuel consumption and automatically emission of harmful gases. As this problem is solvable by many known solutions, some steps should be taken in that direction.

Finally, someone can comment that considerable steps have been taken by manufacturer to improve problems regarding valve train and valve overlap. Yes this is true; overlap is partly reduced by variable valve timing, but just partly. Overlap is reduced on low RPM but still exists. On higher RPM overlap is increased to its maximum. Thus, problem is not solved. On some new generation vehicles valves springs and one camshaft of two are replaced with electromagnetic valve actuators. This system until now showed too many problems as: opening accuracy, noise, sensitivity on temperature, high cost etc. For these reasons it is very questionable will this system be success, reliable and affordable to be installed in average vehicles.

Regardless of all imperfections of new technologies concerning the emission of harmful gases, the race in production of high performance middle range cars is continuing. Instead of reducing engine power by shortening the valve overlap to its minimum and eliminating spring operated valve train, manufacturers are coming up with just partly improved solution which will satisfy still flexible law concerning pollution. One of the good example is i-VTEC Variable Valve Timing and Lift

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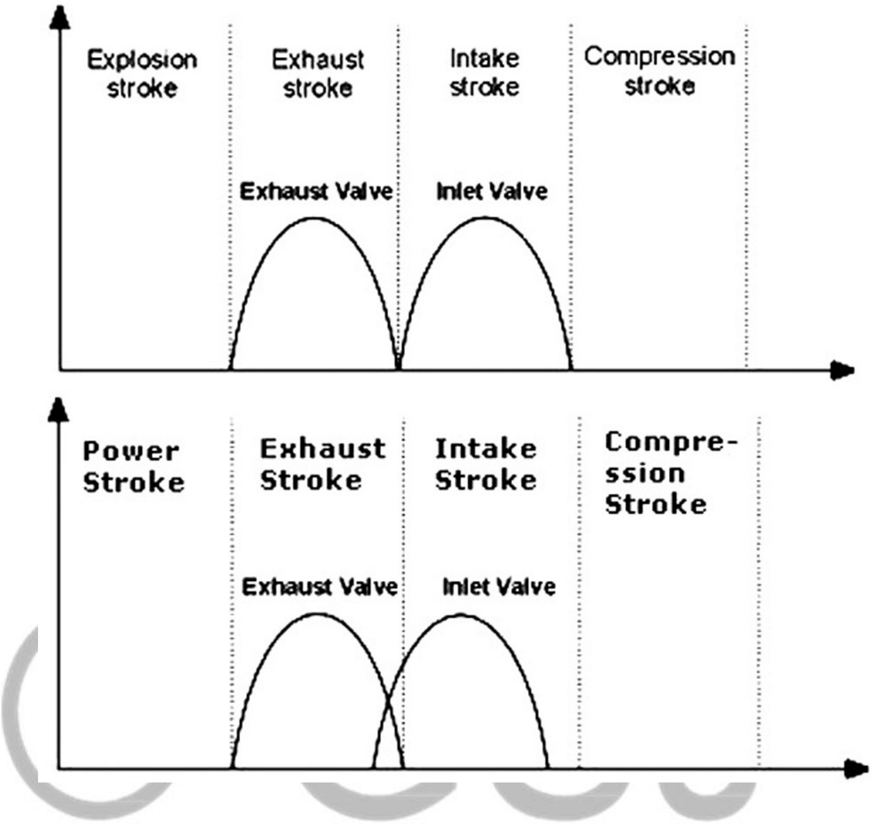
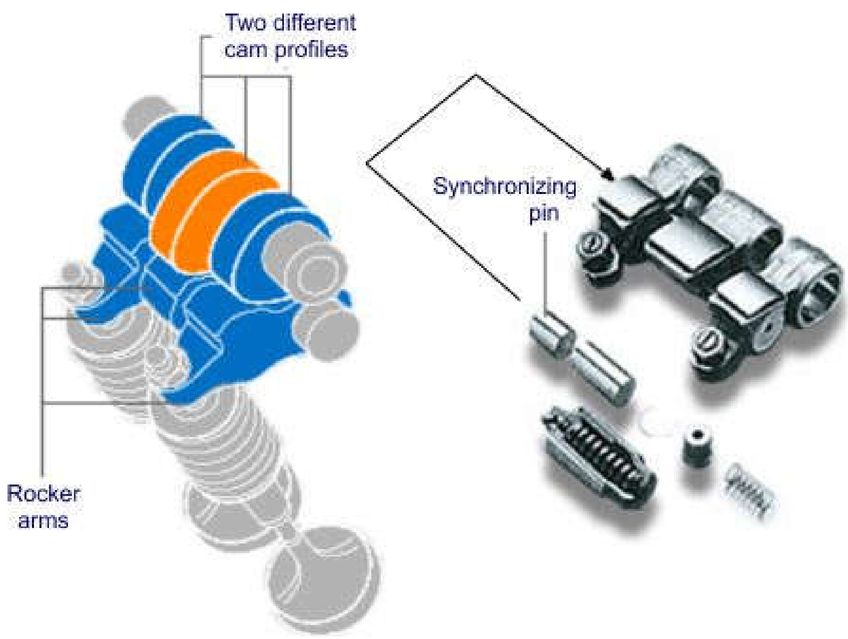
Electronic Control system. This system is certainly very complex and expensive and people welcome this innovation as a system that contributes to less environmental pollution. But here is the question? Was the manufacturer's real intention to reduce pollution or something else? In the race for market, manufactures are offering more powerful middle range cars day after day. Certainly, more power higher fuel consumption. This is certainly a bad side of such vehicles and could easily turn away potential customers. To cope with such problem, manufacturers came out with i-VTEC. The higher fuel consumption of high performance engines was not the only reason to invent i-VTEC. To increase engine power to its maximum, beside other modifications, valve overlap has to be extremely large. In such cases engine will run very rough at low RPM. In other words, to stabilize the engine idle speed RPM has to be increased to an unacceptable value. To overcome this problem i-VTEC was invented. Certainly, manufacturers never mentioned the real reason for this innovation. So, what i-VTEC does? In simple words, instead of one cam lobe per valve, on camshaft is added one more cam lobe per valve. The first lobe has very small lift and thus almost no overlap. This lobe is used when engine is idling or drives very slowly. Of course, without overlap engine has very steady idling and fuel consumption is quite low at that stage as well as at low driving speed. Soon as accelerator is pressed, the lock pin inside the camshaft rockers, operated by hydraulic actuator, locks the other lobe with high lift and car flies with whole available power. So, what has been done in the sense of environmental benefits? Nothing at all! At very low speed emission of harmful gases is not lower than an average low performance car will produce. At higher speed we have the same situation as previously described, large overlap, high fuel consumption and emission of unburned or partly burned air-fuel mixture. Graphs below show normal valve timing when low lift cam lobe is in function and valve timing when second high lift cam lobe is used.





To explain how VVT variable valve timing or VTC variable timing camshaft are not environment friendly innovations but just innovations to improve engine power one simple test was made with Fiat Doblo 1.4, 2007. This vehicle has incorporated VTC variable timing camshaft assembly regulated by ECM engine control unit. The test was taken by following procedure. Firstly, car was driven as it supposes to be, VTC connected to the ECM. Engine performance was great and RPM reached during the driving was over 6000. The next test was done with VTC system disconnected from ECU. Result was satisfying but quite far from previous. With disconnected VTC vehicle had much slower acceleration and could not exceed 4500 RPM or revolutions per minute. In both cases engine had perfect engine idling which could not be achieved if engine had a fixed valve overlap. Here we can easily conclude that mentioned engine has sufficient power as well as performances without VTC system integrated. Certainly, without VTC system this car would not have performances which would compete with similar vehicles on the market, but absolutely good enough to run this vehicle powerfully and achieve the top speed of over 100 miles per hour. So, what happens when VTC is activated? When engine is idling, VTC, in this case only installed on inlet camshaft, retards opening of inlet valves. That means, inlet valve opens soon as exhaust valve closes and there is no valves overlap and no wasted air-fuel mixture. As engine RPM is increased, VTC controlled by ECU advances inlet valves opening when valve overlap occurs. Of course, during the valve overlap fresh air-fuel mixture fills the entire cylinder capacity and produces more power during the expansion stroke. There would be nothing wrong with this modification if combustion chamber of engine cylinder would not let a part of air-fuel mixture out trough exhaust valve, as previously explained. Finally we can say that VVT or VTC are not environmentally friendly innovations as, as such, they let serious quantity of unburned air-fuel mixture out of engine what causes increased fuel consumption at higher RPM and thus increased emission of harmful gases. The world would be better of without such innovations which are not foreseen to prevent emission of harmful gases but used to attract customers with more and more powerful cars at the expense of the health of all of us.

1.1.1.10 Electrical consumers cause increased emission of harmful gases

This problem is rarely mentioned when emission of harmful gases from vehicles is discussed. On the contrary, when discussion of traffic safety takes a place, many additional laws are brought up which supports unnecessary consumption of electric power on vehicles. This mainly applies to the usage of headlights and taillights during the day. As DRL (daytime running lights) law is more present all over the world, the very logical question arises: how much is fuel consumption increased to supply lighting electrical consumers on vehicles? Whatever percentage of additional fuel is used when headlights and taillights are switched on is absolutely irrelevant. As mentioned in previous chapter, even if we are talking of just 1% of unnecessary burned fuel, when multiplied by billions of vehicles which are used worldwide every day, we come to an astonishing amount of harmful gases emissions. Obviously, before such traffic regulations are legally accepted, more researches had to be done concerning contribution of such regulations to traffic safety and increased fuel consumption and thus potion too. Here we can see citation of research made by National Highway Traffic Safety Administration: *Numerous studies done worldwide since the 1970s have tended to conclude that daytime running lights improve safety. A 2008 study by the U.S. National Highway Traffic Safety Administration analyzed the effect of DRLs on frontal and side-on crashes between two vehicles and on vehicle collisions with* *pedestrians, cyclists, and motorcyclists. The analysis determined that DRLs offer no statistically significant reduction in the frequency or severity of the collisions studied, except for a reduction in light trucks' and vans' involvement in two-vehicle crashes by a statistically significant 5.7%.* By above cited study we can simply conclude how the laws related to daytime running lights are nonsense as they contribute much more to the global pollution than to the traffic safety.

Calculations of used engine power by alternator when lights are turned on differ from one examiner to the other. An approximate value is somewhere about 2%. Some of them are calculating just the electrical consumption of headlights low beams. The others are taking in consideration all lights on the vehicle which are automatically turned on together with low beams. Of course, in this other case we have to add tail lights, instrument panel lights, side lights etc. Here we can calculate electrical power consumption between 150 and 200 watts or between 15 and 20 amps. Let's say that 150 Amps alternator consumes about 7-8 hp of engine power at full load. In our case, it means that usage of daytime running lights will use somewhere of 0.8 to 1 hp of vehicles engine. Someone wants to express this engine power consumption in percentage and say that engine power used for usage of daytime light is about 2-3 percents. If we take a middle value of this percentage we can conclude that emission of harmful gasses can be globally reduced by 1.5%.

1.1.1.11 Test methodology

Test was generally made theoretically on the base of the physics law and comparisons of tests made by several examiners from different institutions and individuals.

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For practical test, two types of vehicles were used. One of them was VW Golf with electronically controlled engine and other one was a bit older VW Golf with simple carburetor engine. First vehicle has electronically controlled engine and thus automatically adjusted engine idle. In such case we can not notice any changes in RPM when engine is idling and load is applied by switching lights on. But when a diagnostic device is used, considerable increase of engine load can be read. On the next test with carburetor engine, soon as lights were switched on RPM dropped from 950 to 850 RPM or more than 10%. Certainly, this load will change as RPM increases and engine produces more power. But, does it really mater?

Headlights OFF

Headlights ON

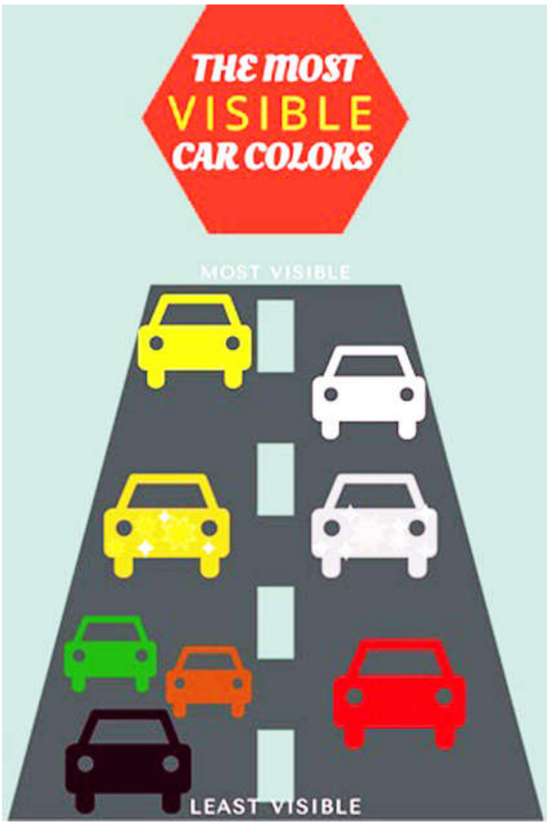
1.1.1.12 Conclusion of chapter 1.1.1.10

In both tests explained above, we proved theoretically and practically that usage of daytime running lights consumes not negligible engine power. Even if we are talking of previously mentioned 2%, this is still enormous unnecessary emitted amount of harmful gases when we know that over one billion vehicles are running over the world every day.

Knowing how extra polluted is our environment by daytime running lights and considering study of U.S. National Highway Traffic Safety Administration, law has to be changed in order to reduce global pollution caused by vehicles. Beside that, regarding traffic safety, the law obliges drivers to use the low beams when there is a poor visibility during the daytime. Of course, we can still do quite a lot on marking vehicles to be easier noticed on the road in order to reduce traffic accidents, but certainly on the ways which would not have influence on air pollutions. Installing bright small LED spot lights is not the brightest idea but would save great amount of engine energy and thus reduce pollution. Stimulating buyers, by reduced cost of car insurance, to buy cars painted in live colors would also contribute greatly in traffic safety. Just these two simple ideas, among many others, would certainly have the same effect as daytime running lights. Someone might say that today's cars already have LED lights installed. Yes, but firstly just some models have such lights. Secondly, those lights are not beams but just a kind of sidelights which certainly would not satisfy the law when daytime running lights are concerned.

Could the bright colors of the vehicles replace the daytime running light?

Visibility of the vehicles painted in different colors is shown on the drawing below.



This question was discussed by numerous institutions all over the world. Conclusion was simple in most of cases. Bright and live colors could be more effective than daytime lights usage.

References:

In an Australian study, white vehicles were about 10 percent less likely to be in a crash during daylight hours than vehicles in lower-visibility colors such as black ,blue, gray, green, red and silver, according to a 2007 report from the Monash University Accident Research Centre.Mar 31, 2014

1.1.1.13 Air conditioning causes increased pollution

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Since the beginning of motor vehicles commercial manufacturing, competitors were trying to attract buyers with luxurious novelties, again, without paying much attention to pollution. Among many others, air-condition system installed in personal vehicles was prestigious. Choosing the personal vehicle with installed climate control system was certainly decisive decision especially in US where the great numbers of states have very hot summers. In the beginning, air-condition systems were installed only in luxurious personal vehicles, but these days climate-control system is almost standard feature of most personal vehicles. Regardless of awareness that air-condition compressor consumes about 4 hp of car engine and increases fuel consumption up to 30% and thus enormously increases emission of harmful gases too, until today nothing much was done about it. We all know, when people buy new toy they want to use it as much as possible, even when it does not make sense. The same behavior applies to AC air-condition. It is very noticeable that people all over the world are using AC even when outdoor air temperature is under 25°C. Of course that it does not make sense, but people just want to think that they feel comfortable even when this is not the case. Simply, they want to use what they paid for. Such behavior makes air pollution problem even worse. Being aware of existing problem, many environmental institutions are trying to influence on car owner’s behavior presenting them a cost of extra fuel they use when AC is in use. One of the tables for car owners with intention to reduce emission of harmful gases is written by *Natural Resources Canada* is shown below.

This table lists the estimated fuel costs and CO_2 emissions associated with a/c use.

Annual distance driven using a/c	Annual increase in fuel consumption with a/c use		Fuel cost of a/c use over 10 years*		CO_2 emissions from fuel used for a/c over 10 years**	
	If your a/c uses 1 L/100 km	If your a/c uses 2 L/100 km	If your a/c uses 1 L/100 km	If your a/c uses 2 L/100 km	If your a/c uses 1 L/100 km	If your a/c uses 2 L/100 km
14,000 km	140 L	280 L	$1,400	$2,800	3,220 kg	6,440 kg
12,000 km	120 L	240 L	$1,200	$2,400	2,760 kg	5,520 kg
10,000 km	100 L	200 L	$1,000	$2,000	2,300 kg	4,600 kg
8,000 km	80 L	160 L	$800	$1,600	1,840 kg	3,680 kg
6,000 km	60 L	120 L	$600	$1,200	1,380 kg	2,760 kg

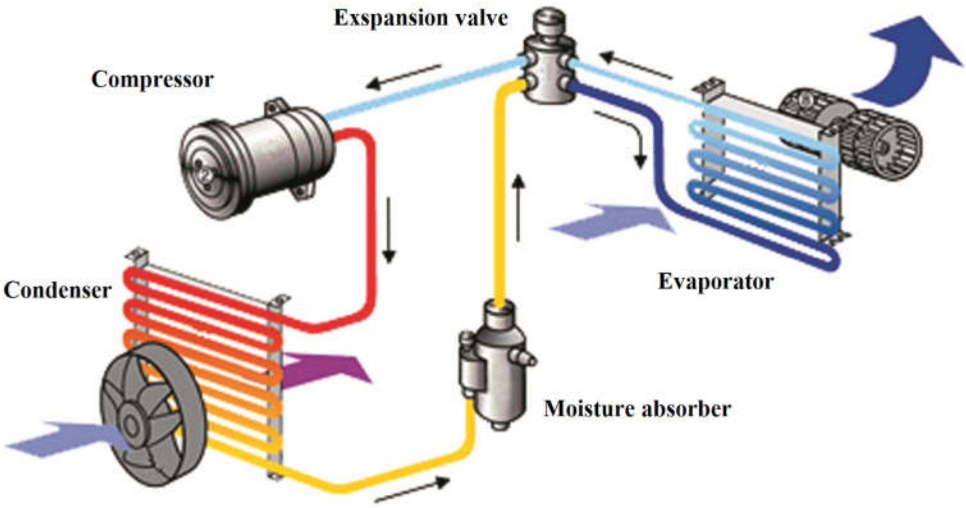
*Based on a fuel price of $1.00/L of gasoline.

**Based on a CO_2 emissions factor of 2.3 kg/L of gasoline.

Similar calculations with drastic figures can be found on hundreds of web pages and basically all refer to the car owners. Not a single article applies to cars manufactures with intention to force them to invent different, environmental friendly, AC system in order to reduce emission of harmful gases. Here we have question again. Is the profit above the safety of people's health?

Beside the enormously increased emission of harmful gases caused by AC, we have to be also concern about refrigerant gases leakage from AC system. Some calculations made by many institutions around the world show that annually leak of refrigerant gases from each vehicle equipped with AC system is around 53 grams.

For better understanding why so much energy is drawn from vehicle engine by air condition system we have to know the basic of AC working principle. The basic problem of below shown AC system is compressor which compresses the gas in the system. The power which compressor needs to compress the gas is transferred by belt from the engine crankshaft pulley. AC system gas is drawn into the compressor and pushed out toward the condenser in liquid form. Liquefied gas is cooled in condenser and pushed under the pressure trough the orifice tube to the evaporator where absorbs the heat from the passing air. Knowing that, we can assume how much power compressor needs to compress enough quantity of gas to make AC capable of providing demanded quantity of cold air. This fact is today very important when we know how the vehicles are equipped with AC. Most of today's cars have installed AC systems which provide very luxurious climate for each passenger. Instead of single or smaller evaporator which will provide just enough cold air to reduce interior temperature to an acceptable value, vehicles are equipped with separate climate control for each passenger. Just this fact tells us how more and more engine energy is used by AC day after day and thus increases air pollution.



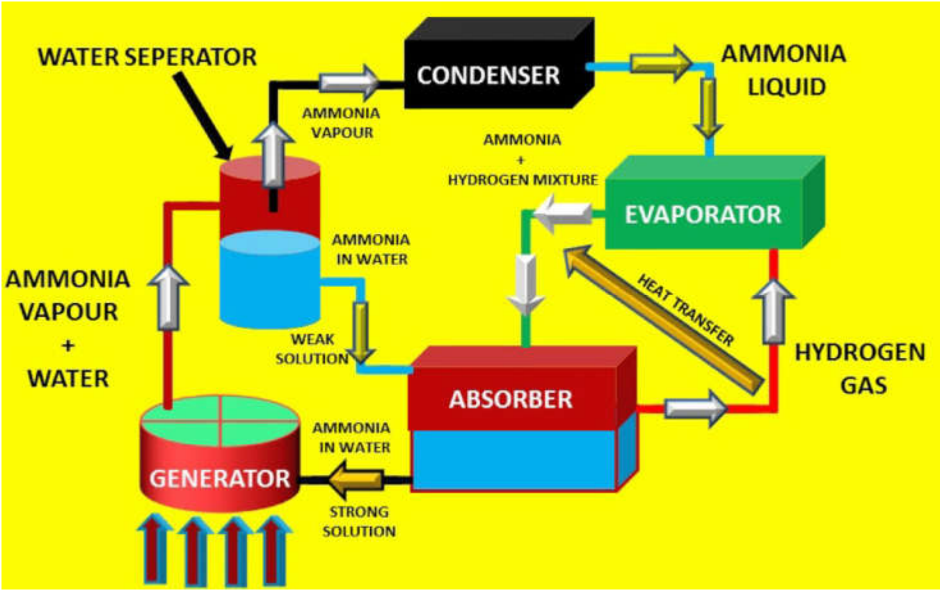
1.1.1.14 Test methodology

Test was made practically by measuring the engine load using diagnostic tools and measuring the engine load with AC On a Off. The difference in engine load was significant as mentioned above. The second test was made by driving the same distance with AC On and Off. Fuel consumption significantly changed in percentage similar to above mentioned. Third very simple test was made on older Mercedes S Class with carburetor engine which has not automatically regulated engine idling. When AC was turned On RPM dropped for almost 200 RPM.

1.1.1.15 Conclusion of chapter 1.1.1.13

Air conditioners are very heavy engine power consumers which significantly affect fuel consumption and thus emission of harmful gases too. Considering seriousness of existing problem which increasement seems to be more and more serious day after day, governments have to be forced to put pressure on car manufactures to make alternative air conditions systems, at least in new produced vehicles. Namely, there are alternative AC systems which can successfully replace existing ones. But certainly, such action and cost will certainly affect prices of new cars or considerable reduce car manufacturers profits.

One of alternative solution offered by innovators is Aqua Ammonia automobile air conditioner system. The main difference compare to existing system is use of exhaust gasses instead of pure engine power. Simply said, the exhaust gases which are wasted trough the exhaust pipes are used to power AC generator. Ammonia refrigerators do not have moving parts. Generator is usually heated bay kerosene, gas or electricity. In case of using Ammonia refrigerator system in vehicles AC, temperature of exhaust gases would transfer the heat to Ammonia generator. Exhaust gases would heat mixture of water and Ammonia in the generator. The Ammonia vapor is pressed trough the tube up to the air cooled condenser. In the condenser Ammonia gas is cooled and liquefied and flows into the receiver. This is just a simple explanation of Ammonia refrigerator principle, but enough to understand that this system needs only heat which is available in engine waste gases.



Similar AC systems are offered by dozens of institutions and individual innovators. Calculations show that almost zero engine power is wasted and thus air pollution is drastically reduced compared to conventional AC. The question arises, why these innovated systems are not used until now. The reason is simple: profit. To implement such new device in modern cars, quite a lot of redesigns have to be done on engine construction as well as on body construction regarding engine compartment. Knowing how serial production of motor vehicles goes today it is easy to imagine what investment is required to undertake such task. The next question which automatically comes up is: what is the price of human's health or finally the human's or any other living creature's life?

References:

Energy saving measures for automotive air conditioning (AC) system in the tropics

https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=2360&context=iracc

Fuel Used for Vehicle Air Conditioning: A State-by-State Thermal Comfort-Based Approach

http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.414.1713&rep=rep1&type=pdf

Influence of Automotive Air Conditioning load on Fuel Economy of IC Engine Vehicles

https://www.ijser.org/researchpaper/Influence-of-Automotive-Air-Conditioning-load-on-Fuel-Economy-of-IC-Engine-Vehicles.pdf

Alternative Technologies for Automobile Air Conditioning

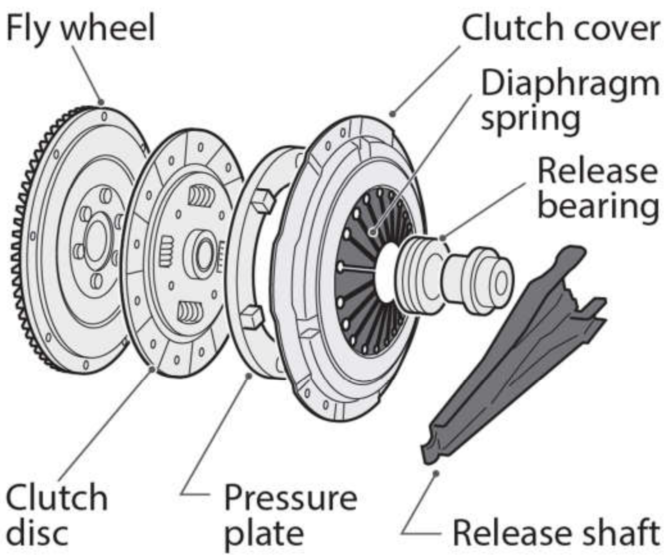
https://core.ac.uk/download/pdf/4822193.pdf

1.2 Transmissions

Transmission is the linkage between engine and wheels. In the following text will be explained how this system works and its influence to the fuel consumption and emission of harmful gases.

1.2.1 Manual gearbox and clutch

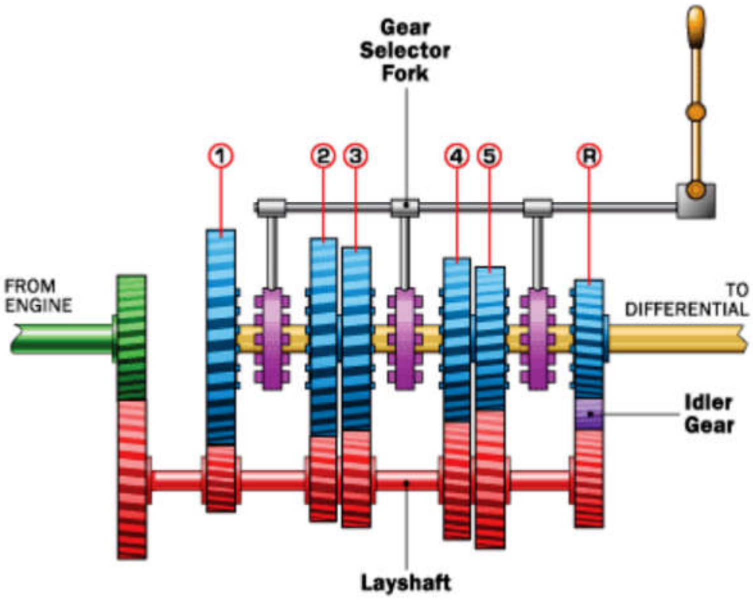
From the time when engines with internal combustion are invented the proportional transmission of the engine speed to the wheels gave engineers quite a headache. Directly engaging engine crankshaft rotation with the vehicle's wheels would make vehicle undriveable. Engine should have possibility to be disengaged from transmission when vehicle was stationary and engine running for very simple reason. To start the engine it has to be disengaged from the wheels or the car will move as soon as we try to turn the engine. The first problem was to invent device which would softly engage and disengage engine from transmission. Any attempt to rigidly engage engine with transmission would cause, in the best case, engine stop running. To overcome this problem engineers invented assembly today called clutch. This assembly composed of three main parts enabled driver to engage and disengage engine from transmission very softly. This was possible by use of friction plate covered with cork on both sides. The second part of clutch was pressure plate which consists of friction plate and springs covered with metal cover firmly attached to friction plate. The third part of clutch assembly was trust bearing which slides along the output shaft attached to the engine crankshaft.



It is difficult to say who invented such coupling as clutch because many people are involved improving material and its principle. But we can say that Englishman Herberd Frood finally improved friction material which was more durable and thus usable on vehicles. These innovators were certainly not aware how ingeniously invention they made which is used even today on all cars with manual gearbox. In addition to its simplicity, this principle of coupling engine and transmission is very ecological as there is almost zero energy lost during the engine and transmission engagement what is not the case with automatic gearbox which uses converter to couple the engine and gearbox.

On the above drawing we can see described clutch assembly elements. So, let's explain their functions. Flywheel is attached to engine crankshaft and has friction surface on its outer side. The center plate or clutch disc covered with durable mixture of cork material is positioned between the flywheel and the pressure plate. Center plate is connected by toothed centerpiece to the output shaft while pressure plate is firmly joined with flywheel by several bolts. When clutch is assembled, center plate is in sandwich under the pressure provided by springs in the pressure plate and turns together with flywheel. Engine rotation is transferred to the output shaft which is directly connected to the transmission via gearbox. If we want to disengage the engine from transmission we have to release the center plate from the pressure plate force which keeps firmly together flywheel, center plate and pressure plate. This is done by pressing clutch pedal in the cabin which is connected with trust bearing by levers or steel cable. By pressing the clutch pedal, force is transferred to the release lever in the clutch housing which forces trust bearing to slide towards the pressure plate and release the center plate of spring's pressure. At this moment, center plate is released from pressure and turns freely between flywheel and pressure plate and does not transfer engine rotation to transmission. When releasing clutch pedal, trust bearing slowly returns to its previous position and allows pressure spring to act again and couple center plate with flywheel. Just before full engagement with flywheel, slight slipping will occur between flywheel, center plate and pressure plate which allows smooth coupling.

When coupling problem was solved, the problem of transmitting proportional engine power to the wheels remained. By coupling the engine and transmission directly the car can be hardly driven. Namely, just to move the car from the place where it is parked we would need to rev engine very high to obtain enough power. With the lack of power, vehicle acceleration would be more than poor. If ratio between the engine and wheels were reduced to the point that vehicle will start moving satisfying, the top speed would be very low. Thus, ratio compromise had to be found to enable vehicle to have enough power at any speed. Thanks to the clutch, such technical improvement was feasible and named manual gearbox. Simple manual gearbox is shown on the drawing below. Beside the purpose of gearbox to distribute proportional engine power to the wheels at desired speed and load when driving up the hill, perfect proportion of gear ratio in the gearbox will have a great influence to the fuel consumption and emission of harmful gases. The typical example of different fuel consumption is noticeable on the vehicles with same type of engine and different gearboxes. Let’s say that we have the same models of vehicles but one is personal car and the other is light commercial vehicle. This other one will have reduced ratio gearbox to provide enough power when loaded. That is to say, if we drive the first personal vehicle at rate of 2000 RPM we can easily achieve the speed of, let’s say, 100 km/h in third gear. In the other commercial vehicle we shall need to rev engine much higher to achieve such speed in third gear. This example shows how important is proper gearbox ratio for every particular vehicle. Now, let’s explain how the gearbox ratio is changed when desired. Watching the lower drawing, the following principle of gear ratio can be seen. On the lower part of the gearbox one piece cog lay - shaft, or commonly known as pyramid, transfers the speed ratio to the drive shaft. This is



possible by engaging the different cog sizes to it on the main shaft of the gearbox. Different sizes cogs are freely rotating on the upper main shaft of the gearbox. Engage rings, which are constantly engaged to the main shaft by teeth, are actuated by gear selector and coupling chosen gear ratio. Simple illustration associated with upper drawing. If we pull gear liver, in this particular case, backwards, engage ring will couple the freely rotating cog of the first gear on the main shaft with the small cog of the first gear on the lay shaft. In this gear ratio, engine RPM will be drastically reduced and transferred to the main shaft or gearbox output shaft. The same principle applies to all gear ratios. Now, it is quite clear how gear ratio influences fuel consumption and thus air pollution too. If inappropriate gear ratio is chosen, vehicle will have too much power in specific gear and power will be wasted or vice versa.

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More efficiency in fuel consumption using gearbox optimization based on Taguchi method
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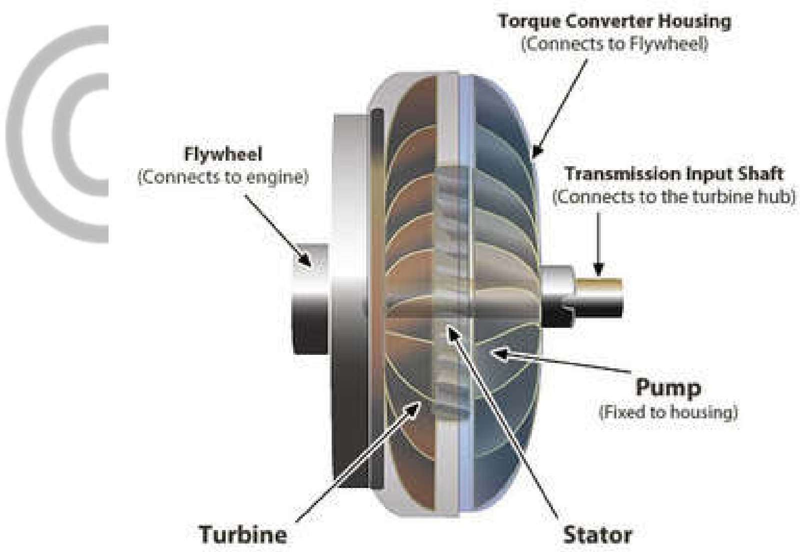
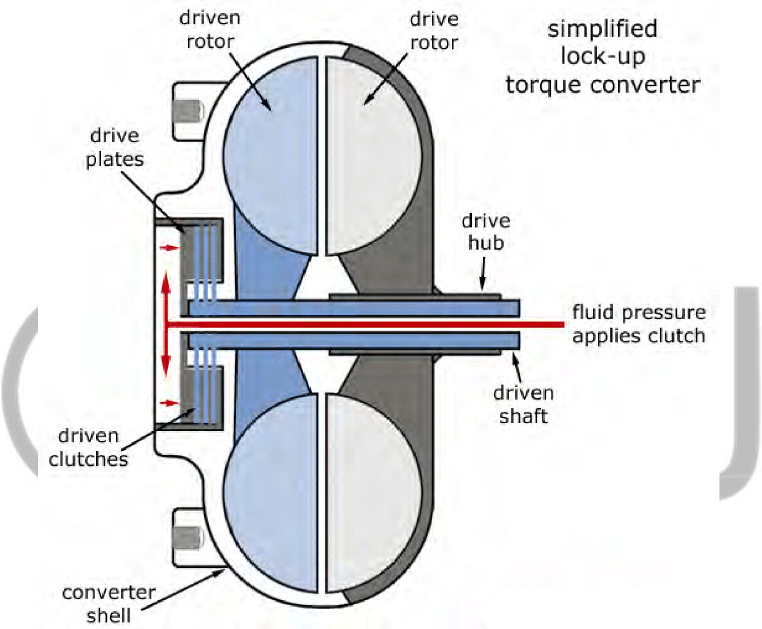
1.2.2 Automatic gearbox

The first automatic transmission was introduced during 1940s by General Motors. Until now, so many researches and calculations of many institutions and individuals have proved that manual gearbox is the most efficient transmission of the engine power to the wheels. However, the market always shows demands in improvement of vehicle's driving simplicity. Unfortunately, such improvements did not always comply with ecological demands. All motor vehicles drivers are aware how complex is to drive vehicle with manual gearbox. Besides just passing the driving license test regarding traffic rules, drivers have to know much more about the vehicle technology. To overcome this problem, car manufacturers invented automatic gearbox. With this modified system drivers just have to select gear lever to forward, backward, neutral or parking position. Automatic gearbox would do the rest of work by itself. Knowing these advantages of automatic gearbox, demands for such vehicles grow up almost instantly. This system was very convenient for disabled people, but ordinary people also find advantage in automatic transmission cars as they did not to have much knowledge of car's technology, and to addition to that, driving license was easier obtainable. The problem with automatic gearbox, besides all its advantages, is much higher fuel consumption compares to the same vehicle with manual gearbox and thus higher emission of harmful gases. As we learned in previous chapter, clutch engages engine with gearbox almost instantly. Prior the clutch engagement, gear ratio cogs in the gearbox are selected and engaged. That it to say, that by using clutch and manual gearbox there is almost none of waste engine power during engagement of engine and transmission. In automatic transmission this is not the case. Instead of using mentioned clutch, such gearboxes are using, so-called, converters. Converter is the main problem regarding increased fuel consumption on automatic transmission systems. Converter is replacement of conventional clutch on the manual gearbox. While on conventional clutch on the manual gearbox driver has to press the clutch pedal and gently engage and disengage engine from transmission, converter has to do this job by itself. Let’s see how converter works in simplified way. Automatic gearbox engages gear ratio by hydraulic system governed by gearbox oil pump and oil pressure controlled by mechanical valves or electronically controlled system. The purpose of converter is to release coupling of engine and gearbox when engine is idling and firmly coupling the engine rotation with gearbox when engine accelerates. This is obviously very demanding task. On bellow simplified drawing, basic principle of automatic gearbox converter is shown. Let’s say that beside the other components of converter we are talking only about two turbines. One is rotating connected to the engine flywheel and the other one is stationary connected to the input shaft of the gearbox. The converter is filled with gearbox oil by pump. When engine is idling, turbine connected to the flywheel rotates together with engine crankshaft. In the same time the other turbine connected to the gearbox input shaft rests. The oil pressure formed by first turbine slips trough the gap between the two turbines. Soon as engine accelerates, pressure between turbines rises and compact oil chambers are formed between turbines. In this moment, turbines are coupled by oil chambers and form one compact power transfer unit. Ones this stage is achieved, engine power is completely transferred to the gearbox and further to the wheels via determined ratio selected by the gear lever. The waste of engine power occurs in the moment when engine accelerates. To form the rigid oil chambers between turbines engine RPM has to be quite high. In the mean time, oil slips between them. In practice, drivers can feel like conventional clutch is slipping. In other words, from the time when we are trying to move the vehicle from it stationary position to some driving speed when two turbines will be rigidly coupled, engine power will be wasted by oil leak between two turbines.



To partly overcome torque converter slipping problem, manufacturers invented combined torque converter. Why partly, as shown on the next drawing, simple oil clutch, widely used on motorcycles, is integrated into the converter to couple engine and transmission immediately when situation allows it. Wee know that prompt coupling of engine and transmission is impossible when vehicle is resting. Thus, this added clutch will only function when vehicle is mowing and engine is rotating at 3000 RPM. In such circumstances clutch will engage and firmly couple the engine and transmission to prevent oil leakage between turbines and save the wasted power. This innovation was not really made to save the world from air pollution but to increase vehicle's performances. As we can assume, this added clutch which works at higher vehicle's speed will hold the engine's flywheel and output shaft firmly together and car will accelerate much faster then one with conventional converter.



How demand for vehicles with automatic gearbox was growing rapidly, especially in USA, automatic transmission was installed in smaller cars with low power engines. This situation additionally contributed to increased air pollution. It is well known that automatic transmission requires very powerful engine with high engine torque. Previously explained, torque converter needs high torque and prompt acceleration of turbine to form the rigid oil chambers between the turbines as quick as possible. This is easily achieved on muscle cars which were manufactured until eighties. When automatic transmission is installed in cars with less powerful engines, it will take

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considerable time until turbines couple firmly and result will be quite great loss of power caused by oil leak between turbines in converter.

Another problem with automatic gearbox is engine load made by converter, especially when car is driven in city traffic. As most drivers know, soon as we start the engine, gear selector is shifted to drive position. It is very noticeable how RPM drops for about two hundred revolutions and vehicle tends to move forward if we do not keep brake pedal depressed. Similar to the RPM drop shown in previously attached photos when head lights are turned On, the same thing happens when we select gear lever to drive or reverse. What causes this engine load? By selecting the gear lever in drive position, first gear transmission is engaged in the automatic gearbox. That means that input and output shaft of the gearbox are coupled and vehicle is ready to start driving. Now we are coming back to oil slip between the turbines in the torque converter. When engine is idling and gear selector is in drive position, engine and transmission are coupled and we need to hold the brake pedal depressed to prevent vehicle to move forward. In such situation, engine is turning fixed turbine in the converter and trying to transfer power to the other turbine by making rigid oil chambers between turbines which will enable engine power transfer to the transmission. As engine RPM is low, oil leaks between turbines and just a small engine power is transmitted to the other turbine in the converter and vehicle tends to move. Here we have a problem with engine load. Engine has a resistance from the converter where rigid oil chambers attempt to be formed. Lack of engine RPM and resistance of locked wheels caused by keeping brake pedal depressed causes oil leak between turbines. Partly formed oil chambers between turbines causes the engine load when ever is vehicle stationary, engine running and gear selector is in drive or reverse position. Now, when we consider the time when vehicle is stationary in city traffic, it is not difficult to calculate how much fuel consumption is increased and thus emission of harmful gases too.

1.2.3 Test methodology

Quite a number of mathematical calculations are made all over the world in last decades about the wasted power on vehicles with automatic transmission. There fore we did not try to do one more, instead we made practical experiment. We drove couple of cars, Volvo 760, with the same Diesel engines but different transmission. One had installed manual gearbox, while the other one was with automatic transmission. In very few minutes of testing, difference was more than obvious. The first car with manual transmission, as we usually say, had a life in it. It started to drive immediately and further acceleration was very good in every gear. The other one with automatic transmission was, as we say, very lazy and acceleration was poor. This difference of performances between those two cars was caused by converter slipping in the vehicle which has installed automatic gearbox.

Conclusion of chapter 1.2.3

Now, it can be easily concluded how the first car with manual transmission used all available engine power to run the vehicle. In other car with automatic transmission a great amount of power was wasted in converter and just part of engine power was used to run the vehicle. If we consider that the most driving is done in the cities where we constantly stop and drive, it is quite clear that fuel consumption between those two cars differ for about 20-30% and thus the emission of harmful gases too. The question is? Why until now nothing has been done about conventional automatic transmissions in order to reduce emission of harmful gases. The answer is simple: profit. There are quite a few new automatic systems as dual clutch tiptronic and many more, but these systems are mostly installed in high class vehicles. For average personal cars conventional automatic transmissions are intended as they are manufactured for long time and their production is cheap.

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Horsepower Review: Automatic vs. Standard Manual Transmissions

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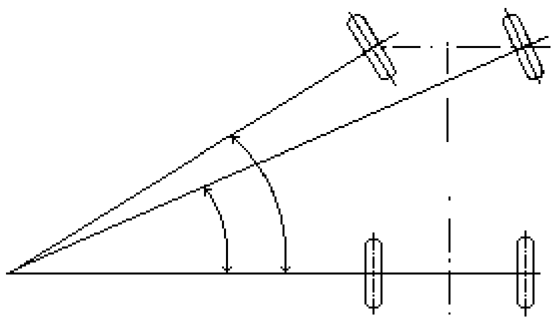
1.2.5 Vehicle wheels geometry

Vehicle wheels geometry develops gradually from the very beginning of motorcars commercial production. One of the first usable and acceptable wheels steering system was Ackerman's layout shown below. As seen on the sketch, this layout is almost perfectly designed as the each wheel follows the circle path. Even so perfectly designed layout which is modified during the time and used until now has some disadvantages. When concerning fuel consumption is incresed and thus emission of harmful gases too.



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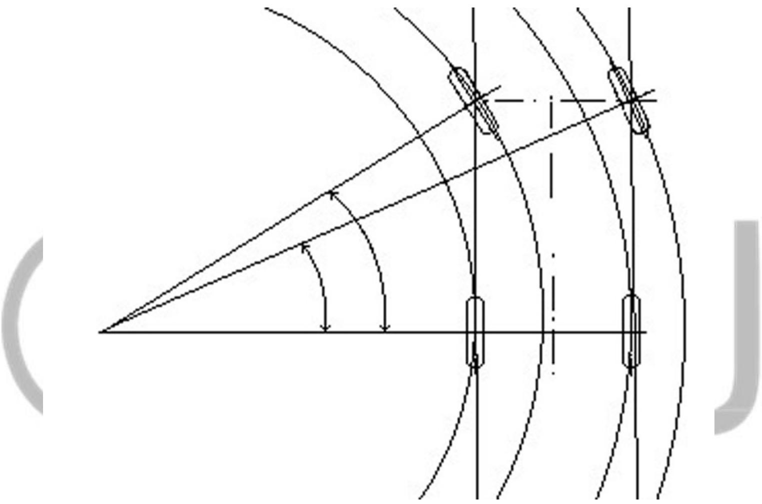
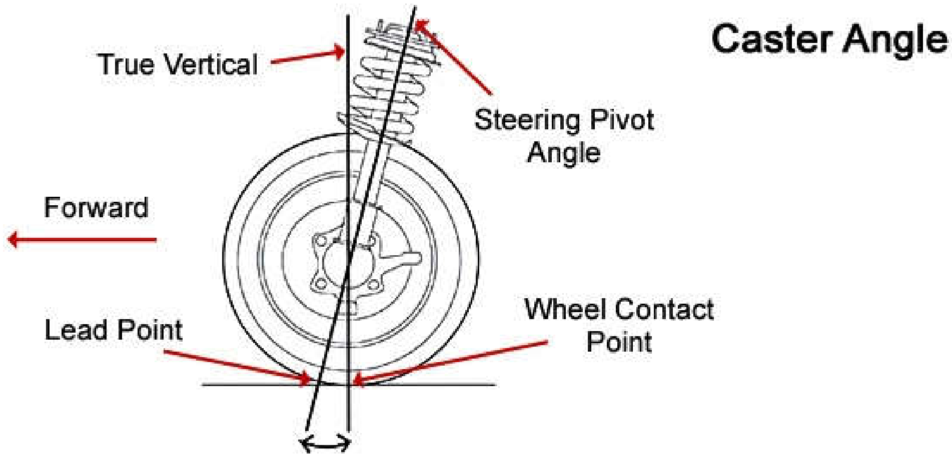
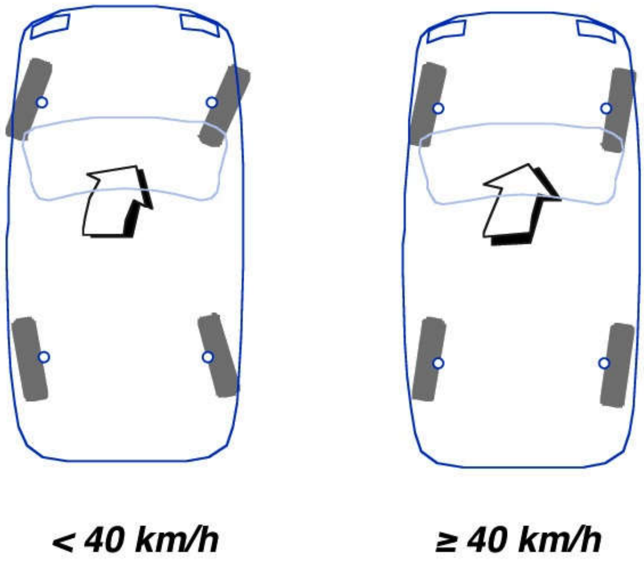
It is well known that before eighties not much attention was paid regarding air pollution when innovations were made on vehicles. The most important factors were performances, safety, exterior and interior designs. In the case of wheels geometry nobody cares much about tires resistance when vehicle is cornering and using more engine power to drive the car than it is needed when vehicle was driving straight forward. More attention was paid to vehicles stability and safety when vehicle is cornering.



Above drawing shows how the rear wheels tend to go strait forward as well as the front wheels which are forced to turn by the force of steering mechanism. This force is very evident when driver tries to turn the vehicle left or right and car is tending to keep straight forward direction. Such vehicle behavior is helped by front wheel Caster angle which is very obviously exposed on bicycle's front wheel. Without Caster angle front wheels would tend to turn left or right by them self in any moment when they are not hundred percent aligned with straight forward path.



Here wee have explained the basic wheels geometry. During the last decades many improvements have been made on the wheels and suspension geometry, but just in purpose to give the vehicles better stability and safety. Nobody actually even mentioned extra engine load or wasted engine power when car is cornering. Again, knowing that most of driving is done in the towns, it is not difficult to calculate how much extra engine power is used to drive the car. What is the percentage of this extra engine power used when cornering can be tested by simple procedure? If we try to push the medium size car in straight forward direction, just a slight human energy has to be used. But, if we try to push the same car with the wheels in cornering position, we shall most probably need assistance of one more person. Now, we can understand how much resistance from wheels we have while cornering and what extra engine power is used every time we turn the front wheels left or right during the driving, especially in towns. On open roads, mentioned resistance will still exist, but vehicle inertia will partly free the engine of extra load. Beside the previous simple test, used tires give the evidence how great is the tire resistance against the road and friction which causes tire wear. Every tire which has been on the same wheel for about thirty thousand kilometers has uneven wear. Regardless of how perfect is wheel alignment adjusted, tire wear is always uneven. This is proof that tire resistance and thus friction is not the same on the tire surface. Uneven worn out surface between the side and center of tire shows how resistance and frictions are different when car is driven straight forward or cornering.



To improve vehicle safe cornering and stability, in last decades Japanese manufactures developed four wheels steering system. We will not go to the construction details and mathematical calculation as we are discussing influence of vehicle construction to the fuel consumption and emission of harmful gases. Very similar to other improvements made on vehicles since they started to be commercially manufactured, implementation of this system was basically made to comfort car's owner and achieve better sale of motor vehicles. Reduced fuel consumption which is obviously and accidently achieved by this innovation is rarely mentioned. As this system is installed on high class vehicles only, some minor saving in fuel consumption was absolutely irrelevant. Question: how much would be air pollution reduced if a billion of middle class vehicles are equipped with four wheels steering system? Just a quick look at the upper drawing makes anyone aware how a great number of the mention problems with Ackerman's layout are considerably reduced. On the left vehicle on above drawing rear wheels are turning in opposite way than front wheels. Such wheels alignment on turns allows the vehicle to make about ten percent smaller circle around the circle center and thus much better maneuverability at low speed. On the second car on above drawing rear wheels are turned in the same direction as front wheels and thus enable smoother driving at higher speed. Certainly, front and rear wheels do not turn under the same angle. Angles of rear wheels are reduced and mathematically calculated. As mentioned before, instead of getting deep in construction and calculations of this system, we shall focus to wheels resistance and frictions when vehicle is trying to turn in either direction. When ever we reed about four wheel steering the two major sentences are pointed out, easy maneuvering and almost no resistance is felt on the steering wheel when cornering. That is to say, wheels resistance and friction is reduced, what automatically reduced the need of extra engine power and thus fuel consumption and emission of harmful gases too.

1.2.6 Test methodology

To prove how wheels geometry affects fuel consumption and air pollutions, very simple practical tests were done. Firstly we tried to push the vehicle in straight forward direction using strength of single person. No greater problem was encountered on this test. But when we turned the steering wheel to the one side, two persons were needed to move the vehicle. In the next case we did the same procedure with the four wheel steering car. One person was able to move the car in straight forward direction and with steering wheel turned on one side. Further more, we did couple more tests just to make sure that theory of this chapter is correct. With the speed of thirty kilometers per hour we drove the car in neutral around the corner of ninety degrees. The car stopped sun as corner was passed. The same test was done with four wheel steering car. The car passed the corner and continued to drive for a while.

1.2.7 Conclusion of chapter 1.2.5

Conclusion is simple. Vehicles with four wheel steering system installed have lesser wheel resistance and friction than vehicles with conventional Ackerman's layout and thus lesser fuel consumption and emission of harmful gases. Are we not here in the same situation as in previous chapters regarding possibilities of reducing emission of harmful gases just by forcing car manufactories to implement any useful innovation in middle class vehicles even if it affects their profit.

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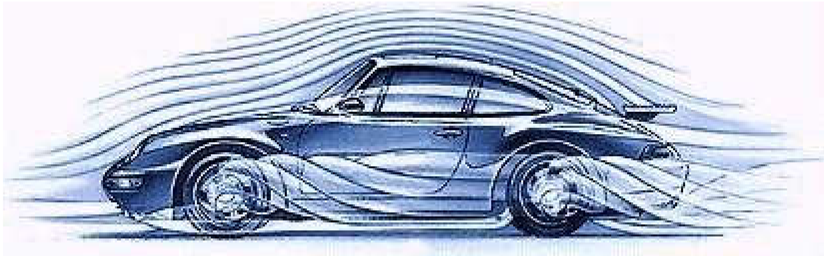
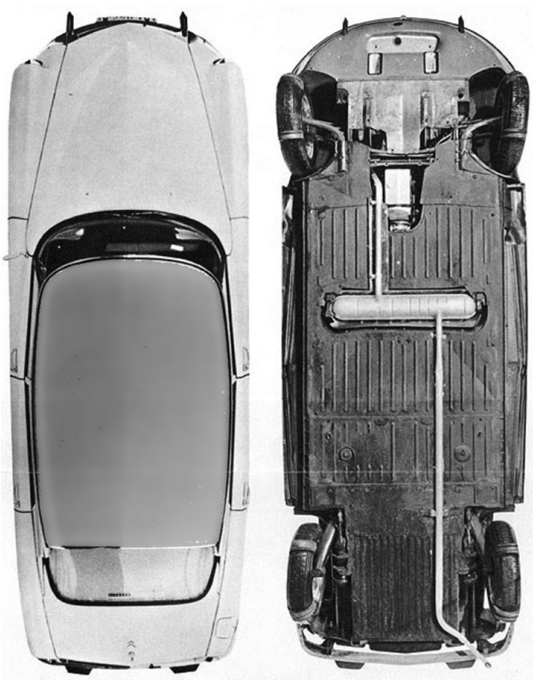
1.3 Vehicles drag koeficient

Aerodynamics is one of the most important factors on cars concerning fuel consumption. Do automobile manufacturers really use all possible potential in this field to reduce the fuel consumption or do they do it just partly sacrificing reduction of fuel consumption and air pollution to offer powerful bulky cars to the market.



As in most cases concerning vehicle's modifications, great effort was put to improve car's performances, while nobody was really concerned about fuel economy. Manufacturers started to think about vehicles aerodynamics and drag coefficient when demand for fast cars took priority. Instead of installing bigger and bigger engines in mostly square shaped cars, someone came up with calculation that speed could be achieved by reducing drag coefficient. So, the fuel economy was by product of aerodynamically shaped cars. Let's say that we want to raise the speed of some car from 170 to 190 kilometres per hour without reshaping the body in aerodynamic way. We would need to raise the engine power for about thirty percent. Instead of doing that, we could spend some time in the wind tunnel and calculate how to reduce drag coefficient. Changing the shape of the vehicles asks considerable investment, but building the new engine is investment too. Choosing the body reshape, demand for higher top speed is achieved with the same engine. New body shape will attract more buyers and as by product fuel consumption will be reduced unintentionally. Actually, this is how all this have started concerning drag coefficient in the car industry. Being aware how aerodynamic shape of the body contributes to the car's performances, almost all manufacturers started to make new aerodynamics body designs. There are many examples from seventies onwards which had almost perfect aerodynamics shape with low drag coefficient, but one of the best is Citroen DS.

This perfectly aerodynamically designed car had drag coefficient 0.31. Having in mind that this was family classic car, this drag coefficient value was incredible comparing to the value of Porsche SC which drag coefficient value was 0.30 at that time. Just to know how drastically is drag coefficient reduced on this car, it should be mentioned that other personal vehicles at that time had drag coefficient value between 0.40 and 0.43 or even higher. Beside the perfect body design, some other factors contributed to such low drag coefficient.



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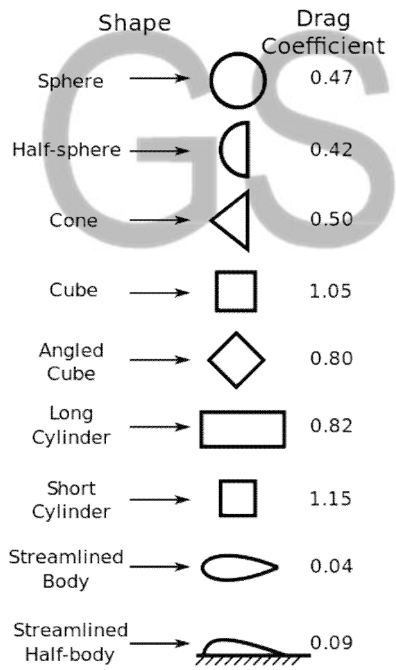
As said, upper part of the car body was perfectly shaped, but air resistance still existed on the car bottom. Vehicle's engine, gearbox, suspension, exhaust and many other parts underneath the car body make resistance to the air which suppose to flow freely without any obstructions which causes air resistance and air turbulence. Citroen DS was one of the first vehicles, commercially manufactured, which had a flat bottom as shown above. Combination of perfectly aerodynamically shaped upper part of the car body and flat bottom with almost no obstacles made pretty good replica of teardrop which drag coefficient is as low as 0.04. Below is the table which shows value of drag coefficients for different shapes of objects.



Measured Drag Coefficients

Of course, there is no way to produce the vehicle which will be hundred percent replica of teardrop without any obstacles. Therefore, Citroen went one step below on upper shown table and made the car body similar to the streamlined half body which suppose to have drag coefficient value 0.09. Such dag coefficient value will be obtainable if there are no number of obstacles which causes air resistance and air turbulence. Such obstacles are: front air opening for engine radiator and engine compartment which are cooled by air, wheel arches, tires, wheel rims openings which help to cool brakes, wings or doors mirrors, doors handles, number of body moulding etc. It is quite evident that Citroen with such shaped body reduced drag coefficient for 25-30 percent compare to the similar size vehicles of that time. Result of such aerodynamically reshaped body was considerably improved performances, as better acceleration and increased top speed. The most important fact is that by products were reduced fuel consumption, compare to other vehicles of similar sizes and engine power, and reduced emission of harmful gases.

Let's see now, where is the problem on today's personal vehicles regarding aerodynamics and drag coefficient? Obviously, there is no problem in knowledge of aerodynamics and testing procedure. Problem lies in market demands for more powerful engines, higher performances, luxurious accessories etc. These demands disenable manufacturers to reduce drag coefficient to its minimum. As mentioned previously, average personal vehicles, of seventies, with mostly square shaped bodies, had drag coefficient value somewhere between 0.40 and 0.43. Today, drag coefficient value of personal vehicle does not differ, at least does not differ much. Let's see some drag coefficient values of today's cars: Ford Explorer II 0.43, Ford Ranger 0.49, GMC Sierra XFE 0.41, Jeep Liberty 0.4, Mercedes SL 600 0,45, Mercedes G Class 0.53, Nissan Murano 4.0, Nissan Terrano 0.44. In the same time, if we see the drag coefficient value of less powerful personal cars, we can notice considerable drop of drag coefficient value. This fact certainly shows how aerodynamic improvement is easily obtainable if vehicle is modestly equipped with engine and accessories.

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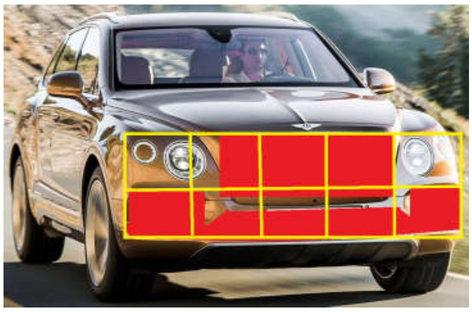

On above photos we see perfectly designed car body. Even aerodynamics form is done perfectly all around, except the front. Now, we are coming to the point explained before. Manufacturer simply could not reshape the front to achieve low drag coefficient as this vehicle needs lot of air to cool the engine radiator, engine compartment, AC radiator, oil radiator and front brakes. If this car was equipped with less powerful engine, smaller amount of air will be needed to cool the engine radiator and engine compartment. Smaller engine gives poorer performances in which case brakes would not radiate so much heat and no extra cooling would be needed. Replacing the compressor air conditioning with simpler system would eliminate need for air flow to cool the AC condenser. These are essential elements which should be respected in order to reduce drag coefficient on the front panel of the vehicle.

On right side of above photos, air openings are marked with reed colour. In the centre of front panel a huge air opening is placed to cool engine radiator, AC condenser and engine compartment. Below is the smaller additional opening to cool oil radiator and other components in engine compartment. On the left and right sides are also quite large air openings foreseen to cool the front brakes. The red area is divided in ten parts by yellow colour. Each yellow square presents ten percent of front panel. With simple calculation we can come to the fact that red area covers about seventy percent of the front panel. Now, we can imagine how great the air resistant is on such flat area. If we use above shown table as a reference, we can conclude that drag coefficient on that flat area, or as stated short cylinder, is 1.15. Even if we consider that thirty percent of air flows freely out through the engine compartment, what is not the case, we still have drag coefficient value of 0.805. Reducing drag coefficient of this huge area to 0.30 will certainly have great contribution to the drag coefficient of the whole vehicle and thus to fuel consumption and air pollution.

1.3.1 Test methodology

Not any physical tests are done as that would require very serious equipment as air tunnel and modified vehicles. But in consideration were taken numbers of tests and results made by independent institutions. All written facts are brought up on the base of physics lows and experience.

1.3.2 Conclusion of chapter 1.3

Anyone who is concerned about vehicle's air pollution will agree with this conclusion. Car manufactures are certainly not concerned about air pollution as they suppose to be. Obviously, profit is above everything else. By reducing the engine power which is absolutely needless on today's roads where top speed is limited, manufacturers will be able considerably reduce drag coefficient value and automatically greatly reduce fuel consumption and emission of harmful gasses. If, by reducing the drag coefficient just for thirty percent, what is possible, and emission of harmful gases is reduced for only ten percent, it would make the big step in resolving air pollution problem. Understanding the difference of drag coefficient value between different vehicles, governments should bring the low which will limit the highest value of drag coefficient. Such law will definitely force the manufacturers to change the technical approach when constructing new car model. With new aerodynamically designed and modestly equipped cars regarding engines, vehicles could still be manufactured very luxuriously to satisfy all customer needs, except the prestige image when car's performances are discussed.

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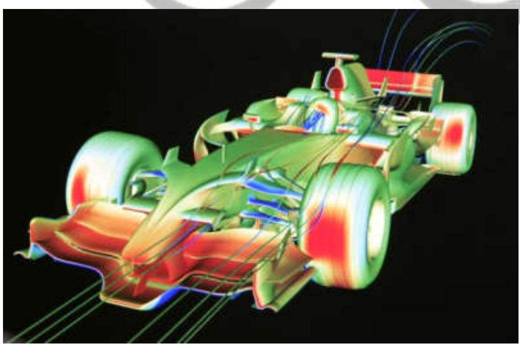
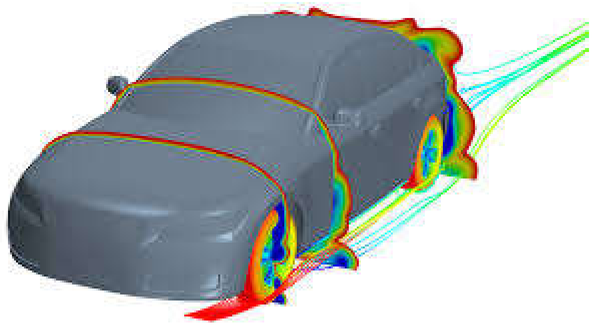
1.4 Tires

Vehicle's tire air resistance cased by its width and friction caused by under-inflation which has very serious influence on increased fuel consumption and emission of harmful gases is never taken as one of the major problems concerning air pollution.

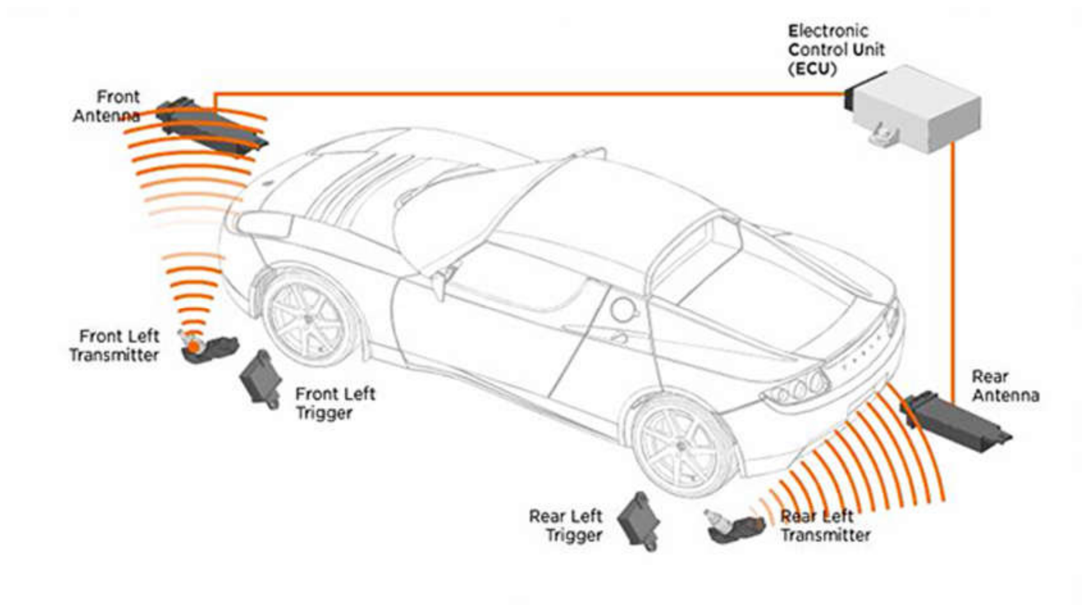
Since yesterday, dimension of tires 195/14/65 was considered as very wide and used on higher class vehicles, while medium class vehicles were mostly equipped with tires sizes 165/13/65. Today's cars are mostly equipped with tire sizes from 195/16/55 to

215/17/50 or even 235/19/50. Undoubtedly, wide tires give a better grip to the road surface and safer driving. On the other hand they have much higher drag coefficient value compare to the narrower tires and does have influence on increased fuel consumption. This could be avoided by reduction of engine power and vehicle's top speed. Increasing the vehicle's top speed, implementation of such wide tires is almost unavoidable. Until yesterday, top speed of average personal car did not exceed 180 km/h and narrower tires were quite safe. Today's cars which achieve top speed up to 300 km/h certainly need wider tires which provides better grip. The question is? Why such powerful cars are manufactured as personal vehicles if top speed is limited, almost all over the world, to 130 km/h. Another words, people who can afford such cars will drive them respecting speed limitation but will burn more fuel and unnecessarily additionally pollute air. Very good example of high drag coefficient value is shown on bellow drawings where we can see air resistance marked in red colour on the tires area.





Under-inflated tires are the most common problem worldwide. Very unfortunate fact is that almost seventy percent of vehicles involved in traffic have at least one tire under-inflated. Numerous tests made by institutions and individuals proofed that ten percent under-inflated tire increases fuel consumption by 2%. Twenty percent under-inflation increase fuel consumption by 4%. An extreme under-inflation of forty percent below factory specifications will increase fuel consumption for as much as 8%. Knowing these facts, we should all be very concerned about emission of harmful gases caused by tires under-inflation. Yes, today's higher class vehicles are equipped with TPCS or tire pressure control system which alarms driver about under-inflated tire. As written in previous chapters when innovations are mentioned, such accessory is point out as advantage in safe driving and rarely as contribution to the green earth.



Let's explain above drawing to see how TPCS works. Inside the each wheel rim, pressure sensor and transmitter is placed. Sensor can be reset to car manufacturer tire pressure specifications. When tire pressure drops below the specified value, transmitter sends the signal via antenna to the electronics control unit which alarms the driver about the low pressure in particular wheel. As mentioned, only higher class vehicles are equipped with this system while middle class cars are not. Beside the original accessory of specific vehicle, TPCS is offered on market as universal accessories which could be easily installed in any car. One of such kits is shown bellow. These kits are inexpensive

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and affordable by any car owner. Even more, some kits are so simple that can be installed by car owner himself. Instead of installing sensors inside the wheel, sensor can be just fixed on existing tire valves.

1.4.1 Test methodology

No special tests are made as they have been done by many institutions which also made very serious calculations mentioned in this chapter. But just in case, to prove the facts mentioned above, we made simple test. One person pushed the average vehicle with properly inflated tires with not difficulties. The same person tried to push the same car with 30% under-inflated tires and could not move the vehicle from its position. This test simply shows what extra power has to be used to drive the vehicle with under-inflated tires.

1.4.2 Conclusion of chapter 1.4

Most of car owners are not technically educated and not aware that under-inflated tires increase air pollution and cost them annually several hundreds dollars regarding increased fuel consumption and rapid tire wear. Informing car owners by media or leaflets about the problems caused by under-inflated tires would be another step forward in reduction of emission of harmful gases. Governments could also do the great job getting involved in this problem by reducing the cost of car insurance policy to the car owners which additionally install the TPCS on theirs vehicles.

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