3C Intelligent Induction Cleaner

Training

Gasoline Direct Injection (GDI) and Carbon Buildup

Anyone familiar with the internal combustion engine understands that these devices produce carbon. This is a result of using hydrocarbon fuel stocks and lubrication oil within the engine. There are many different types of fuels currently used in the U.S. and aboard, however, the two primary fuel stocks used in the U.S. for on-highway transportation are Gasoline and Diesel. Either of these fuel stocks will produce carbon as a result of the combustion process within the cylinder.

The fuel is comprised of chains, rings, and branches of hydrogen and carbon. When fuel reacts with oxygen during the combustion process carbon and hydrogen atoms from the fuel disassociate from one another and form new chemical bonds with oxygen. Hydrogen atoms react with oxygen to form dihydrogen monoxide (H_2O - water), and carbon atoms react with other oxygen to form carbon dioxide (CO_2). If the amount of hydrogen, carbon and oxygen atoms are not in the exact ratio to complete these reactions then some hydrocarbons are not completely combusted. The hydrocarbons that do not combust or do not burn completely either stay as hydrocarbons or form other chemical compounds such as carbon monoxide (CO).

When an organic compound, such as a hydrocarbon based fuel, has a combustion reaction it produces heat. If there is a lack of oxygen during the burning of the fuel then pyrolysis occurs, which is a type of thermal decomposition that occurs in organic materials exposed to high temperatures. Pyrolysis of organic substances, such as fuel and oils, produces gas and liquid products but also a solid residue rich in carbon. Heavy pyrolysis leaves mostly carbon as a residue and is referred to as carbonization. Pyrolysis can occur rapidly or slowly depending on the temperature. An example of slow pyrolysis is the formation of carbon deposits within the induction system of the engine. Lubricating oils and fuels accumulate in the intake system and, when exposed to heat over a period of time, pyrolysis bakes off some of these oils and fuels as light chemicals and leaves heaver chemicals. Over time this becomes heavy carbonization (carbon deposits).

It is important to understand that the carbon produced within an engine is not all the same. The carbon in the combustion chamber is produced under high heat and high pressure. Due to the conditions within the combustion chamber the carbon produced is denser and has low porosity; additionally the carbon thickness is usually low. The carbon that is produced within the induction system is created under very different conditions than the combustion chamber deposits. The carbon in the intake is produced under low heat and low pressure. Due to the conditions within the induction system the carbon produced has high porosity; additionally the carbon thickness can be quite high. Thus due to the conditions that they were produced under, these are two different carbon types.

Another way to produce different carbon types within the engine is the use of different fuel delivery systems. When fueling the engine with a carburetor or port fuel injection the fuel is delivered into the intake manifold of the engine, as illustrated in Figure 1. Thus, the carbon within the intake port area is constantly washed by gasoline. As you already know, gasoline is a very good cleaner and can wash oils and sludge off of parts. Gasoline can remove some of the carbon accumulation from the induction port as well. The gasoline being in contact with the carbon deposit as it is forming will also change the configuration of carbon bonds in the induction system's carbon deposit.

Fig 1

On modern engines that incorporate the method of Gasoline Direct Injection (GDI), the fuel is delivered directly into the combustion chamber as illustrated in Figure 2. Therefore there is no fuel available to wash the carbon deposit in the intake manifold, as occurs with the port fuel injection method. This creates a problem in that the carbon deposits will build without opposition. Additionally the lack of gasoline within the induction system can create a carbon bond configuration that is again quite different. Under these conditions the carbon deposits can become quite large and create drivability problems. On some GDI engines these carbon accumulations that create drivability problems can occur in as little as 15,000 miles. The very design of the GDI engine leads itself to carbon deposit in the induction system. No GDI engine is immune from these inherent carbon deposits.

Fig 2

Some carbon deposits within the GDI intake port area can be as great as 1/4 to 1/2 inch thick as shown in Figure 3. These heavy carbon deposits can cause problems such as; misfiring cylinder(s), hesitation during throttling, low power, rough idle, surging, pinging, fuel trim adaptations, high tailpipe emissions, MAF range or performance DTC, and MAP range or performance DTC.

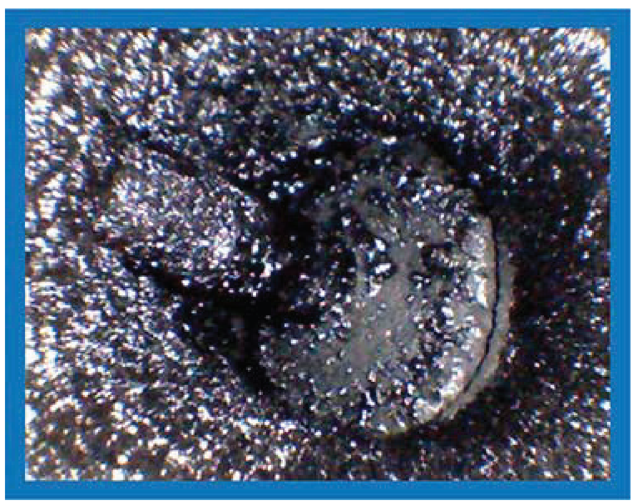

Fig 3

In order to know if there are carbon deposits in the induction system of the engine you are working on, visual inspection using a borescope is the preferred method. One can find an entry point through a vacuum port or by removing a sensor such as the MAP sensor, or IAT sensor. If these will not provide access, with the ignition key off, the throttle plate can be opened and the borescope can be fed through this opening.

The carbon accumulations within the intake port area will create turbulent airflow. Additionally, if the carbon deposits are not deposited uniformly they can create additional turbulent airflow. It is important to understand that these carbon deposits do not need to be heavy in order to create many of these problems. On the GDI engine small carbon accumulations in the intake port area can cause drivability problems. Every racer that has ported heads on a flow bench will attest to the fact that very small changes made within the intake runner and intake port area will create flow differences; both good and bad. These uneven intake carbon accumulations rob power, torque and fuel economy.

The turbulent air caused by carbon deposits is especially harmful in the GDI engine. This can best be understood by analyzing both the port fuel injection and GDI methods. When the port fuel injection method is utilized the fuel is injected directly at the back of the closed intake valve. The intake valve being the hottest part of the intake port, at 400°F to 800°F, will help vaporize some of the fuel so it can burn during the combustion process. Once the fuel is injected the intake valve opens, allowing the Air-Fuel mixture to be mixed by the swirling air movement past the valve. Additionally the piston's upward movement during the compression stroke forces this mixture together further mixing the Air-Fuel charge.

What this accomplishes is a very well mixed Air-Fuel charge that is very close to a truly homogenous mixture, which means that the charge mixture (air and fuel) has a uniform composition throughout the cylinder. When the spark occurs, it takes the fuel beyond its auto-ignition point and the flame front propagates across the combustion chamber. If the Air-Fuel charge is unevenly mixed, the propagation of the flame front will be impeded. This will cause incomplete combustion of the charge. If the Air-Fuel charge is homogenous this flame front will propagate through the combustion chamber allowing complete combustion to occur.

In the GDI engine the fuel is directly injected into the cylinder. With this type of fuel injection there is no ability to premix the Air-Fuel charge prior to the intake valve opening. Additionally the swirl or tumble effect as the intake valve opens cannot be utilized. Therefore the airflow into the cylinder is critical. This airflow must enter the cylinder and swirl correctly in order to catch the aerosolized fuel and completely mix these two components together, as illustrated in Figure 4. Time is another constraint in the mixing of these two components together. There is very little time for the air charge to mix with the fuel delivery, so the conditions must be correct in order to get this event to occur properly.

Fig 4

If the GDI engine's intake port area, and/or intake valve becomes carbonized with deposits to the point where it effects this incoming airflow, then the proper mixing of the air and fuel cannot take place. If this air charge is not properly formed the fuel mixing event will not create a good homogenous mixture which will lead to incomplete combustion.

Since the internal combustion engine is a heat engine, the fundamental operation of the device is the production and use of heat that can then be converted to mechanical energy. In these engines everything that is done prior to the combustion of the fuel type is to set up the Air-Fuel in the cylinder so the charge can be ignited, burned, and combusted. In the spark ignition gasoline engine a well-mixed Air-Fuel blend will have a greater chemical conversion rate during the combustion process. If this mixture is not a homogenous charge the maximum chemical potential will not be converted into thermal energy and hence mechanical energy. Therefore it is imperative to keep carbon accumulations to a minimum in these GDI engines. But how can we accomplished this? Obviously disassembly of the engine and hand cleaning is one possibility. In order to accomplish this the intake manifold will need to be remove from the head. Now that access to the intake port area is provided, rotate the engine until both valves for the port to be cleaned are closed. Now, using a plastic scraper carefully hand scrape the large carbon deposits from the port area. Do not put force behind the scraper. You are just removing the main body of carbon so the media blaster can be more effective. Once you are done use an air nozzle to blow out any remaining carbon from the port. Next, use a walnut shell blaster to clean the remaining carbon from the port area. Clean each cylinder's intake port area while the intake is off. Additionally while the intake manifold is off don't forget to clean the intake runners. GDI engines can have large carbon accumulations within the manifold.

New media and or walnut shell blasters are available and provide good results. However these solutions are time intensive and expensive. Due to these limitations this can only been done when the engine has large carbon accumulations that create severe drivability issues.

Another less labor intensive and less expensive option is to chemically clean these engines. It is always recommended to borescope the induction system before and after a cleaning. Never assume that because the engine has been cleaned that the carbon has been removed. This may allow you to think the carbon is not creating the drivability problem when in fact the carbon has not been change by the cleaning. Over the years chemical cleaning his has proven to not be a very effective method. Anyone that has checked the carbon deposits with a borescope before and after cleaning knows how ineffective the industry chemicals really are. However, there have been recent developments in the chemicals and delivery systems that now provide excellent results on GDI engines. In order to remove these unwanted carbon deposit we need to understand that this is a two part problem. The first problem is the effectiveness of the chemical itself. The second problem is getting the chemical to the carbon deposits. Both the chemical and application method will need to be designed to work together in order to optimize results.

In order to understand how these carbon deposit can be chemically removed we must first understand the carbon itself. The carbon structures that are produced in the GDI are very different from engine to engine. The carbon accumulation within an engine will vary depending on many different variables such as; the type of hydrocarbons the fuel is made of, the detergents added to the fuel base, the type of hydrocarbons the motor oil is made of, the anti-friction additives added into the oil, the operating temperature of the engine, the pressure the carbon is produced under, the load on the engine, the engine drive time, the engine drive cycle, and the engine design. Each of these variables will affect the type of carbon that will be produced and amount of carbon accumulation within the engine.

Perhaps the largest contributor to these GDI carbon accumulations is the engine lubricant. In the GDI engine there are different anti-friction additives put into the oil base. The purpose of these additives is to help the oil during the extreme loads put on the cam lobe that drives the high pressure fuel pump. The engine oil passes into the induction system through the Positive Crankcase Ventilation (PCV) system, along with the anti-friction additives that have been put in the oil base. These oil and anti-friction additives will change the carbon's structure, thus different oils and additive packages will make different carbon types.

Each type of carbon has a different chemical bonding structure that may interact with the cleaning chemical very differently. This means that the chemical will need to be formulated to work on a wide variety of carbon types. The better the chemical is formulated to work on many different carbon types, the better it can remove them from the largest variety of makes and model vehicles. In order to remove multiple carbon types from diverse engines, a new technology has been developed using an entirely new base of chemicals. These new chemicals can rapidly dissolve multiple carbon types within the engine.
The second problem is delivering the chemical to the carbon deposit site. If you have engineered the best chemical and cannot deliver it to the carbon deposit then you still cannot remove the unwanted carbon accumulations.

However, there have been recent developments in the chemicals and delivery systems that now provide excellent results on GDI engines. In order to remove these unwanted carbon deposit we need to understand that this is a two part problem. The first problem is the effectiveness of the chemical itself. The second problem is getting the chemical to the carbon deposits. Both the chemical and application method will need to be designed to work together in order to optimize results.

For the last 30 years the industry standard has been the use of an oil burner nozzle placed in front of the throttle plate as illustrated in Figure 5. The oil burner nozzle provides a fine spray that puts the chemical in an aerosol format needed to keep the chemical suspended in the airflow that is moving into the running engine. The problem is that the nozzle's fine spray is hitting the throttle body and throttle plate. This allows the fine spray to impinge on the throttle components thus no longer being in an aerosol format.

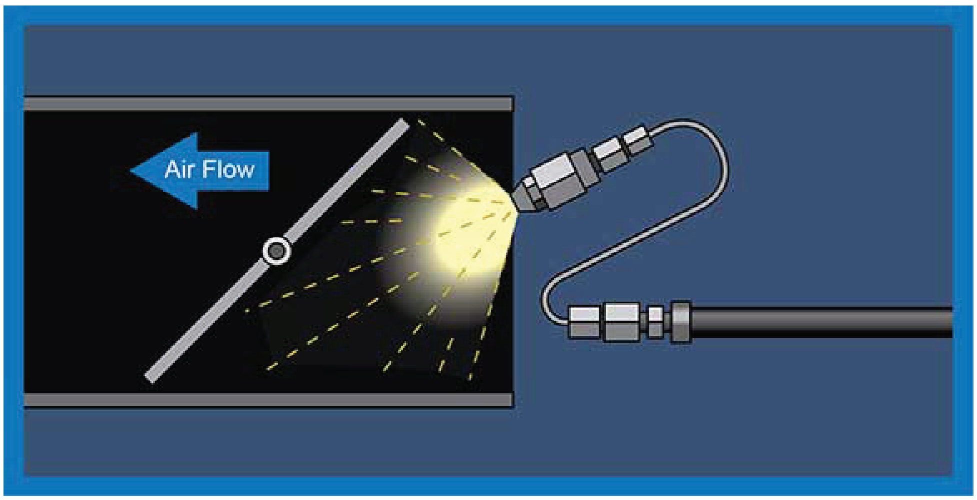

Fig 5

One may think that once the chemical has impinged on the throttle plate and housing and is pulled in to the gap between the throttle bore and throttle plate (shear plain) that the airflow would break these droplets up. However when the chemical enters the shear plain there is turbulent airflow that carries the chemical droplets and redeposits them on the back side of the throttle plate. The chemical droplets then congeal together and become larger. The moving airflow then picks these chemical droplets off of the throttle plate. At this point the droplets are too large to be suspended and carried by the moving air column, so they fall out and pool in the intake manifold. The airflow moving through the engine will drive these pools of chemical along the manifold floor. If the chemical can in fact remove the type of carbon that is in the engine, it will cut a channel through the carbon. This carbon channel will now create turbulent airflow that will cause incomplete combustion events decreasing fuel mileage between 1-3 miles per gallon. This channel can be seen by using a borescope after the cleaning process has been completed. As you can see the chemical must be delivered in a manner that completely covers the entire intake valve and intake port area in order to properly remove the carbon deposits.

Yet another industry standard that has been used for many years to apply chemicals to the engine, is the use of a pressure differential (vacuum) created by the engine. In this method the engine is used to suck the chemical out of a reservoir. These systems use a type of aerator that bleeds air into the chemical flow thus aerating it. Over the years these systems have also been proven to be ineffective. This is because the droplet size produced by this type of device is too large to be suspended and carried by the airflow into the running engine, as illustrated in Figure 6. These chemical droplets will fall out of the airflow and pool in the intake floor thus only cleaning the port floor area, as can be observed by the use of a borescope before and after cleaning.

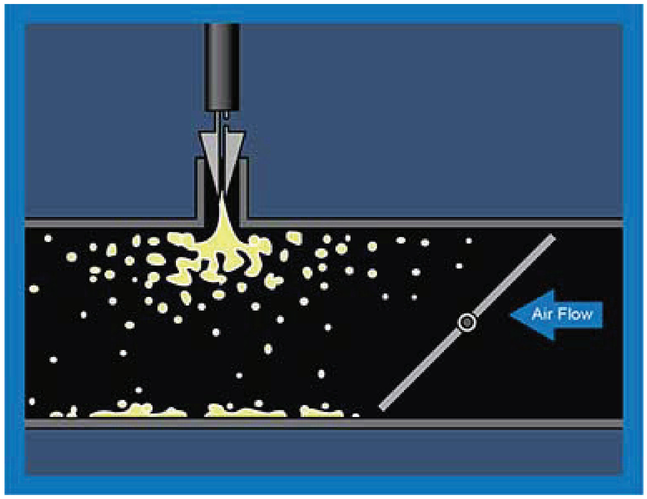

Fig 6

One can clearly see that the chemical will need to be put behind the throttle plate in the form of an aerosol consisting of small droplets of chemical that can be suspended and carried by the moving airflow that will completely cover the intake valve and port area. If the chemical can reach the carbon deposit, and is effective at dissolving the carbon type, the carbon deposit can be removed.

To create this chemical aerosol a high pressure device such as an injector is needed. This must be located behind the throttle plate in order to prevent the chemical from impinging on the throttle components, as illustrated in Figure 7. This will create a chemical aerosol format that the airflow can actually carry. Now that we have addressed the second problem, the application method, it will be important to address what effect the chemical mixture has on your health.

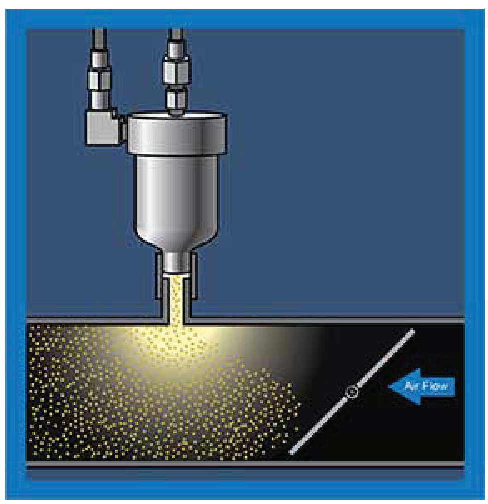

Fig 7

Many of the industry chemicals used are not good for one's health. Take one such chemical that is in many of the industry chemical mixtures, N-methyl-2-pyrrolidne (NMP). This is a known carcinogen that can cause testicular cancer in males. This chemical will also damage the paint and plastic components on the vehicle. So care must be taken when using these chemicals. It is important to always read the Safety Data Sheet (SDS) and to understand what health hazards these chemicals might present. Many of the chemical mixtures commonly used in this industry contain chemicals that are rated at a class 3 or class 4 health hazard in the HMIS system. Always follow the proper safety procedures when handling these type chemicals. At one time it was thought these type chemicals were needed to remove the carbon deposits from the engine. New technology has found less harmful chemical mixtures that can effectively remove carbon deposits without these extreme health hazards.

The gain that chemical cleaning provides on these GDI engines is exponential. The chemical cleaning can remove these unwanted carbon deposits from these GDI engine at a cost effective point. Additionally if you think the carbon deposits are creating a drivability problem you can clean the engine and eliminate the carbon as a possibility without the costly manual cleaning procedure. The GDI engine can now be cleaned as a maintenance service every 30,000 mile thus keeping these unwanted carbon deposits to a minimum so the engine performs at its designed horsepower and torque output. This will add revenue for your shop as well as provide a needed service for your customer. The power and response that a cleaned GDI engine will produce will astound you and your customer.