FUEL SYSTEMS - FUEL INJECTION - PART 1

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INTRODUCTION TO ELECTRONIC FUEL INJECTION

In order to comply with increasingly severe emissions requirements, fuel injection had to be developed to replace carburetors on motorcycles. Nearly 100% of street motorcycles currently manufactured today are fuel injected. Most off-road and all competition motocross motorcycles in the 250cc and 450cc classes are now fuel injected as of 2013.

Carburetors utilize low air pressure in the cylinder, and higher outside atmospheric pressure, during the intake stroke to draw fuel out of the carburetor float bowl through fuel jets. This process supplies the air-fuel mix to the combustion chamber.

The use of vacuum (low air pressure) and fuel jets cannot consistently produce a precise air-fuel mixture that results in the lowest possible emissions after combustion. The result is that carbureted motorcycles are unable to pass increasingly stringent pollution regulations.

Unlike fuel injection systems, carburetors cannot measure changing atmospheric and engine operating conditions that affect the amount of fuel that should be sent to the combustion chamber. This inability to adjust to changing conditions results in carburetors creating an air-fuel mixture that is often too rich. This results in unacceptable levels of emissions from unburned or insufficiently burned fuel.

Carbureted engines simply cannot produce an acceptable low level of emissions with respect to today's strict emissions standards. Carburetors are not smart enough or fast enough to create a perfect combustion mixture thousands of times per minute. For example, an EPA compliant engine turning 5,000 rpm would require 2,500 perfect air-fuel mixtures per minute in a four-stroke engine. That is approximately 41 perfect air-fuel mixtures per second. A carburetor simply cannot meet these requirements.

Electronic fuel injection systems perform precise measurements and analysis of atmospheric and engine operating conditions before choosing a very precise amount of fuel to send to the combustion chamber. This precise air-fuel ratio results in a combustion that produces the lowest possible emissions.

The measurement of atmospheric and engine conditions with fuel injection is accomplished through electronic sensors. Sensor data is collected and analyzed by the onboard computer – the electronic control module (ECM), also called an electronic control unit (ECU).

After analyzing sensor data, the ECM decides exactly how much fuel is needed in the combustion chamber. The ECM then controls how long the fuel injector is turned on, depending on how much fuel is needed for combustion. The fuel is then injected directly into the intake port of each cylinder.

As illustrated earlier, with 5,000 rpm of the crankshaft per minute there are 2,500 full completions of the four strokes in the four- cycle engine. This equates to 41 combustions per second. Consider the fact that the ECM must gather and analyze sensor data for each of the 41 combustions that take place each second. This means the ECM has only a few thousandths of a second to gather and analyze sensor data before choosing the amount of injector on-time, and then turn the injector on and off in those fractions of a second.

The job of the ECM in the fuel injection system is truly huge in scope, and the above example only considers the processing speed required at 5,000 rpm. Modern sport bikes redline at roughly 14,000 rpm.   The extreme processing speed required of an ECM at these rpms is phenomenal.

HISTORY AND DEVELOPMENT OF FUEL INJECTION

In 1980 Kawasaki produced the first production motorcycle with fuel injection – the KZ 1000. Other manufacturers also dabbled with fuel injection in the 1980's, but fuel injection was not yet mandated due to emissions regulations, and carburetors were still cheaper to produce.

In the 1980's computer speed was slow, and computer memory was not only expensive but it also took up too much physical space.

Throughout the 1980's just about every motorcycle manufacturer had produced at least one fuel injected motorcycle. However, BMW and Ducati seemed to have had the earliest and most continuous success with fuel injection. BMW produced the K100 model with a Bosch fuel injection system from 1983 through the mid 1990's. Ducati produced the 851 model from 1987 through 1992 with a Magnetti Marelli fuel injection system.

By the beginning of the 1990's, most cars were fuel injected but the vast majority of motorcycles were still using carburetors. In the mid 1990's Harley Davidson began using fuel injection on their touring models, and by the early 2000's sport bikes were beginning to use fuel injection. By 2010 all street bikes were required to have fuel injection, and as of 2013 all competition motocross bikes in the 250cc and 500cc race classes, from the four major Japanese manufacturers, are equipped with fuel injection.

AIR DENSITY AND FUEL INJECTION

In addition to choosing the amount of fuel to be injected, and the timing of the injection, the ECM must also measure the volume of the air going into the engine. In order to compute the volume of air going into the engine, the ECM must analyze the quality of the air – simply referred to as the air density. Air density information is calculated by gathering information on air pressure, air temperature, and humidity.

The ECM also uses other sensors to help measure the volume of air going into the combustion chamber. These sensors such as throttle position and engine speed will be discussed later.

Air Pressure

There are various terms referring to air pressure that can seem confusing. Air pressure is often referred to as: atmospheric pressure, barometric pressure, ambient air pressure, air density, or simply air pressure.

Let’s talk first about atmospheric pressure. The air of the earth’s atmosphere is pulled down by gravity and this creates weight or pressure as the air sits on the earth and on the oceans.

Atmospheric pressure is defined as the force per unit area exerted against a surface by the weight of air above that surface in the atmosphere of earth.

Areas experiencing low-pressure have less atmospheric mass above their location. Areas experiencing high-pressure have more atmospheric mass above their location.

The amount of air pressure changes depending on where in the atmosphere the air pressure is measured. The higher above the earth’s surface that air pressure is measured, the more the air pressure will decrease. At high altitude the air is “thin”, lighter in weight - there is less atmospheric mass. High altitudes experience lower air pressures.

At higher altitudes, there is less density of oxygen molecules in the air and therefore less fuel is needed to match the lesser quantity of oxygen in a certain volume of air – with respect to air-fuel mixtures. For example, less fuel will be needed if a motorcycle is being operated high in Colorado at an altitude of 12,000 feet, as compared to the amount of fuel needed in Florida at an altitude of 20 feet near the coast.

At lower altitudes oxygen molecules are packed more densely together, the air is “thicker”, heavier in weight - there is more atmospheric mass. Lower altitudes experience higher air pressure. More fuel is needed to match the greater quantity of oxygen in a certain volume of air. More fuel will be needed if a motorcycle is being operated at nearly sea level in Florida, compared to the amount of fuel needed if the motorcycle were being operated high in Colorado.

Fuel injection systems take atmospheric pressure into consideration when computing the amount of fuel needed to match the volume of air in the combustion chamber.