Selective Catalytic Reduction Used In Euro-5 Engines

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Abstract—This SCR is a technology that uses a urea based diesel exhaust fluid (DEF) and a catalytic converter to significantly reduce oxides of nitrogen (NOx) emissions. SCR is the leading technology being used to meet 2010 emission regulations. The purpose of the SCR system is to reduce levels of NOx (oxides of nitrogen emitted from engines) that are harmful to our health and the environment. SCR is the after treatment technology that treats exhaust gas downstream of the engine. Small quantities of diesel exhaust fluid (DEF) are injected into the exhaust upstream of a catalyst, where it vaporizes and decomposes to form ammonia and carbon dioxide. The ammonia (NH3) is the desired product which in conjunction to the SCR catalyst, converts the NOx to harmless nitrogen (N2) and water (H2O).

Index Terms— DEF, SCR, Ad Blue

1. Introduction

SELECTIVE Catalytic Reduction is a technology that injects urea – a liquid-reluctant agent – through a catalyst into the exhaust stream of a diesel engine. The urea sets off a chemical reaction that converts nitrogen oxides into nitrogen and water, which is then expelled through the vehicle tailpipe. While urea is the primary operating fluid presently used in SCR systems, alternatives to the urea agent are currently being explored. One option involves the use of diesel fuel to transform NOx into harmless gases.

SCR technology is one of the most cost-effective and fuel-efficient technologies available to help reduce emissions. SCR can reduce NOx emissions up to 90 percent while simultaneously reducing HC and CO emissions by 50-90 percent, and PM emissions by 30-50 percent. SCR systems can also be combined with a diesel particulate filter to achieve even greater emission reductions for PM. SCR technology may play a key role in achieving emissions reductions that allow light-duty diesel vehicles to meet the new, lower EPA emissions regulations to be phased in through 2015 and potentially expand the diesel vehicle sales market to all 50 states.

2. What Is SCR?

Selective catalytic reduction (SCR) is a means of converting nitrogen oxides, also referred to as NO_x *with* the aid of a catalyst into diatomic nitrogen, N_2, and water, H_2O. A gaseous reluctant, typically anhydrous ammonia, aqueous ammonia or urea, is added to a stream of flue or exhaust gas and is absorbed onto a catalyst. Carbon dioxide, CO_2 is a reaction product when urea is used as the reluctant. Selective catalytic reduction of NO_x using ammonia as the reducing agent was patented in the United States by the Engelhard Corporation in 1957. Development of SCR technology continued in Japan and the US in the early 1960s with research focusing on less expensive and more durable catalyst agents. The first large scale SCR was installed by the IHI Corporation in 1978. Commercial selective catalytic reduction systems are typically found on large utility boilers, industrial boilers, and municipal solid waste boilers and have been shown to reduce NO_x by 70-95%. More recent applications include diesel engines, such as those found on large ships, diesel locomotives, gas turbines, and even automobiles. Selective Catalytic Reduction (SCR) is a method of converting harmful diesel oxides of nitrogen (NOx) emissions, by catalytic reaction, into benign nitrogen gas and water. SCR can deliver near-zero emissions of NOx, an acid rain and smog-causing pollutant and greenhouse gas, in modern highway clean diesel engines. The SCR system does not alter the design of the modern Common Rail Diesel (CRD) engine; therefore it can continue to deliver excellent fuel economy and durability. Rather, SCR provides emissions after-treatment well into the exhaust stack, in a way similar to the soot containment achieved by the Diesel Particulate Filter (DPF). SCR works by injecting Diesel Exhaust Fluid (DEF), such as Ad Blue, into the hot exhaust stack. DEF works in conjunction with the hot exhaust gases and catalyst to break NOx into two components of our normal atmosphere—water vapour and nitrogen.

The SCR technology for reducing nitrogen oxides (NOx) Finds applications worldwide as an after treatment system for power plants and waste furnaces. Ammonia (NH3) could also be used directly as a reagent, but the solution of urea in water is by far the best reagent since it is a non-toxic product and there are no restrictions for its transport on rail, road or ships. The SCR technology, by converting directly NOx to N2 outside the engine, allows the retaining of the engine calibrations, which correspond to the best compromise between fuel consumption and the formation of pollutants during the combustion process.

1. The engine produces toxic NOx (Nitrogen Oxide)

2. The NOx reduction process takes place in an SCR Catalyst, integrated in the exhaust silencer
3. An additive, called Ad Blue is injected in the SCR Catalyst
4. Ad Blue converts the NOx in the exhaust gases to water and nitrogen

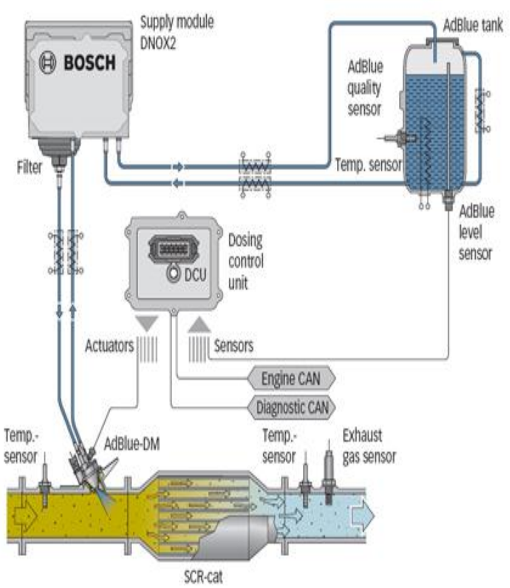

Figure 1: Working Of SCR

Figure 1 shows the layout of a complex SCR system (some components, such as the oxidation catalysts, are optional parts of a SCR system), using a 32.5 % urea solution in water as reagent whilst figure 4 lists the Various chemical reactions, which occur along the system. SCR is an after treatment method that requires a urea based additive, Ad Blue, to reduce emissions. Ad Blue may also need to be filled when the vehicle is refueled. An additional tank is required for Ad Blue. Ad Blue is injected in the exhaust to maintain a reaction in the catalytic converter, which is integrated in the silencer. This after treatment method is used to reduce NOx.

The fig shows the working of scr in which there are different types of component are present like supply module, dosing control unit, Ad Blue tank & various types of sensors are present. The working of each component is explained below:

1. Dosing Control Unit: - this units control the amount of urea & water mixture which will be spread on the Exhaust gas which is coming from the engine.
2. Supply Module: - This units pressurizes the mixture of urea and water by the help of a small electric motor This helps to run the compressor.
3. Ad-Blue Tank: - It is a device in which we can store the urea and water mixture.
4. Temperature Sensor: - It senses the temperature of out coming gases and supplies the data to supply module from which the supply module decides that how many pressure required for the spray on exhaust gas.
5. Exhaust Gas Sensors: - this sensor senses the amount of the NOx & No2 from the exhaust gases & send the feedback towards dosing control unit. From this data supply module controls the supply of urea & water mixture.

3. How it Works?

Ways to reduce nitrogen oxide emissions In order to comply with the increasingly tough emission standards worldwide, engine manufacturers are forced not only to substantially reduce emissions of particulate matter (PM), but also emissions of nitrogen oxides. The main approach pursued by MTU is low-emission combustion, in other words an internal engine solution. However, this means taking into account a basic principle that governs the process of combustion — if the fuel burns at a higher temperature inside the cylinder, little soot is produced, but a large amount of nitrogen oxide. At lower combustion temperatures, nitrogen oxide emissions are low, but the production of soot particulates is high. To find the right balance, therefore, all the key technologies that affect combustion must be perfectly matched. When combined with fuel injection and turbo charging in particular, the use of exhaust gas recirculation results in a combustion process that produces significantly lower levels of nitrogen oxide.

The term Selective Catalytic Reduction (or SCR) is used to describe a chemical reaction in which harmful nitrogen oxides (NOx) in exhaust gas are converted into water (H2O) and nitrogen (N2). In combination with internal engine technologies, such as exhaust gas recirculation (EGR), extremely low nitrogen oxide emissions can be achieved with low fuel consumption. SCR
Using a 32.5 % urea solution in water as reagent whilst figure 4 lists the various chemical reactions, which occur along the system. The SCR technology for reducing nitrogen oxides (NOx) finds applications worldwide as an after treatment system for power plants and waste furnaces. Ammonia (NH3) could also be used directly as a reagent, but the solution of urea in water is by far the best reagent since it is a non-toxic product and there are no restrictions for its transport on rail, road or ships. Furthermore, urea is a product largely used in agriculture and in industry and urea of various quality grades is readily available. An oxidation catalyst may be used to improve the efficiency of the SCR by converting NO into NO2 and by oxidizing CO and hydrocarbons. Accurate dosing of the urea solution and appropriate strategies during transient modes prevents an NH3 slip. The SCR technology, by converting directly NOx to N2 outside the engine, allows the retaining of the engine calibrations, which correspond to the best compromise between fuel consumption and the formation of pollutants during the combustion process.

SCR also uses in boiler for reducing the percentage of Nox2.

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The retrofitting of power plants with NOx control technologies is a cost-intensive undertaking facing many utilities. Key to controlling the economic impact to the utility is the effective execution of these projects. B&W has successfully designed and installed a number of Selective Catalytic Reduction systems for both gas- and coal-fired boilers. The success of these installations is a direct result of the key decisions made during and the integrated techniques applied to the design and installation of these systems. The systems are comprised predominantly of flues, ducts, structural steel, reactors, catalyst, and ammonia systems, but may also need to include modifications to the existing boiler or its ancillary equipment.

4. WHAT IS AD BLUE?

Ad Blue – commercial designation of the 32.5% urea solution used as reagent in vehicles equipped with SCR systems. Today's trucks with SCR technology in Euro 5 consume between 1.5-2 liters of Ad Blue per 100 KM. This is an equivalent to 5.5% Ad Blue of total fuel consumption. Availability of public Ad Blue infrastructure at gas stations is currently rapidly developing. Additionally, 10 liter canisters are procurable at many gasoline stations. For fleet operators it is not uncommon to rely on standardized containers (i.e. 1,000 liter bulk containers IBC) deposited on the fleet's premises. Truck drivers refuel Ad Blue when returning to their home base. Ad Blue prices vary between 0, 29 €/liter and 0, 43 €/liter for 1,000 liter containers up to 0,6 €/liter at public gas stations. Due to numerous Ad Blue producers further price deterioration is expected. Ad Blue is a 32.5% solution of urea (ammonia) in distilled water.

- **How do I obtain Ad Blue?**

Ad Blue is available at many petrol stations In normal practice fuel and Ad Blue are filled up in one stop. For many operators storage of Ad Blue at their own premises is a good solution.

- **Can I keep my own Ad Blue stocks?**

Several ready-made storage systems for private use are available and since there are no special legal or environmental requirements regarding storage of Ad Blue, this is one of the most cost effective ways to maintain stocks.

- **Does DAF supply Ad Blue?**

Through the DAF TRP program Ad Blue is available in 500 and 18 liter cans at every workshop. The five liter can may easily be stored (cab external locker) and covers at least 5of operating rang.

- **How do I know if the Ad Blue is the right quality?**

The required Ad Blue quality according to DIN 70 070 and ISO 22241 must be indicated at the Ad Blue station and on the Ad Blue containers.

- **How do I fill up with Ad Blue?**

Ad Blue is filled in a separate tank on the vehicle. A special nozzle on the filling hose prevents inadvertent filling of the tank with diesel fuel or any other liquid.

- **What if I do not fill up with Ad Blue?**

Without Ad Blue the legal engine torque limitation (OBD) will be activated and will remain so until the Ad Blue tank is filled again. Impure Ad Blue or any other liquid will have the same result and moreover may cause degradation of the SCR catalyst.

- **What if I spill Ad Blue during storage or filling up?**

Ad Blue is non-toxic, not hazardous and not environmentally damaging. Simply rinse away with water.

- **How much Ad Blue do I need?**

The Ad Blue consumption is approx. 1.5 liters per 100 km for a Euro 5 engine. DAF vehicles have Ad Blue tanks that are large enough to avoid additional stops for filling Ad Blue between the regular refueling stops.

- **Does an Ad Blue system need extra maintenance?**

Ad Blue filters need to be changed on the normal service intervals. Otherwise the system is virtually maintenance free if used properly.

- **Can Ad Blue freeze in the tank?**

In operational conditions the SCR system remains active, regardless the ambient temperature. In extreme cold conditions, Ad Blue forms a gel-like consistency, similar to freezing diesel fuel. When this occurs, there is no Ad Blue injection until the Ad Blue defrosts as the exhaust silencer warms up.

The system's behavior in cold conditions is in accordance with the legal requirements and forms part of the vehicle's homologation. Ad blue freezes at -11.5degree c.

- **Do I ever need to replace the silencer with the SCR unit?**

The integrated silencer/SCR catalyst is made from stainless steel and will last for the lifetime of the engine if correctly used.

- **A few facts about Ad Blue and urea**

Ad Blue is a stable, colorless, water-like fluid. 32.5% of its content is urea, the rest is demonized water. Ad Blue is not classified as hazardous to health. Nor is the fluid flammable or explosive. It is not subjected to any special restrictions for handling or transport. Ad Blue is quality-assured and meets DIN 70070 standard. Urea is made of ammonia and carbon dioxide. It is used as an artificial fertilizer, in skin lotions and other products.

5. Before "SCR" "EGR" is the most effective Technique

A widely adopted route to reduce NOx emissions is Exhaust Gas Recirculation (EGR). This involves recirculating a controllable proportion of the engine's exhaust back into the intake air. A valve is usually used to control the flow of gas, and the valve may be closed completely if required.

The substitution of burnt gas (which takes no further part in combustion) for oxygen rich air reduces the proportion of the cylinder contents available for combustion. This causes a correspondingly lower heat release and peak cylinder temperature, and reduces the formation of NOx. The presence of an inert gas in the cylinder further limits the peak temperature (more than throttling alone in a spark ignition engine).

Advantages of EGR

1. Reduced NOx
2. Potential reduction of throttling losses on spark ignition engines at part load
3. Improved engine life through reduced cylinder temperatures (particularly exhaust valve life)

Disadvantages and Difficulties of EGR

Since EGR reduces the available oxygen in the cylinder, the production of particulates (fuel which has only partially combusted) is increased when EGR is applied. This has traditionally been a problem with diesel engines, where the trade-off between NOx and particulates is a familiar one to calibrators.

The deliberate reduction of the oxygen available in the cylinder will reduce the peak power available from the engine. For this reason the EGR is usually shut off when full power is demanded, so the EGR approach to controlling NOxfails in this situation.

The EGR valve cannot respond instantly to changes in demand, and the exhaust gas takes time to flow around the EGR circuit. This makes the calibration of transient EGR behavior particularly complex- traditionally the EGR valve has been closed during transients and then re-opened once steady state is achieved. However, the spike in NOx / particulate associated with poor EGR control makes transient EGR behavior of interest.

The recirculated gas is normally introduced into the intake system before the intakes divide in a multi-cylinder engine. Despite this, perfect mixing of the gas is impossible to achieve at all engine speeds / loads and particularly during transient operation. For example poor EGR distribution cylinder-to-cylinder may result in one cylinder receiving too much EGR, causing high particulate emissions, while another cylinder receives too little, resulting in high NOx emissions from that cylinder.

Although the term EGR usually refers to deliberate, external EGR, there is also a level of internal EGR. This occurs because the residual combustion gas remaining in the cylinder at the end of the exhaust stroke is mixed with the incoming charge. There is therefore a proportion of internal EGR which must be taken into account when planning EGR strategies. The scavenging efficiency will vary with engine load, and in an engine fitted with variable valve timing a further parameter must be considered.

5. CHEMISTRY BEHIND THE SCR.

The NO_x reduction reaction takes place as the gases pass through the catalyst chamber. Before entering the catalyst chamber the ammonia, or other reductant (such as urea), is injected and mixed with the gases. The chemical equation for a stoichiometric reaction using either anhydrous or aqueous ammonia for a selective catalytic reduction process is:

$$4NO + 4NH_3 + 3O_2 \rightarrow 4N_2 + 6H_2O$$

$$2NO_2 + 4NH_3 + 3O_2 \rightarrow 3N_2 + 6H_2O$$

$$NO + NO_2 + 2NH_3 \rightarrow 2N_2 + 3H_2O$$

With several secondary reactions:

$$2SO_2 + O_2 \rightarrow 2SO_3$$

$$2NH_3 + SO_3 + H_2O \rightarrow (NH_4)_2SO_4$$

$$NH_3 + SO_3 + H_2O \rightarrow NH_4HSO_4$$

The reaction for urea instead of either anhydrous or aqueous ammonia is:

$$4NO + 2(NH_2)_2CO + O_2 \rightarrow 4N_2 + 4H_2O + 2CO_2$$

The ideal reaction has an optimal temperature range between 630 and 720 K, but can operate from 500 to 720 K with longer residence times. The minimum effective temperature depends on the various fuels, gas constituents and catalyst geometry. Other possible reductant includes cyan uric acid and ammonium sulfate.

6. CONCLUSION

Due to increased environmental awareness and consciousness that pollution from cars and commercial vehicles cause many of today’s health problems, the cleansing of exhaust gas becomes more and more important all over the world. An SCR system can remove as much as 90 percent of the nitrogen oxides from the exhaust gas. In addition, the engine can be configured for very low particulate emissions. That ensures compliance with stringent emission limits for diesel engines. At the same time, operators save on fuel costs with an SCR system, because internal engine parameters can be configured for ultra-low fuel consumption. Compliance with extremely low emission limits, however, requires a combination of internal engine optimization using exhaust gas recirculation and external optimization by means of exhaust after treatment with an SCR catalytic converter and, if necessary, a diesel particulate filter.

As a result of the tightened emission regulation more and more technological complex and expensive exhaust treatment components are introduced in commercial vehicles. In the EU SCR and EGR technology have been marketed to achieve conformity of Euro 4 and even Euro 5 emission standards. Whilst it appears that SCR is favored by most commercial vehicles manufacturers and thus customers although it is the more complex technological system.

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