POWERED BY

ARENARED

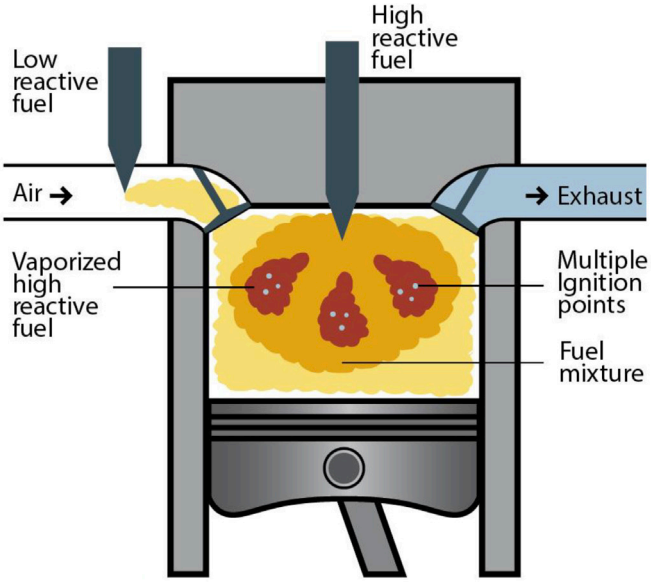
ENGINE MANAGEMENT SYSTEMS

RCCI

REACTIVITY CONTROLLED COMPRESSION IGNITION

GENERAL

RCCI, REACTIVITY CONTROLLED COMPRESSION IGNITION, IS A COMBUSTION CONCEPT THAT CAN BE CONSIDERED AS A HYBRID BETWEEN SPARK IGNITION (SI) (OTTO) (GASOLINE) AND CONVENTIONAL DIESEL COMBUSTION ALSO CALLED COMPRESSION IGNITION (CI). THIS COMBUSTION CONCEPT IS THE TECHNICALLY VIABLE ALTERNATIVE TO HOMOGENEOUS CHARGE COMPRESSION IGNITION (HCCI). BOTH PRINCIPLES ACHIEVE A VERY HIGH EFFICIENCY WITH UTRA-LOW EMISSIONS, PREVENTING THE NEED FOR EXHAUST GAS AFTER TREATMENT LIKE AN SCR AND SO UREA IS NOT NEEDED TO ACHIEVE EURO-6D OR CALIFORNIAN EMISSION LEGISLATION.



Efficiency >50% **Euro-6** **Stage-V**

FUELS AND INJECTORS

RCCI IS ALWAYS OPERATED WITH AT LEAST TWO DIFFERENT FUELS WITH DIFFERENT REACTIVITY, ONE HIGH OCTANE FUEL LIKE HYDROGEN, BIOGAS, ETHANOL AND METHANOL, HEREINAFTER CALLED 'H2' AND ONE LOW OCTANE FUEL LIKE DIESEL, BIODIESEL, GTL, OME3-5, OR ETHANOL WITH CETANE BOOSTER, HEREINAFTER CALLED 'OME-D'. THE OME-D IS TYPICALLY DIRECT INJECTED, THIS TO BE ABLE TO COLD START IN DI MODE AND SHIFT TO RCCI MODE AFTER 10 SECONDS. BESIDE THIS IT'S POSSIBLE OPERATE ON OME-D ONLY IF H2 IS NOT AVAILABLE OR TOO EXPENSIVE. THE H2 CAN BE INJECTED PORT FUEL WHICH MEANS BEFORE THE INTAKE VALVE OR SINGLE POINT WHICH MEANS THERE IS ONLY ONE INJECTOR FOR THE ENTIRE ENGINE, THIS INJECTOR CAN BE PLACED BEFORE THE TURBO TO ALLOW LOW PRESSURE (1,05 BAR) GASEOUS FEED.

RCCI

MIXING AND EMISSIONS

THE H2 HAS WELL MIXED WITH THE AIR ENTERED THE COMBUSTION CHAMBER, THE OME-D WIL NOW BE INJECTED TYPICALLY FOR RCCI 100º BEFORE TOP DEAD CENTRE OF THE PISTON CRANK MOVEMENT, THIS ALLOWS THE H2 TO MIX WELL WITH THE H2-AIR MIXTURE ENABLING BOTH FUELS TO COMBUST BASED ON COMPRESSION 20 BEFORE THE TOP DEAD CENTRE ON 1.000 SPORTS SIMULTANEOUSLY LIKE 1.000 SPARK PLUGS CREATING AN EXTREME STRONG IGNITION. WITHOUT HOTSPOT OF FUEL DROPLETS LIKE IN A CONVENTION DIESEL HAPPENS ELEMENATING NOx AND SOOT AND CREATING HIGH POWER AND HIGH EFFICIENCY.

RCCI TIMING TROUGH REACTIVITY CONTROL

WHEN THE MIXTURE IGNITES 2 DEGREES TOO EARLY, THE ARENARED CPBC SENSOR AND CHIP DETECT THIS AND LOWER THE OME-D FRACTION FROM 1% TO 0,98% AND THIS THAN MOVES THE IGNITION BACK TO ITS SET POINT SAY 2 DEGREES BEFORE THE TOP DEAD CENTRE.

HIGH EFFICIENCY

THE MAIN REASON WHY RCCI IS EXCEPTIONALLY EFFICIENT, IS THAT THE HEAT RELEASE OF THE COMBUSTION HAS A HIGH DEGREE OF CONTROLLABILITY, WHICH MEANS THAT THE THERMODYNAMIC EFFICIENCY CAN BE FULLY OPTIMIZED. TO DAMP (SLOW DOWN) THE CHEMICAL REACTIONS WE OPERATE THE ENGINE IN LEAN BURN WHICH ALSO REDUCES THE HEAT LOSSES. WHEN RUNNING CI, A LOT OF THE HEAT IS TRANSFERRED TO THE CYLINDER WALLS BECAUSE OF HIGH PEAK TEMPERATURES OF BURNING DIESEL SPRAYS. RCCI OPERATES WITH A MORE HOMOGENEOUS MIXTURE RESULTING IN A MORE HOMOGENEOUS TEMPERATURE DISTRIBUTION IN THE CYLINDER, WHICH LEADS TO LOWER HEAT LOSSES. ARENARED ACHIEVED AN EFFICIENCY OF TYPICALLY 10% (10 TO 15%) HIGHER THAN DIESEL ONLY.

LOW EMISSIONS

THE LEAN AND HOMOGENEOUS BURN WHEN USING RCCI, IS THE MAIN REASON THE PEAK TEMPERATURES CAN BE KEPT LOW, WHICH RESULT IN VERY LOW NOx EMISSIONS. THE PREMIXED LEAN COMBUSTION OF RCCI RESULTS IN AN EXCEPTIONALLY LOW SOOT EMISSION. THE HIGH CONTROLLABILITY GIVES ARENARED THE ABILITY TO CONTROL THE PEAK CYCLE TEMPERATURE WHICH DETERMINES THE CARBON MONOXIDE (CO) AND METHANE (CH4) EMISSIONS. ARENARED ACHIEVED STAGE V COMPLIANT EMISSIONS ON THE DOCAT 3500AR ENGINE WITHOUT SCR UREA EXHAUST GAS AFTER TREATMENT. ARENARED CAN ACHIEVE EURO-6D EMISSION STANDARDS WITHOUT SCR UREA EXHAUST GAS AFTER TREATMENT. ANOTHER WAY TO EXPLAIN WHY RCCI IS SO CLEAN IS TO SAY THAT IN A NORMAL DIESEL ENGINE THE DIESEL IS IGNITED AND BURNED FROM THE LIQUID PHASE OF THE DIESEL FRACTION AND IN RCCI MODE IS THE DIESEL IGNITED AND BURNED FROM THE GAS PHASE.

FLUED STAGE

IN A MODERN DIESEL ENGINE FLUED DIESEL IS BEEN INJECTED AND BURNED STARTING AT TYPICAL 17 DEGREES BEFORE TOP DEAD CENTRE. THE MOMENT THE DIESEL IS INJECTED IT STARTS TO BURN AND THIS GIVES THE DETERMINED TIMING OF THE DIESEL ENGINE. THE HOT SPOT BURNING OF THE DIESEL IN THE FLUED STAGE ALSO CAUSES NOx AND SOOT. THE END OF THE COMBUSTION IS TYPICALLY 40 DEGREES AFTER THE TOP DEAD CENTRE.

RCCI

LIQUID STAGE

IN A RCCI ENGINE THE TYPICAL 1% DIESEL IS INJECTED 100 DEGREES BEFORE TOP DEAD CENTER AND VAPORIZES ENTIRELY. THAN THIS GASEOUS DIESEL IS MIXED WITH THE OTHER FUEL AND AIR AND IGNITES BASED ON COMPRESSION ON COUNTLESS PLACES AT THE SAME TIME. THIS GIVES THE RCCI COMBUSTION ENORMOUS POWER, HIGH FUEL EFFICIENCY, COMBUSTION WITHOUT HOT SPOTS, LOW NOx AND NO COMBUSTION FROM THE FLUED STAGE BUT ONLY FROM THE GAS STAGE GIVING ZERO SOOT.

SINGLE FUEL RCCI

RCCI HAS TO BE OPERATED WITH TWO DIFFERENT FUELS, ONE HIGH OCTANE FUEL AND ONE LOW OCTANE FUEL. IN AUTOMOBILE APPLICATIONS THIS CAN BE SEEN AS CUMBERSOME AND CAN DISCOURAGE PEOPLE TO CHOOSE FOR AN ENGINE RUNNING RCCI. A SOLUTION IS THAT FOR A HIGH OCTANE FUEL IS USED FOR BOTH INJECTIONS, BUT THAT A CETANE-BOOSTER IS ADDED TO THE DIRECT INJECTED FUEL TO INCREASE REACTIVITY. THE ADDED CETANE-BOOSTER REQUIRES A REFILL OF 5 LITERS EVERY OIL CHANGE, WHICH COULD BE DONE BY THE CAR MECHANIC. IN THIS WAY THE CAR OWNER HAS ALL THE BENEFITS OF OWNING A VEHICLE OPERATING RCCI WITHOUT HAVING TO WORRY ABOUT FUELING TWO DIFFERENT FUELS.

THE HISTORY OF RCCI

RCCI IS A DUAL FUEL ENGINE COMBUSTION TECHNOLOGY THAT WAS DEVELOPED AT THE UNIVERSITY OF WISCONSIN-MADISON ENGINE RESEARCH CENTER LABORATORIES UNDER THE SUPERVISION OF DR. REITZ. RCCI IS A VARIANT OF HOMOGENEOUS CHARGE COMPRESSION IGNITION (HCCI) THAT PROVIDES MORE CONTROL OVER THE COMBUSTION PROCESS AND HAS THE POTENTIAL TO DRAMATICALLY LOWER FUEL USE AND EMISSIONS WHILE INCREASING EFFICIENCY. RCCI USES IN-CYLINDER FUEL BLENDING WITH AT LEAST TWO FUELS OF DIFFERENT REACTIVITY AND MULTIPLE INJECTIONS TO CONTROL IN-CYLINDER FUEL REACTIVITY TO OPTIMIZE COMBUSTION PHASING, DURATION AND MAGNITUDE.