

NEW CONCEPTS TO AVOID UNWANTED POLLUTANTS FROM D.I. DIESEL ENGINES IN PASSENGER CARS

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Abstract

The self ignition process in Diesel engines with direct injection takes place simultaneously with the disintegration of the injected fuel together with the evaporation of the sprays and the droplets. With shorter ignition delays it is possible to improve the combustion process and reach higher efficiencies of the engine. Also a partly homogeneous combustion could be established in order to reach less formation of soot and NO_x . One way to create this favourable combustion process is to work with a ring piston, which allows to achieve two different compression ratios: a higher one in the ring area for self ignition of the Diesel spray and a lower one for the homogenous combustion in the central main chamber. Another way is a double injection into the main chamber, one for ignition, the other for combustion of the major fuel, which must be injected at the beginning of the compression phase. The first concept uses the common rail injector, the last one the VW unit injector. Both concepts need no particle filter or oxi-cat for the fulfilment of emission regulations.

1. The two different combustion processes [1, 2]

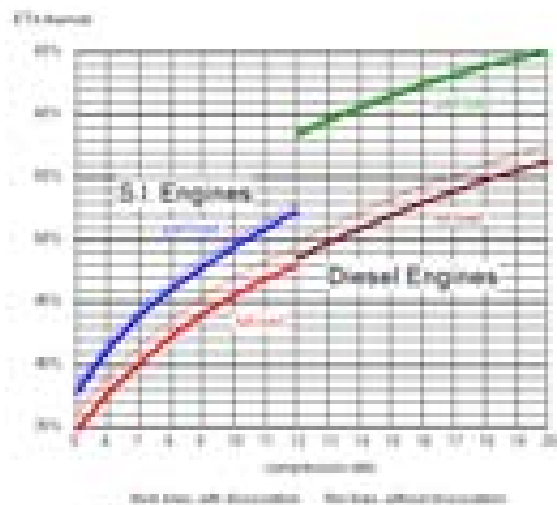


Fig.1. Thermal Efficiencies of I.C. Engines

air fuel ratio: S.I. part load $\lambda = 1.4$ Diesel part load $\lambda = 4$
S.I. full load $\lambda = 1.0$ Diesel full load $\lambda = 1.1$
after F.A.F. Schmidt [1].

The ideal Process is defined:

- Air-charge without residual gases
- Air-fuel ratio as in the real engine
- Complete combustion
- Combustion at Top Dead Center
- No Heat Losses

CALCULATION:

- 1 Using the 3 laws of thermodynamics
- 2 using the real values of matter
- 3 using the maximum work instead of heat values

RESULTS:

1. The Diesel engine is better than the Otto engine.
2. Largest dissoziation at $\lambda = 1$
3. Without dissoziation ETA is better.
4. Re-combination not considered

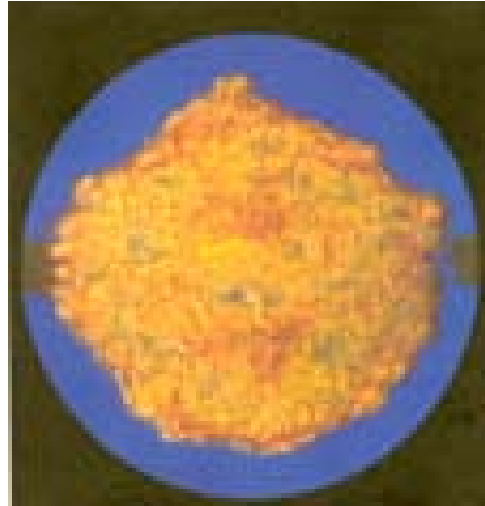
These advantages of the self-ignited Diesel engine over the spark ignited Otto engine is illustrated in the next two self-explaining pictures worked out by A.C. Oppenheim [2]. In the first picture the bears are planting the field in an overcrowded row and disturb each other. The working process is linear demonstrating the combustion in Otto engines by "Flame Transversing the Charge". In the second picture there is plenty of space for each bear. He is only responsible now for a small acre, which means that the flame has to travel just a small distance in contrast to the long one before. If this can be done also in a homogeneous mixture

as it was the case in the Otto-like-combustion process and not in the slow diffusion process common in normal Diesel-like-combustion process, then we reach the full advantage.

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*This Fig. 3 shows a homogeneous
Turbulent combustion field, formed away from the walls
of ist cylindrical enclosure by a double stream Flame Jet
Ignition System, investigated by A.K.Oppenheim [2
—].With his words: "In an engine cylinder adequate
distribution of exothermic centers to prevent the
formation of flames can be obtained by dilution. This can
be accomplished by injecting turbulent jets of super-rich
air/fuel mixture into a piston compressed air combined
with a certain amount of RGR or EGR." – It will be
shown later, in what way we can make use of this
process in real engines.*



2. Volkswagen Vision: the future development of passenger car engines [3]

Fig. 4 shows a recent vision of the Volkswagen Group, in what way future I.C.-Engines should be developed. Here the major advances of Diesel engines with direct injection meet the advances of Otto engines. In these future Diesel-like stratified charge engines a partly homogenisation of the mixture will be established by further development of the electronic control in direct injection systems.

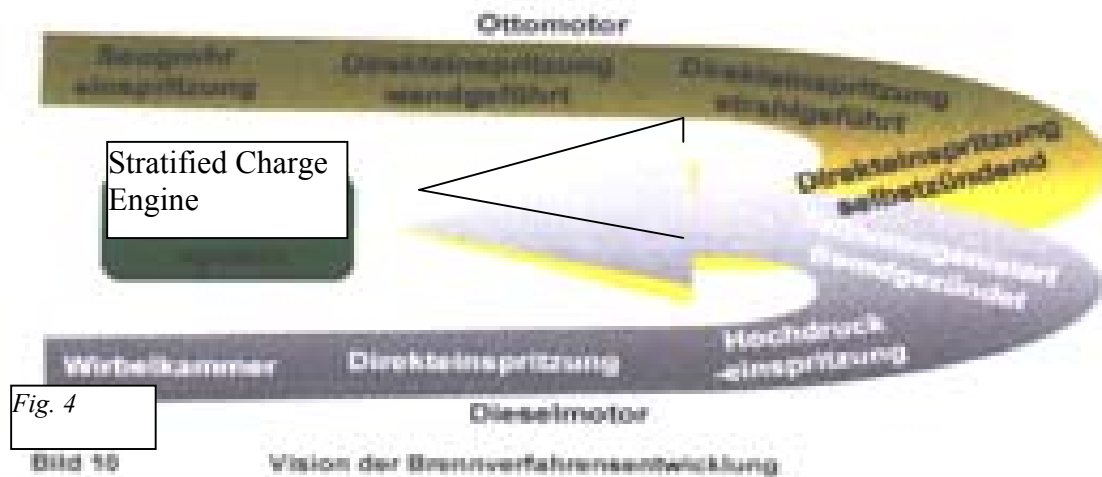


Fig. 5 shows that it is possible by using alternative fuels instead of gasoline or Diesel fuel to fulfil all the emission standards of today and even of the future. At Volkswagen Research Dept. such kind of vehicles are already in the development and testing stage.

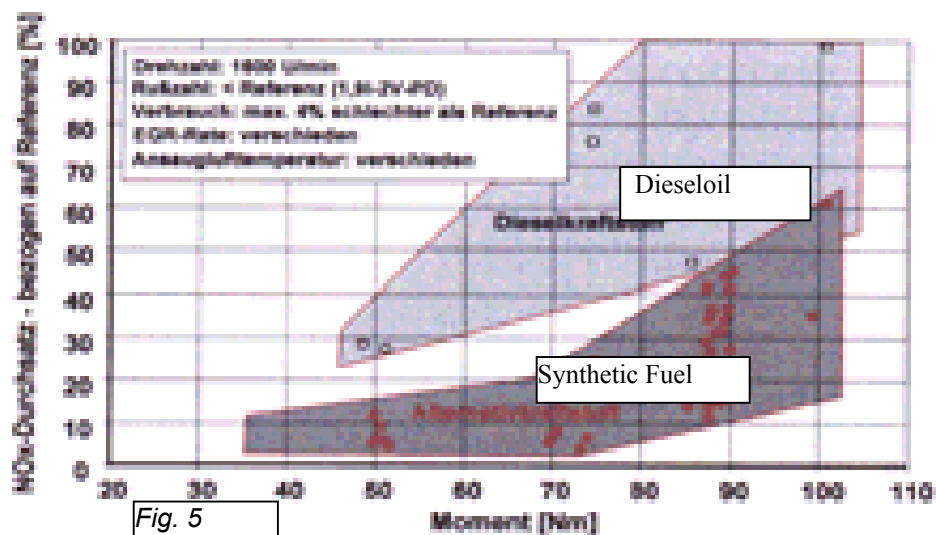


Bild 11 NOx-Reduzierungspotential des CCS Verfahrens

3. The ignition delay period [4, 5, 6]

The ignition delay period consists of all the above mentioned processes, which take place simultaneously. Up today it is not possible, to give a reliable theoretical answer. Therefore we must look to experimental results. At the Technical University Aachen a successful research program has been established combining the efforts of seven institutes of the university . It was sponsored with more than 30 Million DM in 10 years by the Deutsche Forschungsgemeinschaft (DFG) and has covered all the details of the combustion process in Diesel Engines [4].

*Fig. 6 shows excerpts from the book
of Merker/Stiesch [5]: Diesel combustion.*

The whole process is very complex:

- [1] 1. injection through open hole nozzles
- [2] 2. disintegration and spray formation
- [3] 3. evaporation of the droplets
- [4] 4. ignition at favourable air-fuel mixture
- [5] 5. formation of soot in rich regions
- [6] 6. formation of NO_x in hot regions
- [7] 7. remaining unburnt hydrocarbons

Sonderforschungsbereich SFB 224 Teilprojekt 4 : DIESELMOTOREN

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4.3 Selbstzündung

4.4 Verbrennung, Schadstoffbildung und Akustik

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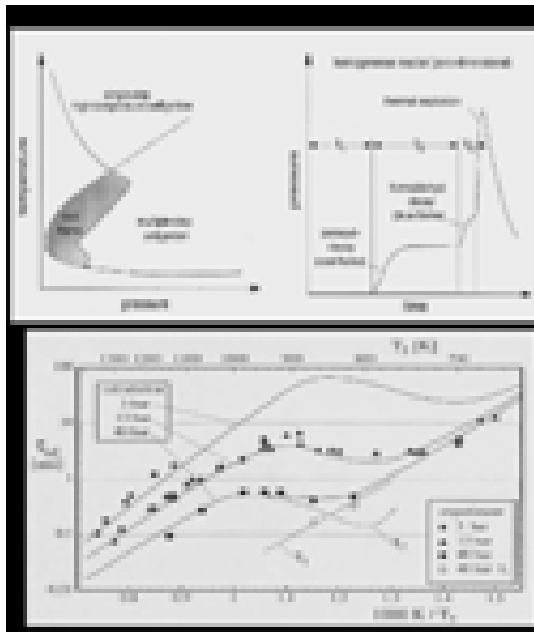


Fig. 7a: 2-stage ignition, pressure trace

Fig. 7b: 2-stage ignition, temperature trace

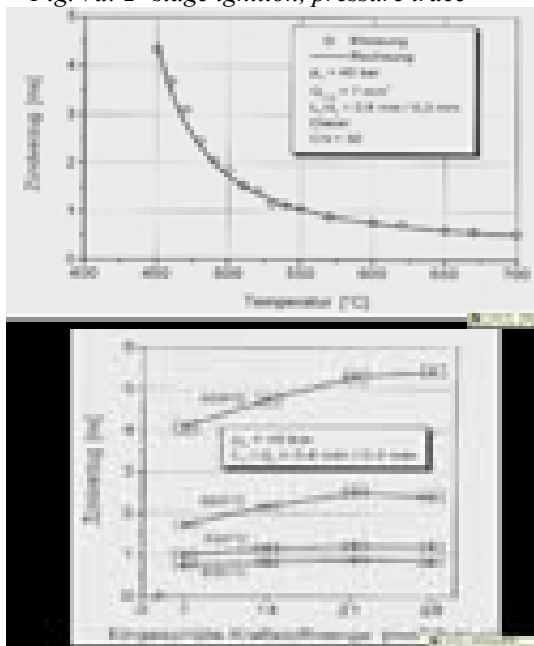


Fig. 7c: Ignition delay of Diesel fuel

Fig. 7d: Dependency on fuel quantity

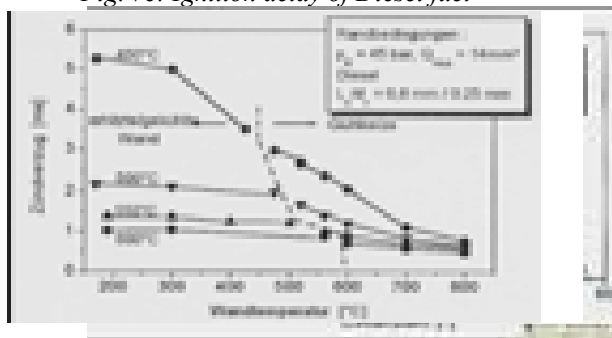


Fig. 7e: Dependency on wall temperature

Fig. 7f: Dependency on cetane number

All these results show a strong dependence of the ignition delay on the kind of fuel and especially on the Temperature of the gas mixture as well as on the wall temperature [5, 6].

Therefore it was obvious to find a way to control the combustion process by methods of variation of the ignition delay with internal and external measures. One good possibility is given by a two stage compression, which will be explained in the following chapter.

4. Two Stage compression Stratified Charge engines [7, 8, 9]

The engine in Fig. 8 is a 4 stroke 4 valve stratified charge engine with direct Diesel injection using the Volkswagen unit injector. It produces a homogeneous mixture at part load. That is possible by double injection. The first injection starts very early during the compression stroke and produces a very lean homogeneous mixture. At Top Dead Centre follows the second injection into the lean mixture formed by the first injection. Due to the heterogeneous mixture ignition occurs immediately in the fine spray wherever a stoichiometric mixture is present. After ignition the burning of the main mixture takes place in a fireball. With residual gas remaining at the cylinder walls flame quenching is prevented. Therefore no CO and HC emissions will occur. Therefore no CO and HC emissions will occur. Most important: the NO_x/Soot production can also be avoided. That allows that this engine can work without Oxidat and soot filter. The VW unit injector injects the fuel in two stages into the main chamber.

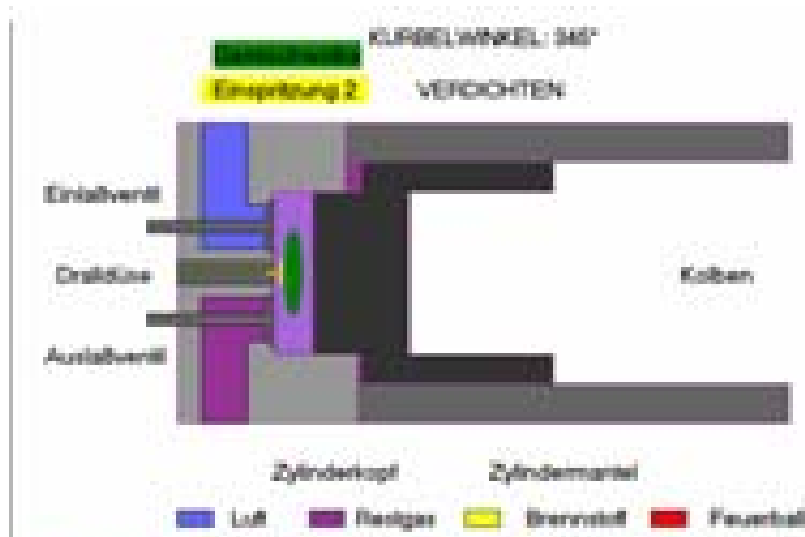


Fig. 8: Diesel-like Stratified Charge Engine with VW Unit Injector

Fig. 8 shows the basic principle, in which a ring piston compresses air above the pressure during combustion, which allows to work with two different compression ratios: a higher one in the ring area for the self ignition of the Diesel spray and a lower one for the homogeneous combustion in the central main chamber. After ignition in the ring chamber the burning gas flows through small connecting holes with high velocity into the main chamber, forming there impinging jets, into which the main fuel is injected in order to form a fireball, in which the fuel/air mixture burns rapidly, without touching the cylinder walls. A common rail injector injects the fuel into the ring chamber and into the main chamber.

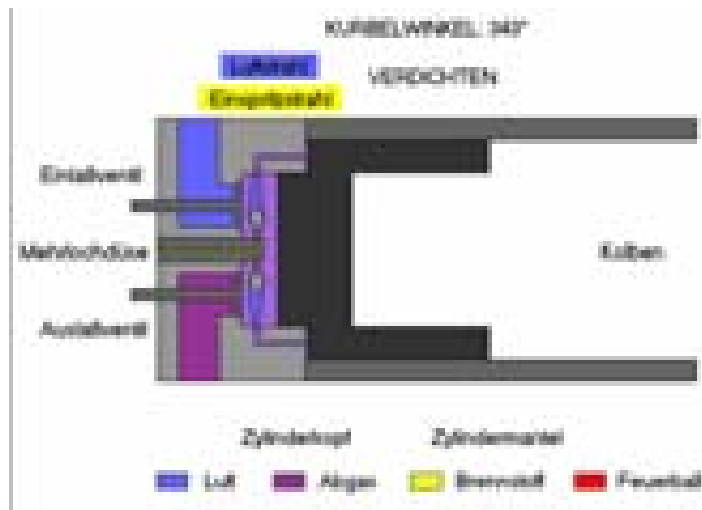


Fig. 8: Diesel-like Stratified Charge Engine with common rail Injector

5. Outlook

Two new principles for Diesel-like stratified charge engines make it possible to avoid unwanted pollutions in the exhaust gas and building cheap engines without Oxi-cat and soot filters. They are based on the dependencies of the results from measured ignition delays in the Diesel combustion process. While at low compression ratios with low temperature and low pressure the fuel sprays get not ignited, at high compression ratios, as they exist at the end of compression in the ring chamber of the stratified charge engine with the common rail injector or in the stratified charge engine with the VW unit injector at Top Dead Centre in the main chamber, ignition will occur. With now available electronic devices for precision control units and special sensors for pressure, temperature and air/fuel ratio it should be possible to develop these two engines for serial application.

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