Matúš LAVČÁK[1], Michal PUŠKÁR[2], Silvia MALÁKOVÁ[3],
Matej URBANSKÝ[4], Peter KAŠŠAY[5], Samuel SIVÁK[6], Michal DEMKO[7]

Supervisor: Michal PUŠKÁR[2]

BADANIE CYKLU SPALANIA, WYDAJNOŚCI ORAZ PARAMETRÓW EMISJI SPALIN W TECHNOLOGII HCCI

Streszczenie: Technologia HCCI to połączenie zalet silnika benzynowego i wysokoprężnego z tą różnicą, że spala on benzynę o niższych emisjach, które są obecnie ściśle monitorowane. Pomimo nierozwiązanych trudności technologia HCCI reprezentuje przyszłość w stosowaniu silników spalinowych.

Słowa kluczowe: silnik HCCI, emisje, zużycie paliwa

THE RESEARCH OF COMBUSTION CYCLE, PERFORMANCE AND EMISSION PARAMETERS OF HCCI TECHNOLOGY

Summary: HCCI technology is a combination of the advantages of a petrol and a diesel engine, with the difference that it burns petrol, which has lower emissions, which are closely monitored today. Despite its unresolved problems, HCCI technology therefore represents the future in the use of internal combustion engines.

Key words: HCCI engine, emissions, fuel consumption

[1] Technical University of Košice; Faculty of Mechanical Engineering, Department of Machine Design and Transport Engineering, matus.lavcak@tuke.sk
[2] Technical University of Košice; Faculty of Mechanical Engineering, Department of Machine Design and Transport Engineering, michal.puskar@tuke.sk
[3] Technical University of Košice; Faculty of Mechanical Engineering, Department of Machine Design and Transport Engineering, silvia.malakova@tuke.sk
[4] Technical University of Košice; Faculty of Mechanical Engineering, Department of Machine Design and Transport Engineering, matej.urbansky@tuke.sk
[5] Technical University of Košice; Faculty of Mechanical Engineering, Department of Machine Design and Transport Engineering, peter.kassay@tuke.sk
[6] Technical University of Košice; Faculty of Mechanical Engineering, Department of Machine Design and Transport Engineering, samuel.sivak@tuke.sk
[7] Technical University of Košice; Faculty of Mechanical Engineering, Department of Materials Technology and Computer Aided Production, michal.demko@tuke.sk

1. Introduction

Thanks to lower emissions and price, the use of a petrol engine is still in the forefront at present. As a result of the tightening of emission standards, increasing resources are being spent on optimizing fuel consumption and also on the development of electronic control systems, which significantly affect the control of engine operation as well as fuel consumption itself. The result of this activity is the development of an engine with homogeneous combustion, which received the designation HCCI (Homogeneous Charge Compression Ignition). This type of internal combustion engine combines the advantages of both a petrol and a diesel engine. The main idea of HCCI technology is that the gases leaving the exhaust system should contain significantly less emissions of nitrogen oxides and strictly monitored CO2.

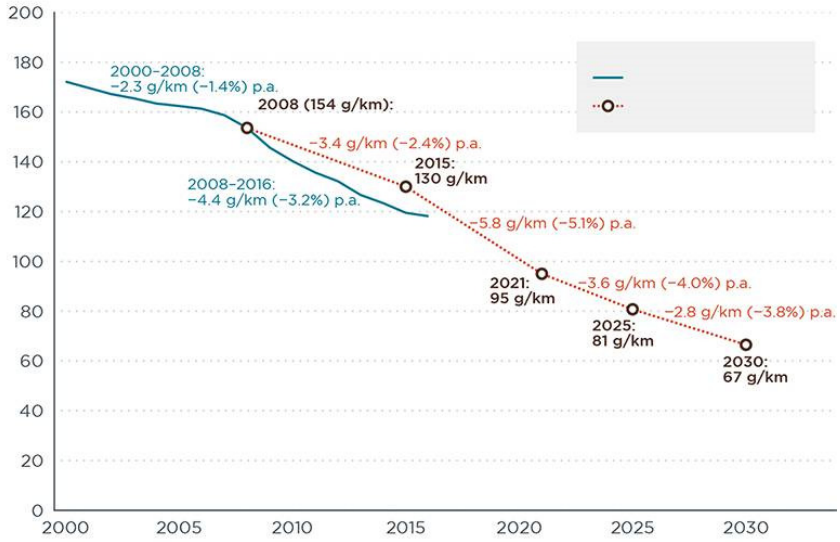

Figure 1. Development of average CO2 emissions for new passenger cars currently in the EU and proposed values for the future

2. Principle of HCCI technology

With HCCI technology (Homogeneous charge compression ignition), a homogeneous mixture of fuel and air ignites spontaneously. This mixture is burned in the cylinder at the same time, so that there is no flame propagating from the candle, the whole mixture is burned without a flame, which forms the boundary between the burned and unburned mixture, resulting in a considerable amount of unwanted nitrogen emissions in the cylinder space. and NOx. In such a process, the entire contents of the mixture are burned at once, so that a smaller amount of fuel-air mixture is required to obtain the desired performance. At the same time, ignition of the entire homogeneous mixture causes no flame to form and the entire mixture burns at a lower temperature than conventional gasoline gasoline engines, resulting in a reduction in temperature differences in the cylinder space. Due to their higher efficiency, HCCI engines

consume less fuel while maintaining the same power as conventional diesel and gasoline engines [1,2].

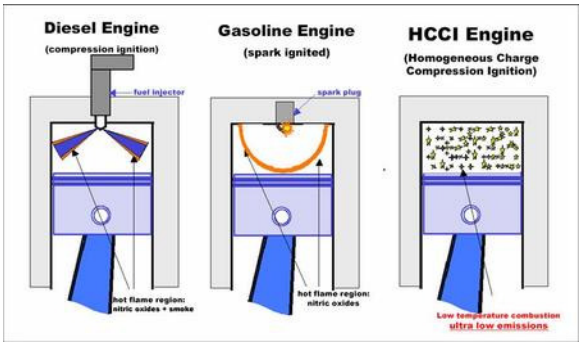

Figure 2. Comparison of fuel / air mixture ignition for petrol, diesel and HCCI engines

A homogeneous mixture of fuel and air is in most cases created by direct injection. The suction valves open during the suction cycle. In this case, more air enters the piston and an extremely lean mixture is formed, and the combustion of such a mixture proceeds rapidly because the mixture ignites simultaneously in its entire volume. Such a mixture is ignited only by the increasing temperature in the cylinder, which increases with the compression.

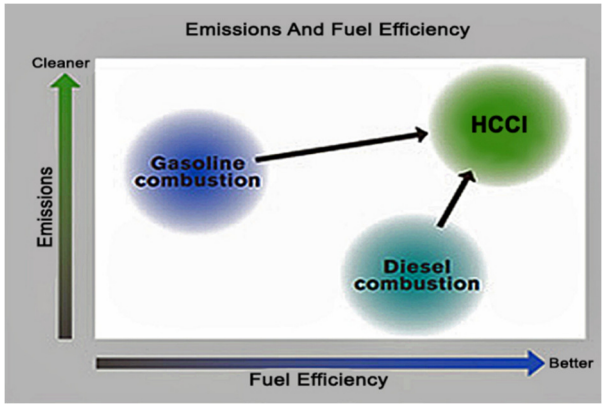

Figure 3. Comparison of petrol, diesel and HCCI engines based on efficiency compared to emissions.

At the right temperature and pressure, the mixture ignites and burns at the same time, and since no boundary is formed between the burned and unburned mixture, neither soot nor unwanted emissions are created in the cylinder space. Achieving a high degree of fuel efficiency also achieves significant fuel savings.

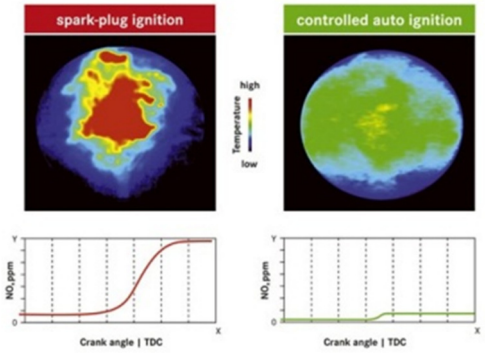

Figure 4. Temperature differences and production of nitrogen oxide emissions in a petrol and HCCI engine

However, this condition has so far only been possible under laboratory conditions, since in real traffic the working cycle is influenced by a number of factors, such as rising cylinder temperature, wide operating speed range and increasing cylinder pressure due to ever-increasing temperature. It follows that the desired effect occurs only under certain conditions.

3. Development of HCCI technology

Research on HCCI engines focuses mainly on the influence of operating conditions that come into play when burning fuel in the cylinder, but also on the possibilities of using different fuels such as natural gas, methanol, ethanol-based fuels, which have different octane numbers. However, it was still not possible to eliminate the problems with the control of the ignition timing of the mixture, so that the engine could run in the widest possible range of revolutions and loads in the diesel mode. Since it is necessary for self-ignition to occur at a specific time, it is necessary to regulate the parameters in real time. In the event of sudden changes in the required power, regulation is difficult.

So far, the closest to HCCI technology and its use in real traffic is a petrol engine with the designation SPCCI (Spark plug controlled compression ignition). Compression ignition controlled by a spark plug has solved the two biggest and most important problems, namely temperature control, the value of which is important to allow spontaneous combustion, as well as the problem of igniting the mixture at low speed, which has disappeared with the addition of the spark plug. The SPCCI engine therefore works with both diesel and petrol modes, which automatically switch between each other depending on speed and load. Like the HCCI engine, the SPCCI engine works with an extremely lean mixture, almost 2 to 3 times leaner, with the difference that the spark plug is left, fulfilling the same role as in a conventional petrol engine. The spark plug is not used to ignite the entire volume of fuel, but only to ignite a small amount, which, in conventional gasoline and diesel engines, causes unwanted and engine-damaging detonation combustion. Detonation combustion causes the pressure and temperature of the fuel-air mixture in the cylinder to increase so that it ignites (Fig. 4). During the combustion process in this engine, a 16: 1 mixture of air

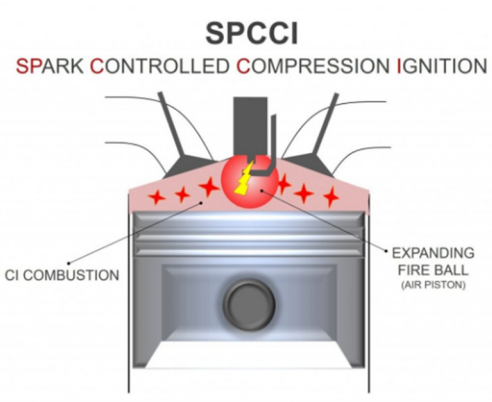

Figure 5. SPCCI technology

and fuel is injected into the engine, which is just below the level required to achieve compression ignition. Thus, the SPCCI engine solves the problem of temperature deficit at low speed and low load by detonating combustion caused by a spark plug. [6]

Another possible solution to the problems with the limited speed interval of the function in HCCI mode is the regulation of the compression ratio in the engine marked VC-T. For optimal control of the combustion process, it would be more advantageous to vary the compression ratio over a wide range and depending on the operating conditions. While a low compression ratio is more advantageous for high performance, especially in conjunction with supercharging, which is currently very common, a high compression ratio is required for economical operation. Engines with a constant compression ratio are therefore always only a compromise between the two opposite requirements. The use of an engine with a variable compression ratio would allow efficient temperature control, which, similarly to the SPCCI engine, would allow to operate at a certain speed range in diesel mode and at other temperatures and loads when operating as a petrol engine.

Figure 6. Cross section of VC-T engine

Change of the top dead center position, resp. compression ratio, causes the movement of an eccentric control shaft located below the crankshaft, which changes the position of the rocker arm anchored to the main crankshaft journal.

Conclusion

Despite its significant disadvantages due to largely unfinished research, HCCI technology has a number of positive aspects compared to other available technologies. Due to higher thermal and chemical efficiency, the HCCI engine has lower fuel consumption, which also results in lower NOx emissions.

Despite the fact that the engine has not yet been resolved over the entire speed range, the technology is pushed between vehicles of many brands and used in certain load modes, which also saves fuel and reduces emissions. However, many physical or technical difficulties caused by the complexity of the operation still need to be resolved.

REFERENCES

1. PUŠKÁR M., BIGOŠ P., PUŠKÁROVÁ P.: Accurate measurements of output characteristics and detonations of motorbike high-speed racing engine and their optimization at actual atmospheric conditions and combusted mixture composition. In: Measurement. 45(2012), 1067– 1076. ISSN 0263-2241.
2. PUŠKÁR M., BIGOŠ P.: Measuring of acoustic wave influences generated at various configurations of racing engine inlet and exhaust system on brake mean effective pressure. In: Measurement. 46(2013)9, 3389–3400. - ISSN 0263-2241.
3. PUŠKÁR M. et al.: Measuring method for feedback provision during development of fuel map in hexadecimal format for high-speed racing engines. In: Measurement. 50(2014)1, 203212. - ISSN 0263-2241.
4. PUŠKÁR M., BIGOŠ P.: Output Performance Increase of Twostroke Combustion Engine with Detonation Combustion Optimization, Strojarstvo 2010: 52(2010)5, 577- 587, ISSN 0562-1887.
5. CRAMER M.: Performance fuel injection systems. HP Trade 2010. ISBN 978-1557885579.
6. PUŠKÁR M.: Inovačné riešenia spľovacích motorov, Technická univerzita v Košiciach, 2020. ISBN-978-80-553-3394-6.

Acknowledgements

„This work was supported by the Slovak Research and Development Agency under the Contract no. APVV-19-0328.“
The article was written in the framework of Grant Projects: VEGA 1/0473/17 “Research and development of technology for homogeneous charge self-ignition using compression in order to increase engine efficiency and to reduce vehicle emissions” and KEGA 006TUKE-4/2020 “Implementation of Knowledge from Research Focused on Reduction of Motor Vehicle Emissions into the Educational Process”