Research project entitled “Use of waste hydrogen for energy purposes” carried out in 2012–2018

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Hydrogen used as fuel for combustion engines

Abstract

Since the 1980s, scientific research has been conducted at the Cracow University of Technology using hydrogen as a fuel for piston combustion engines. In the years 2012 to 2018, a research project was carried out involving the use of waste hydrogen from industrial installations to power generators. Because the hydrogen used in this project was contaminated with other components, mainly nitrogen, carbon dioxide and hydrocarbons, an innovative control system was developed that allows automatic adjustment of the engine regulation parameters to the current chemical composition of the offered fuel. This regulation method was applied to three piston combustion engines powered by waste hydrogen, with a total power of approximately 1 MW. Operational tests of these engines were carried out over a period of 5 years.

Thanks to the experience gained in this project, since 2020, a project to adapt a modern industrial engine to be powered by pure hydrogen or hydrogen-natural gas mixtures has been implemented at the Cracow University of Technology. For this purpose, a system for burning this type of fuel and a modern power supply system operating in adaptive mode were developed. In addition, new safety systems for powering piston combustion engines have been used, protecting the system against flame flashback. Preliminary results indicate a high implementation potential of the project.

"Use of waste hydrogen for energy purposes"
Innovative Economy Operational Program
implementation in 2012-18

Project assumptions:

- **Construction of a pilot installation for the production of electricity and heat from waste hydrogen**

Total electrical power: approx. 1 MW

Generators : 2 x 400 kW
1 x ok. 200 kW

Engines:

6-in line	**MAN E2876**
V-12	**MAN E 2842**

The executed concept of variable chemical composition fuel gas supply systems, for internal combustion engines

- **Detailed tasks:**

- **Development of a system for power supply, combustion and regulation of engine operating parameters in conditions of variable composition and variable technical parameters of fuel supply.**

- **Development of adaptive systems for controlling the operating parameters of cogeneration units.**

- **Development of a combustion system resistant to combustion anomalies of fuels with a high hydrogen content.**

- **Development of a system for dosing and combustion of fuel in the gaseous or liquid phase**

The executed concept of variable chemical composition fuel gas supply systems, for internal combustion engines

Objective and methodology of experimental research

Identifying new problems related to the specificity of the fuel used, as well as achieving the most favourable operating and ecological indicators of the engine in the tests.

All engine measurements regarding energy parameters and emissions of toxic exhaust components were carried out at a constant engine speed of 1500 1/min and a changed engine load. These conditions correspond to the operation of the engine in a power generator.

Among the control parameters of the tested engine that had to be adapted to the type of fuel tested were primarily:

- ***ignition advance angle,***
- ***air excess coefficient.***

Three basic criteria were adopted for the selection of the listed engine control parameters, for which the engine load value was selected when powered by a specific fuel.

- *the maximum temperature of the engine exhaust gases cannot exceed 700 0C,*
- *there cannot be a combustion anomaly in the form of knocking combustion,*
- *there cannot be a phenomenon of flame flashback to the intake manifold.*

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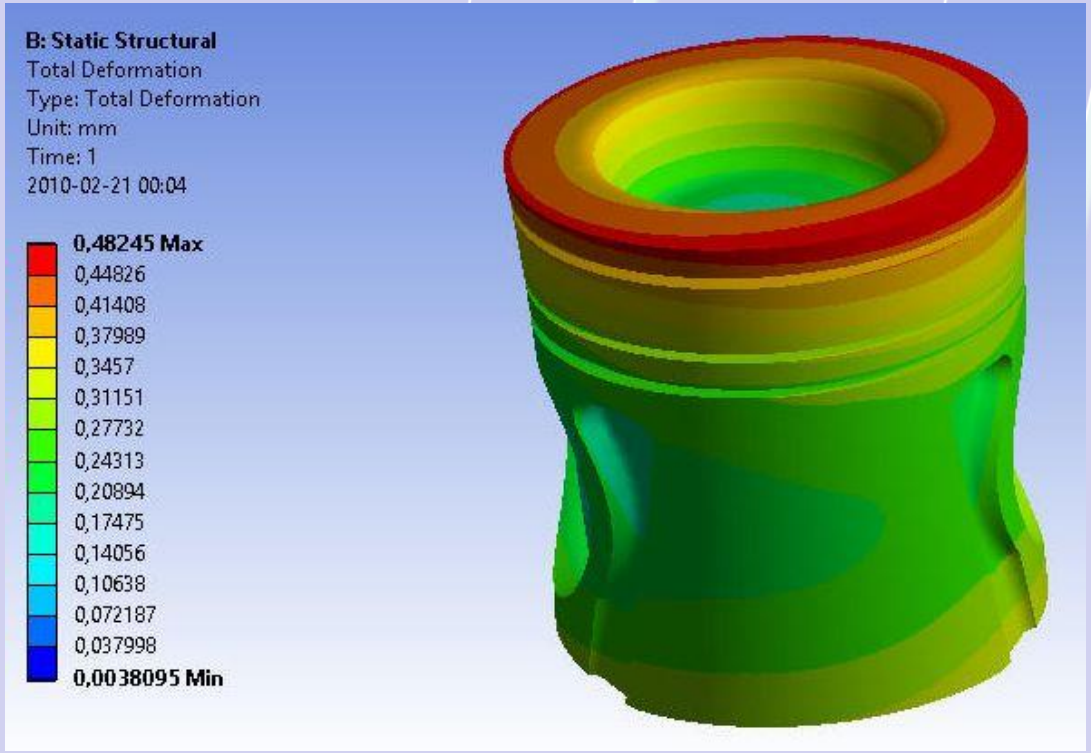
6-cylinder MAN engine during tests at the laboratory of the Cracow University of Technology

Research object and research stand



Simulation tests and selection of MAN engine piston powered by hydrogen or methane

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Innovative Economy Operational Program
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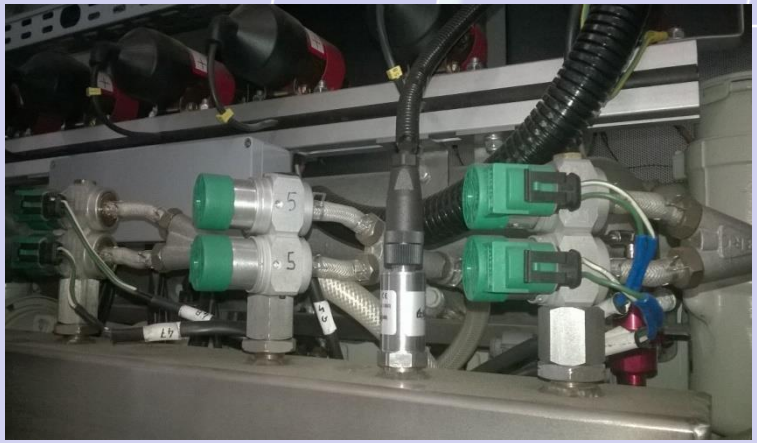
modified V-12 MAN engine powered by waste hydrogen in chemical plants



Indirect hydrogen injection in the V-12 engine (two injectors per cylinder)

Efekts

A remote controller monitoring panel developed at the Cracow University of Technology

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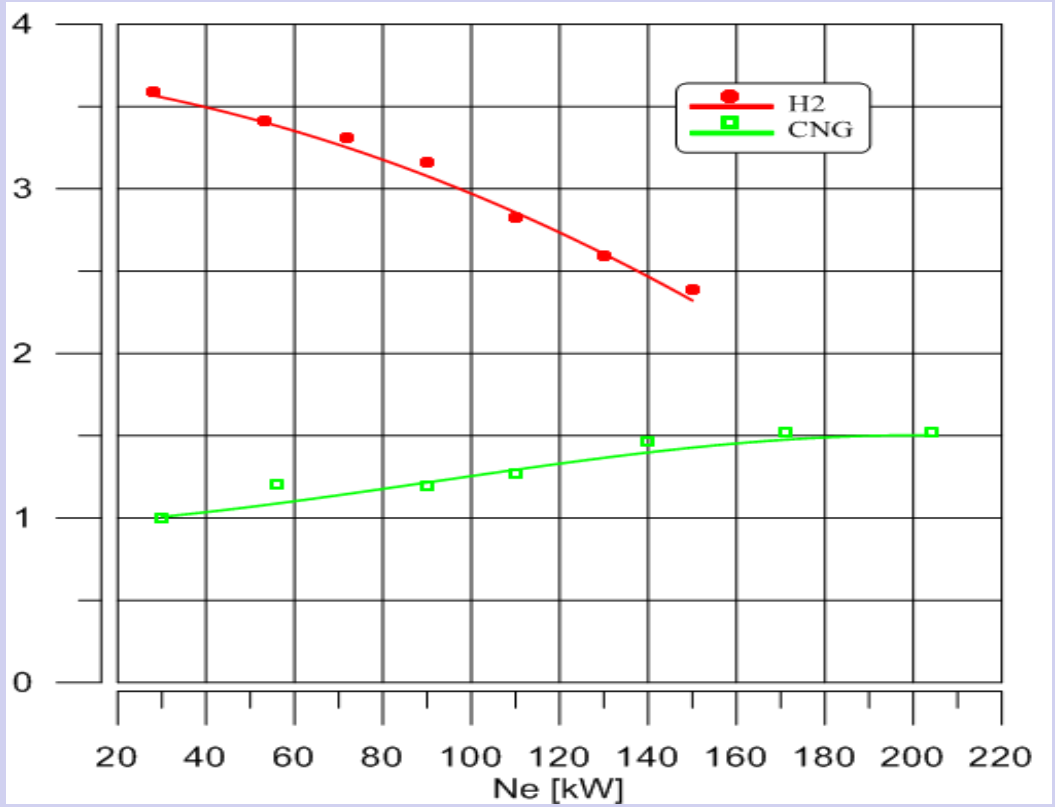
Innovative Economy Operational Program
implementation together with HORUS-Energia in 2012-18

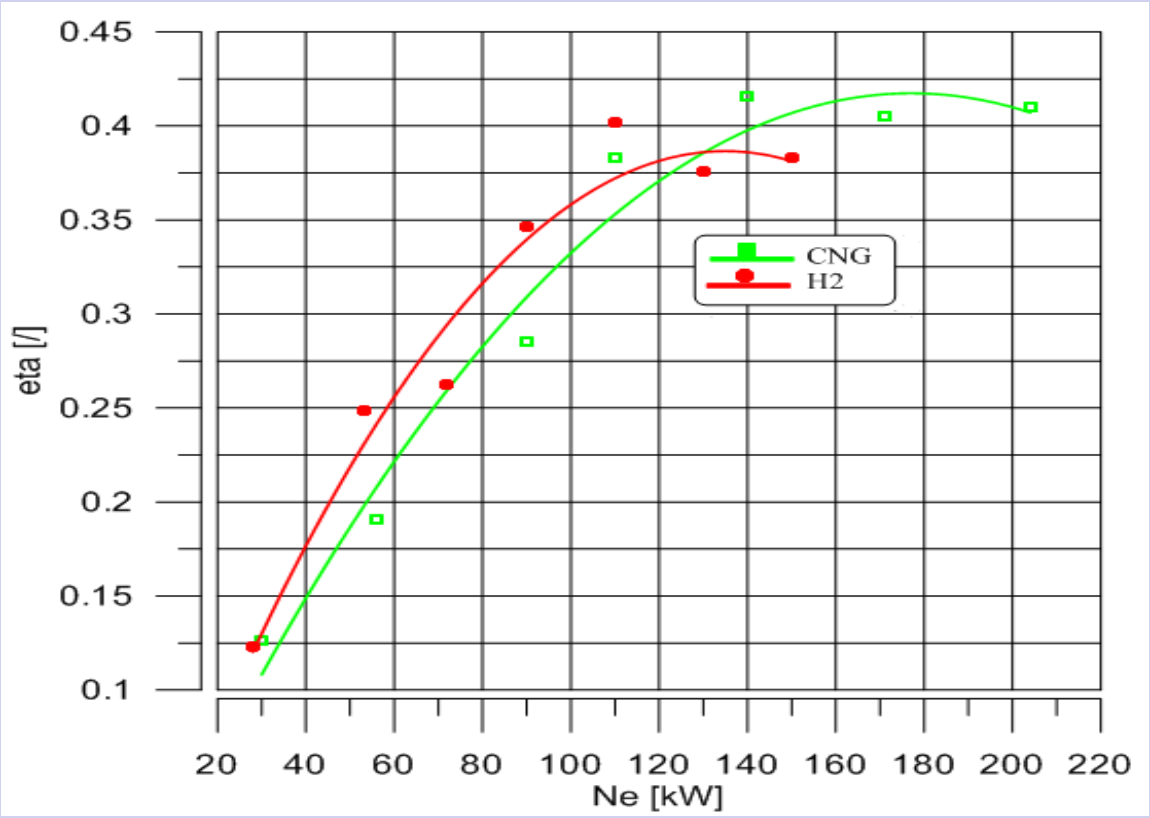
Aggregates powered by waste hydrogen in a hall at a Chemical Plant

The executed concept of variable chemical composition fuel gas supply systems, for internal combustion engines

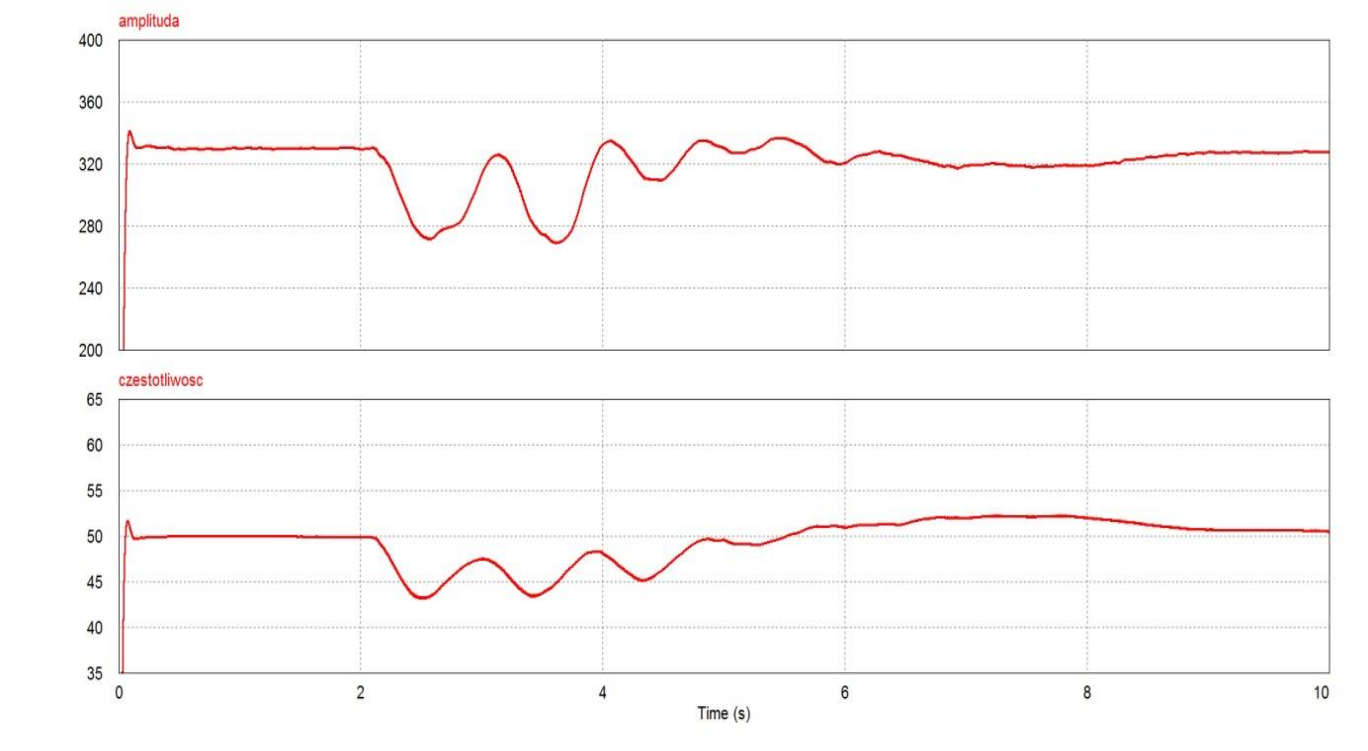
Research results - combustion engine laboratory of the Cracow University of Technology



Characteristics of the mixture composition of a MAN engine powered by natural gas or hydrogen



Overall efficiency of a 6-cylinder MAN engine powered by natural gas or hydrogen



Waveforms of changes in generator current parameters
with load increase: 30-110 [kW]

The executed concept of variable chemical composition fuel gas supply systems, for internal combustion engines

Conclusions

The conducted tests showed the usefulness of some waste products of the chemical industry as an unconventional fuel for the needs of the energy industry.

The results of the tests of the 6-cylinder MAN engine adapted to hydrogen fuel allowed the determination of the power supply and control strategy.

In order to maintain safe continuous power of the engine during hydrogen fuel supply, without the risk of approaching the limit of combustion anomalies, a continuous power of 150 kW was assumed, although in the tests it slightly exceeded 160 kW.

During hydrogen fuel supply, the engine operated without combustion anomalies (knocking combustion, misfires) with appropriate settings of the control parameters (air excess coefficient and ignition advance).

The limitation for obtaining even more favorable results was the criteria of knock combustion or exhaust gas temperature before the turbine.

The final qualification of hydrogen as a fuel for the tested engine type may occur after the initial period of operation of the unit. Particular attention should be paid to the effect of hydrogen on the materials used to construct engine components and the properties of the engine lubricating oil, since it is possible for the properties of the lubricating oil to change as a result of hydrogenation.

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Project assumptions:

Development of a hydrogen combustion system
Development of the ignition system
Development of a power supply system with qualitative and quantitative power regulation
Development of an electronic controller
Development of the concept of an operational safety system

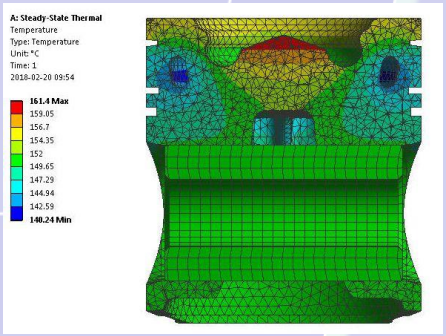
Engine:

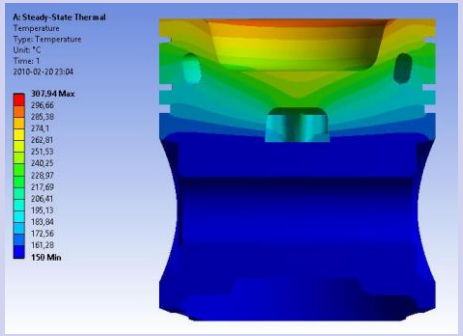
5-cylinder in-line Scania type DI09 074M

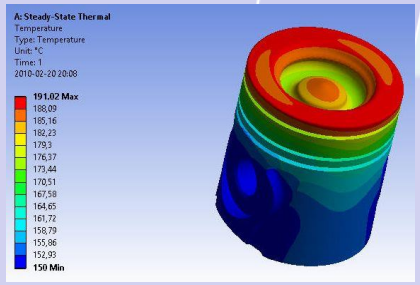
"Adaptation of a modern diesel engine to hydrogen supplying" implementation 2020-2024

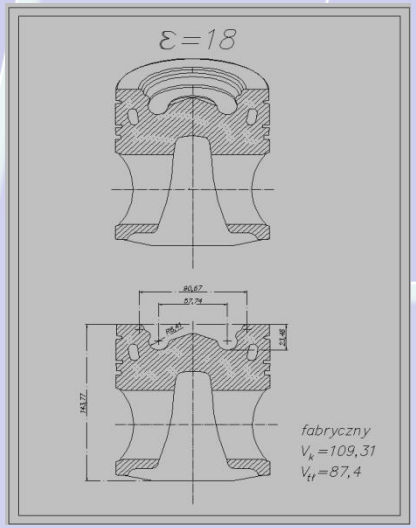
A hydrogen-powered Scania engine on a laboratory test bench
Department of Motor Vehicles of the Cracow University of Technology

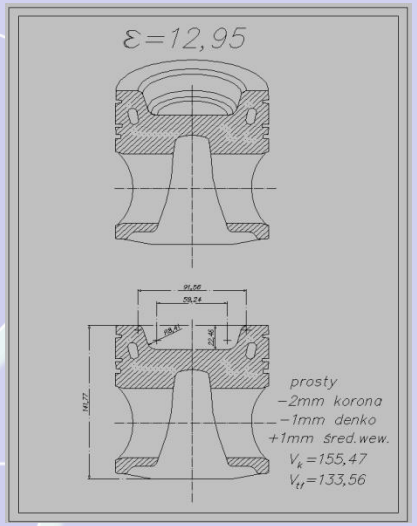
"Adaptation of a modern diesel engine to hydrogen supplying" implementation 2020-2024











Design phases of a piston for a hydrogen-powered Scania engine

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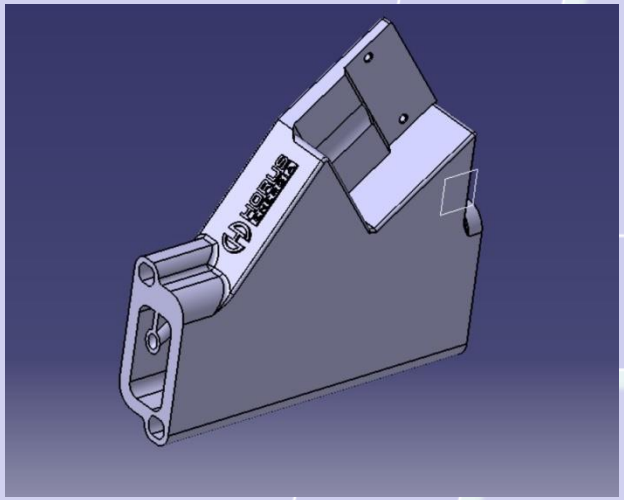

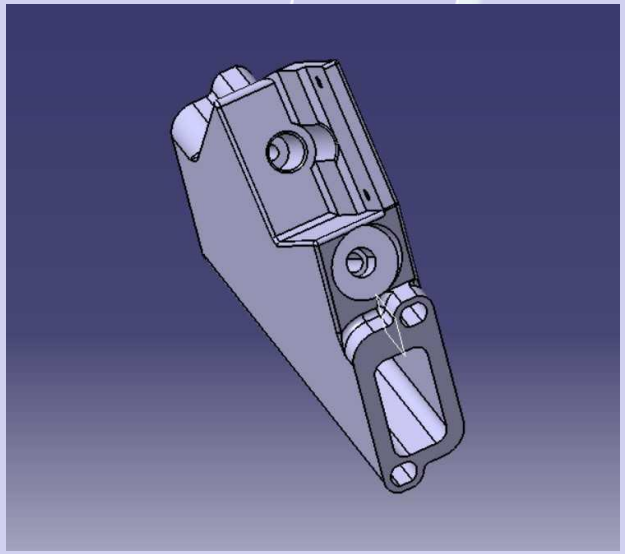

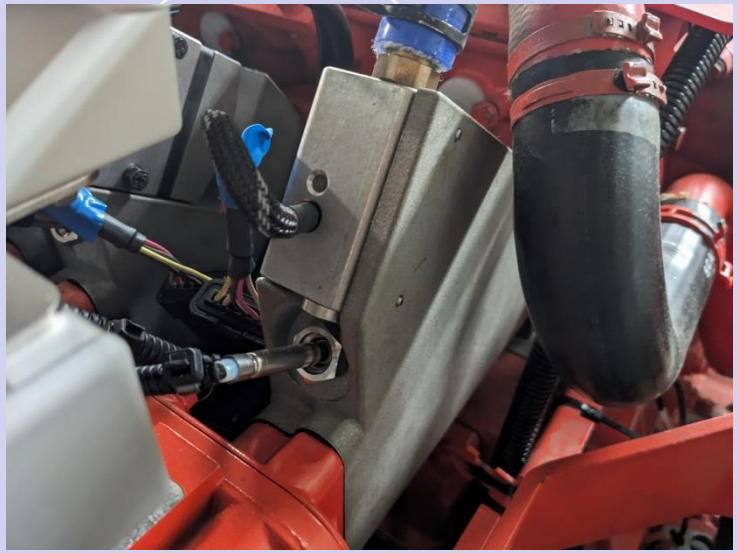

Injection module for a hydrogen-powered Scania engine

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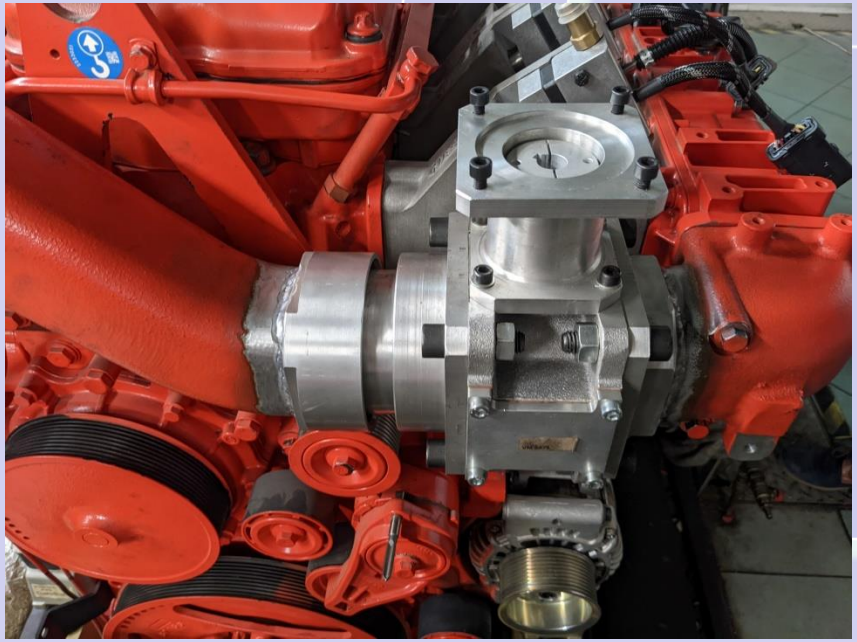

Scania hydrogen engine throttle module

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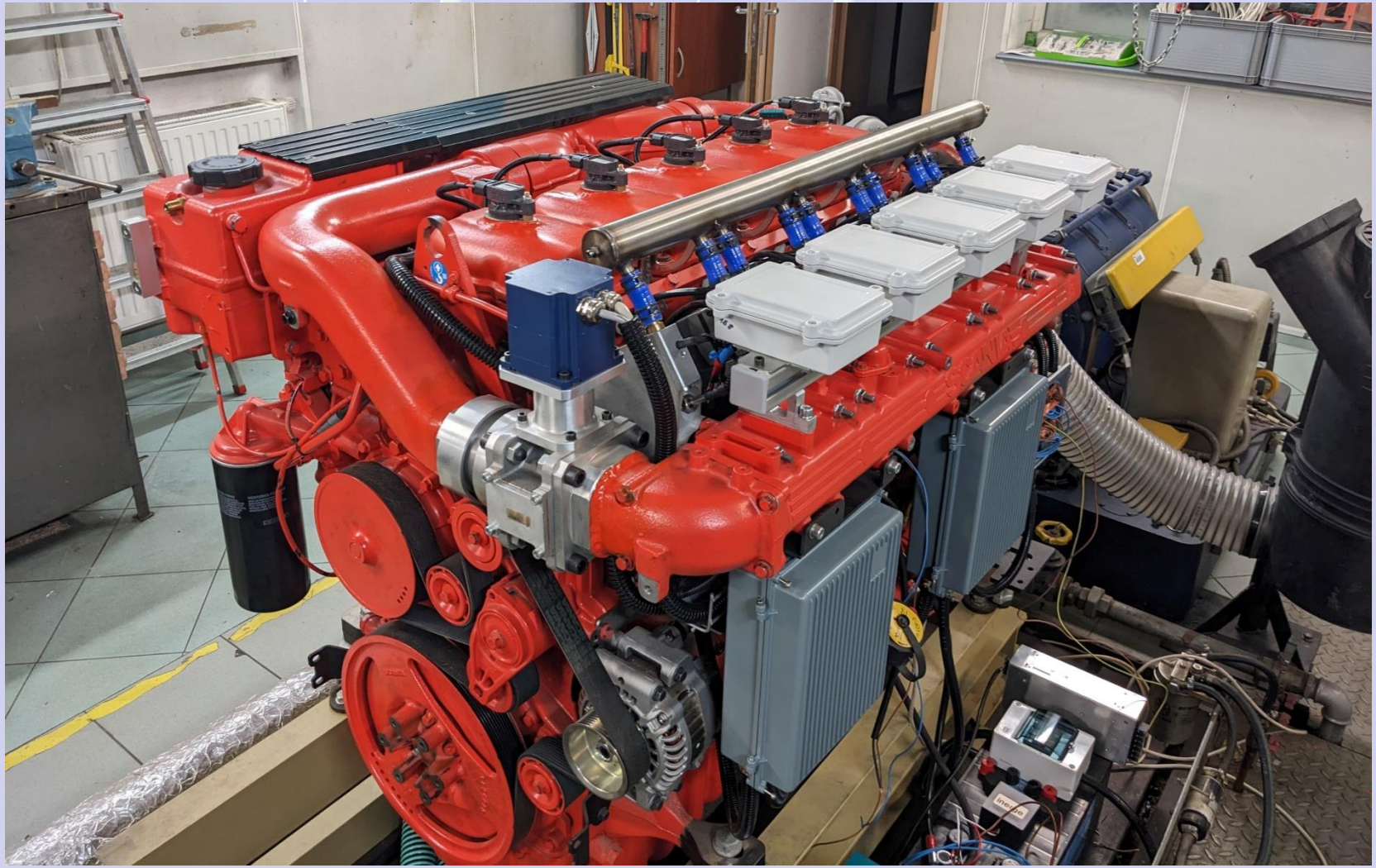

Scania engine during tests
at the laboratory of the Cracow University of Technology

Cracow University of Technology

Poland in Silicon Valley Center for Science, Innovation and Entrepreneurship

Faculty of Mechanical Engineering

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Thank you for Atenttion

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