

## **PRELIMINARY EXPERIMENTAL STUDY OF AUTOIGNITION OF HYDROGEN-OXYGEN MIXTURE BY USING COMBUSTION DRIVEN RAPID COMPRESSION MACHINE**

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**Abstract.** The rapid compression machine designed and constructed at Warsaw University of Technology creates high pressure and temperature at the end of compression stroke, leading to mixture autoignition with the possibility of the process visualization. The unique feature of the machine is the possibility of studying ignition and combustion processes similar to those existing in the engines with gas fuel injected directly to combustion chamber.

The adequate characteristics of piston movement is achieved by conventional crank mechanism, however the required acceleration is introduced by the combustion of fuel-oxygen mixture under the piston.

Calculations and preliminary tests have shown that the method is capable to achieve piston accelerations equivalent to engine rotational speed of 5000 rpm.

The test chamber is equipped with pressure transducer that together with electronic piston movement transducer enables for registration of pressure profile with respect to crank angle. The light signal from the flame in the chamber is transmitted by the light pipe to phototransistor. All signals are collected by computer data acquisition system.

The preliminary study of autoignition of hydrogen-oxygen mixture was performed with the use of this apparatus and the results are discussed.

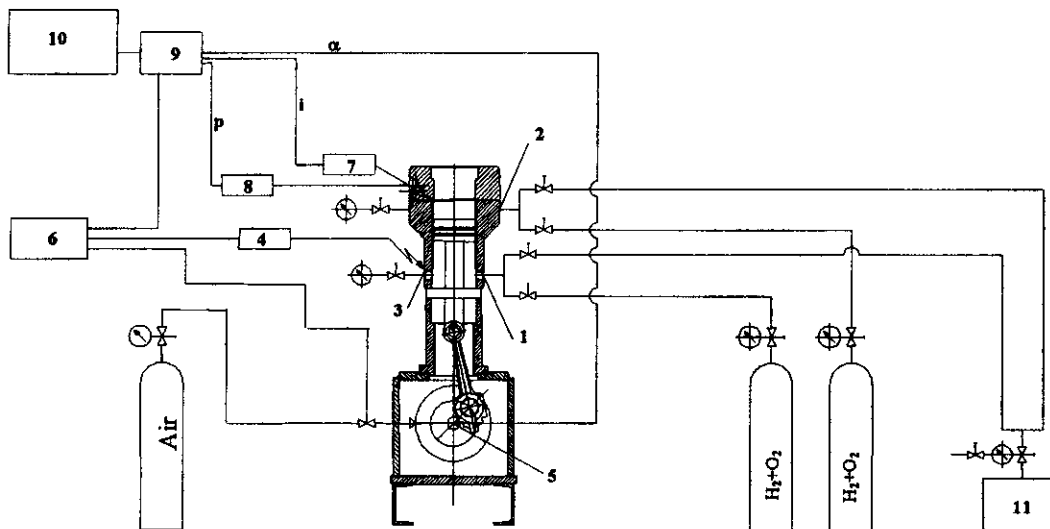
### **1. Introduction**

Rapid compression machines are used in many laboratories for preliminary studies in engine like conditions [1-9]. Many different designs of RCM exist depending on particular use. It is relatively easy to get single compression stroke if the final pressure has to be approximately 10 to 12 bar. This gives the initial conditions for the studies of combustion processes related to spark ignition engines. It is much more difficult to get the final pressure of the end of compression equivalent to fuel autoignition temperature. The process, which constitutes the main problem in reaching this temperature, is heat transfer to the combustion chamber walls, usually cold before commencement of compression. In order to reach the autoignition temperature in the combustion chamber it is necessary to apply high acceleration to the piston, particularly if the conditions in the combustion chamber are required to reflect the conditions of real engine at higher speed.

The rapid compression machine used in this work had original design enabling application of high acceleration to the piston with the adequate characteristics of piston movement achieved by conventional crank mechanism.

## 2. Rapid Compression Machine

The original rapid compression machine was designed and constructed at the Institute of Heat Engineering of Warsaw University of Technology. This machine is designed for the studies of autoignition and combustion processes in conventional gas engines supplied with gas by mixer or with gas injection to the combustion chamber. The adequate characteristics of piston movement are achieved by conventional crank mechanism, while the required piston acceleration is given by the combustion of fuel-oxygen mixture under the piston. Rapid pressure rise in the chamber under the piston causes upward motion of the piston, which in turn compresses the air or combustible mixture in the main combustion chamber above the piston. Calculations and preliminary tests have shown that using this method it is possible to get the piston acceleration equivalent to 5000 rpm of real engine. The schematic of operation and data acquisition of RCM is shown in Fig. 1.



*Fig.1. Schematic of rapid compression machine: 1 - filling the driving chamber; 2 - filling the test chamber; 3 - spark plug; 4 - ignition system; 5 - piston motion transducer; 6 - time sequencer; 7, 8 - amplifier; 9 - acquisition card; 10 - computer; 11 - vacuum pump*

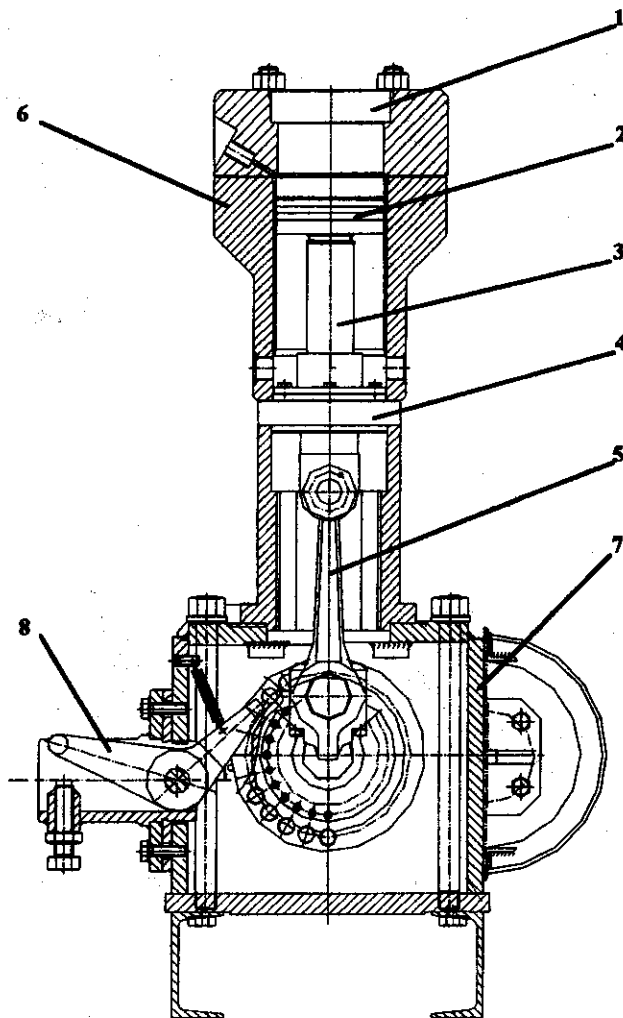
## 3. Design of rapid compression machine

Slide-crank mechanism was chosen in the design of our rapid compression machine. This mechanism enables the simultaneous connection of piston motion with the registered parameters. The parts of prototype Diesel engine DX2000 were used for the construction of the machine (crank mechanism, cylinder).

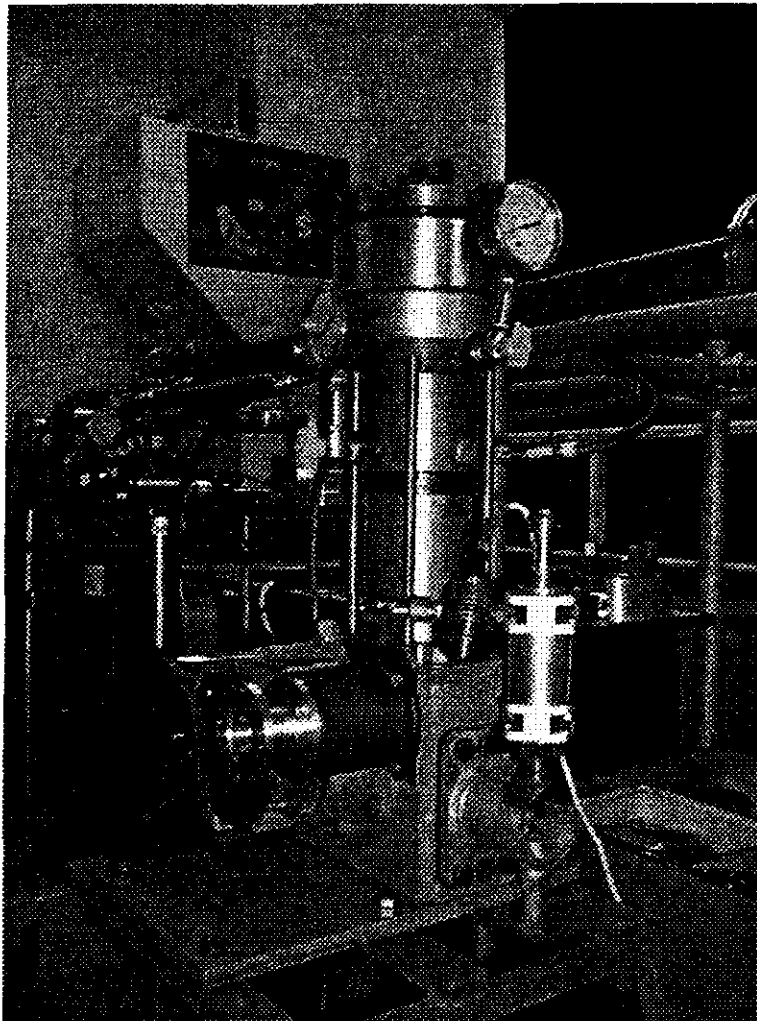
The cross section of the rapid compression machine is shown in Fig. 2. The quartz window (1) is placed in the head of the machine, which enables visualization of combustion process. Piston (2) made of duralumin is connected with piston rod (3). Piston rod is lead in the labyrinth sealing system. Piston rod is also connected with crank mechanism (5). Steel cylinder (6) is mounted in the steel case (7) of the machine. Crank

mechanism in blocked by the lever (8) at chosen position within the range of 20-50 deg after BDC.

The photograph of the rapid compression machine is given in Fig.3.



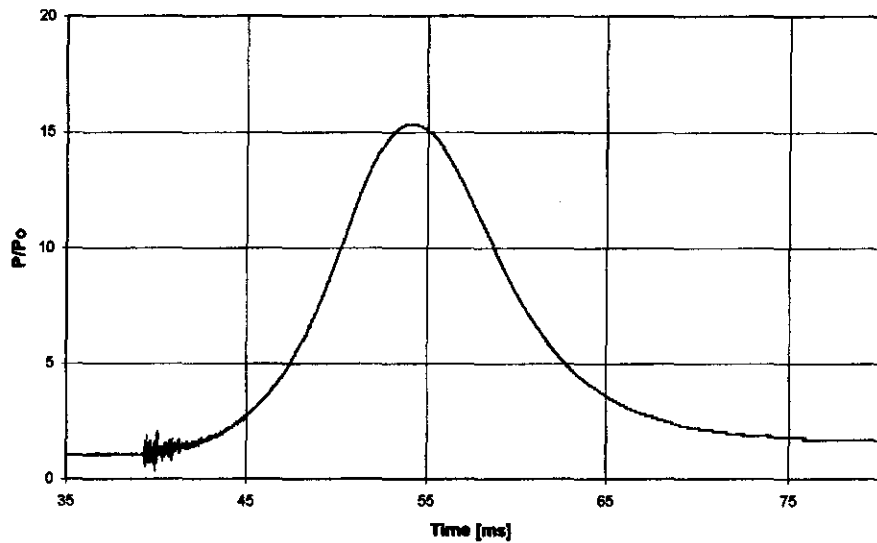
*Fig.2. Cross section of rapid compression machine: 1 - quartz window; 2 - piston; 3 - piston rod; 4 - labyrinth sealing system; 5 - connecting rod; 6 - cylinder; 7 - case; 8 - crank mechanism blocking lever*



*Fig. 3 Photograph of rapid compression machine*

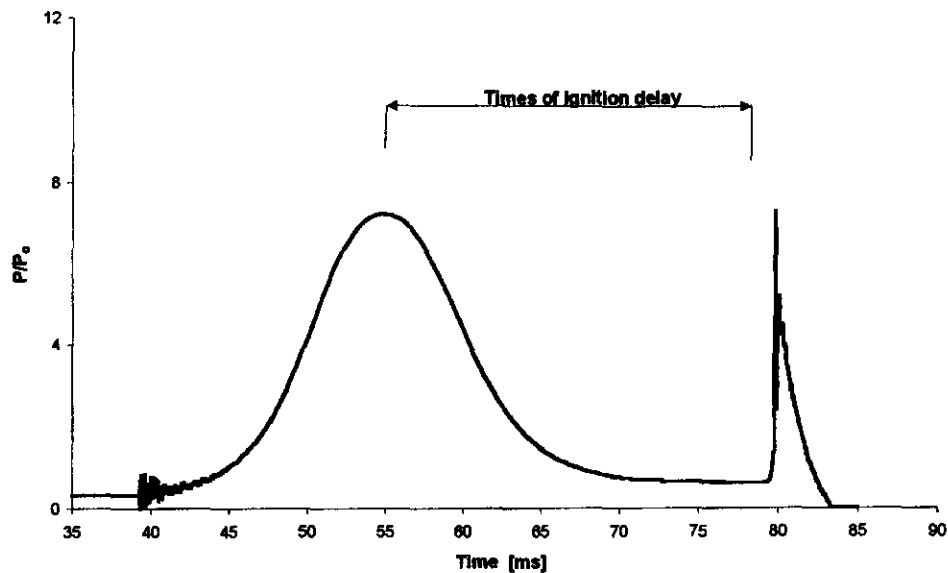
#### **4. Preliminary Studies of Autoignition of Stoichiometric H<sub>2</sub>-O<sub>2</sub> Mixture**

Preliminary studies conducted with the use of rapid compression machine aimed at the determination of machine parameters enabling for autoignition of gas mixture in the test chamber. The machine was driven by stoichiometric hydrogen-oxygen mixture. Choosing proper initial pressure of this mixture in the driving chamber under the piston the characteristics of compressed gas in the test chamber were determined. These parameters are: temperature of the end of compression, compression pressure and piston speed. The example of compression run without autoignition of hydrogen-oxygen mixture in test chamber is shown in Fig. 4.



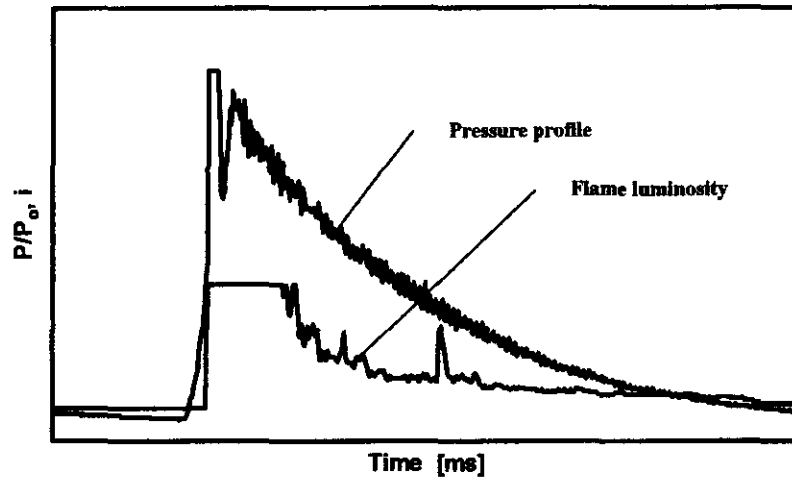
*Fig. 4. Pressure profile for the compression of  $2H_2-O_2$  mixture in test chamber*

The compression run with autoignition and combustion of stoichiometric hydrogen-oxygen mixture is shown in Fig. 5. The driving  $2H_2-O_2$  mixture has the pressure of 3.5 bar, the initial pressure of  $2H_2-O_2$  mixture in the test chamber was 1.5 bar and the temperature was ambient.



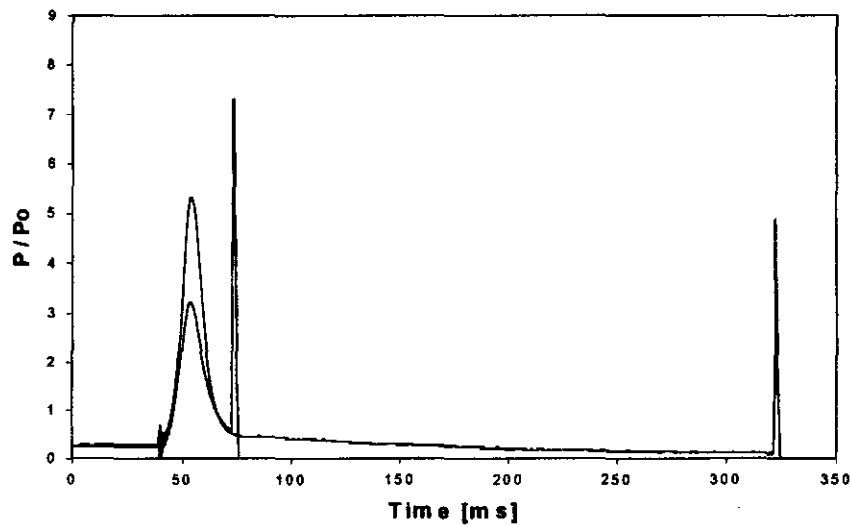
*Fig. 5. Pressure-time profile in test chamber showing compression and autoignition of  $H_2 + 0,5 O_2$  mixture*

The pressure profile from the experiment can be used for the determination of ignition delay time of the mixture tested at given initial conditions. To confirm existence of autoignition the light pipe window was made in the test chamber. Figure 6 shows results of the experiment with simultaneous acquisition of pressure and luminosity.



*Fig. 6. Pressure profile and flame luminosity during combustion in test chamber*

Changing initial conditions in driving and test chamber for the same combustible mixture it is possible to get different times of ignition delay, which is shown in Fig. 7.



*Fig. 7. Comparison of two autoignition processes of different ignition delay*

## 5. Conclusions

In this work a new research apparatus was presented: the rapid compression machine, which is driven by the combustion in the chamber under the piston.

This machine was designed for the studies of ignition and combustion processes at the conditions related to Diesel engines, while its use for gas engines is planned.

The preliminary studies have confirmed the possibility of the use of this machine for the studies of autoignition of gas mixtures. The wide selection of initial conditions made by changing the pressure of gas mixture in driving and test chambers enables for

studies at different conditions. The machine is equipped with pressure registration system and enables for visualization of ignition and combustion processes.

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