Summary

Doctoral Thesis: Analysis of a combustible mixture formation by the injection of pyrolysis oil in a constant volume combustion chamber.

The doctoral dissertation concerns research on pyrolysis oil made of HDPE (high density polyethylene) in terms of its potential use as engine fuel, both for spark ignition (SI) and compression ignition (CI) engines.

The aim of the doctoral dissertation is to present the research methodology and the results of the conducted research in the field of injection and formation of a combustible mixture as well as the combustion progress of pyrolysis oil under pressure and temperature conditions similar to those prevailing in an internal combustion engine. The basic tool for interpreting the results was a comparative analysis on the basis of which a comparison with classic fuels: gasoline and light diesel fuel was performed.

The research work is experimental. Chapters I and II are intended to present the current state of knowledge and justify the research undertaken in the work. Chapter I discusses the justification for taking up the topic and raises the legal, ecological, and economic aspects of waste management with energy potential. Pyrolysis oil is a liquid formed during the condensation of the pyrolysis vapor products of the organic substance. Pyrolysis oil is a liquid that has the characteristics of a fuel that can be used for thermal machines that generate heat and/or mechanical work (combustion engine, gas turbine, and water-steam boiler). Furthermore, the issue of the global problem with the disposal of waste plastics that cannot be recycled was raised. Thus, the positive results obtained from research on the pyrolysis of plastics should contribute to the further intensification of these works and the development of a technology for the thermal utilization of organic waste. Chapter II presents the state of the art in the field covered by the considerations raised in this thesis and concerning the following issues: the mechanism of the injected fuel stream breakdown known as a primary and secondary breakup, injection analysis using the SMD (Sauter Mean Diameter) parameter, the use of Weber and Ohnesorge criterion numbers to evaluate the quality of pyrolysis

oil atomization by a high-pressure injector and a comparative analysis of pyrolysis oil combustion with classic fuels in a piston engine. It was found that there is a shortage of research works dealing with pyrolysis oil injection and its combustion. Based on the presented works, it was shown that the research methodology proposed in the work is appropriate and considered the most reliable in experiments aimed at the investigation of fuel atomization.

Chapter III contains the aim and scope of the work as well as formulated theses. The main goal is to recognize the course of injection of pyrolysis liquid in conditions of temperature and atmospheric pressure and in conditions of increased pressure and temperature in a chamber of constant volume. These tests are aimed at developing guidelines for effective ignition and flame development for pyrolysis oil and mixtures with basic fuels, i.e. gasoline and diesel oil. The following theses were formulated: Thesis 1 - the phenomena of spraying and creating a combustible mixture of pyrolysis oil obtained after distillation of the raw HDPE pyrolysis liquid run similarly to the phenomena occurring for typical 95 gasoline in a direct injection in a SI engine; Thesis 2 - the tested pyrolysis oil can be used as a substitute for 95 gasoline to power a modern automotive engine equipped with a high-pressure direct injection system; Thesis 3 - the combustion progress of pyrolysis oil proceeds faster due to the higher share of the premixed combustion phase compared to this one of diesel fuel combustion.

Chapter IV describes the research methodology used in the work. The basic tool for experimental research and interpretation of results was a comparative analysis of selected parameters for pyrolysis oil in relation to reference fuels, which were: 91 gasoline and light diesel fuel. The values to be measured and then compared were as follows: Sauter's mean droplet diameter (SMD), statistical distribution of the sprayed liquid, speed and penetration of the injected liquid stream, ignition delay, and the main combustion phase, as well as the premixed and diffusion combustion phases. Then the plan of experimental research was presented. On this basis, the following two research test benches were proposed:

- constant-volume chamber for the self-ignition and combustion experiment, equipped with a high-speed video camera for recording images of the fuel cloud and flame propagation,

- a chamber for recording the flow and spraying of the tested liquid by means of a high-speed video camera and a laser optical system.

Chapter V is the main part of the work. It presents the results of experimental research and their analysis. In the beginning, the results of the physicochemical analysis of the pyrolysis oil produced on the laboratory stand were presented. Then, the results of the atomization of the tested liquids were discussed, taking into account the SMD size and Weber and Ohnesorge criteria numbers. Next, results were obtained by processing images from cameras and the course of pressure in the combustion chamber. Based on the analysis of the images, the following information was obtained: the maximum penetration of the combustion chamber by the sprayed fuel stream and the self-ignition kernel development. Based on the combustion pressure in the chamber, the results of the heat release rate, combustion phases, and ignition delay were determined. The final part of this chapter discusses the analysis of errors in the obtained results.

The work is summarized in Chapter VI, which contains findings divided into as follows: general, detailed, methodological, utilitarian, and future conclusions. The obtained results were used to assess the suitability of pyrolysis oil as engine fuel. The usefulness of the research methodology for this type of work was confirmed and the theses of the work were confirmed too. The experiments showed that pyrolysis oil in terms of the injection process and its parameters do not differ significantly from gasoline injection. An important and noticeable difference was the phase of premixed combustion, which is faster for pyrolysis oil in comparison with the same phase of diesel fuel.

The work ends with a bibliography.