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HEAT RELEASE IN SPARK IGNITION ENGINE WITH INTERNAL CATALYST

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Abstract

In the present work there have been shown the results of initial researches concerning heat release process in the spark ignition engine with inner catalyst. There has been presented the calculative model of heat release process and calculative methodology leading to obtaining temperature course, combustion function and its derivative because of measured course of combustion pressure. The pressure courses, which are necessary for calculations, were obtained on the measure seat with AD 1600 engine that is load with eddy- current brake. The engine was equipped with spark plug with miniature pressure sensor f-my Kistler, and the courses of pressure were recorded by the use of f-my Smetec apparatus. The courses of heat release process were analysed in rotations of n=1500 rotations/min and n=3000 rotations/minute and load of 50 Nm and 70 Nm. The analysis was made comparatively for the system with the catalyst and without catalyst.

In the work there have been presented the results of experimental and model researches which aim was the analysis of the issue of influencing the catalytic active surfaces placed in the spark ignition engine combustion space. Those surfaces, catalysing the process of creating combustible mixture and its combustion, influence the combustion process course and, simultaneously, have impact on the engine work parameters and the heat release course.

Keywords: *heat release, catalyst, spark ignition, pressure*

1. Introduction

Systematically increased clarity norms of engine fumes and the necessity to limit CO_2 emission which means in fact the limit of fuel consumption, induce for searching of new combustion systems, and also for searching of solutions which may allow to limit the emission of toxic components in the already existing systems, and in the further perspective to limit fuel consumption [1, 2, 3, 4]. Making use of internal combustion catalyst in the internal combustion engine is one of such solutions. The results of previously executing own researches and data literature allow to affirm that catalytic covers made inside combustion space in engine cylinder may beneficially impact on the combustion process course, and on emission of harmful components of fumes as well.

The researches concerning the influence of introduction of catalytic active factor into the engine combustion space are the new, and rarely found in the literature, issue. The mechanism of catalytic changes in the complicated combustion processes in the engine (and also in the processes of removing toxic substances form exhaust gases from internal combustion engines) is a difficult and not fully recognized problem. The introduction of the factor of catalytic properties into a system makes that the mechanism of physicochemical changes inside cylinder is even more complex.

According to the literature there can be concluded that the modification of engine combustion space that is consisting on the introduction of an active factor (catalyst) may cause shortening of chemical ignition delay through lowering energy of activation of pre-ignition reactions, changing in this way the combustion process course and influencing, among others, on the heat release process [5, 6, 7, 8, 9].

2. Research methodology

The researches of internal combustion AD 1600 engines parameters were made on the basis on load characteristics series, including the most frequently used field of engine work in the vehicle, which include rotation speeds in the scope from 1500 rotation/minute to 3000 rotations/minute, every 500 rotations.

The torque was changed from the value 10 Nm to 70 Nm, every 20 Nm. The characteristics were made repeatedly, and for the studies, the average values were taken into consideration.

During measurements, there were determined:

- engine rotation speed,
- torque,
- fuel consumption,
- fuel components concentration,
- fumes and cooling fluid temperature,
- combustion pressure.

The researches were made for the following cases:

- for zero state- without internal catalyst and with engine factory setting,
- for the I- state- with catalyst applied on suction and outlet valves.

The results of measurement have been presented in the tables and diagrams.

3. Calculative model of heat release

The researches of the combustion process, for different variations of research engine compound, were based on pressure courses in the combustion space in the function of the angle of crankshaft rotation (pointer charts).

The knowledge about pressures and volume of combustion space in the function of the angle of crankshaft rotation (OWK) allows to assign the values of temperature and absolute work of factor and the changes of its internal energy .

Making use of the first law of thermodynamics:

$$dQ = dU + dL, \tag{1}$$

where:
dQ – heat differential formula of thermodynamic transition,
dU – differential of thermodynamic factor internal energy,
dL – differential formula of absolute work,
there can be assigned the heat provided to dQ factor.

Relating the presented amounts of differential of the angle of crankshaft rotation, there appears the derivatives (“jet”) of balance amounts:

$$dQ/d\alpha = dU/ d\alpha + dL/ d\alpha, \tag{2}$$

what may be written as:

$$Q' = U' + L'. \tag{3}$$

The essential thing of heat engine work is the change of heat provided to working factor into mechanical work. In the internal combustion engines, the heat comes from the combusted doze of fuel B_o.

Setting up the relation of heat amount $Q(\alpha)$ produced from progressive combustion process of fuel in the function of the angle of crankshaft rotation $B(\alpha)$to heat Q_o of doze B_o, the function of combustion β is defined:

$$\beta = Q(\alpha) / Q_o, \tag{4}$$

what can be written as :

$$\beta = B(\alpha) / B_o, \tag{5}$$

where W is fuel value of fuel.

Making differential of the abovementioned equation, there is obtained the formula:

$$d\beta / d\alpha = dB(\alpha) / B_o \tag{6}$$

or:

$$\beta' = Q'(\alpha) / Q_o , \tag{7}$$

The jet of heat provided to thermodynamic factor (working) equals to differences of jet of heat produced in the combustion process and the jet of heat carried out to the combustion space walls.

The jet of heat carried out to combustion space walls has been assigned from the dependence:

$$Q'_{II} = \alpha_s A_s (T - T_s) / 6n, \tag{8}$$

where:
α_s – factor of heat penetration,
A_s – surface of combustion space walls,
T_s – temperature of combustion space walls,
N – rotation speed of crankshaft.

The values of the factor of heat penetration were assigned form the Woschni's dependence :

$$\alpha_s = 308{,}2\ D^{-0.214}\ c_{śr}^{0.786}\ p^{0.786}\ T^{-0.525}, \tag{9}$$

where:
D – cylinder diameter,
$c_{śr}$ – average speed of piston,
p – excess pressure in the cylinder,
T – absolute temperature of factor; assigned from gas state equation.

The jet of internal energy has been assigned from the dependence:

$$U' = n_{cz}\ b_{cz}\ T', \tag{10}$$

where:
n_{cz} – the amount of working factor in the cylinder,
b_{cz} – linearization quotient of average internal energy
T' – derivative of absolute temperature on the OWK angle.

The jet of absolute work has been assigned from the dependence:

$$L' = n_{cz}\ MR\ \Gamma\ T, \tag{11}$$

where:
n_{cz} – the amount of working factor in the cylinder,
MR – universal gas constant,
Γ – function of temporary volume changes of cylinder,
T – absolute temperature of factor, assigned from the gas state equation,

4. Research results

The researches were made for two compound states of the researched engine (zero state and state with valves covered by ceramic with catalytic layer), two values of rotation speed of engine crankshaft (n=3000 and 1500 rotations/minute) and three states of its load (M_o-30, 50 and 70 Nm).

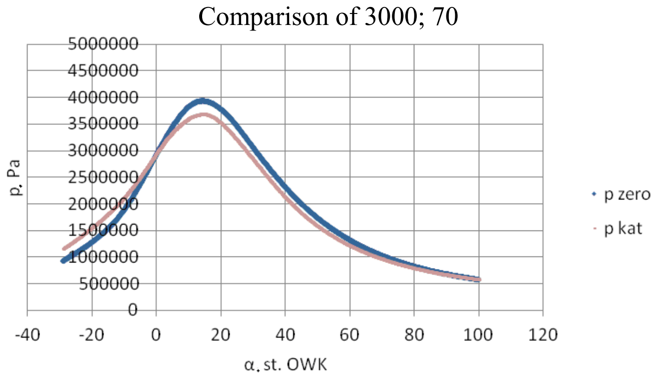

Fig. 1. Comparison of pressure values p of the factor in the cylinder in the function of the angle of crankshaft rotation for states: entrance (zero) and for the vales with ceramic cover and catalyst (kat); n = 3000 rotations/min, Mo = 70 Nm

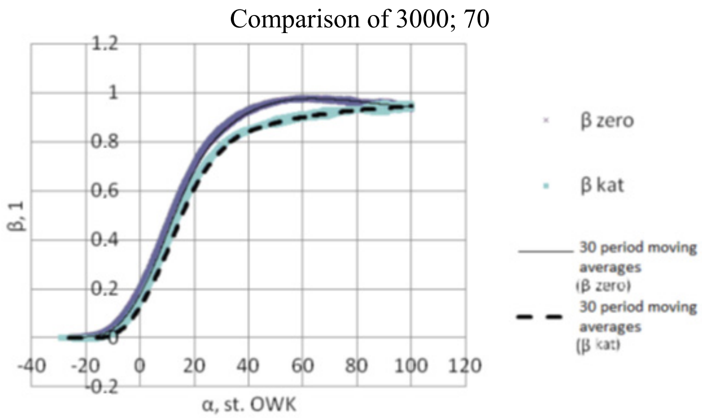

Fig. 2. Comparison of the courses of combustion function values β and their changeable averages in the function of the angle of crankshaft rotation for states: entrance (zero) and for the vales with ceramic cover and catalyst (kat); n = 3000 rotations/min, Mo = 70 Nm

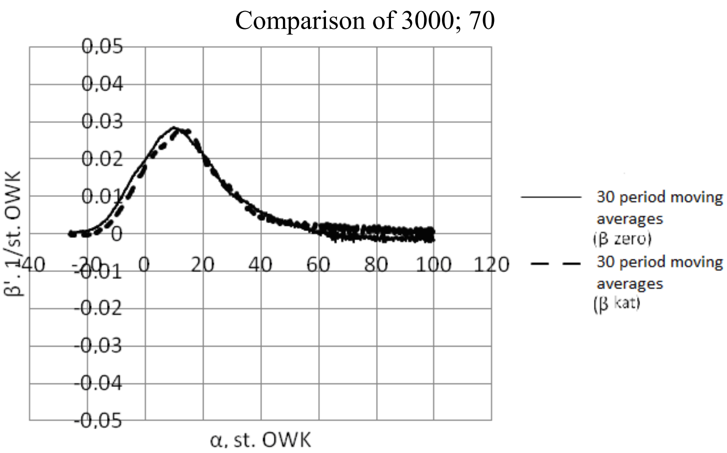

Fig. 3. Comparison of the courses of function β'values of the speed of heat releases as changeable averages in the function of the angle of crankshaft rotation for states: entrance (zero) and for the vales with ceramic cover and catalyst (kat); n = 3000 rotations/min, Mo = 70 Nm

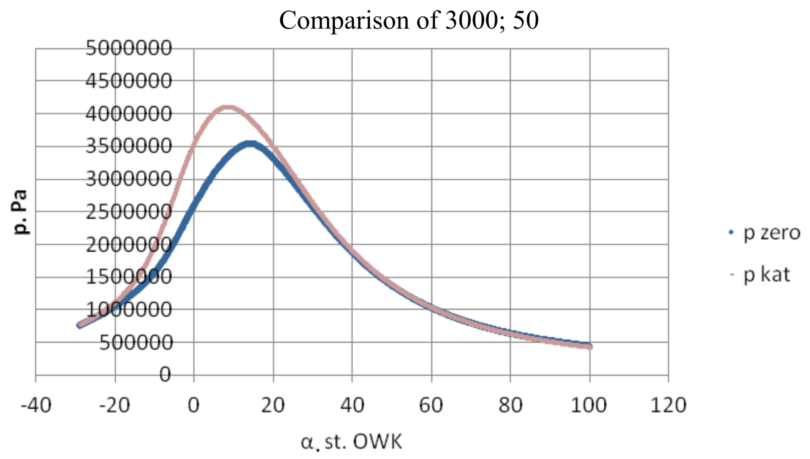

Fig. 4. Comparison of pressure values p of the factor in the cylinder in the function of the angle of crankshaft rotation for states: entrance (zero) and for the vales with ceramic cover and catalyst (kat); n = 3000 rotations/min, Mo = 50 Nm

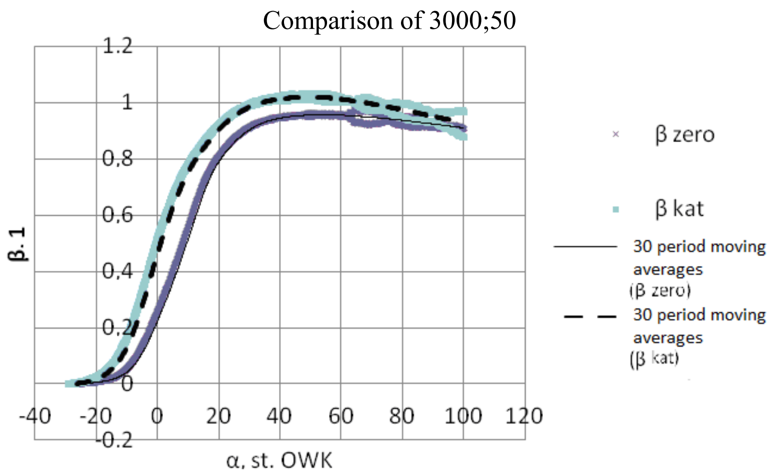

Fig. 5. Comparison of the courses of combustion function values β and their changeable averages in the function of the angle of crankshaft rotation for states: entrance (zero) and for the vales with ceramic cover and catalyst (kat); n = 3000 rotations/min, Mo =50 Nm

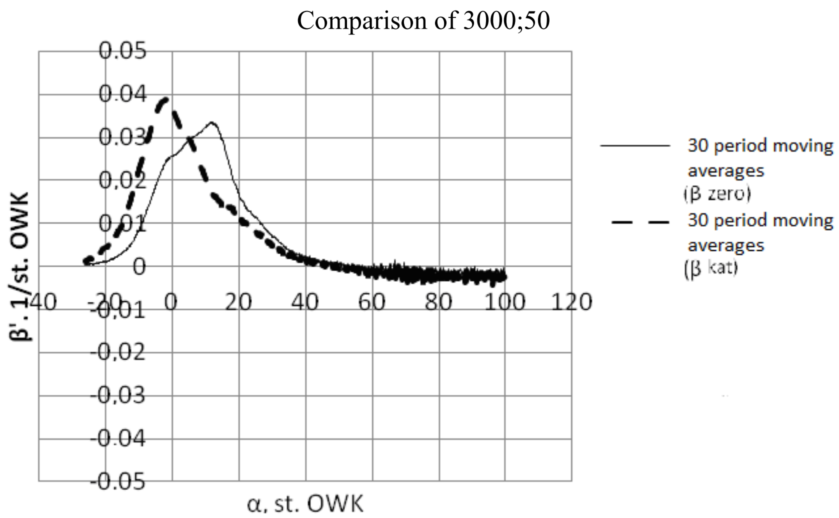

Fig. 6. Comparison of the courses of function β'values of the speed of heat releases as changeable averages in the function of the angle of crankshaft rotation for states: entrance (zero) and for the vales with ceramic cover and catalyst (kat); n = 3000 rotations/min, Mo = 50 Nm

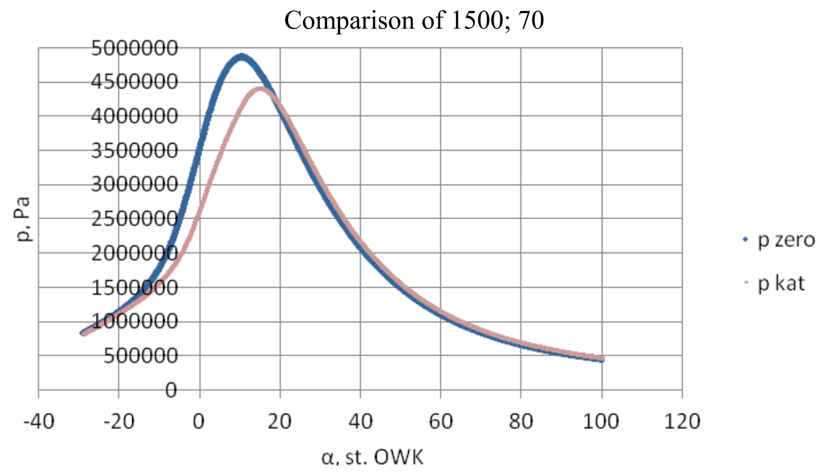

Fig. 7. Comparison of pressure values p of the factor in the cylinder in the function of the angle of crankshaft rotation for states: entrance (zero) and for the vales with ceramic cover and catalyst (kat); n = 1500 rotations/min, Mo = 70 Nm

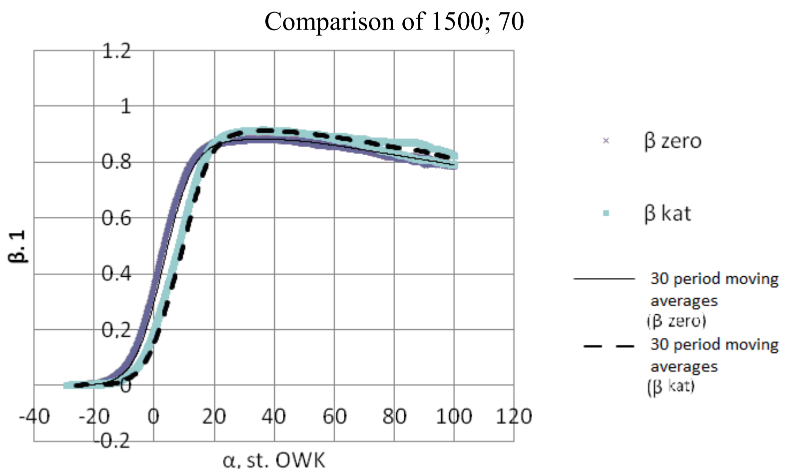

Fig. 8. Comparison of the courses of combustion function values β and their changeable averages in the function of the angle of crankshaft rotation for states: entrance (zero) and for the vales with ceramic cover and catalyst (kat); n = 1500 rotations/min, Mo =70 Nm

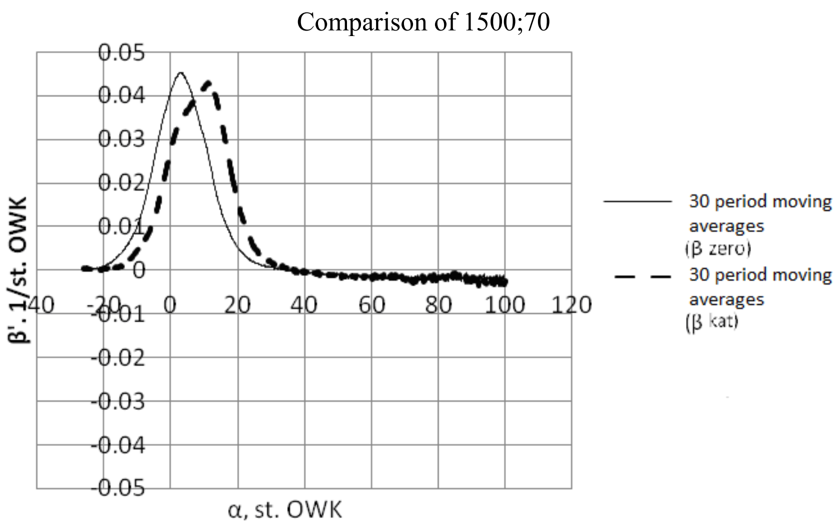

Fig. 9. Comparison of the courses of function β'values of the speed of heat releases as changeable averages in the function of the angle of crankshaft rotation for states: entrance (zero) and for the vales with ceramic cover and catalyst (kat); n = 1500 rotations/min, Mo = 70 Nm

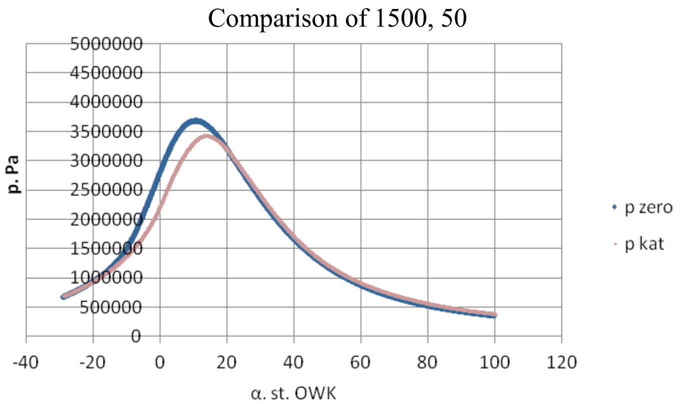

Fig. 10. Comparison of pressure values p of the factor in the cylinder in the function of the angle of crankshaft rotation for states: entrance (zero) and for the vales with ceramic cover and catalyst (kat); n = 1500 rotations/min, Mo = 50 Nm

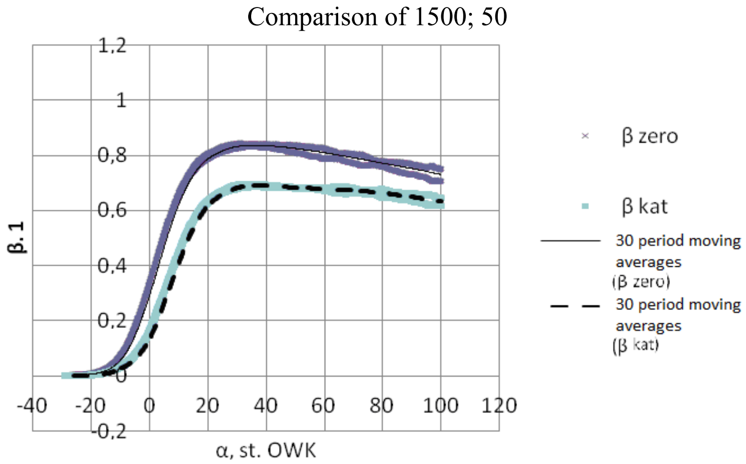

Fig. 11. Comparison of the courses of combustion function values β and their changeable averages in the function of the angle of crankshaft rotation for states: entrance (zero) and for the vales with ceramic cover and catalyst (kat); n = 1500 rotations/min, Mo =50 Nm

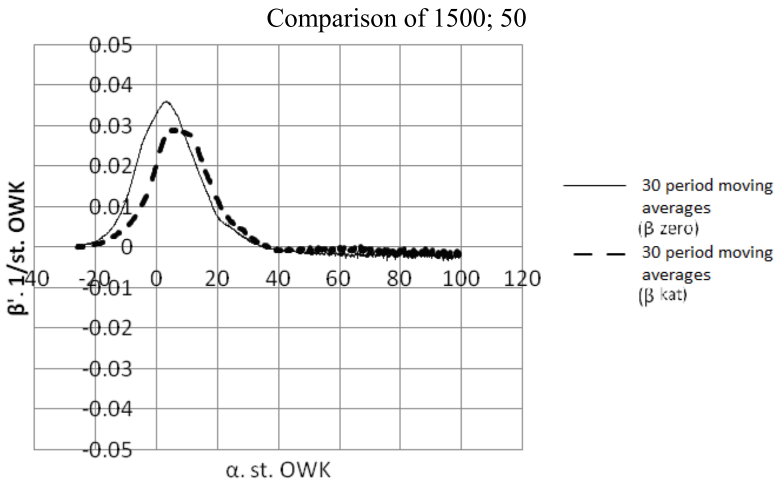

Fig. 12. Comparison of the courses of function β'values of the speed of heat releases as changeable averages in the function of the angle of crankshaft rotation for states: entrance (zero) and for the vales with ceramic cover and catalyst (kat), n = 1500 rotations/min, Mo = 50 Nm

The presented courses of combustion function with the presence of the internal catalyst essentially differ from the courses of combustion function without the catalyst. There have been obtained the decrease of maximum pressure for the large engine loads. In the case of small loads there have been obtained the raise of maximum pressure and their delay. Simultaneously, in all presented cases there have been obtained the positive effects of lowering fuel consumption and the improvement of fumes components. However, to draw further conclusion about the character of catalyst influence, it is required to broaden research works.

5. Conclusions and final remarks

From the presented researches results, there follows that the impact of the internal catalyst on the combustion process course and especially on the heat release course is essential. There can be observed the tendency of maximum pressure raising with significant engine loads, and the fall of maximum pressure with relatively low loads. At the same time, there can be observed lowering of unit fuel consumption and the improvement of fumes components. The complexity of the combustion process and the stage of researches advancement does not allow to interpret the phenomenon unambiguously. The role of the catalyst in the combustion process causes, according to Arrhenius formula, lowering of activation energy and change of the temporary constant value of combustion speed. The function of heat release speed is dependent on the constant combustion speed, and on the parameters of combustion space geometry, engine rotation speed, and combustion function. As it has been mentioned in the introduction, the internal catalyst also influences the process of preparing the fuel-air mixture for the combustion and it changes the condition of combustion in the parietal layer. The above-mentioned factors in connections with the variable turbulence processes in the engine cylinder, which influence the catalyst contact with the fuel molecules , cause that the impact of the catalyst on the combustion process course may be changeable in different phases of this process. The explanation of catalyst impact requires further researches, especially in the aspect of its application in the CAI and HCCI engines.

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