

# ELECTRIC-DISCHARGE CONTROL OF IN-PIPE DETONATIVE COMBUSTION

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Investigations into the transition of slow combustion into detonation have noticeably gathered momentum due to the creation of detonative-combustion engines that hold much promise. The transition of slow combustion into detonation in pipes is preceded by the acceleration of the flame due to periodic wave formation and turbulization in it, which are accompanied by compression wave circulation. As the compression waves are intensified to the point where the fuel mixture ignition is possible, the pre-detonative combustion is completed and detonation occurs. This being so, the problem of controlling pre-detonative flame acceleration is a currently central one.

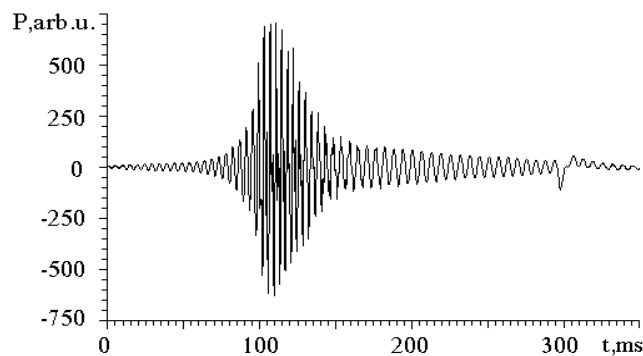
As is evident from [1], the variable Joulean heat release will invariably be in anti-phase with the variable chemical-reaction heat release due to an additional internal negative feedback chain when a current-stabilized diffuse electric discharge is applied to the flame zone. This anti-phase situation will cause suppression of the combustion instabilities.

The following description summarizes the results of experiments conducted by the present authors to study in-pipe pre-detonative flame acceleration control by that technique. The potential offered by the technique is described in [2].

The experiments were conducted with a half-open, 13 x 16 mm section, 1,200 mm long pipe. The two opposite, farthest separated, pipe walls were made of steel and were used as electrodes, between which diffuse discharges were excited from a special-purpose power supply unit. The two remaining walls were made of thick transparent polymethyl methacrylate. The fuel mixture was injected and ignited by a spark at the closed pipe end. The detection unit included a piezo-ceramic pressure transducer mounted at the closed pipe end and two photomultipliers installed 500 mm apart in the vicinity of the open pipe end. The signals from the transducer and the photomultipliers were sent through an ADC to an IBM PC-compatible computer for further processing. The phenomena under study were visualized using a high-speed motion-picture camera on a Toepler unit by a shadow method.

In order for the electric discharges to have their greatest impact on the flame zone during the progress of the experiments, the voltage and the current were applied to the shock pipe electrodes so that the discharges went through the moving flame front.

Experimentally, the pressure oscillation in propane-air mixtures at the shock pipe end would decrease approximately four-fold in amplitude when current-stabilized electric discharges were applied to the flame wave propagating in the pipe (Figure 1). When stoichiometric mixtures were enriched to as much as 40 per cent in oxygen, the pressure oscillation would decrease insignificantly in intensity, by approximately 20 per cent (Figure 2), and the time it took for the pressure oscillation to be enhanced in amplitude would increase by a factor of about two as compared to a no-discharge situation. What this means is that the pre-detonation period tends to be



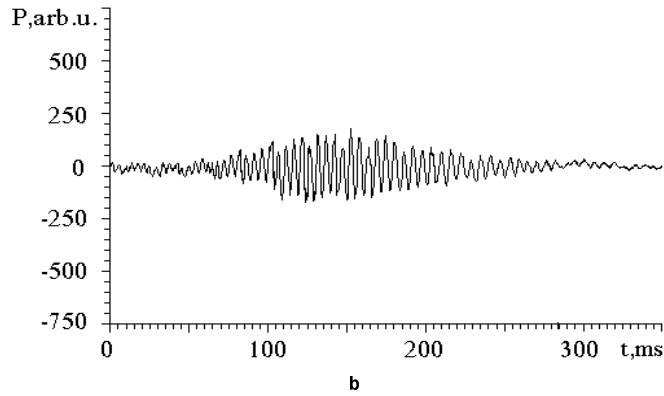


Figure 1. An oscillogram representing pressure oscillations occurring in the closed pipe end region in arbitrary units for a stoichiometric propane-air mixture: (a) no discharge, (b) with discharge.

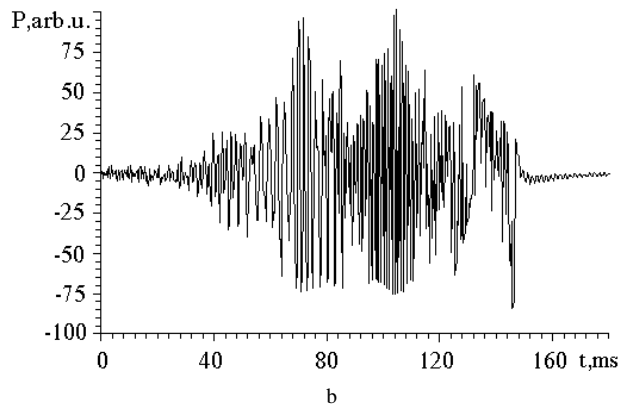
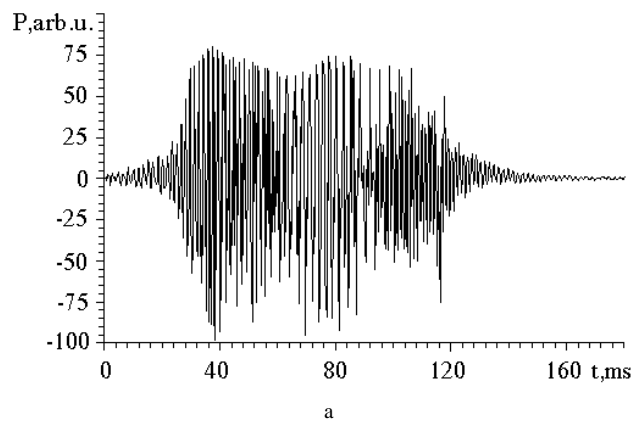


Figure 2. An oscillogram representing pressure oscillations occurring in the closed pipe end region in arbitrary units for a stoichiometric propane-oxygen (30%)-air mixture: (a) no discharge, (b) with discharge.

protracted in high-energy mixtures. The latter is clearly demonstrated by the dependencies of the accelerating flame front propagation velocity ratio on the oxygen percentage in the air for stoichiometric mixtures both when an electric discharge is applied to the flame front and in a no-discharge situation. The curves were obtained by processing the signals of the two multipliers (Figure 3). As is evident from the figure, the average accelerating flame front propagation velocity is lower for low-energy mixtures in the electric-discharge case than when no discharge is applied. As the oxygen percentage is increased the velocity ratio tends to become smaller to the point of being less than unity for higher-energy mixtures.

The observed phenomenon is likely to be due to the Joulean heat release affecting the flame behaviour by two mechanisms: increase in the normal combustion rate and flame surface turbulization. The former mechanism will be dominant in low-energy fuel mixtures and, this being so, the average in-pipe flame propagation velocity

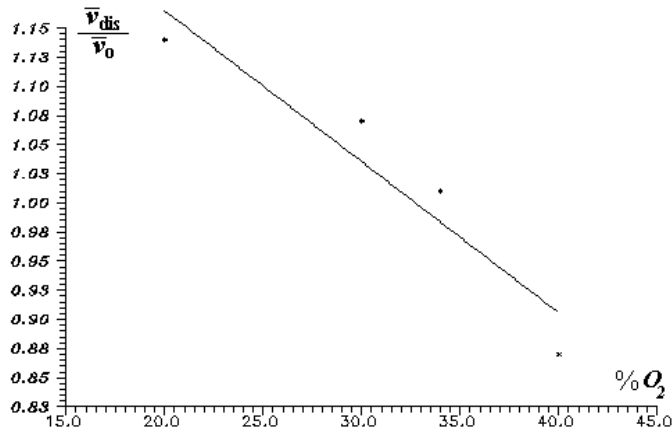


Figure 3. Ratio between the average flame propagation velocity with discharge and that with no discharge in stoichiometric propane-air mixtures ( $N_2 + O_2$ ) versus the oxygen percentage.

will be higher when an electric discharge is applied than in a no-discharge situation. As the oxygen percentage in the air is increased, with the wave formation and flame surface turbulization playing a significant role in the flame acceleration, the latter mechanism will prevail; it will involve a decrease in the pressure oscillation amplitude and the flame propagation velocity due to the suppressed periodic change in the flame surface area, which is supported by the shadow photographs.

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## References

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