Investigation of the thermal ignition phenomena of liquid fuel in a hot atmosphere

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Accidental ignition of fuels is a critical safety and economic concern for the chemical, aerospace, automotive, and petroleum industries. Understanding ignition processes is crucial to reducing accidents and exacerbated pollution emissions. Even though thermal ignition is a well-recognized hazard, it is only superficially understood, and safety guidelines tend to oversimplify the phenomenon.

This study aims to improve the knowledge of the ignition processes of liquid fuel inside a hot atmosphere, providing a close look at the evaporation processes and the ignition kernel. An experimental setup has been designed to give an in-depth optical investigation of fuel ignition.

An important part of the study focuses on the vaporization processes. The behavior of the droplets when impacting the vessel's hot surface is studied for temperatures below and over the Leidenfrost temperature. The first impact is categorized as spreading, bouncing, breaking up, or splashing as a function of adimensional numbers. Each category is linked with a typical vaporization time, and the influence of the impact type on the ignition time is detailed.

Advanced experimental techniques are applied to characterize the ignition processes. Shadowgraphy is used to characterize the injection, the droplet's sizes and the fuel state (liquid or gaseous). The formation and concentration of radicals during combustion are studied via the chemiluminescence optical technique. Finally, the gas temperature is measured via phosphor thermography. The effect of the fuel type and the surface and air temperature is studied. An experimental database is generated and analyzed to detail the different ignition mechanisms.

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