

## Effects of Different Jet Fuel Characteristics on Spray Flame Lift-off Height

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### Abstract

Ensuring economical and clean combustion performance of liquid-fueled engines needs comprehension of the influence of fuel composition and properties on flame behavior, like flame ascent height (LOH) and lean blowout limit (LBO). Spray flame stability is powerfully full of each the fuel reactivity and physical properties. Herein, the flame stability mechanism diagrammatical by LOH is investigated for seven jet rotary engine fuels, as well as surrogate, different and standard jet fuels, employing a laboratory spray burner. supported the experimental observations, this work introduces a brand new analysis, that provides insight into the competing/complementing processes that occur in an exceedingly multi-phase reacting system and highlights the key properties vital in spray flame dynamics, accounting for each the fuel spray/vaporization likewise because the chemical reactivity, to elucidate the relative variations in LOH of complicated multicomponent fuels. Results show that spray flame stabilization happens once there's a balance between the native spray burning speed and therefore the incoming jet speed that is powerfully related to stratified flame speed and therefore the relative quantity of liquid and aerosolized fuel crossing the flame heat region.

**Keywords:** Spray flame; Jet fuel; Surrogate; Atomization; Vaporization

### Introduction

The aviation sector accounts for a big and growing portion of the planet energy usage and contributes to ~2% of carbonic acid gas emissions. In 2018, the US consumed ~623 million barrels of jet fuel, that was appreciate roughly 3.5% of the US primary energy consumption. This diode to regarding a pair of 0.6% of all domestic greenhouse emission emissions. Aviation energy usage and emissions burdens square measure expected to grow chop-chop, because the annual average growth in international rider travel is foreseen to be within the vary of 3.2 to 5.3% over successive twenty years [1]. This growth a lot of motivates researchers toward advancing fuel and engine styles to accomplish a cleaner and more economical energy conversion method. This could be achieved by understanding the influence of the liquid fuels that have wide selection of variations in physical and chemical properties on the energy transformation processes occurring within combustion engines. Every stage throughout the combustion of a liquid fuel, consisting of drop formation (i.e., atomization), vaporization, turbulent air/fuel mixture, and therefore the chemical mechanics, will have an effect on the combustion potency, flame stability/behavior, and emissions [2]. Stabilization of a flame refers to a large vary of conditions that interrupt the steady behavior of a flame; such effects will vary from ascent removed from the burner outlet or a bluff body, to spasmodic blowout, to temporary fluctuations prompted by heat unleash and instable pressure feedback. The understanding of flame LOH phenomena includes a sturdy reference to operation close to LBO and so the reduction of soot emissions. Additionally to the existence of raised flames in gas turbines, they're found in several sensible combustion applications like burners in industrial boilers, wherever the raised jet flame is used to cut back injury to nozzle material by preventing interactions between the flame base/edge and therefore the contrivance tip. not like gas part (premixed and diffusion) flames, spray flame stability is full of the dynamic of the two-phase vapor-liquid equilibrium (VLE) that powerfully impacts the blending time scales, especially, those tied to gas part mixture forming. Thus, these volatility-dependent mixture compositions should even be accounted for. There square measure few studies that have investigated the stabilization mechanism of spray flames [3]. This is often caused by the complexness

of the two-phase spray flame downside that arises from the linkage of variety of processes, as well as atomization, vaporization, mixing, and chemical mechanics. Qualitatively investigated the behavior and stability of raised spray flames victimization alcohol fuel. In their study, they utilized totally different optical maser diagnostic techniques, as well as OH coplanar laser-induced light (OH-PLIF), CH-PLIF, and smoke mental image. They determined that the leading edge-flame stabilizes and sustains within the low-speed flow region, wherever the flame propagates against the incoming flow [4]. Disbursed Associate in nursing experimental investigation on raised kerosene spray flames for a spread of co-flow conditions, as well as many preheated co-flow temperature and N dilution. They found that the flame LOH decreases because the N dilution decreases and therefore the co-flow temperature will increase, each enhancing mixture reactivity with higher temperatures additionally promoting a better fuel vaporization rate. Similar observations were found by identical cluster in an exceedingly later work. Conducted experimental and numerical analysis to check the turbulent spray flame structure victimization n-heptane fuel. They discuss the presence of 2 flame structures, with Associate in nursing inner partially-premixed flame front, that enhance the flame stabilization [5], Associate in Nursing an outer diffusion flame front, largely fed by larger droplets. They additionally determined that the flame base stabilizes wherever the flame speed is quickest and situated around ratio fuel/air quantitative relation regions. Similar observations were found by the experimental work, that characterised the spray jet flame of n-heptane victimization part physicist measure (PDA) and OH-PLIF. in an exceedingly relevant study, Steven Weinberg and polyglot used a mathematical model to check the flame stability,

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diagrammatical by flame LOH and lean blowout limit of a stratified jet spray diffusion flame. They used a straightforward single international reaction to match the flame stability of aerosolized and spray flames and provided discussion on many flame situations associated with variation in drop size and initial spray polydispersity [6].

## Experimental setup and strategies

### Spray burner

An unconfined Associate in Nursing singular Co-flow Spray Burner (ACS Burner) was accustomed promote the theoretical understanding of the mechanism that controls the flame LOH of various liquid fuels [7]. The straightforward axisymmetric unwirled co-flow burner forms a stabilized spray flame in a very platform capable of unveiling the complicated and heterogeneous spray method that a liquid fuel experiences in realistic liquid-fueled turbine. A schematic of the burner [8]. The equipment includes a swirl-pressure dispenser (Delavan 80°, Type-B solid spray pattern), a mass flow controller (Alicat, MCR-3000 SLPM), that includes accuracy of  $\pm 0.8\%$  of reading, and 0.2% of all-out, and a high syringe pump (ISCO, Model 260D). The air co-flow and fuel area unit delivered to the spray burner at a temperature of  $\sim 298$  K generating a flame at laboratory pressure. A lot of details of the used burner and its spray flow characterization area unit according elsewhere [9].

### Fuels

In this study, a complete of seven fuels were tested, together with 3 jet fuel surrogates, (2nd generation, and n-dodecane), 3 standard jet fuels, (Jet-A, JP-8, and JP-5), and one different jet fuel, (Gevo-ATJ). The relevant properties of the tested fuels area unit. Note that the bedded flame speeds for the surrogates, that area unit listed in Table one, were calculated for the neat surrogate composition by linearly averaging the bedded flame speeds of the only parts (weighted by their relative mole fraction), that were according in previous works at 400K (i.e., 127°C), at gas pressure, and ratio mixture fraction, with the exception of the bedded flame speeds for decalin and isocetane, that were measured at a temperature of 443 K [10]. Since the relation between change state mixture temperature and bedded flame speed is almost quadratic, i.e., SLTu2, the flame speeds at temperature of four hundred K for decalin and isocetane were calculable by means that of extrapolation. Show a comparison of flame speeds of isooctane to isocetane at 443 K and with the assistance of the bedded flame speed that was measured for isooctane at four hundred K, further confidence within the mentioned approach for predicting bedded flame speed for the unobtainable conditions has been reached [11]. The surrogate fuels tested here have totally different compositions and physical and chemical properties which permit for insight into however these properties result flame LOH. additionally, the surrogates have a little variety of parts, e.g., Dooley 2012 consists of n-dodecane, isooctane, n-propylbenzene (n-PB), and 1,3,5-trimethylbenzene (1,3,5-TMB), whereas Kim 2017 consists of n-dodecane, isocetane, decalin, and dissolvent, as listed [12]. Thus, the lifespan and also the physical change dynamics of a drop will be simulated by applying VLE with d2 law, as delineate by the drop evaporation model developed. Implementing this model on the surrogate fuels permits the prediction of the compositions at the edge-flame, and so the influence on flame speeds and flame LOH [13].

### Conclusion

The sensitivity of jet fuel properties on the flame LOH has been by experimentation investigated exploitation the ACS burner. Initial

testing of specific revealed jet fuel surrogates with a little variety of species permits simulation of the drop lifespan to grasp the LOH mechanism. a singular changed spray propagation model that accounts for the discriminatory vaporization of multicomponent fuels is employed within the current work. From this, it had been found that the variations in LOH between the surrogates is caused by the twophase spray flame burning speed, that considers each pre-vaporized fuel reactivity (SL) and time scales tied to drop vaporization. within the case of the Dooley 2012 surrogate, discriminatory vaporization of the lighter species within the mixture provided a comparatively a lot of reactive mixture tributary to a shorter upraised flame than the Kim 2017 surrogate at co-flow velocities far-flung from LBO. However, as within the case for Dooley 2012 surrogate, fuels exhibiting high volatilities and little SMD will result in native fuel leaning effects reducing mixture flame speeds and resulting in a non-linear increase in LOH as co-flow velocities area unit accrued. The LOH of the \$64000 jet fuels was found to be for the most part influenced by the physical properties/processes, specifically volatility (T50) and drop size (SMD) and to a lesser extent the flame speed of the fuel volatilized before coming into the flame. it had been noticed that fuels with lower volatility [14], and people that generate larger droplets, lead to larger flame LOH. though n-dodecane incorporates a perceptibly higher flame speed than the opposite jet fuels, its flame failed to stabilize nearer to the burner tip. Moreover, C-1 has rock bottom flame speed and however exhibits one among the littlest LOH among the tested jet fuels. The results counsel that the time scales of vaporization and intermixture area unit a lot of larger than the time scales of reaction and so they're dominant in dominant the flame LOH stabilization mechanism, particularly once complicated jet fuels area unit used each VLE and atomization/vaporization dynamics will have an effect on flame stability and behavior in liquid burning applications, like liquid-fueled turbine engines, and may be rigorously thought of in surrogate and different fuel formulation activities [15].

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