2016/6/20 SIP「革新的燃焼技術」公開シンポジウム

# ガソリン燃焼チーム クラスター大学17 （燃料・ノック班）

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# RON of gasoline surrogates and their weak flame characteristics in a micro flow reactor with a controlled temperature profile under ultra-lean conditions

## 1 Objective

**Background**

- Ultra lean gasoline combustion allows for higher thermal efficiency
- Ignition characteristics and mechanisms are not well validated in ultra lean condition
- Important to avoid engine knocking

**Challenges**

- Ultra lean combustion usually only possible in high temperature/pressure region
- Common approaches are not steady state (RCM, Shock tube)

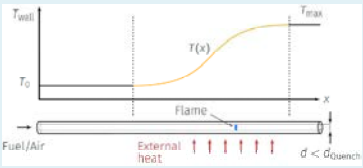
**Solution**

- Investigation by micro flow reactor with controlled temperature profile
- Allows for investigation at atmospheric and elevated pressures and temperatures
- Enables steady state investigation

## 2 Principle

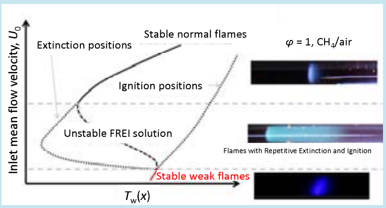
**Micro flow reactor with a controlled temperature profile** [1][2]

- Quartz tube heated by an external heat source ($H_2$/air flame)
- Diameter smaller than quenching diameter
- Gas phase temperature is governed by wall temperature



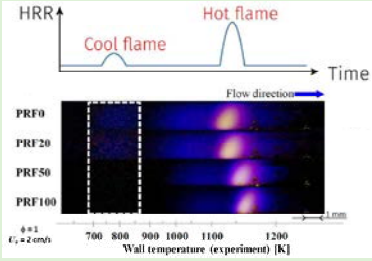

**Flame responses to velocity**[1][2]

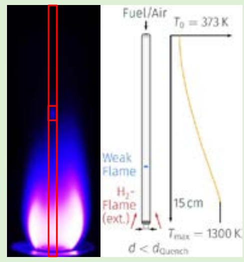
- Three flame branches exist
- Unstable branch connecting normal flame and weak flame
- Stable weak flame occurs at low velocities, represent ignition branch
- Investigation of ignition processes possible by steady weak flames




## 3 Results

**Previous results show relation between RON and flame position**[3]



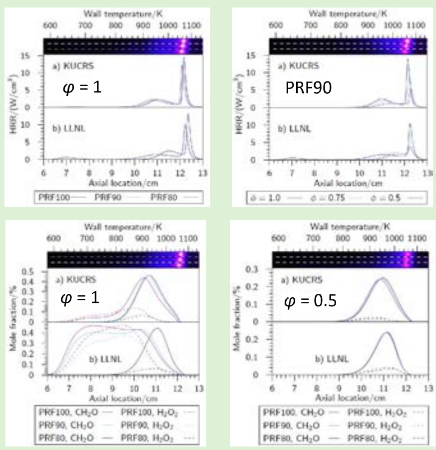

**New vertical setup with higher resolution**

**Numerical simulations**

- PREMIX[4] based 1-D steady code[1]
- Additional term for heat transfer to wall

$$\dot{M}\frac{dT}{dx}-\frac{1}{c_p}\frac{d}{dx}\left(\lambda A\frac{dT}{dx}\right)+\frac{A}{c_p}\sum_{k=1}^{K}\rho Y_k V_k c_{pk}\frac{dT}{dx}+\frac{A}{c_p}\sum_{k=1}^{K}\dot{\omega}_k h_k W_k-\frac{A}{c_p}\frac{4\lambda Nu}{d^2}(T_w-T_g)=0$$

**Effect of RON** **Effect of φ**



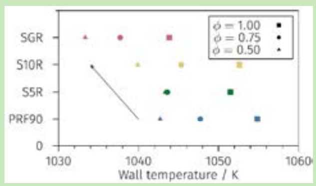

**Accuracy**

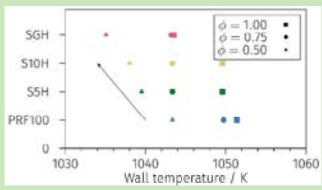
- Experiments and simulations have high accuracy
- Very good agreement for φ = 1
- Opposite trends for φ < 1

**Species analysis**

- Low temperature reactions for φ = 1
- Suppression of low temperature reactions for φ < 1
- Ultra-lean combustion may increase knocking resistance

**Flame locations for RON = 90 fuels** **Flame locations for RON = 100 fuels**




→ **Higher reactivity for surrogates with more species**

## 4 Outlook

**Ultra-lean combustion**

- Ignition properties of a wide range fuel mixtures and conditions will be investigated.
- Experiments will be done at atmospheric and elevated pressures.
- Mass spectroscopy will be employed for species measurement.
- Numerical simulations will help understand complex ignition properties in ultra-lean condition.
- Innovative ignition property index can be derived from data.

**Exhaust gas recirculation (EGR)**

- The micro flow reactor with a controlled temperature profile can be employed to investigate stable normal flame in EGR case

## 5 Research Plan

| 2016 | 2017 | 2018 |
|---|---|---|
| • Elevated pressure and species measurement by MS | • Investigation of EGR conditions | • Compilation of data and creation of index numbers |

## References

[1] K. Maruta, T. Kataoka, N. Kim, S. Minaev, R. Fursenko, *Proc. Combust. Inst.*, 30 (2005), 2429-2436.
[2] S. Minaev, K. Maruta, R. Fursenko, *Combustion Thoery and Modelling*, Vol. 11 No. 2 (2007), 187-203.
[3] M. Hori, A. Yamamoto, H. Nakamura, T. Tezuka, S. Hasegawa, K. Maruta, *Combust. Flame*, 159 (2012), 959-967.
[4] R.J. Kee, et al., Sandia National Laboratories Report (1985), No. SAND85-8240.

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