Hypergolic Ignition Drop Testing of Liquid Propellants with Hydrogen Peroxide

C. Soudarin[1,2,3], M. Bellenoue[1], Y. Batonneau[2], R. Beauchet[2], B. Boust[1], L. Prévost[3]

[1]PPrime Institute, CNRS, ISAE-ENSMA, Université de Poitiers, Chasseneuil-du-Poitou, France
[2]IC2MP, Université de Poitiers, CNRS, 4 rue Michel Brunet B27, TSA 51106, 86073, Poitiers Cedex 9, France
[3]CNES, Space Transportation Directorate, 52 rue Jacques Hillairet, 75612 Paris Cedex

Context

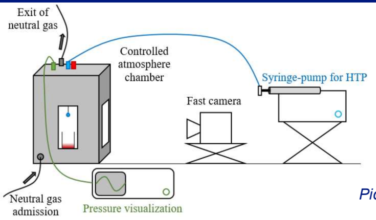
Because of current environmental issues, space industry is looking for green and non-carcinogenic propellants to replace hydrazine. Although hydrazine and its derivatives present very conclusive propulsion performances, the European commission REACH – Registration, Evaluation, Authorization and Restriction of Chemicals – has identified hydrazine as a substance of very high concern. Under such circumstances, hydrogen peroxide, HTP, is a promising candidate to replace hydrazine in hypergolic systems which enable to avoid adding an external ignition system and allow both easy and multiple restarts.

→ **Parametric study on the <u>ignition delay time</u> (IDT) of a reference mixture of triglyme/sodium borohydride with HTP**
→ **Test and compare hypergolicity between HTP and five combinations of three fuels (hexane, heptane, THF) and three additives (TEB, TEA, TMA)**

EXPERIMENTAL SET-UP

A test-bed allowing to control atmosphere during drop test was designed:

- Volume of the chamber: 8.2 L
- Chamber wiped out of air with argon
- Fuel poured in a beaker thanks to a syringe through the top plate
- Syringe-pump to drop HTP onto the fuel
- Camera used for visualization: FASTCAM Mini UX50 type 160K-M-8G
- Acquisition frequency: 4 kHz for triglyme and sodium borohydride
  8 kHz for other additives (uncertainty on the IDT down to 0.25 ms)



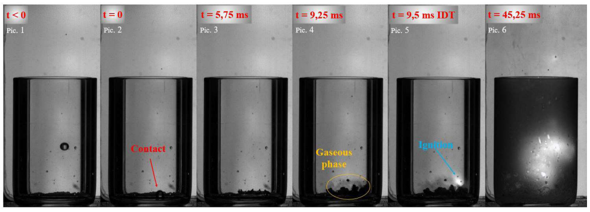
Scheme of the experimental set-up for drop tests

Picture of the inside of the controlled atmosphere chamber

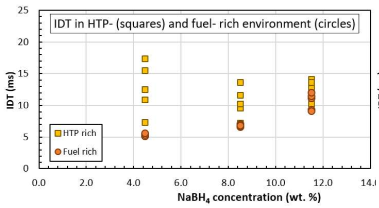
CHARACTERISATION OF THE IGNITION

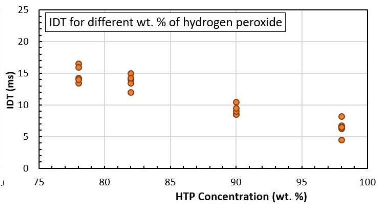
Triglyme and Sodium Borohydride ($NaBH_4$)

IDT = time between the first contact of the HTP droplet with the fuel (pic. 2) and the first flame/bright area (pic. 5)

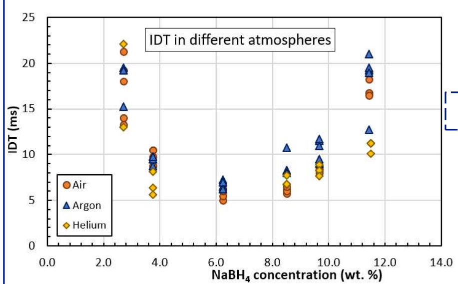


HTP 90 wt. % + triglyme/3.8 wt. % $NaBH_4$ under argon





- IDT ↗ when HTP rich environment
- IDT ↘ when HTP concentration ↗



Drop tests conditions:

HTP 98 wt. %

Fuel rich environment

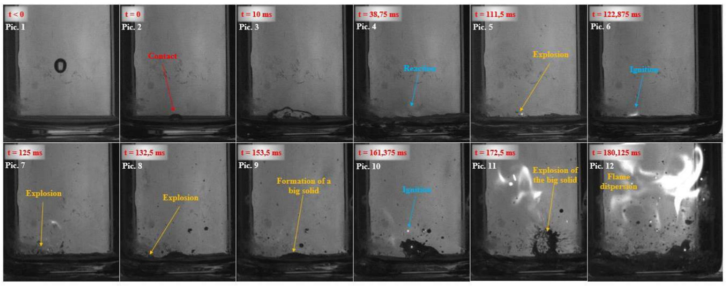
Temperature, velocity and pressure constant [1-5]

- IDT min. between 4 and 8 wt. % $NaBH_4$ (viscosity ↗ with $NaBH_4$ concentration [1])
- No impact of the atmosphere over the IDT

Triethyl-, Trimethylaluminum and Triethylborane

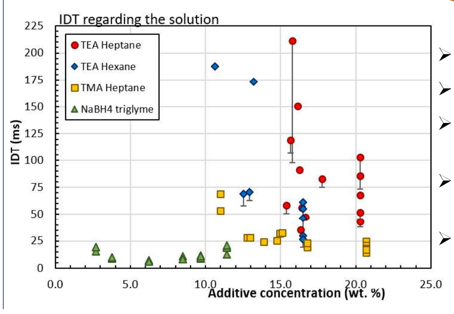
TEB-tetrahydrofuran	TEB-hexane
10.2 wt. % TEB in THF	14.5 wt. % TEB in hexane

TEA-heptane	TEA-hexane	TMA-heptane
20.3 wt. % TEA in heptane	16.5 wt. % TEA in hexane	20.7 wt. % TMA in heptane



HTP 98 wt. % + heptane/15.6 wt. % TEA under argon

Contact fuel/HTP → Formation of solids → Burning of solids, sometimes followed by ignition → Solid explosions



- **<u>TEB:</u>** no ignition
- **<u>TEA heptane:</u>** ignition
- **<u>TEA hexane:</u>** faster ignition (solvent properties)
- **<u>TMA heptane:</u>** faster ignition (acidic strength)
- **<u>$NaBH_4$ triglyme :</u>** fastest ignition

CONCLUSION

Optimum configuration for ignition between triglyme/$NaBH_4$ and HTP: 4-8 wt. % $NaBH_4$ | Max HTP concentration | Fuel rich environment | Velocity, pressure, temperature constant

Triglyme/$NaBH_4$ mixture presents lower IDT than TEA and TMA. However, TMA in heptane shows satisfying ignition delays. Choosing an additive more acid than TMA in a solvent with low autoignition temperature and heat capacity could decrease the IDT down to 10 ms or less.

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CONTACT : *celia.soudarin@ensma.fr*

References

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