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Thermo-Oxidative Stability Under High Reynolds Number Flow: An Alternative Methodology for the Development of Aviation Kerosene

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Introduction

- A complex challenge in aviation is finding alternative fuels, considering flight performance and operating conditions (KATTA et al., 2011).
- New aviation fuels need to be compatible with both older and newer engines, as well as existing transport and storage infrastructures (BLAKEY et al., 2011).
- Jet fuels, besides serving as the primary fuel source for aircraft propulsion, also play a critical role as a coolant for various subsystems (SPADACCINI and HUANG, 2003).
- Modern aviation turbines operate at higher temperatures and pressures for efficiency, necessitating specific fuel requirements.
- Thermo-oxidative instability occurs at high temperatures, leading to liquid-phase reactions and insoluble product formation (ALBORZI et al., 2019; MAURICE et al., 2011).
- The JFTOT is the standard thermal stability test for certifying aviation fuels, assessing pressure drop, coloration, thickness, and composition of deposits.
- Aviation fuel flow is typically transitional or turbulent, so understanding thermal oxidation under such conditions complements current methodologies.

Objectives

The aim of this work is to experimentally assess the thermo-oxidative stability of aviation fuels using an improved version of the High Reynolds Thermal Stability Test (HiReTS Test), quantified by the HiReTS Number (HN). Fuels are considered stable for HN values below 1000.

Materials and Methods

- Samples of Jet A-1, commercial aviation fuel currently in the market, with different storage times.
- Experimental apparatus employed is a modified Stanhope-Seta HiReTS Tester (ASTM D6811, 2007).
- The HiReTS number, HN, is defined as

$$HN = \sum_{i=1}^{N} \Delta T_i = \sum_{i=1}^{N} \left(T_{max,i} - T_{min,i}\right)$$

  where $T_{max,i}$ and $T_{min,i}$ are the maximum and minimum temperature, respectively, measured by an IR camera in position i along the external surface of the capillary tube.
- Test section consists of a stainless steel tube with internal diameter of 0.27 mm, 150 mm in length, with temperature being measured on the last 110 mm.
- Tests were carried out with a fuel flow rate of 35 ml/min and a fuel outlet temperature of 290 °C.

Results and Discussion

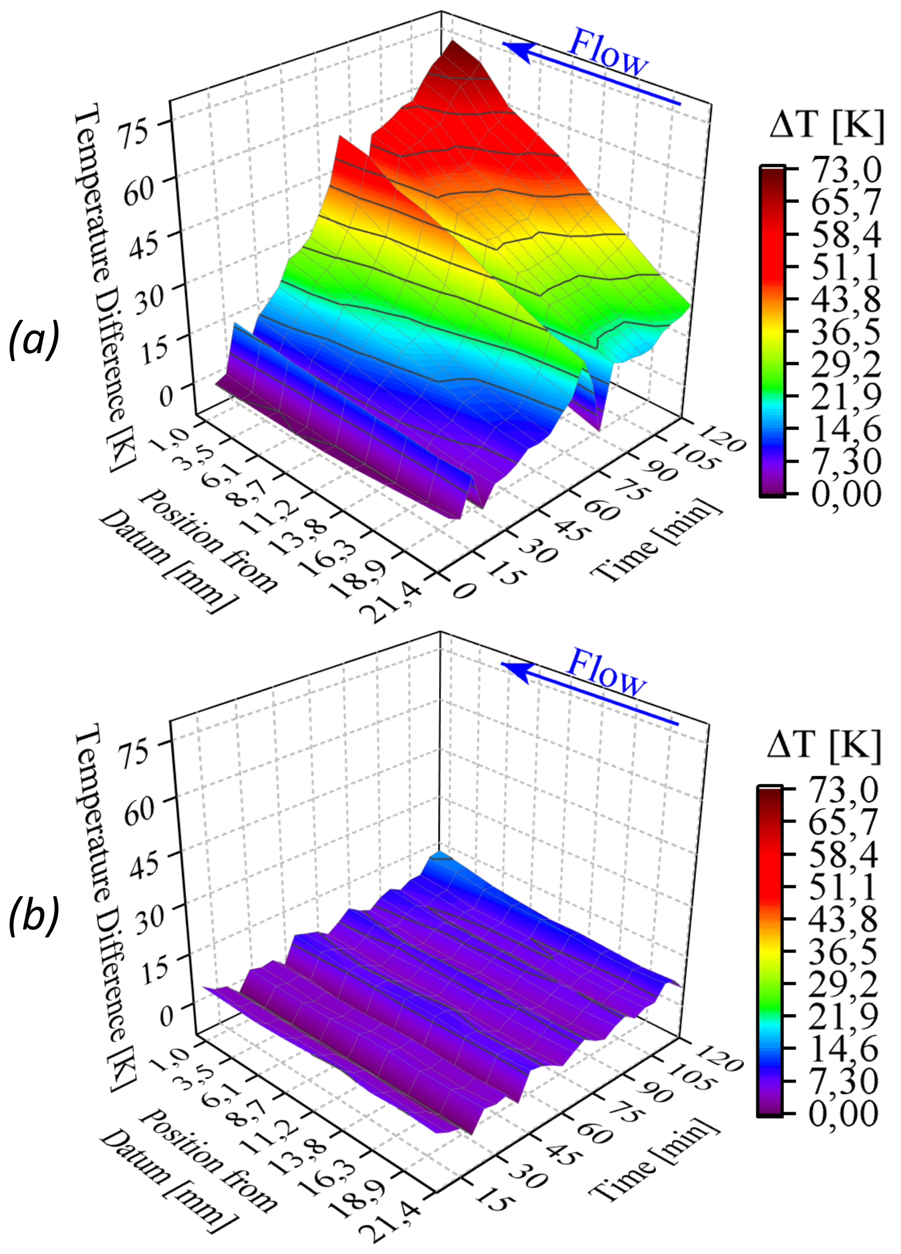
- Table 1 summarizes the tests conditions: duration, the use of recirculation, sample volume, HiReTS Number (HN) and classification of stability.
- Tests T1 and T2 performed with fresh samples, while tests T3 to T5 were carried out with a year-aged sample.
- Test T4 was interrupted due to de pressure rise and almost triggering the pressure relief valve.

Table 1 - Tests data and results from the Tests (T) developed.

Number	T1	T2	T3	T4	T5
Time [min]	120	120	30	45	55
Recirculation	No	No	Yes	Yes	Yes
Volume [ml]	5000	5000	700	700	700
HN	438 ± 74	61 ± 10	905 ± 153	266 ± 45	882 ± 150
Stability	High	High	Low	Low	Low

- Figure 1 shows the temperature difference (ΔT_i) on the surface of the test section as a function of test time.
- The external temperature increases as result of the internal deposition of a lacquer film due to the fuel oxidative thermal degradation.

Figure 1 - Temperature difference at the external surface from the test section as function of the position of the reading and time. (a) Test 1 (T1); (b) Test 2 (T2).



Conclusions

- Tests T1 and T2 showed minimal deposit formation. Test 1 experienced a capillary blockage event, indicated by sudden temperature oscillation, resulting in an HN of 438. Test 2 demonstrated exceptional stability, with deposit effects comparable to measurement uncertainties, yielding an HN of 61.
- Tests 3, 4, and 5, utilizing aged fuel with recirculation, exhibited increased deposit formation, halted at 30, 45, and 55 minutes, with HN values of 905, 266, and 882, respectively. Deposits were predominantly observed in capillary intermediate regions, likely due to oxygen depletion or deposit-forming precursors accelerated by thermal degradation.
- This methodology provides valuable insights and serves as an additional tool for aviation fuel analysis and characterization.

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