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Characterization of Emissions of Wax-Based Products During Combustion

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Abstract

Currently, over 40% of the global burden of disease is attributed to environmental factors; of this, 2.6% of disease is attributed to indoor pollutants. When considering that people currently spend about 85 percent of their time indoors, this is a concerning statistic. Environmental and health concerns have pushed scientists to develop new cleaner and greener burning wax-based products. E3 Fuels has developed an additive that is claimed to reduce the emissions, both particulate and gaseous, associated with the combustion of hydrocarbons in solid wax-based products. In this study, the aforementioned emissions were qualified and quantified in paraffin candles using various techniques including nuclear magnetic resonance and Fourier transform infrared analysis. The difference in the physical and chemical characteristics, the microstructural changes that take place between the pure paraffin and the paraffin containing additive, and the manufacturability of the candles were also analyzed.

Disciplines

Engineering

Characterization of E3 Additive Performance in Surrogate Petroleum Products

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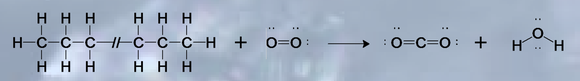
E3 Fuels

- E3 Fuels is a Boise based company that has developed an additive that reduces emissions during combustion of fossil fuels
  - These emissions have immediate and long-term negative effects on environmental and human health
  - Their proprietary formula is claimed to:
    - Be biodegradable, renewable, and sustainable
    - Reduce particulate emissions by 98%
    - Increase fuel efficiency 10-24%
- Preliminary testing of additive performance in wax-based products looks promising

Hydrocarbon Combustion

Propane Flame (C_3H_8)

Complete:



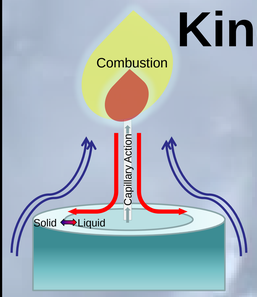
Incomplete:

- Longer hydrocarbon chains cause other by-products
- These emissions cause a rise of indoor pollutants[1]
- Symptoms associated with indoor air quality are the number one environmental health issue doctors face[2]

Paraffin Flame (C_nH_{2n+2}) n = 19-35

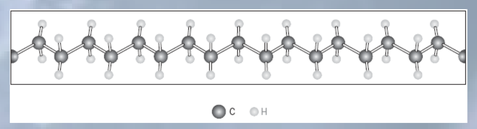
1: Pagels, J., et al., *Chemical composition and mass emission factors of candle smoke particles.* Journal of Aerosol Science, 2009. **40**(3): p. 193-208.
2: Jones, A.P., *Indoor air quality and health.* Atmospheric Environment, 1999. **33**(28): p. 4535-4564.

Kinetics of Candles



- Paraffin is the widest used product in candle making in the US.
- Paraffin is a hydrocarbon chain with the formula of:

$$C_nH_{n+2},\ n = 19\text{-}36$$



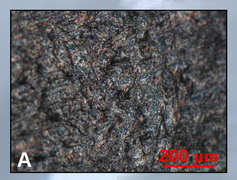
Candle Manufacturing

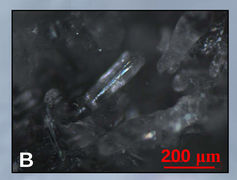
- Pillar candles, dimension 38 x 50 mm
- HTP-31 cotton wicks protruding 13 mm
- Paraffin wax (CAS 8002-74-2)
- Wax was heated to a pouring temperature of 80 C
- Additive was mixed and immediately poured into molds

Particulate Emissions Testing

- Emissions collection hood, left, utilizes a vacuum system to draw emission through a Whatman GF/C 1.7 µm glass microfibre filter.
- The mass of the filter was obtained before and after the experiment to 10 µg.
- 5 g of paraffin was combusted during each test.

Microstructure

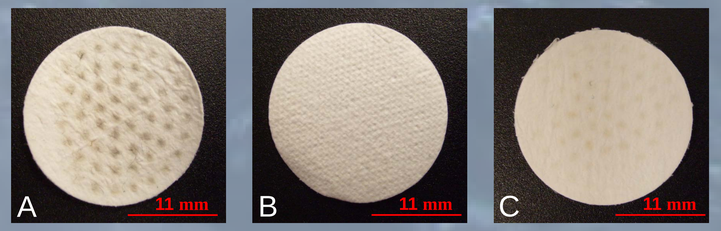




- Figure A:
  - Pure Paraffin
  - Amorphous
- Figure B:
  - 128:2.5 (Paraffin to E3)
  - Crystalline

- Two unique microstructures were observed in the paraffin: amorphous and crystalline.
  - Pure paraffin and the 118:1 ratio exhibited amorphous structure.
  - Large ratios of E3 became a catalyst for crystallization. The driving force of this reaction is unknown.
  - All higher ratios showed crystalline structures which severely deteriorated the mechanical properties of the paraffin.

Particulate Emissions



- Additive could decrease the size of particulates to smaller than 1.7 µm. This could be the reason for no measureable mass change in filters B and C.

Filter	Paraffin to Additive Ratio	Mass Change	Spots
A	118:0	+1.3%	dark black
B	118:1	none	none
C	118:20	none	light burnt orange

Conclusions

- Additive shows a visual reduction in particulate emissions
- Preliminary results show a reduction in particulates greater than PM 1.7
- Small concentrations of E3 exhibit reductions in particulate concentrations
- Successful proof of reduced emissions will result in a decrease in the negative effects candles have on indoor air quality

Future Work

- Obtain additional data on particulate mass during combustion. This will be completed using both previous method and additional instrumentation that give particulate counts and gas emission data.
- Statistical analysis of particulate mass gain in vacuum hood.
- Capture and analysis of gaseous emissions.