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Atmospheric Chemistry and Physics Discussions

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Interactive Comment

Interactive comment on "Emission of ions and charged soot particles by aircraft engines" *by* A. Sorokin et al.

Anonymous Referee #1

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In this manuscript, the authors seek to determine the concentration (and emission index) of chemiions and the charge distribution of soot particles at the nozzle exit of a typical aircraft engine. The authors conclude that the **upper limit** values of concentration and emission index at the nozzle exit are 2E8/cm^3 and 4E16 ion/kg-fuel respectively for ions of both signs. The authors also suggest that the interactions of ions with soot articles may lead to 50% reduction of the exit ion concentration.

This paper has some merit in its comprehensive treatment of various ionic processes in the engine combustion and post-combustion zones. Since it has been observed that the upper limit of ultrafine particle emission index is 1-2E17 /kg-fuel, the conclusions of this paper, if correct, might imply that the Yu and Turco's chemiion theory (on the dominant role of ions in ultrafine particle formation) is not sufficient. However, the conclusions of this paper on ion concentration (and emission index) are probably wrong

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Interactive Discussion

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because the formula, which the authors used to estimate the ion-ion recombination coefficient (Kii), is not valid for the high-pressure combustion zone (see major comment below for details). The values of Kii used in this paper are likely to be much larger than the real values. Since the results presented in this paper are very sensitive to Kii values, this paper has to be revised before it can be published.

Major comments:

The authors use equation (8), Kii(T) = a(300/T) + b[M]P/P $_0$ (300/T) ^{n} , to calculate the ion-ion recombination coefficient (Kii) in the engine combustion and post-combustion zones. It can be seen from equation (8) that Kii increases as P increases which is true only when P< 1 atm. For P> 1 atm, Kii decreases as P increases because the ion mobility decreases [Natanson, 1959; Leob, 1939]*. This nonlinear dependent of Kii on P has also been observed experimentally [Natanson, 1959; Leob, 1939]. While equation (8) may be reasonable to estimate Kii in the troposphere and stratosphere, **it is simply wrong** to use it for the engine combustion zone where the pressure is very high (9 atm in-flight and 16.5 atm on-ground based on this paper).

According to equation (8) and parameters of Beig and Brasseur, Kii = 2.7E-8 cm^3/s at P=1 atm and T = 1200K. Based on theoretical and experimental results presented in the references mentioned above [Natanson, 1959; Leob, 1939], Kii at P= 9 atm should be much smaller than Kii at P= 1 atm (a factor of 4 under the experimental conditions). However, the authors obtain a value of 1.43E-7 cm^3/s at P= 9 atm which is a factor of 5 larger than Kii of 2.7E-8 cm^3/s at P= 1 atm. Obviously, the Kii values used by the authors to obtain their conclusions are too large. Since the calculated ion concentration (and hence emission index) is very sensitive to Kii values, a lower value of Kii will give a higher ion concentration (and emission index) at exit. Even if the authors use a value of 2.7E-8 cm^3/s (for P=1 atm), the estimated ion emission index (one sign) will be above 1E17 /kg-fuel. This value is consistent with the chemiion theory.

I would suggest that the authors use the Langevin's theory [Natanson, 1959] to cal-

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culate Kii for the ions in high-pressure combustion zone. Many numbers in this paper have to be recalculated with a more reasonable value of Kii, and figures and conclusions need to be revised.

* Natanson, G. L., The theory of volume recombination of ions, Translated from: Zhurnal Tekhnnicheskol Fiziki vol. 29, No. 11, pp. 1373-1380, November, 1959.

* Leob, L. B., Fundamental Processes of Electrical Discharge in Gases, John Wiley Sons Inc., New York, pp. 112-131, 1939.

Other comments:

1. Abstract: It will be useful if the authors can include main conclusions here (numbers: concentrations, emission index, charge status, etc) in addition of the "an excellent agreement" statements.

2. Page 2046, line 25 - Page 2047, line 26. It is important to point out in this paragraph that the measured concentrations of chemiions (1E6-1E8/cm^3) are NOT necessary inconsistent with the concentrations needed by chemiion theory (1E9/cm^3). First, the measured values should be considered as low limit because of various ion loss processes during sampling and the detection limit of the instrument (only ions of certain mass range were counted). Second, the measurements were made at certain plume ages in a diluted exhaust. Extrapolation is required to obtain the concentrations at the nozzle exit. Actually, based on their measurements, Arnold et al. [GRL, 27, 1723, 2000] suggested that the ion concentration was at least 1E9 /cm^3 at the nozzle exit. Sorokin and Mirabel [GRL, 2001] estimated a lower concentration at the nozzle exit but their calculations were sensitive to ion-ion recombination coefficients which are not well defined.

3. Page 2055, it will be helpful if the authors can discuss typical values of ion-soot attachment coefficients at the end section 2.4.

4. Page 2064, line 8: it will be useful if the corresponding emission index can also be

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given here.

Technical corrections:

5. Page 2046, line 16: It is necessary to cite Yu and Turco's 1997 GRL paper here (Yu and Turco, Geophys. Res. Lett., 24, 1927-1930, 1997).

6. Page 2051, line 7: "+-" should be "-".

7. Page 2051, equation (1): clarify $K^{-}{}_{is,p}$ and $K^{+}{}_{is,p}$.

8. Page 2052, line 21: "s" is missing in the unit of $Q0/p^2$.

9. Page 2054, lines 21-22: either A in equation (1) or A here needs to be changed to another symbol.

10. Page 2055, equation (6a): why there is a "v" in the equation?

equations (6a) and (6c): why both start with K_{is}?

equations (6a), (6b), and (6c): the symbols for attachment coefficients should be consistent with these in equation (1).

Interactive comment on Atmos. Chem. Phys. Discuss., 2, 2045, 2002.