REVIEW RESPONSE LETTER [2] BOUNCING FLAME

We thank the reviewers for reading our manuscript and for their detailed reviews, which helped us find the problems in this manuscript. We noticed fundamental problems in our previous theory, and the bases were quite wrong (especially the assumed equations of motion with unclear forces and acceleration formula). So we revised the theory leading to whole new theoretical assumptions and formulations using the control volume formulas. We also developed an entire new numerical solution regarding the new theoretical formulations and the numerical solution scheme was also improved. The structure of the manuscript also changed quite a lot. Codes of the numerical method and a video showing the oscillation have been included as supplementary materials.

At the following, the points mentioned by the reviewers will be discussed.

Reviewer 1:

1. "Page 2 – Flame Deviation. "there would be another force applied to the system due to the difference in momentum of input and output particles" – more information is needed.
You consider the forces acting on a single molecular particle of the system (microlevel) or a particle of much larger size (a carbon particle)?
In the first case, there is no buoyancy force and air drag force acting on a single particle (they act on macrolevel).
In the second case, more information needed on the force due to difference in momentum. What is its physical nature? How it is connected to the fact that the system is not isolated?"

The previous theory had major problems as we said. A better theory is now applied.

2. "The corresponding figure (Figure 1) should be improved with necessary descriptions
(What do the letters mean? Which forces do they indicate?)
Also, all notations of forces should be provided with vectors above the letters."

Figure 1 removed.

3."Page 3 – Flame Oscillation. Very small part of your article is devoted to this phenomenon. Try giving more descriptions on the physical behavior of your system.
A figure or a diagram would look really great here, because it is one of the most important parts of your problem."

Some more explanation is now added, as well as a figure and a video which is attached as supplementary material showing the oscillation.

4. “Page 3 – Numerical Analysis. Euler method can be either explicit or implicit one.
You should write definitely which one you used, or not write about the method of ODE solution at all (writing just “Euler method” gives the reader incomplete information).”

Numerical Scheme changed now, with sufficient explanations and references given.

Reviewer 2:

page 2
1.“>> After this process the total flame charge will be positive in the presence of electric field. There are also other negative ions forming in the flame: HCO3-, CO3-, etc., not just positive ion. I admit positive ions will be dominant. See A M Starik: Formation of charged nanoparticles in hydrocarbon flames: principal mechanisms, Plasma Sources Sci. Technol. 17 (2008) 045012”

This is right of course. We do not say no negative ions exist, however we suggest positive ions are more.

2.“>> particles exiting from the upper part of the flame
I am afraid this simplified consideration is not perfectly correct. The combustion occurs not only in the bottom of the flame but also higher up. The combustion increases the number of particles and gives them higher momentum and also temperature. They are certainly not cooled in the flame.”

Right. Corrected with some approximations.

3.“>> toward the lower part of the flame (Figure 1).
make text consistent with Fig. 1.”

Figure 1 replaced.

page 3
4.“>> So in this case the plasma flame does not deviate at all
The space charges are in equilibrium within the plasma but when it is inserted into important external E-filed, they will feel it and will redistribute. I think the real cause why e.g. pre-mixed flames do not deviate is their fast upward flow velocity which dominates over the sideward velocity of exiting ions that cause the flame deviation.”

We are not sure about the plasma flames at this moment, so we removed the statements regarding plasma flame. Pre-mixed flames do deviate.

5.“***>> will be repeated causing the flame an oscillatory motion.***

Even when the flames does not touch the electrode, there will be a positive ion motion towards the cathode and one can measure a current. I admit, this current can be stronger when a discharge occurs between the flame and the cathode - this can indeed cause the oscillations. However, be more careful with your expressions to make them more precise and describing the complete physical phenomenon, not just the desired point of view."

This is correct and now added to the text at the end. And it may be responsible for the disagreement of the theory and experiments.

6.">> There is a force applied to the flame, in its inverse direction
But this force is just to balance the buoyancy and electric force, as you described above. Please precise what is meant here."

Theory was corrected to make sense.

7.">> Electric and mass density are both uniform in the flame
This is certainly not true. The mass density is a function of temperature that is not homogenous in the flame and the density of electric charge (if this is meant under "electric density") is also non-homogeneous."

You are correct. This statement is not correct, however it was assumed as an approximation for us to be able to develop a numerical theory. The explicit statement is now removed.

8.">> electric load of the flame What is "electric load"? What current is due to combustion? If no external field, there is no current. Assumption 3 is unclear."

This assumption is only valid for the case where electric field exists. However in the case where electric field does not exist, it does not violate the motion since no force is exerted.

9.">> used to solve the ODE
What is ODE? Please provide the basic set of equations that were used in numerical calculations."

Equations specified.

page 5
10.">> could get sufficient in high velocities.
Any discussion on the measured/modeled frequency function? Why is there a maximum?"

Some discussion is now added.

11.“>> According to the presented results of Conclusions. Please briefly resume the physical mechanism of the bouncing flame.”
Discussion added.

Reviewer 3:

1.“• When naming the forces acting on the flame, include the symbols from the figure in the text.”

Corrected.

2.“• In the assumptions of the numerical model, the ’electric density’ is not clear. It can be supposed that this is the electric field energy density – please clarify this issue.”

It was the electric charge density. Corrected in the text.

3.“• Have you conducted any tests of the numerical integration scheme? Euler scheme is known to be pretty bad in some situations. Could you comment on the choice of numerical method and its reliability?”

Numerical scheme is now upgraded to the Runge-Kutta scheme, which is known to be very effective. Explanations added.

4.“• Caption of fig. 3 is unreadable. Please adjust it properly.”

Corrected.

5.“• The presented graphs (figs. 5-7) present results of experiments compared with a theory. How do you get these dependencies? Are the curves fitted? It remains unclear what is the source of these predictions.

Results were achieved from the numerical theory. More explanations are now added, as well as the source codes as supplementary material attached.

• The data in figs. 5-7 are shown but not interpreted. Why are these dependencies looking like this? E.g. why is there a threshold value of voltage for oscillations? The data needs further comments!”

A chapter discussing the results now added.

***“Please format the references indicating not the address of the institution but the name and volume of the journal in which the article has appeared. E.g. [5] J.M. Goodings, D.K. Bohme, Chun-Wai Ng, Detailed ion chemistry in methane-oxygen flames. II. Negative ions, Combustion and Flame, Volume 36,
1979, pp. 45-62.”***

Corrected.
"• Add the interpretation of experiments; discuss the theory used in the graphs in more details."

More discussion added.

"• Add a short discussion of the numerical model and integration scheme used. What is the output of your program?"

Explanations were added.

Editorial request

"Please consider revising any parts of the text that are unspecific and do not clarify of what results are obtained and what conclusions are drawn."

We tried to improve it.

References: The literature has been used in the manuscript in a professional way. The list of references, however, is not typeset properly. Please note that the mail address of the authors is not a reference. Please add the detailed journal references or URLs.

Improved.

"Figure 3: consider adding a scale bar."

The measured quantity in that experiment was the Deviation Angle which is independent to the scale. No scale is actually available.

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Again we thank the reviewers and editors, and we hope our response has been acceptable. We improved the theory, but still there are several assumptions made as approximations to let us develop the numerical theory. General solution to this problem needs a very deep understanding on the chemical, physical and mechanical aspects of the problem, and needs the usage of a complicated CFD numerical model. We are working on such a model now and we hope to be able to get to a complete simulation, however it was not possible for this manuscript. Anyway, we hope the current paper to be acceptable as an investigation done by "students" to be published in the IYPT Book.

Regards,
Rojin Anbarafshan,
Hossein Azizinaghsh,
Reza M. Namin