Observation of Candle Flame Oscillation With Schlieren

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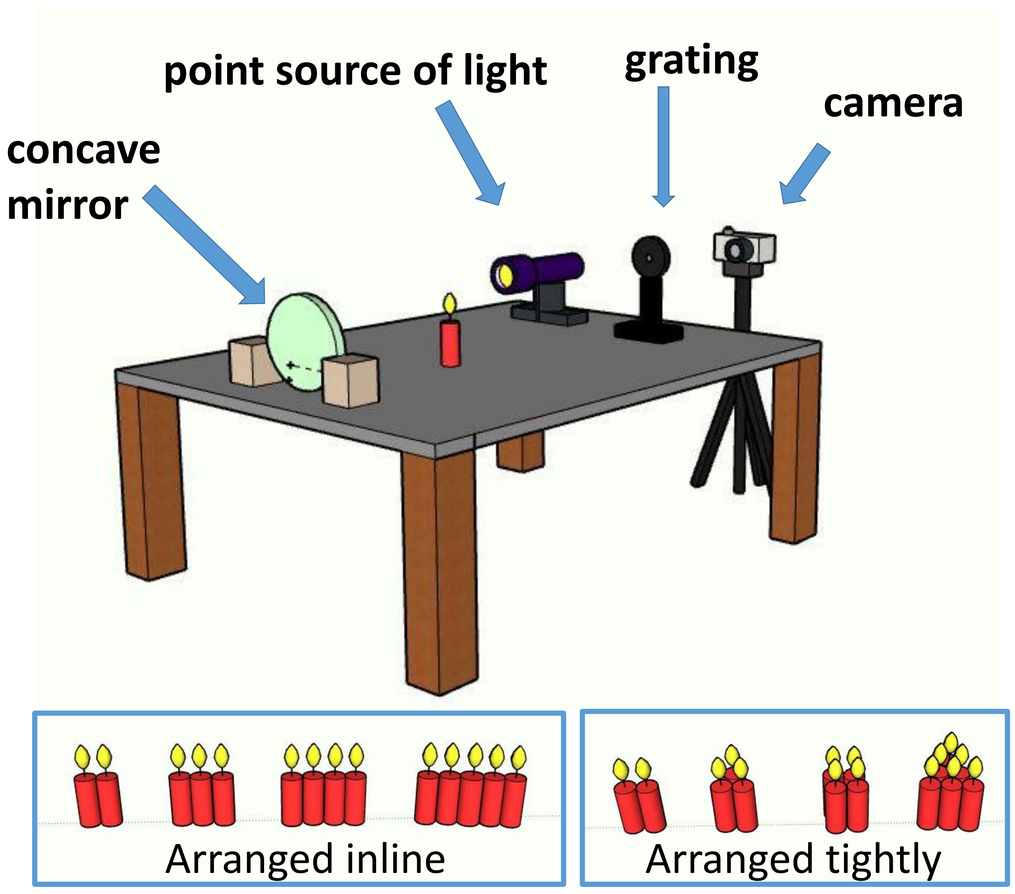
I. Introduction

Flame, an important tool that we used a lot in daily life. Therefore, It is worth our understanding of it more thoroughly. Flames burning together will also cause different frequencies of oscillation. We will focus on the different frequencies of several types of arrangement and the changes of air density among them during a completely period. Changing in air density can not be caught by human's eyes directly, so we need to use the schlieren method to observe our experiment.

II. Apparatus for Experiment

The diagram below shows the schematic of our experimental setup. First, we need a point source of light. Then, the light pass to the concave mirror, candles and then focused on the grating. Finally, the image will imaged in the camera. As for the arrangement of the candles, we used inline and tightly arranging method.



III. Experimental Results

We obtained how the arrangement of the flame influence the frequency. Orange point in figure A,B is the result of the frequency of candles with arranged inline, and tightly, the result shows that the frequency of arranged inline increase with the increase of the numbers of candles, but the frequency of arranged tightly decrease with the numbers.

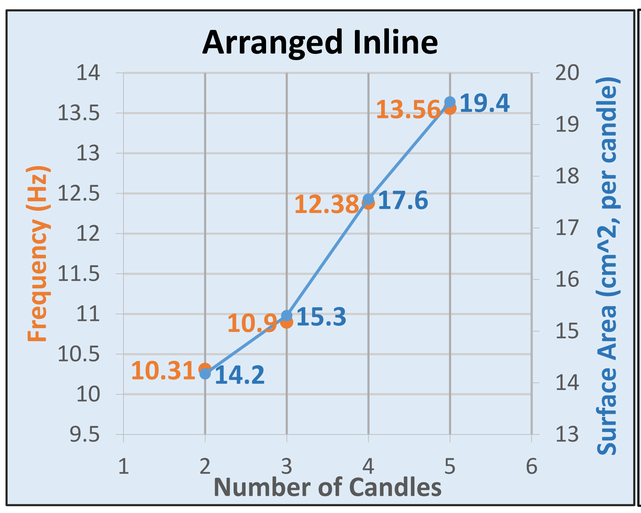


Figure A

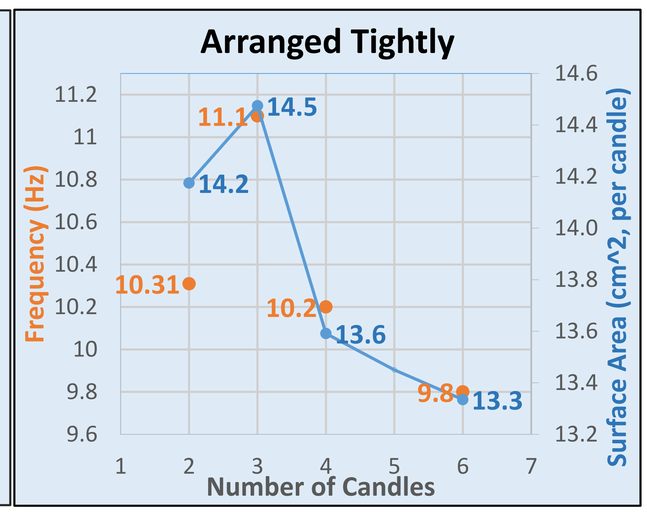


Figure B

We use the surface area of the flame to give the prediction. Because the size of the area would impact on the absorbed air and lead to the change of the frequency. The area of the flame on the candle is simplified as the shape of cone. After obtaining the total area, the result is divided by the number of the candles to get the result in average. Showed in blue points of figure A,B, the prediction of arranged inline has a good approximation to the result. The arranged tightly one also has good fit to the prediction, which also performs that the reason of the decrease is the overlapping of the surface area at the center of the flame.

In white dotted line is low density, which is the high temperature areas among candles. This is the sample of arranging candles to a square by schlieren method. We try to divide air density into six zones and then depict the edges of them.

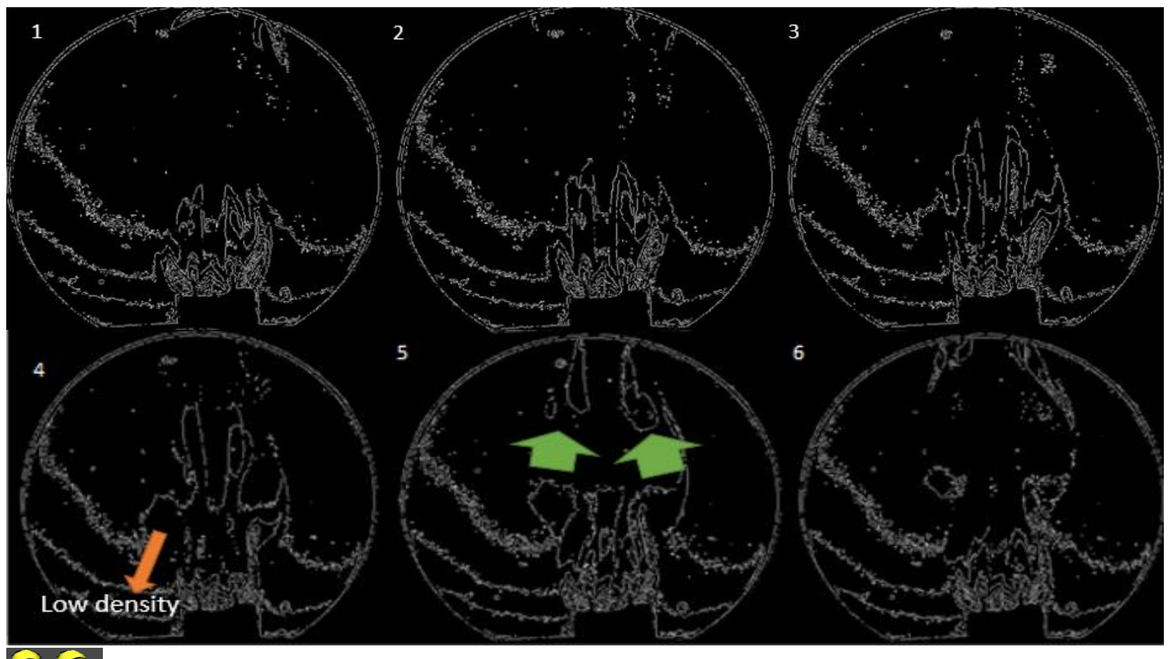


figure C: a complete period of arranging candles in square.

figure D: the last three frames of arranging candles in regular triangle.

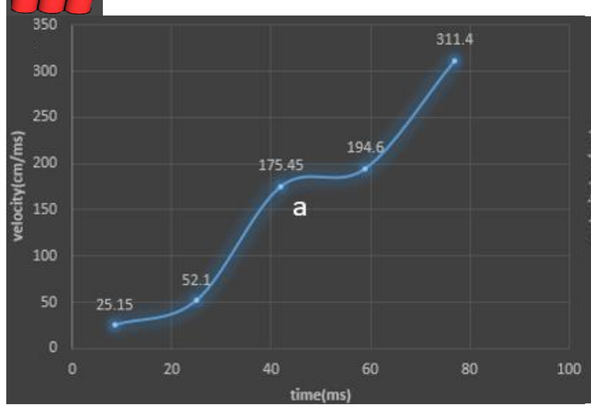


figure E: graph time to velocity by figure C.

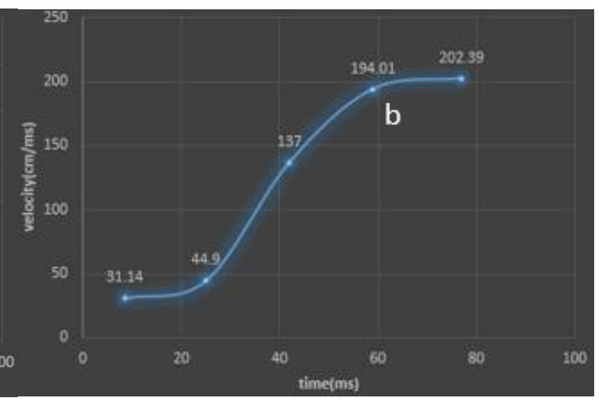
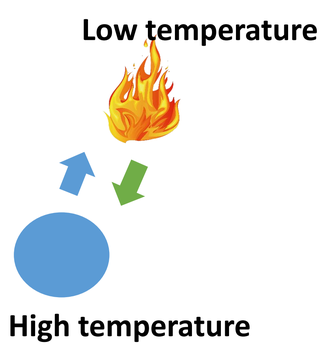


figure E: graph time to velocity by figure D.

IV: Discussion

With the helping of schlieren, the frequency and the flow of the low density area of the oscillation were able to be observed. First, the linear arrangement of the flame would improve the frequency of the oscillation but the tightly arranged flames would on the contrary to reduce the frequency because the surface area of the flame affects the burning speed.

At the point a in figure E, the rising velocity of high temperature area slows down because of the generation of another high temperature areas on both side. Then, these areas will squeeze the upper one to rise. At the point b in figure F, the rising velocity of high temperature area slow down because of the bigger flame itself. The flame itself is the low temperature area so it will sink to block the rising of high temperature area.



V. Conclusion

The linear arrangement of the flame would improve the frequency of the oscillation but the tightly arranged flames would on the contrary to reduce the frequency because of the impact of surface area of flame per candle. The rising velocity of high temperature area can be classify into two main kinds. One is as the form as figure E, the acceleration of high temperature area will slow down at the middle. The other one is as figure F, the acceleration of high temperature area will slow down at the end.

Reference:

[1] Ting Chen, Xiao Guo, Ji Jia & Jinghua Xiao, *Frequency and Phase Characteristics of Candle Flame Oscillation*, Beijing University: Beijing, available at: www.nature.com, (2019)