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論文内容要旨

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学位論文題目	Study on mass transport in turbulent flame using Lagrangian coherent structures (ラグランジアンコヒーレント構造を用いた乱流火炎の物質移動に関する研究)		

内容要旨

The research on turbulent combustion mechanism and transient characteristics in engineering applications is not enough, which seriously hinders the design and application of synthesis gas combustion devices. Based on this background, this study will use the Lagrangian description method to study the characteristics of turbulent flames.

Piloted jet flame burners are often used to study the characteristics of turbulent flame because of their simple flow state and higher combustion stability. Therefore, the piloted turbulent flame is studied numerically using Lagrangian coherent structures (LCS) to study and analyze the mass transport process from the viewpoint of nonlinear dynamic systems.

It is of great significance to study the mass transport process and vortices movement of in turbulent flow. In this study, 2D transient simulations is conducted to investigate a premixed piloted turbulent flame by using LCS. And seven cases are simulated to study the effect of different Reynolds number and CH_4 equivalence ratio on transport process of the piloted flame. The correctness of the numerical simulation results is verified by comparing with the experimental results. The boundaries in the combustion field are captured by Lagrangian Coherent Structures, considering that LCS can be regarded as the boundary of a flow field. Then, the distribution of attracting LCSs and OH radical mass fraction are compared to study the surface of the flame. Finally, the motion of LCSs are tracked to analyze the vortices and the mass transport near the burner. The following conclusions can be drawn:

1) Comparing the OH radical and LCS distributions of piloted flame, it can be found that the attracting LCS near the burner can be considered as the surface of the turbulent piloted flame.

2) The attracting LCSs divide the combustion field into three regions, namely, the main jet region, the piloted jet region and the co-flow region. Serial vortices enclosed by attracting LCSs and repelling LCSs are constantly generated in the piloted jet region near the burner, then it is gradually stretched folded. More, these vortices move downstream. Finally, a part of the attracting LCS enclosed the piloted region breaks, leading to these vortices l

eave the piloted jet region for the co-flow region. Traditional Eulerian description method such as streamlines and temperature distribution cannot locate this kind of mass transport phenomenon and describe the accurate boundaries of vortices.

3) The mass transport phenomenon in the piloted flame is very complicated. The main jet goes into the flow field under the attracting LCS and moves forward and it attracts piloted jet and co-flow. The fluid in the piloted jet region will break through the attracting LCS in the form of a vortex and enter the co-flow region during its downstream movement. However, the fluids in the main jet region have never entered the piloted jet region, and the piloted jet region has not exchanged substances with the co-flow region. Although the air in the co-flow region can't pass through the attracting LCS, it continues to be attracted by the LCS and moves downstream.

4) When the Reynolds number is less than a certain degree, the generation of vortexes near the burner and the mass transport process are basically the same. However, the frequency of vortex formation increases with the Reynolds number. When the Reynolds number increases significantly, the volume of the piloted jet region will be greatly reduced, and the motion of the vortex will be different, and the vortex will leave the main jet region earlier. Also, the vortices will stack on the top of the main jet region, and more and more vortices will stack along with the downstream movement, which will lead to the vortices gradually away from the main jet region. As for the mass transport among the three regions, the flow in the piloted jet region will enter into the co-flow region along with the vortex at different Reynolds numbers. There is no mass transport between the main jet region and the other two regions. Fluid from the co-flow also does not enter the piloted jet region.

5) CH_4 equivalence ratio has little influence on the process of vortex movement and mass transport. With the increase of CH_4 equivalence ratio, the velocity of vortex formation will decrease and the volume of piloted jet region will increase. In addition, the transport process is not affected by CH_4 equivalent ratio.

As discussed above, there is a lack of research on the detailed mass transport process of the piloted turbulent flame. However, current work focuses on this issue. The whole mass transport and mixing process can be displayed more intuitively and accurately by the Lagrangian approach. The detailed description of the mass transport process in this paper can provide a new perspective for the study of the turbulent flame.