

Effect of compressibility on volumetric heat loss and Darrieus-Landau instability of a premixed flame front

和田, 啓吾

<https://hdl.handle.net/2324/2236038>

出版情報 : Kyushu University, 2018, 博士 (機能数理学) , 課程博士
バージョン :

権利関係 : Public access to the fulltext file is restricted for unavoidable reason (2)



氏 名 : 和田 啓吾

論 文 名 : Effect of compressibility on volumetric heat loss and Darrieus-Landau instability of a premixed flame front
(予混合火炎面の体積的熱損失およびダリウス・ランダウ不安定性に対する圧縮性の効果)

区 分 : 甲

論 文 内 容 の 要 旨

A laminar premixed flame front is very thin ($\sim 10^{-4}$ m) and can be viewed as a density discontinuity surface, in the hydrodynamic scale, with a series of complicated chemical reactions occurring in it. Darrieus (1938) and Landau (1944) independently addressed the linear stability of a planar flame front to disturbances of making it wavy deformations and concluded that the front is linearly unstable for any wave number, which is referred to as the Darrieus-Landau instability (DLI). It should be born in mind that the DLI analysis is virtually equivalent to prescribing a constant speed on a flame front. In the laboratory experiment, rather than instability, a stable flame front is commonly observed. In order to improve the DLI, many attempts have been made at deriving the jump (boundary) conditions, replacing the DL's assumptions, across the flame front, for hydrodynamic variables. We address, using the method of matched asymptotic expansions, the weak compressibility effect by taking account of variations in the density and the temperature, in the form of M^2 expansions at small Mach numbers. It is shown that the compressibility effect, combined with the viscous effect, substantially improves the jump conditions, for which only the flame stretch effect has so far been considered. Our study of a flame front structure by the matched asymptotic expansions goes beyond the previous works as represented by Matkowsky and Sivashinsky (1979) and Matalon and Matkowsky (1982), to establish low-Mach-number approximation to the DLI.

We begin with calculation of the laminar flame speed obtained by Bush and Fendell (1970) in the isobaric case. Most of the works on a premixed flame front in free space is restricted to in the incompressible limit, or with an isobaric approximation. A few papers, for example, Kadowaki (1995) and He (2000), examined the finite Mach number effect on the stability of a planar flame front with use of unverified assumptions. On the other hand, inside the channels and tubes, the compressibility effect plays an important role as a mechanism for deflagration-to-detonation transition (DDT). Kurdyumov and Matalon (2016) showed that the propagation speed of the flame enhanced by the pressure change at the ignition end is much larger than the laminar flame speed, the propagation speed in the low-Mach-number approximation.

We show that, even without boundary, increase or decrease of the laminar flame speed is obtained as a result of the pressure variation, of compressibility origin, in the heat-conduction equation. We then look into the reaction and preheat zones which constitute the inner structure of the flame front. Remarkably, we reveal that the volumetric heat loss and the increase of the flame temperature inside a flame front are caused by the compressibility effect, without having to appeal to an *ad hoc* assumption made by Joulin and Clavin (1979). By an multiscale analysis of the flame front, we manipulate the jump conditions which are used to calculate the dispersion relation of waves on a compressible planar flame front. Finally, we show that, if the Prandtl number and the heat release are sufficiently large, the compressibility effect is capable of suppressing the Darrieus-Landau instability.

参考文献

- 1 . G. Darrieus, unpublished works presented at La Technique Moderne (1938).
- 2 . L. D. Landau, Acta Phys. (USSR) **19**, (1944) 77.
- 3 . B. J. Matkowsky and G. I. Sivashinsky, SIAM J. Appl. Math. **37**, (1979) 686-699.
- 4 . M. Matalon and B. J. Matkowsky, J. Fluid Mech. **124**, (1982) 239-259.
- 5 . W. B. Bush and F. E. Fendell, Combust. Sci. Technol. **1:6**, (1970) 421-428
- 6 . S. Kadowaki, Phys. Fluids **7**, (1995) 220-222.
- 7 . L. He, Europhys. Lett. **49**, (2000) 576-582.
- 8 . V. N. Kurdyumov and M. Matalon, Combust. Theory Model. **20:6**, (2016) 1046-1067.
- 9 . G. Joulin and P. Clavin, Comb. Flame **35**, (1979) 139-153.