# Experiments on the growth rate of single and two modes RM instability by re-shock

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**Abstract:** The growth rate of single and two modes RM instability by re-shock is studied in shock tube experiments. The experiments were conducted at shock Mach number 1.2, using the shock tube (200 *mm*×100 *mm*) with a two-zone test cell arrangement of Air/$SF_6$. Gas separation was by means of thin nitrocellulose membranes(≈0.5μm), supported by fine wire(dia.≈0.1*mm*) meshes. The configurations of Air/$SF_6$ interfaces are single and two modes, their shapes are described by the following functions: $\eta_1=7\cos(2\pi y/\lambda)$, $\lambda= 100$ *mm*, $0\le y\le 200$ *mm*; $\eta_2=3\sin(2\pi y/\lambda_1)+5(\cos(2\pi y/\lambda_2)-1)$, $\lambda_1=50$ *mm*, $\lambda_2=100$ *mm*, $0\le y \le 200$ *mm*. The initial perturbation width of single mode equal two modes. The length of the initial $SF_6$ section was changed ( 120*mm,* 230*mm* and 340*mm*) in order to impose different arrival times, thus allowing the Air/$SF_6$ interface to evolve into different phases before the arrival of the reflected shock wave. The turbulent mixing zone(TMZ) evolution was measured using a schlieren diagnostic technique. Their laws of growth rate of single and two modes RM instability by re-shock is presented.

## 1 Introduction

The Richtmyer-Meshkov instability(RMI) results when a shock wave travels across a perturbed interface between two fluids. During the passage of the shock wave, vorticity is deposited at the interface due to misalignment of the pressure and density gradients. The RMI plays an important role in technological applications such as inertial confinement fusion and supersonic combustion, and in natural phenomena such as supernova core overturn.

Many experimental investigations of the RMI have been carried out in shock tubes. However, most of the experiments conducted to date only consider the evolution of the instability in the linear and nonlinear regimes. Relatively few experiments have been performed to study the dynamics of the flow following reshock. The RMI has been described theoretically through the linear , nonlinear and late nonlinear stages for a single shock wave passing through the contact surface separating the two fluids. However, these models all have important limitations and a limited domain of applicability. So, experiments on the growth law of different type RMI, has important count for better understand the fundamental aspects of RMI growth into the nonlinear regime.

## 2 Experimental method

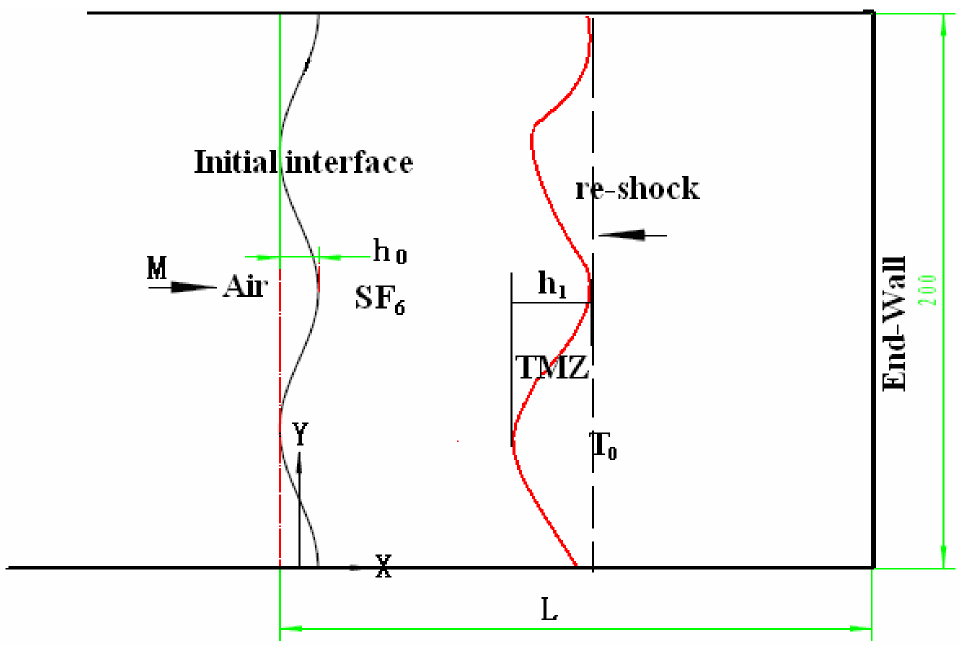
The shock tube is a 200 *mm*×100 *mm* rectangular shock tube of total length of 4.20 *m*. It fist includes a movable 1.00 *m* long high pressure chamber, secondly 2.60 *m* long low pressure chamber and at last a movable 0.60 *m* long experimental chamber. The length of experimental chamber was changed ( 120 *mm,* 230 *mm* , 340 *mm and* 600 *mm*) in order to re-shock different times arrive to TMZ. In this paper, the growth rate of single and two modes RM instability by re-shock is studied in shock tube experiments. In the study of the RM instability of single-mode and two- mode sinusoidal initial perturbations on air/ $SF_6$ interface in a straight test section, the initially sinusoidal interface is formed by a thin nitrocellulose membranes of thickness about 0.5 *μm* and the flow visualization is done using shadowgraph method. The transmitted shock reflects from the shock tube end wall and interacts with the evolving interface during re-shock, further contributing to the appearance of complex interacting fluid and wave structures.

## 3 Experimental results

Two different experimental interfacial configurations were used in order to study the effect of the re-shock at the TMZ on the growth rate of the TMZ. The configurations of Air/$SF_6$ interfaces are single and two modes, their shapes are described by the following functions: $\eta_1=7\cos(2\pi y/\lambda)$, $\lambda= 100$ *mm*,$0\leq y\leq 200$ *mm*; $\eta_2=-3\sin(2\pi y/\lambda_1)-5(\cos(2\pi y/\lambda_2)-1)$, $\lambda_1=50$ *mm*, $\lambda_2=100$ *mm*, $0\leq y \leq 200$ *mm*. The initial perturbation width of single mode equal two mode. When re-shock arrived at the TMZ, the width of TMZ ($h_1$)for two experiments approximately equal.

A sketch map of initial experimental condition (the re-shock travels from right to left) with a single- mode initial interface is presented in Fig.1. Thereinto, $M$=1.2 , $L$=230 *mm*, $h_0$=14 mm, $h_1\approx 49$ *mm*. Each frame in Fig.2 measured using a schlieren diagnostic technique. The light source for the schli- eren was continuous laser(wavelengh 532nm, power 1W). Time of exposure was 1 μs. The zero time when re-shock arrived at the TMZ (Sketch map of zero time $T_0$ in Fig.1) for Fig.2. In fig.2: -0.06 ms, showing interface evolution by the passage of the incident shock before re-shock; 1.24 ms~3.44 ms, showing the phase inversion of the perturbations by the passage of the re-shock.

A sketch map of initial experimental condition (the re-shock travels from right to left) with a two-mode initial interface is presented in Fig.3. Thereinto, $M$=1.2 , $L$=120 *mm*, $h_0$=14 mm, $h_1\approx 47$ *mm*. The zero time when re-shock arrived at the TMZ (Sketch map of zero time $T_0$ in Fig.3) for Fig.4. Fig. 4 present the sequence of laser schlieren images showing the evolution of the TMZ with two-mode initial interface at the -0.07 ms before reshock, 0.23 *ms*、 0.73 *ms* 、1.03 *ms* 、1.73 *ms* after re-shock., respectively.




M - the incidence shock Mach number; L - the length of the initial $SF_6$ section;$h_0$ - the initial perturbation width;$h_1$- the width of TMZ, when re-shock arrived at the TMZ; $T_0$ - zero time when re-shock arrived at the TMZ.

**Fig.1** Sketch map of initial condition of single mode experiments

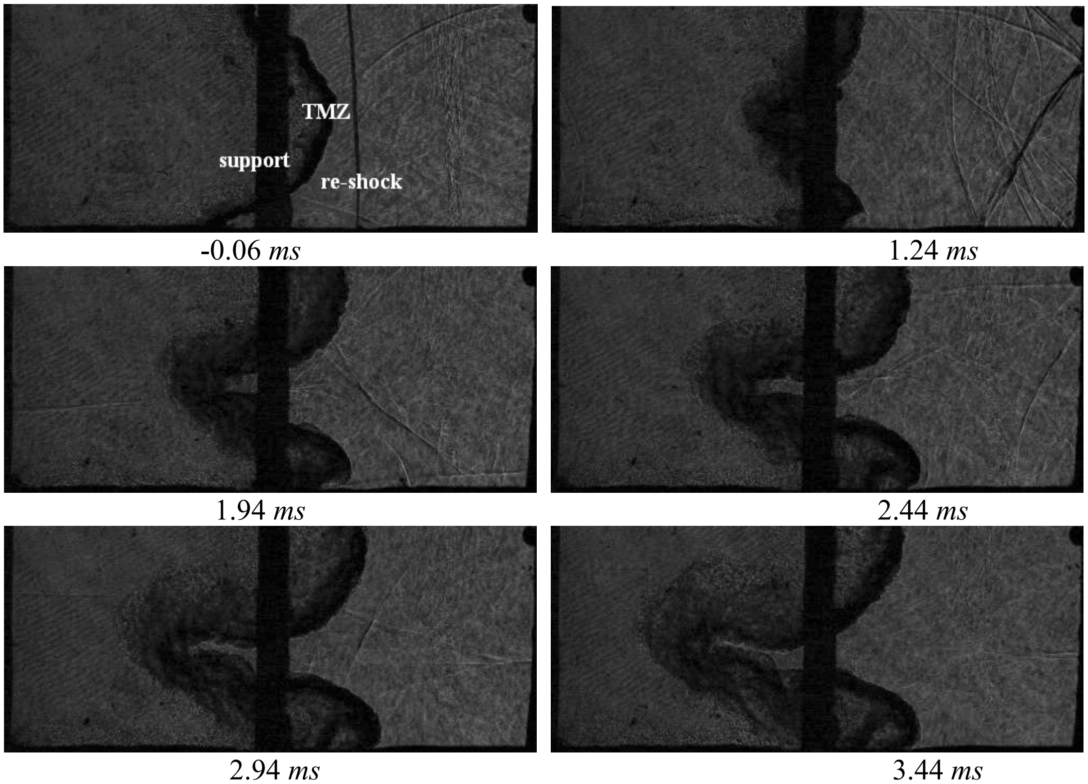
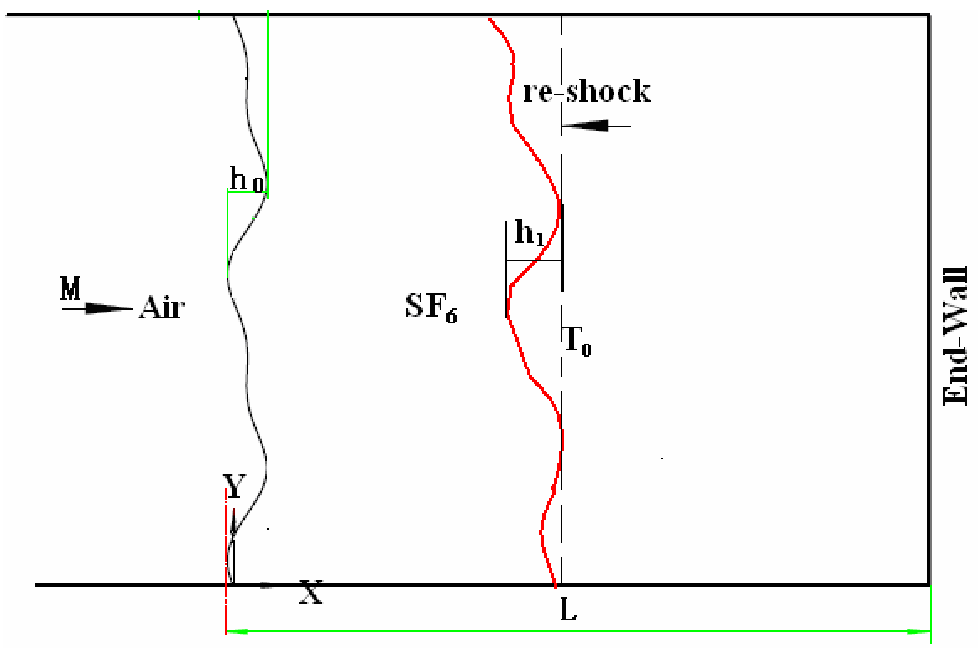


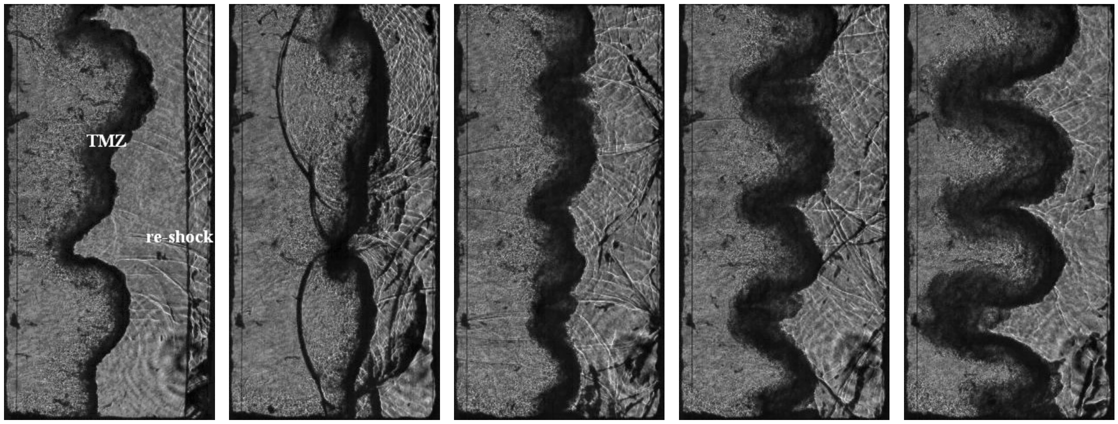

**Fig.2** Schlieren images of evolution of TMZ with single mode by re-shock




M - the incidence shock Mach number; L - the length of the initial $SF_6$ section;$h_0$ - the initial perturbation width;$h_1$ - the width of TMZ, when re-shock arrived at the TMZ; $T_0$ - zero time when re-shock arrived at the TMZ.

**Fig.3** Sketch map of initial condition of two mode experiments

The evolution of TMZ width for two experiments is presented in Fig. 5. When re-shock arrived at the TMZ, the TMZ width for two-mode and single-mode approximately equal. When re-shock pass the TMZ, the TMZ width for two-mode and single-mode approximately equal. When re-shock passed the TMZ, the growth rate of TMZ width for two-mode and single-mode approximately equal.




-0.07 *ms* 0.23 *ms* 0.73 *ms* 1.03 *ms* 1.73 *ms*

**Fig.4** Schlieren images of evolution of TMZ with two mode by re-shock

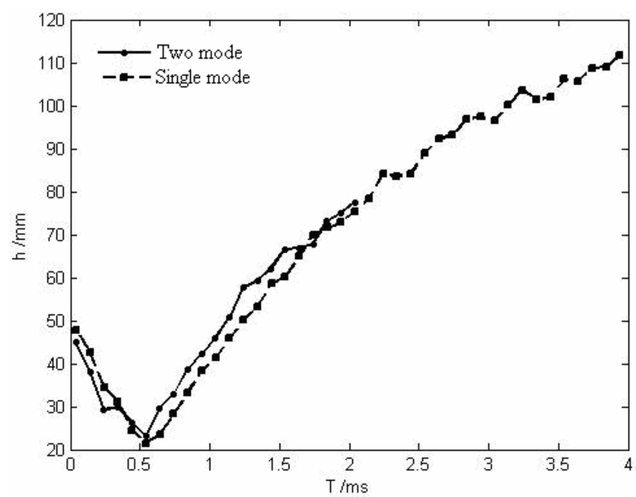



**Fig.5** The evolution of TMZ width for two experiments

## 4 Summary

Single-mode and two-mode experiments were preformed in order to investigate the effect of the initial perturbation geometry on the turbulent mixing zone growth rate . The growth rate of the TMZ width for two-mode and single-mode approximately equal, when re-shock pass and passed the TMZ. Further work should be done in order to understand the relation between the re-shock strength , wavelength , the initial perturbation width and TMZ phases before the arrival of the re-shock with the TMZ growth rate.

## References

[1]. Мешков ЕЕ.Исследования гидродинамических неустойчивостей в лабораторных экспериментах.Саров：ФГУП“РФЯЦ - ВНИИЭФ”,2006

[2]. В.Е.Неуважаев. Математическое моделирование турбулентного перемешивания. Снежинск:РФЯЦ - ВНИИТФ,2007

[3]. Eli LEINOV, Asaf FORMOZA,Oren SADOT. Experimental investigation of hydrodynamic instability induced by multiple accelerations of a contact surface between two fluids.10th IWPCTM(France) July

2006.
[4]. O.Schilling, Marco Latini,Wai-Sun Don. Investigation of the Large-Scale and Statistical Properties of Richtmyer-Meshkov Instability-Induced Mixing. 9th IWPCTM,2004.
[5]. Christian Mariani, Marc Vandenboomgaerde, Georges Jourdan. Investigation of the Richtmyer-Meshkov Instability with Stereolithographed Interfaces. PRL 100,254503(2008).