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NSAERO APPLICATION NOTE
Hydrogen-Air Shock-Induced Combustion

Introduction

Shock-induced combustion is important in many engineering applications. It has been proposed as an ignition in scramjet engines. This application note demonstrates the capability of NSAERO to model the flow field with shock-induced combustion flow feature. NSAERO is a multi block computational fluid dynamics software package available from Analytical Methods, Inc.

Problem description

At low flight speeds (less than the Chapman-Jouguet detonation speed), the temperature behind the bow shock and the combustion front are separated by an induction zone, as shown in Figure1 from the work of Lehr[1]. If the model is flying at speeds above the detonation speeds, the induction zone and combustion front merge to form a coupled shock-deflagration system for the H2/Air mixture. The objective is to reproduce numerically the experimental results for sub detonative and super detonative speeds.

Problem Setup

The computational domain is constituted of a single block around the sphere of 15mm Radius. The combustion model is the one proposed by Yungster et al.[2] that consists of six reacting species (H_2, O_2, H_2O, H, O) and one inert species (N_2), which allowed to undergo eight reactions. The reaction coefficients are taken from Evans[3] and are summarized in Table 1. The initial flow conditions are critical for the ignition of the combustion, a stagnant and hot flow is considered closed to the bluff body.

Results

The runs are summarized in Table 1. No mesh density study has been done for this case. The contour lines of the temperature ratio are depicted in Figure 1 and Figure 2 for the sub detonative and super detonative cases, respectively. The shock location is in good agreement with the experimental results from Lehr[1], as shown in Figure 2. The pressure and temperature ratio distribution along the centerline is shown in Figure 3. The shock-deflagration system appears clearly in Figure 3, the combustion front is separated and coupled for the sub and super-detonative condition, respectively.

H + O2 ↔ OH + O	H2 + X ↔ 2H + X
O + H2 ↔ OH + H	H2O+ X ↔ OH+ H +X
H2 + OH ↔ H20+ H	OH + X ↔ O + H + X
2OH ↔ O + H2O	O2 + X ↔ 2O + X

Table 1 Chemistry model for the H2/Air mixture

Case	Time steps	Run time (min)	Convergence	Memory (kB)
1892 & 2605 m/s	2000	18	5	4568

Table 2 Summary of run times and convergence on PC P4 2GHz (Linux)

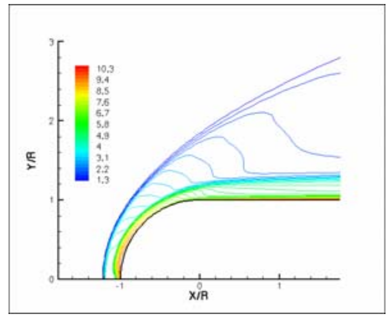

Figure 1 Temperature ratio contours

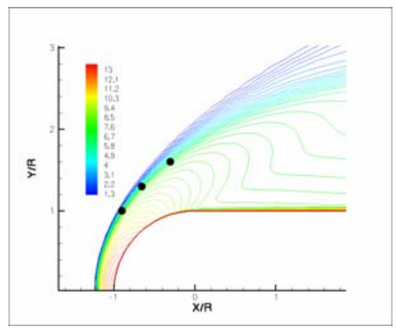

Figure 2 Temperature ratio contours

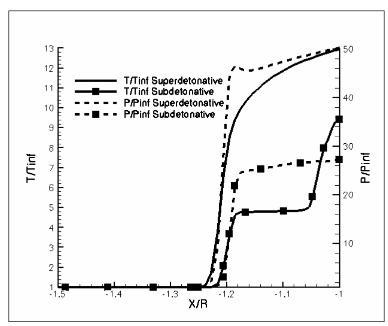

Figure 3 Pressure and temperature ratio distribution along the center line.

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[1] H.F. Lehr, *Experiments on Shock-Induced Combustion,* Astronautica Acta, Vol. 17, 1972, pp. 589-597.

[2] S. Yungster, S. Eberhardt and A.P. Bruckner, *Numerical simulation of Hypervelocity projectiles in detonable Gases,* AIAA Journal Vol.29 No.2, 1991, pp.187-199.

[3] J.S. Evans & C.J. Schexnayder, *Influence of chemical kinetics and undermixedness on burning in supersonic hydrogen flames*. AIAA Journal, 1980, Vol. 18, pp.181-193.