COMBEX
03/05/13, Ramsau, Austria

Influence of Concentration Gradients on Detonation Velocities in Hydrogen-Air Mixtures

Lorenz R. Boeck, Andreas Primbs, Josef Hasslberger, Florian Ettner, Thomas Sattelmayer

Supported by:

Federal Ministry of Economics and Technology

on the basis of a decision by the German Bundestag

Funded by the German Federal Ministry of Economics and Technology (project number 1501425)

Table of contents

Lehrstuhl für THERMODYNAMIK

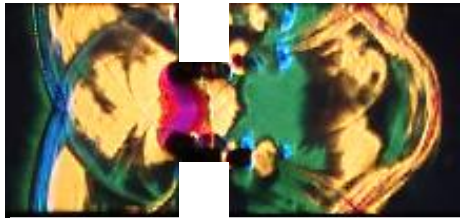
Motivation

- Inhomogeneous mixtures are likely to occur in realistic accident scenarios
- H_2 has a low density → Vertical concentration gradients develop

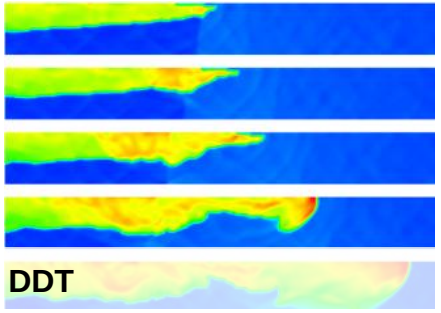
Do concentration gradients lead to a higher hazard potential in case of explosion?

- Characterization of flame acceleration, DDT and detonation needs to be performed

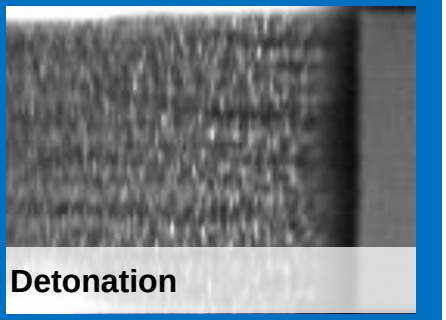
Research overview



Flame acceleration

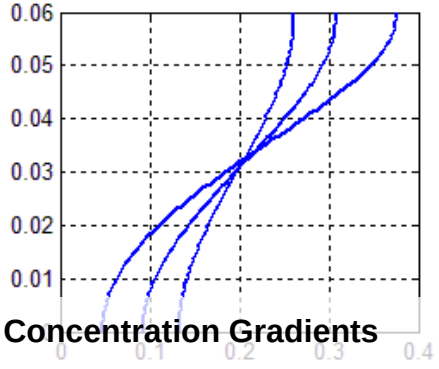


DDT



Detonation

Experiments

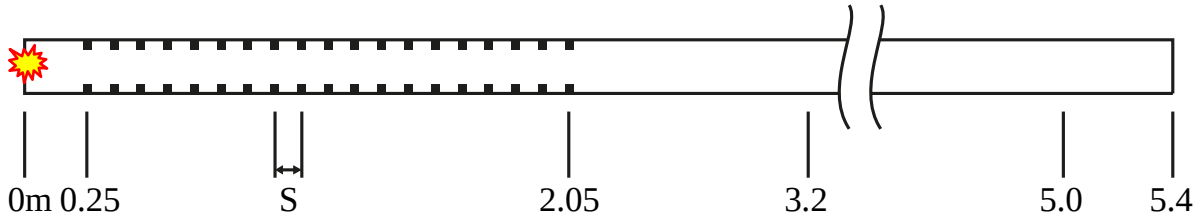


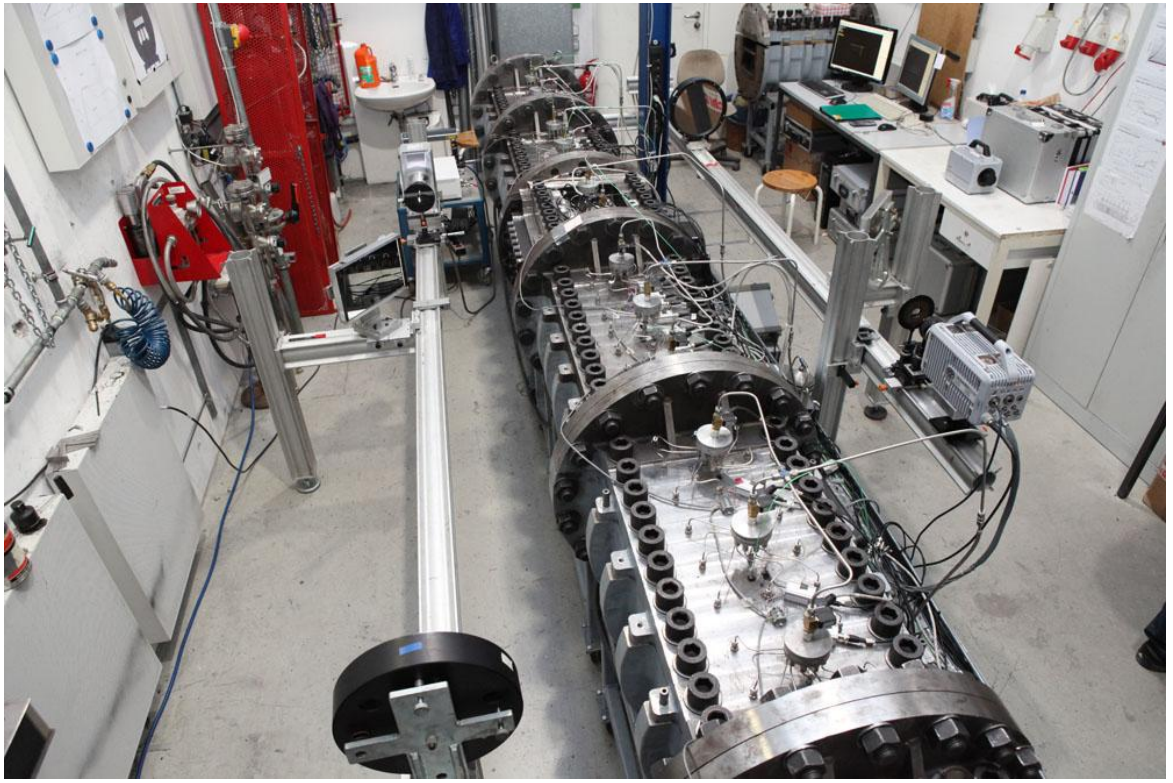
Concentration Gradients

CFD-Simulation

Lehrstuhl für THERMODYNAMIK

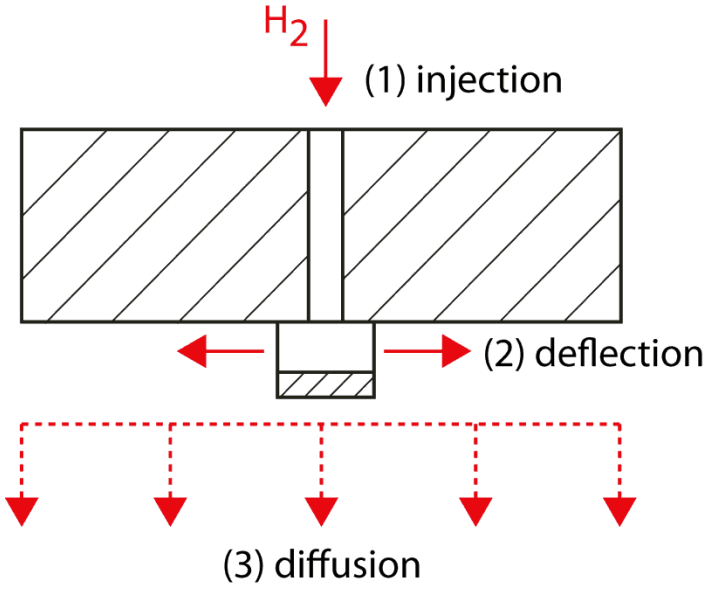
Test Facility (1)

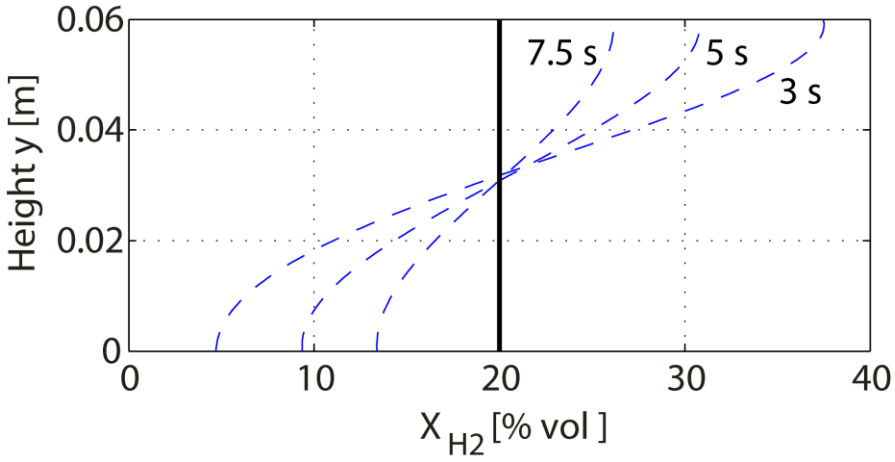




- Closed rectangular channel (5.4m x 0.3m x 0.06m)
- Design-pressure 200bar
- Obstacles (BR30)
- Spark plug ignition

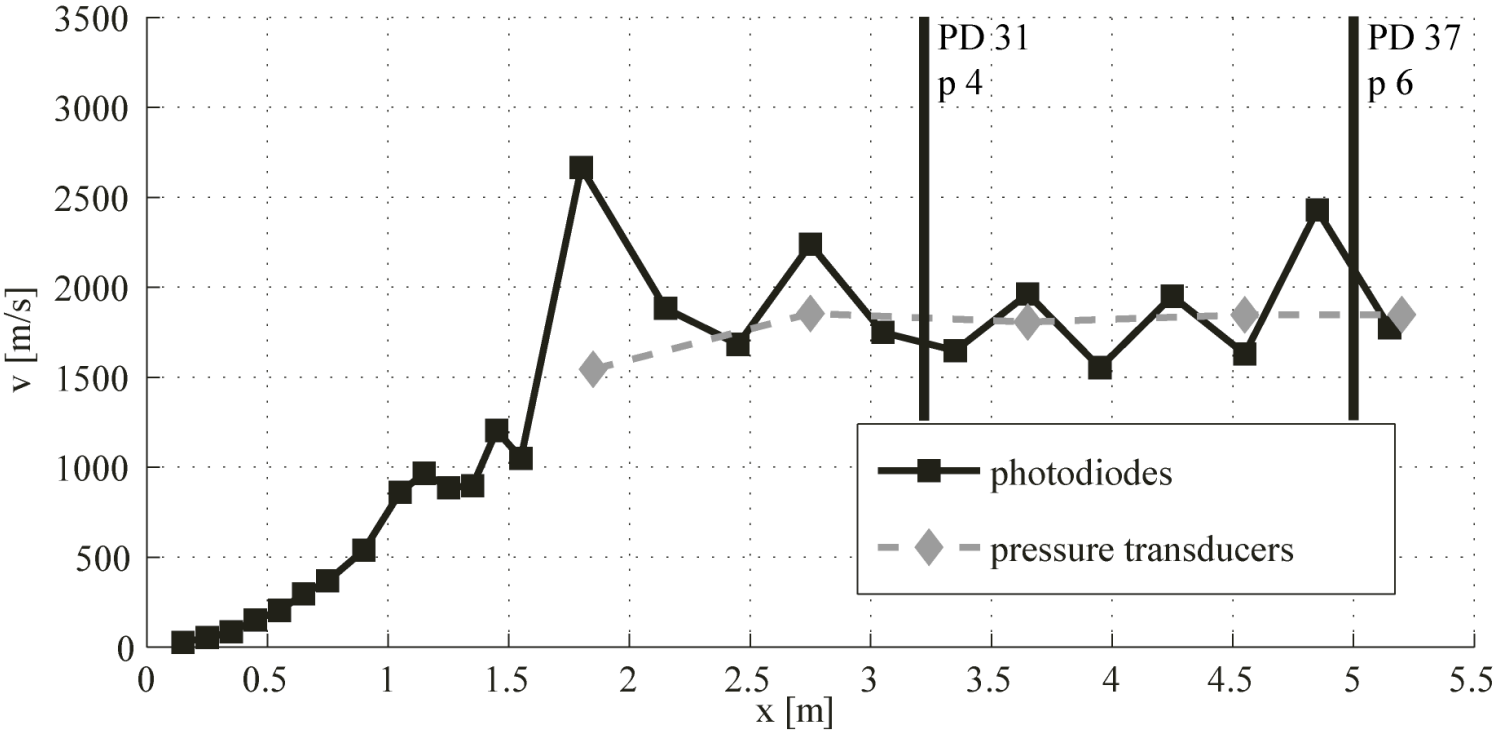
Test Facility (2)





- Atmospheric conditions (T,p)
- Gradient generation by diffusion (steepness depends on diffusion time)
- Concentration profiles from CFD simulation and gas chromatography

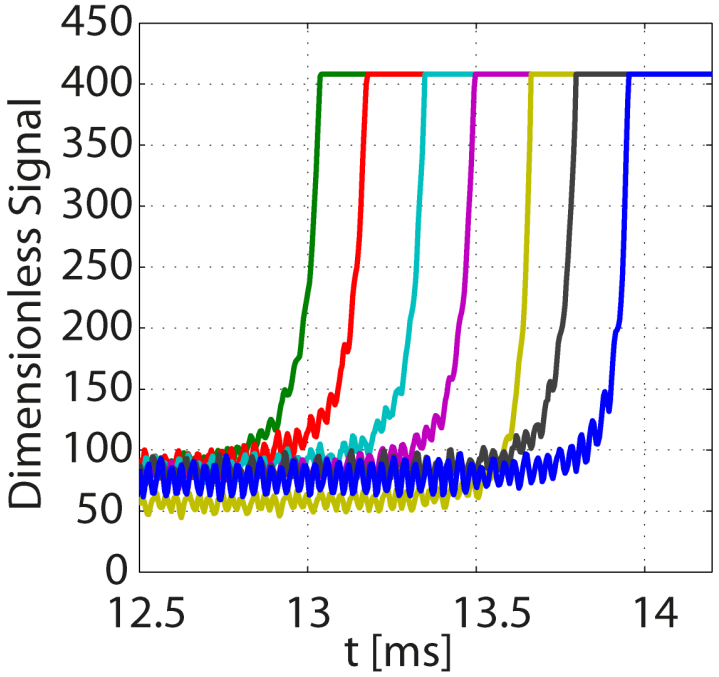
Preliminary Examinations



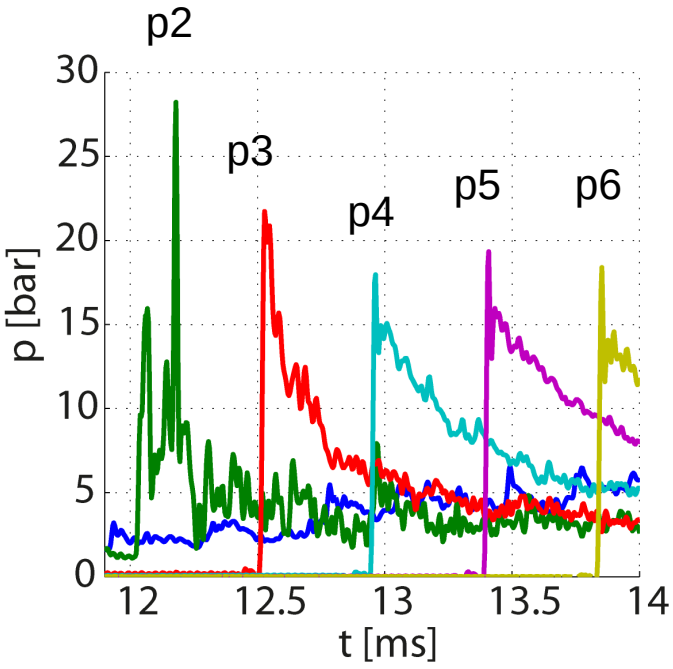
- Detonation occurs at average hydrogen concentrations > 20 %vol
- Photodiodes and pressure transducers can be used for measurement

Preliminary Examinations

Signals from Photodiodes



Signals from Pressure Transducers



- Detonation occurs at average hydrogen concentrations > 20 %vol
- Photodiodes and pressure transducers can be used for measurement

Detonation Velocities (homogeneous mixtures)

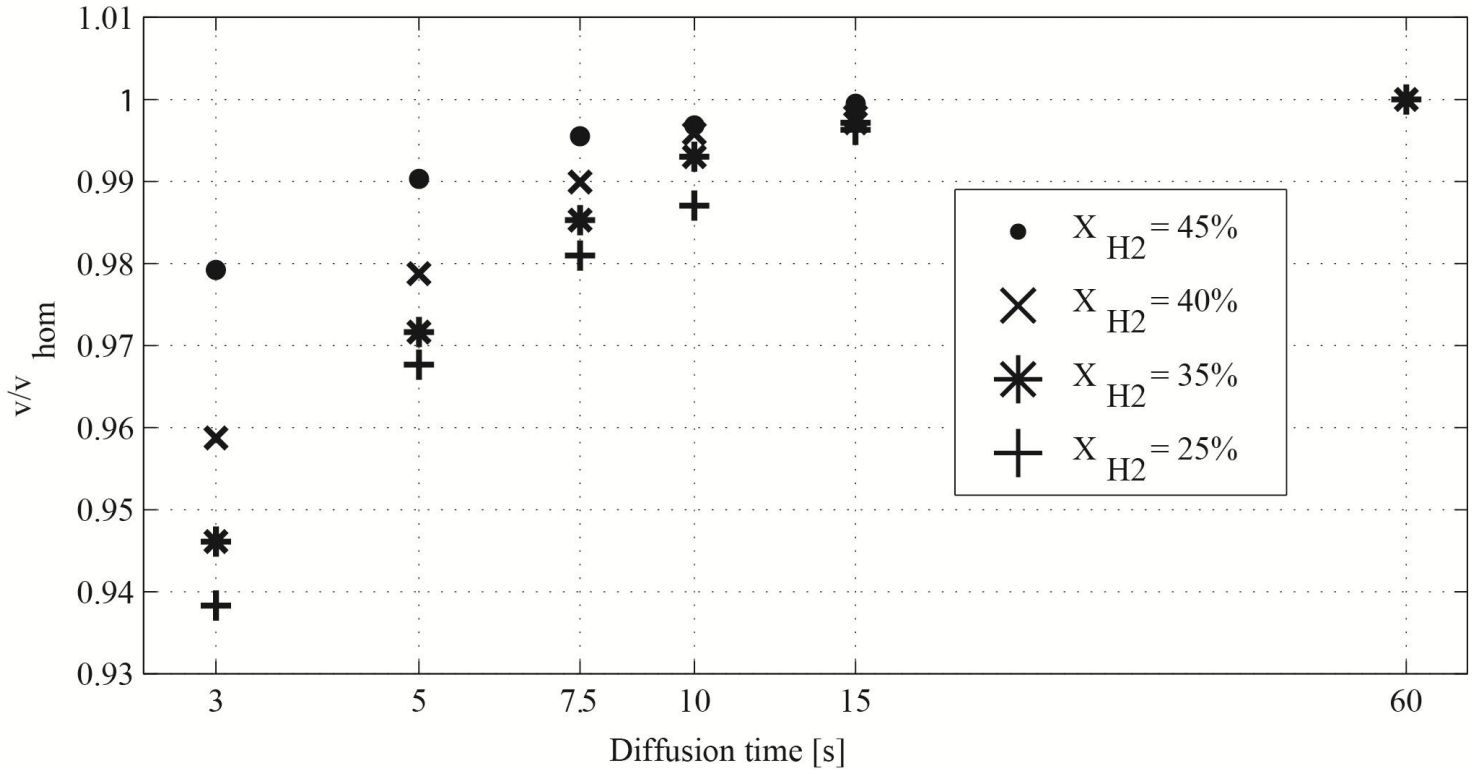
	BR30S100					BR30S300	
X_{H2} [%]	v_{photo} [m/s]	σ_{photo} [%]	v_{pres} [m/s]	σ_{pres} [%]	$\frac{v_{pres}}{D_{CJ}}$	v_{pres} [m/s]	$\frac{v_{pres}}{D_{CJ}}$
25	1796	0.99	1823	0.46	0.977	1839	0.984
30	1924	0.54	1939	0.12	0.978	1951	0.985
35	2038	1.54	2016	0.27	0.982	2024	0.987
40	2046	0.95	2065	0.07	0.984	2072	0.987
45	2080	0.36	2101	0.04	0.983		

- Measured detonation velocity close to Chapman-Jouguet Speed D_{CJ}
- Pressure transducers deliver lower standard deviation from 5 experiments than photodiodes

Lehrstuhl für THERMODYNAMIK

Detonation Velocities (inhomogeneous mixtures)

$$\frac{v_{gradient}}{v_{homogeneous}}$$



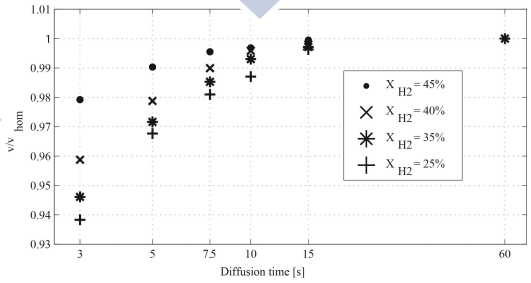
- Velocity deficit found for detonations in mixtures with concentration gradients
- Magnitude of deficit depends on steepness of gradient and average hydrogen concentration

Lehrstuhl für THERMODYNAMIK

Detonation Velocities (inhomogeneous mixtures)

Lean parts of the mixture

Detonation stability



Multi-dimensional structure

Global or local description?

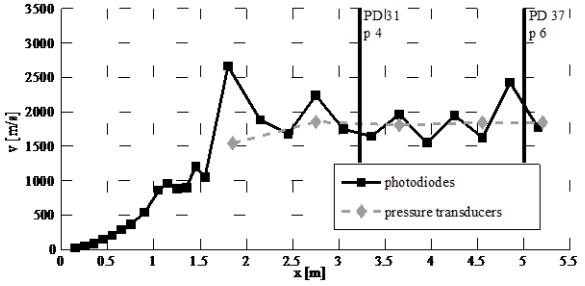
Next step: Optical investigation

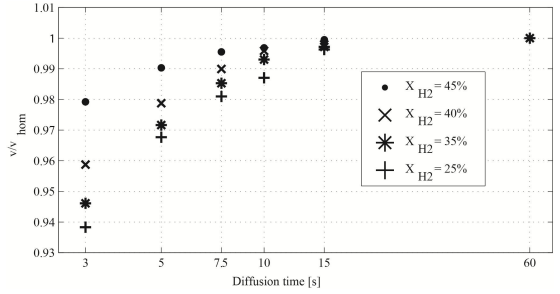
Lehrstuhl für THERMODYNAMIK

Summary and Outlook

- Test facility – concentration gradients and measurement techniques
- Applicability of photodiodes and pressure transducers confirmed
- Detonation velocities in homogeneous mixtures correspond well to 1D CJ-theory
- Velocity deficit characterized in mixtures with concentration gradients

- Further studies: Optical investigations (Shadowgraph, OH* Radiation, LIPF)





	BR30S100					BR30S300	
x_{H2} [%]	v_{photo} [m/s]	σ_{photo} [%]	v_{pres} [m/s]	σ_{pres} [%]	$\frac{v_{pres}}{D_{CJ}}$	v_{pres} [m/s]	$\frac{v_{pres}}{D_{CJ}}$
25	1796	0.99	1823	0.46	0.977	1839	0.984
30	1924	0.54	1939	0.12	0.978	1951	0.985
35	2038	1.54	2016	0.27	0.982	2024	0.987
40	2046	0.95	2065	0.07	0.984	2072	0.987
45	2080	0.36	2101	0.04	0.983		

Thank you very much for your attention!

COMBEX
03/05/13, Ramsau, Austria

Influence of Concentration Gradients on Detonation Velocities in Hydrogen-Air Mixtures

Lorenz R. Boeck, Andreas Primbs, Josef Hasslberger, Florian Ettner, Thomas Sattelmayer

Supported by:

Federal Ministry of Economics and Technology

on the basis of a decision by the German Bundestag

Funded by the German Federal Ministry of Economics and Technology (project number 1501425)