On the 10th Anniversary of the GraVent DDT Database – A Brief Review of Scope, Utilization, and Impact

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1 Introduction

The GraVent DDT Database (https://www.epc.ed.tum.de/td/forschung/ddt/) was established in 2015 as an open-access platform comprising over 8,000 deflagration-to-detonation transition (DDT) experiments conducted at the Institute of Thermodynamics, Technical University of Munich. Created to provide researchers with comprehensive validation data, the database has supported significant advances in understanding DDT phenomena and validating numerical simulations over the past decade.

This paper revisits the scope of the original database, introduces recent additions, and examines how researchers have leveraged the database since its inception to investigate flame acceleration mechanisms, transition to detonation and concentration gradient effects, and to develop new numerical models and methods for predicting DDT behavior.

2 The GraVent Experiment

The original GraVent experimental facility, constructed by Vollmer [1], comprised a rectangular channel (0.3 m width, 0.06 m height, 5.1-5.4 m length) equipped with configurable obstacles. The facility was designed to investigate the effects of concentration gradients and lateral venting on flame acceleration and DDT in H_2-air mixtures, motivating the name GraVent. Concentration gradients were created by injecting H_2 through the top plate of the channel, initially forming a horizontal layer underneath the roof. The slope of the gradients was varied by controlling the time between injection and ignition, allowing for gas diffusion that led to shallower gradients and ultimately homogeneous mixtures for longer diffusion times. Further details on this methodology are available in [1,2] and in the online database documentation. Although lateral venting experiments were conducted, their data analysis remained limited in scope.

Boeck [2] expanded on Vollmer's experiments and established a comprehensive database of over 8,000 experiments, examining the effects of geometric channel and obstacle configurations, concentration gradients, and water mist injection. Optical diagnostics were added over time, including high-speed shadowgraphy, chemiluminescence, and OH-PLIF (planar laser-induced fluorescence of the hydroxyl radical). The facility as operated in 2015 is shown in Figure 1. The facility was later used as a shortened channel to study early flame propagation [3] and modified to investigate H_2-CO mixtures [4].

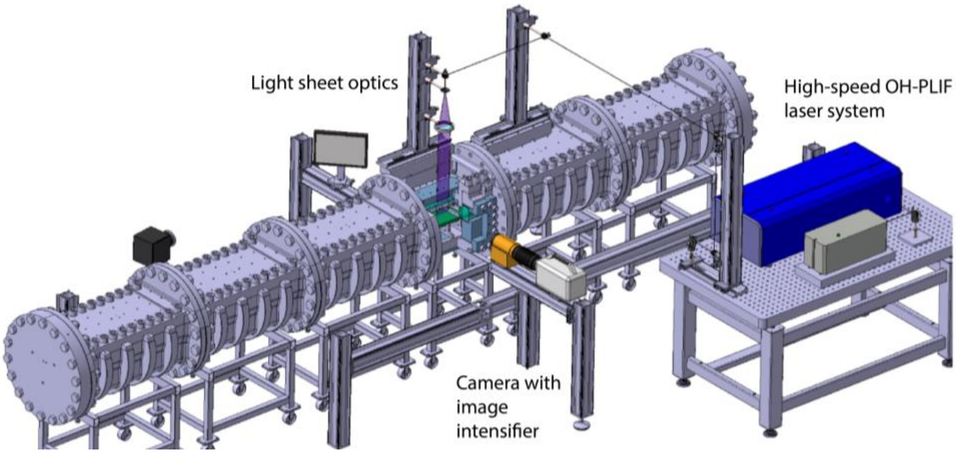

Figure 1: CAD model of the GraVent experiment as operated in 2015.

3 Scope of the Original Database

The majority of Boeck's [2] experiments were compiled to establish the original GraVent DDT Database, which was published online and announced at ICDERS 2015 [3,4].

The original database provided comprehensive data from experiments on flame acceleration, DDT, and detonations in H_2-air mixtures, including flame tip velocity measurements, pressure-time histories, and high-speed visualization through shadowgraphy and OH-PLIF. The experiments covered various geometric configurations both with and without obstacles and a range of blockage ratios and obstacle orientations, examining homogeneous mixtures and concentration gradients as well as water mist effects.

4 Recent Additions to the Database

The most recent addition to the GraVent DDT Database is a series of experiments on flame propagation and flame front morphology in H_2-CO-air mixtures. These investigations were motivated by the potential of these gas mixtures forming during severe nuclear reactor accidents and the finding that current H_2-CO-air combustion models underestimated flame velocities due to limited data and insufficient consideration of flame instabilites. Consequently, experiments in the GraVent facility investigated flame acceleration and flame front wrinkling in a range of mixtures, using high-speed OH-PLIF, dynamic pressure transducers, and ionization probes. The optical data gathered from these latest OH-PLIF experiments by Planötscher et al. [7] were added to the database. Additional OH-PLIF, flame speed, and pressure data will be contributed after future measurement campaigns.

5 Overview of Database Utilization

The GraVent DDT Database utilization has been monitored since its inception, with 34 research publications documented between 2017 and 2025 [8-41]. Authors utilizing the database are encouraged to report their usage, enabling continuous monitoring of its impact. Figure 2 illustrates the annual rate and cumulative trend of publications referencing GraVent data, showing an overall upward trend despite a temporary decline following the COVID-19 pandemic, which coincided with broader reductions in academic publishing activity. The documented publications span nine distinct research groups and include four PhD theses, 24 journal papers, and six conference papers.

All documented studies focused on numerical simulations of DDT and related phenomena, using the GraVent data primarily for validation purposes. While flame-tip position and velocity data were universally utilized across all studies, pressure measurements [18,20,21,28,38] and optical data [24,29,30,37,39,40] saw more selective application.

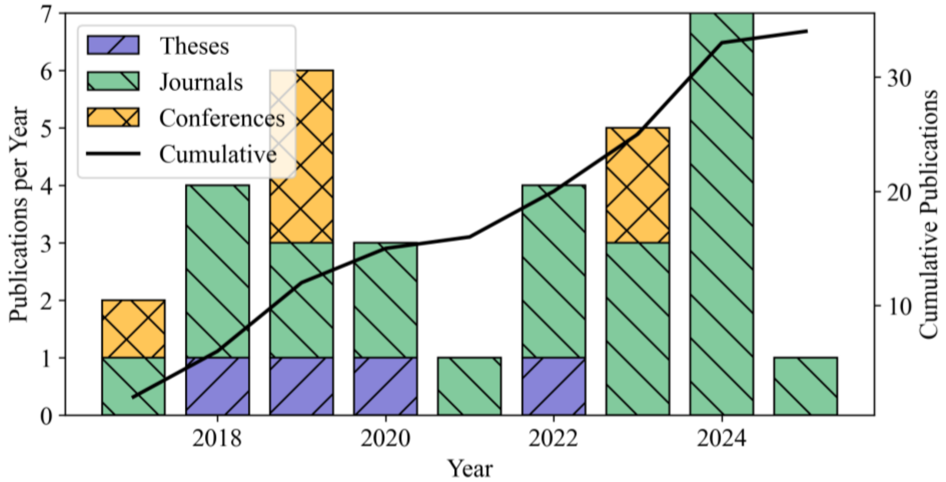

Figure 2: Publications using GraVent data between 2017-2025, categorized by publication type (theses, journals, and conferences). The cumulative publication count (black line) shows sustained interest. Data for 2025 is as of January.

6 Database Impact

The GraVent DDT Database has influenced three key research areas:

First, recent investigations of concentration gradient effects [8-10,14-15,19,20,24-26,28,32-34,36,39,41] have addressed a critical knowledge gap in explosion safety. While GraVent data were mostly used to validate macroscopic observations like flame speed and detonation onset locations, computational studies have provided deeper mechanistic insights. These studies confirmed observations from the early experimental programs at TUM that concentration gradients can promote DDT, particularly in unobstructed channels, by enlarging flame surface area and increasing burning rates.

Second, research on obstacle characteristics [21,30-31,37-38] examined how size, spacing, shape, and fluidic obstacle behavior affect DDT. These studies used GraVent data to validate base configurations before investigating the effects of obstacle properties.

Third, the development of numerical models [11-13,17-18,22-23,29,40] has leveraged GraVent data for validation. These studies furthermore explored various phenomena such as chemical kinetics effects [17] and applications such as DDT in vapor cloud explosions [14] or energetic particle impacts on DDT in pulse detonation engines [11, 18]. While this categorization reflects primary research objectives, most studies inherently involved model development and validation to address their specific research goals.

7 Conclusions

The GraVent DDT Database has served as a resource for combustion research and explosion safety communities over the past decade, has motivated numerous studies, and helped advance our understanding of deflagration-to-detonation transition phenomena. Recent computational studies have highlighted the complex interplay between concentration gradients, geometry, and DDT phenomena, with important implications for explosion safety in practical systems. The past decade has demonstrated significant progress in computational methods, with researchers consistently leveraging this database for validation of increasingly sophisticated models. Looking ahead, the database will continue to expand with new experimental data from ongoing studies. As research continues in this field, the database remains a valuable open-access resource for investigating explosion dynamics and developing explosion safety strategies, particularly for hydrogen systems.

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