Design and Development of a Turbulent Flame Speed Vessel

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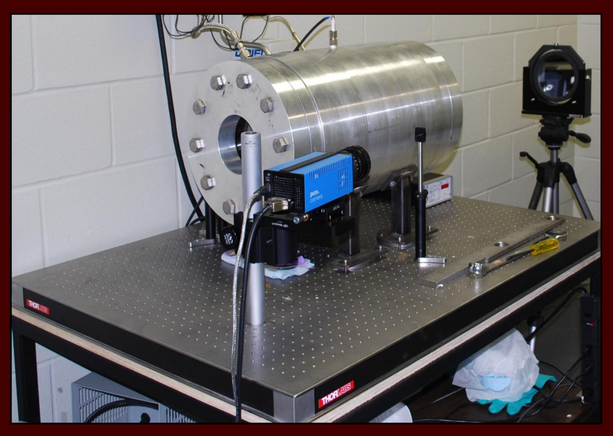
Background

Measurement of flame speed by optically tracking the growth of a spherically expanding flame in intense isotropic turbulence with negligible mean flow was successfully demonstrated by Bradley et al (2003) and Kido et al (1998). Turbulence was induced by the use of mixing fans whose rotational speeds can be precisely controlled to generate an increasing level of turbulence intensities at a constant integral length scale. The facilities described in these studies are spherical, thus enabling symmetric placement of fans to create a central region of turbulence. The flame speed vessel in Texas A&M University is cylindrical (12" ID x 14" L), and hence a statistical approach is being adopted to decide on the optimum fan placement so as to extend the region of turbulence to the entire region of optical access (12.7 cm).

Approach

The flame speed vessel at Texas A&M is a constant-volume, cylindrical chamber with optical access via 12.7-cm diameter, fused quartz windows. The flame propagation is observed using a Z-type schlieren setup. Due to the vessel's large internal size, a maximum flame radius of 4.7 cm can be measured without interference from non-ideal pressure effects.



A model of the flame speed vessel was fabricated using Plexiglas (clear acrylic). The inner diameter is 12" and is 12" long, making it to a 1:1 scale of the current flame speed vessel. The model vessel also provides optical access for turbulence characterization experiments. Four high-speed motors (Dewalt 618K- 2.25Hp,8000-24000RPM) are used to drive the fans.

Impeller Design

The aim of this study is not only to identify a region of isotropic turbulence but also to be able to independently change the integral length scale. The integral length scale was observed to be a strong function of the impeller blade design by Kwon (1991), and hence a design of experiments approach (Taguchi Matrix) is being used to arrive at the optimal fan blade design.

The Taguchi Matrix method is an optimization tool used to access the contribution of various factors by performing the least number of experiments.

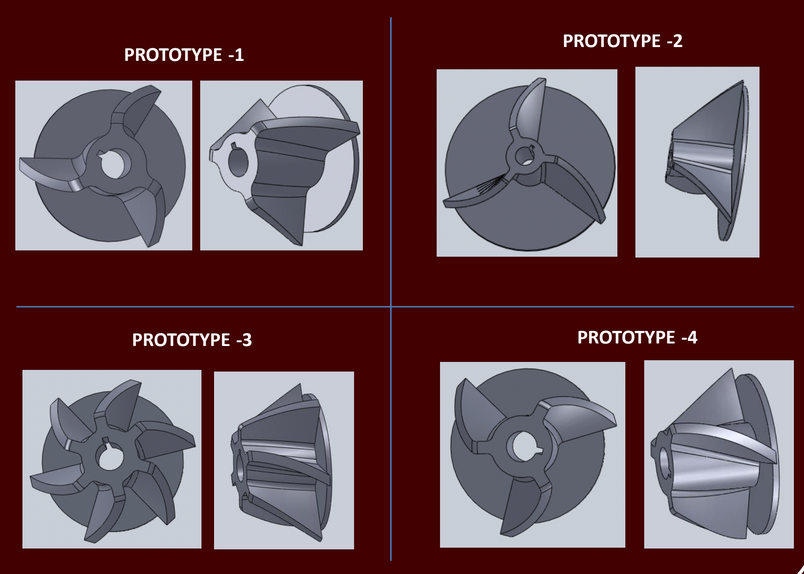
Factors Varied
1. Fan OD (Inches)
2. Number of Blades
3. Blade Pitch (Degrees)

Factors assumed constant
1. Fan Placement: Central Circumference
2. Number of fans: 4
3. Fan Axial Length: 1.5"

The L-4 Matrix was used to generate the prototypes with a two-level variation of each factor. This matrix is shown in the table below. The prototypes were made out of Nylon GF using laser sintering.

Table1: Prototype Details

Prototype	Fan OD	No of Blades	Blade Pitch
1	3	3	20
2	5	3	20
3	3	6	20
4	3	3	60



Future Work

Particle Image Velocimetry will be used to characterize the turbulence. Each prototype is proposed to be run at three different speeds, namely 8000, 12000 and 14000 rpm. Three planes of measurement will be employed (center and ± 2.5") to assess spatial homogeneity.

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