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Analysis of Constant Volume Combustion Model Using Matlab Function

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A B S T R A C T

Due to numerous benefits of constant volume combustion vessels, we have utilized it in the current analysis. They may be used in two different ways: either for imaging the propagation of the flame front under constant pressure circumstances, or for measuring the rise in pressure in conjunction with a constant volume combustion model. When spark ignition occurs via two electrodes, a spherical flame spreads outward through the unburned mixture. This model may be used to compute burning velocities from the pressure record for the range of temperatures and pressures encountered during combustion. Constant volume vessel approach has the advantage of collecting data across a larger range of temperatures and pressures, as well as the possibility to gather several data points from a single experiment. The temperature distribution is calculated using a multiple burnt gas zone model, where pressure increases with mass fraction burned. A simulation of a constant volume experimental laboratory is used to provide data on fuels like propane, ethane, and methane. For situations of high pressure and high temperature, the data currently available in the literature are insufficient or inaccurate. The constant volume combustion approach lacks stretch correction and has inaccurate model parameters. Both factors will be investigated in this research.

Keywords: Constant-volume combustion method, Propagation of the flame, Laminar burning velocity

Introduction

The laminar burning velocity is one of the fundamental properties of a premixed fuel-air flame that propagates. It is mostly influenced by the mixture's temperature, pressure, equivalency ratio, and fuel composition. Gaining knowledge of laminar burning velocity may also help with understanding of things like propagation rates and emission characteristics. Furthermore, because internal combustion engines have laminar early combustion, a laminar burning velocity is necessary.

The creation of exact experimental data on laminar premixed flames and the development of computer code for the estimate of burning velocity based on energy and volume conservation make up the two main components of this research. Comparing the closed vessel approach to other techniques, it has the benefit of calculating burning velocities across a wide range of temperatures and pressures from a single test.

LITERATURE REVIEW

1. 1. The goal of this work, namely by **B. Jochim and C. Felsch**, is to create a dynamic modeling method for combustion using premixed charge compression ignition (PCCI), which might be used to the creation of closed-loop controllers. A comprehensive multi-zone chemistry model is combined with a mean value gas exchange model to account for the low-pressure portion of the engine cycle and the high-pressure portion of the cycle. Consequently, there is a sufficiently developed and effective model that can explain PCCI combustion. To capture cycle-to-cycle dynamics, identified system dynamics influencing the input parameters are integrated.
2. **Chen Z.** studied the propagation of spherical flames at constant pressure or constant volume. He investigated the theoretical and computational impacts of flame stretch and flow compression on the accurate computation of laminar flame speeds at normal and elevated pressures. The results show that the accuracy of determining flame speed is considerably affected by both flame stretch and compression-induced flow motion.
3. The observations of the pressure rise that occurred during burning by **Hopkinson [1]** marked the beginning of research on constant volume combustion vessels. Hopkinson also found the temperature gradient in the burned gas, even though the pressure rise technique has just lately taken this into account.
4. **Hinton, N**. The laminar burning velocity is an essential fundamental property of a fuel-air mixture at a specific temperature and pressure.

Simulated Experimental Apparatus

The bomb used in this experiment is a stainless steel, 160 mm internal diameter, spherical pressure vessel. It can function at pressures as high as 34 bars. The combination is ignited by two opposing collinear electrodes and an inductive HT coil pack. The bomb has a built-in piezoelectric pressure sensor in its wall. This is used in combination with a charge amplifier to record the pressure trace during combustion. The gasoline and air were partially pressurized using three piezo-resistive pressure transducers. Gases were added one at a time, and the thermocouple on the bomb was used to compensate for any little temperature variations that happened during filling.

Data from every sensor is received by an acquisition system. The user may assist in the mixing process by using a LabView program, which offers targets that show the required pressure at each stage of the process together with real-time temperature and pressure measurements. This high-speed data collection is started concurrently by an external circuit that also burns the spark. Data from every sensor is received by an acquisition system.

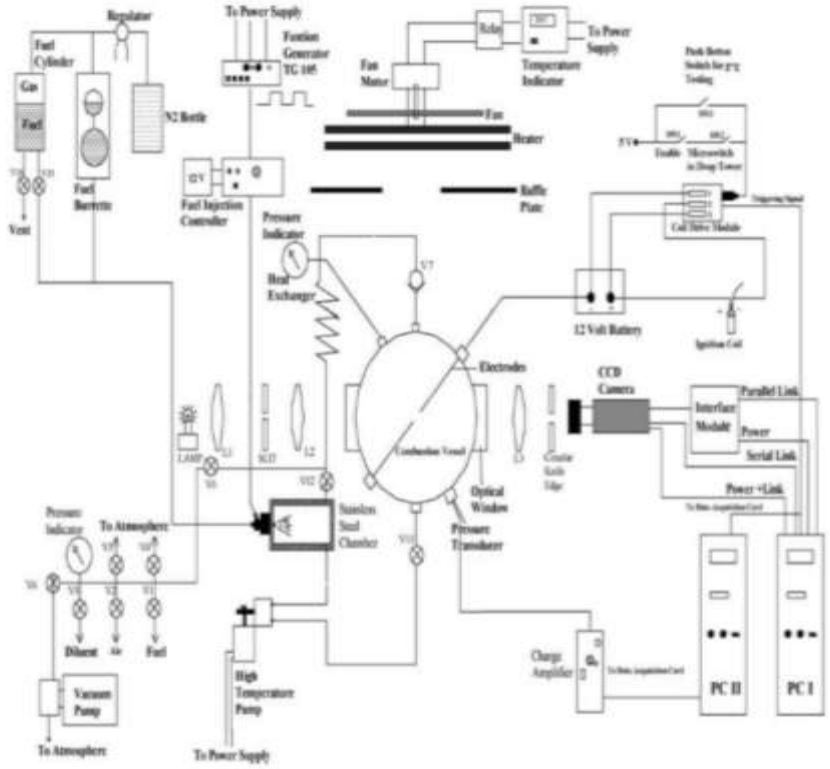

Fig.1 Simulated Experimental apparatus

BOMB PROGRAM

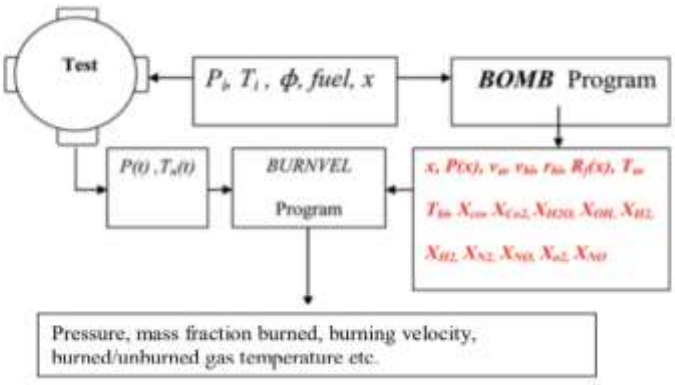

Fig. 2 Schematic representation for calculation of combustion properties.

Flowchart for CALCULATION OF LAMINAR BURNING

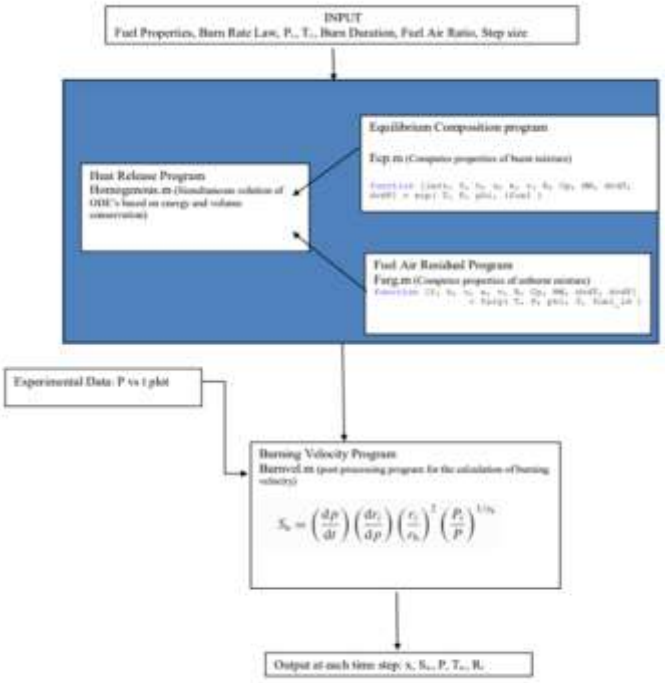

Fig.4. FLOWCHART FOR EXPERIMENTAL CALCULATION

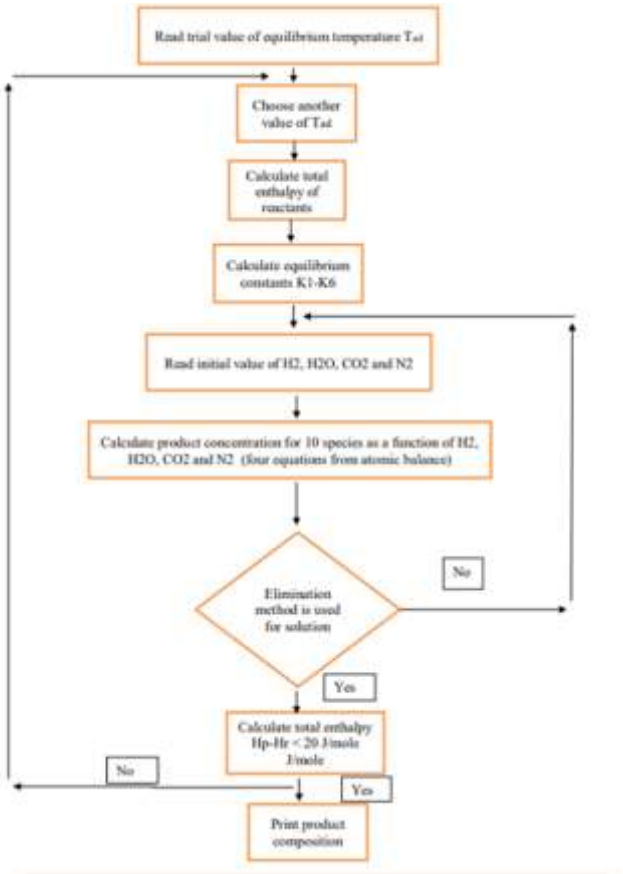

Fig.3. Flowchart For calculation of equilibrium

MATLAB PROGRAM USED FOR THE ANALYSIS:

1. Fuel.m (Compute the fuel properties)

```
% compute thermodynamic properties
h = ao + bo/2*T +co/3*T^2 +do/T;

cp = ao + bo*T + co*T^2;

% Calculate molecular weight of fuel
mw = 12*alpha + 1*beta ;
```

2. fa.m (Computes the fuel air mixture properties)

```
% stoichiometric molar air-fuel ratio
a_s = alpha + beta/4 ;

% mole fraction of fuel, O2, N2
y_1 = 1 / (1 + 4.76*a_s/phi);  % mole fraction for one mole of reactant
y_fuel = y_1; % assuming 1 mole fuel
y_O2 = a_s/phi * y_1; % a_s/phi moles O2
y_N2 = a_s/phi*3.76 * y_1; % a_s/phi * 3.76 moles N2


Y = zeros(6,1);

Y(3) = Y(3) + y_N2*(1);
Y(4) = Y(4) + y_O2*(1);

% compute properties of mixture
h = h_fuel*y_fuel;

Cp = cp_fuel*y_fuel;

MW = m_fuel*y_fuel;

% compute component properties according to curve fits
cpo = zeros(6,1);
ho = zeros(6,1);

for i=1:6
    cpo(i) = A(i,1) + A(i,2)*T + A(i,3)*T^2 + A(i,4)*T^3 + A(i,5)*T^4;
    ho(i) = A(i,1) + A(i,2)/2*T + A(i,3)/3*T^2 + A(i,4)/4*T^3 +A(i,5)/5*T^4 +
A(i,6)/T;

end


for i=1:6
    if(Y(i)>1.e-25)
```

```
        Cp = Cp+cpo(i)*Y(i);
        MW = MW + Y(i)*Mi(i);
    end
end
```

3. Ecp.m (Computes the product concentration and properties at equilibrium)

```
% Get fuel composition information
[ alpha, beta ] = fuel( ifuel, T );


% Equilibrium constant curve fit coefficients.
% Valid in range: 600 K < T < 4000 K
%         Ai            Bi             Ci             Di             Ei
Kp = [ [  0.432168,     -0.112464e+5,  0.267269e+1, -0.745744e-4,  0.242484e-8 ];
...
       [  0.310805,     -0.129540e+5,  0.321779e+1, -0.738336e-4,  0.344645e-8 ];
...
       [ -0.141784,     -0.213308e+4,  0.853461,     0.355015e-4, -0.310227e-8 ];
...
       [  0.150879e-1, -0.470959e+4,  0.646096,     0.272805e-5, -0.154444e-8 ];
...
       [ -0.752364,      0.124210e+5, -0.260286e+1,  0.259556e-3, -0.162687e-7 ];
...
       [ -0.415302e-2,  0.148627e+5, -0.475746e+1,  0.124699e-3, -0.900227e-8 ]
];

K = zeros(6,1);
for i=1:6
    log10ki = Kp(i,1)*log(T/1000) + Kp(i,2)/T  +  Kp(i,3) + Kp(i,4)*T +
Kp(i,5)*T*T;
    K(i) = 10^log10ki;
end


c1 = K(1)/sqp;
c2 = K(2)/sqp;
c3 = K(3);
c4 = K(4);
c5 = K(5)*sqp;
c6 = K(6)*sqp;
```

4. Homogenous.m (Simultaneous solution of ODE's)

```
    % ODE input for simultaneous solution


        if ( 0.001 < X && X < 1 )

            [~, HU, ~, VU, ~ , CPU, ~, DVDTU, DVDPU] = farg( TU, P, PHI,
fuel_type );
            [ierr, ~, HB, ~,  VB, ~, CPB, ~, DVDTB, DVDPB] = ecp( TB, P, PHI,
fuel_type );
            if ( ierr ~= 0 )


            fprintf('Error in ECP(%g, %g, %g): %d\n', TB, P, PHI, ierr );
        end
        AA = ((VU/CPU)*(TU/VU)*(DVDTU))* C1*(1-C0)*(1-TW/TU);


         BB = ((VU-VB)+VB/(CPB*TB)*(HB-HU))* DX;

         CC = X*(VB^2/(CPB*TB)*((TB/VB)*(DVDTB))^2)+(DVDPB);

       DD = (1-X)*(VU^2/(CPU*TU)*((TU/VU)*(DVDTU))^2)+(DVDPU);

       % HL = (1-X^2)*HU + X^2*HB;

        YPRIME(1) = (AA + BB )/(CC + DD );
        YPRIME(2) = -C1/CPB/C0*(TB-TW) + 1/CPB*TB*DVDTB*YPRIME(1) + (HU-
HB)/CPB*(DX/X);
        YPRIME(3) = -C1/CPU/(1+C0)*(TU-TW) + 1/CPU*TU*DVDTU*YPRIME(1);


    end
```

VI. OUTPUT OF EQUILIBRIUM SOLVER AT DIFFERENT INPUT PARAMETER

Comparison of Standard paper result and PRESENT RESEARCH work

Basis	**Base paper-Methanol Working fluid**	**Present Work- Methane-Working fluid**
Pressure in bar	2, 6	2, 6
Equivalence ratio	0.2, 1.01	0.9, 1.2
Temperature in k	373	337
Result Time in ms	140.38,120.13	100, 60
N_{Ox} Decrease	7%	12%
Efficiency increase	5% increase	10% increase

SCOPE OF FUTURE WORK

- To investigate the temperature gradient created in the burnt gas zone, Program Homogenous.m must be corrected. One of the project's future goals is to investigate the laminar burning velocity of fuel mixes, such hydrogen-methane mixtures. Additionally, because most of the combustion is turbulent, models of turbulent velocity needed to be improved.
- Most of the correlations for laminar burning velocity that are currently in use were obtained from the pressure development observed in a constant volume combustion bomb; however, it should be noted that these correlations include the effects of stretch and combustion instabilities, which are largely unknown, and are not of stretch-free burning velocities. Flame stretch adjustment must be used in subsequent work because it is not considered here.
- It would also be beneficial to expand the measurements of heavy hydrocarbon molecules' laminar flame speeds under a variety of operating situations, particularly at high pressure and preheating temperatures.

CONCLUSION

The combustion process within a closed vessel has been studied using a unique multizone model. Among the conclusions are the following.

1) The combustion process inside a constant volume spherical vessel is examined using a multizone model.

2) The MAT-lab methods needed to compute laminar burning velocity are created.

3) The study examines the effects of pressure, temperature, and equivalency ratio on laminar burning velocity.

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