Available online at www.sciencedirect.com
ScienceDirect
Energy Procedia 82 (2015) 125 – 132
Energy Procedia

ATI 2015 - 70th Conference of the ATI Engineering Association

Effects of Pressure, Temperature and Dilution on Fuels/Air Mixture Laminar Flame Burning Velocity

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Abstract

Fuel laminar burning velocity is an important parameter in internal combustion engine modeling and combustion analysis.
The present paper deals with the development of a mathematical correlation able to provide laminar burning velocity for fuels/air mixture at different thermodynamic conditions. Therefore, a mathematical investigation of laminar burning velocity for most significant and used fuels was carried out.
Fifth order logarithmic polynomial functions were implemented to predict the propagating laminar burning velocity of combusting fuels as a function of equivalent ratio at different conditions of temperature and pressure.
On the basis of results obtained, the mathematical model proposed in this paper showed a higher precision in experimental data fitting and the possibility to interpolate and use a single mathematical function for a wider operation field.

Peer-review under responsibility of the Scientific Committee of ATI 2015

*Keywords:*matematical modelling; combustion; laminar burning velocity; equivalence ratio; fuels

1. Introduction

The laminar burning velocity is an important parameter that can be used for both practical applications and theoretical model of internal combustion engines and burners. Most of combustion system mathematical models use this parameter to determine turbulent flame front velocity [1]. Both Internal

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Peer-review under responsibility of the Scientific Committee of ATI 2015
doi:10.1016/j.egypro.2015.12.004

combustion Engine (ICE) and Combustion Turbine (CT) mathematical modeling needs to take into account laminar flame velocity in the equations. That is much more important in combustion studies of not conventional fuels [2] and synthesis gas [3, 4]. Several authors measured laminar burning velocity for a wide variety of fuels as a function of equivalence ratio and highlighted its strong temperature and pressure dependence [5 – 10].

The most common relation used to fit flame burning velocity data for hydrogen, methane, propane, iso-octane, methanol and gasoline, at different pressure and temperature of unburned mixture, is a power law of temperature and pressure where exponents are a function of equivalence ratio. This power law also depends on the laminar velocity at reference conditions (S_{L0}). Iijima et al. [5] proposed an expression for temperature and pressure exponents that linearly depend on the equivalence ratio, used by most of authors [5 – 10]. Metghalchi et al. [6 – 7] used a second-order polynomial function of fuel ratio for laminar flame velocity at the reference conditions for methanol, isooctane, indolene and propane, while Galmiche et.al used a forth-order polynomial function for iso-octane [8]. Verea et al. recently extended the linear power exponent of pressure to contain quadratic term of equivalence ratio. During their calculation for n-butanol, iso-octane, Liu K. et al. [9] found that it is difficult to compromise such range of equivalence ratio of interest unless the power exponent of pressure is extended to include the cubic term. Ravi et al. [10] assumed the laminar velocity at reference conditions and the two exponents to be different order polynomial functions of equivalence ratio for hydrogen-oxygen mixture. To cover whole range of equivalence ratio data, Ravi et al. used different polynomial functions calculating the corresponding coefficients.

In the present work the authors proposed a mathematical method to describe the flame burning velocity as a function of equivalence ratio, pressure and temperature. The method is based on fifth order logarithmic polynomial functions (VoLP) to define the laminar velocity at the reference conditions and for both power exponents of pressure and temperature. VoLP function application presents several mathematical advantages as widely described in [11 - 14]. Laminar burning velocities of several fuels were determined on the basis of experimental data in order to verify method efficacy and precision. Considering the registered errors it can be stated that the mathematical model accurately describes the laminar burning velocity behavior as a function of equivalence ratio, at different pressure and temperature condition in all combustion engineering range.

This method allows predicting laminar burning velocity of combusting air/fuel mixtures in several engineering applications. In particular, in ICE modeling it is necessary to know laminar burning velocity as a function of local equivalence ratio, as well as pressure and temperature in order to calculate turbulent flame speed. The present work represents a first step in a wider research to model combustion in ICE running on non-conventional fuels.

Nomenclature

S_L	laminar burning velocity [cm/s]
α	power exponent of temperature
β	power exponent of pressure
ϕ	equivalence ratio
T	temperature [K]
p	pressure [atm]
X	coefficient matrix