VALIDATION OF A 0D/1D COMPUTATIONAL CODE FOR THE DESIGN OF SEVERAL KIND OF INTERNAL COMBUSTION ENGINES

E. J. LÓPEZ and N. M. NIGRO

Centro Internacional de Métodos Computacionales en Ingeniería (CIMEC)
Instituto de Desarrollo Tecnológico para la Industria Química (INTEC)
Universidad Nacional del Litoral - CONICET
Güemes 3450, 3000-Santa Fe, Argentina
ph: (54342)-4511 494/5, fx: (54342)-4511 169
ejlopez@santafe-conicet.gov.ar, nnigro@intec.unl.edu.ar

Abstract— **A code for computational simulation of internal combustion engines is presented. One-dimensional gas dynamics equations are used for model the flow through pipes and manifolds, and the remaining components in the engine (cylinders, valves, etc.) are modeled by using thermodynamic or 0D models. The numerical code developed is able to simulate spark-ignition and compression-ignition, two-stroke and four-stroke, multi-cylinder and multi-valve engines, naturally aspirated or turbo-charged, and different geometries of the combustion chamber. The code was implemented in the scripting language `Python`, which is a dynamic object-oriented programming language that offers strong support for integration with other languages and tools. The numerical methods used in the discretization of the equations and implementation details are presented. Several test cases are included in order to show the performance of the code.**

Keywords— **Internal combustion engine modeling, 0D/1D internal combustion engine simulation, Python.**

I. INTRODUCTION

The modeling of reciprocating and rotary internal combustion (IC) engines is a multidisciplinary subject that involves thermodynamics, fluid mechanics, turbulence, heat transfer, combustion, chemical reactions, mathematical analysis, and numerical methods. Historically, different levels of approximation have been used to predict the performance of IC engines, from simple air standard cycles to complex 3D models including turbulence, chemical reactions, spray dynamics, etc. IC engine simulation can be classified into four categories, namely zero-dimensional single zone, 0D/1D single zone models, quasi-dimensional multi-zone models and multidimensional models. In 0D/1D models, the engine is represented as a network of pipes (intake and exhaust manifolds) interconnected among them with “devices” that simulate different parts of the machine (valves, cylinders, pipe junctions, etc.). One-dimensional CFD models are used for pipes and thermodynamic (or zero-dimensional) models for the above mentioned “devices”.

For 0D models, most properties are averaged over the total volume and no spatial information is available. A survey of thermodynamic models for cylinders are presented by Blumberg *et al*. (1979), Mattavi *et al*. (1980), Heywood (1980), among others. These models rely on some understanding of the physics involved and try to capture the main features of the processes. By including the description of the most important aspects, the models have performed surprisingly well and are ideally suited for parametric studies. A zero-dimensional single-zone model is capable of predicting engine performance and fuel economy accurately with a high computational efficiency (Krieger and Borman, 1966; Foster, 1985; Assanis and Heywood, 1986). The major drawback of single-zone models is their inability to simulate the wave propagation into pipes and manifolds that strongly influence on volumetric efficiency. Also, these models are unable to account for fuel spray evolution and the spatial variation in mixture composition and temperature, both of which are essential in predicting harmful species formed during the combustion process.

On the other hand, multi-dimensional models, such as `KIVA` (Oran and Boris, 1981; Bracco, 1985; Amsden *et al*., 1985; Amsden *et al*., 1987; Varnavas and Assanis, 1996), resolve the cylinder space into fine grids, thus providing a considerable amount of spatial information. However, multi-dimensional models still employ phenomenological submodels describing fuel spray processes, and their simulation results may vary with assumed initial or boundary conditions. Consequently, the accuracy of the results cannot always be guaranteed. Furthermore, computational time and storage constraints still preclude these models from routine use for design purposes. Currently an intermediate step between zero-dimensional and multi-dimensional models has arisen, called quasi-dimensional. Multi-zone models (Hiroyasu and Kadota, 1976; Hiroyasu *et al*., 1983a,b; Kyriakides *et al*., 1986; Yoshizaki *et al*., 1993; Kouremenos *et al*., 1997; Rakopoulos and Hountalas, 1998; Jung and Assanis, 2005) can be effectively used to simulate new technology engine combustion sys-