Pyrolysis Modelling of PVC Cable Materials

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ABSTRACT

One of the most commonly used materials in electrical cables is flexible PVC. In this work, the effects of the modelling decisions and parameter estimation methods on the pyrolysis modelling of two PVC cables were studied. The kinetic and thermal parameters were estimated from TGA and cone calorimeter experiments. The role of the plasticizers was shown to be important for the early HRR. The effects of the reaction path and reaction order were only minor in the TGA results but significant effects were found in the cone calorimeter results, unless a specific set of thermal parameters was estimated. The results show that the thermal parameters estimated for one kinetic model should not be used for another, unless the kinetic models only differ in fuel yields or different pairs of kinetic coefficients with same reaction order.

KEYWORDS: pyrolysis, modelling, heat release rate, reaction parameters, electrical cables.

NOMENCLATURE LISTING

A	frequency factor (s^{-1})
c	specific heat capacity (kJ/kg·K)
E	activation energy (kJ/kmol)
H_r	heat of reaction (kJ/kg)
H_c	heat of combustion (kJ/kg)
k	thermal conductivity (W/m·K)
N_m	number of material components
N_r	number of reactions
N_s	reaction order
R	gas constant (8.3145 J/(mol·K))
T	temperature (K, °C)
Greek	
β	heating rate (K/s)
ε	emissivity
ρ	density (kg/m^3)
subscripts	
i	component i
j	reaction j
p	reference
s	solid

INTRODUCTION

Polyvinyl chloride (PVC) is one of the most versatile thermoplastic materials due to its processability and range of different applications. PVC is widely used in electrical cables in the form of flexible PVC. Flexible PVC is produced by adding 30–40 wt. % additives, especially plasticizers to lower the glass-transition temperature [1]. Flexible PVC ignites more easily and burns at higher rate than rigid PVC because the plasticizers are usually combustible [2].

Electrical cables are the primary fire load in many fire engineering applications. The numerical simulation of the PVC cable fires requires the modelling of the cable pyrolysis, which is extremely challenging due to the geometrical complexity and the wide range of different PVC compositions and plasticizers. As the cable manufacturers seldom provide information about the exact chemical composition of the material, the fire modelling must be based on testing the modelling decisions against available experimental evidence. The modelling decisions are related to the degree of geometrical complexity, the number of independent material components, number of reactions and the reaction paths. The different approaches for modelling the kinetics of PVC degradation have been studied by Marcilla and Beltrán [3] who concluded that two parallel reactions are needed to describe the first stage of PVC degradation, and a single reaction for the second. The degree of model complexity should be in balance with the amount of experimental evidence and the allowable estimation and computing times. For instance, electrical cables have typically a cylindrical shape but non-symmetric inner structure with several layers of materials. How much of the layer structure is retained in the pyrolysis model, is a modelling decision. Once the model structure has been fixed, the problem becomes a parameter estimation problem, as explained in Refs. [4–8].

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