Investigation of kinetic parameters of thermal decomposition of chosen kinds of wood

Jarosław Chodorowski
Krzysztof Babeł
Zdzisław Salamonowicz

The Central School of State Fire Service, Czestochova, Poland
chodorowskij@cspsp.pl

Introduction

In estimation of the kinetic parameters in thermal decomposition of wood, the kinetics models are the first essential stage in selecting and describing the conditions of wood decomposition in specific thermal expositions.

The methods of estimating kinetic parameters, described in available literature, based on degradation models are considerably differentiated, both in basic model assumptions and in methods of their calculations.

The first model assumption adopted in calculations is the ternary composition of wood, i.e. comprised by hemicelluloses, cellulose and lignin, which undergo pyrolysis both in atmosphere of inert gases and in thermal oxidation decomposition, as three separate components. Although numerous researchers (Wood Fire Behaviour 1966, Beal and Eicknor 1970, Jiang 1994) have confirmed that hemicelluloses, cellulose and lignin decompose independently, the separation of individual components is at present technically very difficult. As a rule the application of decomposition and separation techniques of individual components can change (and do change) the structure of wood as an effect of depolymerisation and change in structure of the components (Prosiński 1984). These changes allow obtaining kinetic degradation parameters, which do not fully reflect the actual decomposition of wood. Substitutes of individual components applied in models, such as xylan, Avicel cellulose and the Klason lignin, can cause obtaining incorrect results of kinetic decomposition parameters (Antal 1998, Cozzari 1997, Koufopanos 1989, Shafizadeh 1992). Moreover, as was shown by results of diverse research (Caballero 1996, Parker 1992) in raw wood, without thermal decomposition, as a rule interactions take place between different components, which cause modification of the properties of individual components. These types of changes are not observed in hemicelluloses, lignin and cellulose separated from wood.

Furthermore, the assumption in models of simple decomposition for particular wood components does not reflect fully the actual decomposition mechanism. During wood heating observed are sequences of overlapping reactions, the course of which depends on thermal conditions. These conditions refer to physical and thermal properties of wood, methods of temperature measurement, rate and direction of heating, type of atmosphere surrounding the sample of wood, configuration of arrangement: wood - source of heat, static - dynamic conditions. An additional hindrance is that 'decomposition models do not take into consideration the above named factors causes as consequences that theoretical descriptions of the decomposition mechanism described in literature are considerably differentiated.

Aim of investigation

The aim of undertaken tests was to find explanation for impact of the rate of heating influence on thermal decomposition of wood and kinetic parameters. The specified experiments were conducted for four kinds of wood. The above-mentioned studies related to correlations constitute an important problem in estimations of rate of fire threats forming, especially in evaluation of susceptibility to initiation of lignocelluloses materials combustion.

In the experiment the use was made of heating rates, which simulate the thermal conditions existing in the I stage of fire and during transformation from the I stage of fire to the II stage. pursuant to the standard of the American Society for Testing and Materials (ASTM 119E/92) which describes I a graphical form the temperature increase in fire as a function of fire duration:

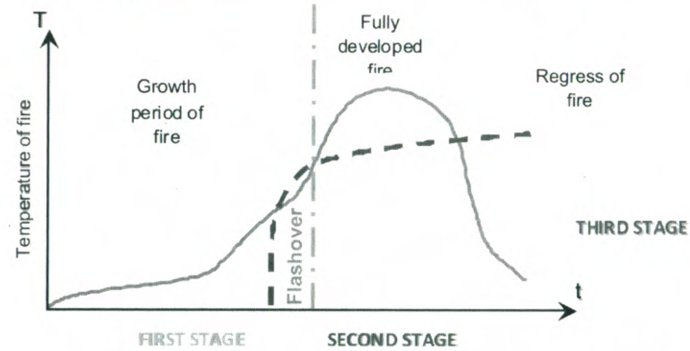

Fig.1. Standard ASTM 119E – temperature of fire as a function of fire duration.

Two types of hardwood: beech (Fagus silvatica), oak (Quercus robur) and two types of softwood: pine (Pinus silvestris) and spruce (Picea excels) were used as experimental materials.

During experiments thermal decomposition of above-named wood types was implemented within the temperature range of 25-10000C, in air atmosphere, with three rates of heating β=25, 50 and 100 deg•min-1, defining the starting temperature (Tpap) and the end of active pyrolysis (Tkap), the temperature of extreme rate of thermal decomposition (Tv), the rate of mass loss (Vmaks) at temperature of extreme rate of thermal decomposition (Tv), the mass loss in temperature of active pyrolysis (Uap) and the maximum mass loss (Um).

A fundamental problem in the research was estimating the kinetic parameters within temperature ranges in active pyrolysis. The conversion coefficient of wood mass to volatile phase was used to calculate kinetics parameters: order of chemical reaction (n), the activation energy (Ea) and pre-exponential factor (A). For this purpose such methods, as Kissinger's (1957), Ozawa's (1965), Borchardt–Daniels's (1957) and Ozawa-Flynn-Wall's (1965-66) were used in calculations. The choice of methods was dictated by their wide application and different kinetic models of decomposition. The adopted methods of calculations differ also by simplifying and analytical assumptions in mathematical algorithm. In thermogravimetric analyses samples were used in the form of cylindrical pieces/cast disks. Such a form of experimental materials was dictated by the most frequent form of wood used as structural timber, in finishing works and interior furnishing in fire environment.

Owing to the average effectiveness of combustion in a fire environment equalling to ca. 60 % and the lack of required air volume in active phase of fire (the active pyrolysis phase), the platinum crucibles with perforated lid were applied in the tests, reducing in this way the speed of air diffusion to decomposed wood samples.

Before the commencement of the experiments the absolute humidity and density of the studied kinds of wood were defined. The absolute humidity of wood was defined by using drying-weighing method pursuant to the Polish standard (PN-56/D-04100). The experimental material used in investigation had an absolute humidity of ca. 12% ± 1%.