Use of Mineral Flame Retardants to Reduce the Combustibility of Thermal Insulating Board Composites from Plant Waste

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Abstract. Thermal insulation boards from unused spinning waste of linen and cotton fibers and soft wood waste have increased combustibility, like all composites with plant filler without mineral binders. To increase the fire protection of composites with plant filler, the use of flame retardants is necessary. The introduction of the composition of mineral combustion inhibitors - sodium carbonate or aluminum trihydrate allowed to reduce the combustibility of the material. The degree of damage by weight during combustion in the “ceramic box” of material samples from unused waste from the production of cotton and linen fibers and wood chips decreased by 1.3 ... 3.2 times depending on the type and proportion of flame retardant additives and the type of plant filler.

1. Introduction

The problem of processing plant waste is relevant primarily from an environmental point of view. The burning of plant waste increases the emission of nitrogen, carbon, soot and other components into the atmosphere. During the combustion of 1 ton plant waste into the atmosphere around 9 kg carbon black microparticles. On the other hand, plant waste can be a renewable raw material for the production of building composites, especially as a filler of insulation boards. Natural cellulose fibers have a number of advantages - low cost, renewability stocks biodegradability. This allows their use in many industries, including the production of thermal insulation board materials [1-4]. The disadvantages of cellulose-containing materials is their combustibility increased [5-7]. Therefore, in the manufacture of composites with fillers plant requires the use of flame retardants [8-12].

Group inorganic flame retardant is about 50% of world production of combustion retarders [13]. The action of the inorganic flame retardant based on increased coke formation and dehydration processes in the condensed phase. In the formation of coke bed decreases the formation of combustible volatile products during the thermal decomposition of plant components.

In addition to the most common combustion retardants, such as aluminum trihydrate, carbonates and urea-containing flame retardants can be used. They begin to decompose in the temperature range 180 ... 340 °C, when heated, they usually decompose endothermally and emit H\textsubscript{2}O. The result is reduced heat discharge water flow is reduced and the temperature in the combustion zone of the combustion. Thermal decomposition carbonates separated in gas phase of carbon dioxide, it promotes the decrease of the concentration of combustible gases in the gas mixture. In comparison with the phosphorus- and halogen-containing flame retardants inorganic retarders efficiency less. The advantage of inorganic combustion retardants is that they are less toxic. Therefore, they are often added to reduce the toxicity of gaseous products of combustion [8]. According to the data of E. V. Antsupova and S. M. Rodivilov [14], according to the activity of the combustion-inhibiting ability, sodium salts are located in the following sequence:
The results of determining the degree of damage by the mass of the boards during combustion in a ceramic box are presented in the table. The results of determining the conformity of composite samples to the state standard of Russia 53292-2009 [19].

2. Methods
In the study the authors, composite thermal insulation boards were made from unused wastes from the production of flax and cotton fibers based on phenol-formaldehyde binder (PF) and urea-formaldehyde binder (UF) using the wet fiberboard technology. To reduce the combustibility of the boards from the spinning wastes of plant fibers, sodium hydroxide Na2CO3 binder (UF) using the wet fiberboard technology. The negative aspects of using flame retardants in a composition include reducing the mechanical properties of the material [15–18]. The most technologically advanced way to increase fire protection in the production of board composites is to introduce flame retardants at the stage of mixing the components.

The results of determining the degree of damage by the mass of the boards during combustion in a ceramic box. Combustibility test methods "in the installation" ceramic tube ("ceramic box") according to the requirements of GOST 30244–94 "Building materials. Combustibility test methods "in the installation" ceramic tube ("ceramic box") according to the state standard of Russia 53292-2009 [19].

3. Results and Discussion
The results of determining the degree of damage by the mass of the boards during combustion in a ceramic box are presented in the table. The results of determining the conformity of composite samples to the combustibility group by the indicators “flue gas temperature”, “degree of damage by mass”, “duration of self-burning” are highlighted in color in Table 1.

| Type of binder, portion of additive (%) | Degree of damage by weight (%) when burning samples with filler | The degree of damage by weight of samples (%) with the share of the additive: Na2CO3·10H2O - above the line, Al2O3·3H2O - under the line |  |
|---|---|---|---|
| No flame retardant | | | |
| Flax | Cotton | Flax + wood shavings | |
| Flax | | 10 | 20 | 30 | |
| PF, 10 | 80.5 | 78.1 | 81.5 | 64.1 | 43.9 | 30.2 | 59.1 | 42.1 | 29.2 | 66.0 | 46.1 | 32.1 |
| PF, 20 | 71.4 | 67.7 | 72.6 | 62.8 | 42.5 | 28.7 | 57.3 | 40.2 | 27.4 | 64.2 | 44.2 | 30.4 |
| PF, 30 | 65.6 | 61.9 | 66.7 | 50.2 | 38.0 | 24.1 | 45.2 | 34.0 | 22.8 | 51.9 | 38.5 | 25.6 |
| UF, 10 | 82.6 | 80.2 | 83.5 | 48.7 | 36.2 | 22.3 | 43.4 | 32.1 | 21.1 | 50.1 | 36.8 | 23.9 |
| UF, 20 | 73.7 | 70.0 | 74.6 | 37.2 | 26.9 | 22.2 | 32.8 | 25.1 | 20.3 | 38.9 | 29.0 | 24.4 |
| UF, 30 | 68.0 | 64.1 | 68.9 | 35.6 | 25.0 | 19.8 | 31.0 | 24.2 | 19.6 | 37.1 | 27.3 | 22.8 |

1) slightly combustible (G1) having a flue gas temperature of not more than 135 °C, the degree of damage along the length of the test sample is not more than 65%, the degree of damage by mass of the test sample is not more than 20%, the duration of self-burning is 0 s;
2) moderately combustible (G2) having a flue gas temperature of not more than 235 °C, the degree of damage along the length of the test sample is not more than 85%, the degree of damage by mass of the test sample is not more than 50%, the duration of self-burning is not more than 30 s;
3) normally combustible (G3) having a flue gas temperature of not more than 450 °C, the degree of damage along the length of the test sample is more than 85%, the degree of damage by mass of the test sample is not more than 50%, the duration of self-burning is not more than 300 s;

4) highly combustible (G4) having a flue gas temperature of more than 450 °C, the degree of damage along the length of the test sample is more than 85%, the degree of damage by mass of the test sample is more than 50%, the duration of self-burning is more than 300 s.

4. Conclusions
The addition of sodium carbonate or aluminum trihydrate to the composition significantly reduces the combustibility of thermal insulation boards from plant waste, the damage by weight of the samples is slightly less when using aluminum trihydrate. When using flax and cotton waste composites UF as a binder, the addition of Al₂O₃·3H₂O provides the flammability group of the G2 material, and when using 30% phenol-formaldehyde binder, the G1 group. It should be noted that the cost of sodium carbonate is less than aluminum trihydrate.

Thus, the study allowed us to conclude that for the manufacture of thermal insulation composite board materials from non-returnable waste from the production of cotton and flax fiber, it is rational to use sodium carbonate decahydrate or aluminum trihydrate in an amount of 30% by weight of the plant filler. This makes it possible to obtain material with a self-sustained burning time of 0 s and with a mass damage rate of not more than 20% [20].

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