Investigation of the Effect of Some Fire Retardant Chemicals and Mineral Materials Used in Surface Coating on Combustion Performance of Particleboard

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The combustion resistance was investigated for dolomite, melamine (MEL), and ammonium polyphosphate used in the surface coating of particleboard. The surface coating materials consisted of a mixture of dolomite, melamine dust, ammonium polyphosphate, calcite, and water. The ratio of dolomite, melamine dust, and ammonium polyphosphate in the mixture was determined to be 10% based on the amount of calcite. The resulting mixture was applied to the surface of the particleboard at a thickness of 0.20 mm. Combustion tests were carried out according to ASTM E 69 standard. As a function of weight loss, the temperature values, amount of oxygen, amount of carbon dioxide, and nitrogen oxides of the test samples were determined. The results showed that the coating increased the combustion resistance of particleboard. Samples containing a 70% dolomite, 25% melamine dust, and 5% ammonium polyphosphate mixture or 100% dolomite produced the best results. The use of ammonium polyphosphate and dolomite positively affected combustion resistance.

Keywords: Dolomite; Melamine; Particleboard; Combustion properties; Fire retardants

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INTRODUCTION

Medium-density fibreboard (MDF) and particleboard from wood-based panels are used in abundant quantities in the furniture industry. Due to the low cost of particleboard, it has a wider application area. Because particleboard consists of organic components such as hydrogen and carbon (Myers and Holmes 1977), its flammability leads to some inconveniences in its application. Therefore, chemical substances are applied in some stages of production to improve this feature. Currently, the most commonly used combustion retardant chemicals are boron compounds. Wood material burns at 275 °C. Fire-retardant (FR) chemicals cannot prevent combustion, but they can retard burning by reducing the emission of flammable gases released by wood at certain temperatures (Winandy *et al.* 2008). Thus, FR chemicals improve the combustion properties of wood materials (Baysal *et al.* 2007).

Borax, boric acid, ammonium phosphate, zinc borate, chloride, and ammonium sulphate compounds are the most commonly used boron compounds for biological activity as well as retarding combustion in the forest industry sector (Kozlowski *et al.* 1995). In addition to boron compounds, dolomite mineral and melamine dust, which is an organic compound, are used as flame retardants (Özdemir *et al*. 2016). Dolomite, a type of calcium magnesium carbonate ($CaCO_3 \cdot MgCO_3$), is abundant in nature (Adesakin *et al*. 2013). Dolomite is used for many purposes in ornamental stone, concrete aggregate, and magnesium oxide for magnesium production or as a fire retardant for plastic composites. In addition to its use in glue production, melamine is also used as a fire retardant in the production of paper, plastics, and paints. There is little research on synergistic effects between boron compounds and mineral matter with regard to the combustion retardant properties. The surface coating method also has the effect of delaying burning according to the properties, thickness, and application method of the coating material (Sparkes 1993). This feature can be improved by adding chemicals that retard combustion to the surface coating.

The purpose of this study was to determine the effect of dolomite mineral, melamine, and ammonium polyphosphate chemicals powder used in certain proportions on the delayed burning of particle board.

EXPERIMENTAL

Materials

The proportions of the added chemical substances were calculated as 10% based on the calcite weight, while the melamine to formaldehyde ratio was set at 22%. Surface coating materials and their proportion in relation to the amount of calcite are given in Table 1. The particleboard, melamine formaldehyde resins, and MEL (melamine powder) were obtained from KEAS (Adana, Turkey). Dolomite was supplied by the Doltaş Incorporation (Izmir, Turkey). Ammonium polyphosphate (APP) was purchased from Özen chemical company, (İstanbul, Turkey).

The calcite, water, melamine formaldehyde resin and FR chemistries containing dolomite mineral, ammonium polyphosphate, and melamine chemical powder were mixed in a blender until the mixture became homogenous. The pH of the mixture was adjusted to 8 to 10, and the viscosity was set to between 100 cP and 150 cP. The resulting mixture was applied with a roller to the surface 6 of the particleboards test specimens at a thickness of 0.20 mm and a density of 120 $g \cdot m^{-2}$. The surface-coated particleboards were stored at 65 ± 5% relative humidity and 23 ± 2 °C for 1 week.

Table 1. Mineral and Chemical Substances Used in Surface Coatings

Composite Code	Dolomite Mineral (%)	Melamine Powder (%)	Ammonium Polyphosphate (%)	Melamine Formaldehyde (%)
A	30	70	-	22
B	40	60	-	22
C	50	50	-	22
D	60	40	-	22
E	70	30	-	22
F	30	65	5	22
G	40	55	5	22
H	50	45	5	22
I	60	35	5	22
K	70	25	5	22
L	100	0	-	22
M	0	100	-	22

Preparation of Combustion Test Apparatus and Test Specimens

The burning test applied to the samples was carried out in the KSU laboratory in accordance with ASTM E-69 (2007). Samples from all groups given in Table 1 were conditioned at 23 ± 2 °C and 65 ± 5% relative humidity for 2 weeks (Sweet *et al.* 1996). Test specimens with dimensions of 9.5 mm × 19 mm × 1016 mm were suspended in the combustion tube in the arrangement shown in Fig. 1(a). The apparatus was prepared so that the butane gas flame length was 25 cm and the temperature did not exceed 1000 °C. The burning test took 10 min for each sample. The first 4 min of the test used a flame source, but the remaining 6 min were carried out *via* self-ignition without a flame source. The values for temperature, O_2, CO, and NO were measured with the Testo 340 M gas analyzer (Kahramanmaraş, Turkey), while the weight losses of the samples were determined by digital scales. The measurements were taken at intervals of 30 s. Burning tests were repeated 6 times for each formulation. The combustion test apparatus and test examples are shown in Fig. 1.

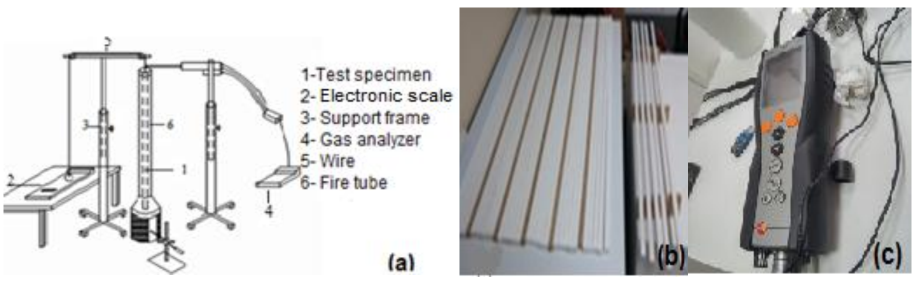

Fig. 1. The combustion test apparatus (a), the test samples (b), the gas analyzer (c)

RESULTS AND DISCUSSION

Fire Performance

Weight loss measurements of all test groups are given in Table 2. The weight loss of L and M control samples containing 100% dolomite mineral and 100% melamine powder were 62.7% and 77.8%, respectively. The highest weight loss occurred in the M group samples, while the least weight loss occurred in the L group. Weight loss was reduced in test groups where both dolomite mineral and melamine powder were used in the surface coating mixture. The weight loss of group M obtained with 100% melamine powder addition was reduced by the addition of dolomite. The weight loss of the samples continued to decrease due to the decrease in the rate of melamine powder and the increase in the addition of dolomite mineral; dolomite has a positive effect on weight loss. A similar reduction was observed in samples with 5% ammonium polyphosphate in the surface coating. Between the F and G groups with 5% ammonium polyphosphate added, there was a positive effect on the amount of weight loss which ranged from 0.5% to 2.6%. Similar results were obtained in studies using boron compounds as flame retardants (Özçifçi and Okçu 2008; İstek *et al.* 2013). Ammonium polyphosphate and boron compounds enhance combustion-reducing effects when used together with dolomite mineral and melamine powder. The coating of the surface of the particleboard with a mixture of calcite, dolomite mineral, melamine powder, and ammonium polyphosphate acts as a barrier to the oxygen required for combustion (Wan Hanafi and Hornsby 1993). This effect reduces the burning speed and the weight loss.

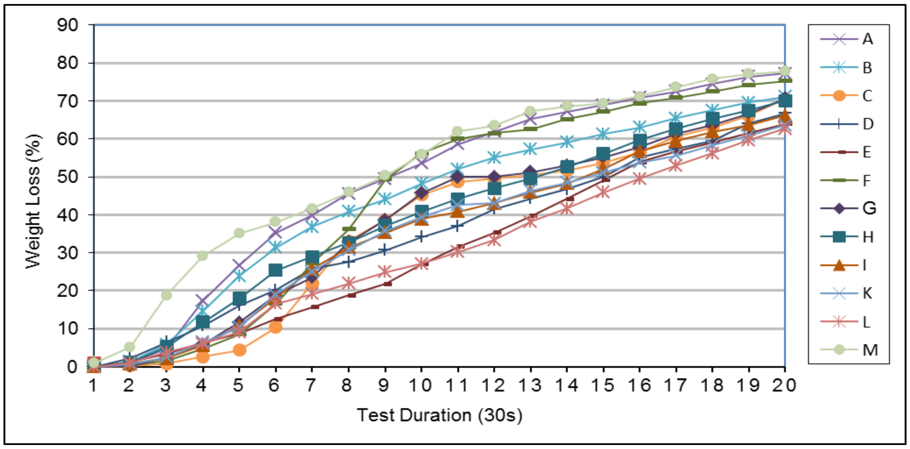

Fig. 2. Changes in the average measured values of weight loss in the combustion test process

Temperature changes during the combustion test are shown in Fig. 3. During the flame-sourced combustion, the lowest temperature was found in samples of the L group (416 °C), and the highest temperature (451 °C) occurred in group A samples. The temperature gradually decreased depending on the increase in the amount of dolomite in the surface coating. In the L group samples where only dolomite was added, the temperature was 416 °C, whereas in the M group where only melamine was added, the temperature was 450 °C. In groups A and E, the increase in dolomite from 30% to 70% led to a reduction of 6.20% in the combustion temperature. This reduction was further enhanced by the use of ammonium polyphosphate. The flame retardant chemicals and minerals used in the surface coating mixture had a positive effect on the reduction of the burning temperature of the particleboard.

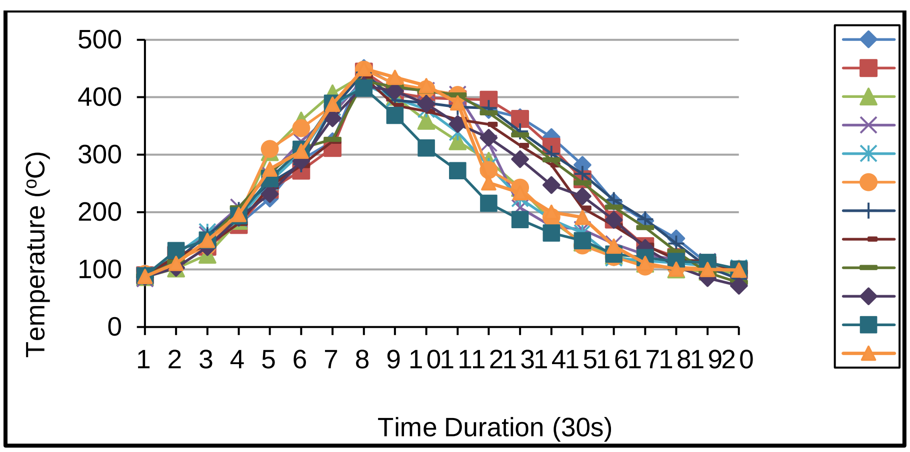

Fig. 3. Changes in the average measured values of temperature in the combustion test

These results agree with previous work by Baysal (2007). The surface coating reduces the diffusion of heat into the particleboard. As a result, low heat input into the internal part of the particleboard causes the burning at low temperature. As the low temperature increases the carbonization, the surface becomes isolative. Reduction of volatile gas output during combustion prevents increased combustion temperature (Özdemir and Tutus 2013).

The highest burning temperature in all test group samples ranged from 400 °C to 450 °C. The loss of weight in this temperature range was due to the decomposition of flammable and volatile gases such as CO, CO_2, CH_4, and CH_3OH from cellulose and hemicellulose (Liodakis *et al.* 2002).

As shown in Fig. 4, the lowest amount of O_2 was found in group A (15.8%). The average values of groups F (15.9%) and M (16.0%) were very similar to group A. The increase in the amount of dolomite, as in the measurement of weight loss and temperature values, led to an increase in the amount of oxygen. At the end of flame source combustion, the amount of O_2 was 16.7% in group C with equal amounts of dolomite and melamine mineral added (50:50%). The amount of O_2 was 19.3% in the H group, in which was added 5% APP, in addition to dolomite and melamine. APP has a positive effect on combustion. The rate of combustion depends on the amount of O_2 present in the environment. The amount of ambient O_2 in the air is 21%, but this proportion decreases with combustion (Yapıcı *et al.* 2011). Because FR substances increase the oxygen demand for combustion, they reduce the burning rate (Ashley and Rothon 1991).

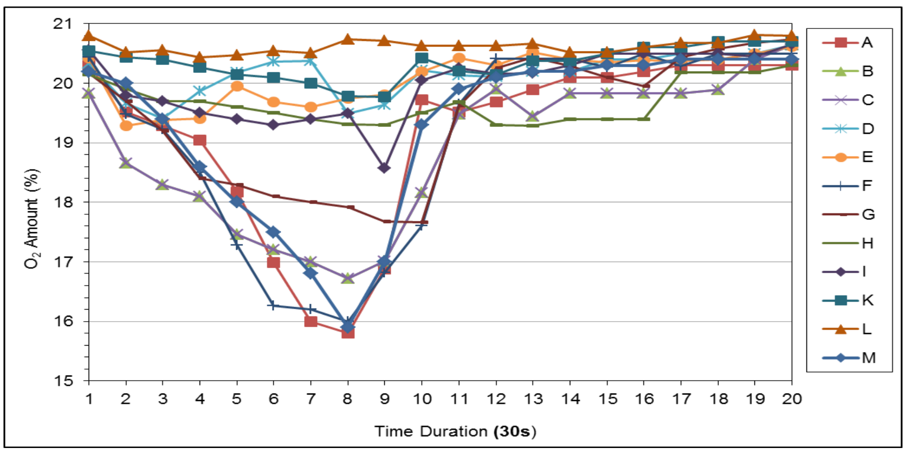

Fig. 4. Changes in the average measured values of O_2 in the combustion test

The average changes in CO during combustion are shown in Fig. 5. The CO emission was 1153 ppm and 1091 ppm in the L and M group samples containing 100% dolomite and 100% melamine, respectively. The amount of CO emitted was the greatest in group A (1302 ppm) and lowest in group L (1091 ppm). The amount of CO released declined due to the increase in the amount of dolomite use. The CO emission was 1160 ppm in group E samples with 70% dolomite compared with 30% dolomite added samples. Among the F (1298 ppm) and K (1153 ppm) groups supplemented with APP, there was a decrease due to the increase in dolomite utilization. This decrease was greater in the groups supplemented with APP. APP is effective in reducing CO emissions. The coating of the particleboard surface is expected to reduce CO emissions. However, the addition of flame-retardant minerals and chemicals to the surface coating materials resulted in further reductions in CO emissions due to their combustion-reducing effects.

The occurrence of volatile gaseous products due to thermal decomposition during combustion is related to factors such as the amount of oxygen in the environment, the combustion temperature, and the chemical structure of the combustible material (Mouritz *et al.* 2006).

Because FR materials absorb heat, they reduce the combustion temperature. As a result, the burning rate is reduced, and the toxic gas and smoke output, which harms human health, is also reduced. CO emissions are an important parameter in the selection of materials in buildings (Lee *et al.* 2011; Özdemir and Tutuş 2016).

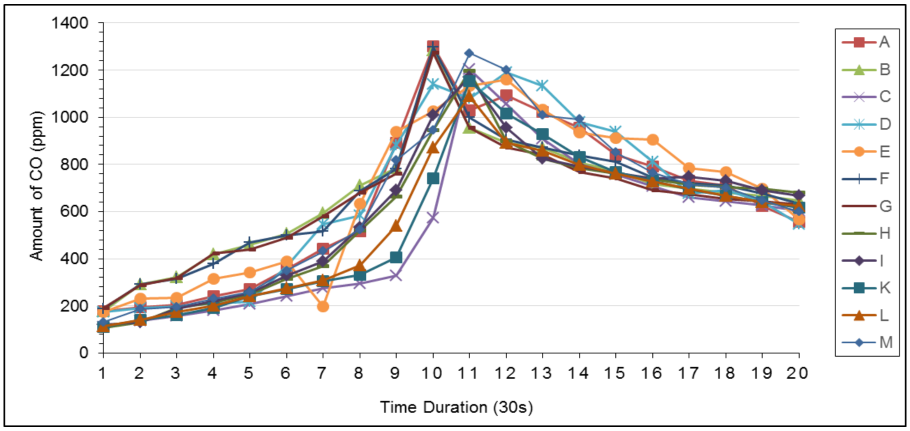

Fig. 5. Changes in the average measured values of CO in the combustion test

The rates of change in the average NO emission values of the particleboard samples measured during combustion were higher at the end of the test with flame sources and at the beginning of the test without flame sources combustion, as shown in Fig. 6. The A group (415 ppm) had the highest NO emission measurements, while the L group (290 ppm) had the lowest NO emission rates. Since the chemical degradation of melamine is a source of NO production, this ratio is higher in A group test samples. The relationship between the measured values of the M group (414 ppm) and the L group (290 ppm) showed that dolomite is more effective against burning.

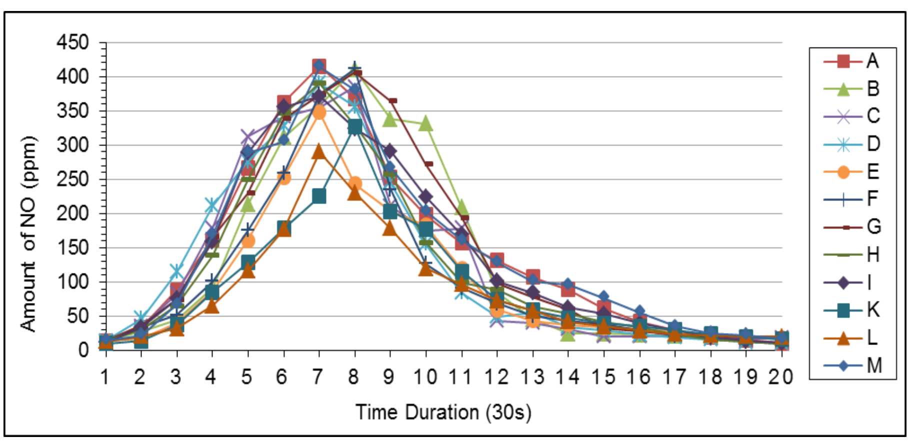

Fig. 6. Changes in the average measured values of NO in the combustion test

The improvement (decrease) of the NO emission values was determined depending on the increase in the amount of dolomite and the decrease in the amount of melamine in the mixture, compared with the measured values of the other groups. The reason for the decrease in NO emissions is that FR materials increase carbonization on the surface of the particleboard, and this carbonation behaves like insulation, preventing heat from entering the particleboard. Previous studies have focused on the effects of FR chemistry on combustion (Winandy *et al.* 2008).

CONCLUSIONS

1. The APP, dolomite, and melamine chemistries used in the surface coating mixture reduced the weight loss during certain burning tests, depending on usage rates. Ammonium polyphosphate, which has a high polymerization degree, good heat stability, and low hygroscopic properties, tended to form an expanding carbon film during combustion. Such a film isolates heat and air and delays burning.
2. The dolomite mineral was effective at preventing weight loss. The least weight loss occurred in the L group (62.7%).
3. For oxygen consumption during combustion, group A (15.8%) was the least resistant, whereas group L (20.7%) was the most resistant. Depending on the content of calcium and magnesium in the chemical structure of the dolomite mineral, the amount of oxygen required for the ignition temperature increased as the amount of dolomite was increased.
4. The surface coating positively affected CO emissions; FR minerals and chemicals improved this property. CO emissions were reduced by dolomite.
5. The coating the surface of the particleboards tended to decrease the NO emissions of the samples because it prevented heat-gas flow. For NO emission, the most positive results for NO emissions were found in L group samples without melamine, which is an important source for NO production. (290 ppm).

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