Kastamonu Uni., Orman Fakültesi Dergisi, 2017, 17 (2): 290-297 Research Article
Kastamonu Univ., Journal of Forestry Faculty
Doi: 10.17475/kastorman.310967

Investigation of the effect on combustion resistance of ammonium polyphosphate and boric acid chemicals added to surface coating

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Received Date: 08.05.2017 Accepted Date: 31.07.2017

Abstract

Aim of study: The purpose of this study were determined the effect of ammonium polyphosphate (APP) and boric acid (BA) as surface coating materials on combustion resistance of MDF panels.

Area of study: To ensure the retardation of combustion properties of wood based panels

Material and Methods: Surface coating mixture consists of calcite, glue, fire retardant (FR) and water. The amount of glue (10%), APP and BA (1%, 3% and 5%) in the mixture was determined by the oven dry weight of calcite. Combustion tests of Medium Density Fiberboard (MDF) test specimens coated with 0.25 mm thickness of this mixture were carried out according to ASTM E 69 standards. Temperature, O_2, CO and NO contents of samples were measured with Testo 340 M gas analyzer while weight loss was measured with digital scales. For each test, 20 measurements were recorded at intervals of 30 seconds.

Main results: According to the obtained results, besides calcite coating, the increase of FR addition rate increased the resistance of combustion. It was found that the weight loss of the samples treated with APP 5% was the lowest (66,7%).

Research highlights: The coating of the surfaces of wood-based boards and the addition of FR chemistry and mineral to this coating delays the burning properties

Keywords: MDF, Ammonium polyphosphate, combustion, weight loss

Yüzey kaplamasına eklenen amonyum fosfat ve borik asidin yanma direnci üzerine etkisinin araştırılması

Özet

Çalışmanın amacı: Bu çalışmanın amacı, yüzey kaplamasına eklenen amonyum polifosfat (APP) ve borik asidin (BA) yanma direnci üzerine etkisini belirlemek olacaktır.

Çalışma alanı: Ahşap esaslı levhalarda, yanmazlık özelliğinin geciktirilmesini sağlamak

Materyal ve Yöntem: Yüzey kaplama karışımı kalsit, tutkal, yanmayı geciktirici kimyasallar ve su karışımından oluşmaktadır. Karışım içindeki tutkal (%10), BA ve APP (%1, %3 ve %5) oranı, kalsitin tam kuru ağırlığına göre belirlenmiştir. Yüzeyi 0.25 mm kalınlıktaki karışım ile kaplanmış MDF test örneklerinin yanma testleri ASTM E 69 standartlarına göre yapılmıştır. Örneklerin ağırlık kaybı miktarları dijital terazi ile belirlenirken, sıcaklık, O_2, CO ve NO değerleri Testo 340 M gaz analizörü ile ölçülmüştür. Her test için 30 saniye aralıklar ile 20 ölçüm yapılmıştır.

Sonuçlar: Elde edilen sonuçlara göre; kalsit ile kaplamanın yanı sıra yanmayı geciktirici (FR) kimyasal eklenmesi yanma direncini artırmıştır. En düşük ağırlık kaybı APP %5 ile muamele edilmiş örneklerde bulunmuştur.

Araştırma vurguları: Ahşap esaslı levhaların yüzeylerinin kaplanması ve bu kaplama içerisine FR kimyasalı ve mineral eklenmesi yanma özelliklerini geciktirmektedir

Anahtar kelimeler: MDF, amonyum fosfat, yanma, ağırlık kaybı

Introduction

Medium density fiberboard (MDF) and particleboard have a wide range of uses. Among the most used sectors are furniture, construction, transport and home decoration sectors. It has many usage advantages. Because its thickness, density is adjustable as well as physical and mechanical properties are good and cost is low. MDF boards are also damaged when exposed to physical, mechanical, combustion, biologic hazards such as solid wood (Roger, 2005). One of the important factors that adversely affect the usage area of MDF is its easy flammability

feature. Therefore, its combustion resistance must be improved. It is necessary to use flame retardants for this purpose.

The most important FR chemicals used against combustion are ammonium and boron compounds. Inorganic salts such as ammonium compounds and boron compounds such as borax, boric acid and zinc borate are the most important FR chemicals used to protect wood and plastic from combustion (Altuntaş et. al, 2016). The usage of inorganic salts has some disadvantages such as causing corrosion due to its hygroscopic property. It can also cause swelling on the surface of the wood, which can adversely affect painting and appearance (Hashim, 1994).

There are many methods for using FR. The addition of FR chemicals between the fibers to the fibers before the MDF boards are produced reduces the mechanical properties due to the absence of bonding of the FR chemistries. Treatment of FR chemicals with fibers as a solution will increase the effect of combustion resistance. The surface coating method is also one of the methods used to prevent combustion (Sparks, 1993). Surface coating serves as a barrier to heat to enter the combustible material and to prevent the environment from reaching the combustion temperature. The effect of fire retardants on MDF boards has been investigated in a number of studies (Akbulut et al. 2004; Ayrılmış, 2007; Ustaömer, 2008). FR chemistry has significantly improved fire resistance of wood and wood based boards. In this study, the effect of the APP and BA chemicals used in surface coating on the combustion resistance of MDF was investigated.

Material and Method

Chemical substances and ratios used in surface coating are shown in Table 1. Ammonuim polyphosphate (APP), boric acid (BA), and melamine formaldehyde (MF) amount were determined according to oven-dry weight of calcite. MDF sheets with a density of 680 g cm^{-3} were obtained from Kastamonu Integrated wood Company, in Adana, Turkey. Boric acid and APP were obtained from Tekkim Company, İzmir, Turkey.

The surface coating material consisting of calcite, water, boric acid, and app was mixed with a blender until homogeneous. During the mixture, the pH value and viscosity of coating materials were set between 8-10 and 100-150 cP, respectively. The mixture was applied to the surfaces of the MDF boards with the help of a roll at a rate of 140 g m^{-2}. The surface coating thickness for each sample was set to 0.25 mm.

Table 1. The ratios of chemicals used in surface coating.

Materials	**Ratio (%)**		
Calcite	100		
MF	20		
Boric acid	1	3	5
APP	1	3	5

Combustion Test

Combustion tests were made by adhering to ASTM E 69 standard tests. The combustion test was carried out for the first four minutes with a flame source for the next 6 minutes without a flame source for a total of 10 minutes. The measurements were recorded every 30 seconds. Test specimens consist of control, calcite-coated and calcite-FR containing specimens. The specimens measured at dimensions of 1016x19x9.5 mm before combustion was air-conditioned at 23±2 ºC degrees and 65±%5 relative humidity for 2 weeks (Sweet et al. 1996). Combustion test apparatus and Testo 340 M gas analyzer are shown in Fig. 1. The measurement of temperature, O^2, CO and NO gas output was performed every 30 seconds with the help of the testo 340 M gas monitor while the weight loss of the test samples during combustion was recorded with a digital scale. For each test sample, the experiment was repeated 6 times.

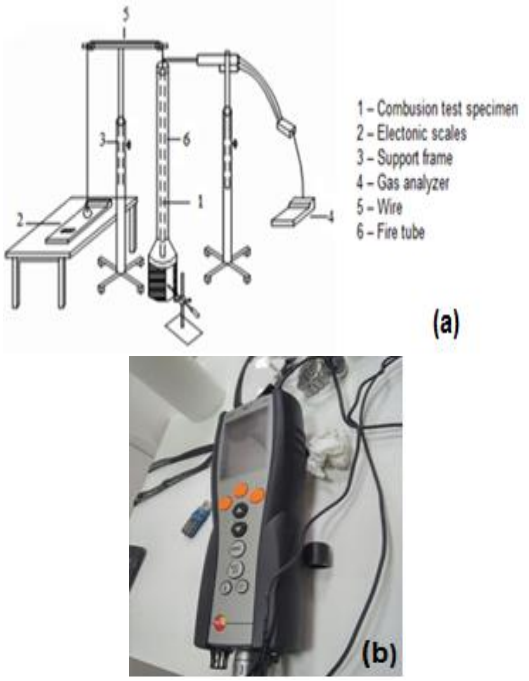

Figure 1. Combustion test instrument (a) and gas measurement analyzer (b)

Results and Discussion

Weight Loss

Control, calcite-coated and calcite-FR coated samples, the measured weight loss values during combustion are given in Fig 2. At the end of the test, the weight loss values were 92% and 85% for the control sample and calcite-coated samples, respectively. The weight loss values of the samples coated with boric acid and APP were found to be lower (66.7-75.2%). According to the control example, the reduction in weight loss in calcite and FR-calcite coated specimens demonstrates that the combustion properties of the MDF boards improve. Calcite surface coating and FR chemicals had a positive effect on combustion resistance of MDF panels. When the ratio of APP and BA were increased, weight loss of MDF panels was decreased. Weight loss values were 75.2%, 70.3% and 67.7% for BA 1%, 3% and 5% respectively, and 71%, 68% and 66.7% for APP respectively. Although the BA (%67.7) and APP (66.7%) are close to each other, the most effective chemical and ratio on weight loss was APP 5%. The BA is known to have the feature of reducing flame and increasing carbonization. However, APP is more effective than BA on combustion resistance (Tomak et al. 2012). The FR absorbs heat during combustion, causing a decrease in the combustion temperature and increases the amount of residue. Similar results were found in previous studies on MDF for determining combustion characteristics (Özdemir and Tutuş, 2013, İstek et al.2013, Özcifçi and Okçu, 2008). There was a significant increase in the combustion resistance properties of MDF boards (Hashim et al. 2009). The results show that surface coating and FRs prevent oxygen from entering the combustion process during combustion and are barrier effect (Wan Hanafi and Hornsby, 1993). Boron compounds and other FRs are widely used in wood and wood based materials (Temiz et al. 2008).

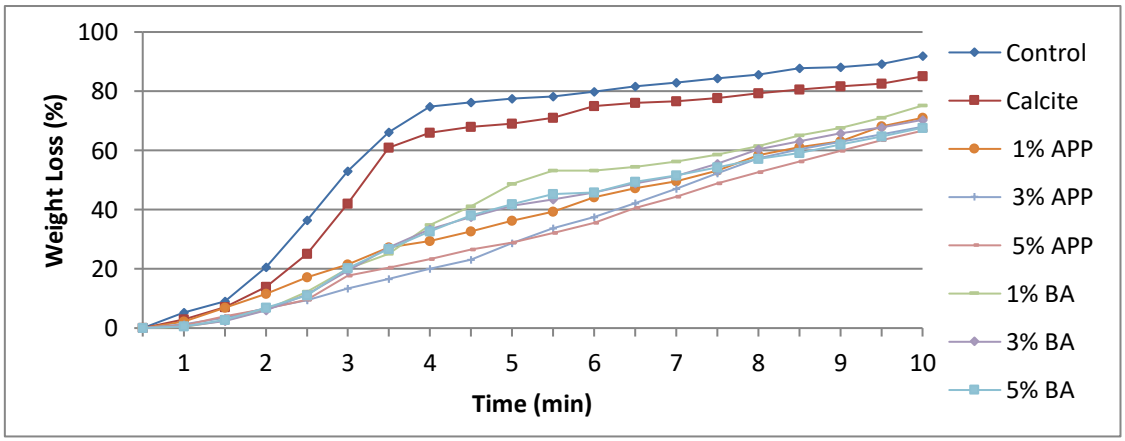

Figure 2. Weight Loss Values

Temperature Change

Temperature changes exhibited by the test specimens during the combustion are shown in Fig 3. In the flame source, the highest temperature value (354 ° C) was found in the control sample.

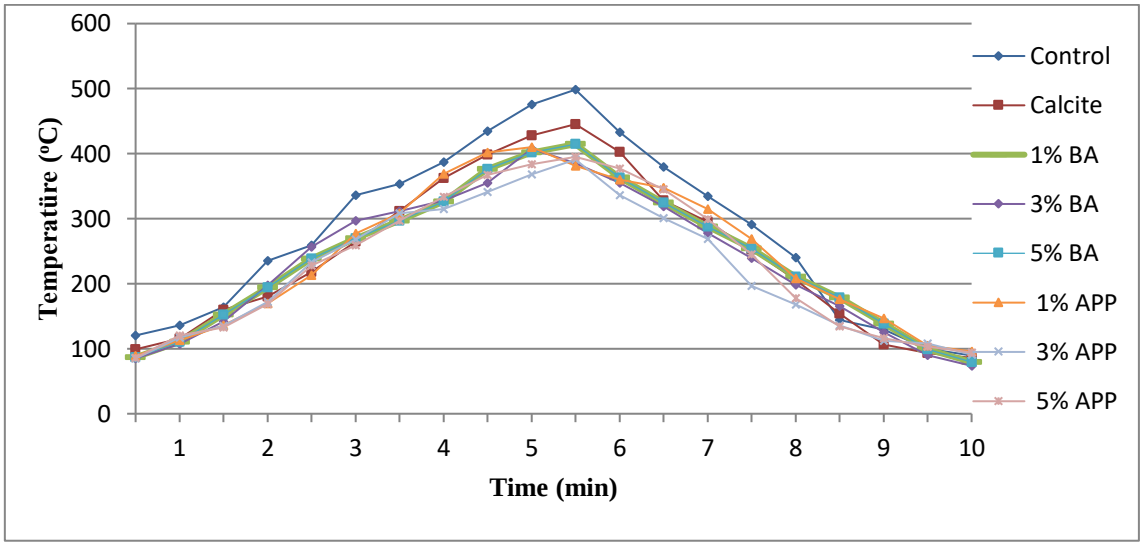

Figure 3. Temperature change value

In calcite-coated samples, the temperature was found to be 311. The calcite coating affected the combustion temperature 12.1% positively. In the test samples added with BA and APP, the temperature values were found to be close to each other. The changes in combustion temperatures were 296, 287 and 278 ^{0}C for BA 1%, 3% and 5%, respectively, and 308, 297 and 280 ^{0}C for APP, respectively. As the rate of use of FR increased, the amount of temperature decreased. Baysal (2003) found similar results in a study. The lowest temperature value was obtained in 5% of BA samples whereas the highest temperature value was found in APP 1% samples. Since FRs increase carbonization during combustion, they have a negative effect on heat transfer and therefore thermal insulation increases and the temperature value is reduced (Kolmann and Cote, 1968). The improvement of thermal insulation also reduces the emission of flammable gases (Özdemir and Tutuş, 2013). reduced. The amount of oxygen in the atmosphere is normally 21% but varies depending on the type and addition rate of FRs during combustion (Yapıcı et al. 2011). The amount of oxygen must be high for the combustion of wood or wood-based boards (Asley and Rothon, 1991). Due to the surface coating of MDF boards and the addition of FRs, the oxygen required for combustion is reduced and the combustion rate is lower. But, if there is a flame, the flame increases the combustion temperature and the required oxygen is obtained from the thermally generated heat.

Amount of Oxygen (%)

The changes in the amount of oxygen in the test samples are shown in Figure 4. In flame sources combustion, O_2 amount control sample and calcite coated samples were found to be 16.1 and 17.6, respectively. At addition rates of 1%, 3% and 5%, the amount of oxygen was found to be 20.0%, 20.4% and 20.2% and 16.0%, 18.2% and 15.8% for BA and APP respectively. As the rate of addition and addition of FRs increases, it has been determined that the combustion and flame characteristics together with the combustion rate are

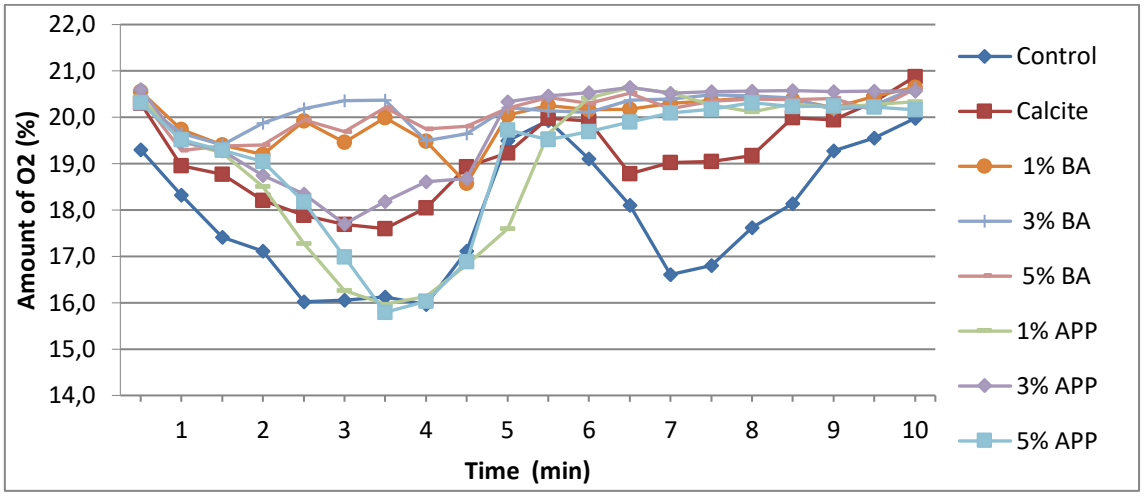

Figure 4. Oxygen value

CO emissions

In flame sources combustion, the highest CO emission in all samples was found in the control sample (934 ppm) and in the calcite-coated sample (675 ppm). The CO emission values of the test samples are given in Figure 5. It has been observed that the coating with calcite of the MDF surface affects the CO emission positively. This effect has improved with the addition of FR. The CO emission measurements for BA 1%, 3% and 5% were 615, 566 and 501 ppm, respectively, while for APP 1%, 3% and 5% 363,329 and 285ppm, respectively. The CO emissions of BA and APP were lower than the control sample. The reason for this is that the FRS has reduced the combustion effect by the delayed combustion effect. FR addition reduces CO emission value. With the beginning of decompression of materials, combustion gas products begin to be released. The amount of gas products is affected by combustion temperature, the amount of oxygen and chemical compositions (Mouritz et al. 2006).

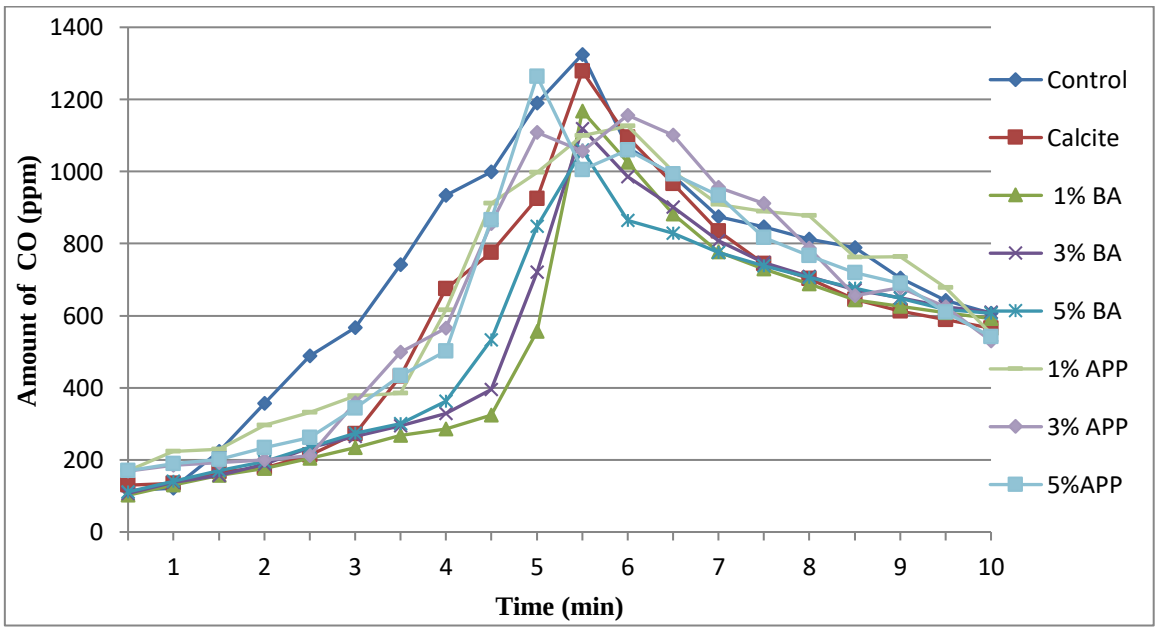

Figure 5. CO emissions values

Although the CO values increased initially with flame sources combustion, the combustion rate and smoke release gradually decreased with the FR effect. When compared to the control samples, FR-added specimens were found to be more prone to lower temperature and smoke release. The amount of CO is very important for both environmental and human health and safety. So the use of potential smoke hazards in living areas should be considered.

NO emissions

As it is shown in Fig. 6, The NO emission amount increased rapidly in all samples during flame-sources combustion, but began to decrease during without flame-sources combustion. NO emissions were found in the highest control samples (467 ppm) and calcite-coated samples (444 ppm).

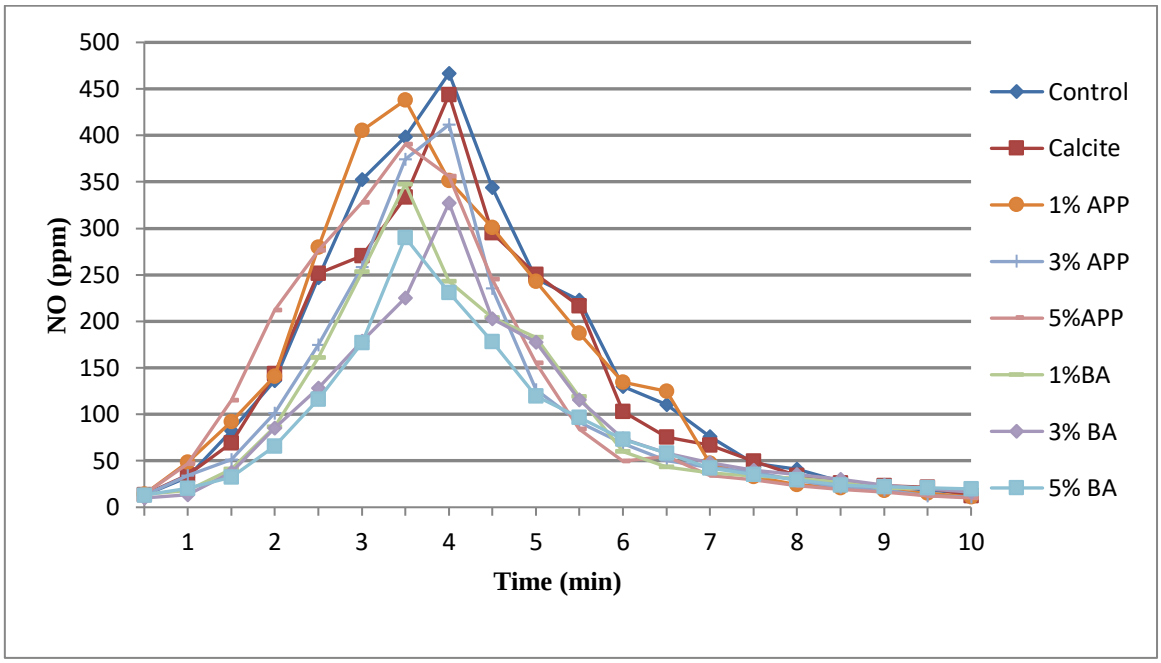

Figure 6. NO emissions values

The 1%, 3% and 5% NO emissions for BA were 243, 327 and 331 ppm. APP NO emission values were slightly higher than BA. APP 1%, 3% and 5% NO emissions were found to be 351,412, and 356, respectively. Coating of MDF sheets with calcite and the use of FR positively affected the reduction of NO emissions. The mixture applied to the MDF surface prevented the release of volatile gases and increased carbonization. The samples treated with FR had lower smoke and heat release (Winandy et al. 2008).

Conclusion

The amount of weight loss was positively affected by the addition of FR and the calcite coating process of MDF board surfaces. Because the surface is covered with calcite, it has retarded the combustion and provided thermal stability. With the increase in FR addition rate, this feature has improved further. The most weight loss amount was in uncoated specimens, while the least weight loss was at APP 5% (66.7%).

The most effective FR on the reduction of temperature is the rate of 5% of BA (278 OC) within the FR chemical ratios. The amount of oxygen during flame source combustion increased with the use of FR. The reason for the reduction of CO emissions in the FR treated samples compared to the control sample is that the chemical decomposition is less. NO emission was found high in uncoated test samples and tended to decrease with increasing FR addition rate.

Acknowledgement

This study was supported by the project of 2015 / 2-9YLS by Kahramanmaras Sütcü Imam University, Scientific Research Projects Coordination Unit.

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