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Performance of different fire retardant products applied on Norway spruce tested in a Cone calorimeter

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Abstract. On the European market there are several fire retardant products available, which reach class B in the European classification system. The producers promise their fire retardants are effective in reducing different reaction to fire parameters of wood such as the time to ignition, the mass loss rate, the heat release rate, the total heat release, the charring rate and the flame spread. This paper discusses the performance of fire retardant products as pressure impregnated wood, non-intumescence surface coatings and intumescence coatings on Norway spruce (Picea abies). The investigations are performed by using a cone calorimeter test according to ISO 5660. The thermal exposures of the investigations are 50 kW/m^2 and the standard IS0 834 test curve. As result information about the heat release rate, the mass loss rate and the total heat release for duration of 900 seconds will be presented in this paper.

INTRODUCTION

Due to its versatile practicability as building material wood is been used in construction both structurally and as a decorative material. The advantages for using wood as building material are the minimal environmental pollution and a range of excellent technical properties. The disadvantage for using wood is its natural combustibility if exposed to severe fire conditions.

However, wood products can be used safely by improving their fire performance which includes chemical, biochemical and physical modification. At present, the level of knowledge of wood products with improved fire performance is not high enough for their extensive utilization. The main problems are not clear defined technical requirements in building standards and not existing investigation regarding the long term behaviour under different environmental conditions [1]. Even though some wood products with improved fire performance exhibit excellent fire properties and reach class B in the European standard EN 13501-1 [3]. Another problem is the selection of an unsuitable product for a certain application [2].

This paper describes the performance of fire retardant products as pressure impregnated wood, non-intumescent surface coatings and intumescent coatings by using the cone calorimeter test according to ISO 5660 [4]. The tested fire retardant products are transparent or colorless to preserve the natural character of wood for applications such as claddings, ceilings and structures.

MATERIALS

Five test series were investigated. Two intumescent coatings, a fire retardant surface coating, a pressure impregnated treatment and the reference test series. The applied quantities of fire retardant treatment can be seen in Table 1.

Table 1. Fire retardant treated Norway spruce – test series.

Test series	Replications	Fire retardant product	colour	applied quantity [g/m^2]	Sample thickness [mm]
A1	3	intumescent coating	transparent	350	30
A2	3	intumescent coating	transparent	350	30
C1	3	fire retardant solution	transparent	300	30
C2	3	fire retardant treatment	transparent	91, 2 kg/m^3	20
REF	3	Natural Wood - reference	-	-	30

For each test series three replications were performed. Each test series were cut out of the same three boards of deflect free Norway spruce. The underlying wood was selected in that way to have twin samples and the influence on the natural wood properties is minimized (see Fig. 2).

After the coating resp. the impregnation the samples were conditioned at laboratory conditions at 65% RH and 20°C for at least four weeks prior to testing to meet equilibrium moisture content (EMC).

The test dimension of the Norway spruce sample is 100 × 100 mm with a thickness of 30 mm for series A1, A2, C1 and REF. Series C1 is tested with a thickness of 20 mm (see Table 1).

METHODS

Test Facility: To obtain a closed system, a mass loss cone is placed in a conditioning cabinet. Two pipes are fixed on the conditioning cabinet – one pipe for the input air on the bottom and one pipe for the exhaust gas on the top of the conditioning cabinet. In each pipe the gas flow velocity and the gas temperature is measured. In the exhaust pipe, on the top of the conditioning cabinet, the exhaust gas components are measured with a flue analyser. The measured values of the flue analyser are the content of oxygen, carbon monoxide, carbon dioxide and carbon hydrates. Furthermore, the mass of the sample and temperatures in different layers of the sample is measured. All the measured values are continuous recorded each second. With this arrangement it is possible to perform investigations according to ISO 5660 [4].

Fire tests: Before testing the specimen were wrapped into aluminium foil to approximate real scale moisture transport behaviour. Then the specimen is placed in a sample holder, which is positioned on a balance. The top of the specimen is located 25 mm under the bottom of the conical heater. The area of the sample, exposed to the radiation, is 0.009 m^2. A split shutter mechanism protects the area of the sample before the test. The shutter is manually opened with a mechanical lever. The start of the test, t = 0 is defined by the moment the shutter is opened exposing the specimen to the radiant heat flux.

The tests were made with two different radiant heat fluxes. A continuous flux of 50 kW/m^2 20 minutes test duration and a stepwise increased flux approximating the standard temperature time curve (according to ISO 834 [5] see Fig. 1) for 30 minutes test duration. The Standard ISO 834 curve increases the heat flux from low levels (< 25 kW/m^2) at test start to high levels (< 35 kW/m^2) after about 9 minutes, which describes a natural fire.

The test results, presented in this paper, are the mass loss rate (MLR), the heat release rate (HRR), the total heat released (THR) and the burning rate for test duration of 900 seconds.

RESULTS AND DISCUSSION

First the mass loss rate (MLR) and the total mass loss (TML) is presented and discussed. The TML_{900} is the integral over the MLR from t = 0 to t = 900 s. The mass loss rate at $t_0 = 0$ is not fully correctly given in Fig. 3 and Fig. 4 due to the calculation method used.

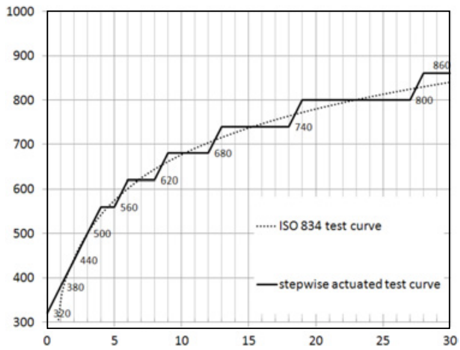

Figure 1. Regulation steps for the standard IS0 834 test curve.

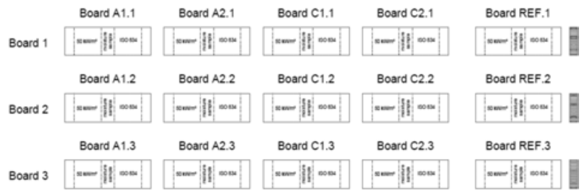

Figure 2. Schematic representation of the sample preparation procedure.

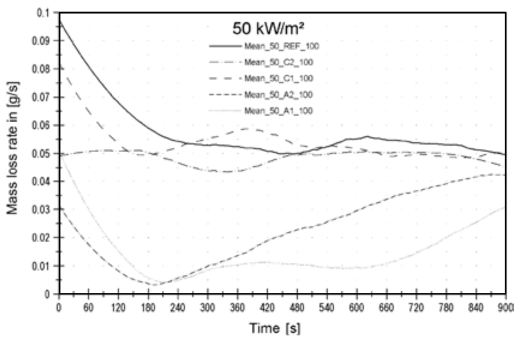

Figure 3. MLR curves with a irradiance of 50 kW/m^2 for different fire retardant products compared to the untreated reference.

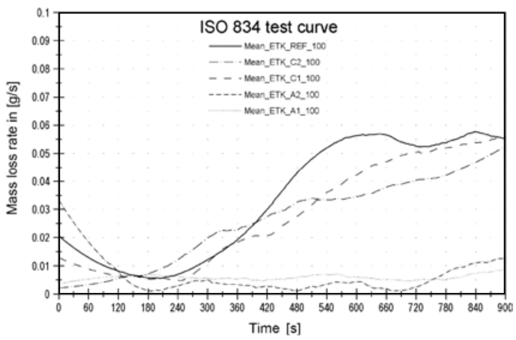

Figure 4. MLR curves with the standard ISO 834 curve for different fire retardant products compared to the untreated reference.

Second the heat release rate (HRR) and the total heat released (THR) is presented and discussed. The THR_{900} is the integral over the HRR from t = 0 to t = 900 s.

Exposure 50 kW/m^2 **:** The results of the MLR, illustrated in Fig. 3, exhibit large differences between the fire retardant products. In the first three minutes, the MLR decreases due to water loss from the exposed surface. Only the pressure impregnated series C2 show a nearly continuous MLR for the test duration of 900 seconds. After water loss also the series C2 and REF show a nearly continuous MLR up to the end of test. The two intumescent series A1 und A2 show lower MLR compared to the other series. After water loss the MLR is nearly to zero, before it rises up to the MLR values of the other series.

The total mass loss (TML) gives an overview about the performance of the fire retardant product. Figure 5 show that only the intumescent products reduce the mass loss significantly.

The results of the HRR, illustrated in Fig. 7, exhibits large differences between the fire retardant products. The two intumescent products are effective in reducing the HRR. The pressure impregnated series C2 also reduces the HRR significant. The series C1 show similar HRR-curve to REF series on a lower level. The steep rise of HRR at test begin can be recognized as ignition of series C1 and REF.

The total heat release (THR) gives information about the combustion behaviour. Figure 8 show the effectiveness of the intumescent products. Also the pressure impregnated series C2 reduces energy release significant.

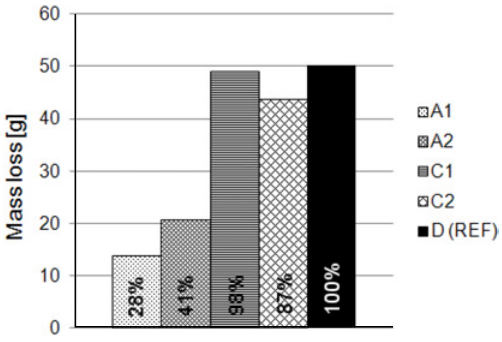

Figure 5. TML_{900} with a irradiance of 50 kW/m^2 for different fire retardant products compared to the untreated reference.

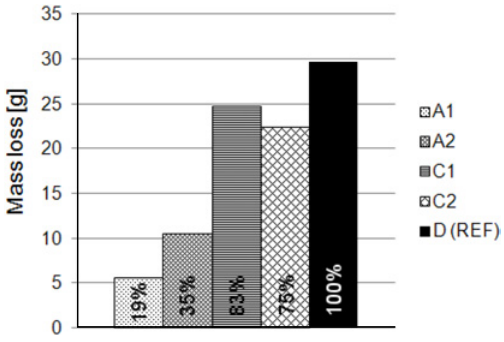

Figure 6. TML_{900} with the standard ISO 834 curve for different fire retardant products compared to the untreated reference.

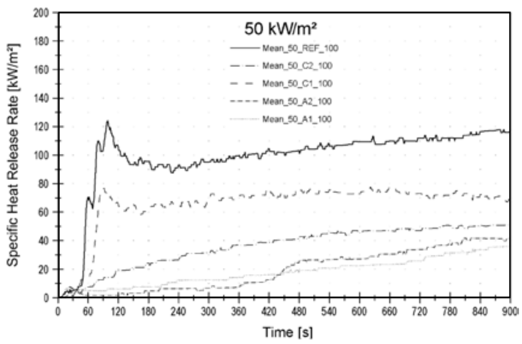

Figure 7. HRR curves with a irradiance of 50 kW/m^2 for different fire retardant products compared to the untreated reference.

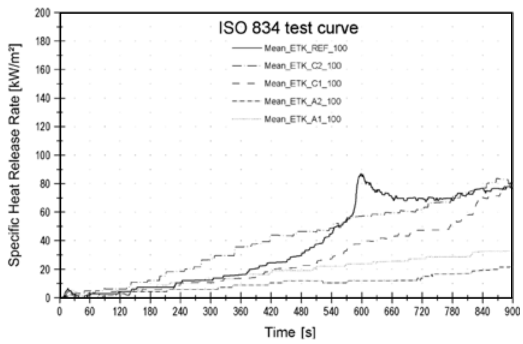

Figure 8. HRR curves with the irradiance of the standard ISO curve for different fire retardant products compared to the untreated reference.

Exposure ISO 834 test curve: If the sample is exposed with the ISO 834 test curve, the differences in MLR between the REF series and the series C1 and C2 are minor (see Fig. 4). The two intumescent series A1 und A2 show significant lower MLR near to zero after water loss.

Figure 6 show that only the intumescent products reduce the mass loss significantly. Also the test series C1 and C2 indicate higher fire performance, exposed with the ISO 834 test curve.

If the heat in the sample rises slower, caused by the ISO 834 exposure, also the differences in HRR between the REF series and the series C1 and C2 are minor. Series C1 show a higher HRR at the beginning than REF series. The ignition of REF series can be recognized in a short steep rise before results in a peak of HRR. The two intumescent products are effective in reducing the HRR. The lower heat flux at test start gives the intumescent products enough time to expand effective isolating foam.

With lower heat fluxes at test start, the series C1 and C2 are in the same range of THR like series REF, see Fig. 10.

SUMMARY

There are large differences in reaction to fire performance of the tested products. The intumescent coatings on wood reduce significant the MLR and the HRR. The reduction in mass loss (TML) is up to 70%, the reduction in energy release (THR) is about 80%, with a test exposure of 50 kW/m^2. Using the ISO 834 curve as the thermal test exposure the TML reduces up to 80%. The results with test exposure

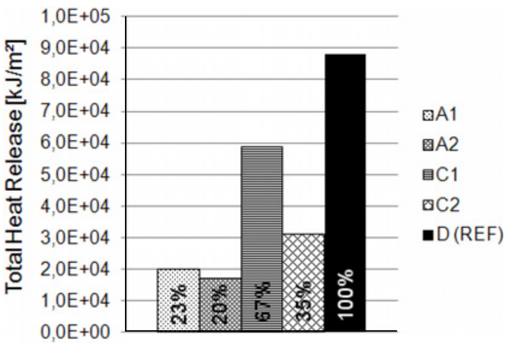

Figure 9. THR_{900} with a irradiance of 50 kW/m² for different fire retardant products compared to the untreated reference.

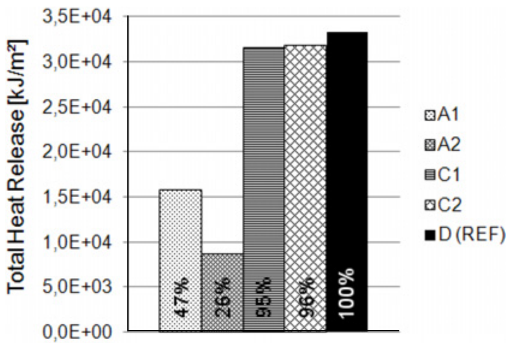

Figure 10. THR_{900} curves with the irradiance of the standard ISO curve for different fire retardant products compared to the untreated reference.

of ISO 834 indicate that the THR can be reduced up to 70% using an intumescent coating under natural fire conditions. The non-intumescent coating and the pressure impregnated treatment show quite similar results within the cone calorimeter test as the untreated reference sample. In this case the question arises if those two products are able to increase fire performance and therefore useful for the protection of structural elements.

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