Coniferous Wood – Reaction on Fire in Forest Condition

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Introduction

Forest fires have always been part of people's lives and have also always impacted on our environment. They are still common today, but their "quality“ and quantity has changed for the worse. They are larger, more difficult to suppresshit and more destructive, especially in our mountainous terrain. Suppression of forest fires requires special fire equipment and, very often, aviation technology. Changes have taken place in the intensity of intervention, duration of intervention and the economic costs of intervention. Tackling this problem must be addressed comprehensively (as in any multidisciplinary field of fire protection). This means addressing this problem is not reliant only on new technology, but also on tactics, the study of fuel and other scientific research.

This paper contributes to the development of improved intervention techniques by characterising the nature of the fuel. Assessment of individual trees (also reported in the literature) was performed even before it was recognised there was a need to evaluate the fire performance of wood when used as a building material. Even in the context of forests there is a broad distribution of plants beyond simply hardwood or softwood. The first hypothesis of our planned experiment anticipated finding some homogeneity among the selected coniferous trees, or between different positions on the tree (branch, root, stem) within a single plant.

However, it became evident that a second hypothesis had to be considered since it was found that there are differences among the surveyed plants and differences within a single plant. This hypothesis arose naturally not only in opposition to the first hypothesis, but also from the experience of certain fire-fighters, or even scouts. Fire-fighters have a problem extinguishing underground fires (a burning root system) and scouts have the experience that if you want a good embers to start a bonfire attach the wood of the root system. The complexity of solutions required considering wood from all three positions, which are related to the physiology of the tree: branch, trunk and root. The amount of fuel individually in thebranches, trunks and roots can be determined with some precision by relying on forest management plans based on stand density, tree age, site additions and the like. However, there is a lack of data on how the individual components of wood react to heat and fire, and how quickly they contribute to the development of fire. The objective of this research was to supplement these limited data.

The results confirm the second hypothesis: That differences exist even within the conifers pine, fir, spruce and larch, but also among the locations (branches, trunk and roots) of a single plant. Surprisingly, the worst results were seen in the most common of our trees; namelyspruce. All endpoints achieved the highest value for this species. Mass loss was chosen as a representative measure because the change of this physical property belongs to the classic and fundamental benchmarks of materials that are tested for fire protection needs. The char layer that is formed during combustion of timber, is welcome in wooden structures. However in forest fires the burning or smouldering of the root system often dictates the duration of burning. Furthermore, this effect is often the cause of a forest fire rekindling and hence is very dangerous.

Coniferous wood after thermal decomposition

Changes in Chemical Composition

There are solid materials that directly enter into reaction with oxygen (e.g. metals). There are other materials which change their chemical composition in the first phase of heating-up, or which change the composition of their basic structural elements, thereby producing inflammable gases and ignite. Wood is an example of the latter material. The main wood components degrade at different temperatures affecting the whole burning process (Karlsson - Quintier 2000).

Hemicelluloses decompose in the temperature range 170 – 240 °C. They are less resistant than other wood components to thermal decomposition. Controlled heating of wood can cause reduction in hemicellusoses with no decrease in solidity, which results in higher dimension stability of the wood (Bučko and coll. team 1988)

Cellulose is more resistant to heat exposure than hemicelluloses. The decomposition of cellulose is moderate up to 250 °C. In the range 250 – 350 °C there is intensive decomposition of cellulose. Bonds in the basic chain are disrupted according to a free radical chain mechanism and the final element of cellulose is changed into laevoglucose (Bučko and coll. team 1988).

Lignin is the most resistant to thermal decomposition. Currently the thermal decomposition of lignin has been described as a two-step process. Etheric alkyl bonds, which are not that solid, decompose in the first step at temperatures 300 - 320 °C. The second step is active decomposition of lignin at 350 – 390 °C. The structure of macromolecules is corroded and volatile products are released. The rapidity of volatile product generation is lower compared to cellulose. As the temperature rises, the speed of decomposition slows down and in the second step condensing aromatic structures are cumulated (Bučko – Osvald 1998).

Wood exposed to temperatures higher than 288 °C (in general the temperature when carbonisation process starts) can be categorized in five degradation zones (according to Schaffer 1977). The heterogeneity of the main wood components' decomposition and heterogeneity of the characteristic reactions (according to Horský - Osvald 1983) in the individual thermal intervals causes differentiation of the burning process into several phases.

Changes in anatomical structure

The anatomical structure, or the individual cellular elements affect the burning process particularly during the first phase, ignition. It is defined mainly by chemical compositon and gemometric shape cellular elements, their dimensions and their number. (Chovanec – Osvald 1992).

Coniferous Trees during Forest Fires

A forest fire damages all components of a forest biocoenosis:the biotope, the plants and animals. It is a sudden, partially or fully uncontrolled event, limited from time and space points of view, with an adverse effect on all social functions of the forest. It causes direct and indirect damage in the forest ecosystem and can be categorized as an anthropogenic (the majority in our region) or as a natural damaging factor. It is a set of physical and chemical phenomena, based on dynamic (changing in space and time) processes of burning, heat transfer and gaseous exchanges (Krakovský 2002).

It can be stated in general, that the cause of forest fires are mainly natural conditions and human beings. Usually it is caused by negligence, not respecting fire prevention measures or underestimating the fire hazard when manipulating with open fire - open fire ban, smoking, burning grass, burning brushwood, kids playing with fire, matches, etc. Intentional fires are less frequent.

These fires are dangerous because they often occur in areas not accessible to fire fighting equipment, with insufficient water sources or water sources that are not suitable for fire extinguishing. They require an enormous number of people to suppress, special fire fighting strategies and sometimes aviation technical equipment (Hlaváč 2005).

Forest fires are Class A fires; that is, fires involving solid substances of organic origin. Burning during a forest fire can be described as a burning of a whole set of organic materials composing the forest stand. All water from the wood tissue evaporates at temperature 80 – 150°C. If the wood is exposed to a flame with temperature 250°C, inflammable gases are produced and spontaneous ignition of wood starts at temperature 300°C. At the temperature exceeding 450°C, gases released from the wood ignite immediately when in contact with external air. When temperature exceeds 600°C the wood itself becomes the source of burning. Temperature of the burning wood is 700 – 800°C. When a coniferous tree top burns, the temperature reaches 1 000°C and flames can reach up to 100 meters. In a burning coniferous forest, the temperature of the flame reaches up to 1 300°C (Osvald 2005).

Forest fires can be categorized based on different criteria. In forestry (but also in fire fighting) they are mainly categorized as:

- Underground fires;
- Ground fires
- Tree-top fires;

The above mentioned forms of fire have been described in detail. Fire in an area affected by wind calamity is specific and therefore cannot be categorized based on the categorization above. Therefore a new category has been established "fire of forest calamity". This type of fire can be characterized as follows:

- the area of the potential seat of the fire is not differentiated based on height, as is typical for the categorization given above, but it is based on breaks, windbreaks, standing trees, remains of trees (dead wood), plant cover and forest floor;
- differentiation of wood mass is not homogenous, wood is accumulated in layers of several meters, including parts of tree tops with assimilated apparatus and ground levels;
- after the calamity when wood is processed, large volumes of timber harvesting waste remains and it represents a high-risk potential of fire ignition and spread of fire;
- after ignition of the trunks fire can be spread in the whole area, from the time point of view (even several days), in the whole area surrounding the seat of the wood, not only in the front (principle of bonfire);
- the area of calamity is hard to access compared the other types of fire. The reason is temporary shutdown of the forest transportation network and accumulated calamity wood mass.

It is very important to know all aspects and risks of forest fires: their course and behaviour, prevention systems, monitoring, modern, ecological effects, saving and safe ways for applying suppressants, but also consequences and methods for their elimination and extinguishment.

Objective

Experimental fires have been designed to representforest fires. This entailed a careful selection of the tree parts (branch, tree trunk, root), which represent the forms of fuel in the cases of a tree-top fire, a fire above ground, a fire underground and also a fire of forest calamity.

The thermal load was represented by just one source. One thermal, radiating source of heat was designed for this purpose so that the results were comparable and the selected evaluation criteria were only affected by fuel.

Distances: – The fuel (test specimen) distance from the heat source was selected so that the temperatures of the source can be demonstrated as well as the sensitivity of the measurement. Therefore the distance between them was incremented in steps of 5 mm to represent a variety of exposures.

Evaluation criteria: The basic changes in physical parameters (decrease in mass, increase in the thickness of the char layer, relative speed of burning and ratio (a)/(b) representing relative speed of burning divided by time of the highest relative speed of burning).

The defined criteria, qualitative selection of the fuel and evaluation criteria will define the sensitivity of coniferous wood to conditions stimulating forest fires.

Methodology

Material and Specimens for the Experiment

Specimens were selected out of four types of coniferous wood: Scotch Pine - *Pinus sylvestris* L., white fir - *Abies alba* Mill., Norway sprure - *Picea abies* (L.) Karst, European Larch – *Larix decidua* Mill., The specimens for the experiment were prepared of 1 m long trunks of wood (pine, fir, spruce, larch). After treatment of the trunk; that is, removing bark and cutting planks, the specimens were dried until the constant moisture content of 8 ± 2 % was reached. Then the planks were cut into required dimensions of 10 x 12 x 150 mm. The surface of the specimens with these dimensions was not treated. The specimens from branches and roots were cut the same way as from the trunk. Branches and roots diameters were 60 mm.

Thermal Load

Equipment

In the experiments simple equipment was used consisting of scales, asbestos boards to protect the scales from thermal radiation, a stand, a bearing frame, a radiating heat source, radiator and a holder of the specimens. The equipment is composed of electronic scales Sartorious Basic plus type BDBC from Sartorius AG Company, precision class I with non-automatic action. The precision is up to two decimal points with a maximum measured mass for this type of scale of 2 100 g.

Source of Radiant Heat

An infrared radiator was used as a source of radiant heat. The transfer of heat from radiators was based on the principle of spreading electromagnetic radiation with wave lengths 0.75 – 12 J.m, which changed into heat after being absorbed by a solid matter. During the experiment an infrared radiator type T – 5 from Elektro Prag Company was used. The radiator had a shape of a plane bent a bit in the direction of lengthwise axis of the body. The radiation was spread from the front wall, back wall and front edges. We decided to ignore the side edges of the radiator, due to their insignificance for the transfer of heat. The radiator body was manufactured from special ceramic substance, cordierite. This material is very resistant to sudden changes of temperature when the temperature difference is greater than 70 °C and it is also very resistant to high temperatures (1,100 °C).

The body of the radiator was equipped with thin aluminium parable. Electromagnetic radiation is the most common one in the nature, because each body is a source. Distribution of energy based on wavelength or based on frequency depends on the body temperature. Colour is changed together with the temperature.
Diameters and parameters of the radiator (Zat'ko1993):

Total length	l = 245 mm
Working length	l_p = 200 mm
External width	$_{w1}$ = 85 mm
Internal width	$_{W2}$ = 64 mm
Thickness	t = 5 mm
Height	h = 30 mm

Temperature (30 mm from the radiator) t = 130 °C

Test Procedure

The test procedure was as follows: The radiator was heated-up for 15 minutes. After the 15 minutes the specimen was inserted into the stand and was exposed to the radiant heat for 3 minutes. Fifteen specimens were tested from each type of wood. The time was invariable – 3 minutes. Only the distance of the body from the radiator was changed as follows: 30, 35, 40, 45, and 50 mm. We recorded after 15 seconds a mass decrease in case of each specimen and calculated the relative speed of heating. If the specimen started burning we extinguished it after 3 minutes. Each specimen was measured before the experiment, including its thickness. After cooling the specimen, the char layer was identified. The char layer was removed down to the preserved healthy wood and it was measured again.

Monitoring Changes of Specific Properties Characterizing the Best Relation to Fire

Loss of Mass

The loss of mass of a specimen exposed to radiant heating was measured. The relative loss of mass was calculated using the formula

$$\delta_m(\tau) = \frac{\Delta m}{m_{(\tau)}}.100 = \frac{m_{(\tau)} - m_{(\tau+\Delta\tau)}}{m_{(\tau)}}.100 \ [\%]$$

Where:

□*m*(□) – relative loss of mass in time (□)[%]
m(□) – masst of sample at time (□)[g]
m(□□□□) – mass of sample at time (□□□□□□)[g]
□*m* - difference in mass [g]

Char layer

The char layer was defined, or more precisely the thickness of the char layer was determined as a ratio of the original thickness of the specimen the intact thickness of the testing body after the heat exposure. It was determined in percentage using the following formula:

$$\Delta h = 100 - \left(\frac{h_1 - h_2}{h_1}.100 \right) \ [\%]$$

Where:

□*h* - thickness of the char layer of the wood after the heat exposure [%]
h_1 - thickness of the specimen before the heat exposure [mm]
h_2 - thickness of the specimen after the heat exposure [mm]

Relative Rapidity of Heating

The relative rapidity of heating was defined based on the formula:

$$v_r = \left| \frac{\partial \delta_m}{\partial \tau} \right| \ [\%.s^{-1}]$$

or numerically

$$v_r = \frac{\left| \delta_{m(\tau)} - \delta_{m(\tau+\Delta\tau)} \right|}{\Delta \tau} \ [\%.s^{-1}]$$

Where:

v_r - relative rapidity of heating [$\%.s^{-1}$]
□*m*(□) – relative loss of mass in time (□)[%]
□*m*(□□□□) – relative loss of mass in time (□□□□) [%]
□□ - time interval when the mass is subtracted [s]

Ratio of (a)/(b)

The relative rapidity of heating is important information; however it is also important to say at what time during the experiment the highest value of relative rapidity of heating was measured. If this value was measured in the initial phase, this material could contribute significantly to fire spread. If it is in the final phase of the experiment this material has more positive assessment. The ratio of relative speed of heating and time to reach the maximum value has been used in several experiments in testing methods for fire protection needs. The equipment employed in these experiments enabled measurement of both types of data, therefore the ratio of relative rapidity of heating (a) and time of heating to the maximum value (b), that is (a)/(b) could be computed. The ratio was then multiplied by 10^6 to get a more useful value.

Statistical evaluation

The data received were processsed using the Statistica 7 software using a multi-factor diffusion analysis. In a multi-factor diffusion analysis the effects of several qualitative or quantitative factors (selected in discrete values) are monitored. The values of the monitored wood properties were loss of mass, char layer, relative rapidity of heating and the ratio(a)/(b)). The important experimental factors were:

- distance of the heat source from the specimen surface;
- type of coniferous wood;
- time recorded every 15 seconds.

If interconnected factors were confirmed (time and distance) as well as their statistically significant effect, a regression analysis was employed.

Measured Values

The measured values are provided in tabular and graphical formats for better transparency:
In the table 2 the average values of all measurements are provided:

Table 2 - Average values of all measurements.

Wood species	Position	Distance	Loss of weight	Thickness of charred layer	Average relative speed of burning	Max. rel. rapidity of burning (a)	Time max. rapidity of burning (b)	Ratio (a)/(b)
		[mm]	[%]	[%]	[%.s^{-1}]	[%.s^{-1}]	[s]	[%.s^{-2}].10^{3}
PINE	branch	30	13,82	23,23	0,081	0,182	180	1,01
		35	11,88	19,63	0,055	0,069	180	0,38
		40	7,15	7,95	0,038	0,062	105	0,59
		45	5,46	4,58	0,029	0,053	120	0,44
		50	4,63	3,21	0,028	0,040	150	0,27
	trunk	30	71,56	100,00	0,636	0,177	105	1,68
		35	14,53	15,03	0,075	0,101	105	0,97
		40	13,71	9,12	0,076	0,164	180	0,91
		45	9,41	6,05	0,047	0,065	105	0,62
		50	6,98	2,51	0,033	0,056	120	0,47
	root	30	25,38	40,45	0,156	0,291	180	1,62
		35	17,28	21,51	0,087	0,187	180	1,04
		40	9,07	18,07	0,057	0,107	180	0,59
		45	6,49	10,71	0,066	0,121	180	0,67
		50	5,43	8,35	0,030	0,045	180	0,25
FIR	branch	30	15,20	23,92	0,077	0,139	180	0,77
		35	10,33	17,89	0,054	0,111	180	0,62
		40	7,34	10,27	0,039	0,065	150	0,43
		45	5,16	6,40	0,030	0,042	165	0,25
		50	4,02	4,90	0,031	0,058	165	0,35
	trunk	30	67,64	84,70	0,353	1,200	180	6,67
		35	18,09	20,21	0,081	0,145	105	1,38
		40	11,35	7,37	0,054	0,074	180	0,41
		45	7,74	4,17	0,041	0,067	165	0,41
		50	6,27	2,96	0,029	0,051	150	0,34
	root	30	29,34	42,14	0,157	0,678	180	3,77
		35	13,62	21,47	0,069	0,128	180	0,71
		40	11,54	18,66	0,069	0,116	180	0,65
		45	7,37	9,55	0,040	0,075	165	0,46
		50	5,60	7,67	0,017	0,029	90	0,33
SM	branch	30	14,73	20,10	0,078	0,233	180	1,30
		35	10,05	14,25	0,042	0,076	165	0,46
		40	7,00	6,01	0,033	0,054	150	0,36
		45	6,11	2,96	0,022	0,032	165	0,20
		50	4,79	2,14	0,018	0,032	180	0,18
	trunk	30	86,55	100,00	0,837	1,934	180	10,75
		35	34,38	36,32	0,202	0,648	180	3,60
		40	17,77	22,94	0,090	0,187	180	1,04
		45	9,56	5,15	0,052	0,078	120	0,65
		50	8,34	4,84	0,045	0,060	180	0,33
	root	30	30,48	44,40	0,185	0,565	180	3,14
		35	15,07	22,16	0,084	0,168	180	0,94
		40	11,00	17,79	0,055	0,088	165	0,53
		45	5,46	9,79	0,041	0,064	120	0,53
		50	5,24	5,65	0,029	0,042	120	0,35

Table No.2 – continues

LARCH	branch	30	14,73	21,44	0,080	0,199	180	1,11
		35	10,05	18,24	0,055	0,088	180	0,49
		40	5,61	10,70	0,038	0,066	180	0,37
		45	5,47	5,65	0,027	0,046	120	0,38
		50	3,43	2,49	0,020	0,031	165	0,19
	trunk	30	36,21	29,64	0,210	0,554	180	3,08
		35	12,68	12,42	0,066	0,097	165	0,59
		40	10,35	7,53	0,055	0,095	165	0,57
		45	7,35	3,06	0,039	0,067	180	0,37
		50	6,83	1,58	0,035	0,046	120	0,38
	root	30	23,73	37,20	0,144	0,208	165	1,26
		35	13,72	24,62	0,077	0,117	120	0,98
		40	10,14	19,45	0,059	0,083	150	0,56
		45	6,29	11,37	0,034	0,048	150	0,32
		50	4,59	6,95	0,028	0,042	165	0,25

Questions and Discussion

The data were evaluated from two points of view: impact of the wood species and impact of the position on the plant. Subsequently the thickness of the charred layer, the relative speed of burning and the ratio (a)/(b) were evaluated relative to the loss of mass and dependencies among them were observed. All measurements regardless of position and wood species have been plotted in these figures.

In all cases a linear dependence was found. The graphical- statistical evaluation is provided in Fig. 2 – 4. In Fig.2 a correlation was found between the loss of the mass and char layer thickness for all wood types and all positions. Linear dependence is defined by the value r^2, which is equal to 0.948 and hence very close to 1. It is not at all surprising to observe a strong linear interdependence between the mass loss and the char layer thickness.

A similar strong interdependence was found for all other evaluated properties.

Fig. 3 presents the correlation between loss of mass and relative rapidity of burning with r^2 = 0,922. Once again, based on the definitions of the terms, one might expect to observe a strong linear interdependence between the mass loss and the relative rapidity of burning.

Fig 4 represents the correlation between loss of mass and ratio (a)/(b) with the value r^2 = 0,944. This is an important observation that could not have been predicted in advance of these experiments.

Tables 3 and 4 provide regression equations in linear form of the individual correlations, evaluation criteria, wood species and positions.

In general it can be concluded that the spruce trunk shows the worst values in the monitored criteria. This must be considered in case of a fire in a calamity territory. There are also differences in positions on one wood plant. This means that when the fuel values are evaluated in an area of the calamity, it is necessary to specify the amount of fuel based on the individual types.

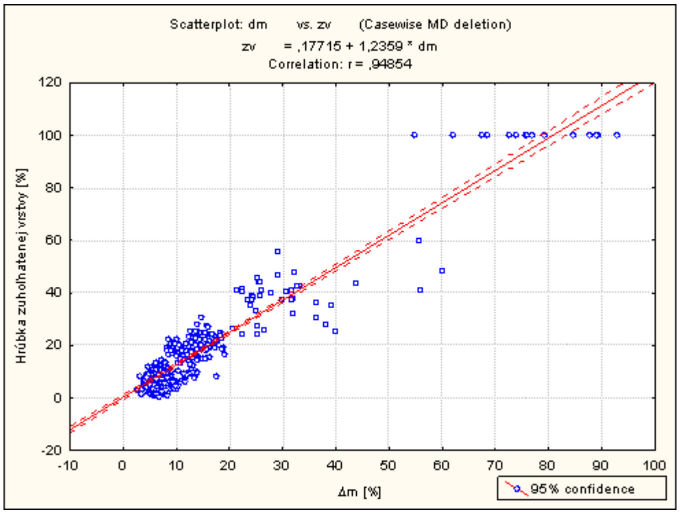

Fig. 2 Correlation between loss of mass and thickness of charred layer for all measurements (wood species and positions)

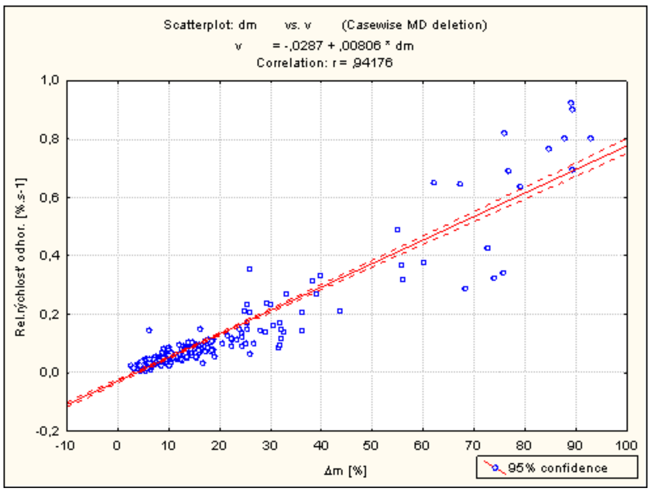

Fig. 3 Correlations between loss of weight and relative rapidity of burning for all measurements (wood species and positions)

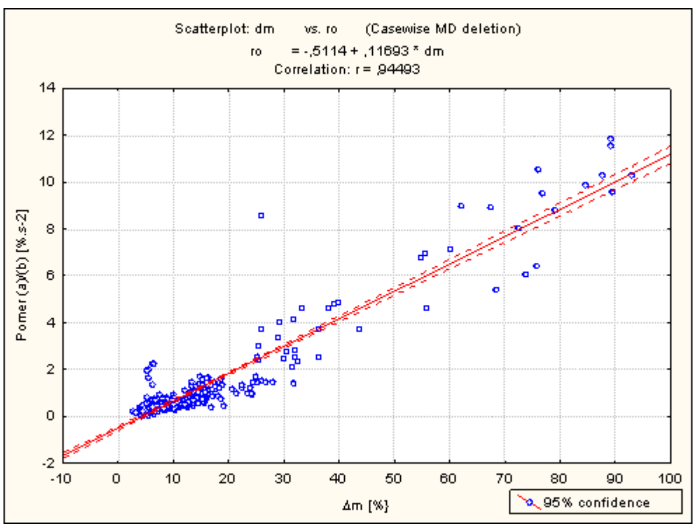

Fig. 4 Correlation between loss of weight and ratio (a)/(b) for all measurements (wood species and positions)

Table 3 Regression equation in linear form and value r^2 for correlation of evaluated criteria for the monitored wood species

Criterion	Wood species	Regression equation	Value r^2
Thickness of burned layer [%]	BO	y = 1,3824.x - 1,167	0,959
	JD	y = 1,2993.x - 0,2893	0,960
	SM	y = 1,1652.x + 0,26212	0,974
	SMC	y = 0,94483.x + 3,3748	0,772
Rel. Rapidity of burning [%.s^{-1}]	BO	y = 0,0098x – 0,0346	0,959
	JD	y = 0,0051x +0,0001	0,839
	SM	y = 0,0095x – 0,0488	0,949
	SMC	y = 0,0061x – 0,0053	0,852
Ratio (a)/(b) [%.s^{-2}]	BO	y = 0,1226x - 0,6248	0,939
	JD	y = 0,0998x – 0,173	0,750
	SM	y = 0,1279x – 0,6566	0,964
	SMC	y = 0,0855x – 0,2591	0,811

Table 4 Regression equation in linear form and value r^2 for correlation of evaluated criteria for the monitored positions

Criterion	Position	Regression equation	Value r^2
thickness of charred layer [%]	branch	y = 1,6639.x -2,592	0,855
	Trunk	y = + 1,2902.x -5,718	0,972
	Root	y = + 1,4117.x +1,7700	0,949
Rel. rapidity of burning [%.s^{-1}]	branch	y = 0,0048x +0,0032	0,581
	Trunk	y = 0,0085x – 0,0415	0,902
	Root	y = 0,0059x – 0,0025	0,708
Ratio (a)/(b) [%.s^{-2}]	branch	y = 0,0619x + 0,0061	0,534
	Trunk	y = 0,1236x – 0,7564	0,952
	Root	y = 0,0905x – 0,1389	0,464

Conclusion

To extinguish forest fires special fire extinguishing equipment is required and often even aerial technical equipment is used. The characteristics of the intervention like seriousness, length and economic costs have changed. Management of this issue must be addressed. This means not only to use new technologies but also to use new strategies, to study the fuel and further scientific development.

This study should contribute. Until now, evaluation of the individual wood species (also available in different reference sources) has been performed mainly for fire prevention purposes and when assessing wood for construction purposes. Also for buildings the wood was mainly categorized into hard and soft wood or into coniferous and foliage woods. The first hypothesis of the planned experiment assumes some homogeneity among the selected coniferous woods or among the individual positions of a tree (branch, trunk, root) within one wood species. Confirmation of this hypothesis (homogeneity) would identify a single value which could be implemented into modelling programmes when modelling the forest fires.

However the second hypothesis was confirmed; that is, it must be assumed i.e. that there are differences among the monitored wood species and differences among the positions (trunk, branch or root) of one tree. This hypothesis results from the opposition to the first hypothesis, but it is also consistent with the experience from scouts and firemen. Firemen have problems to extinguish underground fires completely (burning of root system) and experience of scouts proves that when they want a good bonfire, they use wood from root system.

To get a complex solution all three positions defined by physiology of the tree i.e. brunch, trunk, and root have to be considered. There are differences between burning of trunks in a forest fire when their position is vertical and in a calamity area fire where the trunks are in horizontal position. The volume of the fuel in specific quality (brunch, root, trunk) can be identified to a degree of precision from forest management plans based on the stand density, age of trees, locality, growth etc. The missing parameter was the information on how the individual wood components respond to heat, fire and how quickly they contribute to fire development. This study serves to supplement this information.

The results confirm the second hypothesis that there are differences also among coniferous wood species like pine, fir, spruce, and larch and also among positions (branch, trunk, roots) of the same tree. Surprisingly the worst results were discovered with our most common wood - spruce where all the monitored parameters reached the highest levels in this species of wood. The selected monitored parameters as a function of the loss of masst were chosen because change in this physical property is one of the classic and basic evaluation criteria for materials tested for fire prevention purposes. The char layer developed in the burning process, is welcomed in wood structures (auto-retarding character White 2002). When root system is burning indirectly represents also the length of the burning process, or smouldering. This effect is also very dangerous for starting a forest fire.

Other monitored characteristics like relative rapidity of burning and ratio (a)/(b) describe certain rapidity with which the material contributes to fire development. These four components of monitoring were statistically evaluated as described in the previous chapter.

The results found are comparable to the referenced literature, particularly in thickness of the char layer and burning rapidity. However it is only the spruce trunk data that can be compared with the referenced literature. Other parts of the tree, like branches and roots, have not been described in the literature available to us. The same is applicable also for other wood species monitored described more for wood practise purposes than for fire prevention purposes. This study has brought new information on the above mentioned wood species and their behaviour in forest fires.

This integrated solution could help to fight forest fires which are becoming more and more frequent in our territory.

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