Bulletin of the *Transilvania* University of Braşov
Series II: Forestry • Wood Industry • Agricultural Food Engineering • Vol. 6 (55) No.2 - 2013

FROST-CRACK FREQUENCY IN BEECH STANDS

V. R. CÂMPU[1] R. DUMITRACHE[2]

Abstract: *The purpose of this paper is the study of frost-crack frequency in beech trees and of factors which cause it in Târlungul Superior Watershed and Argesul Superior Watershed. The results obtained show a frost-crack frequency of 18% in Târlungul Watershed and one of 14% in Argesul SuperiorWatershed. Frequency increases with age following a second degree polynomial curve. Likewise, frequency increases with diameter. Trees with diameters above 50 cm may present more than one frost-crack. The most frequent frost-cracks are those with a length between 2 and 4 m, these representing over 50% of frost cracks in both areas.*

Key words: *frost crack, beech, wood defects.*

1. Introduction

Frost-crack is the radial crack developed alongside the trunk. Sometimes it may have a helicoidal development. It is caused by extremely low temperatures which occur suddenly during winter. Frost- crack usually occurs in the lower part of the tree in species with wide medullar radii [5]. Normally, it is more frequent in broadleaves i.e. oak, elm, poplar, walnut, beech, plane tree and chestnut [3] than in resinous trees i.e. fir [2]. Frost-crack is caused by uneven internal tensions inside the tree trunk produced by the different contraction of the wood strata when the temperature drops heavily and suddenly [1], [6]. The inside of the trunk is protected from frost and it has relatively low moisture content. Therefore, it does not contract, while the bark and the periphery of wood contract strongly when they freeze. Internal tensions become very strong so that the bark and the external layers of wood split longitudinally. Deep frost-cracks remain on the tree-trunks for their entire life. They do not heal as every year they open up during winter [7] being lines of minimum resistance. A tree may be affected by multiple frost-cracks in which case a stellar model appears in transversal section. This has been named frost-crack stellar heart [8].

This present paper is an attempt to study the frequency, length and spread of frost-crack according to the main factors which cause it.

2. Research method

Pure, harvestable, uneven-aged beech tree stands from Târlungul Superior and Argeşul Superior Watersheds have been chosen for this research. The research area

[1]Department of Forest Engineering, Forest Management Planning and Terrestrial Measurements, *Transilvania* University of Braşov.
[2]Forest District Muşăteşti, Forest County Administration Târgovişte.

is of approximately 2700 hectares representing 20% of the total area of Târlungul Superior Watershed. In this area twenty-one sample plots have been set up. In order to validate the results obtained two other experimental plots have been set up in Argeşul Superior Watershed. The distribution of trees from these experimental plots according to age classes (Table 1) was based on the tree age determined by an analysis of the increment cores of one hundred beech trees extracted with increment borer.

Distribution of trees according to age classes Table 1

Number of sample plots	Age Class [years] Diameter[cm]				Total	Frequency of trees with frost crack [%]	Age* [years]
	80 < 29	100 [29-39)	120 [39-59)	140 ≥ 59			
1	28	27	21	-	76	14	98
2	26	27	28	-	81	9	100
3	16	13	27	2	58	12	105
4	-	6	18	6	30	23	120
5	1	1	6	17	25	28	131
6	6	21	32	2	61	16	110
7	8	18	26	4	56	18	109
8	3	13	23	5	44	9	114
9	30	28	26	-	84	10	99
10	40	24	28	-	92	4	97
11	-	4	9	21	34	44	130
12	3	14	41	4	62	31	115
13	3	22	36	-	61	16	111
14	-	8	27	22	57	53	125
15	6	16	32	6	60	25	113
16	10	18	43	11	82	10	113
17	2	9	38	17	66	23	121
18	1	12	34	9	56	9	118
19	8	9	27	11	55	7	115
20	4	16	27	10	57	14	115
21	-	3	15	23	41	49	130
Total Târlung	195	309	564	170	1238	18	-
1	1	49	-	-	50	16	104
2	3	-	-	47	50	12	139
Total Argeş	4	49	-	47	100	14	-
General total	199	358	564	217	1338	18	-

*The tree stand age was calculated as a weighted average of the tree stand components.

Experimental plots were installed to cover the entire altitudinal range between 900 m and 1200 m as well as the different aspects. Experimental plots are 2000 m^2, they have a rectangular form (50x40 m) and their number was calculated by the statistical method characteristic of infinite populations with the following formula:

$$n = \frac{u^2 \cdot s_{\%}^2}{\Delta^2} = 17.75 \approx 18 \quad (1)$$

where:

n – number of surfaces;

u = 1.960 – standard deviation of the normal distribution corresponding to the transgression probability $\alpha = 5\%$;

$s_{\%}$ = 21.5 – coefficient of variation of the volumes determined depending on the tree stand homogeneity class, its structure and canopy cover;

$\Delta = \pm 10\%$ - limit error.

Because $n < 30$, the result obtained is considered a temporary value n', n being recalculated with the same formula where instead of u, t is used (t Student distribution) [4]. The value of t is determined according to the number of degrees of freedom $f = n' - 1$ and according to α. For 17 degrees of freedom and α = 5% it results $t = 2{,}110$.

By applying the formula again it results:

$$n = \frac{t^2 \cdot s_{\%}^2}{\Delta^2} = 20{,}58 \approx 21 \qquad (2)$$

Experimental plots included 1338 trees. Each tree was assigned a specific number and its own cardinal direction. Two perpendicular diameters have been measured for each tree at the height of 1.3 m. For each tree the presence of frost-crack and the intensity class defined according to the frost-crack length were mentioned so that:

- intensity class 1, when the frost-crack length is between 0 and 2 m;
- intensity class 2, when the frost-crack length is between 2 and 4 m
- intensity class 3, when the frost-crack length is above 4 m.

3. Results and Discussion

It was found that the frequency of frost-crack in Târlung Watershed is 18% and in Argeş Watershed 14%.

Influence of tree age on frost-crack frequency

A graphic representation of the frequency of trees with frost-crack according to age classes revealed the fact that frost-crack increases with age. The variation of the frost-crack according to the tree age can be better described by a second degree polynomial curve than by a simple linear equation (Figure 1). The fact that the frequency curve of trees with frost-crack is very close to a second degree polynomial curve is indicated by the coefficient of determination R^2 = 0.98 (Poly.) > R^2 = 0.92 (Linear).

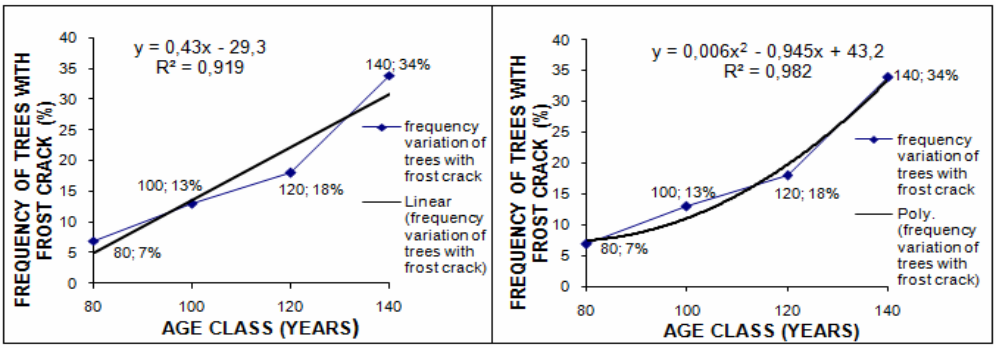

Fig. 1. *Frequency variation of trees with frost crack according to age classes*

Tree age also has an influence upon frost-crack length (Table 2). Thus, in the case of trees included in the 140 years age class the frequency of frost-cracks from intensity classes 2 and 3 is higher.

It can be noticed that in the tree-stands under study frost cracks with the length between 2 and 4 m are the most frequent.

Table 2

Frequency of trees with frost crack according to age classes and intensity classes

Intensity class	Age Class [years]				Total [no. (%)]
	80	100	120	140	
	[no. (%)]	[no.(%)]	[no.(%)]	[no.(%)]	
Târlungul Superior W…					
No. of trees	195	309	564	170	1238
1	4 (33%)	17 (42%)	44 (43%)	16 (23%)	81 (36%)
2	6 (50%)	17 (42%)	52 (51%)	40 (59%)	115 (52%)
3	2 (17%)	6 (16%)	6 (6%)	12 (18%)	26 (12%)
Total	12 (6%)	40 (13%)	102 (18%)	68 (40%)	222 (18%)
Argeşul Superior W…					
No. of trees	4	49		47	100
1	-	2(29%)	-	1(17%)	3(21%)
2	1(100%)	3(42%)	-	3(50%)	7(50%)
3	-	2(29%)	-	2(33%)	4(29%)
Total	1(25%)	7(14%)	-	6(13%)	14(14%)
Frost-crack frequency					
No. of trees	199	358	564	217	1338
General total	13 (7%)	47 (13%)	102 (18%)	74 (34%)	236 (18%)

They represent 52% of the frost-cracks registered in Târlung watershed and 50% of those registered in Argeş Watershed. Frost-cracks from intensity class 2 are the most frequent in all age classes.

Frost-crack frequency distribution by tree-diameter

Figure 2 shows the frost-crack frequency distribution in Târlung Watershed according to the diameter class. It can be noticed that out of the trees with diameters up to 28 cm, only 6% are affected by frost-crack. The reduced frequency of frost-crack at a younger age of trees and at smaller diameters can be explained by a more uniform contraction of wood layers. Decei (1975) states that frost-crack only occurs in trees with diameters above 30-34 cm. In the case of trees with diameters between 30 and 38 cm frost-crack is present in 13% of trees. In the case of those with diameters between 40 and 58 cm frost-crack frequency is 15% and for those with diameters above 60 cm frost-crack frequency is 40 %.

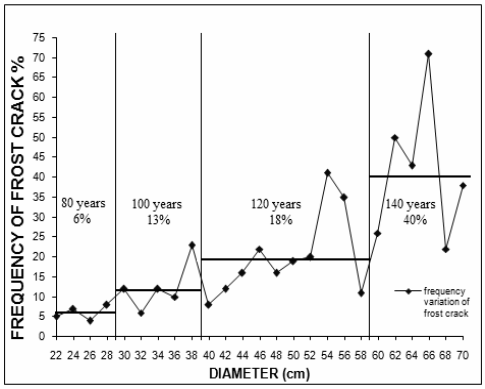

Fig. 2. *Frost crack frequency variation according to diameter classes*

An uneven variation of frost-crack frequency according to the diameter measured at 1.30 m can be noticed at age classes. Still, the average of frost-crack frequency increases with the age class. At

an older age and a bigger diameter the wood layer contractions are different and they create conditions for strong tensions inside wood which are capable of breaking the connections between wood anatomical elements. Thus, trees with diameters above 50 cm may present more than one frost-crack. In the present case 9% of the trees with diameters above 50 cm show two or even three frost-cracks.

Influence of cardinal direction on frost-crack frequency

Further, the cardinal direction of the frost-crack on the tree-trunk was taken into consideration (Table 3).

Frost crack frequency according to cardinal directions and intensity classes Table3

Intensity Class	Cardinal Direction				Total [no.(%)]
	N	E	S	W	
	[no. (%)]	[no. (%)]	[no.(%)]	[no.(%)]	
Târlungul Superior W…					
1	21 (26%)	14 (17%)	25 (31%)	21 (26%)	81 (36%)
2	35 (30%)	19 (17%)	37 (32%)	24 (21%)	115 (52%)
3	4 (15%)	6 (23%)	10 (39%)	6 (23%)	26 (12%)
Total	60 (27%)	39 (18%)	72 (32%)	51 (23%)	222
Argeşul Superior W…					
1	1(25%)	1(25%)	1(25%)	1(25%)	4(29%)
2	-	1(17%)	3(50%)	2(33%)	6(42%)
3	-	2(50%)	2(50%)	-	4(29%)
Total	1(7%)	3(29%)	6(43%)	3(21%)	14

In Târlung Watershed there is a higher frost-crack frequency on south and north directions, 32% and 27% respectively, than on directions west and east, 23% and 21%. The higher frost-crack frequency on the southern side of trees may be due to a higher temperature variation between day and night at the level of the tree trunk. Thus, the southern side of the tree trunk gets warmer than the other sides because of the daytime sun warmth. Therefore, the amplitude of temperature variation between day and night is higher at trunk level.

The higher frost-crack frequency on the western than on the eastern part of trees can be explained in a similar manner. In winter sun's warmth is stronger at noon time and heats the western side of the tree trunk. Then the temperature plummets. Kula et al. (2006) obtained similar results with respect to frost crack frequency on cardinal directions in birch stands. Franklin and Clatterbuck (2004) noticed a higher frost-crack frequency on the south-west direction of the tree trunk. Likewise, the table above shows the distribution of frost-crack according to different lengths and cardinal points. Thus, at all intensity classes the highest frost–crack frequency is on the south direction with a variation between 31% and 39% in Târlung Watershed and between 25% and 50% in Argeş Watershed.

Influence of land aspect on frost-crack frequency

In Târlung Watershed the highest frost-crack frequency was registered in experimental plots situated on north-western facing slopes (24%) followed by plots with south-eastern aspect (20.8%). The lowest values were registered on slopes with south-western aspect (17.6%) and north-eastern aspect (16.7%). Due to the fact that in the research area the dominant winds are from north–west, it

could be said that wind does influence frost-crack frequency in beech stands from Târlung Watershed. Decei (1975) found that the splitting usually takes place on a north east-south-west direction because these are sectors which get on one side the cold winds and on the other side the warm winds, a fact that leads to a high temperature amplitude which favors frost-cracks. In Târlung Watershed the frequency of frost-crack decreases as follows: NW, SE, SW and NE [9]. Thus, it could be said that land aspect influences frost-crack frequency at beech trees by land aspect as related to the dominant wind direction in the research area.

4. Conclusions

Frost-crack is a serious defect which affects 18% of all trees under study. The most frequent frost-cracks are those with the length between 2 and 4 m, representing more than 50% of frost-cracks in both research areas. The frequency of trees with frost crack increases with age and it can be estimated by a second degree polynomial function. Likewise, the frequency of trees with frost-crack increases from smaller to bigger diameters. Moreover, it has been noticed that trees with diameters above 50 cm can display more than one frost-crack. Also, it has been noticed that cardinal direction determines a higher frost-crack frequency on the southern side of trees in all age classes. In Târlung Watershed there is a higher frost-crack frequency on experimental plots situated on slopes with north-western and south-eastern aspect which confront directly the dominant winds coming from north-west.

References

1. Decei I., 1975. Research on beech wood quality as related to tree form. (in Romanian). Ceres Publishing House, Bucureşti.
2. Dinulică F., 2007. Observations on fir-tree frost-crack in fir and beech tree stands from Troainer valley, Braşov. (in Romanian). In: Proceedings of "The 8th national conference on environmental biotechnology and the 5th national conference on ecosanogenesis", Brasov p. 280.
3. Franklin J., Clatterbuck W. K, 2004. Bark splitting on trees. University of Tennessee, 2 p.
4. Giurgiu V., 1972. Mathematical Statistics Applied in Silviculture in Romanian). Ceres Publishing House, Bucureşti.
5. Kula E., Buchta I., Stránský P., 2006. Frost cracks and their effect on the stability of birch stands in the Krušné hory Mts. In: Journal of Forest Science, 52, 8: 348 – 356.
6. Northover P., 2006. Winter sunscald and frost cracking: Tree bark damaged from winter bite. Crops Knowledge Centre, Manitoba Agriculture, Food and Rural Initiatives.
7. Sano Y., Fukuzawa, K., 2006. Timing of occurrence of frost cracks in winter. In: Trees 11: 47 – 53.
8. Shigo A., Edwin vH. L., 1969. A photo guide to the patterns of discoloration and decay in living northern hardwood trees. U.S.D.A. Forest Service Research Paper Ne-127, 1969.
9. *** I.C.A.S. Bucureşti, 1982. A Naturalistic Study of Forests from the Experimental Forest District of Săcele. (in Romanian).