

The Effect of Cryogenic Application on Parallel Fiber Pressure Resistance of Thermowood-Treated *Sorbus Torminalis*

Ayhan AYTİN

Duzce University, Duzce Vocation School, Department of Design, 81010, Duzce, Turkey.

 <https://orcid.org/0000-0002-7938-1111>

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Abstract: This study aimed to analyze the possible changes in the pressure resistance values parallel to the fibers(CS) by subjecting heat-treated wood to sub-zero temperatures. Within the scope of the study, test specimens were first prepared by applying thermowood heat treatment at 190 and 212 °C for 1 h to samples of wild service tree wood (*Sorbus torminalis*). Both the heat-treated samples along with untreated control samples were then kept at -80 °C for 6, 18 and 54 h to obtain the test specimens. When compared to the control samples. Test results showed a difference in the parallel fiber pressure resistance of the heat-treated test specimens held at -80 °C and the values were seen as very positive, especially with the 6-h and 18-h applications. The CS resistance values of the control samples and the heat treated samples as N/mm² at 190 and 212 °C for 1 h were respectively 56.12, 69.28 and 62.12 for initial; 51.38, 73.25 and 80.55 for 6 h; 50.31, 72.82 and 75.66 for 18 h; 55.85, 60.19 and 62.14 for 54 h.

Keywords: Cryogenic treatment, compression strength, heat treatment, *Sorbus torminalis*.

Kriyojenik İşlemin Thermowood Akçaağaç Yapraklı Üvez Odununda Liflere Paralel Basınç Direnci Üzerine Etkisi

Öz: Bu çalışmadaki amaç, ısı işleme tabi tutulmuş odunda kriyojenik işlem uygulandıktan sonra liflere paralel basınç direncindeki olası değişimleri analiz etmektir. Bu kapsamda Akçaağaç yapraklı üvez odunu test örnekleri ilk olarak 190 ve 212°C sıcaklıklarda ısı işleme tabi tutularak Thermowood panelleri üretildi. Her iki gruptaki örnekler kontrol örnekleri ile birlikte sıfırın altında 80°C sıcaklıkta 6, 18 ve 54 saat süre işleme tabi tutuldu. Daha sonra gruplara liflere paralel basınç direnci testi uygulandı. testler uygulandırasında karşılaştırma yapıldı. Test sonuçları özellikle 6 ve 18 saatlik kriyojenik uygulama yapılan test örneklerinde farklılıkların olduğunu göstermiştir. Liflere paralel basınç direnci kontrol, 190 ve 212°C Thermowood örneklerde sırası ile N/mm² olmak üzere; 56.12, 69.28 ve 62.12 (başlangıç); 6 saat için 51.38, 73.25 ve 80.55; 18 saat için 50.31, 72.82 ve 75.6; 54 saat için 55.85, 60.19 ve 62.14 olarak belirlenmiştir.

Anahtar sözcükler: Akçaağaç yapraklı üvez, basınç direnci, ısı işlem, kriyojenik işlem.

INTRODUCTION

Although wood is a widely utilized natural raw material, in a number of applications it exhibits undesirable properties such as dimensional and color changes as well as biological degradation. These features shorten its service life in those areas of application and lead to losses in value (Sahin et al., 2017; Aytin, 2013).

Today, various methods and techniques can be employed to improve these stated negative properties of wood materials in those application areas. One example of these is heat treatment (HT), which is a modification technique that can improve the properties of wood material by increasing dimensional stability and resistance to biological degradation in addition to achieving color homogeneity (Srinivas & Pandey, 2012; Johansson, 2005).

In contrast to the improvements observed in the physical properties of heat-treated wood materials, the values of mechanical properties are generally lower, except for the elasticity modulus and the compression strength parallel to the fiber (CS). There is also an increase in the modulus of elasticity and CS, up to a certain temperature range, and then the values decrease after the heat treatment temperature reaches 205°C (Anonim, 2003). However, in some studies it has been reported that CS decreases with HT (Çaliova, 2011)

Although HT offers significant opportunities for users in the applications of wood materials, mechanical resistance losses are seen as an obstacle to these prospects. It is obvious that allowable safe stresses should be seriously taken into account, especially when a load carrying element is being considered. Hence, in such areas of usage, there is uncertainty in the evaluation of HT wood products compared to natural wood materials. From this point of view, the assessment of potential qualities may actually be quite important for HT wood materials in places where mechanical properties are in the forefront, with preferences for those providing more extensive improvements in physical characteristics.

Cryogenic (Cr) treatment is an application used to increase hardness in steel. In the process for hardened steel, the material is cooled to sub-zero temperatures and held for a certain period of time. It is reported that with cryogenic hardening, steel has higher wear ability and a longer service life (Kam et al., 2016). The application phases of Cr treatment for steel are shown below (Figure 1).

It is evident that the increase in hardness and wear capability which cryogenic processing has brought to bear opens up new areas of application. Reviews of the literature show that to date no study has been conducted examining HT and three versions of Cr on wood materials. This study aimed to reveal the relationship between HT and Cr and between natural wood material, HT and Cr in terms of CS.

Thus, this is considered to be an initial study of the consequences of Cr treatment for natural wood and for HT wood.

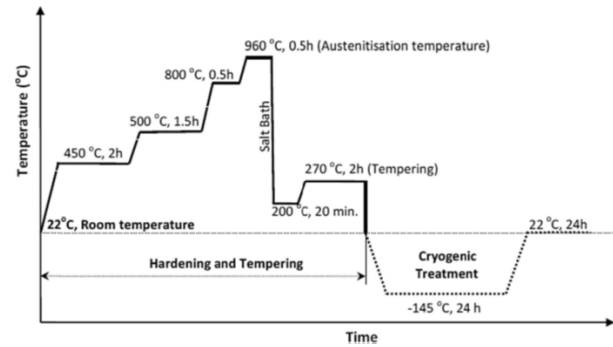


Figure 1. A schematic presentation of the heat treatment schedule consisting of the hardening, tempering, deep cryogenic treatment and tempering cycles of the samples (Aytin, 2016).

MATERIAL and METHODS

The *S. torminalis* trees used in the study were obtained from the Düzce-Odayeri Forest Sub-district Directorate (Duzce, Turkey). Selection of the trees was in accordance with the TS 4176 (1984) standard (7). The trunks of selected trees were cut at the height of 1.30 m from the base and divided into 2-m sections.

Panels with dimensions of 25 mm × 100 mm × 500 mm (thickness, width, length) were prepared from the *S. torminalis* trees and were subjected to heat treatment in an industrial oven using the ThermoWood method (Novawood Factory, Gerede, Turkey) in accordance with the operational production schedule. The heat treatment was conducted at temperatures of 190 °C and The panels were then subjected to Cr treatment. The HT and subsequent Cr process steps are shown in Figure 2.

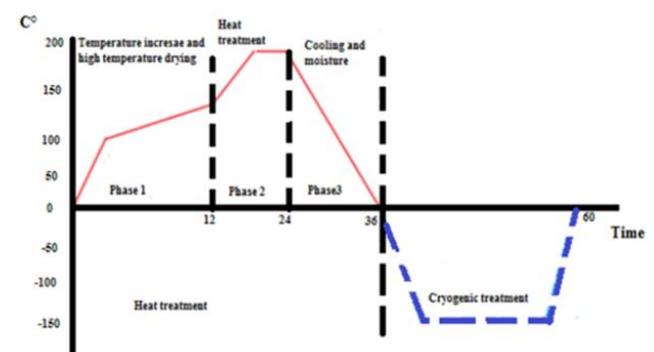


Figure 2. Application stages of HT and Cr in *Sorbus torminalis* wood.

The CS test samples were then prepared according to TS 2595 and left to condition. The experimental design used in the study is shown in Table 1.

Table 1. Experimental design of materials used in the study.

Test samples(TS)	Abbreviation	Cryogenic(Cr)
Control	UT	6*
		18
		54
190 °C 1 h	TW ₁	6
		18
		54
212°C 1 h	TW ₂	6
		18
		54

*Time is given as hour.

After the study was performed according to the experimental design in Table 1, the results obtained were analyzed using the Windows Evaluation SPSS Version 15.0 program, with significance set at $P \leq 0.05$. Homogeneity groups were examined using the Duncan test.

FINDINGS

The results of the variance analysis of the CS values in the *Cr Sorbus torminalis* specimens are given in Table 2.

Table 2. Results of variance analysis of CS values of *Sorbus torminalis* specimens subjected to cryogenic treatment for different time periods.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	10944.262(a)	11	994.933	12.503	0.000	0.560
Intercept	494268.694	1	494268.694	6211.50	0.000	0.983
Tree variety	6972.133	2	3486.067	43.810	0.000	0.448
Cryogenic	1392.496	3	464.165	5.833	0.001	0.139
Tree variety * Cryogenic	2579.633	6	429.939	5.403	0.000	0.231
Error	8593.901	108	79.573			
Total	513806.857	120				
Corrected Total	19538.163	119				

According to the results of the variance analysis in Table 2, among the Cr-applied experimental samples, statistically significant differences can be seen in both the tree species and the cryogenic variations. The Duncan test was applied to determine which groups the differences were between, and the results are given in Table 3.

Table 3. Duncan test results of CS values of *Sorbus torminalis* specimens cryogenically treated for different time periods.

Factor	Variations	N	CS		
			A	B	C
TS	UT	40	53.4186		
	TW1	40		68.9963	
	TW2	40		70.1213	
	Control	30	62.5118	62.5118	
Cr	6 H	30			68.3948
	18 H	30		66.2666	66.2666
	54 H	30	59.5415		

The Duncan test results revealed differences in both tree species (UT + heat treatment) and cryogenic (control + 6 h + 1 h + 54 h) CS values. The highest tree species values were reached in the heat-treated specimens and the highest cryogenic values were with the 6- and 18-h applications.

In Table 4, the CS values and Duncan test results are given for each subgroup after the tree species and cryogenic applications.

Table 4. CS values and Duncan test results for each subgroup after tree species and cryogenic applications

TS	Cr	CS (N/mm ²)	SS	HG
UT	Control	56.12	5.50	A
	6 h cryogenic	51.38	10.78	A
	18 h cryogenic	50.31	11.06	A
	54 h cryogenic	55.86	7.13	A
TW1	Control	69.29	5.12	AB
	6 h cryogenic	73.25	12.60	B
	18 h cryogenic	72.82	12.68	B
	54 h cryogenic	60.62	6.36	A
TW2	Control	62.12	8.54	A
	6 h cryogenic	80.55	2.35	B
	18 h cryogenic	75.66	6.76	B
	54 h cryogenic	62.14	11.15	A

CONCLUSIONS

The CS values obtained in all the cryogenic groups were higher than in the cryogenically untreated (control) samples. The duration of the cryogenic treatment was effective on the CS values. As the time was increased, lower CS values were obtained. For this reason, determining the optimum Cr processing time is an important issue. With the heat treatment temperature increase, the increasing CS value began to decrease as the temperature rose. Decreases in the CS occurring due to the increased HT temperature can be recovered by Cr application. In Figure 3 CS values are seen for the UT, HT and Cr variations.

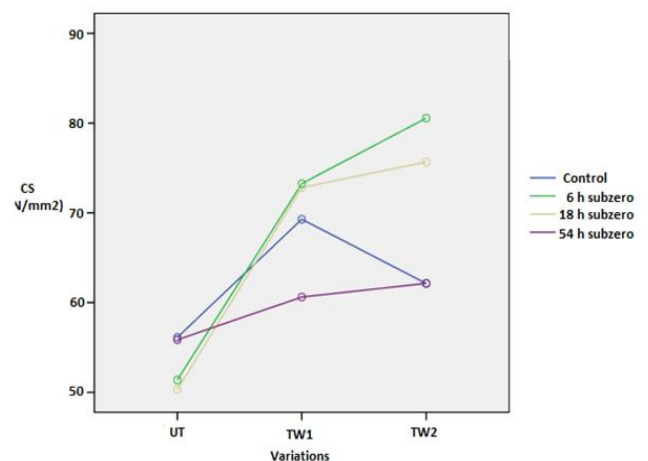


Figure 3. CS values are seen for the UT, HT and Cr variations.

These results show that Cr processing of wood materials is very important after HT and that it is essential to test their threshold values to enable them to be used at the desired locations.

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***Corresponding author's:**

Ayhan AYTİN

Duce University. Duzce Vocation School. Department of Design. 81010. Duzce. Turkey.

E-mail : ayhanaytin@duzce.edu.tr**ORCID** : <https://orcid.org/0000-0002-7938-1111>**GSM** : +90 (533) 526 29 95**Fax** : +90 (380) 524 00 97