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Viscidity Studies of Oak Scantlings and Glued-up Panels

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The paper presents dynamic studies of oak scantlings and glued-up panels. The scheme of sawing of scantlings in a log is presented and their coefficient of damping is determined. Distribution regularities of the coefficient of damping in a log, estimated along and across the grain, are provided. It was found, that the highest coefficient of damping along the grain is in the buttlog (0.0265 – 0.0266), while the lowest – in the top end (about 0.0263). The regularity of coefficient of damping variation across the grain is different – the highest is at the ends of a log (0.0306 – 0.0330), while in the centre – the lowest (0.0304 – 0.0315). The influence of coefficient of damping of scantlings on panel coefficient of damping was estimated. It is shown, that panel coefficient of damping is in all cases lower than mean coefficient of damping of comprising it scantlings. Statistical processing of the obtained results is presented.
Keywords: oak scantling, resonance vibrations, coefficient of damping, glued-up panel.

INTRODUCTION

Wooden articles often experience different loadings. These loadings can be both static and dynamic. Quite frequently different wooden constructions are used to isolate or dampen vibrations. Among them are different wooden partition, floorings in ships, planes etc. In other cases, wooden articles are produced to induce vibrations. In this case, various details of musical instruments are produced. In all the mentioned cases wood coefficient of damping (describing viscidity properties) is very important. In some instances it should be high, in other – as low as possible. The amplitude-frequency characteristics of a product are very important as well. This parameter ensures certain behaviour of the product within a certain frequency range.

It is known, that wood coefficient of damping is dependant on many factors – place on the stem, occurring various defects, features [1, 2].

Mechanical properties of an object may be characterized by its free vibrations. In this case an object is deformed and vibration damping curve is analysed, according to which elastic and viscid properties of the object can be described. In this way, logs are sorted out [3] and new baulks are distinguished from the old ones [4].

The method of free vibrations is used also in the studies of floor systems [5]. It was ascertained, that the frequency of free vibrations of a separate element of a floor system is independent of the place of hitting, however, each of the elements vibrates in different frequencies. Having exchanged the places of elements or one element by another in the floor system, vibration frequencies of the whole system undergo changes.

The sound of electric organ is influenced by its body details [6]. When their resonance frequencies coincide with the frequencies induced by the organ, the sound is distorted. Seeking to avoid such distortions, it is necessary to change amplitude-frequency characteristics of its parts.

It was found, that the sounding of violin depends on the elasticity of its parts [7]. In this case wood with a low coefficient of damping is used. However, to produce the body of a quality stringed instrument, it is necessary not only to choose suitable wood, but also to ensure surface profile of the body itself.

Opposite to body production, wood used for sound absorption in produced constructions should be characterised by a high coefficient of damping. Such constructions include body details of instruments, partition and floorings in houses.

In the cases of both free and forced vibrations, the character of vibration curve of the studied object depends on coefficient of damping.

Quite often it is necessary, that the produced detail or construction is characterised by certain viscid properties. For this purpose, it is necessary to select its individual elements.

The aim of the work was to ascertain coefficient of damping of oak scantlings and their glued–up panels as well as to evaluate, what influence on coefficient of damping have its individual elements – scantlings and glues.

STUDY METHODS AND EQUIPMENT

As it is known, mechanical properties of wood and its products are determined by static and dynamic study methods [8]. One of the dynamic study methods – the method of resonance vibrations was applied to study oak scantlings and glued-up single-layered panels.

Studying dynamically, it is very important to evaluate the way of fastening of the studied object [9]. Beam shape body can be evaluated as a console, both ends can be fastened, it can be placed freely, hanged, etc. Plate shape body also can be fastened in different ways – all four edges may be fastened, two edges may be fastened, fastened or only placed freely. Fastening type has a great influence on bend forms (modes) of the studied object and amplitude-frequency characteristics. They are used to estimate mechanical properties of an object – modulus of elasticity and coefficient of damping.

Studies were conducted using a special stand (Fig. 1).

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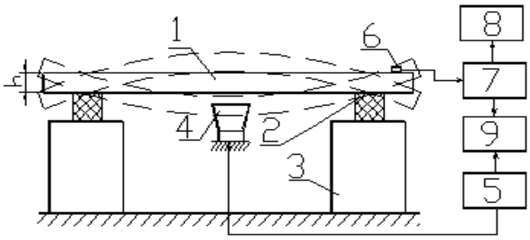

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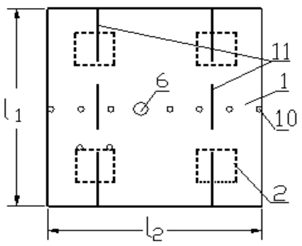

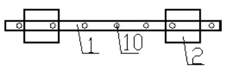

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Fig. 1. Study stand (a) of wooden articles and location scheme of vibration measurement points in the case of plate (b) and beam (c): 1 – wooden assortment and its bend form (dashed line); 2 – elastic elements; 3 – massive supports; 4 – acoustic vibrator; 5 – generator of electric vibrations; 6 – transducer; 7 – measuring device; 8 – oscilloscope; 9 – phase-meter; 10 – fastening points of transducer; 11 – vibration lines of the first bend forms (modes) in longitudinal direction

A plate (glued-up panel) 1 is placed on four elastic elements 2. Studying a beam (scantling), it is placed on two elastic elements (Fig. 1, c). These elements are produced of foam (120×120×100 mm) and fastened to massive supports 3. An acoustic vibrator 4, which is controlled by the generator 5 of electric signals, induces resonance vibrations of the studied assortment 1. These vibrations are recorded by the transducer 6, fastened to the studied object 1. Changing frequency of the generator 5, resonance vibrations of the studied object are induced, which are measured by the measuring device 7. The form of vibrations is observed on the screen of an oscilloscope 8. To determine bending direction of an assortment by phase-meter 9, vibration phase is measured. For this purpose, signals from the measurement device 7 and the generator 5 are sent to the phase-meter 9.

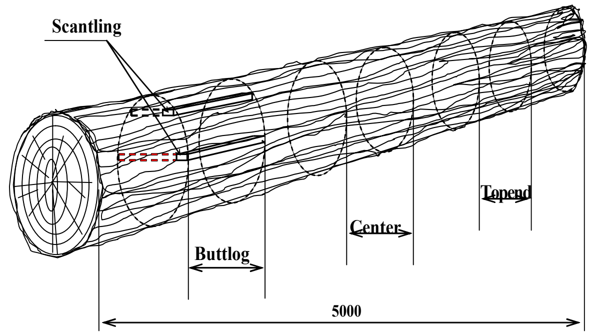
As far as the studied object 1 is freely placed on elastic elements 2, this case corresponds to the extreme conditions of an unfastened beam and an unfastened (freely placed) plate [10].

Using this stand, amplitude-frequency characteristics of individual scantlings and glued-up panels were recorded within 20 Hz – 2000 Hz frequency range. Seeking to obtain more precise results, the amplitude of vibration acceleration was measured.

Having ascertained amplitude-frequency characteristics of the studied assortment, its coefficient of damping is estimated [11].

EXPERIMENTAL RESULTS AND DISCUSSIONS

Oak scantlings and glued-up panels were used for the studies. Scantlings were sawn from the dried central and side 5 m long boards: buttlog (about 0.5 m from the butt end), central part, top and planed on four sides. Samples were sawn from three edge boards K_1, K_2 and K_3 as well as three central boards – C_1, C_2 and C_3. Totally, 84 scantlings were sawn. Grain direction in the scantlings was parallel to the edge. The schemes of log sawing and scantlings are given in Fig. 2.



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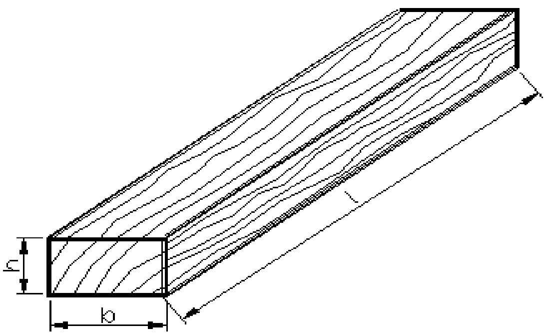

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Fig. 2. Scheme of sawing scantlings from a log (a) and scantling (b) scheme

Moisture content of scantlings was (8.3 – 12.5) %, density – (670 – 780) kg/m^3, dimensions – (250×40×15) mm (across the grain) and (670×60×30) mm (along the grain). Studies were conducted in laboratory conditions – air humidity (65 – 73) %, temperature – (17 – 20) °C. Such a selection of scantlings allowed estimating the distribution of coefficient of damping in the log. Later they were correspondingly used to form a set of scantlings in the panel.

Studying scantlings, resonance frequency, under which scantling bends in the first mode, and amplitude-frequency characteristics as well as coefficient of damping of scantlings were ascertained. It changes within 0.015 – 0.039 range. It is known, that coefficient of damping of wood comprises 0.032 – 0.0032 [12]. Bend forms of a scantling are determined recording the amplitude and phase of vibrations in respect of generator signals in each vibration measurement point (Fig. 1, 10).

The regularities of coefficient of damping distribution in a log are presented in Fig. 3. In each point of the curves mean coefficient of damping of all central or side boards is marked.

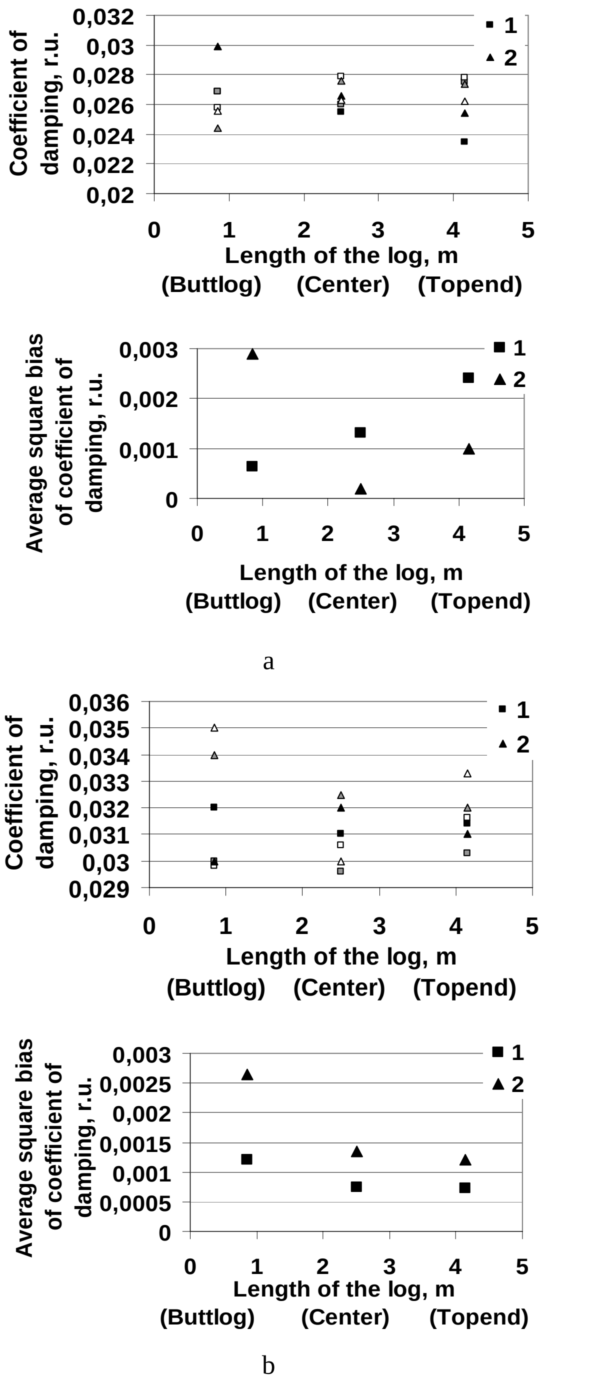


Fig. 3. The regularities of coefficient of damping distribution in an oak log and average square bias of coefficient of damping: a – along the grain; b – across the grain; where 1 – in central boards, 2 – in side boards

As it can be seen, that both in side and central boards the highest mean coefficient of damping along the grain is found in the buttlog (Fig. 3, a). “Moving” towards the top, it decreases. It was found, that in central boards mean coefficient of damping decreases from 0.0265 to 0.0263 (0.75 %), while in side boards – from 0.0266 to 0.0263 (1.1 %). Mean coefficient of damping across the grain in a log changes according to another regularity (Fig. 3, b). Both in central and side boards the least values of coefficient of damping are in the centre. In central boards mean coefficient of damping in the buttlog is 0.0330, in the centre it decreases down to 0.0315 (diminishes by 4.6 %), while towards the top it again increases up to 0.0321 (augments by 1.9 %). In side boards mean coefficient of damping in the buttlog is 0.0306, in the centre it decreases down to 0.0304 (diminishes by 0.7 %) , while towards the top it increases up to 0.0311 (augments by 2.3 %). It can be seen also, that both along and across the grain mean values of coefficient of damping are higher in side boards (except in the top along the grain).

In some central and side boards the regularities of coefficient of damping distribution is fractionally different than general regularity (Fig. 3, a). The data of average coefficient of damping along the grain in these boards are presented in Table 1.

Table 1. Average coefficient of damping along the grain distribution in separate boards

	Number of board	Buttlog	Center	Topend
Central boards	C2	0.0269	0.0260	0.0275
	C3	0.0258	0.0279	0.0278
Side boards	K2	0.0244	0.0276	0.0274
	K3	0.0256	0.0263	0.0262

From Table 1 it can be seen, that in boards C_3, K_2 and K_3 the highest coefficient of damping is in the central part of a board. In board C_2 – on the contrary – coefficient of damping in the central part is the lowest. Such a different distribution of coefficient of damping may be explained by the presence of various wood features and defects, i.e. knots, slope of grain, etc. The distribution of coefficient of damping in another direction – across the grain, also not always accords the general regularity (Fig. 3, b).

Later it was found, how the coefficient of damping of scantlings and the glue used influence the coefficient of damping of a glued-up single-layered scantling panel. Panels were glued up from the mentioned scantlings under laboratory conditions. Gluing of scantlings and measurement of vibrations were performed in the following order: initially two scantlings were glued up and coefficient of damping was determined, later three and so on, until a square panel was obtained. For the studies, 9 panels of three types (T_1, T_2, T_3) were prepared. Following panels of scantlings were glued from the above-mentioned scantlings, joining their edges. Dimensions of scantlings was $(670 \times 60 \times 30)$ mm, and dimensions of glued-up single-layer panels was $(670 \times 660 \times 30)$ mm. Volume of glue layer was about 4 cm^3. Coefficients of damping of scantlings of the first type panels were close and varied within the following range: in panel $T_{1.1}$ – 0.023 – 0.033, panel $T_{1.2}$ – 0.021 – 0.028, panel $T_{1.3}$ – 0.018 – 0.025. Coefficients of damping of scantlings of the second type panels differed more: $T_{2.1}$ – 0.027 – 0.039, $T_{2.2}$ – 0.019 – 0.029, panel $T_{2.3}$ – 0.022 – 0.038. Panels of the third type were glued up from scantlings, coefficients of damping of which were changing even within a wider range. Panel $T_{3.1}$ glued up from scantlings, coefficient of damping of which was 0.020 – 0.035, $T_{3.2}$ – 0.017 – 0.036, $T_{3.3}$ – 0.015 – 0.028. Data of these panels are presented in Table 3.

Panel bend forms in longitudinal direction are ascertained analogically as those of a scantling [13]. For this purpose, in each vibration measurement point (Fig. 1, b) vibration amplitude and then phase in respect of the generator signal was recorded. Later amplitude-frequency characteristics were ascertained, and having conducted corresponding dimensions, coefficient of damping estimated. Data of coefficient of damping along the grain of the used scantlings are presented in Table 2.

Initially scantlings were glued with adhesives based on PVA pitch, corresponding to D2 class.

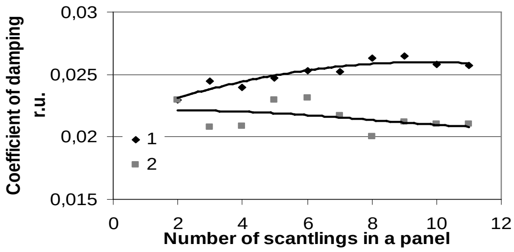
Table 2. Comparison of coefficient of damping values of scantlings used in panels

Number of panel	Range of the coefficient of damping values of scantlings used in panels	Mean coefficient of damping values of the scantlings used in panels
T1.1	0.023 – 0.033	0.028
T1.2	0.021 – 0.028	0.025
T1.3	0.018 – 0.025	0.021
T2.1	0.027 – 0.039	0.034
T2.2	0.019 – 0.029	0.023
T2.3	0.022 – 0.038	0.030
T3.1	0.020 – 0.035	0.027
T3.2	0.017 – 0.036	0.026
T3.3	0.015 – 0.028	0.0205

Variation of the values of panel coefficient of damping depending on the number of scantlings per panel (panel width) is shown in Fig. 4. In this case, in each point of curve 1 mean coefficient of damping value is marked while in corresponding points of curve 2 – coefficient of damping of the glued-up panel.

Using scantlings with close values of the coefficient of damping, mean coefficient of damping value of scantlings slightly increases (from 0.023 to 0.0265) with greater number of scantlings and stabilizes (Fig. 4, a). The value of coefficient of damping of the glued-up panel at the same time insignificantly decreased. When the panel consisted of 9 – 11 scantlings, the difference in mean coefficient of damping values of the scantlings used and the panel stabilized and comprised about 18 %. Using scantlings with more different values of the coefficient of damping (Fig. 4, b), mean coefficient of damping value of the used scantlings decreased from 0.026 to 0.0227. At the same time coefficient of damping value of the glued up panel was also decreasing from 0.024 to 0.02. With increasing number of scantlings (panel width), initially the difference between mean coefficient of damping value of scantlings and that of the panel was increasing. When the panel consisted of 6 scantlings, this difference was 13 %. Later it slightly decreased and stabilized within the limit of 11%. In the third case, when scantlings with highly different values of the coefficient of damping were used, the difference between mean coefficient of damping of scantlings and that of the panel initially augmented up to 28 % (Fig. 4, c). However, later this difference stabilized, remaining within the limit of 23 %. Besides, it was found, that having added a scantling with lower coefficient of damping, coefficient of damping of the panel decreased as well, while having added one with higher coefficient of damping – that of the panel used to increase.

As it can be seen (Fig. 4), independently of coefficient of damping combinations of scantlings comprising panel, the regularity of coefficient of damping variation of panels in general corresponds to the regularity of coefficient of damping variation of glued up scantlings. Gluing up scantlings with lower coefficient of damping, lower panel coefficient of damping is obtained, and vice versa. It was found, that in all cases panel coefficient of damping is lower, because mean coefficient of damping of comprising it scantlings was lower (on an average 18 %).



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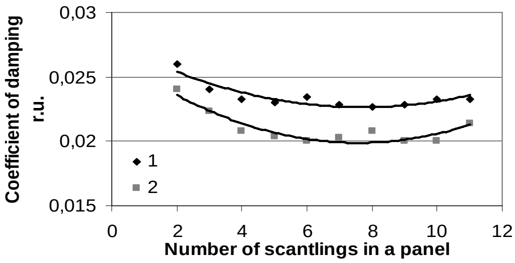

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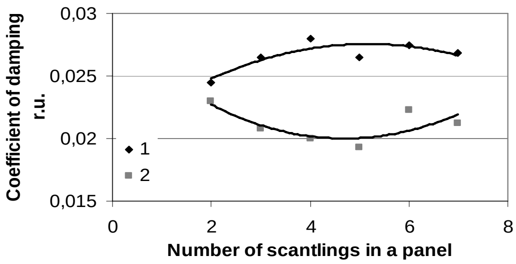

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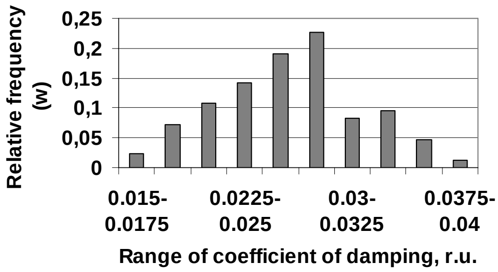
Fig. 4. Variation of panel coefficient of damping depending on the number of scantlings in the panel (panel width): a – gluing up scantlings with close values of coefficient of damping; b – gluing up scantlings with more different values of the coefficient of damping; c – gluing up scantlings with highly different coefficients of damping; 1 – mean coefficient of damping of the used scantlings, 2 – panel coefficient of damping

The obtained study results were processed statistically. Distribution of the values of scantlings and panel coefficients of damping is presented in Fig. 5. It can be seen, that distribution of coefficient of damping values of both scantlings and panels corresponds to the Gauss's distribution (for scantlings average square bias of asymmetry $\sigma_A = 0.288$, index of asymmetry $A = 0.327$, average square bias of excess $\sigma_E = 0.552$, index of excess $E = -0.539$, for panels – $\sigma_A = 0.633$, $A = 0.780$, $\sigma_E = 0.919$, $E = 0.766$).

Values of coefficient of damping of scantlings most often fluctuate within 0.025 – 0.03 range. Most of the coefficients of damping of panels fall within 0.02 – 0.023

range. Mean coefficient of damping value of all scantlings is 0.0264, while that of panels – 0.0207. The values of variation coefficients of scantlings and panels are given in Table 3.



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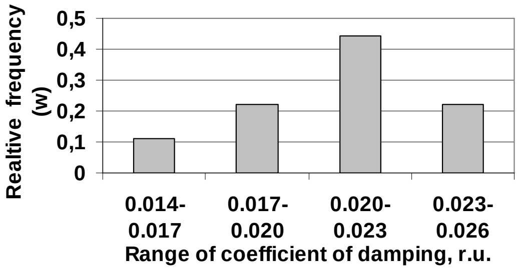

b

Fig. 5. Distribution of the values of coefficient of damping: a – scantlings; b – panels

Table 3. Variation coefficients of scantlings and panels

The group of scantlings	Variation coefficient, %
Of buttlog	23.01
Of center	25.00
Of topend	27.45
All scantlings	25.15
Glued-up panels	16.42

It can be seen, that the dispersion of coefficient of damping values of oak scantlings is sufficiently high. Variation coefficient obtained in separate zones fluctuates from 23 % to 27.5 %. This shows, that mechanical properties of wood are unevenly distributed in all the zones of a log. It is obvious, that the dispersion of coefficient of damping values of panels glued up from such scantlings is far lower (in this case 16.42 %).

Analogous results were obtained studying scantlings and panels across the grain and using D4 class adhesives based on PVA pitch as well as "PUR LEIM 501" glue.

4. CONCLUSIONS

By corresponding selection of scantlings it is possible to form panels of the required coefficient of damping. It was found, that sawing scantlings from different places of a log, a sufficiently high dispersion of coefficient of damping is obtained. As a result of the studies it was ascertained, that coefficient of damping of oak glued-up panel in all cases is lower than the mean coefficient of damping of comprising it scantlings. Study results lead to the following conclusions.

1. It was found, that mean coefficient of damping of oak scantlings is 0.0264, while that of panels – 0.0207. The average square bias of coefficient of damping of scantlings is 0.0067, while that of panels – 0.0030.

2. It was determined, that viscid properties in an oak log are distributed unevenly – the highest mean coefficient of damping is in the buttlog (0.0265 – 0.0266), the least – in the top end (0.0263). The average square bias is respectively 0.0059 and 0.0073.

3. It was determined, that viscid properties of a glued-up panel depend on the viscid properties of scantlings. In all cases the value of coefficient of damping of a glued-up panel is on an average by 18 % lower than mean coefficient of damping value of comprising it scantlings.

4. It is shown, that value of coefficient of damping of separate scantlings influences coefficient of damping value of the panels – having added a scantling of lower coefficient of damping, coefficient of damping of the panel decreases as well, and vice versa.

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