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# INFLUENCE OF SOME PRODUCTION PARAMETERS ON LAMINATE FLOOR PRODUCT PROPERTIES

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***Abstract:***
*Influence of décor paper raw (40 and 50 gr m⁻²) and final weight (105 and 115 gr m⁻²), and corundum ($Al_2O_3$) amount (8, 10, and 12 gr m⁻²) on surface abrasion count, abrasion resistance, impact resistance (small ball) and cure properties of the laminate floor with high-density fiberboard core was evaluated. Nine different types of laminate floor products were produced and tested. The averages of surface abrasion, abrasion resistance, impact resistance, and cure properties ranged from 2667 to 5000 revolutions, 4.5 to 5.5 N, 70 to 90 N, and level 4 to 5, respectively. According to the results, products meet both domestic and commercial levels of use regarding BS EN 13329:2023. The overall performance of B-type products was higher than A and C-type products. It should be noted that the products evaluated in this study were factory-made instead of laboratory applications. Furthermore, some production parameters are kept confidential due to marketing concerns.*

**Key words:** *laminate floor, surface properties, overlay, décor paper.*

## INTRODUCTION

Housing and feeding are primitive challenges for humankind and trees provide opportunities for both needs by fruit etc. for nutrition and wood for the construction of shelters or houses as later with the advancing construction tools. Ensuring the primitive requirements, humankind searched for further such as aesthetics. Flooring is one of the essential elements for the aesthetic of ordinary or luxury flats or houses. However, just being aesthetic is not enough in today's expectations because physical and mechanical properties should meet the requirements. For example, solid wood flooring products are natural but have some important disadvantages such as being prone to abrasion, nondurability, interaction with environmental factors such as humidity, etc. A wide range of floor covering products have been developed till now. However, not only providing good performance in terms of physical and mechanical properties but also easy installation are the prominent factors of laminate flooring products. Furthermore, since the emergence in Sweden in the late 70s, laminate floor is the most commonly applied surface covering (Arenas and Sepulveda 2022). The overlay, decor paper, high-density fiberboard (HDF) or core, and balance paper are the essential elements of laminate which is a layered composite. Each layer has specific purposes such as providing scratch resistance, aesthetic appearance, main element for interlocking the surrounding part, and balancing, respectively. In the literature, abrasion resistance improvement of a laminate floor (particleboard-PB core and without overlay) by curing (Nandipati and Suman 2021), the influence of overlay on the surface quality of laminate floor made of HDF core (1:1 *Pinus nigra* and *Fagus orientalis* fibers) (Kara *et al.* 2022), psychoacoustics of laminate floor for the perception of sound quality (Wilson and Cunefare 2008), impact noise of laminate floor (Arenas and Sepulveda 2022), consumer preferences for wooden and laminate flooring in Sweeden (Roos and Hugosson 2008), thermal conductivity of underlay foam for laminate flooring to reduce heating energy (Seo *et al.* 2016), indoor air quality assessment of laminate flooring (Yetiş and Tuna Kayili 2021), influence of overlay paper on surface quality of laminate floor (Kara *et al.* 2022) were evaluated. However, the influence of laminate floor layers (individual or combined) on physical and mechanical properties is scarcely evaluated. Kara *et al*. (2016, 2022) are two of the limited studies focused

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on both physical and mechanical properties of laminate floors. Jimenez *et al.* (2015) evaluated the physiological aspects of laminate floors and stated that solid wood floor products were perceived as warmer and cozier than laminate floor products. Borrell *et al.* (2016) evaluated the acoustic properties (loudness and sharpness) of laminate floors by dropping a steel ball and finite element modeling and analysis.

Apart from laminate floor products, İstek *et al.* (2010) evaluated the effect of décor paper and resin type (Urea formaldehyde-UF, melamine formaldehyde-MF, and UF+MF) on physical (thickness swelling-TS and water absorption-WA), mechanical (bending strength-BS, modulus of elasticity-MOE, and tensile strength-TS) and surface quality (cracking, water vapor, cigarette burn, staining, abrasion and impact scratch) of PB coated with impregnated décor papers. The authors stated that the décor paper pattern has influences on the scratch and abrasion properties of the PB. Furthermore, İstek *et al.* (2016) evaluated the influence of resin paper coating on TS, WA, internal bonding-IB, BS, MOE, surface soundness-SS, and screw withdrawal-SW of PB.

## OBJECTIVE

As it is seen in the literature, the influence of décor paper on laminate floor properties is still undefined. From this respect, this study tried to figure out the influence of décor and overlay paper and corundum on surface abrasion, abrasion resistance, impact resistance, and cure properties over six different laminate flooring products.

## MATERIALS AND METHODS

### *HDF production*

Spruce (*Picea orientalis* L) and beech (*Fagus orientalis* L) were used for HDF production. The fiber mixture was 70% and 30% respectively. Andritz AG 2008 (Graz, Austria) was used for refining. At the blow line, 11.5% kg $m^{-3}$ UF resin (50% solid matter, 20-50 cP viscosity, 1.25 gr $cm^{-3}$ density, and 8.8-9.8 pH), 0.8% kg $m^{-3}$ hardener ($Al_2(SO_4)_3$), and1.17% kg $m^{-3}$ liquid paraffin (Mecan Kimya Co., Denizli, Türkiye) sequentially applied to fiber mixture. The fiber mixture was dried to 12.5% moisture content. The mat was pre-pressed and then hot-pressed using the Siempelkamp (Krefeld, Germany) press. The pressing speed, temperature, and duration were 980 mm $s^{-1}$, 230 °C, and 61 s, respectively. The 880 kg $m^{-3}$ density and 7.4x209x7365mm sized HDFs were stored for five days at 20 °C temperature and 65% relative humidity and then sequentially sanded using 60, 80, 100, and 140 sand sandpaper to obtain final thickness (7.3±0.1mm). The solid matter of the melamine urea formaldehyde (MUF) was 54%, while other properties were the same.

Gray oak décor paper was impregnated in two stages. First, UF resin penetrated at 110°C oven temperature and 850 revolutions per minute(rpm) fan speed, then MUF resin penetrated at 135°C oven temperature and 850 rpm fan speed. The final weight and moisture of the décor paper following impregnation were 105 and 115 gr $m^{-2}$, and 6±0.2%. The impregnation process parameters for the Alaçatı decor paper were the same. The UF and MUF ratio was 1:1 in décor paper production.

Overlay paper impregnated with MUF at 130 °C oven temperature and 850 rpm fan speed. The final weight and moisture of the overlay paper were 90 gr $m^{-2}$, and 6.9±0,2%, respectively. Three different amounts (8, 10, and 12 gr $m^{-2}$) of corundum ($Al_2O_3$) were applied to overlay paper. Kraft balance paper contains only MUF resin instead of a mixture.

Balance paper (50 gr $m^{-2}$), following the $2^{nd}$ washing stage in the impregnation process, was impregnated using MUF at 145°C oven temperature and 800 rpm fan speed. The final weight and moisture of the balance paper following impregnation were 115 gr $m^{-2}$, and 6.8±0,2%, respectively.

Modifying chemicals (hardener, antibacterial agents, etc.) were applied both for overlay and décor paper resin. The jelling time of the overlay, décor paper, gravure unit, and balance paper resins (300 kg for each) were 4.35m, 4.5m, 4.2m, and 3.3m, respectively.

Laminate flooring production was done using Wemhöner Press (Herford, Germany). The temperatures of the top and bottom heating platens were 200°C and 202°C, respectively. Pressing was done for 14.5 s at 40kg $cm^{-2}$ pressure.

Produced HDF laminate floor products (Fig. 1), and samples prepared according to standards were conditioned at 20°C temperature and 65% relative humidity and then surface abrasion (AC3≥2000 revolution, BS-EN 13329:2023), scratch resistance (AC3≥3.5 N, BS-EN 14323:2021), small ball (AC3≥10 mm, BS-EN 13329:2023), and cure properties were determined in accordance with the mentioned standards.

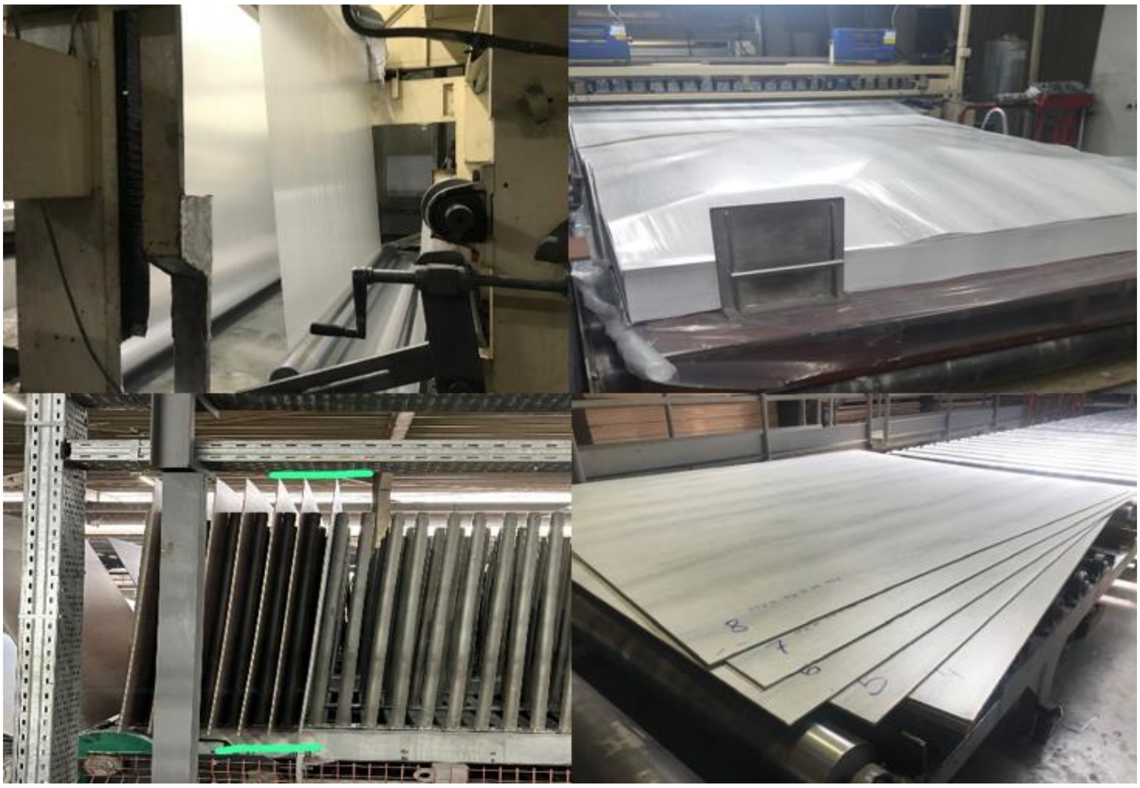

***Fig. 1.***
***Production phases and final laminate flooring panels.***

***Abrasion resistant***

Surface abrasion was determined using 100mm x 100mm samples (including a hole in the center) and Taber Abrasion tool seen in Fg. 2 left. The 100 sand sandpapers were attached to the weight wheels. For each 100 revolutions, sample surfaces were checked, and sandpapers were changed per 200 tours. As can be seen in Fig. 2 right, the first abrasion presents the initial removal of the patterns and when the patterns became invisible (or completely removed through the circle) test was finished. Therefore, abrasion resistance was calculated using the Eq. 1.

$$AR = \frac{(IRP + FRP)}{2} \qquad (1)$$

where: *AR* is the abrasion resistance (revolution);
IRP and FRP are the initial and full removal of the pattern, respectively.


***Fig. 2.***
***Taber Abraser and tested samples.***

***Scratch resistance***

The scratch test was performed to determine the scratch resistance of the surface and to reveal the maximum load without creating a permanent surface scratch. As seen in Fig. 3, measurements were done using 100mm x100mm samples which had a hole in the center. The surface of the samples was cleaned using a cotton fabric containing acetone. A diamond tip, rotates 360°, applied loads on the surface starting from 3 N and increases by 0.5 steps to 6 N. When continuous scratch (1 mm gaps between the scratch lines) occurred on the surface, the test ended, and values were noted.


***Fig. 3.***
***Scratch resistance test.***

***Small ball test***

A carbon paper was placed on the sample (Fig. 4 left). To apply 15, 20, 25, and 30 N load on the sample surface the dropping distance of the ball is increased each time. Following each drop, the surface was cleaned, and marks left by the ball were marked. Whatever force is applied to the specified point and the ball is thrown, that value was determined as a small ball test result.

***Fig. 4.***
***Small ball test (AC3≥ 10 mm, BS-EN 13329+A1) (left) and cure test solution (right).***

***Cure test***

As can be seen in Fig. 5, a solution, prepared by 37% hydrochloric acid (HCl) and Rhodamine B, dropped on the sample surface. Five minutes after dripping, the surface was cleaned using a cotton fabric containing alcohol. Penetration ability of the solution and cloudiness or obliqueness of the surface were evaluated according to the tone of the pink color. It is desired that the parquet surface has no pink color. It is not desired to have a pink color on the surface.

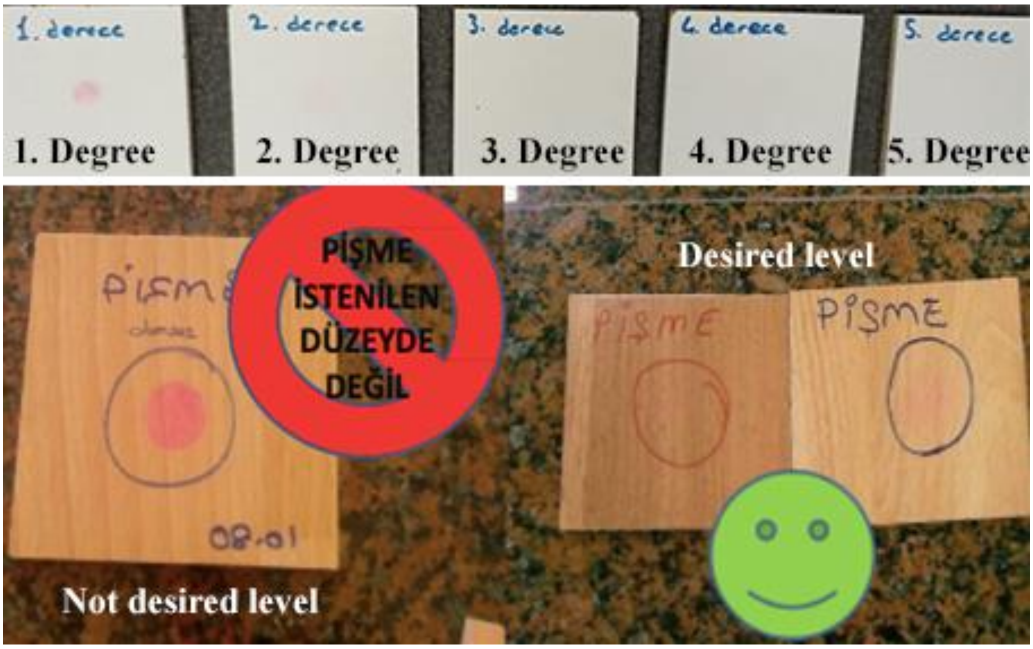


***Fig. 5.***
***Cure test samples***

*Table 1*

***Experimental design of products***

<table>
<tr><td rowspan="2">Product Groups</td><td colspan="2">Decor Paper (gr m⁻²)</td><td colspan="2">Overlay Paper (gr m⁻²)</td><td>Corundum (gr m⁻²)</td></tr>
<tr><td>Raw</td><td>Final</td><td>Raw</td><td>Final</td><td>$Al_2O_3$</td></tr>
<tr><td>A1</td><td rowspan="6">40 (Gray Oak)</td><td rowspan="3">105</td><td rowspan="9">18</td><td rowspan="9">90</td><td>12</td></tr>
<tr><td>A2</td><td>10</td></tr>
<tr><td>A3</td><td>8</td></tr>
<tr><td>B1</td><td rowspan="3">115</td><td>12</td></tr>
<tr><td>B2</td><td>10</td></tr>
<tr><td>B3</td><td>8</td></tr>
<tr><td>C1</td><td rowspan="3">50 (Alaçatı)</td><td rowspan="3">115</td><td>12</td></tr>
<tr><td>C2</td><td>10</td></tr>
<tr><td>C3</td><td>8</td></tr>
</table>

**RESULTS AND DISCUSSION**

The averages of the properties are presented in Table 1. Revolution counts for surface abrasion ranged from 2400-5600 but the average is 2667 to 5000 (Fig. 4). When considering the BS EN 13329+A2 (2021), the abrasion classes (AC) of the A1 and B1 groups is AC4 (≥4000). Therefore, these groups meet the general use for commercial purposes. The rest of the groups were AC3 (≥2500) and are suitable for heavy use for domestic and moderate use for commercial purposes. Furthermore, abrasion resistance ranged from 4.5 to 5.5 N which is around 28.6% to 57.1% higher than the 3.5 N of the standard value.

Kara *et al.* (2016) reported 3150 to 3650 rev. abrasion for laminate floor composed of 7.3 mm thick HDF core (1:1 *Pinus nigra* and *Fagus orientalis* fiber mixture). Kara *et al.* (2022) reported 4000 rev. (Brand A @23 gr $m^{-2}$ corundum and 140 gr $m^{-2}$ overlay paper final weight) to 5000 rev. (Brand B @28 gr $m^{-2}$ corundum and 140 gr $m^{-2}$ overlay paper final weight) for surface abrasion of laminate floor manufactured using 8 mm thick and 870 kg $m^{-3}$ density HDF core which was composed of 1:1 *Pinus nigra* and *Fagus orientalis* fibers (5% MC) binded by MUF (9 wt% and 60 wt% solid content). The authors also expressed that surface abrasion increased (4.4 to 15% varying by the corundum brand) when the corundum amount increased from 23 to 28 gr $m^{-2}$. In this study, when corundum amount increased from 8 to 10 and 12 gr $m^{-2}$,

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A2 and A1 23.4% and 31.9%, B2 and B1 21.7% and 63%, and C2 and C1 17.5 and 40% increased within the final décor paper amount, respectively. In this study, the overlay paper's final weight was fixed for all products. However, Kara *et al.* (2022) reported that abrasion 4.4% and 4.8% decreased by the increase in overlay paper final weight when the corundum amount was 23 gr $m^{-2}$, and a 4.2% increase was observed when the corundum amount was 28 gr $m^{-2}$. For this contradiction, further studies should be carried out. As can be seen in Table, abrasion resistance of A and B type products around 5.5 and 5.7% decreased when the corundum amount increased from 8 to 12 gr $m^{-2}$, and no differences were observed between 10 and 12 gr $m^{-2}$ groups. Contrarily, 4.4 and 6.7% increases were observed for C-type products when corundum increased from 8 to 10 and 12 gr $m^{-2}$, respectively.

The reported surface scratch is 4 N to 5 N (Kara *et al.* 2022). Kara *et al.* (2016) reported 20 to 25.25 N impact resistance (large diameter ball). As can be seen in Table 1, the impact resistance averages of the groups ranged from 70 to 90 N and the impact class (IC) of the groups is IC2. A stable influence of corundum on the impact resistance was not observed because, C-type products presented a linear decrease, while others fluctuated. The adverse effects ranged from 11.1 to 22.2%.

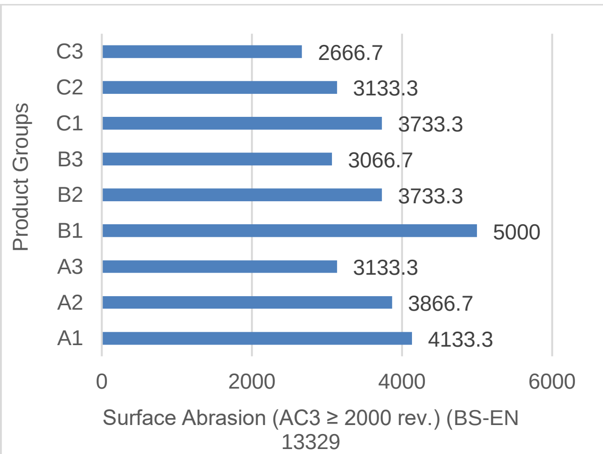
The cure values of the products ranged from 4 to 5. C-type products presented the lowest values and positive relationship between corundum by 7.5% and 17.5% increase with the increase from 8 to 10 and 12 gr $m^{-2}$, respectively. On the other hand. There is no difference between A and B-type products.

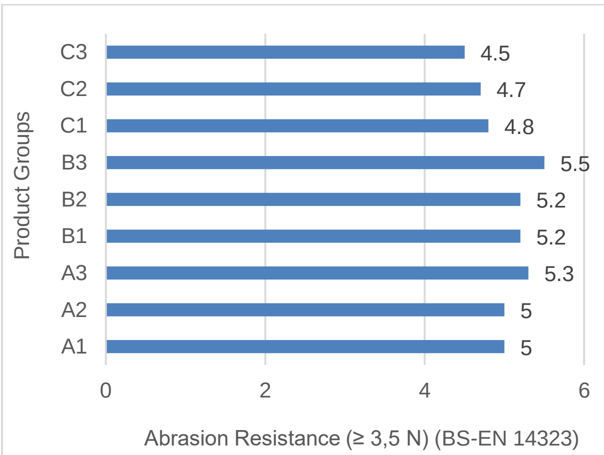
*Table 2*

***Averages of the tests***

| Product Groups | Surface Abrasion (Rev.) (BS-EN 13329) | | | Abrasion Resistance (N) (≥ 3,5 N) (BS-EN 14323) | | | Impact Resistance-Small Ball (≥ 10 mm) (BS-EN 13329) | Cure (1-2-3-4-5) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Left | Mid. | Right | Left | Mid. | Right | Mid. | Left | Mid. | Right |
| **A1** | 4000 | 4600 | 3800 | 5 | 5 | 5 | 80 | 5 | 5 | 5 |
| **A2** | 3600 | 4200 | 3800 | 5 | 5 | 5 | 70 | 5 | 5 | 5 |
| **A3** | 3000 | 3200 | 3200 | 5.5 | 5 | 5.5 | 90 | 5 | 5 | 5 |
| **B1** | 4800 | 5600 | 4600 | 5.5 | 5 | 5 | 90 | 5 | 5 | 5 |
| **B2** | 3600 | 4000 | 3600 | 5.5 | 5 | 5 | 80 | 5 | 5 | 5 |
| **B3** | 3200 | 3000 | 3000 | 5.5 | 5.5 | 5.5 | 90 | 5 | 5 | 5 |
| **C1** | 3800 | 3800 | 3600 | 5 | 4.5 | 5 | 70 | 5 | 4 | 5 |
| **C2** | 3000 | 3200 | 3200 | 5 | 4.5 | 4.5 | 80 | 5 | 4 | 4 |
| **C3** | 2600 | 2400 | 3000 | 4.5 | 4.5 | 4.5 | 90 | 4 | 4 | 4 |

Increase in décor paper final weight (105 to 115 gr $m^{-2}$) caused 21%, 4%, 12.5%, and 4%, -3.4%, 4%, 14.3%, and 4%, and -2.1%, 3.8%, 0%, and 3.8% differences between A1 to B1, A2 to B2 and A3 to B3 in SA, AR, IC, and cure for 12 gr $m^{-2}$, 10 gr $m^{-2}$, and 8 gr $m^{-2}$ corundum amounts, respectively. It cannot be considered that the influence of décor paper on laminate floor products is fully revealed.



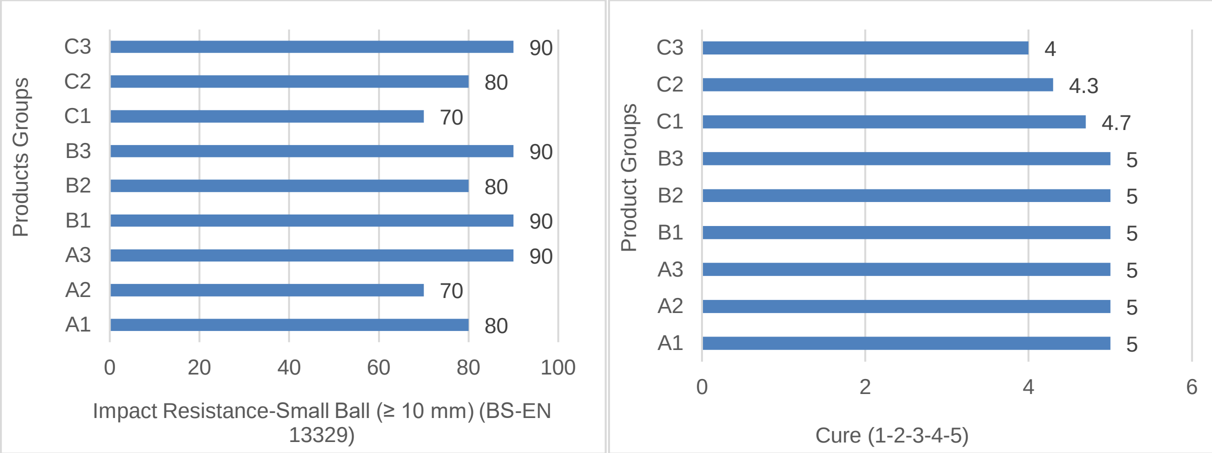



***Fig. 6.***
***Products properties.***

Besides the advantages of laminate floors, parameters, and raw materials such as chemicals used in the production should be well-defined because the final product may cause various emissions either in installation or in service (Yetiş and Tuna Kayili 2021).

Press pressure has significant influences on surface strength impact resistance and abrasion resistance of the laminate floor. Furthermore, press duration significantly influences the abrasion resistance ($P<0.05$) (Kara *et al.* 2016). Nandipati and Suman (2021) stated that abrasion resistance is dependent on the curing temperature for laminated PB. It should be kept in mind that “A laminate floor is made up of multiple layers that have resin and heat-pressure bonded together. A thin layer of synthetic overlay and a decorative design layer cover the floor's surface. Thick high-density fiberboard (HDF) composite makes up the floor's core, which supports the outer layers. An impermeable base layer that acts as a moisture barrier and structural stabilizer supports the laminate (Arenas and Sepulveda 2022). Furthermore, because of the expansion of the residential and commercial building industries, there is an unprecedented demand for wood flooring products. Wood flooring is becoming more and more popular because of its inherent wear resistance, hypoallergenic nature, and aesthetic appeal when compared to other floor finishing materials like vinyl, concrete, ceramic tile etc. (Nandipati and Suman 2021). Therefore, a comprehensive study that evaluates both material and production parameters may provide valuable data.

## CONCLUSION

When considering the final amounts of the décor and overlay paper, B-type products presented better performance than others. Results proved that all product types fulfill the BS EN 13329:2021 requirements in terms of evaluated properties. The experimental design of this study was limited to the effect of production parameters (décor and overlay papers, and corundum amounts) on six different factory-manufactured laminate floor products. However, further studies including all aspects of related standards should provide valuable data for producing advanced, economical, and sustainable products.

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## DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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