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## **COMPARATIVE STUDIES OF FURNITURE LACQUER COATINGS' RESISTANCE TO LINEAR SCRATCHING ACC. TO THE METHOD DESCRIBED IN TS 15186:2005**

*The article presents results of comparative studies of the resistance of lacquered furniture surfaces to linear scratching. The studies were performed in cooperation with industrial laboratories and using a new method for evaluation of this functional property of the surface. The effect of the studies performed was the assessment of reproducibility and repeatability of the test final results for tested set of furniture surfaces. The results of the studies also served to assess the differentiation of furniture surfaces in terms of their resistance to scratching.*

**Keywords:** furniture surface, surface resistance to linear scratching, reproducibility of the scratch test final result, repeatability of the scratch test final result, differentiation of furniture surfaces

### **Introduction**

Resistance to scratching is a functional property of furniture surfaces that is important in both furniture production processes and furniture service life. This property together with other essential features of furniture surface coatings, such as abrasibility and impact value, decides the coating mechanical resistance, especially by reflecting its hardness. Hence, the resistance to scratching is also called the scratch hardness. The wood-based substrate also influences furniture surface resistance to scratching, but this influence is significant only when the coating applied on this substrate is thin, i.e. of the thickness of less than 50  $\mu\text{m}$ , and the substrate is characterised by considerable heterogeneity. Testing of coating's resistance to scratching is a subject considered in theoretical approach concerning complex phenomena connected with the appearance of scratches on coatings made of various lacquer products [Shen 2006a, b], as well as in practical approach concerning usefulness and credibility of defined methods for testing this surface property [Emmler, Nothelfer-Richter 2005; Krzoska-Adamczak 2001].

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For many years the Clemen method, described in PN-65/C-81527, was the procedure used for testing resistance of furniture surfaces to scratching. In that method a steel graver with the sintered carbide tip of defined geometry serves as the scratching tool. That method was intended for testing lacquer coatings cured on standardised steel plates. Therefore, if used for testing coatings produced on porous wood or wood-based substrates, the impossibility of unambiguous determination of minimum tip load, which causes appearance of a continuous visible scratch without damaging the substrate's structure, often was pointed out. Another method for assessment of coating resistance to scratching that was used in Poland was the procedure according to PN-88/F-06100-11 which employed sapphire gramophone needle as the scratching tool. That method was used to evaluate hardness of coatings on furniture surfaces by determining the tip load causing appearance of a scratch of the width of 50  $\mu\text{m}$  [Paprzycki, Serafinowska 1990]. Another way of evaluation of lacquer coating resistance to scratching is the method described in BN-78/6110-03 which employs a set of graphite pencils by "Koh and Noor" in which there are pencils of 17 standardised graphite hardness values. Nominally this procedure is used for determination of so-called pencil hardness of lacquer coatings cured on a steel or glass plate. The scratch test according to Taber is an example of another, less known, method for determination of lacquer coating resistance to scratching. This test is used in comparative studies of functional resistance of coatings produced from various products [Lange et al. 1997; Poitoux 2006]. A separate group consists of workshop methods that are applied in current rough assessment of coating resistance to scratching. Amongst these methods is the procedure using 318 DBGM tool according to Erichsen or so-called "coin test" performed using, for instance, the Hamberger Planer device (coin). These test methods are not standardised.

In the last few decades tests of furniture surface resistance to scratching, depending on the type of tested furniture finish and specification of requirements [Krzoska-Adamczak 1996,1999], have been carried out according to methods described in the following standards: EN 438-2:1991, EN 438-2:2005, ISO 1518:1992, and SIS 839117:1973 [Krzoska-Adamczak 2001]. Except for the procedure according to EN 438-2:2005, the principles of methods described in the other above-mentioned standards are similar, i.e. all the methods look for the least load of the tip of defined geometry which will produce on tested furniture surface a visible or measurable trace of a scratch of defined continuity or width. The diversification of basic elements of the above-mentioned test methods caused a lack of possibility of unambiguous comparison of the final results of tests for resistance to scratching carried out using these methods. This fact was an important reason for taking up methodological research on development of a new method for assessment of surface resistance to scratching which would encompass a wider range of furniture finishes. An original method of testing furniture surface resistance to scratching was developed under the Euro-

pean research project entitled "Test methods on wear resistance and long-term stability of furniture surfaces" (FUNFACE) [Banecki et al. 2004; Emmmler et al. 2004, 2005; Krzoska-Adamczak, Nowaczyk 2004a]. The said test procedure was validated by carrying out two series of inter-laboratory comparative tests in co-operation with the research laboratories which participated in FUNFACE project. The conclusions from those comparisons were used to appropriately modify the preliminary version of the method, and then to draw up a draft of a technical standard containing the modified test procedure [Krzoska-Adamczak, Nowaczyk 2004b].

The developed test method was granted the status of technical requirements and is described in technical standard TS 15186:2005 as method A. The method is characterised by such things as: optimised geometry of the scratching diamond tip, new definition of the scratch trace which is independent of the type of furniture surface finish (all finishes except for laminate coatings), and an objective way of the scratch assessment based on the scratch width measurement. The results of successive comparative studies of the developed method and procedures according to EN 438-2:1991 and SIS 839117:1973, carried out in two series of tests on 11 different furniture surfaces in the laboratory of the Wood Technology Institute (ITD) in Poznan, allowed a statement that test procedures according to TS 15186 (method A) and SIS 839117 to a large extent differentiate furniture surfaces finished with various materials (clear lacquers, enamels, foils, short cycle laminates) [Banecki, Krzoska-Adamczak 2007]; however, the procedures demonstrate a bit worse repeatability of the test final result (90%) compared with the method according to EN 438-2:1991 (100%). Moreover, a strong linear correlation between method A described in TS 15186 and the procedure set forth in SIS 839117 was proved. The results of the analyses allowed a conclusion that method A described in TS 15186 can replace the procedure according to SIS 839117:1973. As a result of successive standardisation activities carried out in the framework of CEN/TC207/WG7, method A described in the above-mentioned technical standard, after taking into account only some minor corrections, was included in a draft of EN 15186:2010. Currently, this draft is being at the stage of public survey.

Within the framework of the programme of inter-laboratory comparative studies, the method for determination of surface resistance to scratching according to TS 15186 was presented to selected producers of lacquer products and furniture operating in Poland. Additionally, the reproducibility and repeatability of the final assessments of resistance to scratching, obtained for six different furniture surfaces in two test sessions, at each participating laboratory (5 entities) were evaluated. The article presents the results of those studies.

The aims of the studies were:

- to determine reproducibility and repeatability of the results of tests of furniture surface resistance to linear scratching carried out in industrial laboratories

and in the ITD laboratory using test method A described in technical standard TS 15186,

- to determine the ability of the test method applied to differentiate furniture surfaces.

The programme of the studies comprised:

- preparation of samples of board furniture elements (6 types) of surfaces finished in various ways, i.e.:
  - with lacquer coating made of pigmented solvent-based 2K products, also of high solids type, and of UV-cured products,
  - with lacquer coating made of thermosetting powder paint,
  - with tinted lacquer coating made of transparent 1K waterborne product,
- thickness measurements of lacquer coatings on the samples prepared for tests,
- acquaintance of selected industrial laboratories with the new test method during the informational and training meeting, organised by the ITD in Poznan, whose agenda contained such items as:
  - presenting description of the test method to the participants; the description was prepared in the ITD based on TS 15186 (method A),
  - carrying out by the qualified staff of the ITD laboratory demonstrative tests of resistance to scratching using the said test procedure,
  - common assessment of resistance to scratching of furniture surfaces subjected to demonstrative scratch tests,
- carrying out inter-laboratory tests by the participants, i.e. four industrial laboratories and the ITD laboratory were to carry out two series of tests of resistance to scratching of each of 6 furniture surfaces using the above-mentioned test method,
- performing an analysis of the test results as regards selected features of the test method applied (reproducibility and repeatability of the test final results furniture surfaces differentiation).

## Test materials

Board furniture elements of surfaces finished in various ways, 6 different types of surface finish, were used in studies. Those elements were: MDFs of different thicknesses, HDF, wet-pressed fibreboard, and particleboard covered with beech veneer; the boards were finished with pigmented or clear lacquer coatings. The board furniture elements used in comparative studies were produced in industrial conditions. Characteristics of the substrate material and its surface finish for every board furniture element is given in table 1.

**Table 1. Characteristics of furniture panels applied in comparative studies**  
**Tabela 1. Charakterystyka płytowych elementów meblowych zastosowanych w badaniach porównawczych**

Code of furniture surface <i>Kod powierzchni meblowej</i>	Substrate material <i>Material podłożowy</i>	Type of surface finish <i>Typ wykończenia powierzchni</i>	Average thickness of lacquer coating <sup>1)</sup> [μm] <i>Średnia grubość pokrycia lakierowego<sup>1)</sup> [μm]</i>
PM – 1	MDF (18 mm) <i>Płyta MDF o grubości 18 mm</i>	3-layer coating made of solvent-based pigmented 2K PUR lacquers of High Solids type (HS) <i>Pokrycie lakierowe 3 – warstwowe wytworzone z rozpuszczalnikowych poliuretanowych wyrobów kryjących (2K) typu high solids</i>	71
PM – 2	Wet-pressed fibre-board (3 mm) <i>Mokro formowana płyta pilśniowa o grubości 3 mm</i>	Pigmented lacquer coating made of UV-cured products of HS type <i>Pokrycie lakierowe wytworzone z emalii typu high solids utwardzonej promieniowaniem UV</i>	21
PM – 3	MDF (16 mm) <i>Płyta MDF o grubości 16 mm</i>	3-layer coating made of solvent-based pigmented 2K Ac lacquer in base and top layers <i>Pokrycie lakierowe 3 – warstwowe wytworzone z akrylowej rozpuszczalnikowej emalii (2K) w warstwach podkładowej i nawierzchniowych</i>	230
PM – 4	HDF (3 mm) <i>Płyta HDF o grubości 3 mm</i>	5-layer coating made of UV-cured Ac putties, base Ac lacquers and top Ac enamel <i>Pokrycie lakierowe 5 – warstwowe wytworzone z użyciem szpachlówek akrylowych, wyrobów podkładowych i nawierzchniowej emalii akrylowej utwardzonych promieniowaniem UV</i>	39
PM – 5	MDF (19 mm) <i>Płyta MDF o grubości 19 mm</i>	Structured coating made of low bake thermosetting powder paint <i>Powłoka strukturyzowana wytworzona z użyciem niskotemperaturowej termoutwardzalnej farby proszkowej</i>	286
PM – 6	Particleboard (18 mm) covered with beech veneer (0.5 mm) on both sides <i>Płyta wiórowa o grubości 18 mm oklejona dwustronnie formirem bukowym (0,5 mm)</i>	3-layer coating made of water-based stain and waterborne 1K Ac transparent lacquer in base and top layer <i>Pokrycie lakierowe 3 – warstwowe wytworzone z użyciem bejcy wodnej, warstwy podkładowej i warstwy nawierzchniowej z akrylowego wyrobu wodorozcieńczalnego (1K)</i>	91

<sup>1)</sup> Presented values were calculated on the basis of results of thickness measurements

<sup>1)</sup> Podane wartości obliczono na podstawie wyników 10 jednostkowych pomiarów grubości

Samples of board furniture elements intended for comparative studies were prepared in the ITD in Poznan. Preparation of the samples included:

- cutting to size of test samples of the dimensions of (10×10×thickness) cm,
- marking cut-to-size samples with a description code containing information on: participant of studies, furniture surface, test series, and test sample number,
- seasoning and conditioning of test samples in the period of 4 weeks preceding performance of scratching resistance tests in a given laboratory; samples were conditioned for 7 days in a Thermocold KK-08 climatic chamber under normal conditions: temperature of  $23\pm 2^{\circ}\text{C}$  and relative humidity of  $50\pm 5\%$ ,
- after the 3-week period of seasoning and the 7-day conditioning, sets of test samples were put into plastic packaging (polyethylene foil) protecting the samples' surfaces from possible scratching during transport to target industrial laboratory.

The thickness of lacquer coatings of furniture elements for testing was measured by the ultrasonic method. The thickness measurement was done using a QuintSonic PRO ultrasonic thickness gauge by Elektro-Physik GmbH. The final result of measurements for a given surface finish variant was the arithmetic mean value from ten thickness measurements taken at randomly selected points of tested furniture surfaces (table 1).

## Test methods

To acquaint industrial laboratories with the test method intended for use in comparative studies, the following forms of transfer were applied:

- passing on the information on the developed test procedure in the form of Power Point presentation together with commentary during the informational and training meeting organised in the ITD,
- demonstration of making a linear scratch on a furniture surface and taking measurements of the widths of scratches produced on the demonstrative surface,
- demonstration of apparatuses used in the ITD laboratory for making surface scratch and taking measurements of the width of scratches produced on the surface.

The following industrial partners participated in the inter-laboratory comparative studies: Becker Acroma Polska Sp. z o.o., Czerska Fabryka Mebli KLOSE Sp. z o.o., Fabryka Mebli BALMA S.A., and Fabryka Mebli FORTE S.A. Division in Suwałki. The fifth participant of the studies was the Wood Technology Institute (ITD) in Poznan. Individual laboratories taking part in the studies were randomly marked with the codes: LAB1 – LAB5.

Tests of resistance of described furniture surfaces to linear scratching were performed by each of the above-mentioned participant at the time suitable for them within the period from August to November 2008. All participants of comparative studies carried out 2 series of surface scratching resistance tests of each of the

6 furniture surfaces using method A described in TS 15186. A departure from that methodical description, which occurred during execution of tests in all participating laboratories, was taking measurements of the width of scratches produced on the tested surfaces only by 2 observers using the same optical measuring device. The scratch width measurement was taken in its middle part.

To carry out the scratch tests and assess scratches produced on tested furniture surfaces, particular laboratories applied the following testing and measuring apparatuses as well as auxiliary materials:

- device for surface linear scratching – Scratch Hardness Tester model 239/II by Erichsen GmbH & Co KG – equipped with electric drive allowing tip's movement with the velocity of  $20 \pm 10$  mm/s in the range of its load  $1 \div 20$  N,
- diamond scratching tip of cone geometry: radius of tip's rounded part  $R = 0.30 \pm 0.01$  mm, cone angle  $\alpha = 60 \pm 1^\circ$ ,
- measuring stereoscopic microscope – MOTIC model SMZ-140/143 – of the magnification range of  $10 \div 40\times$ , equipped with digital camera MOTICAM 2000, co-operating with the computer programme Motic Images Plus in the scope of its measuring function, allowing scratch width measurement with the uncertainty of  $\pm 0.01$  mm,
- workshop measuring microscope by PZO of the magnification of  $20\times$  allowing scratch width measurement with the uncertainty of  $\pm 0.01$  mm,
- graphite of HB hardness and water-soluble ink (black) as materials for contrasting the route of scratch edges on tested furniture surfaces.

The reproducibility of the test final result in laboratories participating in the comparison was assessed for a given test object, i.e. for a defined furniture surface and within a given test series, using the value of variation coefficient of scratch test final result. Taking into account values of variation coefficient of scratch test final result calculated for individual furniture surfaces, mean values of that coefficient were determined for each of two test series. Those values characterised average level of variability of the final results in 5 laboratories participating in the comparison, corresponding with the set of furniture surfaces used in the tests.

The following criterion was adopted for the need of assessment of repeatability of the final result of test of furniture surface resistance to scratching:

“The final result of scratch resistance test is considered repeatable for a given furniture surface if final results of its resistance obtained in the same laboratory in two consecutive test series do not differ between one another by more than 1 N” [Banecki, Krzoska-Adamczak 2007; Krzoska-Adamczak, Nowaczyk 2004b]. Applying the hereinbefore described repeatability criterion to each laboratory participating in the comparison, the percentage share of furniture surfaces for which the criterion was fulfilled was determined. The calculated percentage share was considered the measure of repeatability of the test final result in a given laboratory for the set of furniture surfaces used.

For the assessment of differentiation of furniture surfaces by the test method applied, it was assumed in the carried out tests that the measure of that differentiation was the parameter defined by equation (1):

$$D = \frac{(Max. - Min. )}{\Delta L} \times 100 \quad (1)$$

where: D – degree of furniture surfaces differentiation as regards their resistance to scratching determined by using the test method applied, %,

Max ÷ maximum resistance to scratching which was observed amongst furniture surfaces subjected to tests, N,

Min. ÷ minimum resistance to scratching which was observed amongst furniture surfaces subjected to tests, N,

$\Delta L$  – difference between maximum and minimum load of the scratching tip applied in the test method used – it was the interval of the tip loads in the method applied, N.

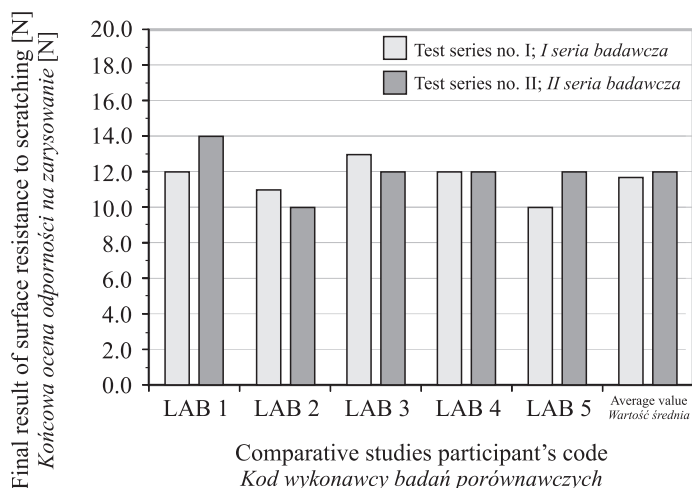
The value of the degree of furniture surfaces differentiation as regards their resistance to scratching was determined for every laboratory participating in the comparison, separately for the first (I) and the second (II) test series. The divergence in values of that parameter amongst individual laboratories were evaluated by determination of the value of variation coefficient of the degree of surfaces differentiation in test series I and test series II.

## Discussion of test results

Fig. 1-6 present values of final results of resistance to scratching of furniture surfaces PM-1 to PM-6, respectively, in relation to the participant of comparative studies and the test series. The values of those results indicate high resistance to scratching of furniture surfaces PM-3 and PM-1 finished with lacquer coatings of chemo-hardened solvent-based products based on acrylic or urethane binders. Furniture surface PM-5, finished with structured coating of thermosetting powder paint, demonstrated comparable resistance to scratching. In the case of those three furniture surfaces, the influence of the substrate material on their scratch resistance was insignificant due to the thicknesses of respective lacquer coatings (over 50  $\mu\text{m}$  – table 1) and the fact that the substrate in all above-mentioned furniture surfaces was made of MDF, i.e. of a material of high homogeneity of surface and stable hardness. A different situation occurred in the case of furniture surfaces PM-2 and PM-4 finished with lacquer coatings of UV-cured acrylic products. Due to low thickness of those lacquer coatings (less than 50  $\mu\text{m}$ ), it should be recognised that the type of the substrate material had a bearing on scratch resistance of those furniture surfaces. Average values of final results of scratch resistance calculated for those furniture surfaces indicate clear difference in their resistance values, i.e.

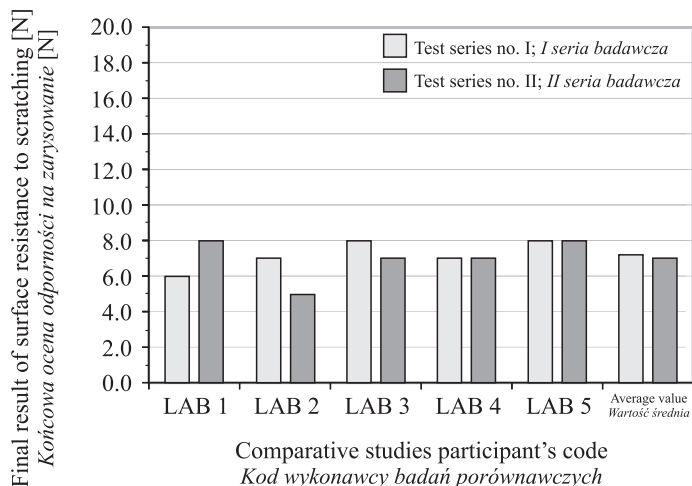


7.0 N for surface PM-2 (fig. 2) and 11.0 N for surface PM4 (fig. 4). The observed difference in scratch resistance values for both considered furniture surfaces may result from differentiation of hardness values of wet-pressed fibreboard and HDF, which were the substrates for those surfaces, and it may be an effect of the difference in average thicknesses of both lacquer coatings (table 1).



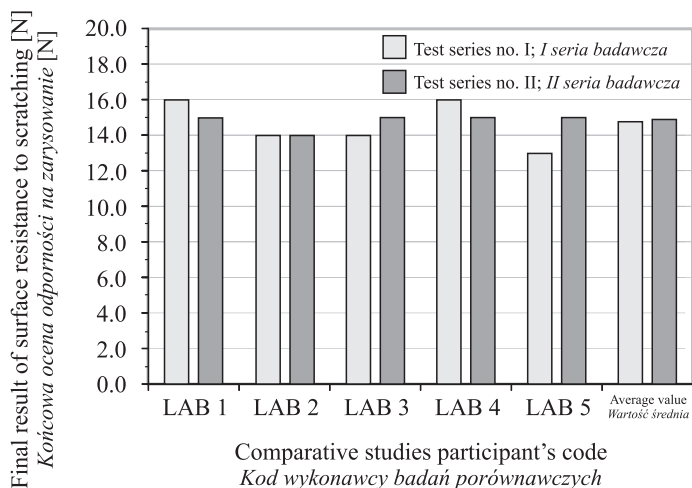
**Fig. 1. Final assessment of PM-1 surface resistance to scratching depending on the participant of comparative tests and the test series**

*Rys.1. Końcowy wynik badania odporności na zarysowanie powierzchni meblowej PM-1 w zależności od wykonawcy badania i serii badawczej*



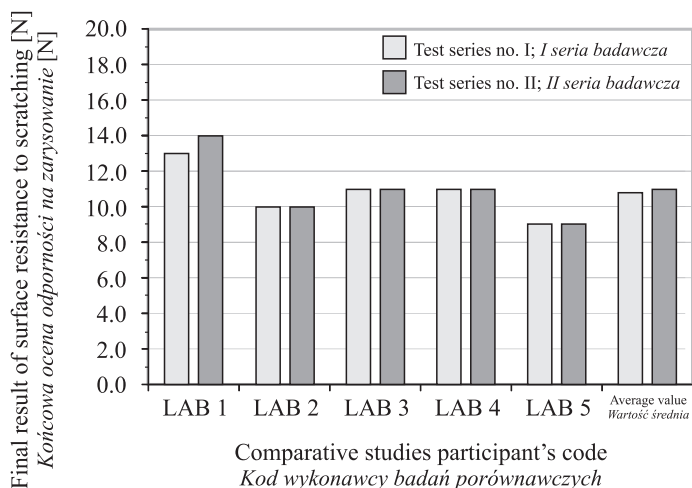
**Fig. 2. Final assessment of PM-2 surface resistance to scratching depending on the participant of comparative tests and the test series**

*Rys.2. Końcowy wynik badania odporności na zarysowanie powierzchni meblowej PM-2 w zależności od wykonawcy badania i serii badawczej*



**Fig. 3. Final assessment of PM-3 surface resistance to scratching depending on the participant of comparative tests and the test series**

*Rys.3. Końcowy wynik badania odporności na zarysowanie powierzchni meblowej PM-3 w zależności od wykonawcy badania i serii badawczej*

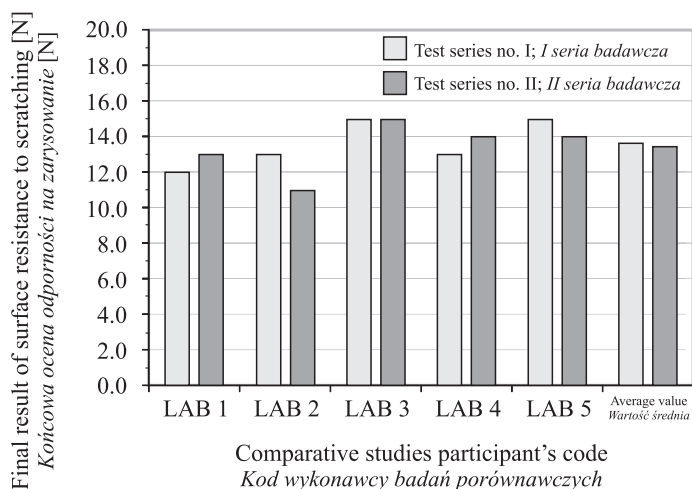


**Fig. 4. Final assessment of PM-4 surface resistance to scratching depending on the participant of comparative tests and the test series**

*Rys.4. Końcowy wynik badania odporności na zarysowanie powierzchni meblowej PM-4 w zależności od wykonawcy badania i serii badawczej*

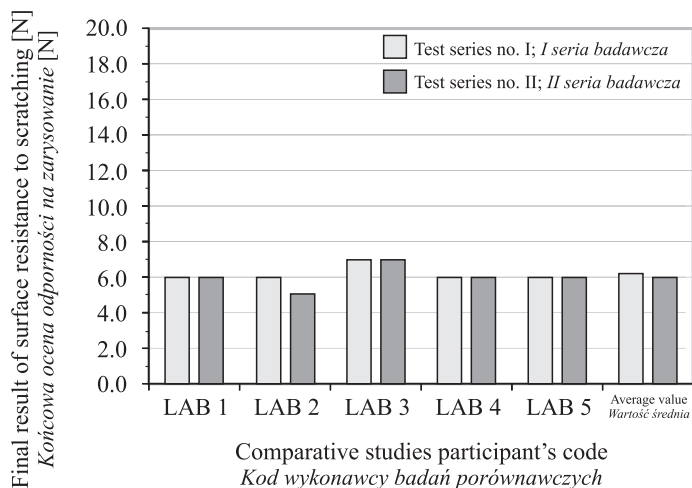
The last of tested furniture surfaces marked with the code PM-6 demonstrated the lowest scratch resistance at the level of 6.0 N (fig. 6). This test result probably reflects low hardness of the lacquer coating produced from waterborne product dried in the air in relation to much harder substrate which was beech veneer. Nevertheless, it should be noticed that average thickness of the lacquer coating on

furniture surface PM-6, which was about 90  $\mu\text{m}$ , limited the influence of the substrate material on the coating's scratch resistance.



**Fig. 5. Final assessment of PM-5 surface resistance to scratching depending on the participant of comparative tests and the test series**

*Rys.5. Końcowy wynik badania odporności na zarysowanie powierzchni meblowej PM-5 w zależności od wykonawcy badania i serii badawczej*

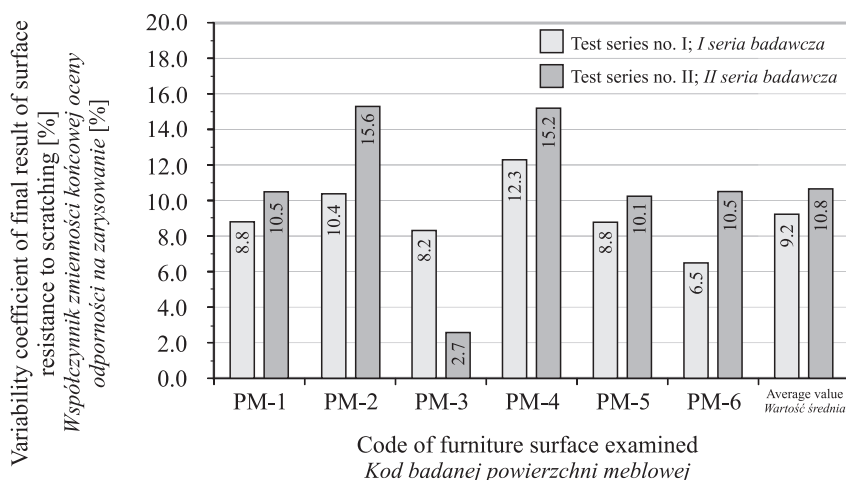


**Fig. 6. Final assessment of PM-6 surface resistance to scratching depending on the participant of comparative tests and the test series**

*Rys.6. Końcowy wynik badania odporności na zarysowanie powierzchni meblowej PM-6 w zależności od wykonawcy badania i serii badawczej*

Based on the values of scratch resistance final results, presented in fig. 1-6, the analysis of their variability was carried out amongst laboratories participating

in the comparative studies of a given furniture surface. Fig. 7 illustrates results of that analysis carried out for particular tested surfaces within each of the two test series separately. The values of variability coefficient of the final result of scratch resistance suggest that reproducibility of the final result of the test carried out using method A according to TS 15186 was not satisfactory for furniture surfaces PM-2 and PM-4 within both test series no. I and test series no. II. The variability of final results obtained by individual participants of the comparative studies for furniture surfaces PM-1 and PM-5 was at the level close to 9% (in test series no. I) and to 10% (in test series no. II). Therefore, reproducibility of the test final result for those objects was clearly better than in the case of surfaces PM-2 and PM-4. The final results determined for furniture surfaces PM-3 and PM-6 were characterised by relatively lowest variability, which indicates the best reproducibility of the test final result obtained for those surfaces. It should be noticed that furniture surface PM-3 demonstrated high reproducibility of the scratch resistance final result in individual laboratories, especially in test series no. II (fig. 7).



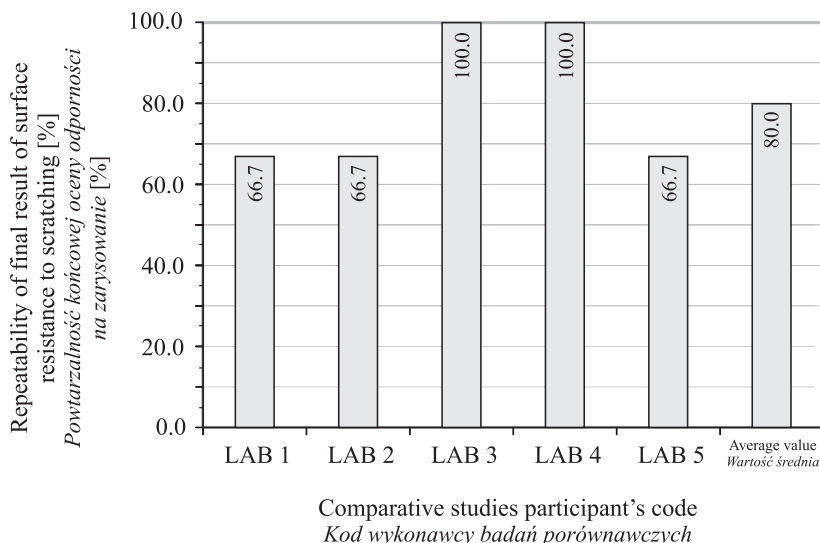
**Fig. 7. Variability of final results of surface resistance to scratching among the laboratories participating in comparative tests, depending on the furniture surface examined and the test series**

*Rys. 7. Zmienność końcowych ocen odporności na zarysowanie w laboratoriach uczestniczących w badaniu porównawczym, w zależności od badanej powierzchni meblowej oraz serii badawczej*

Averaging the values of variability coefficient of scratch resistance final result for all tested furniture surfaces, separately within each of the test series, allows a statement that in both test series the average level of variability of final results in 5 laboratories participating in the comparison was around 10% ( $v_{av.} = 9.2\%$  for test series no. I and  $v_{av.} = 10.8\%$  for test series no. II), see fig. 7.

Table 2 presents comparison of scratch resistance final results determined for particular furniture surfaces within the two consecutive test series in each of the laboratories participating in the comparative studies. Taking advantage of the values of final results given in this table, it was verified whether defined repeatability criterion was fulfilled for the individual objects of comparative tests. Based on the results of the verification, it may be said that only for two of six tested furniture surfaces, i.e. for surfaces PM-4 and PM-6, the assumed repeatability criterion was met irrespective of test performer.

Table 2 also gives calculated percentage shares of furniture surfaces for which the observed convergence of scratch resistance final results was consistent with defined repeatability criterion within each of the laboratories participating in the studies. In the case of three participants of the comparative tests, i.e. LAB1, LAB2, and LAB5, such a convergence of final results was observed for four of six tested surfaces; whilst in the other two laboratories, i.e. LAB3 and LAB4, fulfilment of assumed repeatability criterion was observed for all tested surfaces which meant 100% repeatability of scratch resistance final results (fig. 8). Taking into consideration percentage shares of furniture surfaces for which the defined criterion was fulfilled, calculated for individual comparative studies participants, average repeatability of the test final result was determined for all 5 laboratories taking part in the comparison. The calculated average value was 80% (fig. 8). This value was by around 10% lower compared to repeatability of scratch resistance final results determined by using the same test method, but for a set of 11 various furniture surfaces tested exclusively in the ITD laboratory [Banecki, Krzoska-Adamczak 2007].



**Fig. 8. Repeatability of the final result of surface resistance to scratching**  
**Rys. 8. Powtarzalność końcowego wyniku badania odporności powierzchni na zarysowanie**

**Table 2. Evaluation of scratch tests final results repeatability within two test series depending on the participant of comparative studies**  
**Tabela 2. Ocena powtarzalności końcowego wyniku badania odporności na zarysowanie w zależności od wykonawcy badania porównawczego**

Code of furniture surface tested Kod badanej powierzchni meblowej	Final result of surface resistance to scratching [N] Końcowa ocena odporności na zarysowanie [N]												
	LAB 1		LAB 2		LAB 3		LAB 4		LAB 5		Repeatability criterion fulfillment <sup>1)</sup> Spełnianie kryterium powtarzalności <sup>1)</sup>	Repeatability criterion fulfillment <sup>1)</sup> Spełnianie kryterium powtarzalności <sup>1)</sup>	
	Test series I I seria	Test series II II seria	Test series I I seria	Test series II II seria	Test series I I seria	Test series II II seria	Test series I I seria	Test series II II seria	Test series I I seria	Test series II II seria			
PM-1	12.0	14.0	11.0	10.0	13.0	12.0	12.0	12.0	10.0	12.0	+	+	-
PM-2	6.0	8.0	7.0	5.0	8.0	7.0	7.0	7.0	8.0	8.0	+	+	+
PM-3	16.0	15.0	14.0	14.0	14.0	15.0	15.0	15.0	13.0	15.0	+	+	-
PM-4	13.0	14.0	10.0	10.0	11.0	11.0	11.0	11.0	9.0	9.0	+	+	+
PM-5	12.0	13.0	13.0	11.0	15.0	15.0	13.0	14.0	15.0	14.0	+	+	+
PM-6	6.0	6.0	6.0	5.0	7.0	7.0	6.0	6.0	6.0	6.0	+	+	+
Repeatability <sup>2)</sup> [%]	66.7		66.7		100.0		100.0		100.0		100.0		66.7

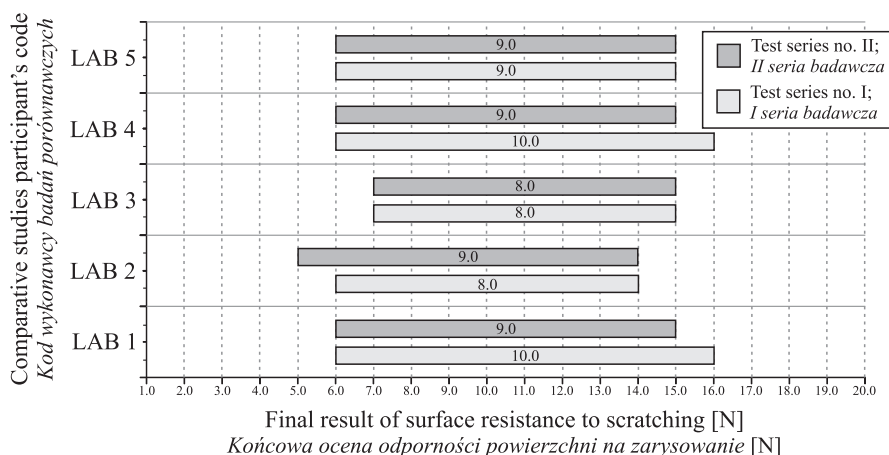
1) Mark “+” means that defined final result repeatability criterion was fulfilled, whereas mark “-” indicates that this criterion was not fulfilled.

1) Znak “+” oznacza, że zdefiniowane kryterium powtarzalności końcowego wyniku badania zostało spełnione, natomiast znak “-” wskazuje, że to kryterium nie zostało spełnione.

2) Final result repeatability was calculated as the ratio of quantity of furniture surfaces which fulfil defined repeatability criterion to total quantity of furniture surfaces subjected to scratch tests, expressed in percentage.

2) Powtarzalność końcowego wyniku badania obliczono jako udział procentowy powierzchni badanych powierzchni meblowych, dla których w I i II serii badawczej stwierdzono zbieżność końcowych ocen odporności na zarysowanie zgodną ze zdefiniowanym kryterium powtarzalności.

Differentiation of tested furniture surfaces is illustrated in fig. 9 by the width of the dispersion interval of final results of scratch resistance of those surfaces. Data presented in fig. 9 allows a statement that the average width of the dispersion interval of final results calculated for all comparative studies participants was 9 N in test series no. I and 8.8 N in test series no. II. Therefore, it may be accepted that at the level of the average values, the differentiation of tested surfaces was very similar in test series no. I and no. II. Taking into account unit values, it should be noticed that in the case of laboratories LAB1 and LAB4 the width of the dispersion interval of final results in test series no. I exceeded the average value and reached 10 N; whereas in test series no. II the width of that interval was at the level of the average value (9 N). In the case of laboratory LAB3 the widths of dispersion of final results were the same in both test series and distinctly less than the average value. Similarly as in the case of laboratory LAB3, final results obtained by laboratory LAB5 also were evenly dispersed in both test series, but the width of their dispersion corresponded with the average value (fig. 9).



**Fig. 9. Dispersion intervals of final results of scratch resistance of furniture surfaces examined depending on the participating laboratory and the test series**

*Rys.9. Przedziały rozproszenia wartości końcowych ocen odporności na zarysowanie zbadanych powierzchni meblowych w zależności od wykonawcy badania i serii badawczej*

Table 3 presents values of the furniture surface differentiation degree while using method A according to TS 15186. The values were calculated based on the widths of dispersion intervals of scratch resistance final results. Depending on the test performer, calculated values fluctuated between 42% and about 53% in test series no. I and between 42% and 47% in test series no. II. In table 3 variability of the furniture surface differentiation degree among laboratories participating in the comparison was evaluated. The values of variability coefficient given in table 3 suggest that variability of the surface differentiation degree within the set of fur-

niture surfaces used in studies in 5 different laboratories was at a level lower than 10%, which allows a statement that the parameter demonstrated low variability, taking into account the scale of comparative studies carried out (i.e. the number of participants and the number of objects tested).

**Table 3. Differentiation of furniture surfaces tested depending on the participant of comparative studies and variability of furniture surface differentiation degree for all participating laboratories**

*Tabela 3. Różnicowanie badanych powierzchni meblowych w zależności od wykonawcy badania porównawczego oraz zmienność wartości stopnia zróżnicowania powierzchni meblowych w laboratoriach uczestniczących w porównaniu*

Test series <i>Seria badawcza</i>	Comparative studies participant's code <i>Kod wykonawcy badania porównawczego</i>					Average value [%] <i>Średnia arytmetyczna [%]</i>	Standard deviation [%] <i>Odchylenie standardowe [%]</i>	Variability coefficient [%] <i>Współczynnik zmienności [%]</i>
	LAB 1	LAB 2	LAB 3	LAB 4	LAB 5			
	Furniture surface differentiation degree <sup>1)</sup> [%] <i>Stopień różnicowania powierzchni meblowych <sup>1)</sup> [%]</i>							
Test series no. I <i>I seria</i>	52.6	42.1	42.1	52.6	47.4	47.4	4.7	9.9
Test series no. II <i>II seria</i>	47.4	47.4	42.1	47.4	47.4	46.3	2.1	4.6

<sup>1)</sup> Expresses the ability to differentiate tested furniture surfaces as regards linear scratch resistance determined by method A acc. to TS 15186. This parameter was calculated according to formula (1).

<sup>1)</sup> *Wyraża zdolność do różnicowania powierzchni meblowych ze względu na ich odporność na zarysowanie prostoliniowe określoną przy użyciu metody A wg TS 15186. Wskaźnik ten obliczono stosując równanie (1).*

## Conclusions

Based on the results of studies conducted and analyses done, the following conclusions may be formulated:

1. Reproducibility of test final result, expressed by the value of variability coefficient of scratch resistance final result determined by method A according to TS 15186, is diverse depending on the tested furniture surface and assumes values from 2.7% (the highest reproducibility for surface marked with the code PM-3) to 15.6% (the lowest reproducibility for surface marked with the code PM2).



2. For most of tested furniture surfaces reproducibility of test final result is higher in the first test series (I) than in the second test series (II), and differences in the values of final result variability coefficient between the two test series range from 1.3% to 5.5%, depending on the tested surface.
3. In 4 industrial laboratories and in the ITD laboratory the average variability coefficient of scratch resistance final results determined by the above-mentioned test method for the furniture surface set used was at the level of 9.2% in test series no. I and 10.8% in test series no. II.
4. Repeatability of test final result, expressed by the percentage share of furniture surfaces fulfilling defined repeatability criterion, was at the level of 66.7% or 100%, depending on the comparative studies participant.
5. In 4 industrial laboratories and in the ITD laboratory the average repeatability of the final result of scratch test, carried out using the above-mentioned test method, for six tested furniture surfaces was at the level of 80%.
6. Differentiation of furniture surfaces tested using the above-mentioned test method, expressed by the value of furniture surface differentiation degree, fluctuates between 42% and around 53% in test series no. I and between 42% and 47% in test series no. II, depending on the comparative test performer.
7. In 4 industrial laboratories and in the ITD laboratory variability coefficient of differentiation degree of the six lacquered furniture surfaces was at the level of 9.9% in comparative test series no. I and 4.6% in comparative test series no. II.

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### List of standards

- BN-78/6110-03** Wyroby lakierowe – Pomiar twardości powłok metodą ołówkową
- EN 438-2:1991** Decorative high-pressure laminates (HPL) – Sheets based on thermosetting resins – Part 2: Determination of properties
- EN 438-2:2005** High-pressure decorative laminates (HPL) – Sheets based on thermosetting resins (Usually called laminates) – Part 2: Determination of properties
- ISO 1518:1992** Paints and varnishes – Scratch test
- PN-65/C-81527** Wyroby lakierowe – Próba odporności powłok na zarysowanie
- PN-88/F-06100-11** Meble – Metody badań właściwości powłok lakierowych i laminowych – Oznaczanie twardości
- prEN 15186:2010** Furniture – Assessment of the surface resistance to scratching (draft)
- SIS 839117:1973** Furniture and fittings for housing – Determination of surface resistance to scratches
- TS 15186:2005** Furniture – Assessment of the surface resistance to scratching

## **BADANIA PORÓWNAWCZE ODPORNOŚCI MEBLOWYCH POKRYĆ LAKIEROWYCH NA ZARYSOWANIE PROSTOLINIOWE Z ZASTOSOWANIEM METODY WEDŁUG TS 15186:2005**

### **Streszczenie**

Praca stanowiła kontynuację wcześniejszych badań, których efektem było opracowanie oryginalnej metody oceny odporności powierzchni mebli na zarysowanie, a następnie określenie jej podstawowych cech i zbadanie korelacji w ramach badań porównawczych z metodami dotychczas stosowanymi do oznaczania odporności powierzchni na zarysowanie. Kolejnym etapem były międzylaboratoryjne badania porównawcze z udziałem laboratoriów przemysłowych w zakresie oceny odporności na zarysowanie prostoliniowe wybranych lakierowanych powierzchni meblowych z wykorzystaniem metody A według TS 15186. Wybrane rezultaty tego etapu pracy posłużyły dalszej walidacji tej metody badawczej.

Celem pracy było określenie odtwarzalności i powtarzalności wyników badań odporności powierzchni meblowych na zarysowanie prostoliniowe, wykonanych w warunkach laboratoriów przemysłowych i laboratorium ITD z zastosowaniem metody badawczej A opisaną w standardzie technicznym TS 15186, a także określenie zdolności zastosowanej metody do różnicowania powierzchni meblowych wykończonych różnymi wyrobami lakierowymi.

Program pracy obejmował między innymi: zaznajomienie wybranych laboratoriów przemysłowych z nową metodą badawczą, wykonanie przez uczestników badań porównawczych dwu serii badań odporności na zarysowanie każdej z sześciu lakierowanych powierzchni meblowych, przeprowadzenie analizy wyników badań ze względu na wybrane cechy zastosowanej metody badawczej (odtwarzalność, powtarzalność końcowego wyniku badania, różnicowalność powierzchni meblowych). Przedmiotami badań były płytowe elementy meblowe o powierzchniach uszlachetnionych pokryciami wytworzonymi z pigmentowanych lub przezroczystych wyrobów lakierowych.

W wyniku przeprowadzonych badań porównawczych stwierdzono, że odtwarzalność końcowego wyniku badania, wyrażana za pomocą wartości współczynnika zmienności końcowej oceny odporności na zarysowanie, jest zróżnicowana w zależności od badanej powierzchni meblowej. Średni współczynnik zmienności końcowych ocen odporności na zarysowanie, określonych przy użyciu powyższej metody we wszystkich 5 laboratoriach uczestniczących w porównaniu, kształtuje się na poziomie około 9% w I serii badawczej, oraz około 11% w II serii badań. Powtarzalność końcowego wyniku badania, wyrażana procentowym udziałem powierzchni meblowych, dla których zostało spełnione zdefiniowane kryterium powtarzalności, w zależności od wykonawcy badania porównawczego kształtuje się na poziomie około 67% lub 100%. Natomiast, średnia powtarzalność końcowego wyniku badania kształtuje się na poziomie 80%. Zdolność do różnicowania badanych powierzchni meblowych, wyrażana wartością stopnia różnicowania powierzchni meblowych, waha się od 42% do około 53% w I serii badań oraz od 42% do 47% w II serii badawczej, zależnie od wykonawcy badania porównawczego. Oszacowana zmienność

stopnia różnicowania sześciu różnych lakierowanych powierzchni meblowych, badanych w 5 laboratoriach uczestniczących w porównaniu, kształtuje się na poziomie poniżej 10% zarówno w I, jak i II serii badań porównawczych.

**Słowa kluczowe:** powierzchnia meblowa, odporność powierzchni na zarysowanie prostoliniowe, odtwarzalność końcowego wyniku badania, powtarzalność końcowego wyniku badania, różnicowanie powierzchni meblowych.