USE OF NEW SPRING CORE CONSTRUCTIONS IN MATTRESSES

Dr. sc. Zoran Vlaović

Prof. dr. sc. Ivica Grbac

Emanuel Varošanec

Sveučilište u Zagrebu
Šumarski fakultet
Hrvatska
vlaovic@sumfak.hr

SUMMARY

According to an old Chinese saying: There are only two really important things in the world – a good bed and a good pair of shoes, because if you're not in one, then you most definitely are in the other. We spend as much as a third of our lives in bed, sometimes even a bit more. Our body is most sensitive about the part of bed with which it is in direct contact – mattress. The most important and the most burdened part of the mattress is definitely its core, regardless of whether it's from metal or from other materials. Therefore, in order to provide proper support for our backs, the mattress on which we sleep has to have quality core.

This research examines durability, elasticity and hardness of bonnell spring and pocket spring cores. The aim of the research was to determine correlation between quality of the product and characteristics of the materials, and application of results in practice or, in other words, to demonstrate dependency of spring core elastic characteristics on different characteristics of built-in springs.

Key words: mattress, bonnell spring core, pocket spring core, elasticity, durability, hardness, HRN EN 1957.

1 INTRODUCTION

Mattress is the most demanding product of the modern industry. The trend is to develop new technologies that allow construction of "healthy" mattresses that will be able to completely adjust to each body (Grbac, 2006). Mattress quality improvement is almost always based on quality improvement of supporting the body or increased comfortability of mattress, both mattress core and topper above the core. One of those technologies is the principle of constructing multi-zone mattress cores born out of desire for the better body support while lying. Since they raise comfort to a higher level, such mattresses are nowadays considered to be of high-quality (Grbac, 2005).

This research examines durability, elasticity and hardness of bonnell and pocket spring cores (TFK, German: Taschenfederkerne), with the aim of determining correlation between quality of the product and characteristics of the materials (height, diameter and thickness of a core wire), as well as application of research results in practice. The research is based on the method of determining functional characteristics of mattresses according to HRN EN 1957: Domestic furniture – Beds and mattresses – Test methods for the determination of functional characteristics.

2 MATTRESS SPRING CORES

A prerequisite for mattress comfortability is the exactly determined elasticity and flexibility of the surface for lying. mattress and elastic pad adjust to every movement and body shape in a way to try to evenly support it in every position. The choice of the most suitable mattress is the result of the fact that a man chooses what is the most comfortable for him (Savić et al., 2003). Manufactured industrially and with long durability and high quality, cores are nowadays almost the most important component of the mattress.

The most commonly used material in spring production is steel, along with some other materials such as brass, phosphor and silicon bronze, new silver, etc. Materials for the production of springs have to have high elasticity limit, high lasting dynamic hardness due to dynamic load and vibrations of own springs and to be tractable. While in use, steel springs, that are at the same time the basic spring core element, are subject to high static and dynamic loads of short-term or longer durability. Due to that, springs must have lasting elasticity, as well as enough plasticity to allow wire to be flexed and intertwined during core construction. Deformation of the core has to be mild and not too big (Fig. 1).

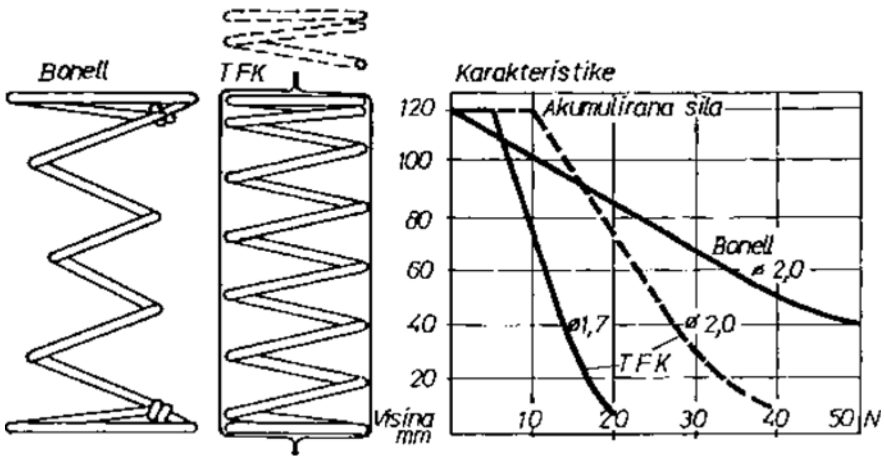

Figure 1. Comparison of bonnell and pocket (TFK) spring characteristics

Classic spring is determined by wire thickness, coil number, diameter of the upper, middle and lower ring. Springs are smeared with agents that ensure better lying of the appropriate materials, protect from corrosion and ensure noiseless use. Certain inner strains that remain within springs after production are the result of deformation of the cold wire. Those strains are eliminated by annealing on the temperature of 200-300 °C. Spring quality is the ability of the springs not to take on permanent deformation as long as possible while being affected by the force (Ivoš, 1997).

3 MATERIALS AND METHODS

3.1 Samples

The research was conducted on six samples in total, from which four were bonnell spring cores and two were pocket spring cores. Their characteristics (and manufacturer) differentiated them. Codes were subscribed to samples. Letters in sample code (A, B and C) indicate differences in spring characteristics, and numbers (1 and 2) indicate different manufacturers.

Sample A1_BNL was bonnell spring core with dimensions 1920×820×150 mm (with spring wire thickness of 2.2 mm and declared spring height 150 mm with 5 coils, while in the core there were 192 springs in 24 rows and 8 columns). The core was of standard design, one-zone and without steel framework (Fig. 2).

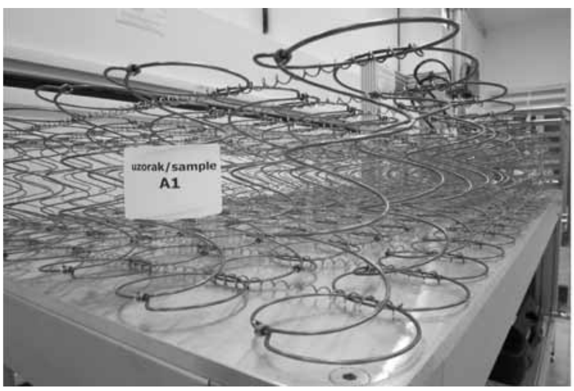

Figure 2. Sample A1_BNL

Figure 3. Sample A2_BNL

Sample A2_BNL was bonnell spring core with dimensions 1920×820×150 mm (2.2 mm / 150 mm / 6 coils / 24×8=192 springs). The core design is standard, one-zone and without steel framework. Difference between the core A1_BNL and A2_BNL was in number of spring coils and manufacturer (Fig. 3).

Sample B1_BNL was bonnell spring core with dimensions 1920×820×150 mm (2.4 mm / 150 mm / 5 coils /24×8=192 springs). Design is standard, one-zone and without steel framework (Fig. 4).

Figure 4. Sample B1_BNL

Figure 5. Sample B2_BNL

Sample B2_BNL was bonnell spring core with dimensions 1920×820×150 mm (2.4 mm / 150 mm / 6 coils / 24×8=192 springs). Design is standard, one-zone, and without steel framework (Fig. 5). Difference between samples B1_BNL and B2_BNL was in number of spring coils and manufacturer.

In other words, samples A1 and B1 differ from samples A2 and B2 (except in manufacturer) in number of spring coils (the former have five coils, and the latter six coils), while samples A (2.2 mm) differ from samples B (2.4 mm) in spring wire thickness.

Sample C1_TFK was pocket spring core with dimensions 1890×780×120 mm (1.8 mm / 120 mm / 32×13=416 springs). The core has one steel framework in the middle of spring height which was connected to springs with metal joints. Pockets were made from unwoven textile and glued together (Fig. 6).

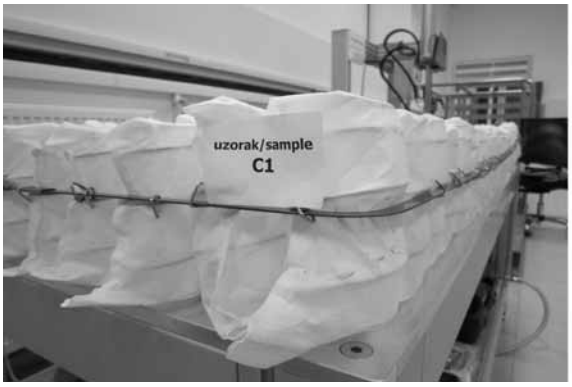

Figure 6. Sample C1_TFK

Figure 7. Sample C2_TFK

Sample C2_TFK was pocket spring core with dimensions 1890×780×120 mm (1.8 mm / 120 mm / 32×13=416 springs). The core has one steel framework on the lower side which is connected to springs with metal joints. Pockets were made from unwoven textile and glued together (Fig. 7). These two samples differ in the core framework design and manufacturers.

3.2 Research method

The research is based on the test from the standard HRN EN 1957: Domestic furniture – Beds and mattresses – Test methods for the determination of functional characteristics. The standard describes methods for determining durability, elasticity and hardness of the mattress, and all types of beds equipped with mattresses, except for the water, air and children beds. Testing mechanical properties of the wires from which springs were built wasn't subject of this research. All tests were conducted in the Laboratory for furniture of the Faculty of Forestry with modern, computer-controlled devices (Fig. 8).

Figure 8. Device for determining mattress durability and elasticity

Details regarding conditioning, tolerance, shapes and design of the loading pads, procedures and manners of measurement, as well as testing sequence can be found in the above mentioned standard. After the initial conditioning in the prescribed conditions, sample is tested in laboratory conditions, and testing begins with height measurement.

Spring core height was measured with device for determining elasticity by measuring distance of loading pad from the base on which core was put while under the acting force of only 0.5 N. Measurement was repeated few times in order to obtain more correct results (Fig. 9).

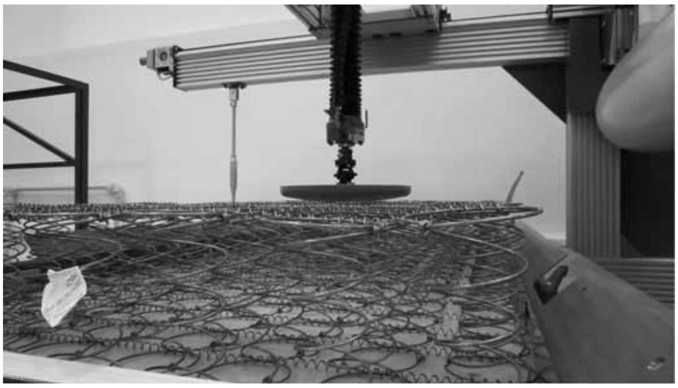

Figure 9. Display of measurement of height on the elasticity determining module

After determining height, before the testing itself (zero testing), sample elasticity was measured, followed by durability test.

Durability test is performed by rolling, and it simulates load caused by the long-term use. Roller is set in the direction of the longitudinal axis of the mattress and it moves on the surface with the help of electric drive (Fig. 10). The amplitude of the roller axis motion is 50 cm, and rolling frequency was 18 cycles per minute. After 100 initial rolling cycles, sample is again conditioned for at least five hours, and sample height and elasticity are measured again after 100 cycles.

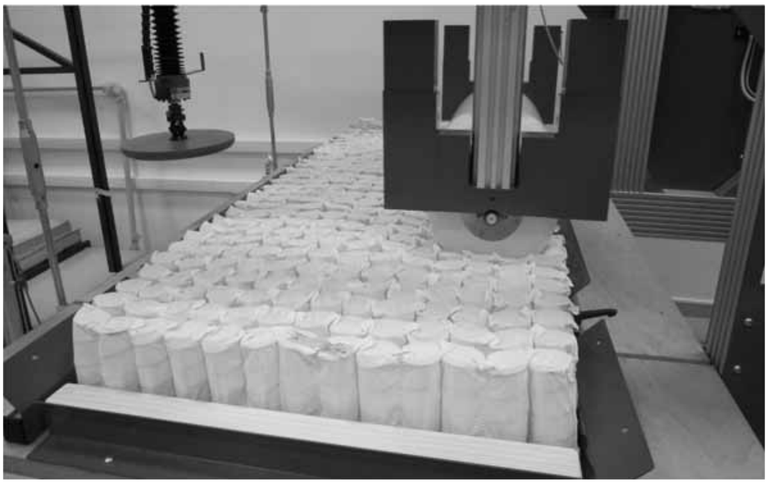

Figure 10. Device in sample C2_TFK rolling procedure

Hardness value (H) is measured with the module built in the rolling device and consists of hard bracket on which, via pressure body that is driven by electromotor and computer controlled, the force of 0 to 1000 N is acted upon the spring coil centre (Fig. 11). Elasticity determining process is prescribed by the norm. During the measuring process computer uses collected data of relation between force and deflection to make load/deflection curve.

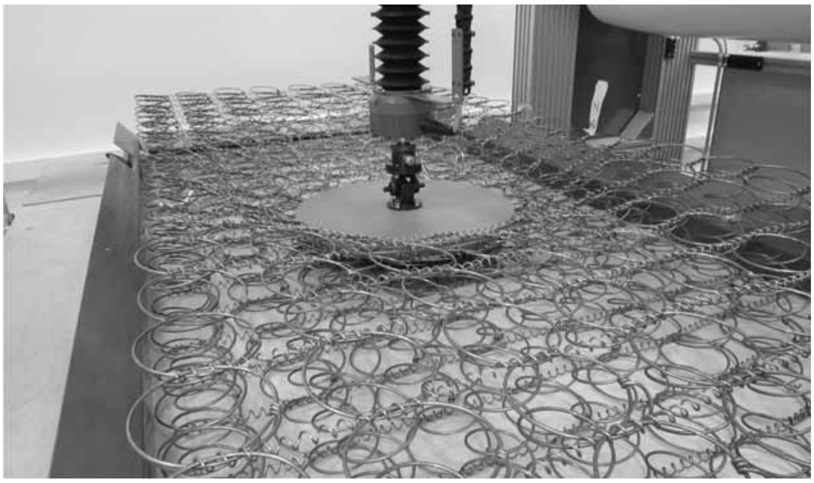

Figure 11. Hardness measurement – impressing pad into the sample

The norm prescribes obligatory hardness measurement after the initial 100 cycles and after the 30000 cycles, after the testing. However, if necessary, inter-measurements are allowed, which was the case in this testing. In order to get more data and visual control of the cores during testing, five inter-measurements were conducted, approximately every 2200 cycles (which corresponded to time span of 2 hours). It should be mentioned that the entire cycle of quality testing lasts 27 hours and that time span includes working of devices during the night. Therefore, besides basic measurements before starting and after 100 and 30000 cycles, inter-measurements were additionally taken after 2260, 4420 and 6580 cycles before night work and after 24580 and 26740 cycles during the next day. During rolling, core was inserted in textile cover to prevent roller damage, and during height and hardness measurement, it was taken out of the cover. In addition to the said, the norm includes a method for firmness rating (Hs) which is determined on the basis of measured hardness value obtained in sample testing. Spring cores height and elastic characteristics measurement was made with the help of industrial software program LabMaster, ver. 2.3.4. Obtained data were later processed with MS Excel program.

4 RESEARCH RESULTS

The results obtained in the research are summarized in Table 1. Since the paper is limited, results of inter-measurements are left out. However, it should be mentioned that, although not statistically processed, among them there were no significant changes. All the results can be found in the original paper (Varošanec, 2010).

Table 1 show measured core heights, all the parameters obtained by hardness measurement and, finally, firmness of each core before all the exposures to dynamic loads, after 100 and 30000 cycles.

Table 1. Aggregated data of the samples A, B and C before testing and after 100 and 30000 cycles

Sample	Measured core height [mm]	C1	C2	C3	**H [N/mm]**	A [mm²]	K	**Hs**
A1_BNL-0	158	7,35	6,40	7,56	**7,10**	13138,56	1849,53	**5,1**
A2_BNL-0	155	6,42	6,89	7,40	**6,91**	14820,74	2146,20	**5,7**
B1_BNL-0	151	10,12	10,67	10,94	**10,58**	9728,01	919,56	**2,5**
B2_BNL-0	159	7,86	8,59	8,89	**8,45**	12345,86	1461,65	**4,1**
C1_TFK-0	130	5,14	4,88	5,67	**5,23**	18348,93	3509,34	**8**
C2_TFK-0	141	15,42	12,12	8,58	**12,04**	10819,70	898,65	**2,4**
A1_BNL-100	156	7,62	8,10	8,14	**7,95**	13137,21	1651,97	**4,6**
A2_BNL-100	153	6,73	7,12	7,22	**7,03**	14805,25	2107,63	**5,7**
B1_BNL-100	148	8,58	9,24	10,21	**9,34**	11318,90	1211,42	**3,4**
B2_BNL-100	158	7,20	7,73	8,16	**7,70**	13396,96	1740,50	**4,8**
C1_TFK-100	122	5,09	4,98	4,93	**5,00**	18834,78	3767,60	**8,2**
C2_TFK-100	138	11,97	9,89	7,75	**9,87**	11101,76	1124,80	**3,1**
A1_BNL-	152	7,17	8,16	8,32	**7,88**	13155,08	1668,62	**4,6**
A2_BNL-	151	6,77	6,66	7,52	**6,98**	14324,03	2051,32	**5,5**
B1_BNL-	147	10,18	10,66	11,20	**10,68**	9684,03	906,93	**2,5**
B2_BNL-	156	8,30	9,03	9,68	**9,00**	11867,56	1318,23	**3,7**
C1_TFK-	124	4,29	4,97	4,29	**4,51**	20033,75	4438,71	**8,8**
C2_TFK-	135	14,17	11,17	7,24	**10,86**	12082,87	1112,36	**3,1**
Note:	C1 - slope at 210 N load				K - coef. calculated from load/deflection			
	C2 - slope at 275 N load				H - hardness value			
	C3 - slope at 340 N load				Hs - firmness rating			
	A - area under load/deflection curve (under the load curve from 0 to 450 N)							

Figures 12 to 14 show load/deflection curves of all the cores before testing and after 100 and 30000 cycles. It is interesting to note that TFK cores (C-samples) keep their interrelation from beginning until end while elasticity curves of bonnell cores (A- and B-samples) change their position with regard to the other.

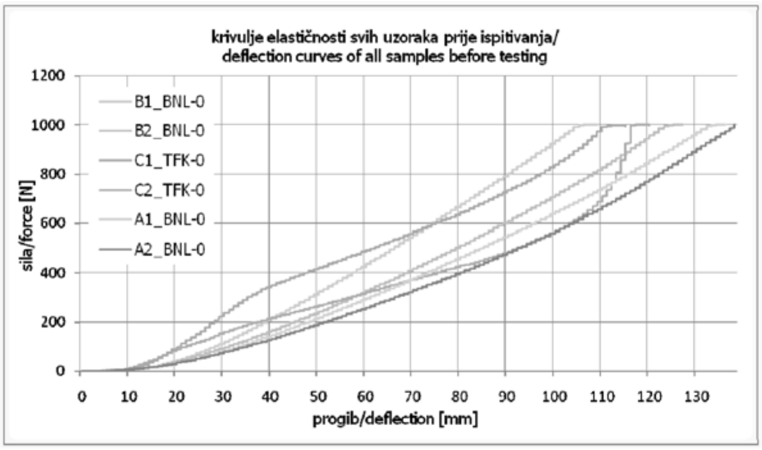

Figure 12. Load/deflection curves of all samples before rolling test

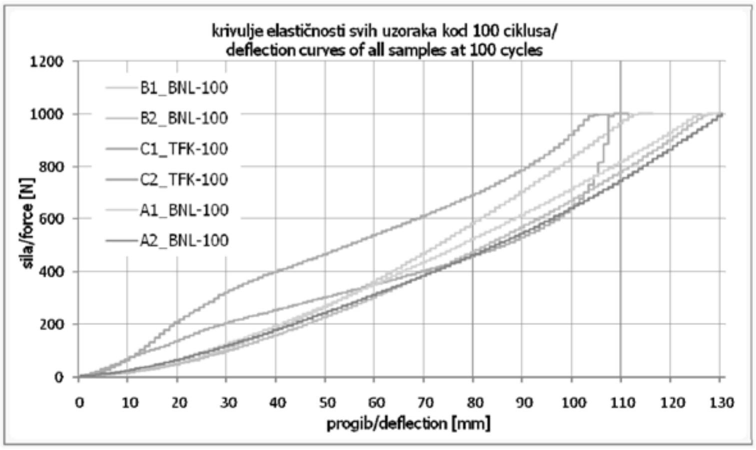

Figure 13. Load/deflection curves of all samples after 100 rolling cycles

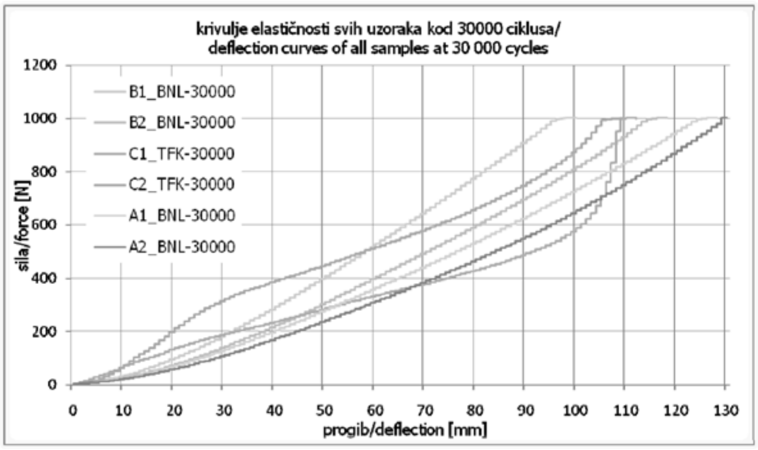

Figure 14. Load/deflection curves of all samples after 30000 rolling cycles

Columns H and Hs in table 2 show values of hardness and firmness of all samples that were included in the research. Comparison of the samples A1_BNL, A2_BNL, B1_BNL and B2_BNL shows that A2_BNL has the lowest and B1_BNL the highest hardness value after 30000 cycles. Comparison of A-samples shows that between them there is no big difference in hardness value after 100 and 30000 cycles, and the same applies to B-samples.

Comparison of their firmness rating (Hs is expressed with a number from 1 to 10, less is firmer) after 30000 cycles leads to the conclusion that the sample A2_BNL is the softest, while the sample B1_BNL is the firmest. Comparison of the samples A1_BNL and A2_BNL between themselves notes that the sample A1_BNL is firmest, but their values after the first 100 and final 30000 cycles haven't significantly changed, while firmness relations remained the same. Among B-samples, B1_BNL is firmer, and the change of firmness rating is somewhat more pronounced than among A-samples, while the relations here too remained the same.

Table 2. Display of hardness value (H) and firmness rating (Hs) of all samples after 100 and 30000 cycles

Sample	Hardness value (H)		Firmness rating (Hs)	
	100 cycles	30000 cycles	100 cycles	30000 cycles
A1_BNL	7,95	7,88	4,6	4,6
A2_BNL	7,03	6,98	5,7	5,5
B1_BNL	9,34	10,68	3,4	2,5*
B2_BNL	7,70	9,00	4,8	3,7
C1_TFK	5,00*	4,51*	8,2**	8,8**
C2_TFK	9,87**	10,86**	3,1*	3,1
			(less is firmer)	
Note:	* the lowest values			
	** the highest values			

Height loss is calculated from the value of core height after 100 and 30000 cycles. The lowest value of height loss has sample B1_BNL (0.5 mm), and the highest sample A1_BNL (3.17 mm). Comparison among them shows that sample A2_BNL (1.58 mm) has lower value of height loss than A1_BNL, while among B-samples sample B2_BNL has higher height loss (2.56 mm). Sample C1_TFK has height loss of 1.60 mm, and C2_TFK of 2.68 mm.

From data on hardness value and firmness of samples C1_TFK and C2_TFK it is obvious that sample C1_TFK has twice as low hardness than sample C2_TFK, and in regard of their firmness, sample C2_TFK is much firmer than sample C1_TFK. Value of hardness after 100 and 30000 cycles isn't significantly different in relation to other samples, and the same is true for their firmness (table 2).

Height loss of sample C2_TFK is higher than sample C1_TFK, which is due to different characteristics of each sample. Besides few slightly torn pockets on sample C1_TFK, no specific damage occurred in these types of samples.

Comparison of results of all A, B and C samples would show that the highest value of hardness has sample C2_TFK, and the lowest C1_TFK. Considering value of firmness rating, sample B1_BNL is the firmest, and sample C1_TFK is the softest. Height loss is the highest in sample A1_BNL, while it is the lowest in sample B1_BNL. Regarding durability of samples, samples C1_TFK and C2_TFK are, therefore, better than the rest because no core damages occurred after test ended, while other samples experienced damages such as breakage of springs or spiral wires.

It is here appropriate to mention that researches (Savić et al., 2003) on parallel tests on mattresses conducted according to the previous HRN and current HRN EN standards have shown that values of height loss are significantly lower under the methods of the current HRN EN, and that, according to the endurance test method, testing pursuant to HRN EN corresponds to the high quality degree (QII) from the old HRN.

5 CONCLUSIONS

The aim of the research was to explore characteristics of cores for mattresses construction and to determine which core system is more durable with regard to different characteristics, which is their height loss value, firmness and hardness in comparison within type and comparison with the examined types.

Based on the conducted researches and measurements of bonnell cores and pocket spring cores characteristics, the following conclusions can be made:

- Hardness value: By observing hardness value relations of all bonnell and pocket spring cores samples, it can be concluded that the sample with pocket spring core with wire thickness of 1.8 mm and steel framework on the bottom/end of springs (C2_TFK) has the highest value of hardness value after the initial 100 and final 30000 cycles, while the sample with pocket spring core with wire thickness of 1.8 mm and steel framework in the middle of the spring height (C1_TFK) has the lowest value. Regarding other samples, their values are approximately equal. Considering that mechanical characteristics of wire were not tested, it can be only assumed that difference in quality depends exactly on those characteristics of wire for springs. Since the products in question are from two manufacturers, it is highly likely they do not use the same raw material, and technological procedures can partially vary.

- Firmness rating: By observing firmness relations of all the tested samples, sample C2_TFK is the firmest sample after the initial 100 cycles. At the same time, the softest is sample C1_TFK (with steel framework in the middle of springs height).The situation changed after the final 30000 cycles so the firmest became sample B1_BNL (with wire thickness of 2.4 mm and 5 coils), and the softest remained the sample C1_TFK. Firmness of other samples is approximately around middle value for firmness rating.

- Durability and height loss: Generally speaking, if from all the examined samples one should be pointed out as the worst, it would be sample with bonnell spring core with wire thickness of 2.4 mm and 6 coils (B2_BNL) because it has shown to be the weakest in most of the observed characteristics. Namely, while observing durability, two spring wires that connect springs broke, as well as the two springs, which was not the case with other samples. Height loss of the sample in question after testing was also among the highest, hence the worst. Among bonnell spring core samples, B1_BNL has to be singled out as the sample with the lowest height loss from all the tested samples, hence the best. The samples of pocket spring core have justified their status as durable spring core system because at the end of the testing there was no serious damage. Regarding height loss, it is somewhat higher in the pocket spring core sample C2_TFK than in sample C1_TFK.

Due to a small number of samples, conclusions based on the results can only be general and can confirm the expected interrelations of the samples. To obtain more reliable conclusions new researches have to be conducted. Having in mind research methods and stated conclusions, it cannot be claimed that there is a significant influence of the number of spring coils or that there is an influence of the wire thickness. However, by classifying the observed sample characteristics (hardness value, durability and height loss) as “bad” or “good” results, and with regard to manufacturer (1 or 2), it can be concluded that samples labelled with “1” achieved more results that were better (hardness value – B1; durability – C1; height loss – B1 and C1) and fewer results that were bad (hardness value – C1; height loss – A1). On the other hand, samples of the manufacturer labelled with “2” achieved more bad results (hardness value – A2; durability – B2; height loss – B2 and C2), and fewer good results (hardness value – C2; durability – C2; height loss – A2) when compared among themselves.

For future researches, in addition to the higher number of samples, it would most certainly be interesting to conduct same researches with complete mattresses and identical cores and compare them with these results.

REFERENCES

1. Grbac, I., Ivelić, Ž. (2005): Ojastučeni namještaj, Sveučilište u Zagrebu, Šumarski fakultet, Zagreb.
2. Grbac, I. (2006): Krevet i zdravlje, Sveučilište u Zagrebu, Šumarski fakultet, Zagreb.
3. Ivoš, H. (1997): Istraživanje opružnih konstrukcija ležaja-madraca, diplomski rad, Sveučilište u Zagrebu, Šumarski fakultet.
4. Savić, Z., Fiala, S., Vlaović, Z., Ivelić, Ž., Grbac, I. (2003): Poredbeno ispitivanje ležaja-madraca prema novim i starim hrvatskim normama, Drvna industrija 54 (1), Sveučilište u Zagrebu, Šumarski fakultet, str. 5-16.
5. Varošanec, E. (2010): Istraživanje elastičnih karakteristika opružnih jezgri – diplomski rad, Sveučilište u Zagrebu, Šumarski fakultet, Zagreb
6. *** (2000): HRN EN 1957:2001 Domestic furniture – Beds and mattresses – Test methods for the determination of functional characteristics (EN 1957:2000), Techical Committee CEN/TC, Bruseeles