VOLUMINUOS WAVEMAKER NONWOVENS FOR MOBILTECH

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Abstract:
The market for voluminous nonwovens in automotive applications is increasing due to better fulfilment of functional as well as comfort related properties. This is a good option to be used as a cushion material for automotive seats and headliner and to replace the polyurethane foams and other materials. They offer a wide range of properties depending on fibers, bonding technique, fiber orientation and process parameters. In the field Santex CH Wavemaker technology is advantageous due to vertical fibers orientation and higher productivity. The present paper describes effect of fiber fineness, structural parameters and type of feeding web structure i.e. normal carded web and pre-needled web on various properties of Wavemaker nonwovens for automotive application. These structures are analyzed for static and dynamic compression properties, both direction tensile properties and compression set for the GSM and thickness range 200-770 and 5-42 mm respectively. Compared with the normal nonwovens structures the Wavemaker nonwovens offer much higher recovery with softer structure due to less material fraction. The Wavemaker nonwoven density has significant influence on MD and CD breaking force, compression set while the dynamic compression properties are a function of fiber fineness, orientation and bonding fiber type. Type of feeding web i.e. carded or pre-needled affects the Wavemaker nonwovens thickness and relative compressed thickness significantly, while insignificant influence on the compression recovery, compression hysteresis and compression set.

Key words: Nonwovens, breaking force, static compressibility, compression recovery, compression hysteresis, compression set and bending rigidity

1. Introduction

Highloft Nonwovens are defined as low density fiber network structure characterized by a high ratio of thickness to weight per unit area, consisting no more than 10% solid by volume and greater than 3 mm in thickness [1-6]. In the field, the perpendicular laid nonwovens offer excellent compression recovery and softness compared with typical cross-laid and air laid nonwovens, because majority of fibers are oriented perpendicular to the plane of the fabric. Thus these nonwovens are one of the best choice for the automotive cushion material. There are mainly two mechanisms to lay the feeding web in the vertical form [7-16].

1. Vibration vertical lying called STRUTO / STRATO: In the case a reciprocating lapping device called hacker continuously consolidates the feeding web into a vertically folded batt immediately prior to through thermal bonding.

2. Rotational vertical lying called WAVEMAKER® / SANTAFLEECE: In the case a continuously rotating toothed wheel consolidates the feeding web into vertical folds or waves immediately prior to thermal bonding oven.

1.1 Rotational vertical lying called WAVEMAKER® (WM)

The working wheel feeds the in coming web in between the teeth of the rotating forming wheel (FW). Here the feeding web acquires the form of vertical folds. The perpendicular laid folds are carried out from the FW teeth by the comb and transported between the conveyor belt and a wire grid towards the thermal bonding oven, Fig. 1. In the thermal bonding oven bonding among the fibers takes place by means of circuiting hot air.

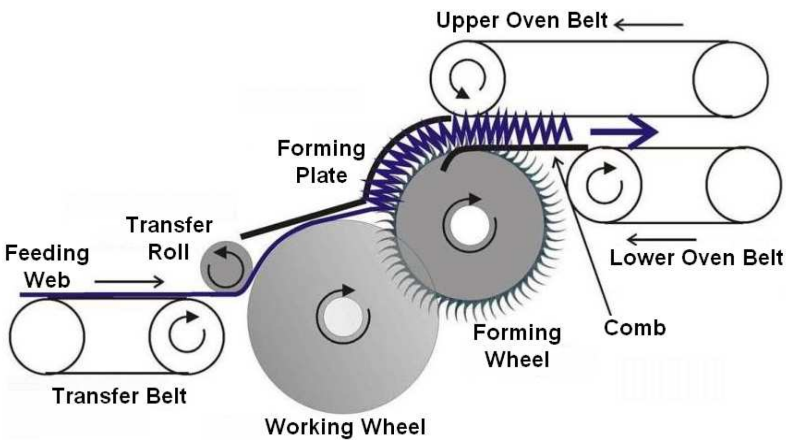

Figure 1. Wavemaker working principle, Set-up at ITV Denkendorf

1.2 Properties of the Wavemaker nonwovens

The following crucial parameters decide the properties and performance of WM nonwovens.

- *Fiber type and structure:* Fiber fineness, length, cross section profile and crimp
- *Blend Percentage:* Matrix fiber : Bonding fiber
- *Bonding Fiber:* Mono-component or bi-component
- *Nonwoven:* Area density and thickness
- *Fiber orientation:* Fiber orientation in the feeing web and in the WM nonwoven

2. Materials and Methods

2.1 Fiber materials and properties

To produce Wavemaker technology based nonwovens a blend of round profile polyester as matrix fiber and core sheath type bi-component polyester as bonding fiber is used, see Table 1. For bonding a sheath core type bi-component fiber is selected because on melting the lower melting point sheath will distribute along the core fiber length and will provide higher number of bonding points with softer feel compared with mono-component bonding fiber.

Table 1. Fiber Materials and Properties

Code	Fiber Type	Fine-ness (dtex)	Cut Length (mm)	SFG (cN/tex)	T_m (°C)	Description
A	T274	4.4	50	32.4	140	Bicomponent Flame-retardant fiber, C/S 70/30 (PES/Co-PES)
B	M1440	4.8	55	33.0	110	Bicomponent fiber core/Sheath 70/30 (PES/Co-PES)
1	T270B	3.3	60	45.5	270	Flame-retardant round cross-section
2	T270A	6.7	60	35.8	270	Flame-retardant round cross-section
3	M1033	7.0	50	34.0	270	Round cross-section
4	M1054	17	60	30.4	270	Round cross-section

****** T – Trevira Fibers; M – Wellman Fibers; SFG – Single Fiber Strength, T_m – Melting Temperature

2.2 Material blend

A blend of 70/30 PET/Bicomponent fibers by weight was used to produce Wavemaker nonwovens, Table 2. For seat cushion materials a combination of two types matrix fibers is selected to achieve good compressibility from coarse denier fiber and good bonding and softer structure from the fine denier fibers.

Table 2. Considered Process Parameters

Blend	Blend Percentage	Web Weight (g/m^2)	Thickness (mm)	WM Nonwoven GSM	Considered Machine Parameter
2 : A	70 : 30	9 – 12	6/11/18/23	200-250	Influence of matrix fiber fineness
1 : A	70 : 30	9 – 12	6/11/18/23	200-250	
3:4:B	35 : 35: 30	14-17; 60,80(NV)	36-40	400-725	feeding web type: preneedled and carded

2.3 Norms for considered Wavemaker nonwoven properties

DIN standards are used to measure various properties of the Wavemaker nonwovens, Table 3.

Table 3. Standards for considered Wavemaker nonwoven properties

Property	Standard
Area Density (g/m^2)	DIN EN 12127
Thickness	DIN EN ISO 9073-2
Tensile Strength	DIN EN 29 073-3: 1992
Static Compressibility	DIN 53885
Dynamic Compressibility	DIN 54305
Compression Set (CDR)	DIN EN ISO 1856

2.3.1 Compression Set: It indicates permanent deformation in the material thickness and was tested according to a test recommended by AUDI. Under the test a certain number of WM nonwovens layers (to fulfil the minimum thickness requirement i.e. 50 mm) of 100 cm^2 area are subjected to 5 kg load at 70 ºC for 22 hours and then are allowed to relax for 30 minutes under normal atmospheric conditions. The ratio of specimen thickness difference before placing into the oven to the after 30 minutes relaxation to the initial thickness of the specimen under testing pressure 0.2 cN/cm^2 is termed as CDR, Eq. 1.

$$CDR_{5kg}\,(\%) = (C_0 - C_{0.5}) \times 100 / C_0 \qquad (1)$$

Where C_0 = Original thickness of the test specimen under 0.2 cN/cm^2 pressure
$C_{0.5}$ = Thickness of the specimen after 30 minutes relaxation

2.3.2 Dynamic compressibility: It was tested on Zwick Z020 tester and the following parameters were calculated, Eq. 2, 3, 4.

$$\text{Compression Recovery } (a_{30\text{-}5H3}\,\%) = a_{30\text{-}5H3} * 100 / a_{30} \qquad (2)$$

$$\text{Relative Compressed thickness } (a_{30\text{-}5H}\,\%) = a_{30\text{-}5H} * 100 / a_{30} \qquad (3)$$

$$\text{Hysteresis } (H_n) = A_{n,2} * 100 / A_{n,1} \qquad (4)$$

Where a_{30} = Initial thickness of the specimen (under 30 g/100 cm^2 load)
$a_{30\text{-}nH}$ = Thickness of the specimen immediately after each compression cycle
$a_{30\text{-}5H3}$ = Thickness of the specimen after fifth compression cycle and 3 minutes relaxation
$A_{n,1}$ = Area under the compression curve
$A_{n,2}$ = Area between the compression and recovery curve
n = Number of testing cycle

3. Results and Discussions

3.1 Effect of forming wheel speed (FWS) and nonwoven density on tensile properties

On machine direction loading of WM nonwoven, the rupture occurs first due to unfolding of folds followed by fiber slippage. Lower FWS renders lower folds density (number of folds per unit length), thus reduces the probability of weaker vertical folds in the nonwoven. As per weak link theory, the material strength should be improved. But at the same time lower FWS increases weight of each fold, which further creates a weak link between the successive folds. Thus the FWS does not influence the both directions breaking force, Fig. 2. Since higher number of fibers contribute to strength during loading of a denser material, causes an enhancement in the both directions breaking force, Fig. 2. In a denser WM nonwoven although higher number of fibers contribute to strength, but simultaneously the increased folds density at same machine settings diminishes the improvement in the MD strength.

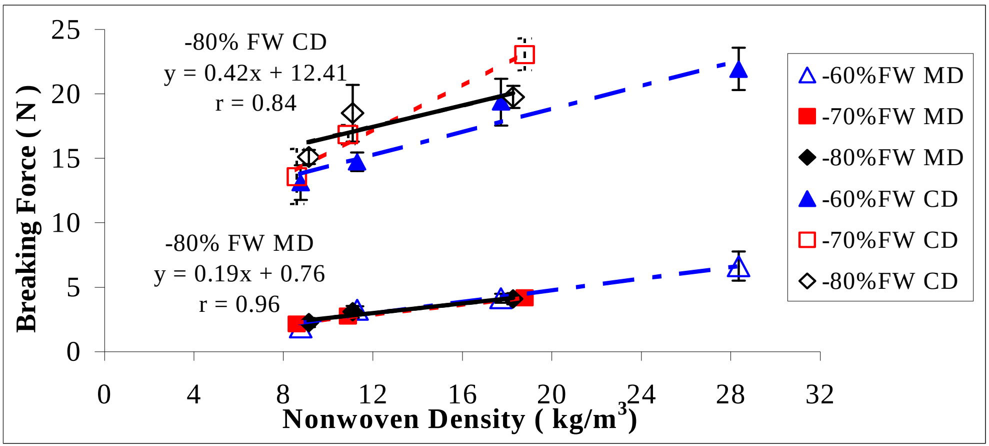

Figure 2. Effect of FWS and nonwoven density on tensile strength (FWS lagging to working wheel speed, each set of WM nonwovens belong to a particular thickness for same the GSM)

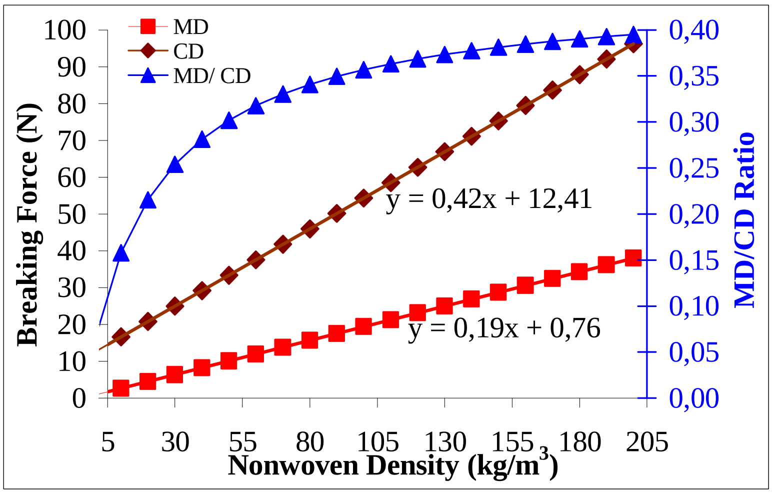

Figure 3. Effect of nonwoven density on tensile behavior

For the present case with increasing WM nonwoven density the MD/CD ratio increases in asymptotic nature and ranges from 0.13 to 0.40, see Fig. 3. The reason behind poor MD/CD ratio is different rupture mechanisms in the MD and CD directions. Thus the MD/CD ratio of the WM nonwovens can not exceed 0.40 for the present fiber blend and process parameters. But the tensile strength is of less importance during processing of the WM nonwovens.

3.2 Effect of fiber fineness and nonwoven density on static compressibility

For each particular load condition i.e. 2, 5, 10 cN/cm^2, with increasing WM nonwoven density the static compressibility decreases significantly, since a higher number of fibers per unit volume offer higher resistance to compression, Fig. 4. At same material density fiber fineness (3.3dtex, 6.7dtex) does not influence the WM nonwovens static compressibility significantly, as the increased total number of finer fibers per unit volume and the increased number of bonding points compensates the decrement in the static compressibility due to lower bending rigidity of finer fibers. Since at the same process parameters and machine settings higher bending of finer fibres is inevitable than coarser fibres, yields more compact structure.

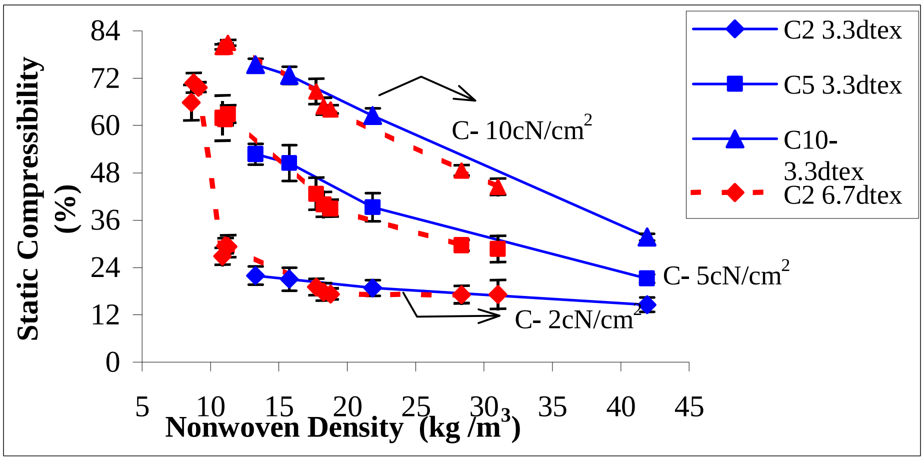

Figure 4 Effect of fiber fineness and nonwoven density on static compressibility

3.3 Effect of fiber fineness and nonwoven density on compression set (CDR)

Due to vertical fiber orientation the WM nonwovens afford better CDR performance than the cross laid nonwovens at same material density, Fig. 5. The standard CDR limit i.e. 22 percent (set by AUDI) was achieved at 58 kg/m^3 WM nonwoven density; made with T270 (3.3 dtex) 70 percent/ T254 (2.2 dtex) 30 percent fiber blend, Fig. 5. With increasing material density the compressibility of the WM nonwoven decreases, causes an improvement in CDR. Since under intensive CDR testing conditions (5 kg load at 70 °C for 22 hours) permanent deformation of the WM nonwoven thickness occurs, fiber fineness does not affect the CDR.

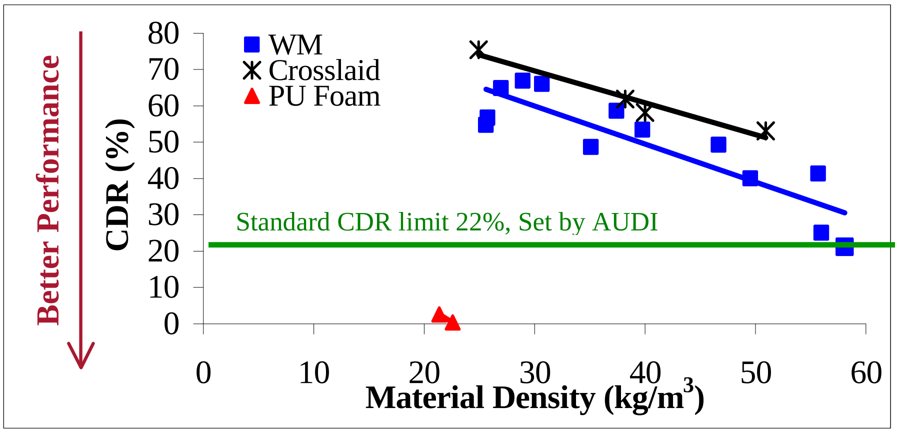

Figure 5. Effect of material density and structure on CDR [17]

3.4 Effect of feeding web type on Wavemaker nonwovens thickness

Due to limitation of the carding machine at ITV Denkendorf and to feed heavier web to WM unit, the carded web were overlapped (lapping angle 30°-60°) and slightly needled for better handling. A comparison between WM084-03, WNV089-07 and WM084-10, WNV089-04 samples shows that for about similar GSM, the pre-needled sheet (NV) made WM nonwovens (WNV) possess significantly lower thickness than the carded web made WM nonwoven at 95 percent confidence limit, Fig. 6. The NV has poor penetration in between the teeth of the FW due to higher bending rigidity, yields smaller fold height thus lower material thickness. The folds height between the take-up belts (compression belt) is higher for normal carded web than NV, Fig. 7 and 9; where the take up belt is set to just touch the vertical folds without compression to lead their smooth transportation. To some extend higher thickness of the WNV nonwoven can be achieved by increasing the final WM nonwoven GSM. The major reduction in the WNV nonwoven thickness occurs at the thermal bonding oven at the same compression belt distance, see Fig.7 and 8.

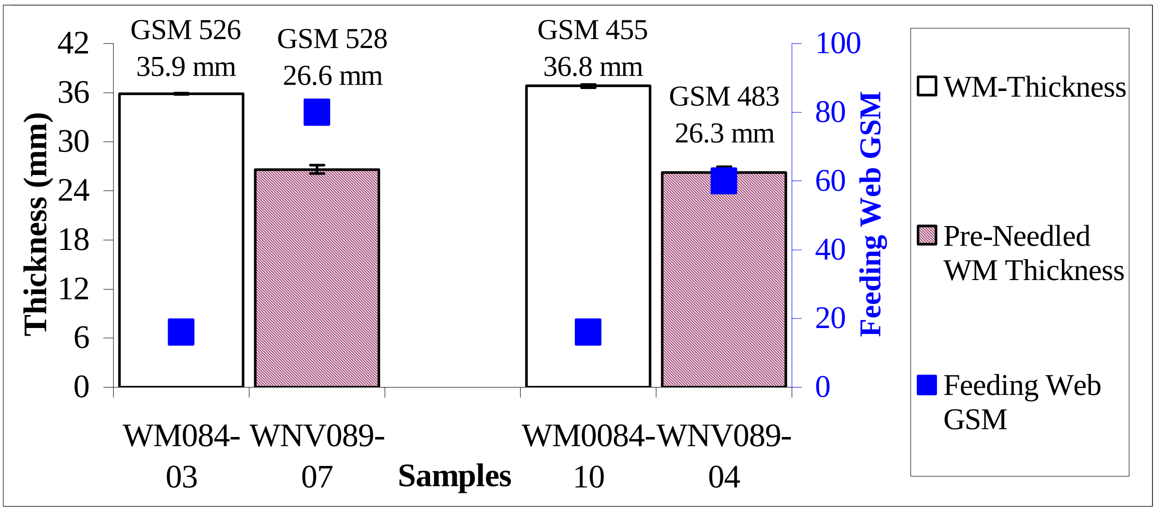

Figure 6. Effect of feeding web type on Wavemaker nonwoven thickness

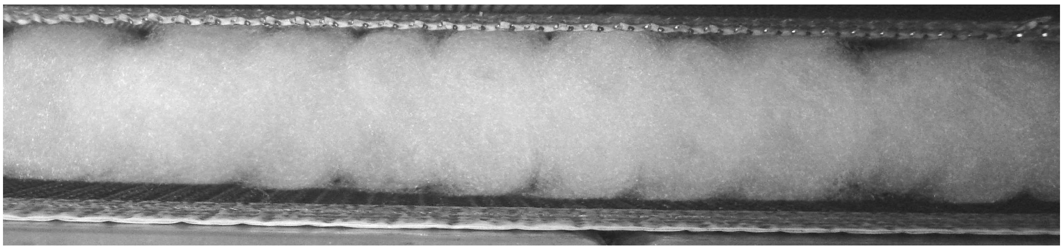

Figure 7. WNV nonwoven between compression belts (at 55 mm distance) before entering in thermal oven

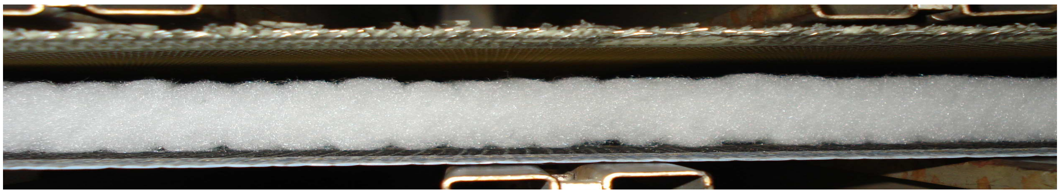

Figure 8. WNV nonwoven between compression belts (at 55 mm distance) in the thermal bonding oven

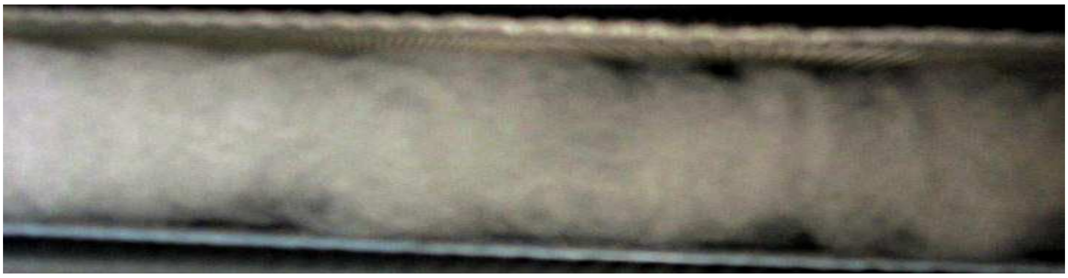

Figure 9. Normal (carded feed) WM nonwoven between compression belts (at 70 mm distance) before entering in the thermal bonding oven

3.5 Effect of feeding web type and nonwoven density on dynamic compression properties

The relative compressed thickness (RCT) after five compression cycles ($a_{30\text{-}5H}$) strongly depends on feeding web structure and increases with increasing nonwoven density, Fig. 10. At same material density heavier and more compact structure with random fiber orientation in the pre-needled sheet allows less compression of WNV nonwovens or provides a harder structure. Thus by increasing the area density of carded type feeding web, softer and more compressible WM structures can be achieved. The WNV density has significant influence on the relative compressed thickness due to significant change in the folds density, see Fig 10.

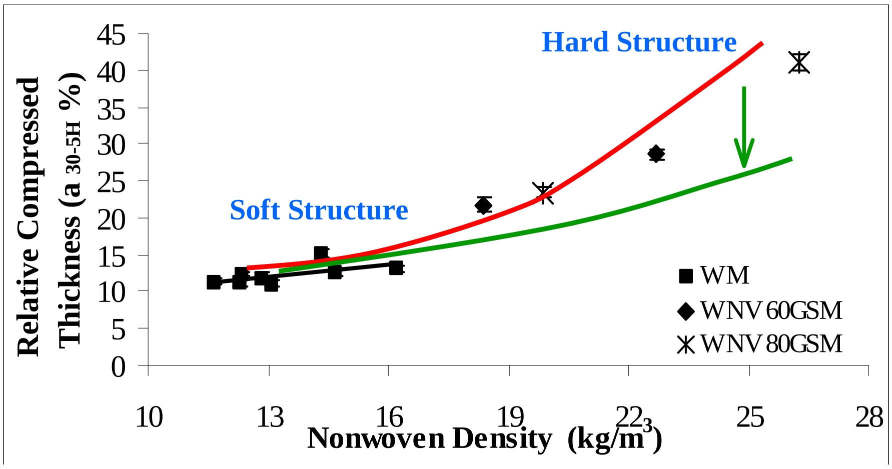

Figure 10. Effect of feeding web type and nonwoven density on RCT ($a_{30\text{-}5H}$)

The compression recovery after 5 compression cycles ($a_{30\text{-}5H3}$) and compression hysteresis (H_5) are independent of type of feeding web structure, Fig 11. The dynamic compression properties are a function of fiber orientation and fiber fineness. The poor fibers orientation in the compact and heavier pre-needled sheets hinders these both dynamic compression properties of the WNV. These both properties are independent from the normal WM nonwoven density while possess significantly poor relation with WNV density. The normal WM structure is too soft to render larger within variation with breaking of bonding points during dynamic compression cycles, causing insignificant impact on the dynamic compression properties with the material density. While compact and rigid structure of the heavier pre-needled folds in the WNV and harder final nonwoven structure is responsible for smaller within variation and a small but significant change in these two dynamic compression properties with increasing WNV nonwoven density at 95 percent confidence limit.

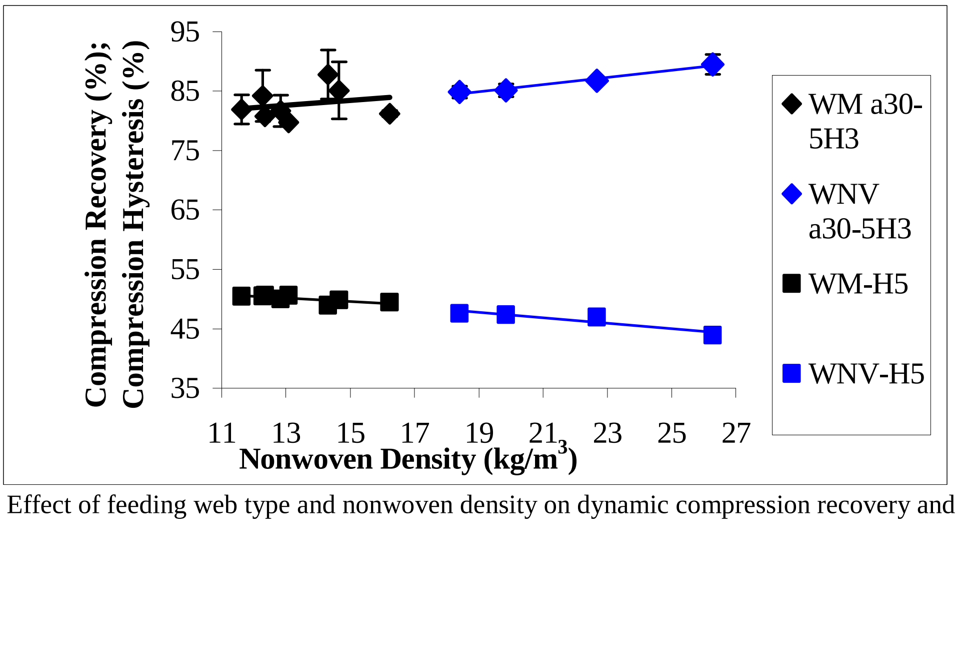

Figure 11. Effect of feeding web type and nonwoven density on dynamic compression recovery and hysteresis

4. Conclusions

1. Nearly linear dependence between WM nonwoven density and various properties
2. The MD/ CD ratio shows an asymptotic nature with increasing nonwoven density with the maximum value 0.40.
3. For the present process parameters a change in fiber fineness (3.3 and 6.7 dtex) does not influence the static compressibility and compression set.
4. More pronounced vertical fiber orientation renders higher compression recovery.
5. Feeding web type affects the WM nonwovens thickness and relative compressed thickness significantly while does not influence the compression recovery, compression hysteresis.

5. References

1. Albrecht W., Fuchs H., Kittelmann W. & Massenaux G., *Nonwoven fabrics - raw materials, manufacture, applications, characteristics, testing processes: Introduction to nonwovens,* Wiley-VCH, Germany, 2002, Chapter 1, 4 & 6.
2. Russell S. J., *Handbook of Nonwovens*, The Textile Institute: Woodhead publishing limited, UK, 2007, 201-254.
3. Fung W. & Hardcastle M., *Textiles in automotive engineering*, The Textile Institute: Woodhead publishing limited, UK, 2001, Chapter 3 & 6.
4. Holiday T. & Thomas M., *Highloft nonwovens update*, Paper presented at High loft 95 Conference and Showcase, INDA, Charlotte, North Carolina, June 1995.
5. Jirsák O., Burian T. & Sasková P., *Fibres and Textiles in Eastern Europe,* Vol. 11(3), 2003, 80-83.
6. Jirsák O., Hanuš J. & Lukáš D, *Comparative study of perpendicular laid highloft fabrics,* Presented at INDA-TEC96, Crystal City, VA., September 1996.
7. Jirsák O., Krcma R., Mackova I. & Hanuš J., *Perpendicular laid bulky textiles in sportswear,* Presented at Textiles in sports & sportswear, Huddersfield, UK, April 1995.
8. Jirsák O., Mackova I. & Parikh D. V., *Vlákna a Textil,* Vol. 7 (2), 2000, 109-110.
9. Krema R. & Jirsák O., *New perpendicular nonwoven & their properties*, Paper presented at EDANA, International Nonwoven Symposium, Monate-Carlo, June 1991.
10. Kerma R. & Jirsák O., *New structures in bulky nonwovens,* Presented at Fourth annual TANDEC conference, Knoxville, TN, November 1994.
11. Krema R., Jirsák O. & Hanuš J., *Nonwoven Industry,* Vol. 28(10), 1997, 74-78.
12. Russell S. J., *Handbook of Nonwovens,* The Textile Institute: Woodhead publishing limited, UK, 2007, 298-327.
13. Horrocks A. R. & Anand S. C., *Hand book of technical textiles,* The Textile Institute: Woodhead publishing limited, UK, 2000, 140-149.
14. Vasile, S. & Van Langenhove, L., *Journal of Textile and Apparel,* Technology and Management, Vol. 3(4), 2004, 1-5.
15. William C. Smith, *International Nonwoven Journal,* Fall, 2004, 60-63.
16. Wuagneux E., *Nonwoven Industry,* 12, 2005, Retrieved from http://www.nonwovens-industry.com/articles/2005/12/its-whats-inside-that-counts
17. Rieger C. & Dauner M., *Untersuchung von wavemaker-vliesstoffen mit fokus auf ihren schallabsorptionsgrad,* Bachelor Thesis at FH Reutlingen, ITV Denkendorf, 2007.

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