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The Impact of Machine Gauge and Type of Regenerating Cellulosic Fibers on Functional Characteristic of Socks

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Abstract
Socks are a main sector of the knitting garment; it is daily and widely used in our life. Its characteristics are known as highly extensible with elastic recovery and semi-permanent deformation which give it easy wear and foot comfortable. Regenerating cellulosic fibers are type of eco-friendly fibers which have good moisture absorbent, biodegradable and antibacterial. The produced study is concerned with producing socks with 30/1 ring spinning yarns from three different kinds of regenerated cellulosic fibers (viscose, bamboo, Tencel), using two different socks machine in number of needles (200, 168 needles per diameter). The effect of machine gauge and type of material on the performance properties of the produced socks are investigated. The tested properties were thermal conductivity, air permeability, bursting, Surface roughness (MIU, SMD), abrasion and pilling. The results pointed to both factors (No. of machine needles and type of yarn are significant effect on tested properties. Also, it was found that the bamboo material is highly significant for the most properties.

Keywords: socks; regenerated fibers; air permeability ; thermal conductivity; pilling ; abrasion.

1. Introduction
Socks from regenerated fibers may be more suitable to restrict foot problems such as Tinea “Ringworm” which is caused by the fungus, Herpes which is caused by viruses, and Staphylococcus aureus “Staph” which is caused by bacteria. Also, may protect from Infectious diseases. Traditional cellulosic and synthetic fibers become incompatible with the environmental criteria, so they are ecologically unfriendly. So, new trends for naturally renewable resources with the help of some chemical processes become sought. Bamboo fibers are one of these new green biodegradable materials. It is fast growing plant without using any pesticide which is processed through hydrolysis-alkalization and multi-phase bleaching. Bamboo fibers are characterized by strong durability, stability, and tenacity, antibacterial and deodorizing in nature in even after washing up to fifty times, hydroscopic more than cotton [1].
Bamboo is one of the regenerated fibers that is considered an eco-friendly alternative to cotton material, whereas traditional cotton fibers are not considered eco-friendly because of its large consumption of water and pesticides during its cultivation. Polyester-bamboo (PB) and polyester- cotton (PC) blended were studied and employed in single jersey weft knitted fabrics using open-end spinning yarns. It was found that the tensile strength of (PB yarns is higher than PC yarns [2].
A study is concerned with the thermal comfort properties of single jersey knitted fabric structures made from cotton as natural fibers, regenerated bamboo, and cotton-bamboo blended yarn with different ratios. It was concluded that the thermal conductivity of tested fabrics decreased with an increase in the proportion of bamboo fibers, but water vapor permeability and air permeability increased with an increase in bamboo fiber percentage. Statistical analysis proves that the results are significant for all tested properties [3].
A study was evaluated the abrasion properties of Tencel fabrics by Martindale, and the breakdown mechanism of fibers was scanned by electron microscopy. The fabrics were treated with two different methods [4]. Good ultraviolet protection, thermal and moisture transfer properties are very important factors for knitted garments especially for sportswear. They study the effect of type of fibers on ultraviolet protection factor (UPF) and absorption properties of knitted fabrics from natural and regenerated cellulosic yarns which are Tencel, bamboo, Modal and their blend with cotton. It was found that Egyptian cotton fabric has the highest thermal insulation compared to the other regenerated cellulosic fabrics, the tested properties are significantly affected by fiber type and fabric structure [5].
The lyocell fibers are which are produced form out of a solution in N-methyl morpholine-N-oxide (NMMO). Solvent spun fibers consist of amorphous cellulose and crystalline cellulose-II. The tencel fibers have a higher degree of crystallinity (80%)

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in comparison to other regenerated fibers, but bamboo has degree of crystallinity (49%) and viscose has (41%) degree of crystallinity [6]. Lyocell fibers are mostly used for outerwear apparel. Under certain conditions, lyocell fibers fibrillate which enables fabrics to be developed with interesting aesthetics. Non- fibrillating versions are also available., but it has been shown that due to the fibrillating property, some very interesting nonwoven fabrics can be made as well [7].
A recent study investigated the use of eco- friendly yarns from bamboo, modal, and their blend 50/50 with single jersey knit fabrics to study their Relevance for high-performance garment applications. It evaluated the mechanical, physical, comfort, thermal, and appearance properties of the tested samples. It was concluded that bamboo material has higher performance characteristics such as antibacterial characteristics, a soft surface, and thermal insulation [8].
Regenerated cellulose fibers can combine adaptability with safety, comfort, renewability, and biodegradability, which can lead to the development of highly effective, ecologically friendly textile products [9].
A study was carried out on the functional properties of regenerated fibers (lyocell (Tencel), bamboo). Surface roughness is one of the comforts propertied of clothes, especially clothes which face the skin like socks. The higher values of this property pointed to greater friction with skin and less comfort during wearing. The Kawabata Evaluation System (KES) is very important for the evaluation of this property. This system helps in discovering the fabric surface problems to avoid by dying or surface treatment. [10, 11].
Air permeability is one of the comfort properties of textiles which affects the flow of vapour from the human body to the environment and the flow of fresh air to the body, therefore the skin can breathe. As known knitted fabrics have several times more air permeability than other types of fabrics. So there was a study to evaluate the air permeability of the knitted sportswear made from viscose and modal yarns [12].
Another study tested comfort properties like thermal conductivity and air permeability of viscose, cotton, cotton/Lycra, and viscose/Lycra for scarves and knitted fabrics in the Egyptian market. They found that increasing Lycra percent increased abrasion and thermal resistance **[13]**.

2. Materials and Methods

The socks were produced on The socks were produced on single jersey socks m/c , FURONG- Model G300D socks machines with 3.5 inch diameter with two different numbers of needles / diameter. It was used Lycra yarns with a count of 150 denier for all types of tested socks with the same ratio (3yarn: 1 Lycra), the machine (m/c) Specifications were illustrated in table (1).

Table 1: The specifications of the Socks machines

No of needles	m/c type	DIAMETER
200	FURONG- Model G300D	3.5’’ (inch)
168		

2.1 Samples preparation

The used yarns in this work were produced from regenerating cellulosic fibers, all the socks samples were relaxed before testing for at least 48 hours. All measurements were performed under the standard atmospheric conditions of 20°±2°C and 65±2% RH. Table (2) shows the yarn Specifications. Also Table (3) illustrates the Socks Specifications.

Table 2: Specifications of yarn

Raw material	Count	Tenacity (N/tex)	Max. load (gm)	Elongation %
Viscose (V)	30/1 Ne	1.61	0.29	14.84
Bamboo (B)		1.86	0.33	16.82
Tencel (T)		2.7	0.47	9.34
lycra	150 denier	---	---	---

Table 3: Specifications of Socks

Samples	Thickness mm	Weight/unit area (g/m^2)	Loop length mm	Stitch density	
				w/cm	c/cm
V1	1.07	259.3	1.6	26	35
V2	1.21	234.4	2	23	35
B1	1.1	253.3	1.83	25	35
B2	1.21	220	2	23	32
T1	1.17	225.6	1.63	25	35
T2	1.16	213.8	2.14	22	32

2.2 Test methods

All the structure, physical and mechanical properties were tested according to its standard methods in laboratories of National Research Centre as follows:

- **Fabric weight per unit area** (GSM) using digital measuring balance was measured according to the standard method (D3776/D3776M − 20) [14].

- **Fabric thickness** was measured according to standard (D 1777 – 96 (Reapproved 2002) [15].
- **Stitch length and yarn linear density** in weft knitted fabrics were Determined according to standard (BS EN 14970-2006) [16].
- **Thermal conductivity** measured the heat transfer through fabric using Permetest apparatus according to standard method (ISO11092). The thermal conductivity means energy per unit area per unit time divided by the temperature gradient, so it was expressed in w/cm*oC
- **Air permeability** which was evaluated according to the standard method (ASTM D737)[17].
- **Bursting strength** refers to the perpendicular force required to break or rupture the fabric. The using size sample was cut in the of 112 mm^2, dimension [kPa]. It was measured according to (ASTM D3786) [18].
- **Surface roughness** means fabric surface friction. Two properties indicated to Surface roughness
- Were measured on Kawabata Evaluation System (KES). The first one was the coefficient of friction (MIU) its ranges values from 0 to 1, where the higher value pointed to greater friction. The other friction property was mean deviation of fabric surface profile (SMD) the measured value expressed in µm; the higher values correspond to higher geometrically rougher surface [19,20**]**.
- **Abrasion Resistance** (cycles) was tested on Martindale tester according to (ASTM-D4966) [21].
- **Pilling** is an unwanted effect on the fabric surface caused by protruding fiber. It is very common in knitted fabrics due to fabric loose structure and the use of low twist yarn. Pilling test was performed on Martindale tester according to standard method ASTM D4970 [22]. The measured readings were taken on the stem of the socks (flat surface), and socks but.

3. Results and Discussion

The result data of this work is statistical analysed by One-Way ANOVA test with P-value at 95% confidence limit, where the significant effect of the two selected factors (m/c needles, type of yarn) on the selected socks properties were investigated.

3.1 The relation between the selected factors and Thermal conductivity

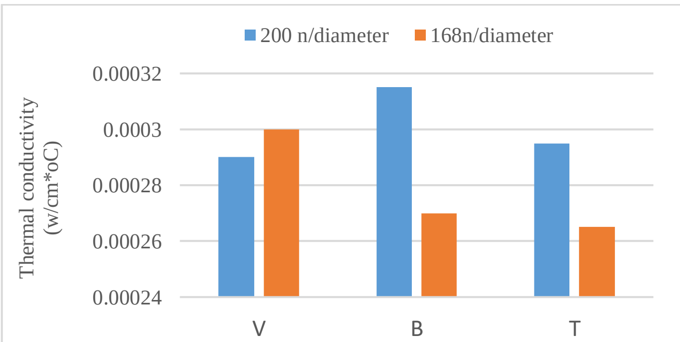

Fig. 1. Comparison between sample materials and needles m/c no. with thermal conductivity

Table 4: Results of ANOVA test for thermal conductivity

Thermal conductivity (w/cm*oC)	SS	df	MS	F	P-value	F crit
Between materials						
thermal 200n	1.05E-09	2	5.25E-10	31.5	0.000658*	5.143253
thermal168n	2.15E-09	2	1.08E-09	129	1.17E-05*	5.143253
Between Machines						
Thermal V	0.013254	1	0.013254	25.66946	0.007148*	7.708647
thermal B	0.012604	1	0.012604	42.55768	0.002851*	7.708647
thermal T	0.007004	1	0.007004	176.5756	0.000185*	7.708647
*Significant effect using confidence limit 95%						

It is observed from fig (1) that thermal conductivity in the heavy fabric is better than the light one specially in bamboo and tencel instead of for viscose fabric.

As it is clear from table (4) all factors are Significant effected on thermal conductivity. The fabric with 168 n was more significant effect than 200 n. Also, all types of fabrics have high significant effect on thermal conductivity. The tencel fabric was the most significant.

3.2 The relation between the selected factors and Air permeability

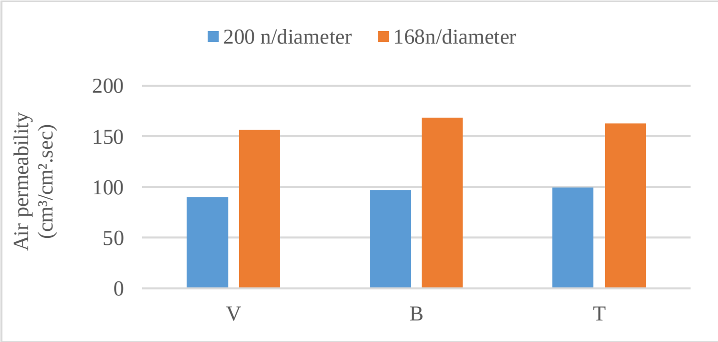

Fig. 2. Comparison between sample materials and needles m/c no. with air permeability

Table 5: Results of ANOVA test for Air permeability

Air permeability (cm^3/cm^2.sec)	SS	df	MS	F	P-value	F crit
Between materials						
Air permeability 200n	136.4689	2	68.23444	15.50391	0.004262*	5.143253
Air permeability 168n	216.0556	2	108.0278	41.37234	0.000309*	5.143253
Between Machines						
Air permeability V	6547.207	1	6547.207	6255.293	1.53E-07*	7.708647
Air permeability B	7604.16	1	7604.16	882.1531	7.65E-06*	7.708647
Air permeability T	5966.107	1	5966.107	7005.213	1.22E-07*	7.708647
*Significant effect using confidence limit 95%						

From fig (2) it is seen that air permeability for all sock are significant, and it is higher for bamboo fabrics, then tencel, later than viscose, related to its material nature.

From table (5) it appears that all factors are significant effected, but 168 needles' machine is more significant than 200 needles on this property. Also all types of fabrics have high significant effect on air permeability, but the Bamboo fabric was more significant.

3.3 The relation between the selected factors and Bursting

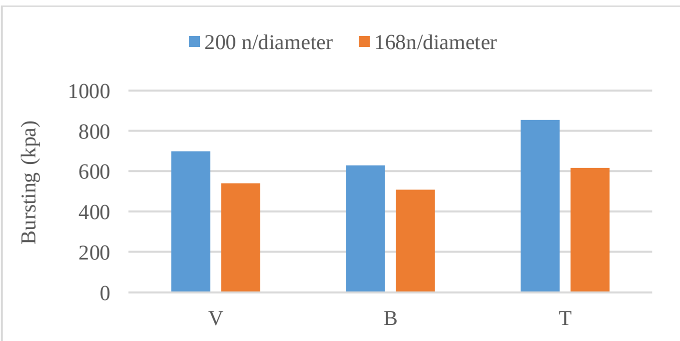

Fig. 3. Comparison between sample materials and needles m/c no. with Bursting

Table 6: Results of ANOVA test for Bursting

Bursting (kPa)	SS	df	MS	F	P-value	F crit
Between materials						
Bursting 200	80302.33	2	40151.16	21.99408	0.001729*	5.143253
Bursting 168n	18248.73	2	9124.363	6.053011	0.03639*	5.143253
Between Machines						
Bursting V	37477.61	1	37477.61	84.55344	0.000777*	7.708647
Bursting B	22374.83	1	22374.83	10.4019	0.032122*	7.708647
Bursting T	86568.08	1	86568.08	35.9927	0.003884*	7.708647
*Significant effect using confidence limit 95%						

Fig (3) shows that the max values for bursting were for tencel fabric for both m/c needles, due to higher tenacity, then viscose at last bamboo. For all fabrics the tight fabrics (related to higher stitch density) with 200n have greater values for bursting.

Table (6) illustrates that all factors are significantly affected bursting property, but the strong significance was for type of fabrics. The higher effect was for viscose fabric, then tencel at least bamboo. Also, 200 n is more significant than 168n for all fabrics.

3.4 The relation between the selected factors and MIU-Kawabata

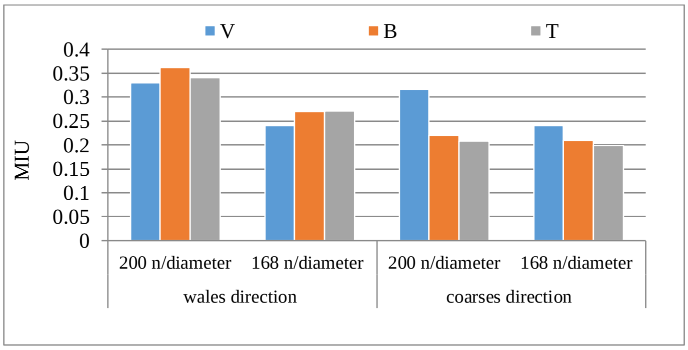

Fig. 4. Comparison between sample materials and needles m/c no. with MIU in wales and courses direction

Table 7: Results of ANOVA test for MIU – Kawabata

MIU	SS	df	MS	F	P-value	F crit
Between materials						
MIU Wales 200n	0.008808	2	0.004404	67.75385	7.62E-05*	5.143253
MIU Wales 168n	0.024527	2	0.012263	24.37522	0.001316*	5.143253
MIU Courses 200n	0.023478	2	0.011739	24.80676	0.001256*	5.143253
MIU Courses 168n	0.002322	2	0.001161	15.07504	0.004572*	5.143253
Between Machines						
MIU Wales V	0.013254	1	0.013254	25.66946	0.007148*	7.708647
MIU Wales B	0.012604	1	0.012604	42.55768	0.002851*	7.708647
MIU Wales T	0.007004	1	0.007004	176.5756	0.000185*	7.708647
MIU Courses V	0.009204	1	0.009204	11.5606	0.027275*	7.708647
MIU Courses B	0.00015	1	0.00015	12.16216	0.025182*	7.708647
MIU Courses T	0.000104	1	0.000104	6.188119	0.067659	7.708647
*Significant effect using confidence limit 95%						

From fig (4) it is observed that less value of MIU at Tencel with 168n in course direction because of the less thickness and less stitch density in wales direction. For all types of fabrics it is noted the light weight with 168n are less value for MIU and this is normal for light weight.

As it is appeared from table (7) that all factors are significantly affected MIU, but 200 n is more significant than 168n for this property, and in wales direction than in the course direction. In addition to all types of fabrics have high significance on MIU, and the tencel fabric was the most significant in wales direction than in course direction.

3.5 The relation between selected factors and SMD-Kawabata

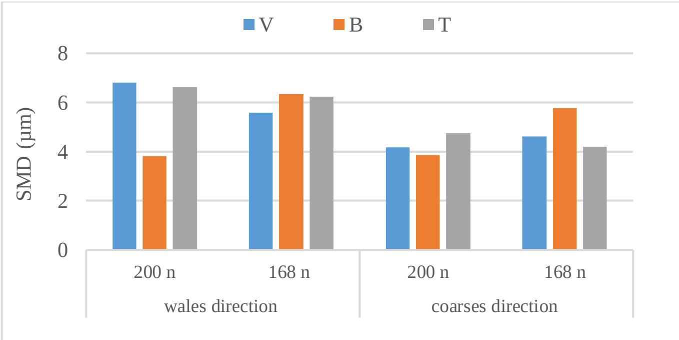

Fig. 5. Comparison between sample materials and needles m/c no. with SMD in wales and course direction

Table 8: Results of ANOVA test for SMD – Kawabata

SMD (µm)	SS	df	MS	F	P-value	F crit
Between materials						
SMD Wales 200n	16.85596	2	8.427979	86.02837	3.83E-05*	5.143253
SMD Wales 168n	0.989153	2	0.494576	1.658447	0.267079	5.143253
SMD Courses 200n	1.230134	2	0.615067	4.582235	0.06194	5.143253
SMD Courses 168n	3.918654	2	1.959327	6.681659	0.029752*	5.143253
Between Machines						
SMD Wales V	2.23382	1	2.23382	37.13945	0.003667*	7.708647
SMD Wales B	9.502934	1	9.502934	25.07116	0.007453*	7.708647
SMD Wales T	0.251331	1	0.251331	1.62054	0.271971	7.708647
SMD Courses V	0.286891	1	0.286891	0.677317	0.456746	7.708647
SMD Courses B	5.430211	1	5.430211	124.9181	0.000365*	7.708647
SMD Courses T	0.455953	1	0.455953	2.61797	0.180969	7.708647
*Significant effect using confidence limit 95%						

From fig (5) it is noticed that SMD property has low values in the course direction than wales direction due to the difference in stitch density, also the values at 200 n are less than 168 n.

Table (8) illustrates that the most significant effect was for 200 n in wales direction and for bamboo fabric in both directions.

3.6 The relation between selected factors and Abrasion

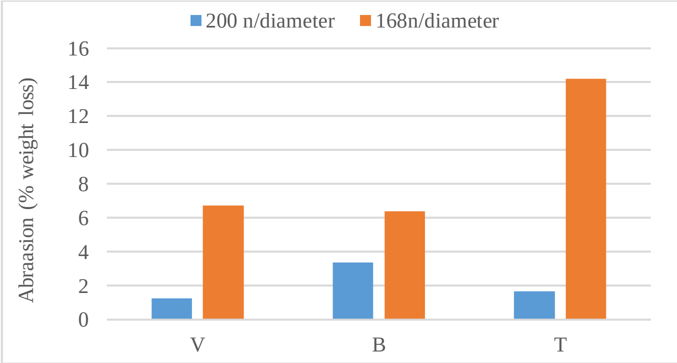

Fig. 6. Comparison between sample materials and needles m/c no. with abrasion

Table 9: Results of ANOVA test for Abrasion

Abrasion (%loss of weight)	SS	df	MS	F	P-value	F crit
Between material						
Abrasion 200n	7.5102	2	3.7551	21.13168	0.001921*	5.143253
Abrasion 168n	116.2289	2	58.11444	13.63122	0.005869*	5.143253
Between Machine						
Abrasion V	44.99082	1	44.99082	295.054	6.74E-05*	7.708647
Abrasion B	13.5	1	13.5	16.2	0.0158*	7.708647
Abrasion T	234.375	1	234.375	41.29422	0.003015*	7.708647
*Significant effect using confidence limit 95%						

Fig (6) shows that the lowest value of abrasion was for viscose because of lowest thickness, then tencel later than bamboo. For all fabrics the values of abrasion at 200 n are less than at 168n.

From table (9) it is clear that all factors have a significant effect on abrasion. but the higher significance was for the type of fabrics which indicate to firstly viscose fabric, then tencel later than bamboo. Also, 200n is more effective than 168n for all fabrics.

3.7 The relation between each of tested factor on Pilling

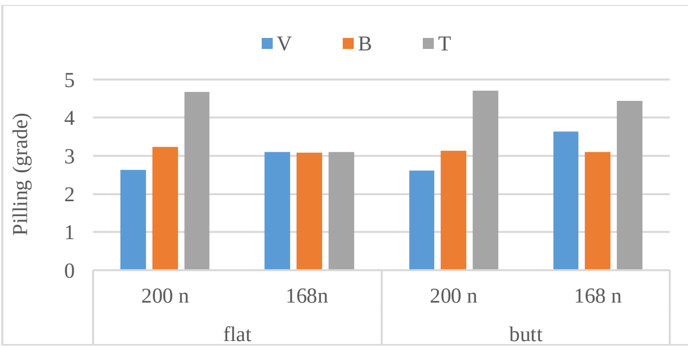

Fig 7. Comparison between sample materials and needles m/c no. with pilling

Table 10: Results of ANOVA test for Pilling

Pilling (grade)	SS	df	MS	F	P-value	F crit
Between material						
pilling-flat-200n	6.479756	2	3.239878	31.85721	0.000638*	5.143253
pilling-flat-168n	0.001867	2	0.000933	0.003024	0.996982	5.143253
pilling -butt - 200	7.044356	2	3.522178	20.89762	0.001978*	5.143253
pilling -but -168n	2.739756	2	1.369878	6.014684	0.036856*	5.143253
Between Machine						
pilling-flat- V	0.312817	1	0.312817	0.979644	0,378316	7.708647
pilling-flat- B	1.570817	1	1.570817	19.52133	0.011526*	7.708647
pilling-flat- T	0.03375	1	0.03375	0.368316	0.576685	7.708647
pilling-but- V	0.001667	1	0.001667	0.005435	0.944772	7.708647
pilling-but- B	3.84	1	3.84	18.76986	0.012326*	7.708647
pilling-but- T	0.098817	1	0.098817	0.476646	0.527916	7.708647
* Significant effect using confidence limit 95%						

From fig (7) it was seen that bamboo and viscose fabric have least values of pilling than tencel this may be related to Surface smoothness due to its fibers nature.

From table (10) declare that factor 200 n is more significant effect on pilling in case of flat and butt, Also bamboo type in both flat and butt are the most significant effect.

4. Conclusions

- All factors have a significant effect on thermal conductivity, but the 168 n related to machine effect, and tencel fabric related to material effect were more significant.
- All factors have a significant effect on air permeability , but the 168 n related to machine effect, and Bamboo fabric related to material effect were more significant
- All factors are significantly affected on bursting property, but the higher significance was for. Viscose fabric and 200 n on bursting, but the max values for bursting were for tencel fabric.
- All factors have a significant effect on MIU, but Tencel in wales direction with 200 n is the more significant than others for this property.
- Bamboo in course direction with 200 n is more significant than other samples on SMD property
- All factors have a significant effect on abrasion. But higher significance is for type of fabrics which indicates firstly viscose fabric, then Tencel and finally bamboo. Also, 200n is more significant than 168n for all fabrics, viscose has higher Weight/unit area (g/m^2) so, abrasion will be improved.
- Bamboo in flat and but with 200 n is more significant than other samples on pilling property.
- Material type has a more significant effect than m/c needles for all properties, 168n is higher significant for the comfort properties (thermal conductivity and air permeability), but 200 n is higher significant for the mechanical properties.
- Bamboo material is highly significant for the most properties.

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