Copyright © 2012 Tech Science Press CMC, vol.27, no.2, pp.179-188, 2012

Experimental Study and Simulation on Compression Character of Warp Knitted Spacer Fabrics

Jing Qian[1], **Xuhong Miao**[2] **and Yao Shen**[3]

Abstract: Based on experimental data, the research work on warp knitted spacer fabrics gives compression laws when structural parameters (such as diameter of spacer yarn, areal density, spacer yarn angle and the thickness of spacer fabrics) of spacer fabric change. ANSYS calculation models were developed, and simulation results matched with experimental data well. The computer simulation on this area provides a fundamental tool which can help designer to decide structural parameters when working stresses are given.

Keywords: Warp knitted spacer fabrics, compression character, finite element, structural parameter, simulation.

1 Introduction

Warp knitted spacer fabrics is a kind of three decker fabric. It keeps two surfaces of knitted fabrics separately by middle monofilaments or yarns and meanwhile links them together. The middle monofilaments or yarns are called spacer yarn. The fabrics are consisted of two surfaces and a middle wall, and also are called Sandwich fabrics (see Fig. 1). This unique construction makes the fabrics with good ventilating, sound-proofing, compression resisting and vibration resisting. The fabrics are widespread applied on automobile industry, medical treatment, agriculture and construction industry. Based on experimental data and computer aided analysis, the changing regularities of fabrics stresses on flat and spherical compression were discussed while its construction parameters were changed. (Karl Mayer, 2006; Gross-D, 2003).

---

[1] School of Mechanical Engineering, Jiangnan University, Wuxi, Jiangsu, China.
[2] School of Textile Engineering, Jiangnan University, Wuxi, Jiangsu, China.
[3] School of Mechanical Engineering, Jiangnan University, Wuxi, Jiangsu, China.

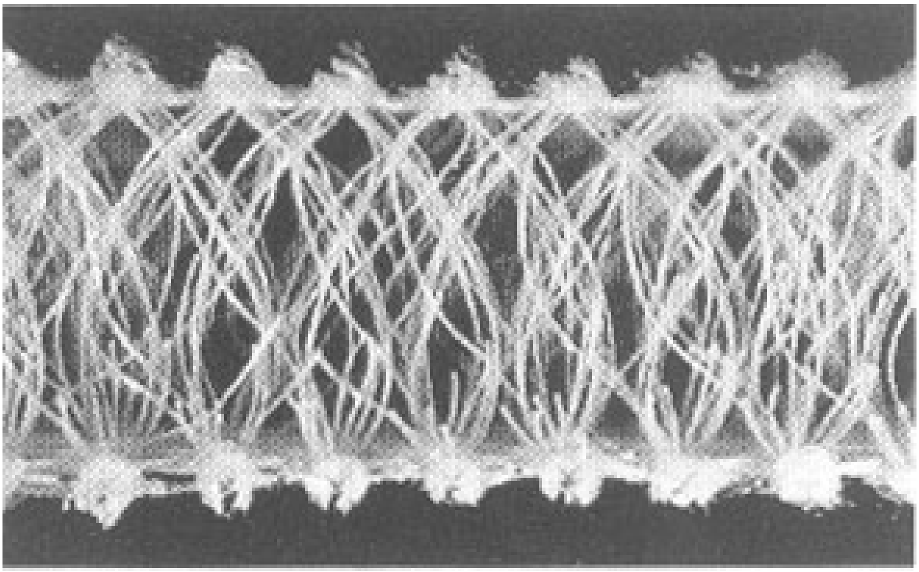

Figure 1: Enlargement of warp knitted spacer fabric

2 Structure and compression character

2.1 Structure of warp knitted spacer fabrics and its parameters

When warp knitted spacer fabrics are compressed, thickness of fabrics decreases with stress increase. The thickness of fabrics almost returns to original as stress disappears. Therefore, the compression character of warp knitted fabrics is different from normal fabrics. The study on compression character of warp knitted spacer fabrics based on poly-foam compression standard by flat and spherical compression experiment (ASTM D3571-11; Bartels-VT, 2002). Normally, spacer yarns cross banding like 'V'. Its mechanical structure is shown as Fig. 2.

Main structural parameters which impact the compression character of warp knitted spacer fabrics are diameter of spacer yarn, areal density, angle of spacer yarn and thickness of fabric.

To compare compression character of different warp knitted spacer fabric in compression experiment and simulation process, these fabrics were selected as in Tab. 1.

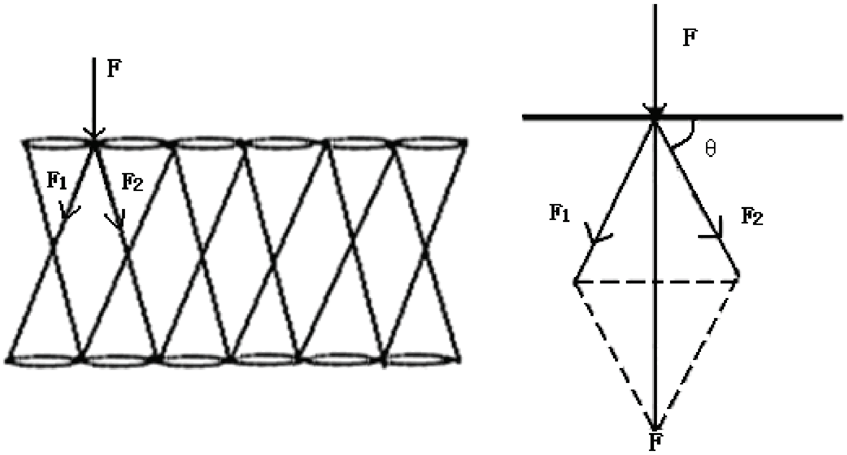

Figure 2: Mechanical structure of warp-knitted fabrics

Table 1: Structural parameters of spacer fabric in researching

No.	diameter of spacer yarn ϕ(mm)	areal density ρ(cpc)	angle of spacer yarn $\theta(^o)$*	thickness of fabric d(mm)**
A1	0.22	10	90	4×9
A2	0.18	10	90	4×9
A3	0.15	10	90	4×9
B1	0.22	8.5	60	4×9
B2	0.22	7.5	60	4×9
B3	0.22	6.5	60	4×9
B4	0.22	4.5	60	4×9
C1	0.22	8	90	4×9
C2	0.22	8	75	4×9
C3	0.22	8	60	4×9
D1	0.22	10	90	4×9
D2	0.22	10	90	4×20

Notes *: With a view to instability when spacer yarn angle is 90^o, there are some spacer yarns whose angle is 45^o existing.

**: According to experiment standard on sample thickness, 4-layer sample was used in compression test.

2.2 Flat compression experiment

The flat compression experiment by universal testing machine was shown as Fig.3. The speed of up-platen was 12±3mm/min. The force on fabrics was almost static.

With force increasing, thickness of fabric decreased, and deflection increased. The machine recorded force-deflection curves of different fabrics automatically. To represent the mechanical character of materials, these force-deflection curves were changed to stress-strain curves, which stress is force divided by area of sample thrust surface and strain is deflection divided by primary thickness of sample, shown in Fig.4 to Fig. 7. These σ-εcurves were average curves of five experiments on same fabrics.

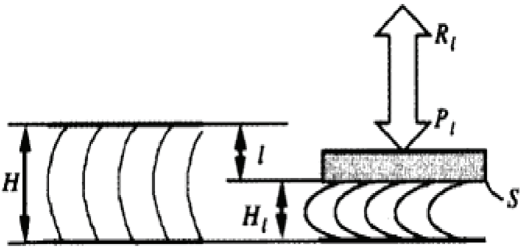

Figure 3: Flat compression experiment

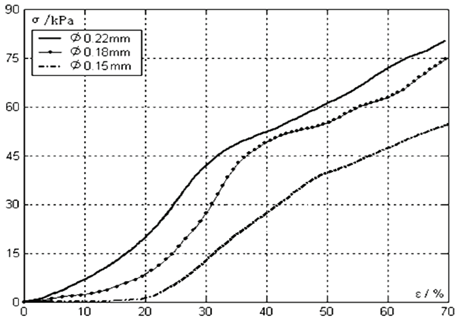

Figure 4: $\sigma\varepsilon$ curves on different diameters

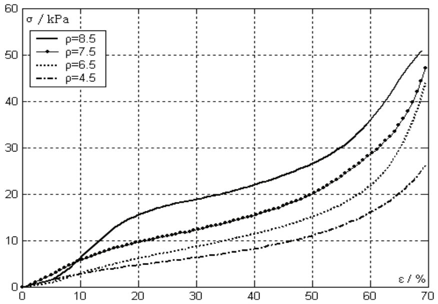

Figure 5: $\sigma\varepsilon$ curves on different areal densities

In these curves, it is clear that the carrying capacity of fabrics increases while diameter of spacer yarn is bigger, areal density raises and the angle of spacer yarn increases. In same physical parameters, the carrying capacity of fabrics decreases while the thickness of fabrics increases. Adjusting structural parameters like diameter of spacer yarn, areal density, angle of spacer yarn and thickness of fabrics, the requested compression character of fabrics could be achieved.

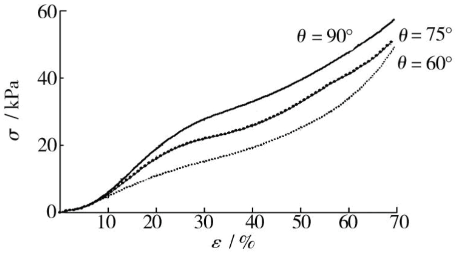

Figure 6: $\sigma\varepsilon$ curves on different yarn angles

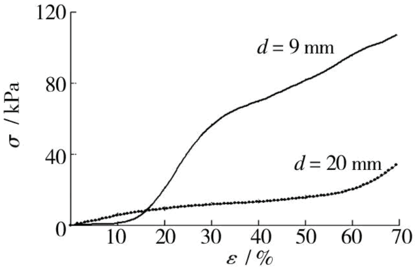

Figure 7: $\sigma\varepsilon$ curves on different thickness

2.3 Spherical compression experiment

In spherical compression experiment, a self-made spherical indenter was put on fabrics. Considering the weight of spherical indenter, the preload was set. Pressure value of top point was measured by pressure sensor, shown as Fig.8. Normally, spherical compression test is a kind of judgment for comfort level of fabrics. In the test, the stress values were recorded when strains of material is 25%, 40% and 65%, respectively, instead of compression curves. After five same experiments, the averages of data were shown in Tab.2.

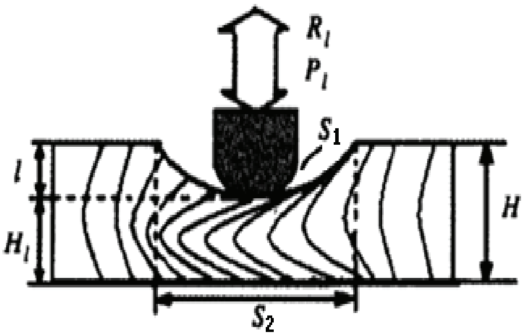

Figure 8: Spherical compression test

3 Cushion property of warp knitted spacer fabrics

For cushion material, representation of cushion capacity is critical issue in engineering. Cushion coefficient ‘C’ is a familiar physical quantity to describe cushion property of material. It could be calculated as:

$$C = \sigma / E \tag{1}$$

where $E = \int_0^{\varepsilon} \sigma d\varepsilon$, is unit strain energy.

Calculating onσ-εcurves by computer software, cushion coefficient-Max stress (C-σ_m) curves can be obtained. This curves shows cushion property of material in different load bearing, and could be applied on cushion design.

Fig. 9 to Fig. 11 show C- σ_m curves which are transformed from theirσ-εcurves. They report the basic laws of cushion coefficient while structural parameters of fabrics change.

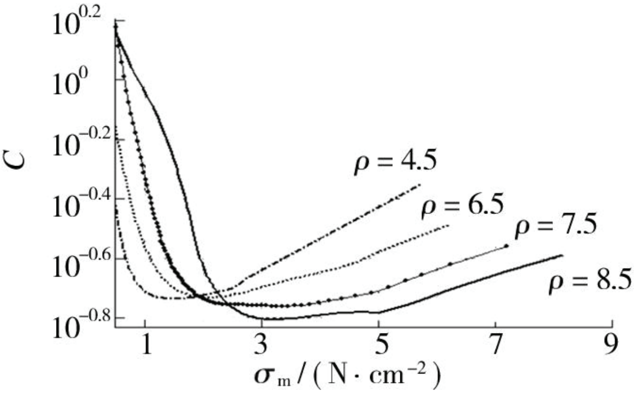

Figure 9: C- σ_m curves on different areal densities

These figures show that the stresses which cushion coefficients is minimum increase while diameters of spacer yarn increase, areal densities increase, angles of spacer yarn increase and thickness of fabrics decrease. It also declares that different structural parameters of fabrics achieve their best cushion effect in different compression bearing. Therefore, the best choice for cushion materials depends on stress status of applying.

4 Computer simulation

From flat and spherical compression tests on warp knitted spacer fabrics, it clears that structural parameters, such as diameter of spacer yarn, areal density, spacer yarn angle and the thickness of spacer fabrics, could give much more effects on cushion property of fabrics. All changes of these structural parameters are integrated into the compression character of fabrics. Computer simulation on compress

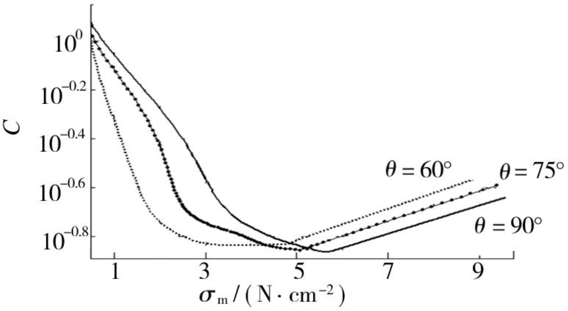

Figure 10: C- σ_m curves on different yarn angles

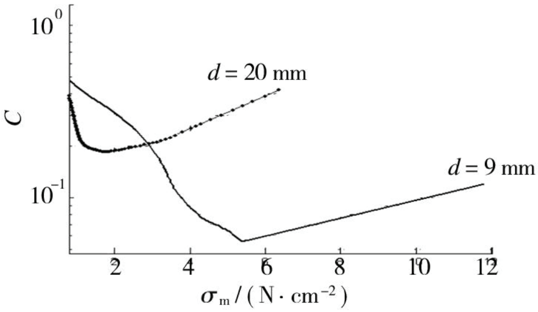

Figure 11: C- σ_m curves on different thickness

experiments will develop basic models as a tool for structural parameters design of warp knitted spacer fabrics. According to the structure of fabrics and also to simplify the simulation, reasonable assuming is as following. (Marek Musiol, 2005; Aung Kyaw Soe, etc, 2003)

- The thickness of two surface fabrics is ignored, and there are no relative displacement between spacer yarn and surface fabrics;
- Spacer yarns are independent, and there are no extruding among them;
- Spacer yarn is ideal elastomer, and two surface fabrics are ideal elastic shell.

Fig. 12 shows the simulation result and experimental data in flat compression test. Comparing these two curves, the simulation result is matched experimental data quite well till strain of sample is over 60%. Normally, the best cushion stress point of cushion material is not over 50% of strain. That means the flat model is satisfied enough for fabric design.

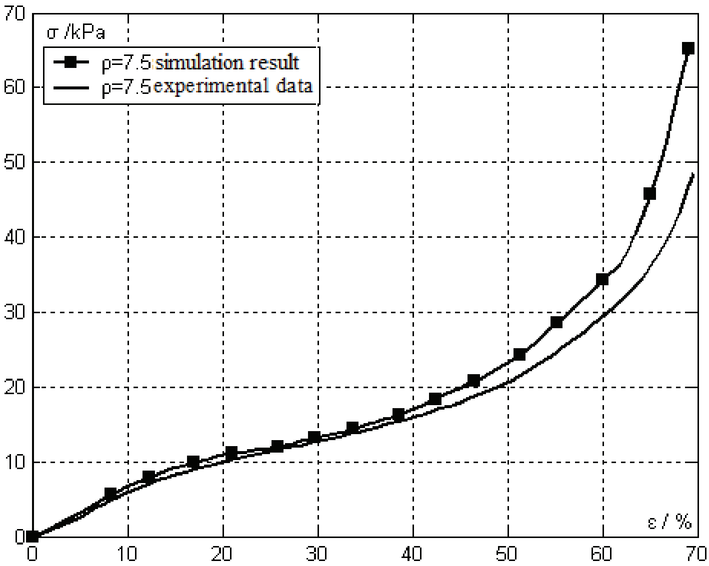

Figure 12: Simulation and test curves when parameters are B2

In spherical compression, simulation results are shown in Tab. 2. Comparing experimental data and simulation results, when strains are 25% and 40% the stress errors are mostly not more than 15%, seldom errors are increase to 20%; when strain is 60%, the stress errors increase, is about 20%, some errors was almost up to 30%. The reason is the assuming of spacer yarn's ideal elastomer in ANSYS model development. In this assuming the deformation of spacer yarn complies with Hook's Law. When the strain increases to 60%, the deformation of spacer yarn is not completely so. Even so, the simulation results still give a good reflection on the variation tendency of stress. The stresses in fabric will be decrease when the diameter of spacer yarn increases, areal density is bigger, the angle of spacer yarn decreases and the thickness of fabric increase.

5 Conclusion

Warp knitted spacer yarn fabrics are required to have enough compression elasticity, especially when it works as a cushion or mattress. The fabrics should give support and meanwhile relieve the pressure to provide favorable comfort level. In this case, the fabrics must be with specific structural parameters to satisfy different users. The study on compression character of warp knitted spacer yarn fabrics by experiment and computer simulation gives the variation tendency of structural pa-

Table 2: Simulation and test data on spherical compression

No.	Stress in 25% strain(KPa)			Stress in 40% strain(KPa)			Stress in 60% strain(KPa)		
	Actual	Simulation	Error	Actual	Simulation	Error	Actual	Simulation	Error
A1	77.2	65.6	15%	100.	94.6	6%	148	121.	19%
A2	46.3	38.3	17%	81.6	77.2	5%	126.	105.	17%
A3	24.9	21.1	15%	37.7	32.5	14%	92.1	71.7	22%
B1	28.8	26.6	7%	37.1	33.7	9%	88.1	75.2	15%
B2	20.1	18.0	10%	26.8	23.7	12%	64.0	51.0	20%
B3	18.5	16.4	12%	24.5	21.0	14%	50.2	39.3	22%
B4	15.9	14.3	10%	20.9	17.9	14%	45.3	36.2	20%
C1	56.1	53.2	5%	81.3	76.3	6%	108	91.3	16%
C2	25.5	23.6	7%	35.6	31.6	11%	85.7	69.4	19%
C3	16.6	14.4	13%	22.7	18.5	19%	52.9	37.6	29%
C4	14.5	12.4	14%	20.0	16.4	18%	45.5	34.1	25%
D1	77.2	65.6	15%	100	94.6	6%	148	121.	19%
D2	30.7	25.6	17%	37.7	29.5	22%	95.7	71.1	26%
D3	19.4	17.1	12%	24.8	20.5	17%	47.2	36.1	23%

rameters with fabrics compression character. The development of ANSYS models provides a computer aid design tool, which could confirm the structural parameters of fabrics according to its specific compression character.

Acknowledgement: Ministry of Education zoology spinning key laboratory in Jiangnan University supports the research work.

References

Karl Mayer. (2006): Spacer Fabrics in Clothing. *Kettenwirk Praxis*, vol. 38, No. 2, pp. 6-7

Gross-D. (2003): D3 Spacer Knit Fabrics for Medical Devices. *Knitting Technology*, Vol. 25, No. 1, pp. 26-29.

ASTM D3571-11. *Standard Test Methods for Flexible Cellular Materials-slab, Bonded, and Molded Urethane Foams.*

Bartels-VT. (2002) Warp-knitted Spacer Fabrics versus Neoprene. *Kettenwirk Praxis*, vol. 35, No. 1, pp.20-22.

Marek Musiol. (2005): Analysis of Transverse Deformability of Spacer Products. *AUTEX Research Journal,* vol. 5, No. 1, pp. 60-70.

Aung Kyaw Soe, etc. (2003): Compression of Plain Knitted Fabrics Predicted from Yarn Properties and Fabric Geometry. *Textile Research*, vol. 73, No.7, pp. 861-866.