The Relationship between Sound and Mechanical properties of Korean Traditional Silk Fabric

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Abstract

The purpose of this study was to measure sound parameters and mechanical properties of Korean traditional silk fabrics quantitatively, and to investigate the effect of mechanical properties on sound parameters. Five different specimens were randomly selected among Korean traditional silk fabrics commercially available. Those included Gapsa (GS) of leno weave construction, Nobangju (NB), Myoungju (MJ) and Shantung (ST) with plain weave, and Gondan (GD) of satin construction. The rustling sound of each fabric generated by MAFN (Measuring Apparatus for Fabric Noise) was analyzed by a Sound Quality System in order to calculate its objective sound parameters such as LPT (Level Pressure of Total sound), ⊿L (level range), ⊿f (frequency differences), and Zwicker's psychoacoustic parameters including loudness (Z), sharpness (Z), roughness (Z), and fluctuation strength (Z). The fabrics were also investigated in terms of 17 mechanical properties by using KES-FB system. The FFT spectra of the specimens with the same weave structures showed similar shapes of the fluent curve to one another, and their amplitudes varied from low amplitudes to high ones. Gapsa was the traditional silk fabric showing the lowest values for both LPT (42.30 dB) and ⊿f(-11929.4 Hz) while Shantung was the one having the highest values for LPT (60.60 dB), loudness (Z) (8.69 sone), and sharpness (Z) (2.6 acum). The other hands, Nobangju had the highest ⊿L (38.24 dB) while the lowest ones for both ⊿f (-11929.4 Hz) same to Gapsa. As for Myoungju, it showed the lowest ⊿L (25.70 dB) among the silk fabrics. Finally Gongdan was the fabric of which ⊿f and fluctuation strength (Z) were the highest whereas its roughness (Z) (1.70 asper) was the lowest. The sound parameters were affected significantly by mechanical properties. LPT had negative relations with linearity of compression-thickness curve (LC) while positive correlations with weight (W). As for ⊿f, bending rigidity among the mechanical properties showed negative relations with it. Loudness (Z) was positively related with compression energy (WC). Sharpness (Z) was negatively related with compression resilience (RC), mean deviation of MIU (MMD) and hysteresis of bending moment (2HB). Fluctuation strength (Z) had negative relation with bending rigidity (B), mean deviation of MIU (MMD) but positive relation with elongation at maximum load (EM). Both LPT and loudness (Z) which had significantly correlated to each other were found as affected by compression properties. Bending properties influenced both ⊿f and fluctuation strength (Z) although they didn't show any significant correlation to each other. Conclusively, by controlling the mechanical properties as indicated above in the textile manufacturing process, it may be possible to manage the frictional sounds of Korean traditional silk fabrics and to help the textile manufacturers design the pleasant sound of synthetic fabrics that imitate silk.

Keywords: Korea traditional silk fabric, FFT spectra, sound parameter, mechanical property

1. Introduction

In order to satisfy sensorial comfort of textiles when we wear clothes, we have found that frictional sound of fabrics is an significant attributes which should be dealt. The auditory characteristic of textiles is an important sensual peculiarity so it is up to a factor of sensibility fabric developments [7]. Therefore, some studies have been done to examine the sound of fabrics of which parameters could be explained using mechanical properties [1, 3]. According to the previous works, woolen fabrics' sound parameters were affected by tensile, surface properties and weight. Nylon for outerwear and silk for blouse had sound parameters influenced by compression properties. With polyester, bending and share properties determined the sound parameters. And sound parameters of bedclothes fabrics were determined by tensile property, thickness and weight. From these findings, each kind of fabrics with their own uses could be thought to have the significant relationships between their sound parameters and mechanical properties differentiated from those of other fabrics. Therefore, according to fabric kinds and uses, the prediction models for sound parameters by mechanical properties need to be established, respectively to utilize in textile industries.

Silk fabrics are composed of fibrous proteins from silkworms which are composed mainly by fibroin and sericin. Due to the protein composition, silk fabrics create unique sounds. Precisely speaking, when the sericin is eliminated to make the silk smoother and more flexible and the fibroin is broken down to make it soft, silk sound becomes to be pleasant as we have known as scrooping [8]. According to Fujimoto (1986) and Fukuhara (1993), imitative silk made similar sound waveforms to natural one owing to its triangular cross sectional shapes. These days even though performances of synthetic fibers are being excellently advanced, natural silk fabrics are still concerned to outperform synthetic ones in many respects [8].

The Korean traditional silk fabrics still used presently have been well known as having their own unique fabrications and mechanical characteristics. So they have been expected to have sounds influenced by the mechanical properties. There have been meaningful studies on human psychological and physiological responses to silk fabrics' sounds [4, 11], which found that sound of traditional silk fabrics evoked better psychological and physiological responses than other woven fabrics did. Now, we need to identify significant mechanical properties determining their sound parameters and how they affect the sound.

The purpose of this study was to investigate quantitative sound parameters and mechanical properties of Korean silk fabrics, and to identify the effect of mechanical properties on sound parameters. Therefore, this study will be valuable and helpful in developing auditory sensible silk fabrics and synthetic ones which are purposed to imitate scrooping.

2. Experimental

2.1 Selection of specimens

Specimens were five different 100% silk fabrics for Korean traditional clothing called Hanbok which were randomly selected among ones commercially available. Those were Gapsa (GS) of leno construction, Nobangju (NB), Myoungju (MJ) and Shantung (ST) of plain construction, and Gondan (GD) of satin construction. The characteristics of specimens were shown in Table 1.

Table 1 Characteristics of specimens

Specimens	Fiber Content	Yarn Type	Const-ruction	Korean Traditional Fabric Name
GS	Silk 100%	Filament	Leno	Gapsa
NB			Plain	Nobangju
MJ				Myoungju
ST				Shantung
GD			Satin	Gongdan

2.2 Fabric sound recording

Rustling sounds of each silk fabric were generated using MAFN (Measuring Apparatus for Fabric Noise, patent no. 2001-0073360) [11]. The specimens were two respectively, one of two samples was connected to a belt conveyer and the other to a circumference. At this point both samples were facing each other. And then, to keep speed of 1.2 m/min, the belt conveyer was moved and produced a friction sound with the fixed silk fabric on the circumference. And the generated sound was recorded under anechoic chamber (loudness of background noise=10dB) using highly efficient microphone (Type 4145, B&K) at 1.5cm distance from generated point of sound.

2.3 Fabric sound analysis

The Recorded sound was analyzed using a FFT (fast fourier transform) analyzer (Model 35670A, HP) and the sound file was converted to a wave file. The file's frequency was limited from 0 to 17,000 Hz and setting the axis on frequency and sound pressure, spectrum was determined. In order to calculate its objective sound parameters, a sound quality system (Type 7698, B&K) was used determined LPT (level pressure of total sound), ⊿L (the level of rage), ⊿f (the frequency difference) and Zwicker's psycho acoustic parameters such as loudness (Z), sharpness (Z), roughness (Z), fluctuation strength (Z) [12].

2.4 Measurement of mechanical properties

Using KES-FB system (Kato Tech, LTD. Co), total 17 mechanical properties were measured including tensile, bending, shear, compression, surface properties, thickness and weight. The measurement was based on standard condition [9].

3. Result and discussion

3.1 FFT Sound spectrum of Korea traditional silk fabrics

The result of FFT analysis of Korean traditional silk fabrics, it displayed from 0 to 13,000 Hz in spectrum [11], and similar waveforms were displayed with the same construction among specimens. Thus, Nobangju (NB), Myoungju (MJ), Shantung (ST) had a similar waveform since they had the same construction. However, Gapsa (GS) and Gongdan (GD) had a different waveform since they had a different construction. The range of the sound pressure was between from 30 to 60 dB [11], and each specimen had different sound pressure. On this, we could consider that according to different weaving process, weaving condition, and mechanical property, a sound pressure range was different.

3.2 Sound parameters of Korea traditional silk fabrics

Table 2 shows quantitative values of sound parameters of 5 Korean traditional silk fabrics [11]. LPT - one of physical sound parameter, reflects fabrics' loudness - of Korean traditional silk fabrics ranged from 42.30 (GS) to 60.60 (ST) dB. Comparing to other fabrics, all of specimens displayed lower LPT than Nylon taffeta for sportswear (61.91 dB) and polyester's LPT (61.30 dB). Also, Gapsa (GS), Nobangju (NB), Myoungju (MJ)'s LPT was even lower than silk fabrics for blouse (52.49 dB), and Gongdan (GD)'s LPT was comparable to woolen fabrics for suit (54.97 dB) [2]. Even thought traditional silk fabrics had lower or similar sound level comparing to other fabrics, it was still similar or higher than around environment sound level such as office and classroom sound level (40~50 dB) [10]. So, it was considered Korean traditional silk fabrics’ sound level could not be ignored.

Delta L (⊿L) ranged from 25.1(MJ) to 38.2 (NB) dB. This was higher value than nylon taffeta for sportswear which was around 18.56dB and woolen fabric for suit which was around 21.42 dB, but it was smaller than polyester which was around 47,75 dB and silk fabric for blouse which was around 52.37dB [2]. As the value of ⊿L got higher, FFT spectrum displayed steep rapid waveforms. Therefore, Korean traditional silk fabrics' FFT spectrum was steeper than nylon or wool, but fluent to polyester and silk fabric for blouse.

Delta F (⊿f) ranged from -11929.4 to -3057.7 Hz. Comparing to other fabric's absolute value of ⊿f [2], all samples had a higher value than nylon taffeta for sportswear(-2592.0 Hz). Gapsa (GS) and Nobangju (NB) had a larger value than polyester (-8526 Hz), silk fabric for blouse (-7424.0 Hz) and woolen fabric for suit (-4704.0 Hz), but Myoungju (MJ), Shantung (ST), Gongdan (GD) had a smaller than above other fabrics in value. The absolute value of ⊿f gets higher as the interval between frequency increases and FFT spectrum becomes fluent. Therefore, slope of the Korean silk fabric's FFT spectrum became fluent comparing to nylon taffeta, but steeper with woolen fabrics, polyester, silk fabrics for blouse.

According to the study done on Zwicker's psychoacoustic parameters, loudness (Z) ranged from 2.5 (NB) to 8.7 (ST) dB. This was similar in sound level to LPT of specimens. Sharpness (Z) ranged from 2.06 (NB) to 2.58 (ST) acum and roughness (Z) ranged from 1.7 (GD) to 2.1 (GS) asper. The range of the fluctuation strength (Z) ranged from 0.49 (NB) to 1.56 (GD) vacil in value [11].

For all that some specimens had a similar fabric construction, its values of sound parameters were various. So, we could consider that mechanical properties play important part for the sound parameter.

Table 2 Sound parameters of Korean traditional silk fabrics

Speci-mens	LPT (dB)	⊿L (dB)	⊿f (Hz)	Loud - Ness (Z) (sone)	Sharp - Ness (Z) (acum)	Rough – ness (Z) (asper)	Fluctuation strength(Z) (vacil)
GS	42.30	25.77	-11929.40	2.87	2.34	2.10	1.06
NB	47.80	38.24	·11929.40	2.52	2.06	1.81	0.49
MJ	46.40	25.06	-2196.39	4.25	2.41	2.03	1.55
ST	60.60	35.05	-2756.25	8.69	2.58	1.93	1.33
GD	53.80	33.96	-3057.71	7.28	2.38	1.70	1.56

3.3 Correlation coefficients among sound parameters

Pearson's correlation coefficient analysis was chosen as a method to investigate seven different parameters of sound parameters. With the result, only LPT and loudness (Z) had a significant positive correlation (r=0.92) (Table 3). In sound level, LPT is a calculative value physically and loudness (Z) is a psychological value based on human subjective interpretation, therefore, LPT reflects physical sound parameter of the loudness (Z) [2]. In this study, as the value of the physical sound level increased, the psychological sound level also increased as well. Even though the relationship between ⊿f and fluctuation strength (Z) did not show a significant correlation (r=0.87, p=0.057), but there seemed to be a deep relationship exist between two factors. Therefore, as the interval between the frequencies increased, fluctuation strength (Z) also increased as ⊿f did. This brought to a conclusion that in case sound parameters of the fabrics were affected by common mechanical properties, the sound parameters would have a special relation between themselves.

Table 3 Correlation coefficients among sound parameters (n=5)

	LPT	⊿L	⊿f	Loud ness(Z)	Sharp ness(Z)	Rough ness(Z)
LPT						
⊿L	0.59					
⊿f	0.63	-0.10				
Loudness(Z)	0.92*	0.29	0.29			
Sharpness(Z)	0.57	-0.32	0.75	0.57		
Roughness(Z)	-0.49	-0.78	-0.19	-0.37	0.27	
Fluctuation Strength(Z)	0.33	-0.47	0.87	0.64	0.80	0.05

3.4 Effect of mechanical properties on sound parameters

As indicated above, each specimen had different sound parameters because the parameters were affected by different mechanical properties. In order to find the relationship between them, measured mechanical properties by KES-FB system (Table 4) was applied as independent variable, and a stepwise regression analysis was performed which was shown in Table 5. In result, it showed that the sound parameters of the silk fabrics could be predicted very exactly by mechanical properties. Therefore, in order to design particular sound parameters, related mechanical properties should be considered.

In detail, from among mechanical properties, LPT was affected by weight (W) positively whereas by linearity of compression-thickness curve (LC) negatively. This means that the heavier the fabrics they seemed to make sounds louder. Specifically, weight (W) could predict LPT better in that Shantung (ST) which had the largest weight (W) also showed the largest value of LPT while Gapsa (GS) less heavier than any others had the lowest LPT value of all. On the other hand, ⊿f was affected negatively by bending rigidity (B). Myoungju (MJ), Shantung (ST), and Gongdan (GD) which had lower values of bending rigidity (B) showed higher values for ⊿f, but Gapsa (GS) and Nobangju (NB) with higher values for bending rigidity (B) had lower values for ⊿f. Thus, more flexible traditional silk fabrics tended to have larger interval of frequencies between maximum levels and minimum ones.

Table 4 Mechanical properties measured by KES-FB system

		GS	NB	MJ	ST	GD	mean
Tensil Properties	EM(%)	2.15	**1.48**	2.03	2.40	**2.45**	2.10
	LT(-)	**0.90**	0.79	0.76	0.79	**0.73**	0.79
	WT(gf.cm/cm2)	**4.93**	**2.78**	3.85	4.63	4.41	4.12
	RT(%)	**54.18**	**66.53**	61.04	56.67	65.48	60.78
Bending Properties	B(gf.cm2/cm)	0.15	**0.22**	**0.03**	0.08	0.06	0.11
	2HB(gf.cm/cm)	0.06	0.06	**0.02**	**0.09**	0.03	0.05
Shearing Properties	G(gf/cm.deg)	0.57	0.30	**0.29**	**0.66**	0.38	0.44
	2HG(gf/cm)	0.51	**0.07**	0.13	**1.79**	0.52	0.60
	2HG5(gf/cm)	2.83	**0.31**	0.80	**3.45**	0.89	1.66
Compression Properties	LC(-)	**0.76**	0.42	0.37	**0.27**	0.48	0.46
	WC(gf.cm/cm2)	**0.02**	0.03	0.03	**0.10**	0.09	0.05
	RC(%)	63.16	**76.92**	58.62	**44.79**	63.08	61.31
Surface Properties	MIU(-)	0.82	1.00	0.93	**1.35**	**0.28**	0.88
	MMD(-)	1.49	**4.79**	1.52	2.00	**0.01**	1.96
	SMD(micron)	4.75	7.05	4.93	**9.35**	**0.50**	5.32
Thickness	T(mm)	0.09	0.15	**0.08**	**0.21**	0.18	0.14
Weight	W(mg/cm2)	**3.69**	5.23	4.48	**11.99**	9.38	6.95

Table 5 Regression models for sound parameters by mechanical properties (n=5)

	Regression Model	Adj. R^2
LPT	$= 1.798 \cdot \boldsymbol{W} - 8.033 \cdot \boldsymbol{LC} + 41.927$	0.996
Δf	$= -61408.181 \cdot \boldsymbol{B} + 258.254$	0.810
Loudness(z)	$= 70.238 \cdot \boldsymbol{WC} + 1.329$	0.921
Sharpness(z)	$= -0.015 \cdot \boldsymbol{RC} - 0.026 \cdot \boldsymbol{MMD} - 0.011 \cdot \boldsymbol{2HG} + 3.303$	1.000
Fluctuation strength(z)	$= -4.162 \cdot \boldsymbol{B} - 0.072 \cdot \boldsymbol{MMD} + 0.061 \cdot \boldsymbol{EM} + 1.660$	1.000

As for Zwicker's psychoacoustic parameters, compression energy (WC) affected loudness (Z) positively. That is, Shantung (ST) with the largest compression energy (WC) value also had the largest loudness (Z) value. However, Gapsa (GS) had the least compression energy (WC) value and was measured as having the lowest loudness (Z). From these results, it can be thought that LPT and loudness (Z) which were closely correlated together were also similar to each other in that both of them were explained by compression properties. This indicates compression properties may be main factors determining sound loudness for traditional silk fabrics. Sharpness (Z) displayed the negative relation to compression resilience (RC), mean deviation of MIU (MMD), and hysteresis of bending moment (2HB). Especially, compression resilience (RC) predicted better sharpness (Z) than the others did. Therefore, after compressed, the more easily recoverable to the primary conditions the silk fabrics were, the lower the values of sharpness (Z) of them. Thus, Shantung (ST) that was less easily recoverable after compressed had higher sharpness (Z) value, but fluffier Nobangju (NB) had lower sharpness (Z) value.

Fluctuation strength (Z) had a negative relation with bending rigidity (B) and mean deviation of MIU (MMD) but positive relation with elongation at maximum load (EM). Particularly, fluctuation strength (Z) was explained by bending rigidity (B) better than the others. Thus, Nobangju (NB) which was the stiffest, roughest, and the least stretchable among the fabrics had lower fluctuation strength (Z). Gongdan (GD) and Myoungju (MJ) were more flexible, smoother, and more stretchable had higher values for fluctuation strength (Z). Prior to this, in correlation among sound parameters, ⊿f and fluctuation strength (Z) did not have a significant correlation coefficient, but they had a considerable one compared to others. This relationship was thought to cause the effects of bending rigidity (B) on both ⊿f and fluctuation strength (Z).

In summary, sound parameters of Korean traditional silk fabrics seemed to be determined mainly by three different categories of mechanical properties - compression property, bending propery and weight. Using these properties, we could predict the sounds of Korean traditional silk fabrics.

4. Conclusion

The purpose of this study was to investigate the effects of mechanical properties on sound parameters of Korean traditional silk fabrics.

1. Korean traditional silk fabrics had similar FFT spectrum among them, but each specimen had different sound pressure.

2. The physical loudness, LPT values ranged from 42.30 to 60.60 dB, which is lower than those for nylon taffeta did. Gapsa showed the lowest values for both LPT and ⊿f while Shantung was the one having the highest values for LPT, loudness (Z), and sharpness (Z). The other hands, Nobangju had the highest ⊿L while the lowest ones for both ⊿f same to Gapsa. As for Myoungju, it showed the lowest ⊿L among the silk fabrics. Gongdan was the fabric of which both ⊿f and fluctuation strength (Z) were the highest whereas its roughness (Z) was the lowest.

3. In the prediction models by stepwise regression analysis to extract mechanical properties affecting sound parameters, compression property, bending property and weight influenced significantly the sound parameters. Precisely, compression property had positive effects on LPT and loudness (Z), and bending property did negatively on both ⊿f and fluctuation strength (Z).

Therefore, in the textile manufacturing process, by controlling the mechanical properties identified in this study, it could be possible to design the frictional sound of Korean traditional silk fabrics, and to help give a pleasant sound to synthetic fabrics that imitate silk.

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