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THE ABRASIVE WEAR BEHAVIOUR OF A THAI SILK FABRIC

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Friction and wear characteristics of general engineering materials have been studied extensively in the past few decades. However, just a few papers reported on tribological features of silk fabrics. In this particular work, Thai silk fabric abrasive wear behaviour characteristics were investigated. The influences of silk fabric wear factors or cause variables such as the applied load, speed, and grain size of abrasive media were evaluated.

Key words: abrasion, fabric, silk.

1. Introduction

Silk is a protein fiber like wool. This gives it many of its characteristics. Out of the numerous species of silk moths, scientists have enumerated about 70 silk moths, which are of some economic value. The 4 commercially known varieties of natural silk are (1) Mulberry silk (2) Tasar silk (3) Muga silk and (4) Eri silk (Morton and Wray, 1962). Although the bulk of world silk supply comes from the domesticated silk moth, the other varieties of silk (include most of the Thai silk fabrics) are known as wild silk, as they are grown in remote forest trees in natural conditions (Hudson *et al*., 1993). Silk is the strongest of the nature fibers, offers luxuriousness, resiliency, good drapability and beauty. This means that silk is very strong in terms of tensile strength. It can withstand a lot of pulling type pressure without breaking. This should not be, however, confused with wear ability or abrasion resistance. Silk will not stand up to the heavy wear that other fibers will. It, however, has only fair abrasion resistance, tends to water-spot easily, and is expensive (Corbman, 1983). Silk can wear out when it is rubbed against another surface, usually another fabric. This property is measured using an abrasion tester. There are various designs as per ASTM D 3884 – 92, D 3885 – 99, D 3886 – 92, and D 4966 – 98 (ASTM D 3884 – 92, 1999; ASTM D 3885 – 99, 1999; ASTM D 4966 – 98, 1999; ASTM D 4970 – 98, 1999), but the most common is the one that has a holder containing the fabric to be tested placed with the fabric touching a pad of standard abrasive media, and a small weight applied. The test fabric is then rubbed backwards and forwards across the standard abrasive media at a constant speed and in a specific manner for a given number of times, after which it is examined for wear. When the fabric shows wear, usually by having some of the threads worn through, the test is stopped, and the number of strokes taken to produce the wear is quoted as the resistance to wear (Booth, 1968).

Properties of silks vary within and between batches. Testing on a single specimen would not provide a sufficient and accurate estimate of bulk properties. On the other hand, testing the whole of a production batch of fabric, yarn or garments would be impractical because:

- some tests are destructive,
- some tests involve cutting test specimen,
- it would take too much time.

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It is therefore necessary to select one or more samples. A sample may be defined as a small fraction selected to represent the bulk. Factors to be considered when selecting a sample include (Booth, 1968):

- amount and form of textile available,
- nature of test,
- type of equipment to be used,
- information and accuracy required.

In some cases, the test method will specify the type of sample that needs to be taken, and the method to choose in preparing the specimen(s) for testing.

2. Design and program of experiments

The most important cause variables affecting silk fabric tribological characteristics are as follows.

(1) basic silk material: type, yarn structure and weaving pattern,
(2) counter material (abradant): type, grain size and shape,
(3) stress conditions: reciprocating and/or sliding speed, pressure and test duration.

The reciprocating abradant sheet testing machine was selected for the trial. With the help of this testing machine, a number of the cause variables can be varied and evaluated according to the design of the experiment. The operating principle (Fig.1) is as follows.

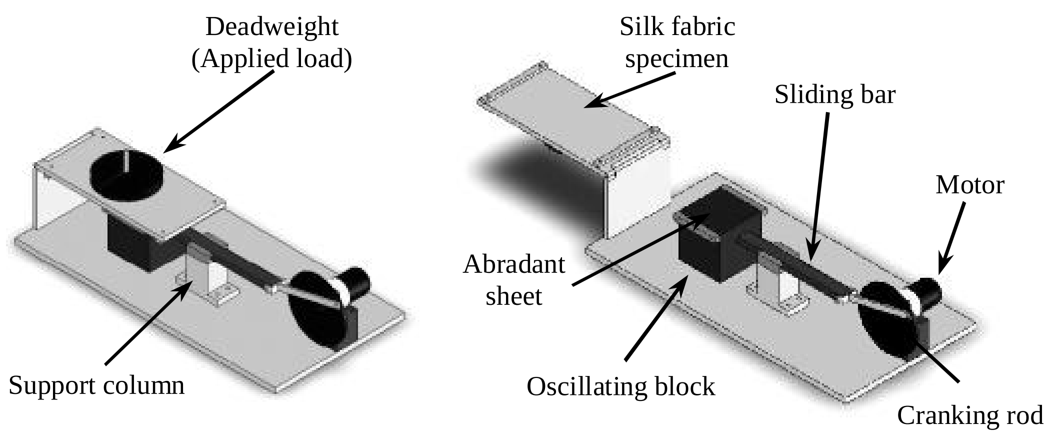

Fig.1 View of test apparatus.

The apparatus, shown in Fig.1, consists of a fixed rectangular plate furnished with edge clamps to permit mounting of a sheet of silk fabric specimen over its surface. The plate has surface that prevents slippage of the specimen. Load can be applied by putting an appropriately chosen deadweight at the locating pin on the top of the plate. The oscillating block where the abradant sheet is attached, is capable of reciprocating at 30 to 60 ± 5 double strokes per minute of $20 \pm 2mm$ stroke length. Clamps are secured to the left and the right of the block to permit mounting of the abradant sheet. The machine is equipped with resettable counters to indicate the number of cycles and speed during the test. The driving mechanism consists of a motor-driven cranking rod connected to the sliding bar by a connecting pin. The operating principle is as follows. A silk fabric specimen reciprocates over the abradant sheet. The specimen and the abradant sheet can be adjusted vertically and/or horizontally with respect to each other whereby the stress intensity can be adjusted to a certain extent. The silk fabric abrasion test machine has the following experimental characteristics. For the specimen: dimensions, $8cm \times 36cm$; useful surface $240cm^2$ reciprocating speed (abradant sheet) *90* to $120\ rev\ \ min^{-1}$; Silicon Carbide (SiC) abrasive media No. 600 and 1200.

To satisfy practical requirements and to utilize fully the technical boundaries of the silk fabric abrasion wear testing machine and the principles of the statistical planning of the experiments, the cause variables, given in Tab.1, were varied within the levels stated. The following quantities will remain constant: type and shape of abrasive media, type (rate 5: extra heavy weight Thai silk as per standard for Thai silk fabric (Thai Industrial Standard, TIS 179-2519)), size and weaving pattern of the silk fabric (plain weave; 1up: 1 down); reciprocating speed at *100* and *120rpm* of the driving motor were used.

Table 1. Cause variables and their levels.

Standard Order	Run Order	Center Point	Blocks	Applied Load (g)	Reciprocating Speed (rpm)	Abrasive Media No.
5	*1*	*1*	*1*	*100*	*100*	*# 1200*
8	*2*	*1*	*1*	*300*	*120*	*# 1200*
3	*3*	*1*	*1*	*100*	*120*	*# 600*
7	*4*	*1*	*1*	*100*	*120*	*# 1200*
4	*5*	*1*	*1*	*300*	*120*	*# 600*
6	*6*	*1*	*1*	*300*	*100*	*# 1200*
2	*7*	*1*	*1*	*300*	*100*	*# 600*
1	*8*	*1*	*1*	*100*	*100*	*# 600*

3. Experimental results – univariate statistical presentations

Figures 2 to 7 illustrate the effects of wear variables, namely; the applied load, abrasive media and speed on weight losses of silk fabric test specimens. Figure 2, in the case of abrasive media No. 600, shows that at a lower reciprocating speed $(100rpm)$ wear of the silk fabric was increased significantly when the applied load was increased to *300g*. However, at a higher speed, wear was not changed substantially as the load was increased.

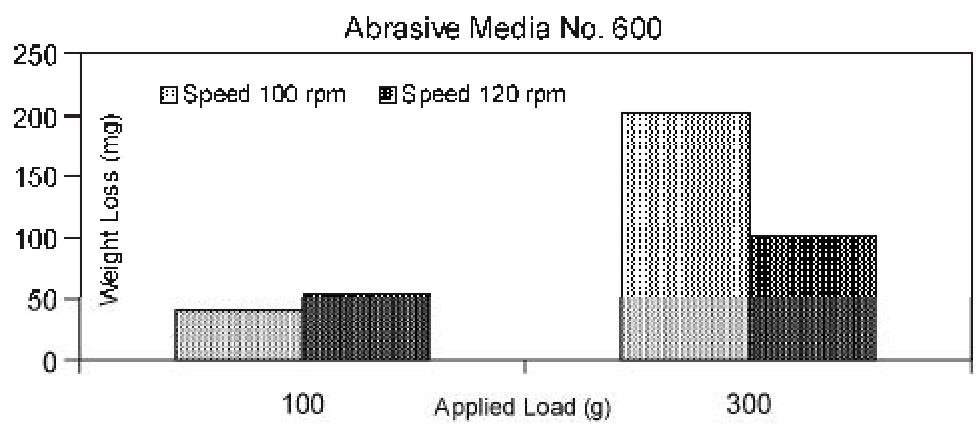

Fig.2. Effect of applied load on weight losses.

Figure 3, in the case of abrasive media No. 1200, shows that at a higher reciprocating speed $(120rpm)$ wear of the silk fabric increased significantly when the applied load was increased to $300g$. However, at a lower speed, wear was not changed substantially as the load was increased.

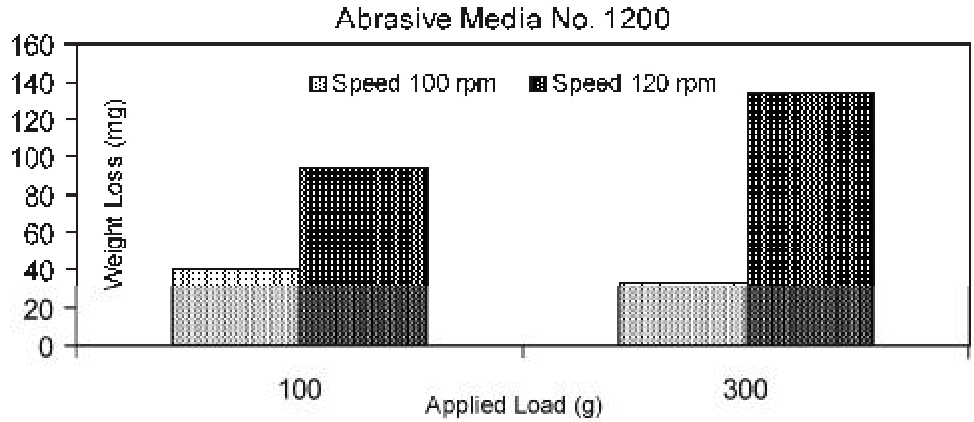

Fig.3. Effect of applied load on weight losses.

Figures 4 and 5 show the effects of abrasive media on weight losses of fabric specimens. It can be seen in Fig.4, in the case of lower applied load $(100g)$, there was no effect of the abrasive medias on wear of the specimens for a lower speed test $(100rpm)$. In contrast, there was a significant increase in weight loss of the specimens at higher speed level $(120rpm)$.

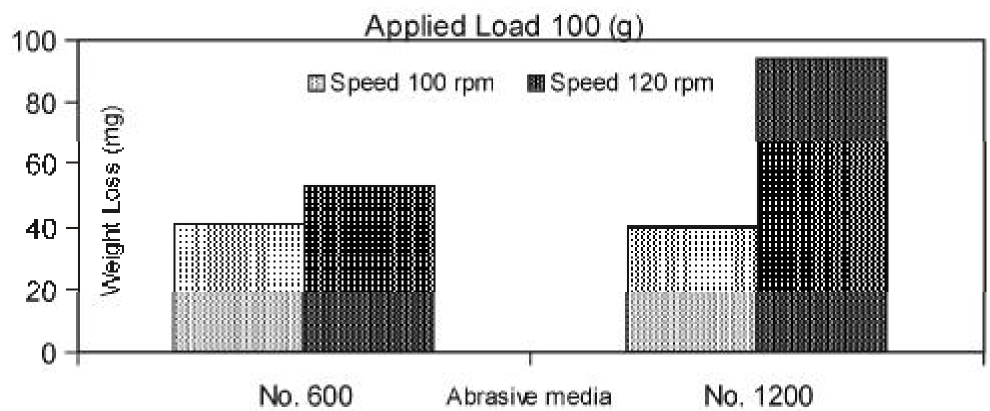

Fig.4. Effect of abrasive media on weight losses.

Figure 5, in the case of higher applied load $(300g)$, there was a significant effect of the abrasive medias on wear of the specimens for a lower speed test $(100rpm)$. In contrast, there was a reasonable increase in weight loss of the specimens at higher speed level $(120rpm)$.

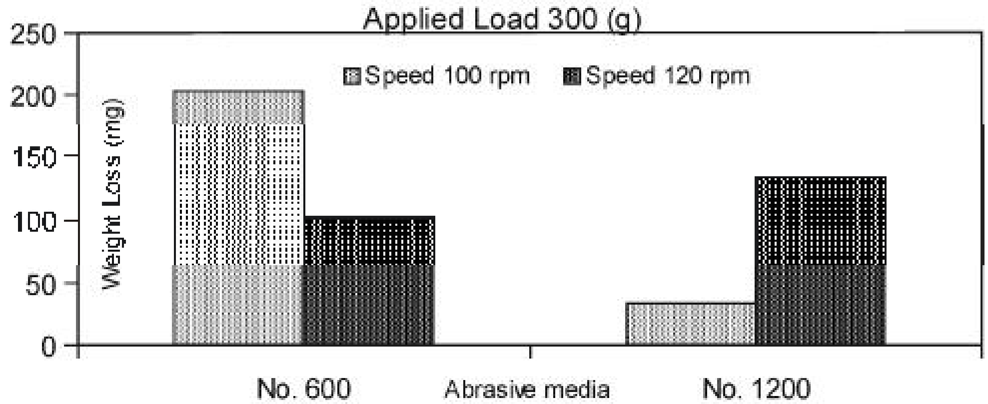

Fig.5. Effect of abrasive media on weight losses.

Figures 6 and 7 show the effects of reciprocating speed on weight losses of fabric specimens. It can be seen in Fig.6, in the case of lower applied load $(100g)$, there was a resonable effect of the speed at $100rpm$ on wear of the specimens. In contrast, there was a significant increase in weight loss of the specimens at higher speed level $(120rpm)$.

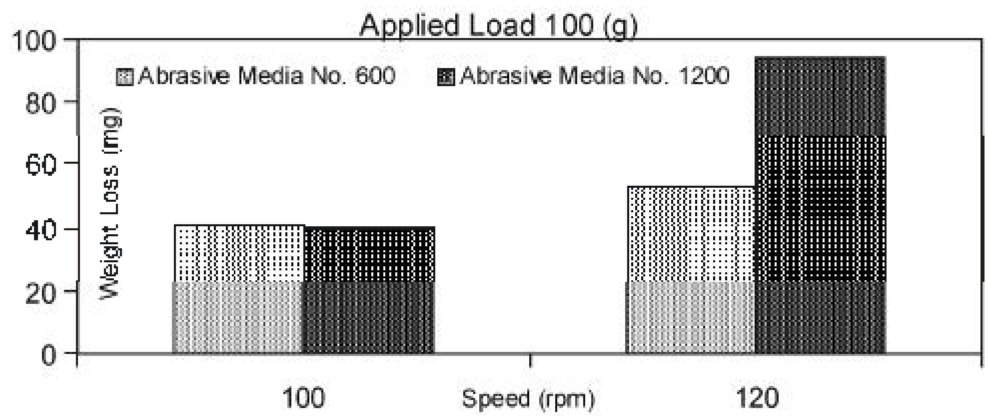

Fig.6. Effect of reciprocating speed on weight losses.

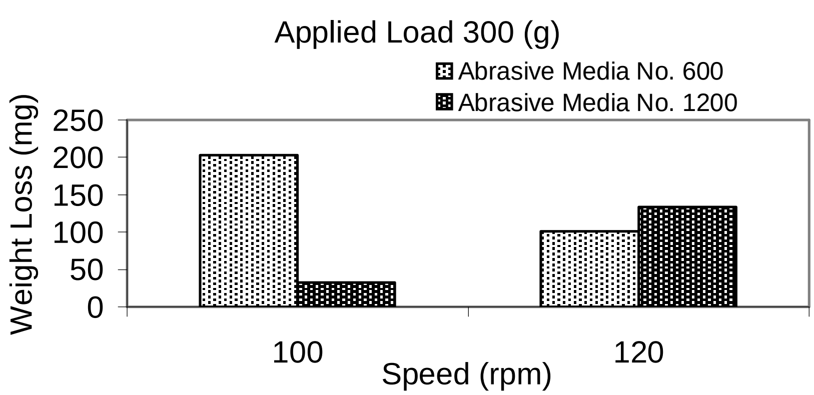

Fig.7. Effect of reciprocating speed on weight losses.

It can be seen in Fig.7, in the case of lower applied load $(300g)$, there was a significant reduction of weight loss as the speed was increased to $120rpm$ (abrasive media No. 600). However, there was a reverse trend for the weight loss of the specimens at higher speed level $(120rpm)$ for abrasive media No. 1200.

4. Experimental results - physical meaning from the analysis of silk fabric specimens

Often silks develop unsightly "bobbles" of fiber, which are attached to the surface of the fabric. This is called "pilling". This can be simulated by rubbing the silk fabric with hard abrasive media just like the experiment in this work. In addition, each stroke of the reciprocating abrasive wear test induces the loose fibers to form single pilling, i.e., in cylindrical form or "agglomerated" a group of cylindrical pilling. Pilling is the term used to indicate whether a fabric "bobbles". This "pilling" resistance test is also carried out using the abrasion wear test apparatus. The silk specimen is rubbed against the same standard test that is used in the abrasion test. However, there is no weight applied. Afterwards, the appearance of the item is compared with standard photos, designated 1 (worst) to 5 (best) (Booth, 1968). Pilling is a failure appearance consisting of unsightly balls of fiber attached to the surface of the fabric. Rubbing of the fabric produces these balls of fiber, or pills, during use. Pilling requires loose fiber at the fabric surface, or fibers that can easily be loosened by rubbing, as shown in Figs 8 to 11. The appearance of the pills is controlled by the different rate at which a series of process occur. The rate of formation of pills is controlled by the rate at which fiber can be loosened. This is a function of the yarn structure and fiber strength. Fibers can be loosened easily from staple yarns of relatively low twist, from multifilament yarns with little or no twist, and from textured or bulk yarns, especially if the filament is fine or of low strength.

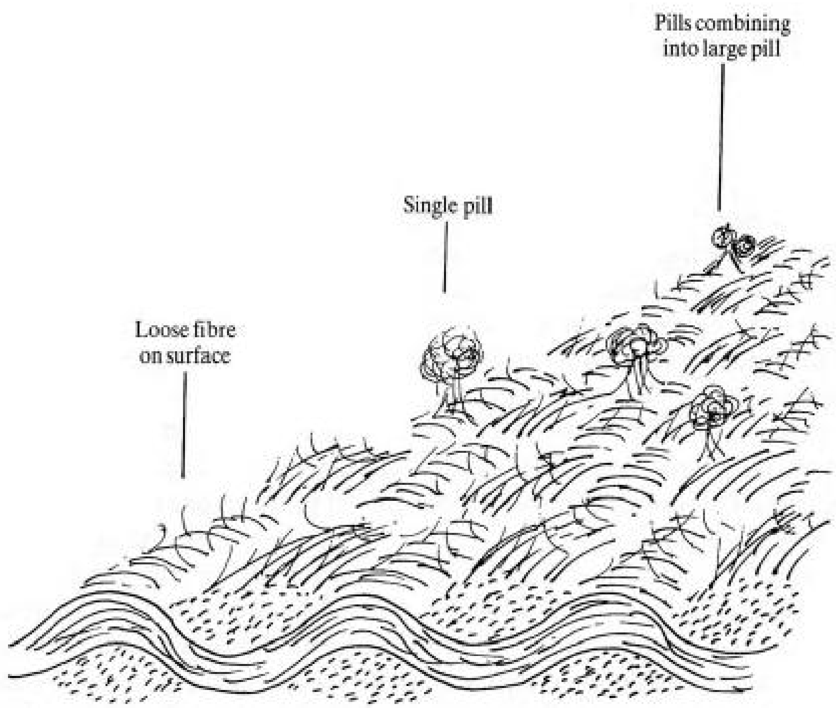

Fig.8. The mechanism of pill formation (Mason *et al*., 1989).

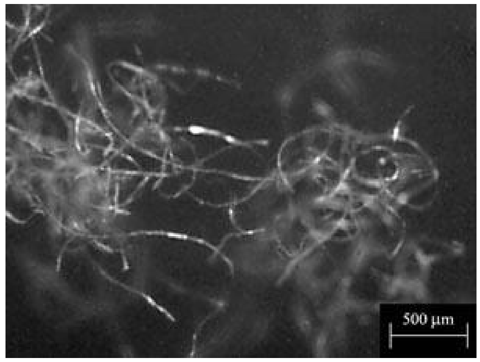

Fig.9. Loose fibers (normal abrasive wear).

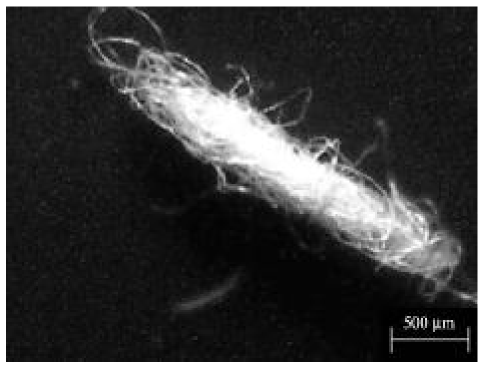

Fig.10. Single pill (mild to severe abrasive wear).

Fig.11. A group of pills (severe abrasive wear).

The appearance of the pills is further controlled by the rate at which small pills coalesce to form fewer, larger pills, and by the rate at which pills break away and are lost. The rate of loss of pills is determined by the strength of the fibers that attach the pills to the surface (Brody, 1994).

Because silk fibers tend to be weaker than man made fibers, pills tend to be lost at a faster rate with natural fibers. This particular characteristic can clearly be seen in Figs 12 to 14. Controlling pill formation then becomes a matter of limiting the availability of loose fiber; using yarns with higher twist gives silk fabrics with enhanced pilling resistance (Warner, 1995).

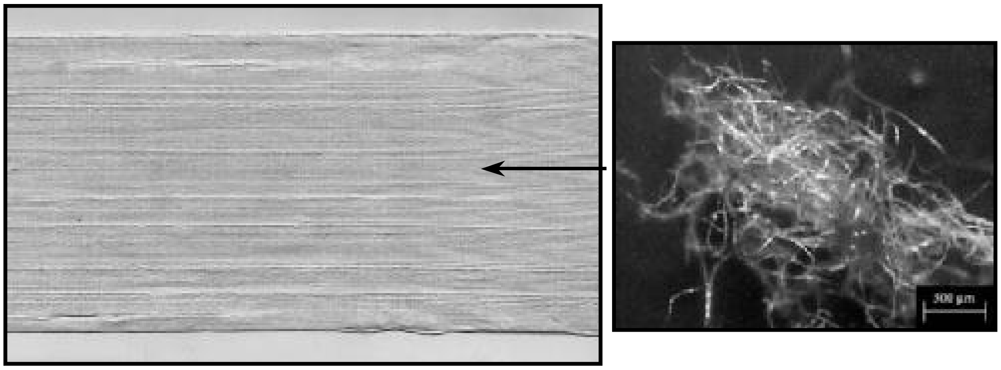

Fig.12. Normal worn surface of silk fabric specimen.

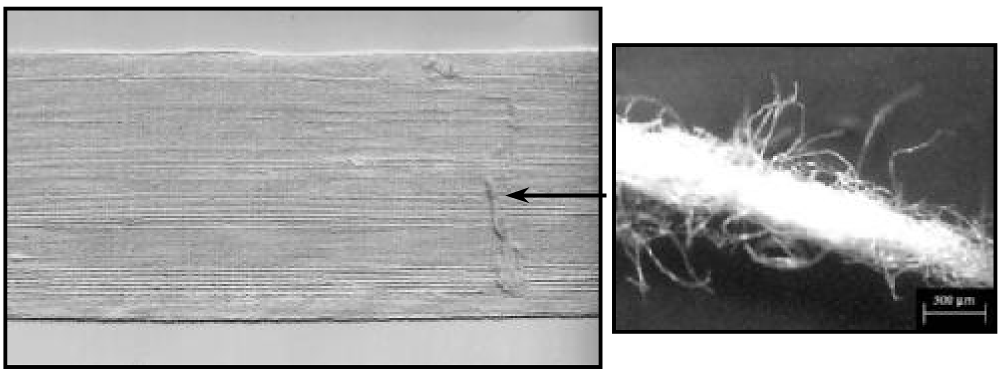

Fig.13. Typical mild-severe worn surface of silk fabric specimen.

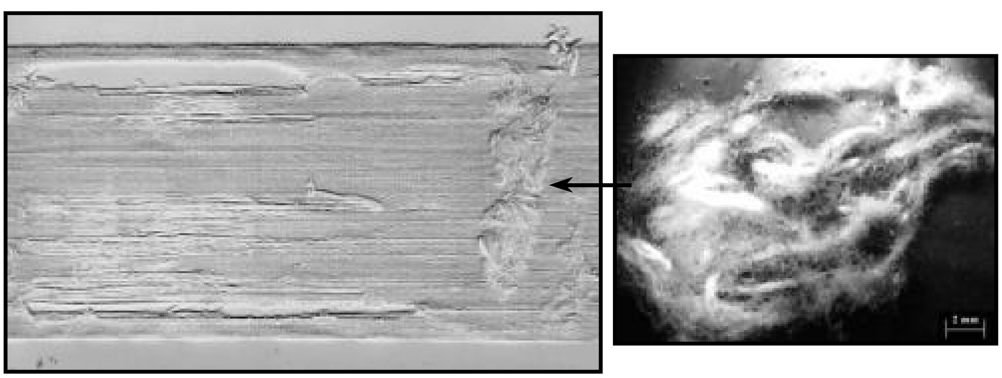

Fig.14. Typical severe worn surface of silk fabric specimen.

If loosened fiber is lost from the surface before pills can form, a process of abrasion wears the silk fabric away. Factors that increase the resistance to abrasion include using high twist yarns, using coarser filaments and yarns of greater linear density, and employing a tighter silk fabric structure (i.e., more thread per centimeter) and a greater number of interlacing. These factors all assist in preventing fibers from being pulled from the yarn and broken (Hudson *et al.*, 1993; Corbman, 1983).

5. Conclusions

With the experimental results, conclusions can be summarized which concern both the main and interaction effects of cause variables on the abrasive wear resistance of Thai silk fabrics tested in this work.

1. The abrasive media grain size, applied load and speed have a significant effect on the abrasive wear of silk fabrics.
2. In general, increasing speed and larger abrasive grain size have the effect of increasing weight loss significantly, in other words there is a significant interaction effect between these two cause variables.

Acknowledgment

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