Thread Breakage in Modern Loom and Efficiency

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ABSTRACT

The study is to find out the relation of thread breakage rate on modern loom to the relative humidity and fabric specifications. This result supports thread breakage rate increased with the choice of rapier loom instead of air jet loom. It also shows that loom width has negative relation towards thread breakage and in the production floor relative humidity has insignificant relation with thread breakage rate. Key part of the study shows that warp and weft breakage rate has interrelation. In the production floor loom types and fabric constructions are studied for thread breakage at floor temperature and found no relation to the relative humidity. But, significant relation of warp and weft thread breakage rate to EPI, loom categories, loom width, fabric length produced, weft count and interrelation between warp and weft breakage rate.

KEYWORDS: Breakage rate, Woven fabrics, Modern loom.

INTRODUCTION

Thread breakage is the certain actions in the different sections of weaving. It increases the stoppage time of the loom and thus reduce the efficiency of the weaving. Modern loom has been developed to increase the productivity and efficiency in weaving. Different types of picking like-water jet, air jet, multiphase and rapier picking has been developed with the parts like reed, heald wires, shedding mechanism etc. This study focuses on the thread breakage rate in modern loom specially three different models air jet, rapier (optimax) and rapier (gamma) for different fabric construction at the room temperature in the production floor. Using correlation and regression analysis, the breakage rate for warp and weft are analyzed for 24 days in 15 looms of which five are air jet, five are rapier (optimax) and five are (gamma) loom. Finally, average and total thread breakage rate also calculated to analyze the correlation among the parameters.

This study found interrelation between warp and weft breakage rate but, found no relation to the relative humidity. Again, significant relation of warp and weft thread breakage rate to EPI, loom categories, loom width, fabric length produced, weft count and interrelation between warp and weft breakage rate have been observed by the correlation and regression analysis.

LITERATURE REVIEW

The weaving machines used in many old textile industries, jute industries, and power loom factories for weaving conventional fabrics are of primitive type and hardly have undergone any modification. While designing any modification of such weaving machines needs attention for improvement of weaving efficiency for weaving such yarn having low extensibility as in case of jute. In the conventional weaving machines there are inadequate arrangements for controlling the strain on the warp yarn during weaving. After conducting some studies in jute mills, it has come to light that the efficiency of hessian loom varies within a range of 48-60% in which the loss in efficiency is 12-14% for warp breakages and 4-5% for manual weft replenishment. Thus, it was felt necessary to overcome this problem by simple machine modifications to improve the weaving efficiency. In the conventional jute loom the free length of the warp yarn provided is comparatively much less than all other modern looms used in the textile industry, in spite of jute yarn having very low extensibility. There are inadequate arrangements for controlling the strain of warp yarn during weaving. There is no automation in the system. These factors influence the warp breakage rate, which lowers the weaving efficiency to some extent. Early works shows that the tension peak at beat-up is proportional to the maximum fell displacement and is independent to basic warp tension. The warp breakage rate can be minimized by controlling the strain on the yarn during a loom cycle (Marks & Robinson, 1976). The height of tension peak during shedding may be controlled either by controlling the size of the warp shed or by controlling the free length of the warp (Greenwood, Weaving: Control of Fabric Structure, 1975). Other found in their study the study of warp tension variations and felt that it is necessary to measure the warp tension upon a single thread rather than upon the whole warp, as the latter would give average effects in which significant features might be concealed. He opined that the tension is much greater at the bottom than at the top shed, and the beat-up with the falling

thread is stronger than with the rising thread, and consequence of the common practice of depressing the closer shed. The inertia, or weight and size of the beam influence the form of tension cycle, which therefore varies as a beam empties. He also stated that throughout one turn of the beam, the tension in the single thread commonly varied by 40-50% of its mean value. He also studied the effect of vibrating backrest, which increases the tension in the lower parts of the cycle and reduces it at the bottom shed (Owen, 1928). Again study shows that the effect of cloth fell position on pick spacing on power loom and established the relation between the cloth fell and the intensity of the beat-up force. The relation between beat-up force and pick spacing is also established (Greenwood & Cowhig, J Text Inst, 1956). Warp tension has measured under static condition. The behavior of such mechanism when running at weaving speed is often very different from what would be anticipated from the study of the mechanism at rest or in slow movement (Snowden & Chamberlain, 1956). Peak tension on warp during weaving is high particularly during the position of beat-up and open shed. The generation of high peak tension in the yarn is one of the main reasons for warp breakages. To reduce peak tension the attachments of oscillating backrest and front rest was developed, which not only improved the fabric cover but also eliminated the reed mark (Neogy, 1976).

In this study influence of loom types, fabric specification and relative humidity on thread breakage are analyzed by correlation and regression models.

OBJECTIVES OF THIS STUDY

1. To analyze the correlation of thread breakage rate with fabric specifications
2. To analyze the correlation of thread breakage rate with modern looms (Air jet and Rapier)
3. To analyze the effect of Relative Humidity% on thread breakage rate in the production floor.
4. To find a new scope of research in this area of interest.

MATERIALS AND METHODS

Materials: In this experiments production of 10 different fabrics constructions are taken which are being produced in 15 different looms for 24 days in the production floor consisting 155 looms. The production floor temperatures are recorded to measure the relative humidity of the specific production date. Warp breakage rate is calculated per 1000 ends per 100 m length, and weft breakage rate is calculated per 100 picks per 100 inch width of fabrics.

For this experiment, the Z-score at 95% confidence level 1.96, Standard deviation 0.5 and margin of error is considered 0.05165.

And thus we get the respondents required is

$$(1.96)^2 \times 0.5 (1-0.5)/(0.05165)^2 \approx 360$$

Sample respondents from the production floor.

Methodology: Sample looms are taken randomly available in the production floor. In this study, 5 Airjet looms, 5 Rapier (optimax) looms and 5 Rapier (gamma) looms (total 15 looms of three types) are selected to collect data for different fabric specifications for 24 days consequently at production floor temperature and relative humidity (as standard temperature and relative humidity is important criteria).

The data are tabulated and the breakage rates are calculated with loom specification and the correlation and regression analysis are used to test the hypothesis developed.

Table 1: Loom specifications

Rapier (Optimax) loom	Rapier (Gamma) loom
Machine Name: PICANOL OPTIMAX.	Machine Name: PICANOL GAMMA.
Origin: Belgium	Origin: Belgium
Machine R.P.M: 600-650	Machine R.P.M: 600-650
Reed width:	Reed width:
Shedding mechanism: Dobby.	Shedding mechanism: Bobby.
Rapier type: Flexible.	Rapier type: Flexible.
Color: maximum-8 (2 Color use.)	Color: maximum-8 (2 Color use.)
Held frame: 6	Held frame: 6
Weave: 2/1, 3/1, 4/1 "Right hand Twill"	Weave: 2/1, 3/1, 4/1 "Right hand Twill"

Variables:

Dependent variables: Warp and Weft breakage rate

Independent variables: Threads/inch, yarn count, fabrics length and width, production in meter/day, total ends, relative humidity.

Level of significance: Here, level of significance is considered between 5%.

RESULTS AND DISCUSSION

Warp and weft break at different fabric constructions are listed in the A1: Air jet loom, A2: Rapier (Optimax) loom and A3: Rapier (Gamma) Loom. Then, the breakage rate is tabulated in table A4-A6 respectively for the three modern looms. The comparative results are shown in A7 and A8.

Table 2: Correlation co-efficient for breakage rate

	Category	Warp count	Weft count	EPI	PPI	Loom width	Ends	Length	R.H%	Warp Breakage rate	Weft Breakage rate	Production per day (m)
Warp Breakage rate	.603**	-.023	-.094	-.051	.009	-.224**	-.178**	.051	-.063	1	.193**	-.082
Weft Breakage rate	.203**	-.061	-.068	.041	-.117*	-.332**	-.124*	-.175**	-.036	.193**	1	.121*

**, Correlation is significant at the 0.01 level (2-tailed).

*, Correlation is significant at the 0.05 level (2-tailed).

Table 3: Regression model summary for thread breakage rate

Independent variables	Warp Breakage Rate (a)	(2)Weft Breakage Rate
(Constant)	2.191**	0.286**
Category	0.360**	
Weft Count	.019**	
EPI	-.011**	
Loom width	-.029**	-0.004**
Fabric Length	.000**	
Warp Breakage Rate		0.017**
Production (m/day)		0.000**
F	52.18	22.125
R	0.651	0.396
Adj. R ²	0.416	0.150
Std. Err. of the estimates	0.38	0.06
*. Correlation is significant at the 0.05 level (2-tailed).		
**, Correlation is significant at the 0.01 level (2-tailed).		

From the table 1 and table 2, warp breakage rate is significantly influenced by loom category, weft count, EPI, loom width and fabric length table 2 (a) at 1% level of significance ($p < 0.01$). The goodness of fit for the model of warp breakage rate is 65.1%.

On the other hand, weft breakage rate is significantly influenced by loom width, loom width and production per day of the fabrics

at 1% level of significance ($p < 0.01$) and goodness of fit for the model is 39.6%.

Here, EPI and loom width have negative influences on breakage rate and other parameters shows positive influences on breakage rate of respective type of thread.

Warp breakage rate = $2.191 + 0.36$ (Loom category) + 0.019 (Weft count) – 0.011 (EPI) – 0.029 (Loom width) + $.000$ (Fabric Length)

Weft breakage rate = $0.286 - 0.004$ (loom width) + 0.017 (Warp breakage rate) + 0.000 (production per day)

To find out the relation of the thread breakage rate and relative humidity in the production floor excluding the types of loom, table- A4-A6 are prepared to analyze the correlation with the relative humidity percentage.

Table 4: Correlation Coefficient for Relative Humidity and Thread Breakage Rate

	Warp breakage rate	Weft breakage rate
R.H.%	-.294	-.141

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

From table 4, correlation coefficient shows no significant relation of thread breakage rate either in warp way or in weft way direction which is same as results from table 1 and 2. Thus, there is no significant relation of relative humidity and thread breakage rate which fails the hypothesis H4.

The average value for specific fabric construction and choice of yarn the following A8 is prepared to analyze the relation of thread breakage rate in warp and weft direction for the three different modern looms.

Table 5: Correlation co-efficient

Warp breakage rate	Air jet	Rapier (Optimax)	Rapier (Gamma)
Weft breakage rate			
Air jet	-.442*	.299	-.067
Rapier (Optimax)	.158	-.026	.315
Rapier (Gamma)	-.170	.321	.484*

Table 6: Regression co-efficient of warp and weft breakage rate in air jet and rapier loom

	Air jet Warp Breakage Rate	Rapier (Gamma) Warp Breakage Rate
Constant	.834	.751
Air jet Weft Breakage Rate	-4.023**	
Rapier (Gamma) Weft Breakage Rate		3.792**
R	.442	.484
Adj. R ²	.159	.200
F	5.343	6.742
Std. Error of the Estimate	.11544	.22437

From table 5 and 6, warp breakage rate is decreased 4.023 times for air jet loom and in Rapier (Gamma) it increases 3.792 times respectively with the unit increase of weft breakage rate at 1% level of significance ($p < 0.01$).

Table 7: Comparative Breakage Rate for Air jet and Rapier Loom

	Average warp breakage rate	Average weft breakage rate
Air	0.47	0.09
Rapier (Optimax)	0.88	0.06
Rapier (gamma)	1.21	0.12

Figure 1: Bar Chart for Breakage Rate

From the above figure 1 based on table 7, it is clear that, thread breakage rate are more in rapier looms than air jet loom (prominent in warp than weft breakage). But, difference is also clearly observed in two different models of Rapier looms (Optimax and Gamma).

Again, considering average relative humidity for specific construction of fabrics, table 8 is as follow-

Table 8: Yarn Count, Relative Humidity and Thread Breakage Rate

Loom	R.H.%	Warp count	Weft Count	Warp Breakage Rate	Weft Breakage Rate
0	76.33	11.33	14.7625	0.32	0.07
0	77.77	10	14.7625	0.42	0.08
0	76.33	28	14.7625	0.42	0.07
0	77.77	16	16	0.34	0.07
0	76.33	10	10	0.63	0.15
0	77.77	11.33	14.7625	0.73	0.13
0	76.33	14	8.44	0.29	0.07
0	77.77	10	14.7625	0.44	0.07
0	76.16	10	20	0.59	0.08
0	77.58	30	30	0.61	0.08
1	76.33	14	14.7625	1.4	0.06
1	77.77	14	8.44	1.16	0.06
1	76.33	30	30	0.9	0.07
1	77.77	10	20	0.64	0.07
1	76.17	11.33	14.7625	0.82	0.05
1	77.58	20	14.7625	0.98	0.05
1	76.89	14	8.44	0.46	0.08
1	76.87	10	14.7625	0.68	0.05
1	76.88	10	14.7625	1.18	0.05
1	76.67	8	8	0.57	0.06
2	77.17	11.33	14.7525	1.59	0.33
2	77.58	8	8	0.96	0.09
2	76.89	28	14.7625	1.46	0.09
2	76.87	10	10	1.21	0.11

2	76.89	11.33	14.7625	1.2	0.28
2	76.87	10	10	1.28	0.15
2	76.33	14	8.44	1.3	0.09
2	77.78	10	10	1.2	0.1
2	76.17	28	14.7625	0.89	0.12
2	77.58	14	8.44	0.97	0.08

Loom categories: 0→air jet loom, 1→Rapier (Optimax) loom and 2→ Rapier (Gamma) Loom

Table 9: Correlation Co-efficient for Thread Breakage and Relative Humidity

	Loom	R.H. %	Warp count	Weft Count	Warp Breakage Rate	Weft Breakage Rate
Warp Breakage Rate	.801**	.000	.007	-.144	1	.435*
Weft Breakage Rate	.376*	.010	-.133	-.055	.435*	1

** . Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

From table-9 correlation coefficient shows no significant relationship of average relative humidity to the either warp or weft thread breakage rate for specific fabric construction. This opposes the results found by Vicky Ashok Patil et al., in their productivity experiments. But, it also gives us further scope of study in this respect (Patil, Gulhane, Turukmane, & Patil, 2017). The result might have been vary due to the production floor temperature variation in uncontrolled manner.

Table 10: Time required to repair thread break

Sl. No.	Parameter	Required time(min)s					Avg.
01	Weft yarn repair time	0.30	0.33	0.32	0.34	.31	0.32
02	Warp yarn repair time	1.25	1.17	1.23	1.18	1.22	1.21

Table 11: Efficiency loss in % for loom to produce a fabric having 100 EPI, 100 PPI and 72 inch width fabric (Example)

	PPM	Production (m/day)	Warp Breakage rate	No. of warp breaks per day	Wastage in time	Weft Breakage Rate	No. of weft break per day	Wastage in time	Total waste	Efficiency loss in %
Air Jet	650	237.74	0.47	8.05	2.57	0.09	6.07	7.34	9.91	0.69
Rapier (Optimax)	625	228.60	0.88	14.48	4.63	0.06	3.89	4.70	9.34	0.65
Rapier (gamma)	625	228.60	1.21	19.92	6.37	0.12	7.78	9.41	15.78	1.10

From time study of the repairing thread breakage in the industry, we see the efficiency of Air jet and Rapier (Optimax) lose 0.65-0.69% due to thread breakage on the other hand Rapier (Gamma) loses 1.1% efficiency. Thus, loom categories influence the productivity of the industry in a great deal throughout the annual production amount.

CONCLUSIONS

In this study the thread breakage rate are found to be related to the types of looms. In air jet loom the thread breakage rate are less

than other models of Rapiar looms. Fabric width, epi, fabric length produced and production per day have influence on the thread breakage rate. But, the effect of relative humidity on the thread breakage rate was insignificant in this study which leads to the requirement of further study in this field. This concludes that the fabric and loom parameters influences the thread breakage rate in different way. It is also found that the interrelation of the warp and weft thread breakage is significant. So, by choosing the right setting of the loom and fabric construction to reduce the thread breakage up to the minimum. It is recommended that similar studies should be conducted to find out correct level of relative humidity and achieve maximum production and quality fabric production. The effectiveness control on the loom shed efficiency leads to control on warp breakage rate. As the whole experiment is completed in a particular time bound. The result may vary in environmental change of the production floor. If the limitations of the research can be reduced and the experiment can be performed in versatile experimental conditions the result would be more precise to draw the conclusion.

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A1: Thread breakage rate in Air jet loom

SL no	Temperature		Relative humidity	Machine-1			Machine-2			Machine-3			Machine-4			Machine-5		
	Dry (°C)	Wet (°C)		Code	Warp	Weft	Code	Warp	Weft	Code	Warp	Weft	Code	Warp	Weft	Code	Warp	Weft
1	26	22	70	1	9	8	3	4	26	5	13	17	6	5	12	8	4	6
2	24	21	76	1	6	12	3	7	15	5	3	39	6	6	13	8	5	8
3	22	21	92	1	5	11	3	2	12	5	4	44	6	5	7	8	5	6
4	26	22	70	1	7	8	3	6	10	5	6	56	6	4	6	8	8	7
5	24	21	76	1	13	15	3	8	23	5	10	8	6	8	19	8	20	23
6	26	22	70	1	6	6	3	7	32	5	20	14	6	7	13	8	32	12
7	24	21	76	1	7	6	3	18	14	5	16	12	6	5	12	8	25	16
8	22	21	92	1	11	13	3	9	13	5	19	21	6	9	14	8	23	14
9	26	22	70	1	8	18	3	7	9	5	15	23	6	11	16	8	9	22
10	26	22	70	1	10	20	3	9	11	5	18	30	6	5	13	8	15	11
11	24	21	76	1	9	17	3	8	11	5	14	22	6	8	9	8	21	17
12	24	21	76	1	7	13	3	11	9	5	22	21	6	9	11	8	23	16
13	24	22	84	1	6	12	3	7	14	5	32	19	6	9	13	9	22	15
14	26	23	77	1	10	7	3	9	14	5	22	18	6	5	16	9	8	14
15	26	22	70	1	6	11	3	11	16	5	20	17	6	6	9	9	11	17
16	26	21	64	2	8	12	4	8	22	1	13	14	7	5	13	9	13	16
17	22	21	92	2	6	10	4	6	10	1	21	23	7	9	8	9	12	16
18	24	21	76	2	13	19	4	8	9	1	19	22	7	6	11	9	16	6
19	22	21	92	2	10	13	4	13	7	1	10	30	7	8	14	9	12	12
20	24	22	84	2	13	16	4	8	9	1	18	11	7	8	16	9	9	20
21	26	22	70	2	8	12	4	9	13	1	17	20	7	8	14	9	23	7
22	24	21	76	2	10	15	4	8	10	1	22	48	7	13	9	9	14	15
23	24	21	76	2	9	13	4	7	11	1	28	13	7	9	12	9	15	6
24	26	22	70	2	13	11	4	9	21	1	14	22	7	5	11	9	12	18

1. (12+12+10)x450L40D/71x50
2. 10OE x 150L40D/83 x 60
3. 28/2 x450L40D /71 x 60
4. (16+16) x (16+16)/71 x 50
5. 10 ring x 10 ring/71 x 46
6. 14 ring x 20L70D/71 x 52
7. 10 ring x 150L40D/ 60 x 58
8. (20Tencel+20Tencel) x 20Tencel/ 99 x 60
9. 30Tencel x 30Tencel / 99 x 70

A2: Thread Breakage in Rapier (Optimax) Loom

SL no	Temperature		Relative humidity	Machine-1			Machine-2			Machine-3			Machine-4			Machine-5		
	Dry(°C)	Wet(°C)		Code	Warp	Weft	Code	Warp	Weft	Code	Warp	Weft	Code	Warp	Weft	Code	Warp	Weft
1	26	22	70	1	22	11	3	11	6	5	12	5	2	21	7	8	16	10
2	24	21	76	1	35	9	3	8	8	5	21	4	2	9	7	8	21	6
3	22	21	92	1	28	12	3	26	9	5	16	6	2	11	10	8	17	11
4	26	22	70	1	32	10	3	24	11	5	18	10	2	10	14	8	35	4
5	24	21	76	1	22	8	3	37	8	5	24	7	2	12	11	8	18	2
6	26	22	70	1	27	15	3	9	5	5	20	16	2	8	9	8	40	13
7	24	21	76	1	26	7	3	20	43	5	14	21	2	13	7	8	21	5
8	22	21	92	1	24	6	3	11	8	5	16	9	2	12	5	8	23	8
9	26	22	70	1	29	9	3	12	9	5	16	4	2	12	10	8	19	3
10	26	22	70	1	22	17	3	8	9	5	11	6	7	11	7	9	14	11
11	24	21	76	1	16	8	3	43	11	5	16	4	7	10	9	9	17	14
12	24	21	76	1	23	12	3	38	10	5	12	5	7	9	7	9	11	10
13	24	22	84	1	18	11	3	17	8	6	18	7	7	12	10	9	13	8
14	26	23	77	1	22	14	3	19	7	6	17	8	7	8	8	9	15	6
15	26	22	70	1	19	11	3	14	11	6	22	8	7	10	8	9	18	5
16	26	21	64	2	18	10	4	18	10	6	13	7	7	14	7	9	12	13
17	22	21	92	2	24	9	4	9	12	6	24	6	7	16	6	9	11	12
18	24	21	76	2	26	13	4	14	14	6	15	10	7	17	11	9	15	21
19	22	21	92	2	14	9	4	16	11	6	14	14	7	11	14	9	13	13
20	24	22	84	2	32	8	4	23	9	6	14	9	7	12	11	9	14	9
21	26	22	70	2	36	10	4	21	8	6	26	11	7	10	11	9	12	8
22	24	21	76	2	22	10	4	10	8	6	23	13	7	11	10	9	16	9
23	24	21	76	2	41	14	4	21	22	6	28	7	7	11	8	9	21	9
24	26	22	70	2	26	9	4	16	11	6	32	6	7	15	9	9	28	11

1. 14ring x 159L40D/60 x 58
2. 14ring x20L70D/ 71 x 52
3. 30Tencel x 30Tencel / 99 x 70
4. 20Tencel+20Tencel) x 20Tencel/ 99 x 60
5. (12+12+10)x(16L40D+450L40D)/83x60
6. 20 OE x 75L40D/71 x 65
7. 10 ring x 150L40D/ 60 x 58
8. 10OEx150L40D/83x60
9. (16+16)x (16+16)/71x 44

A 3: Thread Breakage in Rapier (Gamma) Loom

SL no	Temperature		Relative humidity	Machine-1			Machine-2			Machine-3			Machine-4			Machine-5		
	Dry(°C)	Wet(°C)		Code	Warp	Weft	Code	Warp	Weft	Code	Warp	Weft	Code	Warp	Weft	Code	Warp	Weft
1	26	22	70	1	23	14	3	57	7	1	21	67	6	28	11	7	16	18
2	24	21	76	1	27	16	3	12	6	1	22	75	6	20	7	7	12	21
3	22	21	92	1	58	19	3	35	9	1	24	32	6	24	13	7	10	23
4	26	22	70	1	53	17	3	22	14	1	28	20	6	16	10	7	16	18
5	24	21	76	1	19	11	3	28	8	1	25	55	6	23	9	7	12	9
6	26	22	70	1	27	12	3	23	22	1	29	48	6	56	14	7	47	56
7	24	21	76	1	28	31	3	29	28	1	22	18	6	38	28	7	18	15
8	22	21	92	1	23	14	3	12	16	1	20	19	6	13	17	7	14	9
9	26	22	70	1	19	16	3	24	9	1	24	27	6	27	14	7	9	8
10	26	22	70	1	55	8	4	27	20	1	32	16	6	34	18	7	15	10
11	24	21	76	1	22	14	4	22	14	1	24	19	6	24	19	7	9	27
12	24	21	76	1	24	46	4	28	32	1	28	32	6	44	22	7	17	9
13	24	22	84	2	25	19	4	32	17	5	44	17	6	49	19	3	20	14
14	26	23	77	2	40	22	4	36	18	5	23	33	6	28	14	3	29	11
15	26	22	70	2	18	17	4	26	22	5	26	22	6	23	11	3	17	11
16	26	21	64	2	44	13	4	36	13	5	36	35	4	28	13	3	19	13
17	22	21	92	2	16	12	4	32	17	5	34	27	4	23	20	3	29	8
18	24	21	76	2	32	18	4	23	16	5	42	32	4	39	19	3	19	21
19	22	21	92	2	22	13	4	19	14	5	21	18	4	30	15	3	15	22
20	24	22	84	2	20	11	4	29	15	5	29	15	4	29	11	3	18	12
21	26	22	70	2	19	11	4	31	19	5	31	19	4	25	10	3	31	11
22	24	21	76	2	28	14	4	28	12	5	18	19	4	16	9	3	26	11
23	24	21	76	2	21	16	4	23	16	5	48	23	4	48	28	3	22	16
24	26	22	70	2	28	11	4	44	22	5	25	21	4	20	9	3	21	18

1. $(12+12+10) \times (16L40D+450L40D)/83 \times 60$
2. $(16+16) \times (16+16)/71 \times 44$
3. $28/2 \times 450L40D / 71 \times 60$
4. $10 \text{ ring} \times 10 \text{ ring} / 71 \times 46$
5. $10 \text{ ring} \times 10 \text{ ring} / 71 \times 46$
6. $14 \text{ ring} \times 20L70D / 71 \times 52$
7. $14 \text{ ring} \times 20L70D / 71 \times 52$

A4: Warp and Weft Breakage rate in Air jet Loom

Sl.	R.H%	Air Jet Loom											
		Breakage rate											
		1		2		3		4		5		Avg	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
1	70	0.36	0.05	0.21	0.16	0.52	0.11	0.21	0.07	0.15	0.04	0.29	0.08
2	76	0.24	0.07	0.37	0.09	0.12	0.24	0.25	0.07	0.19	0.05	0.23	0.11
3	92	0.20	0.06	0.10	0.07	0.16	0.27	0.21	0.04	0.19	0.04	0.17	0.10
4	70	0.28	0.05	0.31	0.06	0.24	0.35	0.17	0.03	0.30	0.04	0.26	0.11
5	76	0.53	0.09	0.42	0.14	0.40	0.05	0.34	0.11	0.75	0.14	0.49	0.11
6	70	0.24	0.03	0.37	0.20	0.80	0.09	0.29	0.07	1.19	0.07	0.58	0.09
7	76	0.28	0.03	0.94	0.09	0.64	0.07	0.21	0.07	0.93	0.10	0.60	0.07
8	92	0.45	0.07	0.47	0.08	0.76	0.13	0.38	0.08	0.86	0.09	0.58	0.09
9	70	0.32	0.10	0.37	0.06	0.60	0.14	0.46	0.09	0.34	0.14	0.42	0.11

10	70	0.40	0.11	0.47	0.07	0.72	0.19	0.21	0.07	0.56	0.07	0.47	0.10
11	76	0.36	0.10	0.42	0.07	0.56	0.14	0.34	0.05	0.78	0.10	0.49	0.09
12	76	0.28	0.07	0.58	0.06	0.88	0.13	0.38	0.06	0.86	0.10	0.60	0.08
13	84	0.24	0.07	0.37	0.09	1.29	0.12	0.38	0.07	0.96	0.09	0.65	0.09
14	77	0.40	0.04	0.47	0.09	0.88	0.11	0.21	0.09	0.35	0.09	0.46	0.08
15	70	0.24	0.06	0.58	0.10	0.80	0.11	0.25	0.05	0.48	0.10	0.47	0.08
16	64	0.34	0.07	0.32	0.13	0.53	0.08	0.28	0.07	0.57	0.10	0.41	0.09
17	92	0.25	0.06	0.24	0.06	0.85	0.13	0.50	0.05	0.52	0.10	0.47	0.08
18	76	0.55	0.11	0.32	0.05	0.77	0.13	0.33	0.06	0.70	0.04	0.53	0.08
19	92	0.42	0.08	0.52	0.04	0.40	0.17	0.44	0.08	0.52	0.07	0.46	0.09
20	84	0.55	0.09	0.32	0.05	0.73	0.06	0.44	0.09	0.39	0.12	0.49	0.08
21	70	0.34	0.07	0.36	0.07	0.69	0.11	0.44	0.08	1.00	0.04	0.57	0.08
22	76	0.42	0.09	0.32	0.06	0.89	0.28	0.72	0.05	0.61	0.09	0.59	0.11
23	76	0.38	0.08	0.28	0.06	1.13	0.07	0.50	0.07	0.65	0.04	0.59	0.06
24	70	0.55	0.06	0.36	0.12	0.57	0.13	0.28	0.06	0.52	0.11	0.46	0.10

A5: Warp and Weft Breakage Rate in Rapier (Optimax) Loom

Sl.	R.H%	Rapier (Optimax)											
		Breakage rate											
		1		2		3		4		5		Avg	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
1	70	1.27	0.07	0.50	0.04	0.60	0.03	0.80	0.04	0.81	0.07	0.80	0.05
2	76	2.02	0.05	0.36	0.05	1.06	0.03	0.34	0.04	1.06	0.04	0.97	0.04
3	92	1.61	0.07	1.18	0.06	0.81	0.04	0.42	0.05	0.86	0.08	0.97	0.06
4	70	1.85	0.06	1.09	0.07	0.91	0.07	0.38	0.07	1.76	0.03	1.20	0.06
5	76	1.27	0.05	1.68	0.05	1.21	0.05	0.46	0.06	0.91	0.01	1.10	0.04
6	70	1.56	0.09	0.41	0.03	1.01	0.11	0.31	0.05	2.02	0.09	1.06	0.07
7	76	1.50	0.04	0.91	0.28	0.71	0.15	0.50	0.04	1.06	0.03	0.93	0.11
8	92	1.38	0.04	0.50	0.05	0.81	0.06	0.46	0.03	1.16	0.06	0.86	0.05
9	70	1.67	0.05	0.54	0.06	0.81	0.03	0.46	0.05	0.96	0.02	0.89	0.04
10	70	1.27	0.10	0.36	0.06	0.55	0.04	0.63	0.04	0.52	0.07	0.67	0.06
11	76	0.92	0.05	1.95	0.07	0.81	0.03	0.58	0.05	0.63	0.08	0.98	0.06
12	76	1.33	0.07	1.72	0.06	0.60	0.03	0.52	0.04	0.41	0.06	0.92	0.05
13	84	1.04	0.07	0.77	0.05	0.86	0.04	0.69	0.06	0.48	0.05	0.77	0.05
14	77	1.27	0.08	0.86	0.04	0.81	0.04	0.46	0.05	0.55	0.04	0.79	0.05
15	70	1.10	0.07	0.63	0.07	1.05	0.04	0.58	0.05	0.67	0.03	0.80	0.05
16	64	0.79	0.06	0.70	0.06	0.62	0.04	0.81	0.04	0.44	0.08	0.67	0.06
17	92	1.05	0.05	0.35	0.08	1.14	0.03	0.92	0.04	0.41	0.07	0.77	0.05
18	76	1.14	0.08	0.54	0.09	0.72	0.05	0.98	0.07	0.55	0.13	0.79	0.08
19	92	0.61	0.05	0.62	0.07	0.67	0.07	0.63	0.08	0.48	0.08	0.60	0.07
20	84	1.40	0.05	0.89	0.06	0.67	0.05	0.69	0.07	0.52	0.05	0.83	0.05

21	70	1.57	0.06	0.82	0.05	1.24	0.06	0.58	0.07	0.44	0.05	0.93	0.06
22	76	0.96	0.06	0.39	0.05	1.10	0.07	0.63	0.06	0.59	0.05	0.73	0.06
23	76	1.79	0.08	0.82	0.14	1.33	0.04	0.63	0.05	0.78	0.05	1.07	0.07
24	70	1.14	0.05	0.62	0.07	1.53	0.03	0.86	0.05	1.03	0.07	1.04	0.05

A6: Warp and Weft Breakage rate in Rapier (Gamma) Loom

Sl.	R.H%	Rapier (Gamma)											
		Breakage rate											
		1		2		3		4		5		Avg	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
1	70	1.16	0.10	3.11	0.05	1.06	0.47	1.22	0.07	0.87	0.12	1.484	0.158
2	76	1.36	0.11	0.65	0.04	1.11	0.52	0.87	0.04	0.65	0.14	0.93	0.17
3	92	2.92	0.13	1.91	0.06	1.21	0.22	1.05	0.08	0.55	0.15	1.527	0.128
4	70	2.67	0.12	1.20	0.09	1.41	0.14	0.70	0.06	0.87	0.12	1.37	0.105
5	76	0.96	0.08	1.53	0.05	1.26	0.38	1.00	0.05	0.65	0.06	1.08	0.125
6	70	1.36	0.08	1.25	0.14	1.46	0.33	2.45	0.08	2.56	0.36	1.817	0.201
7	76	1.41	0.22	1.58	0.18	1.11	0.13	1.66	0.17	0.98	0.10	1.348	0.157
8	92	1.16	0.10	0.65	0.10	1.01	0.13	0.57	0.10	0.76	0.06	0.83	0.099
9	70	0.96	0.11	1.31	0.06	1.21	0.19	1.18	0.08	0.49	0.05	1.029	0.099
10	70	2.77	0.06	1.13	0.13	1.34	0.10	1.49	0.11	0.82	0.06	1.508	0.092
11	76	1.11	0.10	0.92	0.09	1.00	0.12	1.05	0.11	0.49	0.17	0.914	0.12
12	76	1.21	0.32	1.17	0.21	1.17	0.21	1.92	0.13	0.93	0.06	1.279	0.185
13	84	0.92	0.11	1.34	0.11	1.84	0.11	2.14	0.11	0.87	0.08	1.422	0.106
14	77	1.48	0.13	1.50	0.12	0.96	0.21	1.22	0.08	1.27	0.07	1.286	0.122
15	70	0.67	0.10	1.09	0.14	1.09	0.14	1.00	0.07	0.74	0.07	0.917	0.103
16	64	1.63	0.08	1.50	0.08	1.50	0.23	1.17	0.08	0.83	0.08	1.327	0.11
17	92	0.59	0.07	1.34	0.11	1.42	0.17	0.96	0.13	1.27	0.05	1.115	0.106
18	76	1.18	0.11	0.96	0.10	1.75	0.21	1.63	0.12	0.83	0.13	1.272	0.133
19	92	0.81	0.08	0.79	0.09	0.88	0.12	1.25	0.10	0.66	0.13	0.879	0.102
20	84	0.74	0.07	1.21	0.10	1.21	0.10	1.21	0.07	0.79	0.07	1.032	0.08
21	70	0.70	0.07	1.29	0.12	1.29	0.12	1.05	0.06	1.35	0.07	1.138	0.088
22	76	1.03	0.08	1.17	0.08	0.75	0.12	0.67	0.06	1.14	0.07	0.952	0.081
23	76	0.78	0.10	0.96	0.10	2.00	0.15	2.01	0.18	0.96	0.10	1.342	0.125
24	70	1.03	0.07	1.84	0.14	1.04	0.14	0.84	0.06	0.92	0.11	1.134	0.102

A7: Relative Humidity% and Thread Breakage Rate

R.H. %	Warp breakage rate	Weft breakage rate
70	0.86	0.10
76	0.71	0.11
92	0.89	0.10
70	0.94	0.09
76	0.89	0.09
70	1.15	0.12
76	0.96	0.11
92	0.76	0.08

70	0.78	0.08
70	0.88	0.09
76	0.79	0.09
76	0.93	0.11
84	0.95	0.08
77	0.85	0.09
70	0.73	0.08
64	0.80	0.09
92	0.79	0.08
76	0.86	0.10
92	0.65	0.09
84	0.78	0.07
70	0.88	0.07
76	0.76	0.08
76	1.00	0.09
70	0.88	0.08

A8: Average Warp and Weft Breakage Rate in Air jet and Rapier Loom

Warp Breakage			Weft Breakage		
Air jet	Rapier (Optimax)	Rapier (Gamma)	Air jet	Rapier (Optimax)	Rapier (Gamma)
0.29	0.80	1.48	0.08	0.05	0.16
0.23	0.97	0.93	0.11	0.04	0.17
0.17	0.97	1.53	0.10	0.06	0.13
0.26	1.20	1.37	0.11	0.06	0.10
0.49	1.10	1.08	0.11	0.04	0.12
0.58	1.06	1.82	0.09	0.07	0.20
0.60	0.93	1.35	0.07	0.11	0.16
0.58	0.86	0.83	0.09	0.05	0.10
0.42	0.89	1.03	0.11	0.04	0.10
0.47	0.67	1.51	0.10	0.06	0.09
0.49	0.98	0.91	0.09	0.06	0.12
0.60	0.92	1.28	0.08	0.05	0.18
0.65	0.77	1.42	0.09	0.05	0.11
0.46	0.79	1.29	0.08	0.05	0.12
0.47	0.80	0.92	0.08	0.05	0.10
0.41	0.67	1.33	0.09	0.06	0.11
0.47	0.77	1.12	0.08	0.05	0.11
0.53	0.79	1.27	0.08	0.08	0.13
0.46	0.60	0.88	0.09	0.07	0.10
0.49	0.83	1.03	0.08	0.05	0.08
0.57	0.93	1.14	0.08	0.06	0.09
0.59	0.73	0.95	0.11	0.06	0.08
0.59	1.07	1.34	0.06	0.07	0.12
0.46	1.04	1.13	0.10	0.05	0.10

Average values

0.47	0.88	1.21	0.09	0.06	0.12
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