Impact of Different Fillers During Papermaking Using Multi-layer Fabrics

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ABSTRACT

The configuration of the machine wire has an impact on the properties of process as well as those of paper. The machine wires having different layers are used by the papermakers depending upon the requirement and speed of machine. In the present study, the impact of different layered machine wire on water drainage and formation of paper has been studied in the laboratory. The wires having single, double and triple layers were used for making handsheets of 60 g/m^2 using bleached eucalyptus pulp and different fillers. The effect of fillers such as talc, ground calcium carbonate and precipitated calcium carbonate at fixed addition level on the wear/ tear of the wire was also examined at different magnifications using Image analyser. The water drainage, retention of filler and formation index of paper were increased with increasing layers of wire.

Keywords: Machine wire, filler, papermaking, paper properties, wear & tear

Introduction

The fabric of the machine wire is characterized by the material & dimensions of the threads and the fabric pattern. Initially the bronze wire was used during papermaking which was single-layered. Later in 1970's, the plastic wire replaced the bronze wire since the increasing machine speeds gave the bronze wire too short a lifespan, due to the poor wear resistance of the bronze threads. The lifespan was increased radically by a transition to wear-resistant polymer threads [1].

For a single-layered wire, the geometry of the paper side is by definition opposite to that of the wear side. It was therefore difficult to construct a single-layered wire so that both the paper side and the wear side have mainly transversely running threads in the surface. To facilitate an optimum construction of both the paper and wear side of the wire, first the double-layered wire was introduced and subsequently the multi-layered wire [1].

In the forming section of papermaking process, improving paper properties is the biggest choice of the papermakers [2]. Machine clothing is essentially the conveyor system that transports the papermaking material from the forming section to the press area and finally through the dryer section. The quality and configuration of machine wire are one of the tools the papermaker can use to obtain varying drainage rate, retention of fibre, fibre fines & filler, sheet formation and thereby paper properties. Therefore, the machine wire must be designed for particular applications to meet specific papermaking objectives [3].

Some of the major variables of the papermaking process include the pulp furnish, machine type & speed, and machine wire. The design of machine wire during papermaking process should be compatible with other elements in the forming section. The materials that clothe modern paper machines are sophisticated engineered fabrics, and suppliers have differing views on how to best support their customers' needs with these fabrics [3-5].

Runnability without breaks at ever increasing production speeds is a very important feature of any fabric to a papermaker as well as reliable life expectancy. The machine wires for getting higher fibre support and thinner caliper for increased drainage capacity, smoother sheet surfaces and increased consistency at couch roll are desired [2].

Different types of paper machine clothing using monofilaments providing improved cleaning characteristics are available worldwide. For forming fabrics, a blend of polyester with a small amount of polyvinylidene fluoride is popular in many countries. Depending on the particular conditions on a paper machine, the effects are usually positive [6].

The requirement of papermakers could be achieved by proper selection of machine wire. Now-a-days the machine wire with different configurations, designs and layers are available for different types of machines. It has been claimed that the formation of paper is considerably improved due to triple-layer, whereas the regular double-layer could achieve maximum fibre retention [2, 7, 8].

Moreover, the papermakers use various types of pulps, fillers and other papermaking chemicals. The abrasion in machine wire due to the loading of filler decreases the life of the former and thus increases the cost of papermaking. In the present communication, the effect of configuration of machine wire; single, double and triple layer on water drainage and formation of paper has been studied. Three types of commonly used fillers (talc, GCC, PCC) were used at a fixed dosage to analyse the effect on the said properties as well as on the wear & tear of wire.

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Experimental

Pulp

A bleached eucalyptus pulp was sourced from an integrated pulp and paper mill in north India. The pulp had an initial freeness of 590 CSF, measured on Canadian Standard Freeness tester following TAPPI test method T227 om-09. It was refined in a PFI mill following TAPPI test method T248 sp-00 to a freeness level of 430 CSF before use.

Chemicals

Three different fillers viz., talc, ground calcium carbonate (GCC) and precipitated calcium carbonate (PCC) were sourced from different manufacturers in north India and added to pulp at 380 kg/t addition level. The fillers were dispersed in water (20% w/v) for 30 minutes prior to its addition into pulp stock.

The commercial grade medium to high molecular weight cationic polyacrylamide (CPAM) and high molecular weight anionic polyacrylamide (APAM) were procured from a chemical manufacturer in India, and used for the retention of filler and fibre fines. The dry powder of CPAM/ APAM was mixed with ~40°C deionized water in a beaker and agitated at 300 rpm for 30 minutes to prepare 0.1% (w/v) solution.

Machine Wires

Three different machine wires viz., single, double and triple layered were sourced from a manufacturer in India. All three wires were used in the handsheet former in place of standard mesh for making the handsheets. The image analysis of the wires before and after making of 60 handsheets using each filler was carried out at different magnifications on an Image analyzer (Axio Scope A1, Carl Zeiss Microimaging GmbH, Gottingen, Germany).

Methods

The fillers were characterized for physico-chemical and optical properties including brightness, particle size distribution (PSD), abrasivity and charge demand. The moisture-free fillers were compacted into cubes using an Arbour press prior to the measurement of brightness using a Datacolor brightness spectrophotometer (Spectraflash 300). The filler suspensions of 10% (w/v) were prepared, filtered through a 300 µm screen and the pH of the filtrate was measured. Mütek particle charge detector (PCD-03 pH) was used to determine the colloidal charge and ionic behaviour of filler slurry. The abrasion of the filler slurry was also determined using an Einlehner AT1000 abrasion tester at 174,000 revolutions using the phosphor bronze mesh screen. The loss in bronze mesh screen was calculated using the following formula:

$$\text{Abrasion loss, g/m}^2 = W/A \qquad (1)$$

where W is the weight loss (g) and A is the abrasion area (0.000305 m^2)

The average particle size and PSD of the fillers were measured using Horiba LA950S2 laser scattering particle size distribution analyzer. Talc fillers were wetted with ethanol, whereas both GCC and PCC were wetted with 5% (w/v) sodium hexametaphosphate solution. The wetted fillers were then dispersed with deionized water to make 10% (w/v) filler slurry for the determination of PSD.

The drainage time of the pulp slurry was measured on handsheet former using TAPPI test method T 221 cm-99. After the standard stirring of pulp slurry and a pause of 5 seconds, the drain valve of the sheet former was opened and the time taken for the level of the pulp suspension to fall from the 350-mm mark to the wire was measured and reported as drainage time in seconds.

Handsheet Preparation and Testing

Various filler slurries dispersed in water (10% (w/v)) were added to the refined pulp of 1% consistency (w/v). Paper handsheets of 60 g/m^2 were prepared following TAPPI test method T 205 sp-02. The ash content of the handsheets was determined at 525°C as per TAPPI test method T 211 om-93 and calculated using the following formula:

$$\text{Ash content in paper, \%} = \frac{\text{o.d. weight of ash in paper (g)}}{\text{o.d. weight of handsheet (g)}} \times 100$$

The first pass ash retention (FPAR) was calculated using the following formula:

$$\text{FPAR, \%} = \frac{\text{Ash in paper (\%)}}{\text{Filler added based on pulp and filler (\%)}} \times 100$$

The formation of paper was measured using Optest Microscanner after conditioning the sheets at constant temperature (27±2°C) and humidity (65±5%). The higher value of formation index indicated better formation.

Results & Discussion

The paper properties in a filled paper are dependent upon the nature of fibre, filler and machine wire configuration. The structural developments in the paper matrix are decided by the physico-chemical characteristics of filler. The chemical characteristics of filler attribute the chemical charge balance and the retention of filler in paper. Among the three varieties of fillers; talc, ground calcium carbonate (GCC), and precipitated calcium carbonate (PCC) the last one was the brightest. Talc filler was having the coarsest particle size followed by PCC and GCC. As shown in Table 1, the median particle size of talc was the coarsest (9.9 µm) followed by PCC (4.8 µm) and GCC (3.0 µm). The similar trend was observed when the particle sizes below different size fractions (2, 5 and 10 µm) were compared. Measurement of colloidal charge demand indicated that the talc filler was anionic, and both GCC and PCC were cationic. The cationic colloidal charge demand of talc was 1.7 µeq/g, whereas the anionic colloidal charge demand of PCC and GCC was 6.9 and 6.5 µeq/g, respectively. The Einlehner wire abrasion of the talc filler (26.2 g/m^2) was the lowest among all fillers followed by PCC (27.5 g/m^2) and GCC (34.1 g/m^2).

Table 1: Characteristics of different fillers

Parameter	Talc	GCC	PCC
ISO brightness, %	90.7	94.0	95.8
Particles less than 2 µm, %	0	27.6	9.6
Particles less than 5 µm, %	4.3	79.9	53.8
Particles less than 10 µm, %	50.7	98.4	96.4
Median particle size (D50), µm	9.9	3.0	4.8
pH of 10% (w/v) slurry	9.0	8.6	9.7
Charge demand, µeq/g	1.7 (cationic)	6.5 (anionic)	6.9 (anionic)
Einlehner wire abrasion, g/m^2	26.2	34.1	27.5

Effect of Filler on Wire

The different fillers (talc, PCC and GCC) were loaded in paper using three different machine wires viz., single layer, double layer and triple layer. All fillers were loaded at a fixed dose level of 380 kg/t pulp; about sixty handsheets were prepared using one filler. After preparation of sixty handhseets, the image analysis of the wire was carried out. The images of the fresh machine wires at two different magnifications (5 and 10x) are shown in Figure 1. They clearly differentiate the configuration of the wire. As shown in the figure, the single layer wire was having the highest opening as compared with double and triple layer wires. The images of fresh wires also reflected the cleanliness and no deformity in the wire.

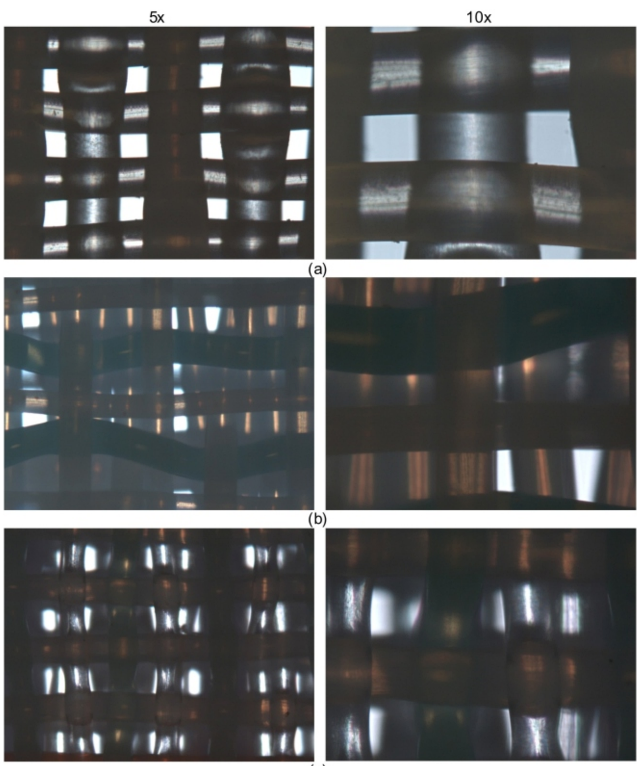

Figure 1. Images of fresh machine wires taken at 5 and 10x magnification using Image analyzer: single layer (a), double layer (b), triple layer (c)

The images of all three wires taken after using talc, PCC and GCC filler during papermaking are shown in Figure 2, 3 and 4, respectively. The images show that the single layer wire was having more wear & tear as compared with double and triple layer wires. The image taken at 10x magnification clearly supported this

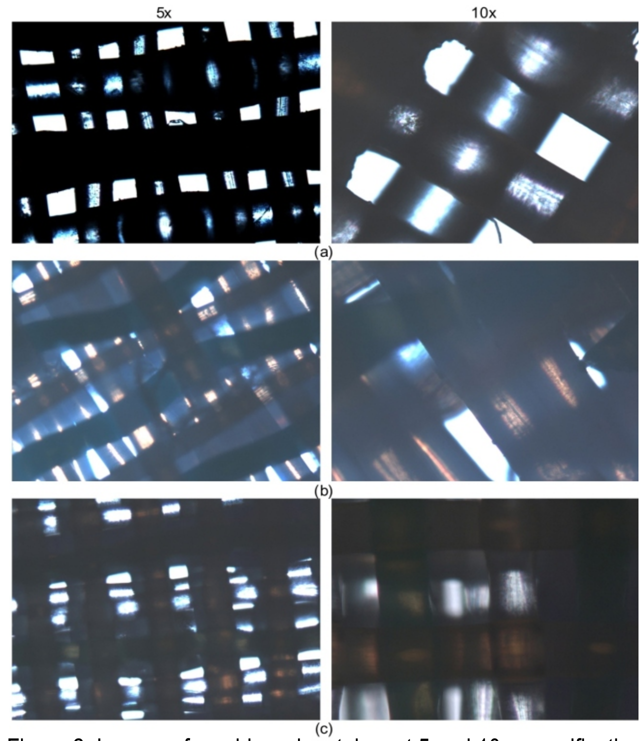

Figure 2. Images of machine wires taken at 5 and 10x magnification using Image analyzer after making sheets with talc filler: single layer (a), double layer (b), triple layer (c)

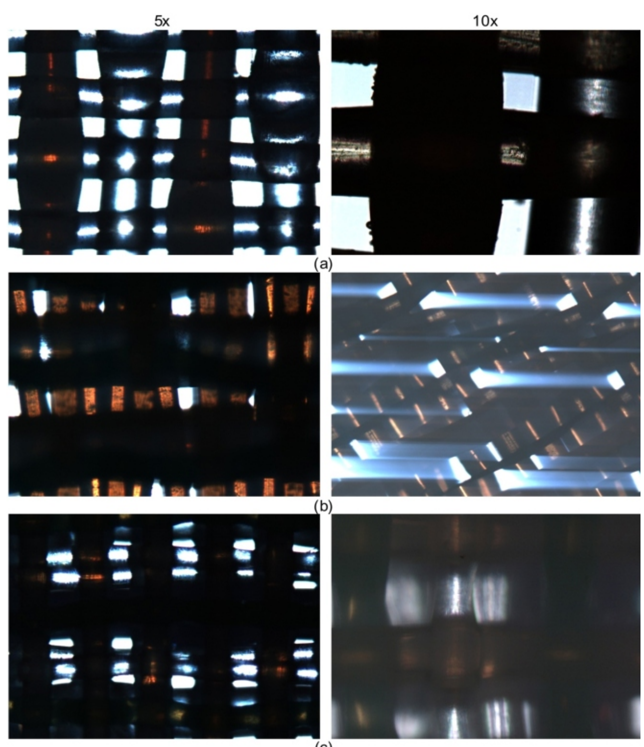

Figure 3. Images of machine wires taken at 5 and 10x magnification using Image analyzer after making sheets with PCC filler: single layer (a), double layer (b), triple layer (c)

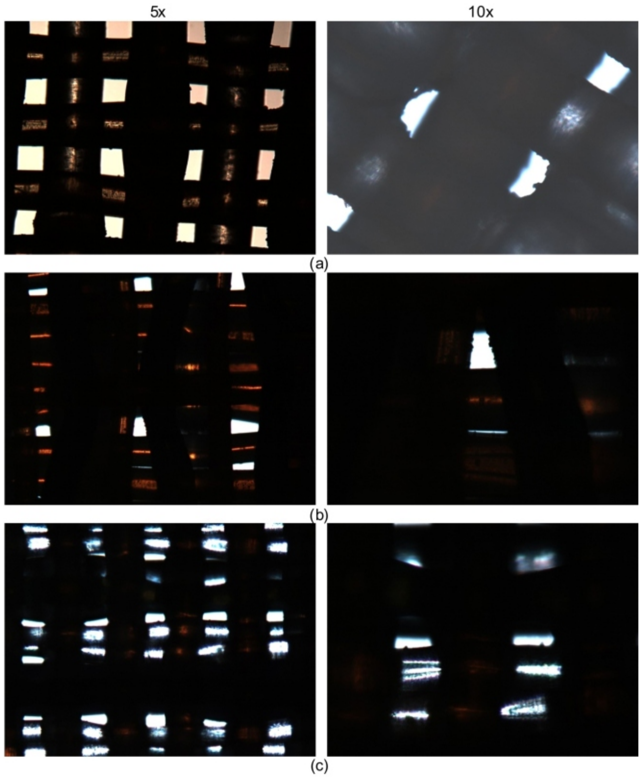

Figure 4. Images of machine wires taken at 5 and 10x magnification using Image analyzer after making sheets with GCC filler: single layer (a), double layer (b), triple layer (c)

statement. The wires were having slightly more wear & tear after usage of PCC (Figure 3) and GCC filler (Figure 4). The more pronounced effect of the wear & tear was observed after using GCC filler. Figure 3 and 4 also show that the wear & tear in wire was the highest in single layer wire followed by triple and double layer wires.

The possible reason of the wear & tear in wires was the abrasivity of the filler. The mills use the wires for making paper and need to discard it after usage for some specific time. The usage time basically depends upon the type of machine, wire, papermaking furnish and filler. The above finding demonstrate that the highest wear & tear in wire was observed using GCC filler due to its own abrasivity which was the highest among all fillers used in this study. Moreover, the type/configuration of wire would also impact the wear & tear or deformation in wire as well.

Effect of Wire on Water Drainage

The effect of machine wire on drainage time of pulp is shown in Figure 5. All three fillers (talc, PCC and GCC) added to the pulp at constant dosage showed slight difference in the drainage time measured on handsheet former. The drainage time was also slightly different when measured using different machine wires viz., single layer, double layer and triple layer. It was the highest for single layer wire followed by double and triple layer wires. This was applicable for all type of fillers used in the study. The drainage time of pulp using talc filler was the lowest followed by GCC and PCC. It was true for all machine wires. The drainage time using talc filler on single layer wire was 14.3 seconds which was slightly decreased to 14.1 and 13.4 seconds while using double and triple layer wires, respectively. The drainage time using GCC filler on single layer wire

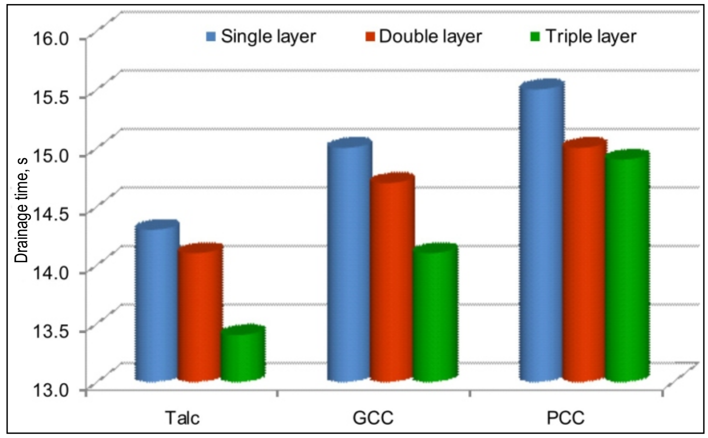

Figure 5. Effect of machine wire on water drainage using different fillers at 380 kg/t pulp

was 15.0 seconds which was slightly decreased to 14.7 and 14.1 seconds while using double and triple layer wires, respectively. Similarly, the drainage time using PCC filler on single layer wire was 15.5 seconds which was slightly decreased to 15.0 and 14.9 seconds while using double and triple layer wires, respectively. The similar results were reported elsewhere [7].

Effect of Wire on Retention of Filler

The effect of machine wire on ash in paper and first pass ash

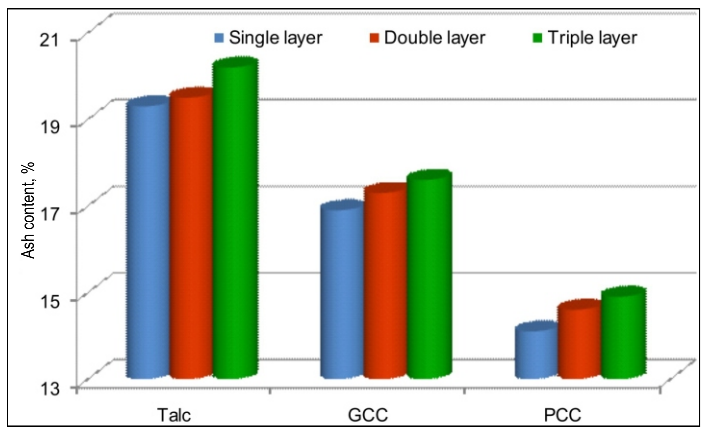

Figure 6. Effect of machine wire on ash content using different fillers at 380 kg/t pulp

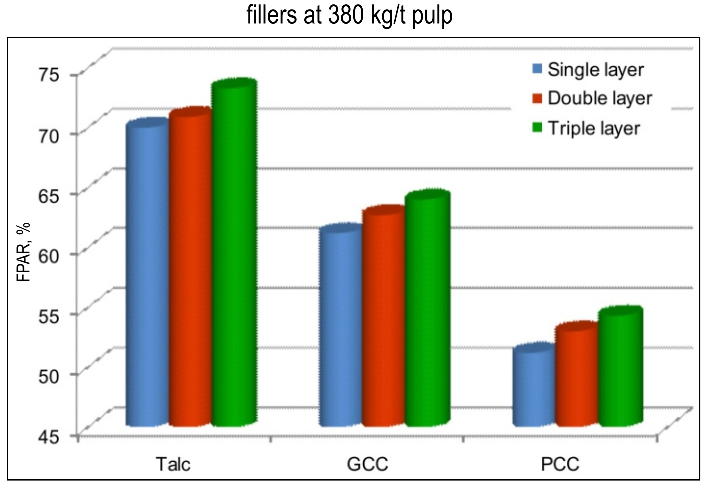

Figure 7. Effect of machine wire on first pass ash retention using different fillers at 380 kg/t pulp

retention (FPAR) is shown in Figure 6 and 7, respectively. The ash content in sheet was increased on increasing the layer of wire (Figure 6). This was applicable for all type of fillers used in the study. The ash content in paper using talc filler on single layer wire was 19.3% which was increased to 19.5 and 20.2% while using double and triple layer wires, respectively. The similar results were observed using other two fillers (GCC & PCC). In case of GCC filler, the ash content in sheet was increased from 16.9 to 17.6% when changing single layer by triple layer wire. The FPAR was also having the similar trend for all fillers and wires (Figure 7). All three fillers (talc, PCC and GCC) added to pulp at constant dosage showed difference in the ash content and FPAR. The highest ash and FPAR were obtained using talc filler. Johnson [7] also showed the similar results of retention while using multi-layer machine wires.

Effect of Wire on Formation

The effect of machine wire on formation of paper using different fillers is shown in Figure 8. The higher value of formation index indicated the better formation of sheet. The formation of paper was the best with talc filler followed by GCC and PCC filler. The formation index of paper with talc, PCC and GCC filler on single layer wire was 97, 82 and 89, respectively. Similarly, the formation index of paper with talc, PCC and GCC filler on double layer wire was 130, 121 and 127, respectively. The similar trend was observed with triple layer wire where the formation index of paper with talc, PCC and GCC filler was 159, 141 and 155, respectively. Among all three wires, the formation of paper sheets was the best for the triple layer wire followed by double and single layer wires.

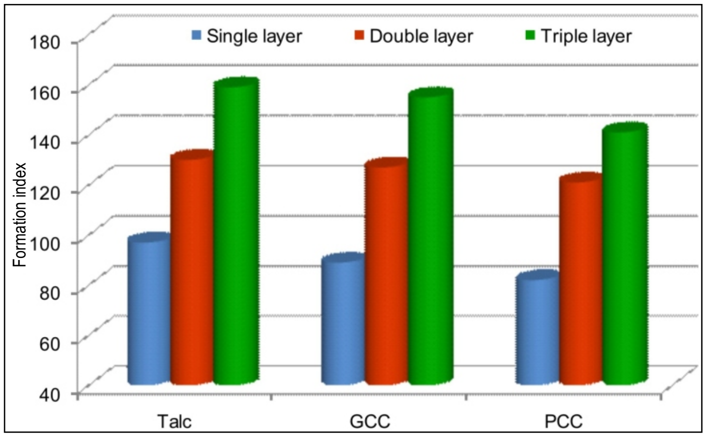

Figure 8. Effect of machine wire on formation of paper using different fillers at 380 kg/t pulp

Conclusion

The three machine wires having single, double and triple layers were used for making of sheets using three different fillers (talc, PCC and GCC) at fixed dosage. The Einlehner wire abrasion of talc, PCC and GCC filler was 26.2, 27.5 and 34.1 g/m^2 showing that GCC had the highest abrasion and talc had the lowest abrasion. The images taken on Image analyser revealed that the single layer wire was having more wear & tear compared with double and triple layer wires when used for making sheets using all three fillers. The highest wear & tear in the machine wires was observed using GCC filler due to its own high abrasion.

The water drainage time was the highest for single layer wire followed by double and triple layer wires. The drainage time of talc filler was the lowest followed by GCC and PCC. The ash content and FPAR were highest for triple layer wire followed by double and single layer wires. The configuration of machine wire had great impact on the formation of paper. Among all three wires, the formation of paper was the best for the triple layer wire followed by double and single layer wires. The formation of paper was the best with talc filler followed by GCC and PCC filler.

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