

High Wet Modulus Viscose: Performance and Market Opportunity Study

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Abstract - Viscose is a regenerated cellulosic fiber which loses ~50% of its strength in wet state, leading to certain limitations in its application and processing. The current study aimed to understand how does an increase in wet modulus of the viscose fiber impact the performance of various textile processes. The study shows that high wet modulus (HWM) viscose fiber has better toughness or “work of rupture” compared to standard viscose which helps it to give better performance in high speed wet processing machines, better working with fine counts such as 60s Ne and addressing the issue of “hole” formation in circular knitted fabrics. It has the potential to create value for the textile chain by addressing few of these known limitations faced by the industry today.

Key Words: Viscose, Fiber, High Wet Modulus (HWM), Toughness, Textile, Modal, Wet Processing, Work of Rupture

1. INTRODUCTION

Viscose is a regenerated cellulosic fiber [1], which is chemically similar to cotton but differs in molecular weight and crystallinity. Viscose fibers are widely used in textile applications, and provide the softness, drape and fluidity to fabrics. However, viscose loses ~50% of its strength in the wet state which lead to certain limitations in its application and processing. In the current study an attempt was made to understand if increasing the wet modulus of viscose fiber can bring in additional capability and infuse new properties in the fiber which can address few of these known limitations. High Wet Modulus (HWM) viscose fiber performance was compared against standard viscose fiber which is commercially available and used in the market today. The scope of the study was to understand if higher wet modulus leads to improved performance during different textile processes and explore if this property can be used to derive any advantage over standard viscose. “Toughness” or the work of rupture has been used as a measurement tool to assess performance.

The study attempts to evaluate the benefits with this fiber at different stages of textile processing and explores the possible market opportunities from these benefits.

2. MATERIALS AND METHOD

2.1 Materials

1. Fiber Used: 1.2 denier, 38mm standard viscose fiber and 1.2 denier 38mm HWM viscose fiber.

2. Fine weight fabrics with following constructions with HWM viscose, were used for processing trials in textile mills. Commercial fabrics with standard viscose in the same construction were used for the study.

| S.N. | Warp Yarn Count, Ne | Weft Yarn Count, Ne | Greige Fabric EPIxPPI | Greige Fabric Width, inch |
|------|---------------------|---------------------|-----------------------|---------------------------|
| 1 | 30s | 30s | 68x64 | 63 |
| 2 | 30s | 34s | 68x48 | 48 |

2.2 Measurement of “Toughness”

Toughness is the ability of a material to withstand cracks, i.e. to prevent the transfer or propagation of cracks across its section hence causing failure [2, 3]. Toughness is defined as the amount of energy required (both plastic and elastic deformation energies) to fracture the material. It is the inherent property of material that describes the nature of the material to break. Toughness is determined by measuring total area under the stress-strain curve.

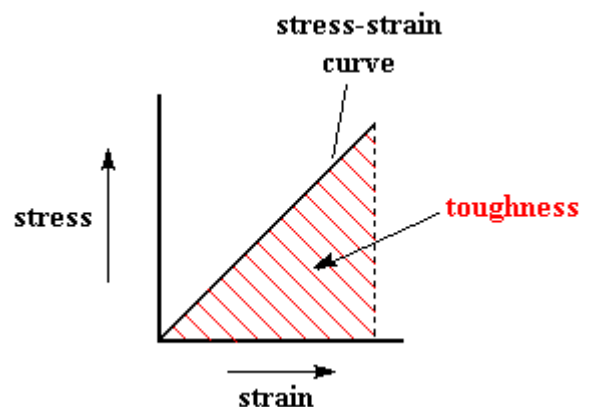


Fig-1: Toughness of material

Fig-1 represents a stress strain curve. The area under the load – elongation curve represents the work of rupture or the toughness of the material [4].

3. RESULTS AND DISCUSSION

3.1 Fiber Properties

Table-1: Fiber Tensile Properties

| Fiber (1.2d x 38mm) | Standard VSF | HWM VSF | Modal |
|-----------------------------------|--------------|---------|---------|
| Dry Tenacity, gpd | 2.8-2.9 | 3.1-3.2 | 4.1-4.3 |
| Wet Tenacity, gpd | 1.3-1.4 | 1.7-1.8 | 2.4-2.5 |
| % Crystalline (X-Ray Diffraction) | 38.8 | 39.3 | 44.6 |

*VSF denotes Viscose Staple Fiber; "gpd" denotes grams per denier

Fig-2: Fiber toughness measured as area under stress (gpd) & elongation (%) curve

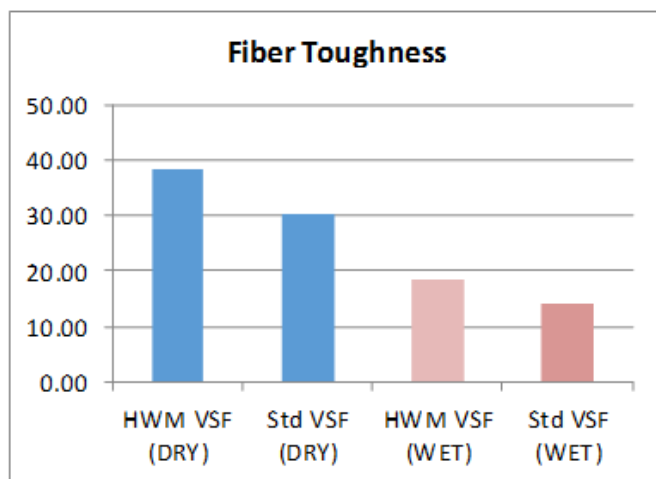


Table-2: Summary of Fiber Toughness Increase for HWM VSF

| Fiber | % Increase in Toughness over standard VSF | |
|---------|---|-----------|
| | DRY Fiber | WET Fiber |
| HWM VSF | ~26% | ~30% |

Table-2 shows that the "toughness" or the "work of rupture" of HWM viscose is ~25%-30% higher compared to standard viscose fiber, which leads to advantages during different processing.

3.2 Performance in Wet Processing

Textile greige fabrics are given a wet pretreatment [5, 6] to make them ready for dyeing. Knitted fabrics are generally processed in soft flow machines due to their delicate structure; while woven fabrics are processed preferably on Continuous Bleaching Range (CBR) due to higher speeds and productivity. However fine weight woven fabrics made of

100% viscose (with weight range of 120 GLM and 140 GLM, where GLM represents grams per linear meter) in India are pre-treated in Soft Flow machines, which is much more expensive than processing on Continuous Bleaching Range (CBR). These fine fabrics when processed in a CBR under hot wet condition face a problem of fabric tearing, which leads to stoppages, downtime and quality issues. Few mills have optimized their processes on CBR, but many of them report the issue of fabric tearing. Therefore, HWM viscose woven fabrics were made in the same construction as commercial fabrics in the market and processed together with standard viscose fabrics on CBR to observe if higher toughness of these fabrics give any advantage during processing. Trials were taken in commercial textile processing unit on CBR and it was observed that the HWM viscose fabrics ran well without the problem of tearing during. The fabric (120GLM fabric, 30s Ne Warp & 34s Ne Weft as described in materials section) was tested for toughness after different stages of processing. Table-3 illustrates how data was collected, and Table-4 gives the summary of the increase in toughness of fabrics at different stages of processing.

Table-3: Toughness of Ready-for-Dye fabric in WET state

| RFD Fabric (WET Fabric) | Toughness, kgf*mm | No. of Thread per inch | Total no. of thread in test area of 5cm | Toughness per unit thread, kgf*mm | % Increase per unit thread |
|-------------------------|-------------------|------------------------|---|-----------------------------------|----------------------------|
| HWM VSF - Warp | 336.18 | 76 | 150 | 2.25 | 66.0 |
| Standard VSF - Warp | 202.5 | 70 | 138 | 1.47 | |
| HWM VSF - Weft | 181.21 | 52 | 102 | 1.77 | 9.1 |
| Standard VSF - Weft | 166.06 | 48 | 94 | 1.76 | |

Fig-3: Toughness of Wet RFD Fabric

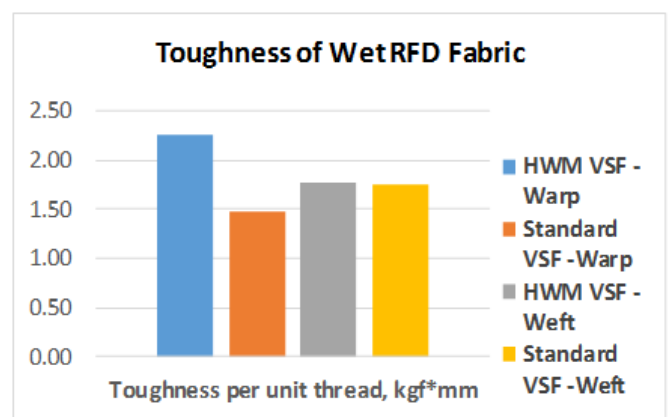


Table-4: Toughness increase at different stages of processing

| Process | % Increase in Toughness per unit thread for HWM vs standard VSF | | | |
|----------------------|---|------|------------|------|
| | WET Fabric | | DRY Fabric | |
| | Warp | Weft | Warp | Weft |
| Ready For Dye on CBR | ~60% | ~9% | ~35% | - |
| Dyed & Finished | ~15% | ~15% | ~18% | ~25% |

It is evident from table-3 and table-4 that for ready-for-dye fabric the toughness of wet fabric for HWM is significantly higher, which explains better performance of the fabric in high speed CBR machines during pretreatment.

The toughness of the final dyed and finished fabrics are higher for HWM viscose (table-4), which may be indicative of a more durable garment life and easy wash care options in home laundering compared to standard viscose.

3.2.1 Cost Benefit for HWM VSF

Cost calculations based on figures given by the processing mills, show the potential saving of ~25-30 US\$ Cents/kg of fiber if the fabric pretreatment is done on high speed continuous processing machines (CBR) to prepare the RFD fabric. The calculations take into account the advantages of lower processing cost in CBR compared to soft flow machine, higher processing speeds and productivity in CBR, savings on account of non-tearing of the fabric with HWM VSF, reduction in downtime, reduction in production loss and lost profit, and also benefits of consistent quality. In continuous processes large batches can be produced with consistent quality. It therefore avoids the variation resulting in batch processes due to smaller lot size.

3.3 Resistance to Acidic and Alkaline Conditions

Some textile processes use tough acidic and alkaline conditions. To find the resistance of the HWM viscose to alkaline and acidic conditions compared to standard viscose, fabrics with similar construction were desized enzymatically and then subjected to acidic condition (polyester dyeing condition, pH 5, 130°C, 30minutes) and alkaline condition (Cold Pad Batch dyeing condition at pH 12.5, 7gpl caustic flakes, temperature 25-30°C, 8 hours batch). The toughness of fabrics after the acidic and alkaline tests are summarized in table-5.

Table-5: Fabric toughness after acidic and alkaline treatments

| Process | % Increase in Toughness per unit thread for HWM vs standard VSF fabric | | | |
|------------------------|--|------|------------|------|
| | WET Fabric | | DRY Fabric | |
| | Warp | Weft | Warp | Weft |
| Acid Resistance Test | ~35% | ~18% | ~15% | ~3% |
| Alkali Resistance Test | ~20% | - | ~15% | ~6% |

Table-5 shows better toughness of fabric made with HWM viscose under both alkaline and acidic conditions. This is indicative of a better performance of HWM indicating ability to perform under more robust conditions. The inference can be extrapolated to suggest that HWM viscose is likely to give better performance in latest dyeing machines using low liquor ratio (1:4). Industry is moving towards low liquor ratios as the concept of ZLD (zero liquid discharge) is gaining attention.

3.4 Fine Count Spinning and Weaving

Fine count yarn such as 50s Ne and 60s Ne have their own challenges with viscose. Due to the lower strength of viscose there are limitations in spinning and weaving fabric with these yarns on high speed Air Jet looms. Only a limited number of textile mills are therefore able to use 100% viscose yarns in fine counts. In the current study, 60s Ne yarn was made with HWM Viscose and run on Air Jet Loom. It was observed that there were no issues in the sizing of these yarns while preparing the beam, and showed improved runability on air jet loom. Table-6 gives below the data on toughness of 60s Ne yarn and table-7 gives data on runability on air jet loom.

Table-6: Toughness of Fine Count 60s Ne Yarn

| Yarn Toughness, gf*mm | | % Increase |
|-----------------------|--------|------------|
| WET STATE | | |
| HWM VSF | 886.3 | 28.10 |
| Standard VSF | 691.9 | |
| DRY STATE | | |
| HWM VSF | 1329.1 | 9.06 |
| Standard VSF | 1218.7 | |

Table-7: Performance on Air Jet Weaving Loom

| AIR JET WEAVING | Total breaks per shift |
|-----------------|------------------------|
| HWM VSF | 35 |
| MODAL | 26 |

Table-6 and 7 indicate that HWM VSF gives improved performance in fine counts and therefore has the potential to open new market opportunities.

3.5 "Hole" Elimination in Knit Fabrics

Knitted fabric is one of the biggest application segment for viscose. The low wet strength of viscose leads to certain limitations in this segment as well. India has a big market for leggings made from single jersey circular knitted fabric. The trade follows a subjective assessment with the "thumb test" for deciding the pass or fail criteria for circular knit fabrics. The fabric is wetted with water completely and the thumb of one hand is pushed against it. If the fabric tears and the thumb makes a hole in the fabric, this is failed by the trade.

Standard viscose due to its lower wet strength has failed the "thumb test" as described above. As the toughness of HWM VSF is higher, and the benefits were shown in wet state in our earlier studies as discussed above, this product was expected

to give a better performance in the knits. Circular knit fabrics (~220 gsm finished fabrics with spandex) were made with standard viscose and HWM VSF and given to the customer to do the “thumb test” on wet fabric. It was observed that the knitted fabric made of HWM VSF did not face the problem of fabric hole.

3. CONCLUSION

The current study shows that it is advantageous to use HWM viscose fiber and obtain significant improvements in downstream processing, particularly during wet processing which results into more efficient running on high speed continuous processing machines and making it more commercially viable with improved product quality and durability. More importantly, it eliminates the issue of hole formation in circular knit legging, and provides new opportunities in fine count spinning and weaving. Thus products obtained from HWM viscose fiber show the potential to overcome some of the current limitations of usage of viscose in the textile trade.

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REFERENCES

- [1] Moncrieff, R. W. (1975). Man-made fibres (6th edition). London: Newnes-Butterworths.
- [2] Toughness—An overview | ScienceDirect Topics. (n.d.). Retrieved September 27, 2019, from <https://www.sciencedirect.com/topics/materials-science/toughness>
- [3] Hearn, E. J. (1997). Mechanics of materials 1 (3rd edition). London: Butterworth-Heinemann.
- [4] Tensile properties of Textile Fibers | Textile Study Center. (n.d.). Retrieved September 27, 2019, from <https://textilestudycenter.com/tensile-properties-of-textile-fibers/>
- [5] Trotman, E. R. (1968). Technology of scouring and bleaching. London: Charles Griffin & Company.
- [6] Peters, R. H. (1967). Textile chemistry (Vol-2). London: Elsevier Publishing Company.

BIOGRAPHIES



Amit Dayal had his education from IIT Kanpur and IIT Delhi, and has been associated with the textile value chain for about 25 years. He has spent significant amount of time in the industry while working with global MNCs like DuPont and Aditya Birla Group. His key interest area is to explore how scientific concepts can be used as a tool for value creation in the industry.