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An Investigation on the morphology, chemical, and physical properties of singed and singed-mercerized twisted cotton yarn

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Abstract:

Singeing of yarns and fabrics is one of the textile finishing processes that modifies the surface of textiles and affects some properties such as luster, light reflection, printing, dyeing, and draping,(Wang & Xiao, 2020; Hossain et al., 2021). Singeing takes place on the fabric produced from staple fibers which are known to cause hairiness on the yarns and fabric surface. All the research that has studied the effect of singeing on the properties of yarns and fabrics has not been devoted to studying the effect of singeing on the structure of fibers, which can affect the properties of yarns and fabrics. Cotton mercerization is a physico–chemical process (Brahma et al., 2018) that has been used for a long time and is still at the forefront of processing because it gives the cotton luster, and increases tenacity and smoothness to its surface. Crystallization is affected, depending on the conditions used in mercerizing, as well as the type of alkali used and its concentration ratio Mercerization improves the Physical, and chemical properties, and can remove ratio of the yarn hairiness(EL-Moursy& Mohamed, 2015) which improves dye exhaustion (Hilal et al., 2020), and increases total hand values.

This is the first study concerned with the change in the physical and chemical structure of the cotton fiber as a result of the process of singeing and mercerizing for singed yarns through investigation using SEM, IR, and XRD to calculate the crystallite size, Crystallinity Index and degree of crystallinity using Gaussian fitting.

Results and discussion:

Morphology analysis revealed a significant reduction in yarn hairiness post-singeing and a further decrease after mercerization as shown in Microscopic photographs. SEM images depicted untreated yarns with convoluted structures, which became straightened, swollen fibers post-mercerization. The combination of singeing and mercerization enhanced yarn luster and reduced hairiness by penetrating the NaOH solution into the fibers.

FTIR of untreated, S, and SM yarns revealed broader peaks at 3334 and 3267 cm−1 attributed to OH group stretching vibrations, more pronounced in SM due to its ability to form cellulosic components like H2O. SM yarns exhibited weak peaks at 3439, 3491, and 3156 cm−1 indicative of CII. Peaks at 2848 and 2914 cm−1 corresponded to C-H stretching vibrations, while 897 cm−1 indicated rocking vibration of methyl and methylene groups which is more pronounced in SM. A broad peak at 1623 cm−1 suggested stretching vibration of the C=O group in hemicellulose. Peaks at 1428 and 1370 cm−1 represented bending vibrations of CH2 and OH, respectively. Significant changes occurred below 1500 cm−1 in the fingerprint region, due to NaOH treatment of S, indicating new bond formation and increased functional groups above 1500 cm−1.

XRD of untreated, S, and SM samples exhibited four peaks for untreated and S samples, attributed to cellulose I (CI) based on Miller indices. Singeing caused a decrease in peak intensity and almost disappearance of a peak at 15.6˚, indicating increased amorphous areas due to cotton chains disorientation. SM yarns displayed five peaks, with shifts from untreated positions, attributed to planes (1-10/100), (110), (110), (020), and (004), suggesting conversion to cellulose II (CII) after NaOH treatment. Peaks at 12.7˚ and 21.2˚ appeared in SM due to NaOH treatment, with increased intensity at 23.3˚ and 35.5˚, indicating enhanced crystallinity and formation of sodium cellulose. Singeing's impact on chain orientation and NaOH's penetration through both amorphous and crystalline regions led to these structural changes. Singeing also induced a light yellowish color in the yarns due to the trapped center phenomenon, resulting from free radicals gaining thermal energy and leaving holes.

The Origin software facilitated peak fitting to determine FWHM and DÅ, revealing an inverse relationship between peak width and crystallite size. Singeing reduced crystallite size, decreasing CrI due to chain disintegration by the flame. Mercerization after singeing restored crystallinity, with NaOH penetrating amorphous regions and enhancing CrI. SM exhibited increased CrI compared to S, attributed to NaOH treatment. Cx in SM surpassed S due to decreased CrI of S and elimination of non-cellulosic substances, allowing for better chain orientation. S experienced reduced Cx compared to untreated yarns, as singeing prevented chain rearrangement. Singeing positively influenced mercerization by enhancing NaOH penetration, evident in increased Cx in SM. Singeing and mercerization mutually influenced each other, demonstrating their interconnected effects on yarn properties.

Conclusion:

- Singeing followed by mercerization of cotton yarns led to significant surface modifications and alterations in their chemical and physical properties. The crystallite size decreased as FWHM increased and vice versa.
- Mercerization increased the degree of crystallinity and decreased the crystallinity index.
- Singeing reduced hairiness, imparted a yellowish hue, and decreased crystallinity, while mercerization further reduced hairiness and enhanced luster.
- Mercerization induced swelling of fibers, increasing luster, and transitioning CI to CII.

Keywords:

Singeing, mercerization, cotton yarns, IR, XRD, SEM.

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