# STRUCTURE AND PROPERTIES OF COMMINGLED YARNS AND THEIR COMPOSITES

*by*

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1. Commingled yarns
2. Hybrid yarns

Dedicated to

**My Parents**

## CERTIFICATE

This is to certify that the thesis entitled "**Structure and Properties of Commingled Yarns and their Composites**" being submitted by Mr. Vinayak Ogale, to the Indian Institute of Technology, Delhi, for the award of the degree of Doctor of Philosophy in the Department of Textile Technology is a record of bonafide research work carried out by him. Mr. Vinayak Ogale has worked under my guidance and supervision and has fulfilled the requirements for the submission of the thesis.

The results contained in this thesis have not been submitted, in part or in full, to any other University or Institute for the award of any degree or diploma.

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## ABSTRACT

Hybrid yarns have reinforcing and matrix forming filaments combined together in order to reduce the problems associated with high melt viscosity of thermoplastic matrices. Among hybrid yarns, commingled and air textured yarns, which are produced with air jets have demonstrated high flexibility and good mixing of constituent filaments.

Commingling of different filaments is typically done using air jets. The studies reported in the literature on the mixing of the two different types of filaments using air jets used only commodity type of filaments. There are no systematic studies conducted with mixing of high performance reinforcing filaments with matrix forming thermoplastic filaments. The limited literature available on commingling for composite materials hence used the standard mingling/air-jet nozzles commonly used for commodity filaments.

Improper mixing of reinforcing and matrix forming filaments in commingled yarns leads to resin rich areas and presence of dry fibers in the resulting composite materials. This results in lower strength/modulus of the composites from commingled yarns as compared to powder coated tows. This problem further aggravates because of demingling of commingled yarns on application of repeated load during textile preforming. Hence there is a need for investigation of structure development in commingled yarns with respect to mixing of constituent filaments and the stability of the structure against repeated loading.

In the present investigation, the effect of nozzle configuration on the structure of commingled yarns have been investigated and related to the simulated air flow behavior in the corresponding configuration and based on the results most suitable nozzle configuration has been identified and further studies are carried out on commingled yarns produced with this nozzle.

A CFD (Computational Fluid Dynamics) model is applied to study the air-flow patterns inside the commingling jets for different configurations. The design parameters of commingling jets are related to the flow characteristics and also to their effect on structure and properties of glass-PP commingled yarns.

The results show that the number of air orifice and angle of orifice have significant effect on air flow profile inside jet and consequently on structure of commingled yarns. The jet orifice angle affects axial velocity. The effect of air pressure is also important. This is because the nip frequency of commingled yarns is the function of the speed of rotation of the vortex and it is observed that with increase in air pressure, axial and tangential velocities in the nozzle increase. This study shows that, the CFD modeling can be used to optimize nozzle design parameters to develop commingled yarns with better properties.

Nonuniform stretching of commingled yarns during textile and other preforming processes lead to separation of inflexible reinforcing filaments and flexible matrix forming filaments. Consequently, this results in poor mechanical properties of composites. Therefore, present research is focused on enhancement of stability and homogeneity of commingled yarns during preforming processes.

The structural parameters such as nip frequency, nip length and degree of interlacing of glass-polypropylene, glass-polyester and glass-nylon commingled yarns are studied. The results show that commingling process parameters, as well as the type of matrix forming filaments significantly affect the structure and properties of commingled yarns.

To understand the influence of commingled yarn structure on the impregnation quality of laminates, the laminates are characterized for their microstructure and mechanical properties and related with degree of interlacing. For this study degree of interlacing of the commingled yarns is taken as a measure of structure of commingled yarns. The structures of glass-PP, glass-nylon and glass-PET commingled yarns have been characterized. It has been found that glass-PP yarns have lower nip frequency and degree of interlacement.

Consolidation of laminates is performed on a laboratory scale compression molding machine using glass-PP commingled yarns. Laminates are also made with another two methods namely: film stacking and winding glass roving and PP yarns Side By Side (SBS). Properties of laminates made from film stacking and SBS methods are compared it with laminates made from commingled yarns.

The results show that degree of interlacing has significant influence on void content, fiber impregnation and tensile behavior. Composites made from SBS and film stacking show dry fibers as in these cases the molten PP has to travel more distance across the glass filaments to fill the gaps.

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