

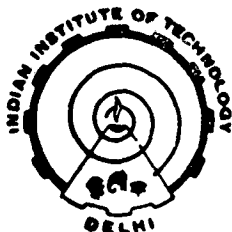
# **COMPRESSIONAL BEHAVIOUR OF NONWOVEN FABRICS**

by

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*Thesis submitted  
in fulfilment of the requirements  
of the degree of*  
**DOCTOR OF PHILOSOPHY**



to the

**INDIAN INSTITUTE OF TECHNOLOGY, DELHI**

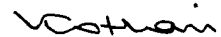
**March, 1994**

*Dedicated to my Parents*

## CERTIFICATE

This is to certify that the thesis entitled "**COMPRESSIONAL BEHAVIOUR OF NONWOVEN FABRICS**" being submitted by Mr. Apurba Das, 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. Apurba Das has worked under my guidance and supervision and 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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(Apurba Das)

## ABSTRACT

Characterization of compressional behaviour of different types of fabrics is of interest to textile technologist, as compressional behaviour is an important mechanical property of textiles, which determines many fabric characteristics during use. Nonwoven fabrics are extensively used in a number of technical uses due to their physical, tensile and hydraulic characteristics. In many applications, these fabrics are subjected to normal compressive loads which change their tensile and hydraulic properties. The changes in the properties of these fabrics depend on their compressional behaviour.

Parameters to characterize compression and recovery behaviour of different types of nonwoven fabrics have been proposed and empirical equations for compression and recovery of different types of nonwoven fabrics have been developed using a least-square technique. Two parameters  $\alpha$  and  $\beta$ , describing the compression and recovery behaviour respectively of different types of nonwoven fabrics have been evaluated for a wide range of nonwoven fabrics with different structural parameters using Essdiel thickness tester. Knowing  $\alpha$ ,  $\beta$  and the initial fabric thickness,  $T_0$ , one would be able to get the other compression-recovery related parameters like fabric thickness values at different pressures, percentage energy loss, percentage thickness loss, resilience etc. during compression-recovery cycle. Equations for predicting the compressional and recovery parameters of a number of nonwoven fabrics in series have also been developed and these equations have been verified with the experimental results.

The influence of various needling parameters such as depth of needle penetration and

needling density on the compressional behaviour of needle punched staple fibre nonwoven fabrics have been studied. It is found that as the depth of needle penetration and needling density increases, the resultant nonwoven fabric becomes more compact and the compressibility and the percentage energy loss during compression-recovery cycle reduces. The effect of fabric weight and individual fibre denier on the compressional behaviour of the staple fibre needle punched nonwoven fabrics has also been studied.

In some filtration and geotextile applications, layered nonwoven fabrics may perform better than a single fibre nonwoven fabric structure. The compressional behaviour of layered fabrics produced by needling two or more than two separate layers of fibre webs of different characteristics has been studied.

A detailed study on the compressional behaviour of different types of spunbonded nonwoven fabrics has been carried out. Three categories of spunbonded nonwovens used in the present study are needle punched, heat-sealed and needle punched surface calendered. The compressibility of spunbonded heat-sealed fabrics has been found to be much lower and their compressional resilience much higher than the compressibility and compressional resilience of needle punched spunbonded nonwoven fabrics. Effect of dynamic loading on the compressional behaviour of spunbonded nonwoven fabrics has also been studied. After the application of known dynamic load with a particular frequency for different durations, the needle punched nonwoven fabrics show very prominent changes in their compressional behaviour while the changes in the compressional behaviour in case of the heat-sealed spunbonded nonwovens are relatively small.

A theoretical model has been developed to predict the compression of nonwoven fabrics as pressure is increased. The compression of nonwoven fabric involves several processes, but the problem is considerably simplified when reduced to that of simple bending of fibres, as bending plays a major role during compression of nonwoven fabrics. An iterative algorithm, in which the system geometry is updated on successive increment of loads, is used to cope with the large and nonlinear deformation. Knowing a few fibre and fabric parameters, namely fibre denier, fibre initial modulus, fabric mass per unit area, fabric initial thickness and extreme fibre orientation angles within the fabric, the extent of compression due to increasing pressure on nonwoven fabrics can be predicted.

An instrument for measuring the compressional behaviour of nonwoven fabrics at a constant rate of deformation (CRD) has been developed. The instrument consists of a compression unit, a control unit, and a recording unit. The compressional load and the fabric deformation are measured by transducers. The up and down movement of the pressure foot is governed by the control unit. A predetermined number of compression and recovery cycles can be performed. The analog signals from the transducers are converted to the digital values using A/D card and these data are processed on a personal computer. A software has been developed for on-line plotting of the curves on the computer screen during the experiment and compression and recovery parameters are available just after the tests. The compression and recovery parameters for a wide range of nonwoven fabrics obtained using this instrument are compared with the results obtained using Essdiel thickness tester.

The effects of rate of compression and recovery, number of compression-recovery cycles

and size of pressure-foot have been studied. It is observed that as the rate of deformation increases, the compressibility and energy loss of nonwoven fabrics decrease due to less time available for compression. On cyclic loading, the compressibility, initial thickness and energy loss decrease sharply after the first cycle but after a few cycles these parameters remain unchanged. The size of pressure-foot has no effect on these parameters. The effect of these factors on heat-sealed spunbonded fabrics is relatively much lower than that on needle punched fabrics. Time dependent behaviour of compressional properties of needle punched and heat-sealed spunbonded nonwoven fabrics show that with increasing relaxation time, recovery in case of heat-sealed structures is nearly total while needle punched fabrics show permanent deformation.

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