STRUCTURE OF NON-WOVEN FABRICS

Part III: The Relationship Between The Number of Fibres Drawn By The Needle And The Magnitude of Penetration.

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ABSTRACT

Although there are many investigations about mechanically bounded non-woven fabrics, but most of the results published in these investigations are explained qualitativly /1-3/ rather than quantitativly. This could be partially due to lake of any mathimatical models in this field. This work is considered to be an attempt to establish a mathimatical model that could relate the number of fibres around the needle barbs within pentration depth (x), with the maximum number of fibres drawn by the needle and the differential number of fibres in the batt in depth ranging between (x) and (x + dx).

Such model would be enable the estimation of the effect of each of these factors seperatly and could also be used to predict the stitiching efficiency and stitiching index.

Key-Words:-

N_x = number of fibres around the needle barbs in length (x),

N_p = maximum number of fibres drawn by the needle,

dN_n = differential number of fibres in the batt in depth ranging between (x) and (x + dx),

dN_t = number of fibres missed (or left) by the needle during the needle upper-stroke,

N_d = needling density (needle/m^2),

I = needling index,

t = thickness of batt (mm),

Ω_1 = down -stroke constant and

Ω_2 = up-stroke constant.

1. INTRODUCTION

Non-woven is compartively a new technology to produce textile fabrics. The basic idea of this technology is to produce a fabric direct from fibres.

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Non-wovens can principally be manufactured by three major methods namely:-

1- Mechanical bonding; using needle felting machines,
2- Chemical bonding, using binders,
3- Thermical bonding, using thermoplastic fibres or fibres with lower melting temperature.

To produce NW. fabrics direct from fibres the following processing steps are absolutely necessary:

1- Fibre opening and blending - these processes are the same or similar as in every spinning mill,

2- Fibre carding on woollen cards - generally high - production carding machines are necessary,

3- Cross - lapping; the carded web - with this process the area weight and the laying width are determined,

4- Mechanical bonding with the help of needle felting machines (needle loom) and

5- Finishing process.

1.1. Needling Process

Figure (1) illustrate schematically the constructive features of downstroke needle loom and the action of felting needles. The felting needles catch some of the fibres during their downward movement through the fibre batt and transport them through the holes of the stitching plate. The whole fibre structure becomes in this way active and a considerable number of fibres is displaced from their horizontal position twoards vertical position.

The fibres are feed at the moment when the needles start their upstroke movement. Many fibres jump back due to the crimp and elasticity, many are broken and many slip just through the barbs. Some fibres protrude out of the stitching plate and their tails are flattened during the forward movement (advance) of the felt. At the same time needles once again start their downstroke movement and bring other fibres with them. There is the possibility that many get bound (interlcaed or entangled) during this continous fibre transport.

2. THE THRORITICAL NEEDLING

Suppose the following:-

No. of fibres around the needle barbs in length $(x) = N_x$,
Maximum number of fibres drawn by the needle $= N_p$,
Differential number of fibres drawn by barbs in depth ranging between x and $x + dx = dN_n$.

$$dN_n = Q_1 \left(\frac{N_p - N_x}{N_p}\right) . dx$$

$$= Q_1 \left(1 - \frac{N_x}{N_p}\right) . dx \qquad (1)$$

Suppose the number of fibres missed (or left) by the needle during the needle upper-stroke is dN_z

$$dN_z = Q_2 \left(\frac{N_x}{N_p}\right) . dx \qquad (2)$$

from equs. (1 and 2) the number of reinforcing fibres in a distance dx is:

$$dN_x = dN_n - dN_z$$

$$= Q_1 \left(1 - \frac{N_x}{N_p}\right) dx - Q_2 \frac{N_x}{N_p} . dx$$

$$= \left[Q_1 - N_x \left(\frac{Q_1}{N_p} + \frac{Q_2}{N_p}\right) \right] dx$$

$$= \left[Q_1 - \frac{N_x}{N_p} (Q_1 + Q_2) \right] dx \qquad (3)$$

by integrating equ. (3)

$$\int dN_x = \int \left[Q_1 - \frac{N_x}{N_p} (Q_1 + Q_2) \right] dx$$

$$\int \frac{d\, N_x}{Q_1 - \frac{N_x}{N_p} (Q_1 + Q_2)} = \int dx$$

$$x + C = -\frac{1}{\frac{Q_1 + Q_2}{N_p}} \ln . \left| Q_1 - (Q_1 + Q_2) \frac{N_x}{N_p} \right| \qquad (4)$$

But from the initial conditions:-

$$N_x = 0 \text{ at } x = 0$$

$$C = - \frac{N_p}{Q_1 + Q_2} \ln \left| Q_1 \right| \qquad (5)$$

Subs, in equ. (4)

$$x = - \frac{N_p}{Q_1 + Q_2} \left[\ln \left| Q_1 - \frac{Q_1 + Q_2}{N_p} N_x \right| - \ln \left| Q_1 \right| \right]$$

$$= - \frac{N_p}{Q_1 + Q_2} \cdot \ln \left| 1 - \frac{Q_1 + Q_2}{Q_1} \cdot \frac{N_x}{N_p} \right|$$

$$- x \frac{Q_1 + Q_2}{N_p} = \ln \left| 1 - \frac{Q_1 + Q_2}{Q_1} \cdot \frac{N_x}{N_p} \right|$$

$$e^{-\left(x \frac{Q_1 + Q_2}{N_p}\right)} = 1 - \frac{Q_1 + Q_2}{Q_1} \cdot \frac{N_x}{N_p}$$

$$N_x = \frac{Q_1 N_p}{Q_1 + Q_2} \left[1 - e^{-\frac{x}{N_p} (Q_1 + Q_2)} \right] \qquad (6)$$

at $x = 0$, $N_x = 0$, which means that the needle has not penetrated yet the batt of fibres, and when $x = \infty$, then

$$N_x = \frac{Q_1}{Q_1 + Q_2} \cdot N_p \qquad (7)$$

But actually this does not occur, and the number of fibres pushed by the needle will be less than that of equ. (7), but more than that of equ. (6). From equ. (7), the ratio N_x/N_p could used to indicate the effeciency of needling, and the ratio $\frac{Q_1}{Q_1 + Q_2}$ will represent the same thing.

Subs. from equ. (6) in equ. (2)

$$dN_z = Q_2 \cdot \frac{N_x}{N_p} \cdot dx$$

$$= \frac{Q_1 \; Q_2}{Q_1 + Q_2} \left[1 - e^{- x \frac{Q_1 + Q_2}{N_p}} \right] dx \qquad (8)$$

and

$$\frac{dN_z}{dx} = \frac{Q_1 \; Q_2}{Q_1 + Q_2} \left[1 - e^{- x \frac{Q_1 + Q_2}{N_p}} \right] \qquad (9)$$

where x = displacement of the needle,

if $q_1 = \frac{Q_1}{N_p}$ and $q_2 = \frac{Q_2}{N_p}$.

$$\text{then, } \frac{dN_z}{dx} = N_p \frac{q_1 \; q_2}{q_1 + q_2} \left[1 - e^{- x (q_1 + q_2)} \right] \qquad (10)$$

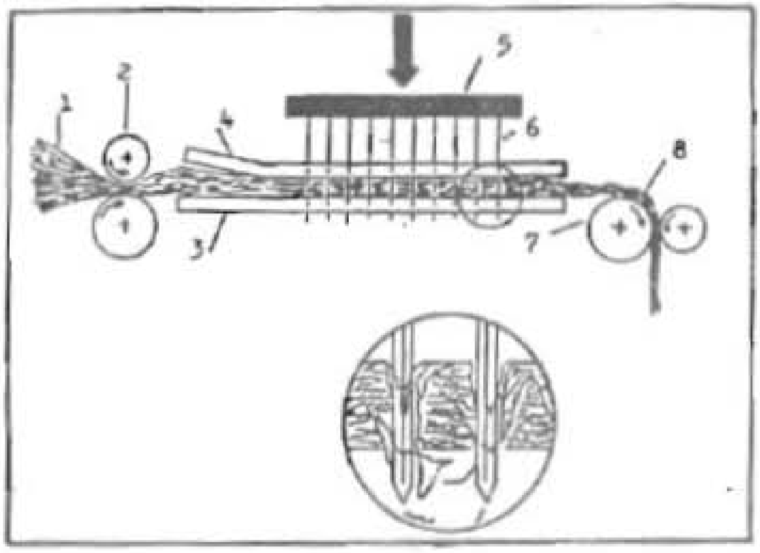

Fig.(1) Basic principles of needle felting technology.

1- fibre batt	2- feeding roller
3- bottom plate	4- stripper plate
5- needles board	6- felting needle
7- drawing-off roller	8- needle felt.

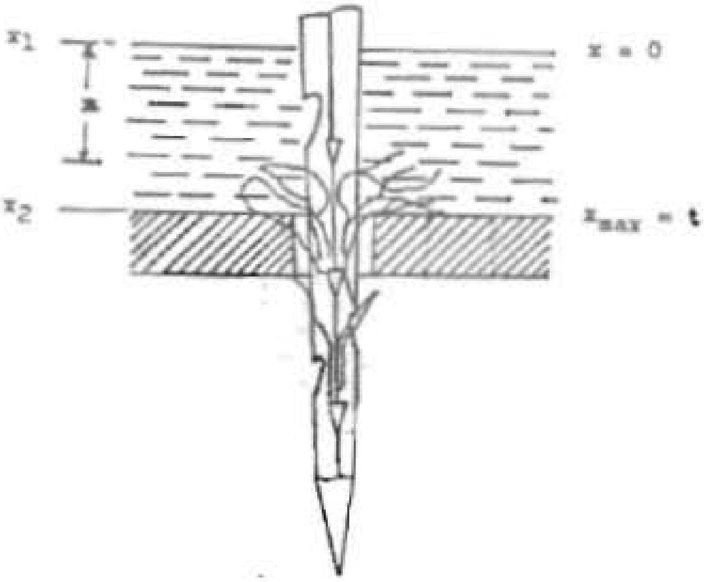

Fig.(2) Needle penetration through the batt.