our future through science

The energy transfer mechanism in the hydroentaglement nonwoven process

D MOYO AND R ANADJIWALA
CSIR Material Science and Manufacturing, PO Box 395, Pretoria, 0001, South Africa
Email: dmoyo@csir.co.za – www.csir.co.za

NONWOVENS

Nonwoven fabrics are engineered assemblies of natural and man-made fibres bonded together mechanically, thermally, chemically or by a combination of these techniques[1]. The nonwoven industry has a huge growth potential compared to weaving and knitting which constitute the traditional textiles manufacturing sector. Production is much faster with nonwovens because fibres are converted to finished products in a single operation without having to be spun to yarns first as in weaving and knitting.

APPLICATIONS

Nonwovens can be engineered for numerous applications in a number of different areas with new applications continuously being found. Some of these include geotextiles, building, thermal and sound insulation materials, hygienic products, health-care, automotive industries, agriculture, construction, and household amongst others[2].

MANUFACTURING NONWOVENS

The production of nonwoven fabrics follows a much shorter route or process from raw material to finished products compared to apparel fabric production through weaving and knitting. The short route of production is the main attraction of this sector because of the high production speeds employed, higher profit margins and the general versatility of the production process. The process involves initially laying loose fibres into a web which is then consolidated by any of the several methods available namely chemical, spunbonding, thermal, needlepunching and/or hydroentanglement[3].

HYDROENTANGLEMENT

Hydroentanglement is a common mechanical method of bonding fibres together to form a nonwoven fabric. This process employs collimated high pressure water jets issued from a series of parallel jet-heads (manifolds) for entangling the fibre-web which is carried on a perforated belt producing a fibrous structure of high integrity. The high pressure waterjets impinging on fibres are the sources of energy for twisting and entangling them in a complex process of displacement and rearrangement which eventually forms a fabric from a cohesive network of fibrous assembly[3,4]. The hydroentanglement process is depicted in **Figures 1 and 2**.

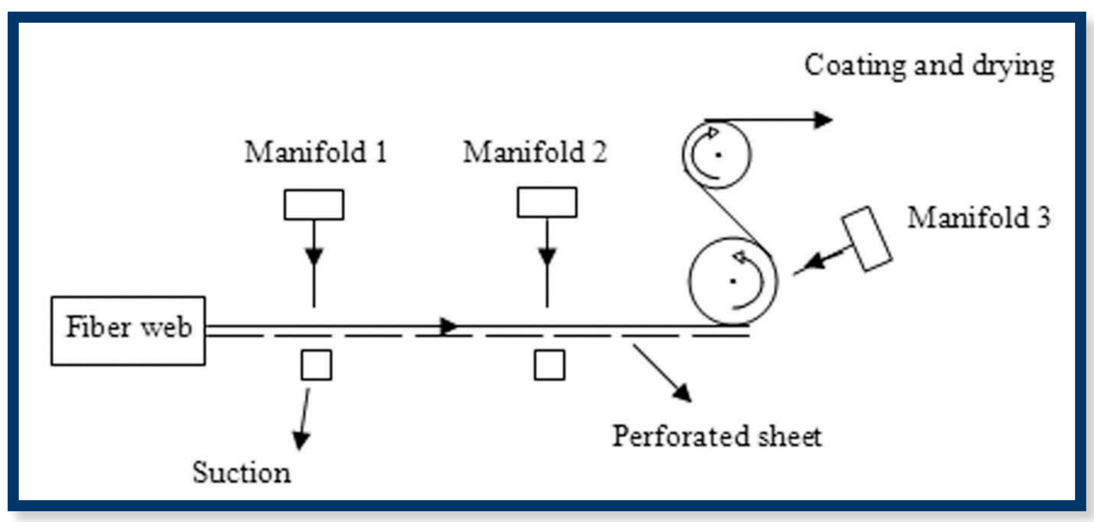

Figure 1: Schematic representation of the hydroentanglement process

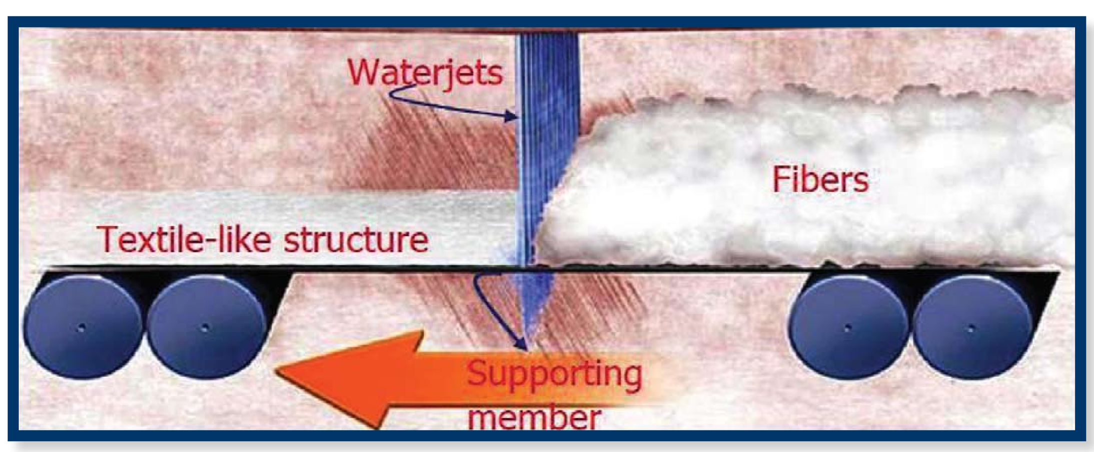

Figure 2: The hydroentanglement process[5]

The hydroentangled nonwoven fabrics have a large area weight ranging from 30 to 600 gsm and possess excellent properties. They are largely used for producing common nonwoven fabrics for the health care sector such as gowns, bandages, wipes, diapers, filters and many others for industrial applications.

Advantages of nonwovens from hydroentanglement process[4]

- Higher strengths and work-products (tenacity x elongation)
- Excellent absorbance properties
- High softness and smoothness
- High drape and fabric like feel
- High permeability (air and liquid)
- Environmentally friendly since no additional chemicals used
- High productivity.

RESEARCH OBJECTIVES

The main objective of the research is to address the high energy utilisation of the non-woven production process which has limited investment in this technology in South Africa despite the nonwovens industry having a higher growth potential compared to other traditional textile sectors (such as weaving). The research aims to quantify the energy supply, losses, and utilisation of the process, and ultimately develop an optimised system which can be utilised to manufacture nonwovens in an energy efficient way. Quantifying the energy used and impact forces responsible for entanglement has previously been a challenge.

MATERIALS AND METHOD

The experimental setup of the research comprised of a plant hydroentanglement production machine (Aquajet), a stand designed to hold in place a measuring device, an electronic measuring machine, viscose and polypropylene fibres and laboratory nonwoven characterisation equipment. The Electronic-Tensiometer R-2000 model from Rothchild Instruments is used in the experiment to measure the waterjet impact forces. When the waterjets strike the rigid sensor probe, the signal is delivered to the Data Acquisition System where it is amplified and converted from an analogue to a digital signal and displayed on the screen. The measuring unit analogue-to-digital converter is connected to a computer with an interface/software loaded for data recording, storage, evaluation and analysis. The measuring rod held by the stand allowed the measuring head to slide across the waterjet column so that the jet pressure could be determined at different position. The setup is shown in **Figure 3**.

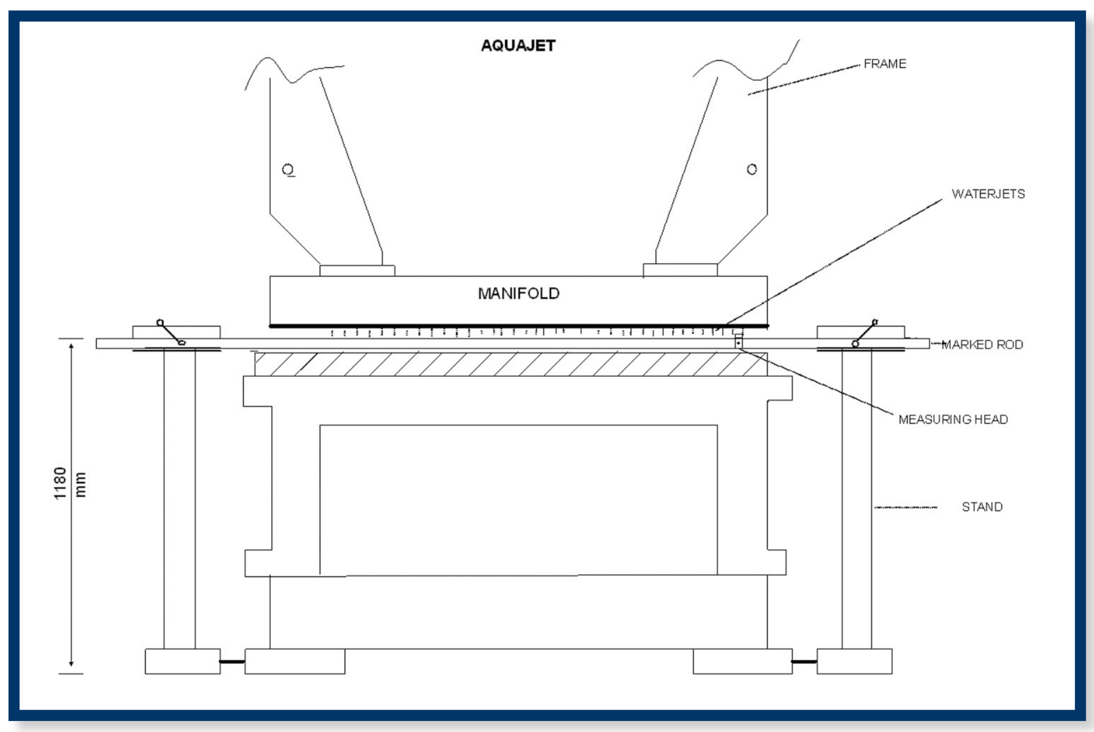

Figure 3: Schematic of the experimental set-up to measure impact force

Optimisation of this non-woven production process involves producing a series of hydroentanglement fabric while varying the manifold pressure, speed of the machine, different jet strip sizes and area weight of the fibre-web. For this part, the data of the hydroentangled fabrics produced from the machine at varying jet pressures is used. Three different levels of water jet pressure were selected in the manifolds for the development of filter samples. For filter sample S1 the jet pressures in bars were 10, 120, 120, and for filter sample S2, 10, 200, 200, for the first, second and third manifolds respectively. After hydroentanglement an acrylate chemical binder of 25 % concentration was applied on the filtration nonwoven material and cured at 150°C. Dust particles in the range of 0.6-180 μm are fed at a constant rate to the filtration device and deposited on the samples having an area of 0.0095 m^2. The pore size and its distribution are measured on capillary flow porometer.

OUTCOME

Preliminary results obtained are shown in **Figure 4**.

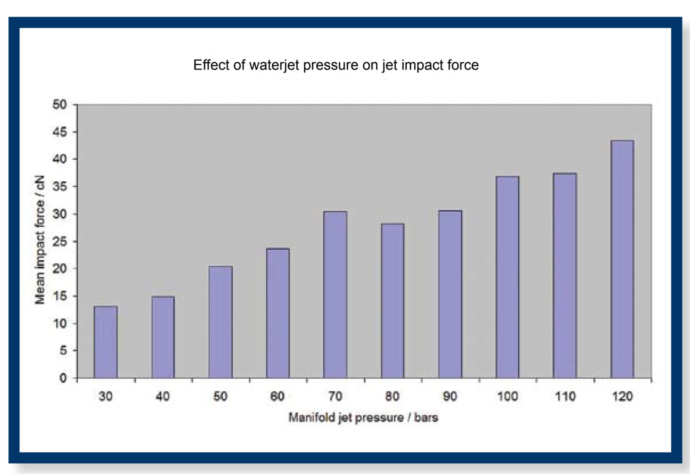

Figure 4: Effect of the manifold pressure on the impact force of the waterjets

The mean impact force of the water jets increased with an increase in manifold jet pressure. The results support the strong view of characterising the hydroentanglement non-wovens in terms of quantified energy transferred to the fibrous web. The energy usage of the system depends on the manifold pressures used because the largest amount of energy is consumed in pressurising the water but the transference of that energy to bond the fibres needs further investigation.

The surface topography and pore size and filtration distribution of the hydroentangled filter material produced at 120 and 200 bars of waterjet pressure is shown in **Figures 5** and **6** respectively.

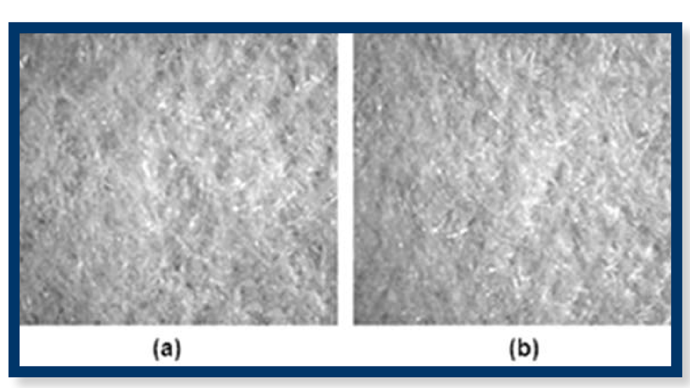

Figure 5: Photograph of high efficiency particulate absorbing filters produced at different water jet pressure: a) 120 bar and b) 200 bar.

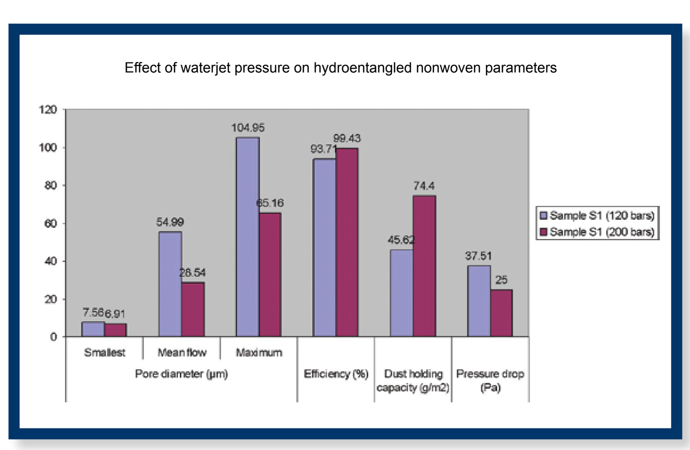

Figure 6: Pore size and filtration parameters of nonwovens

The filtration efficiency of any material is generally defined from the mean flow pore diameter. From **Figure 6**, the minimum, mean flow, and maximum pore diameter decrease when the water jet pressure is increased from 120 to 200 bars. It was shown in Figure 4, that an increase in water jet pressure results in an increase in the impact force acting on the fibres, which would result in the greater entanglement of the fibres, hence reduced pore diameters are expected. Additionally the amount of dust particles passing through the filter is less and a larger amount of particles are now deposited on the filter for a higher water jet pressure. As a consequence of this, the filtration efficiency is increased which is a measure of the amount of dust particles retained in the filter when introduced in the air stream. Also dust holding capacity increases and there is a smaller pressure drop. The developed filters can be used in various industries, hospitals, and in homes where high degree of purity is required in the air.

The energy transfer mechanism in the hydroentaglement nonwoven process.

The ultimate objective of this study is to optimise the energy efficiency of the hydroentanglement process for non-woven production such that less energy is required in the process to produce fabrics and would then make this process more attractive for investment. Further investigations are currently on-going at the CSIR in Port Elizabeth.

ACKNOWLEDGEMENTS

The author is grateful to CSIR for Parliamentary Grant funding and MSM Polymer and Composites Competence Area for studentship support.

REFERENCES

1. www.edana.org
2. Cary, N. C. 1998. The Nonwoven Fabrics Handbook, Association of the Nonwoven Fabrics Industry. 2-10.
3. Russell, S. J. 2007. Handbook of Nonwovens, Cambridge, Woodhead Publication, UK, 255-275.
4. Anand, S. C.; Brunnschweiler, D.; Swarbrick, G. and Russell S. J. 2007. Mechanical Bonding (In S. J. Russell. Handbook of Nonwovens, Cambridge, Woodhead Publishing Ltd) 255-6.
5. Anantharamaiah, N. et al. Hydroentangling Process Modelling, College of Textiles, North Carolina State University, 2, 41-57. www.ncrc.ncsu.edu