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Experimental Investigation Of Properties Of Polypropylene And Non-Woven Spunbond Fabric

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Abstract: *Polypropylene(PP) is the homo-polymer that is widely used for production of non-woven fabric. In the manufacture of polypropylene resins, considerable advances have been made. In this paper, thermal behavior of polypropylene granules was studied as a function of temperature by melt flow index of the polypropylene. For this purpose temperature range of 453K to 513 K was taken with a difference of 5 K. The results obtained from the melt flow indexing showed a linear behaviour between temperature and melt flow index (MFI) for the polypropylene. An empirical equation has also been established to interpret the linear curve obtained. The Spunbond process is a manufacturing system of non-woven fabric that involves the conversion of a PP granules into continuous filaments. Its mechanical performance is quite different from woven fabrics. They show lower strength and stiffness, but their energy absorption and capability to deform during loading and deformation is much greater than woven fabrics. Mechanical behaviour of non-woven fabric has been studied as percentage elongation that occur at fracture point. Variation along the width in GSM of the samples came out in the uneven form of waviness. This variation in gsm along the width occurs mainly due to uneven quenching of the molten part. The influence of strength and ductility is discussed from the experimental observations.*

Keywords: *Melt flow index, Non woven Fabric, Packtech, Polypropylene, Technical textile*

I. Introduction

Technical Textile is a product of textile, manufactured for its application as the primary criterion not for the aesthetic purposes. Technical textile is a fabric structure engineered directly from fibers or from materials from which fibers themselves are made. [1] It is used as a generic description of a fabric that has been produced by a process different from weaving, knitting and other traditional processes. Raw materials of Technical Textile are so chosen as to achieve chemical, mechanical and physical properties. The product can be engineered to fine limits of softness, absorbency, flexibility, elasticity, strength, porosity, electrical resistance, bacterial resistance depending on the end use. Technical textiles have different applications such as agro textiles (textiles for crop protection), geo textiles, medical textiles (e.g., implants), automotive applications, and protective clothing as shown in figure 1.

Especially, Agrotech products are used in agriculture, horticulture (incl. floriculture), fisheries and forestry [2]. They are beneficial in terms of lesser crop diseases, water saving, soil borne pathogens control, increase in yield, weed control, etc. whereas, Clothtech type of textiles mainly consist of textile components used for particular applications in shoes and garments. Clothtech products are an important part of the garment that ensures accurate fit and optimum wearer comfort [3].

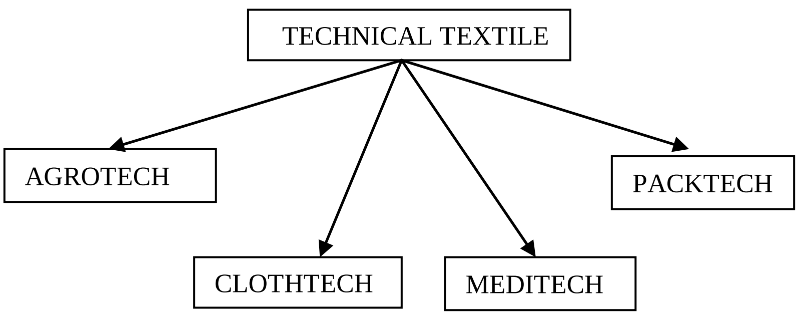

FIGURE 1. Types of technical textiles

Especially, Agrotech products are used in agriculture, horticulture (incl. floriculture), fisheries and forestry [2]. They are beneficial in terms of lesser crop diseases, water saving, soil borne pathogens control, increase in yield, weed control, etc. whereas, Clothtech type of textiles mainly consist of textile components used for particular applications in shoes and garments. Clothtech products are an important part of the garment that ensures accurate fit and optimum wearer comfort [3]. Interestingly, Meditech products are used in surgical applications as well as for health and hygiene. These helps in prevention of cross-infection, hospital acquired infection, etc. Improved Meditech products will provide comfort and quicker healing. Presently, its application lies in making of masks, overcoat and diapers used in industries or by doctors. Lastly, Packtech includes packaging materials used for consumer, agricultural, industrial and other goods. It provides solutions to packing problems such as packaging foodstuffs, anti-static packaging for computer equipment and oxygen scavenging. They are used for packing moisture sensitive goods due to the advantage of moisture proof quality [2].

Nonwoven fabrics (or simply nonwovens) are widely used in other applications such as thermal insulation, liquid-absorbing textiles, fireproof layers due to the lower processing costs, ballistic protection and improved properties. Polypropylene has various advantages such as good processability, good chemical resistance, almost zero water adsorption as well as wide availability and low cost [4]. One of the product of technical textile is Non-Woven Fabric made from polypropylene which is used in various purposes like carry bags, covers etc. Different properties can be incorporated through unique manufacturing process called Spun Bond Process (SBP). Polypropylene is most widely used polymer for SBP. Processing of nonwoven fabric is significantly cheaper, since they are manufactured from disordered random fibers which are bonded by means of chemical binding, local thermal fusion or mechanical entanglement [5].

In calendar-bonded nonwovens, the fibrous filament web is passed through a pair of hot calendar with a pattern embossed on it. Bonding occurs at calendar's raised areas (embossed pattern) which results in bond points. Remaining unaffected part from the pattern of calendar forms fibre matrix that acts as a link between the bond points [6,7]. The mechanical performance of nonwoven fabrics is different from their woven counterparts. Generally, they present lower stiffness and strength, but their energy absorption and deformation capability during deformation is far greater [8]. Understanding and designing the mechanical behaviour of nonwovens for specific applications before manufacturing a product is a crucial task.

Deformation and damage behaviour of nonwovens is complicated a bit because of discontinuity, randomness and presence of voids in their microstructure[9-11]. The study of tensile deformation of nonwoven fabrics was initiated by Backer and Petterson [12], and they applied well-known orthotropic theory for predicting the tensile properties of nonwovens. Mechanical anisotropy is one of the most important deformation characteristics of nonwoven materials that leads to their direction-dependent mechanical response. This phenomenon is related to random orientation of fibers constituting complex microstructures of nonwovens, which is inherited from the web formation process in manufacturing [13]. Denier is used to measure the mass in grams per 9000 meters of the fiber. The denier is based on a natural reference where one denier is approximately equal to a single strand of silk weighing about one gram in a 9000 meter strand of silk [14].

In this paper, the task of study of mechanical properties and dependence of polypropylene is done on a commercial PP based nonwoven material using various experimental techniques to establish the influence of the properties (fibers). Different loading conditions were considered to study the tensile properties of non woven fabric.

II. Samples And Its Preparation

The nonwoven material and PP granules under study was Polypropylene (PP) homopolymer commercial trade name Repol, grade H350FG manufactured by Reliance Industries Limited (RIL). Polypropylene granule is the major raw material used for the production of Spunbond non-woven fabric. Figure 2 shows the Polypropylene granules.

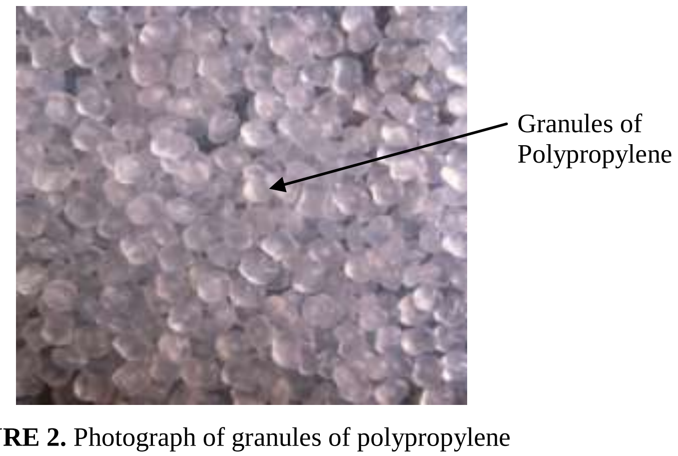

FIGURE 2. Photograph of granules of polypropylene

Manufacturing process of the Spun bond Non woven fabric: The Spunbond process is a non-woven manufacturing process that results in conversion of a polymer granules into continuous filaments, randomly laid and then bonded to form non-woven fabric. Spunbond products met important market needs since its initial introduction. The major elements and steps involved in the manufacturing process are:

Polymer PP granules is conveyed from hoppers to the feeder section. Hoppers have several sections that contains additives, stabilizers, resin modifiers, color master-batch or other additives. Then feed from hoppers is transferred to extruder where it is melted and passed through screen changer for filtration of molten material that is coming from extruder so that any dust particle that's present in it is removed. Metering pump is a gear pump used for monitoring the flow of molten material. From here adjustment of the melt flow rate of the molten material is done so that the desired thickness of the non woven fabric sheet is achieved. The molten polymer is then pumped through the spinnerets units (nozzles present in die). The spinnerets usually consist of a perforated plate arranged across the width of the line. The molten material is forced through the many small holes in the spinnerets plate to form continuous filaments. As the filaments comes out of the die or spin pack, they are directed downward for quenching. When the filaments travel through the quench chamber, for solidification of the molten filaments, a cool air is directed across the filament bundle. To make filament to flow downwards, a second stream of high velocity air used and directed parallel to the direction of the filaments, which also results in stretching of the individual filaments. This mechanical stretching helps in orientation of the polymer chains that results in increased filament strength as well as changes in other filament properties, including the filament thickness or denier. Deposition of the filaments on the conveyor belt in a random manner takes place and a filament web is formed on the forming belt as shown in figure 3. The continuous filament web is passed between the calendar rollers having embossed patterns that binds the filaments with bond points into a strong, integrated fabric and hence slitting and winding is done. [15]

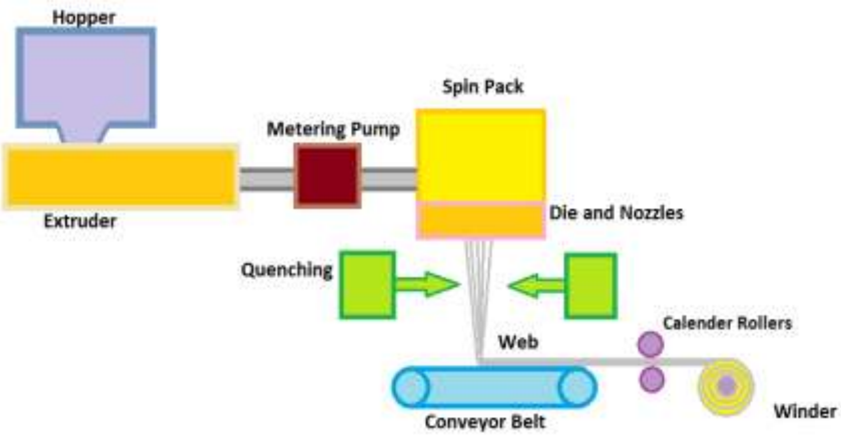

FIGURE 3. Flow diagram of manufacturing process

The structure of the resulting thermally bonded fibre nonwoven obtained is as shown in the Scanning Electron Microscope (SEM) taken 30 times magnified in figure 4a. This figure shows fibres and bond points. Figure 4b shows 150 times magnified SEM of fibres and the random manner of fibres can be seen. Denier of the polymer plays major role in its mechanical functioning.

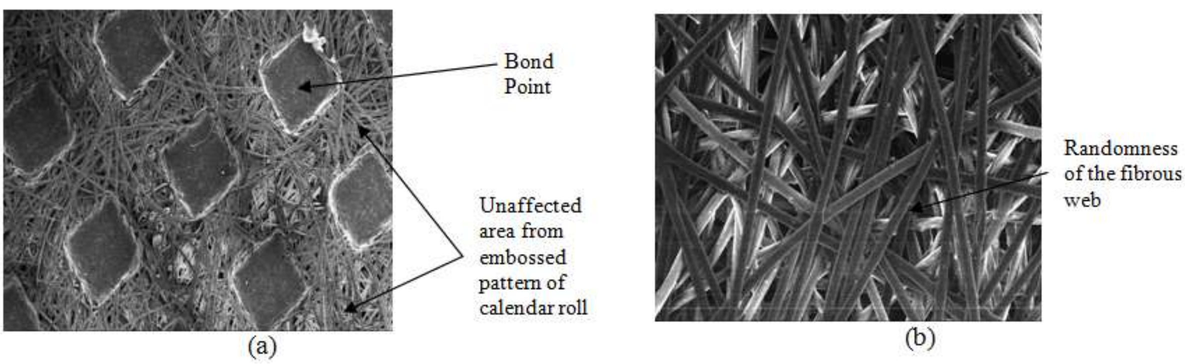

Figure 4: (a) SEM of the fabric 30 times magnified showing bond points and unaffected area from pattern of calendar roll (b) SEM of the fabric 150 times magnified image showing randomness of fibrous web.

III. Experimental Setup & Procedure

III. I. MELT FLOW INDEX TESTING

This test method measures the melt flow index of Polypropylene Chips. A specified force is applied on polymer at constant temperature. The unit mass flows from the capillary in a specified time. In this method, machine used is MFI Tester RL-11B. Capillary tube used is of diameter 1 mm, load applied is 2.16 kg, temperature is defined in accordance to the experimental needs and then Melt flow index (MFI) is calculated as,

$$\mathbf{MFI} = \mathbf{Avg.\,weight\ of\ \ PP\ melt} * \frac{\mathbf{Total\ time\ kept\ in\ tester}}{\mathbf{Time\ in\ one\ revolution}}$$

Melt which flows from capillary is taken after 20 seconds each and total time kept in tester is 600 seconds. Figure 5 (a) and figure 5 (b) shows the MFI machine and the melt that is coming out of the capillary. Figure 6 shows the melt collected after 20 seconds which is thereafter weighed and average is taken for each temperature change made.

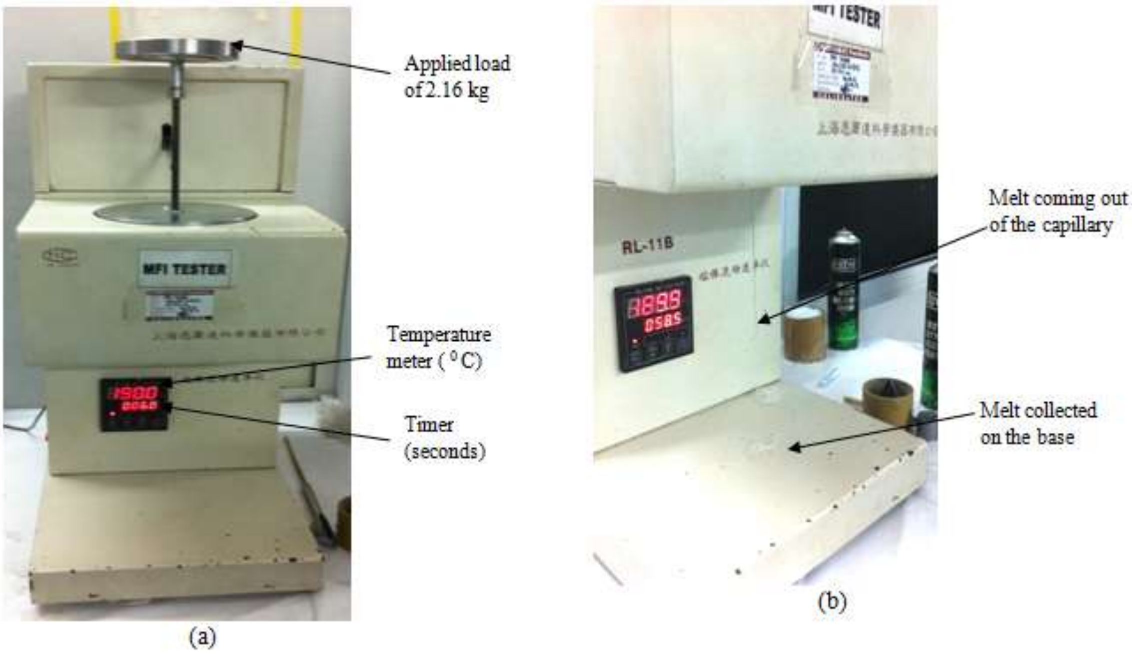

FIGURE 5. (a) Melt Flow Index testing machine. (b) Mass flowing through capillary

III.II FABRIC GSM TEST

A specified weight of a unit area shows the GSM (Grams per square meter). A circular cross section of diameter 114 mm is cut from fabric and then weighs it in grams. With the help of Round Cutter circular pieces were cut by keeping cutter at the middle fold of fabric and pressed slightly and rounded. One of the specimen used for gsm testing is shown in figure 7. This process was repeated up to another edge without keeping any distance. The specimen were weighed and recorded.

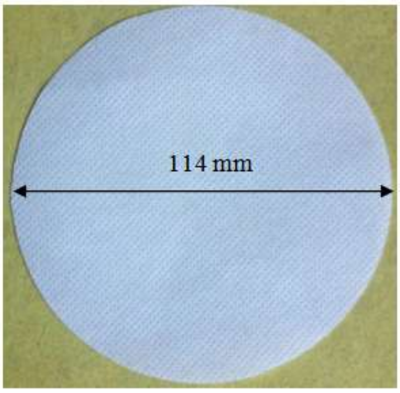

FIGURE 7. Piece of material used for GSM testing

III.III STRENGTH AND ELONGATION TEST OF FABRIC

The Force applied on the specified size of a fabric. When it breaks, the Machine automatically shows the force and elongation .It shows the capacity of fabric before fabric strip breaks. It is the incensement with respect to its primary length before strip breaks. Elongation is then recorded in percentage change. With the cutter, 8 strip from longitudinal direction and 8 strips from transverse direction of size 230mmX50mm from the fabric were taken as shown in figure 8. Strip of MD direction were placed and fixed between upper jaw and lower jaw of strength tester. Machine used for strength testing is Universal Testing Machine - Zeus Ultimo. The strength tester machine is then started and reading of force and elongation is taken one by one of strips which is shown on machine's monitor. Figure 9 shows the loading condition of the strip on the testing machine. Above process is repeated for CD direction's strips. All forces and elongation's reading is collected.

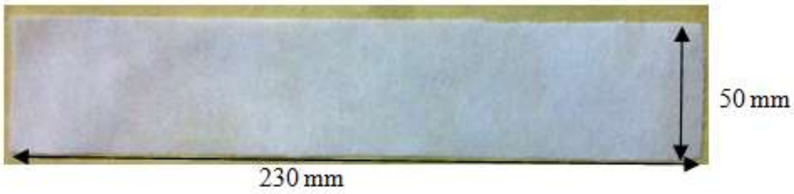

FIGURE 8. Sample used for strength testing.

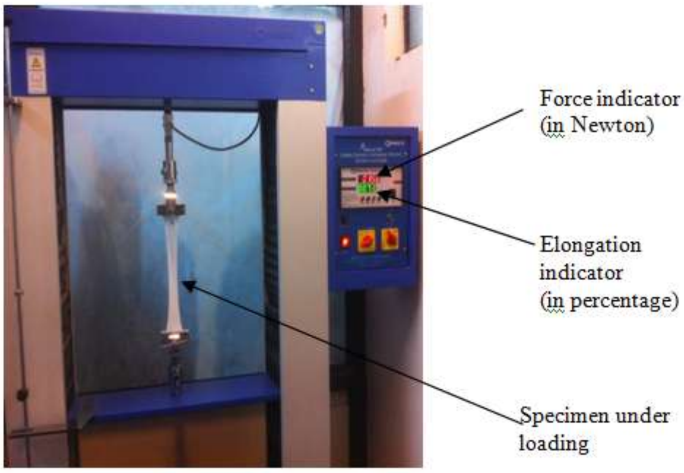

FIGURE 9. Specimen under loading condition on testing machine

IV. Results And Discussion

IV.I VARIATION WITH TEMPERATURE

Experiments with different temperature were done and respective MFI has been calculated and plotted on graph as shown below in figure 10. An equation has been derived to establish the linear relation between MFI and Temperature using statistical methods shown below

MFI = 0.483* Temperature -72.704

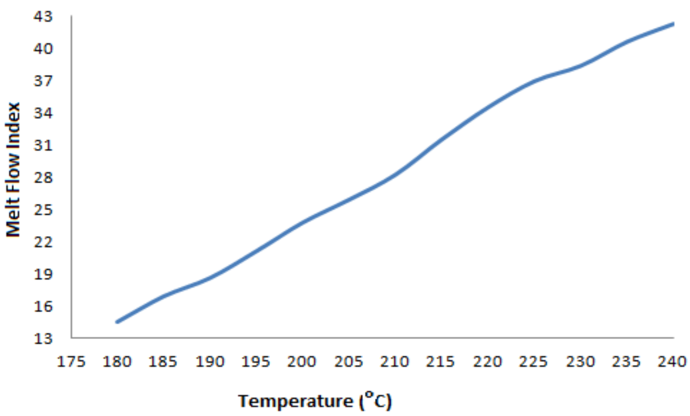

FIGURE 10. Graph shows the variation of MFI with temperature

IV.II VARIATION IN GSM OF THE PRODUCT ALONG ITS WIDTH

After undergoing set of analysation on GSM testing, it has been observed that GSM of the product is varied along its width (However this variation falls under acceptable range). Figure 11 shows variation in GSM of Samples of 50 GSM PRODUCT which is in the uneven form.

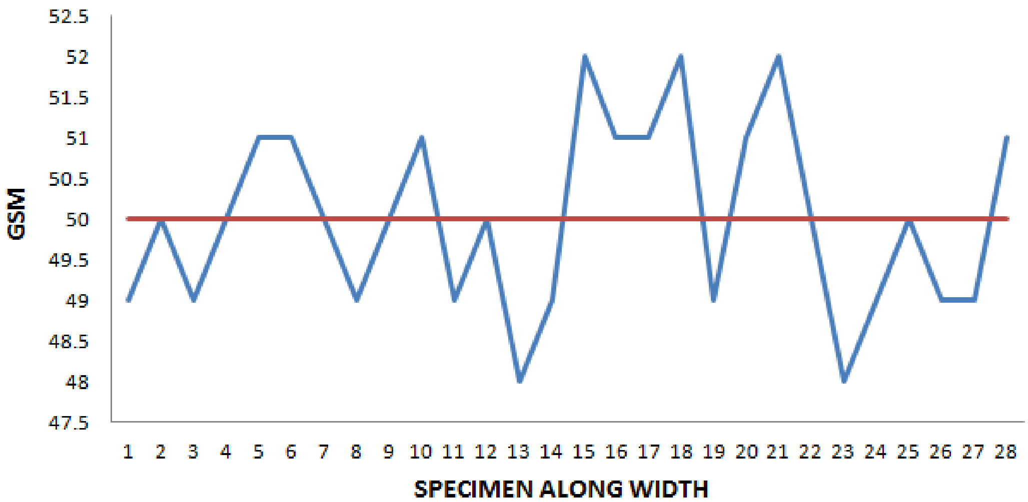

FIGURE 11. Graph shows the variation in gsm

IV.III VARIATION IN FRACTURE POINT IN LONGITUDINAL DIRECTION

After undergoing set of testing on different samples of products of different GSM, it has been observed that on applying certain amount of load on samples, there is elongation in length and this elongation is different for different gsm product. Figure 12 shows variation in Fracture point after elongation in different samples of products of different GSM. Firstly, it keeps on increasing with increasing gsm but after a certain limit nearly after 70 GSM it decreases.

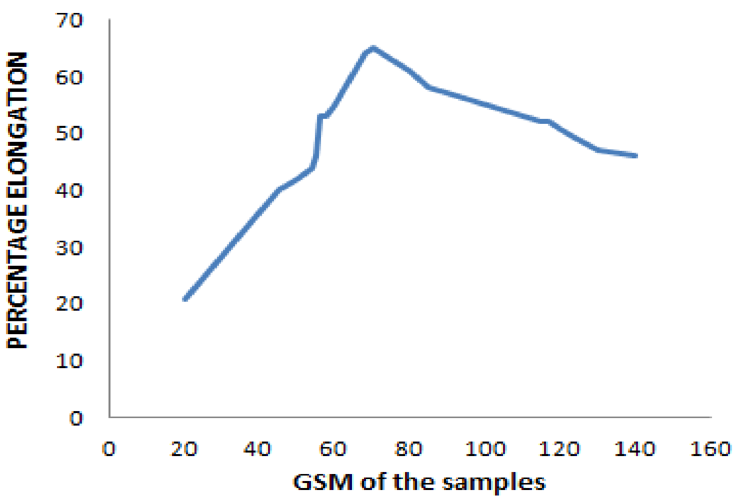

FIGURE 12. Graph shows the variation in elongation in longitudinal direction.

IV.IV Variation In Fracture Point In Transverse Direction

After undergoing set of testing on different samples of products of different GSM, it has been observed that on applying certain amount of load on samples, there is elongation in length and this elongation is different for different gsm product. Figure 13 shows variation in Fracture point after elongation in different samples of products of different GSM. Firstly, it keeps on increasing with increasing gsm but after a certain limit nearly after 70 GSM it decreases.

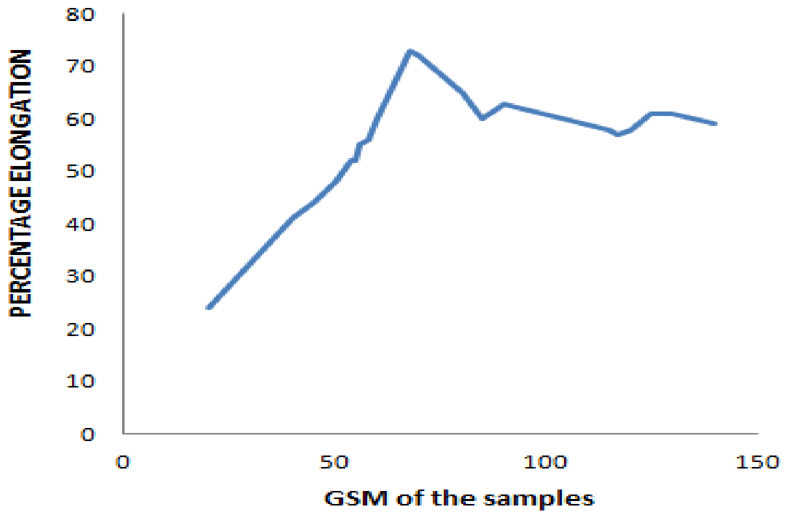

FIGURE 13. Graph shows the variation in elongation in transverse direction.

V. Conclusion And Future scope

Melt Flow Index of the polypropylene varies linearly with temperature. i.e. M.F.I. α Temperature. Variations in gsm of the product along its width. On analysing variation in gsm of samples, the possible causes of it has been found that this happens due uneven quenching of the molten part and a suitable solution for this problem is under consideration. Variation in fracture point in longitudinal direction. Firstly, it keeps on increasing with increasing gsm but after a certain limit nearly after 70 GSM it decreases. Same is the case with variation in fracture point in transverse direction. Firstly, it keeps on increasing with increasing gsm but after a certain limit it decreases. This happens due to change in denier of the fibre of the various gsm fabric. Lower gsm fabric have lesser denier and higher gsm fabric have comparatively more denier. As denier is less of lower gsm fabric more elongation can be achieved because it is the result of high quenching and much fibre stretching. But in higher gsm fabric denier is more due which less quenching is done that results in comparatively lesser fibre stretching. Further work can be done on analysing the behaviour of non woven fabric with parameters like metering flow, effects of auxiliary materials, speed and temperature of quenching air and roller speeds.

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