International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

# Manufacturing of Hollow Fiber Membrane

**Venkatesh D. Vandekar**

Department of Chemical Engineering, All India Shri Shivaji Memorial Society's, College of Engineering, Pune, Maharashtra, India

**Abstract:** ***This article shows information collected on manufacturing of hollow fibre membranes. The polymer liquid used can be polysulphone (PSF), polyethersulphone (PES), polyacrylonitrile (PAN), polyvinyl alcohol (like PVC) and polyvinylidene fluoride (PVDF) any one of them is also be used or they can be used in different ratios. After manufacturing of membranes, potting is done on them. After potting the membranes are sealed in the module/cartridge. These modules/cartridge are then used in various industries.***

**Keywords:** Hollow fiber membrane, wet spinning, potting, module making, &molecular weight cut off.

## 1. Introduction

Membrane is a thin film which separates two fluids. It acts as an obstacle, allowing some particles or chemicals to pass through. In some cases, in anatomy, membrane usually means a thin film that is primarily a separating structure rather than a selective barrier. A membrane is a layer of material which acts like a barrier among two phases and remains impermeable to specific particles, molecules, or substances when exposed to a driving force. Some components are allowed to pass by the membrane into a permeate stream, whereas others are retained by it and accumulate in the stream. Membranes can be of various thicknesses, with homogeneous or heterogeneous structure. Membrane can also be classified according to their pore diameter. According to IUPAC, there are three different types of pore size classifications: microporous (dp < 2 nm), mesoporous (2 nm < dp < 50 nm) and macroporous (dp > 50 nm). Membranes can be neutral or charged, and particles transport can be active or passive. The latter can be facilitated by pressure, concentration, chemical or electrical gradients of the membrane process. Membranes can be generally classified into synthetic membranes and biological membranes. Applications include water treatment, waste water treatment, water recycling, RO pre-treatment, protein separation/concentration, juice filtration, endotoxin removal [1 to 16].

### a) Synthetic membrane:

An artificial membrane, or synthetic membrane, is a synthetically manufactured membrane which is usually intended for separation purposes in laboratory or in industry. Synthetic membranes have been successfully used for small and large-scale industrial processes since the middle of twentieth century. A wide variety of synthetic membranes is known. They can be produced from organic materials such as polymers and liquids, as well as inorganic materials. The most of commercially utilized synthetic membranes in separation industry are made of polymeric structures. The best known synthetic membrane are used in separation processes such as water purification, reverse osmosis, dehydrogenation of natural gas, removal of cell particles by microfiltration and ultrafiltration, removal of microorganisms from dairy products, and dialysis[1 to 16].

### b) Polymeric membranes:

Polymeric membranes lead the membrane separation industry market because they are very competitive in performance and economics. Many polymers are available, but the choice of membrane polymer is not a trivial task. A polymer has to have appropriate characteristics for the intended application. The polymer sometimes has to offer a low binding affinity for separated molecules (as in the case of biotechnology applications), and has to withstand the harsh cleaning conditions. It has to be compatible with chosen membrane fabrication technology. The polymer has to be a suitable membrane former in terms of its chains rigidity, chain interactions, stereoregularity, and polarity of its functional groups. The polymers can form amorphous and semi crystalline structures (can also have different glass transition temperatures), affecting the membrane performance characteristics. The polymer has to be obtainable and reasonably priced to comply with the low cost criteria of membrane separation process. Many membrane polymers are grafted, custom-modified, or produced as copolymers to improve their properties. The most common polymers in membrane synthesis are cellulose acetate, Nitrocellulose, and cellulose esters (CA, CN, and CE), polysulfone (PS), polyether sulfone(PES), polyacrilonitrile (PAN), polyamide, polyimide, polyethylene and polypropylene (PE and PP), polytetrafluoroethylene (PTFE), polyvinylidene fluoride (PVDF), polyvinylchloride (PVC)[1 to 16].

### c) Hollow fibre membrane (HFM):

There are different methods used for manufacturing of hollow fibre membrane. They are listed as bellow. Information shown in this paper/article was collected from different journals and from internet. A vast literature survey was done. The development of commercial reverse osmosis seawater desalination membranes has been of great influence on the development of hollow fibre membranes. Nowadays hollow fibre membranes are used in a wide range of applications. The primary advantage of hollow fibres over other configurations is the large surface area over volume ratio. There are three main techniques: melt spinning, dry spinning and wet spinning. Artificial polymer is used as basic material for manufacturing of HFM. HFM manufacturing or production is called as Spinning. Following are the three methods used for manufacturing [1 to 16].

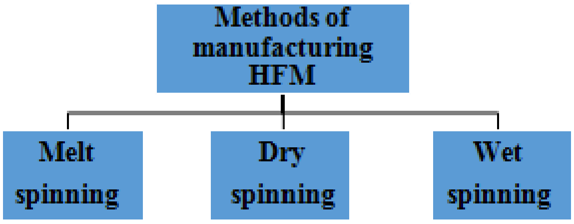


**Figure 1:** HFM manufacturing methods

**d) Melt Spinning**

In melt spinning the polymer is heated above its melting point in an inert atmosphere and then the liquid polymer is extruded through a spinneret. By immediate cooling a phase transition occurs and the polymer solidifies. In this way a capillary or hollow fibre is obtained with a uniform structure. By stretching very thin fibres can be obtained with diameters less than 50 pm and a wall thickness of N 5 pm. The spinning rate is very high and can be over 1000 meters per minute [3].

**e) Dry Spinning:**

In the dry spinning technique the polymer is dissolved in a very volatile solvent. After extrusion the polymer solution is heated and because of evaporation of the solvent the polymer will solidify. Also in this way very thin fibres may be obtained [3].

**f) Wet Spinning**

The majority of the hollow fibres employed in technical membrane processes are spun by a wet spinning technique. Any type of membrane morphology can be obtained with this technique since many parameters involved can be varied. Methods used for manufacturing of HFM also depends on the type of polymer used, its molecular weight. Here the polymer solution is extruded into a nonsolvent bath where demixing occurs because of exchange of solvent and nonsolvent. Between the spinneret and nonsolvent bath there is an air gap where in fact the membrane formation starts. This implies that a good control of this phase is a first requirement. This is especially the case for the preparation of integrally skinned hollow fibres for gas separation and pervaporation since the top layer must be completely defect-free. The tube-in-orifice spinneret which is now mainly used for this wet spinning technique has the disadvantage that the conditions in the air gap are difficult to control. Therefore a new triple orifice spinneret has been developed which allows a much better control of the conditions applicable for the spinning of all types of hollow fibres [3]. Wet spinning process and the general components involved in it are given below. Following are the general components used in the process [1 to 16].

**g) Nitrogen Tank**

Nitrogen tank is attached to the solution tank where $N_2$is passed to the solution tank. When Polymer dope gets in contact with air it solidifies and it is very difficult remove it and to clean the tank, hence nitrogen is used so that the contact between the dope and air is prevented and also to prevent the solidification of the dope, so that there is no damage to the solution tank.

**h) Solution Tank**

In this polymer liquid or dope is kept. This tank is attached to the Spinneret. The polymer liquid is polysulphone (PSF), polyethersulphone (PES), polyacrylonitrile (PAN), polyvinyl alcohol (PVC) and polyvinylidene fluoride (PVDF). They can be used alone or in combination with different ratios.

**i) Spinneret**

Spinneret refers to a single or multi-bored device through a plastic polymer is extruded to form fibres, streams of viscous polymer usually exit to cool air or liquid the individual polymer change tent to align fibre because of viscous air the process may be referred to as gel spinning or polymer spinning.

**j) Filter**

Water from the tank is passed to the filters for purification. Filter is attached to the spinneret where water is then passed to spinneret

.

**k) Water Tank**

Water tank is kept to store the water which is then passed to the spinneret via filters.

**l) Water Bath**

It is used for extrusion of polymer fibre which comes from spinneret. Extrusion is a process used to create objects of a fixed cross-sectional profile. A material is pushed or drawn through a die of the desired cross-section.

**m) Bobbin**

It is used to wound the extruded hollow fibre membrane. The fig. 1 shows the block diagram of these components.

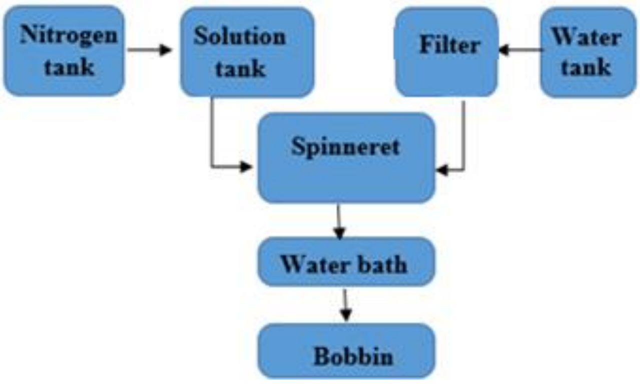


**Figure 2:** Block diagram

## 2. Process

Polymer solution used is polysulphone (PSF), polyethersulphone (PES), polyacrylonitrile (PAN), polyvinyl alcohol (PVC) and polyvinylidene fluoride (PVDF). Anyone can be used or they can be used in various combinations and various ratios as well. They are in liquid state and they are also called as dope, they are kept in the solution tank. The polymer and water from their respective tank are then passed through the spinneret at different velocities. Usually water is used for keeping the bore diameter of the HFM constant. The fibre is then extruded and then passed through constant water bath and then it is winded at bobbin. Actual formation of HFM begins at the air gap between the spinneret and water bath. HFM's become smooth and little bit flexible in water tank. Based on requirements, Spinneret used will be of different types. It may be multi- bored or single bored. It may be having two concentric bores for single layered or three concentric bores or double layered. Multi-bored spinneret is used to increase the number of layers of HFM [1 to 16].

**Figure 3:** Bundles before potting

## 3. Potting and Module/Cartridge Making Process

After the spinning process fibers are cut to a specific size according to the housing or shell length. After this, the fibers are kept in bundles for potting. Potting is a process of encapsulation of fibers. Before potting the cross-section of bundled fibers are usually filled very slightly with Plaster of Paris (POP) so that bores of fibers are closed, this is done so that the potting solution will not enter inside the fiber during the process. Potting is done only on small sectional of the both ends of the HFM bundle [1 to 16].

**Figure 4:** Bundles after potting

After potting is done a very small portion of cross section at both ends of bundled fiber is cut so that the bores of fiber which blocked by POP or by potting solution are opened. And then the potted fibers are sealed in housing. Better way is that to seal the fiber in housing first and then carry out the potting process [1 to 16].

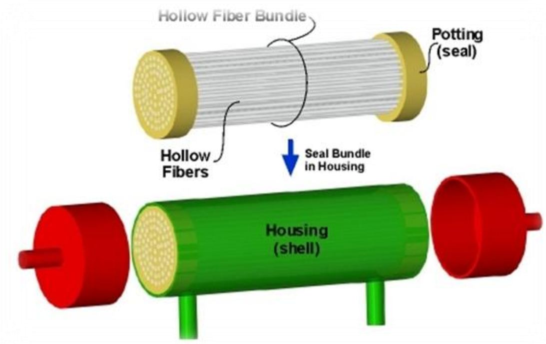


**Figure 5:** Module/Cartridge making

(Fig. 5 referred from: J.P. Montoya, Membrane Gas Exchange Using Hollow Fiber Membranes to Separate Gases from Liquid and Gaseous Streams, MedArray, Inc., **2010**, 1-7.)

HFM have been successfully employed in industrial water, industrial waste water, and beverage processing applications worldwide. Hollow fiber cartridges operate efficiently, with fluid flowing through the centre and permeate passing through the fiber wall to the outside of the membrane, a design that is highly flexible and easily handles large volumes for circulation, dead-end, and single-pass operations.HFM are used in, dairy industry, water purification, wine industry, citrus upgrading (separation), beer industry and various other industries [1 to 16].

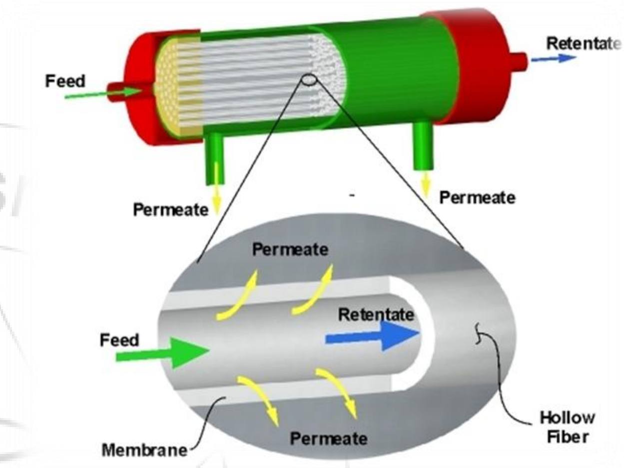


**Figure 6:** Module working

(Fig. 6 referred from: J.P. Montoya, Membrane Gas Exchange Using Hollow Fiber Membranes to Separate Gases from Liquid and Gaseous Streams, MedArray, Inc., **2010**, 1-7.)

The hollow fiber membranes have the pore sizes in the range of 0.01 to 0.1 microns. They are capable of rejecting bacteria, viruses, cyst, colloidal matter and turbidity and hence produce biologically safe drinking water at also to treat the impure water [4]. MWCO (Molecular weight cut off can be defined as the molecular weight at which 80% to 90% of the analytes i.e. solutes are prohibited from membrane diffusion.) of hollow fiber membrane are of 100 kD, 40 kD, 10kD.Pore size usually ranges from 0.01-0.1 micron. Flux rate of module depends on size, length and volume of module/cartridge [4].

## 4. Conclusions

The majority of the hollow fibers employed in technical membrane processes are spun by a wet spinning technique. Any type of membrane morphology can be obtained with this technique since many parameters involved can be varied. This article shows the information that was collected from internet, journals, and various other sources, on process of making hollow fiber membrane, and its potting and module making process. Modules can be utilized in out-to-in and in-to-out mode and backwashing at regular intervals and minimizes the fouling due to accumulation of solutes on the membrane surface [1 to 16].

## References

[1] G.E. Chen, J.F. Li, L.F. Han, Z.L. Xu, and L.Y. Yu, Iranian Polymer Journal,**2010**, 19(11), 863-873.
[2] D. Puppi, A.M. Piras, F. Chiellini, E. Chiellini, A. Martins, I.B. Leonor, N. Neves, and R. Reis,Journal of Tissue Engineering and Regenerative Medicine, **2011**, 5, 253–263.
[3] S.G.Li, G.H. Koops, M.H.V. Mulder, T. van den Boomgaard, C.A. Smolders, Journal of Membrane Science, **1994**, 94, 329-340.
[4] Uniqflux Membranes LLP, Hollow fiber ultrafiltration membranes, Indian Patent Application No. 0136NF2010.
[5] A. Mansourizadeh,& A.F. Ismail, Jurnal Teknologi, **2008**,49(F), 81–89.
[6] X. Shen, Y. Zhao, Q. Zhang, L. Chen, Journal of Polymer Research, **2013**, 20,136
[7] M. Essalhi, L. Fernández, P. Arribas, M.C. García-Payo, M. Khayet, Procedia Engineering, **2012**, 44, 1786-1787
[8] D. Wanga, W.K. Teoa, K. Li, Journal of Membrane Science, **2002**, 204, 247–256.
[9] S.A. McKelvey, D.T. Clausi, W.J. Koros,Journal of Membrane Science, **1997**,124(2), 223–232.
[10] https://en.wikipedia.org/wiki.
[11] T.S. Chung, S.K. Teoh, X. Hu, Journal of Membrane Science, **1997**, 133(2), 161–175.
[12] X. Tan, S. Liu, K. Li, Journal of Membrane Science, **2001**, 188(1),87–95.
[13] D. T. Clausi, W. J. Koros, Journal of Membrane Science, **2000**, 167(1), 79–89.
[14] J.J. Qin, J. Gu, T.S. Chunga, Journal of Membrane Science, **2001**, 182(1–2), 57–75.
[15] J.P. Montoya,Membrane Gas Exchange Using Hollow Fiber Membranes to Separate Gases from Liquid and Gaseous Streams, MedArray, Inc., **2010**, 1-7.
[16] S.C. Pesek, W.J. Koros, Journal of Membrane Science, **1994**, 88(1), 1–19.

## Author Profile

**Venkatesh Dhairyashil Vandekar** has successfully completed his Bachelors of Engineering (B.E.) in Chemical Engineering with a grade/class of **First Class with Distinction,** in 2015, from All India Shri Shivaji Memorial Society's, College of Engineering, affiliated to Savitribai Phule Pune University (Formerly University of Pune). In 2015, author has published two research papers in Scholars Research Library, Journal of Natural Product and Plant Resources, Volume 5, Issue 2. First research paper titled **"Extraction of natural dyes from rose, pomegranate rind, common marigold, and walnut"**(page no.: 33-36), and second research paper titled **"Extraction of natural dye (Flavonoid) from common marigold flower"**(page no.: 43-52).