

Estimating Service Life of Wound Cartridges Produced with Different Media Thickness

Pragnya Kanade¹, Someshwar Bhattacharya²

Associate Professor, Dept. of Textile Engg., Faculty of Tech & Engg. The M.S.Univ. of Baroda, Vadodara, Gujarat,
India¹

Professor, Dept. of Textile Engg., Faculty of Tech & Engg. The M.S.Univ. of Baroda, Vadodara, Gujarat, India²

ABSTRACT: Global scenario related to water and its resources is alarming. The available sources may get contaminated due to various reasons and hence removing the impurities from water has now becoming imperative. Water purification can be carried out by various methods like boiling water, adding chemicals, or using simple methods like filtration/separation using some filter media. Filtration is the most common technique used in solid-liquid separation and can be achieved by using membranes or candle filters. Domestic water filtration is a huge market that makes use of different types of filters; string wound filters being a very popular option. In a filtration system a combination of pre and post filters is often used. Pre-filters mainly remove relatively larger sized particles that indirectly increase the life of final filter. Performance of wound filter is characterized by pressure drop it can withstand and its filtration efficiency. In general if the media thickness is more; in case of wound filters the number of layers of yarn is more, then such filter will exhibit lower pressure drop and its capacity to trap particles of different sizes may also be better. Service life of filter depends upon the pressure drop it experiences and on achieving it, filters needs to be replaced. The capacity of the wound filter to trap suspended solids depends upon the area available which in turn depends upon the media thickness. The media thickness that can give the best performance should be chosen. This paper deliberates on filtration with string wound filters manufactured by means of winding technology. Wound filter candles with different diameter (outer) were produced and later on tested as per destructive test method to obtain results for pressure drop and filtration/retention efficiency. Along with this, MATLAB has been used to find the time span after which it is recommended to change the filter. Increasing the media thickness resulted in lowering the pressure drop and better retention of most of the particle sizes.

KEYWORDS: Pressure drop, retention efficiency, service life, string wound filters, winding.

I. INTRODUCTION

Out of the variety of filter media options available to purify water; membranes and candle filters are quite popular and can be branded as surface and depth filters respectively. String wound filters/melt blown filters etc. are nominally rated implying that they are not capable of removing a given particle size in totality. Absolute rating is given to membranes (surface filters) insinuating that they can remove 100% of a given particle size (depending on the pore size). A string wound filter cartridge/candle is characterized by its shape and the method of manufacturing it. The term candle indicates its shape; that is cylindrical while string wound points at the method of manufacturing it. The raw material of yarn can be chosen according to the environment in which it shall be placed. The string wound filter cartridges come under the umbrella of depth filters; are a small but important part of the filter family. They usually function as pre-filters and besides being able to trap wide range of particles, they have large dirt holding capacity and can withstand higher pressure drop compared to the surface (membrane) filters. As the name depth indicates, this type depend on their thickness to trap the particles, rather the contaminant enters inside the filter matrix to get arrested. The thickness of this media plays an important role in its performance. This paper highlights findings related to performance of wound filter cartridges with special focus on the pressure drop, produced on special filter winder with electronic controls.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

II. MATERIAL AND METHOD

2.1 Raw material:

For the present study polypropylene fibres having fineness of 19 μm and 51 mm long were spun into yarn using friction spinning technology.

2.2 Winding method:

A string wound cartridge is nothing but a mechanical barrier whose function is to trap the suspended particles. Normally the feed material for wound filter cartridges is a coarse yarn (DREF spun) laid spirally on a perforated core. Wound cartridges with the specific requirements were produced on a special filter winder with electronic controls [1]. The winding principle ensures that the yarn is precisely laid. In this study three different outer diameters of wound cartridge were considered viz, 60 mm, 65 mm and 70 mm and the other unchanged winding parameters include number of coils, winding tension, speed, fineness of the feed yarn etc.

2.3 Filter tests:

It is usual practice to judge performance on the basis of pressure drop attained and the micron rating achieved for which test methods are existing. Despite numerous non destructive tests available usually destructive tests [2] give a better idea about the performance of the filter though they may render the tested filter useless. The wound cartridges were tested on test apparatus designed to operate on Single pass test method with constant flow rate conditions as per ASTM F 795 (88) [4 & 5]. ISO A3 standard test dust was used to contaminate water before using it for conducting filter test trials.

III. EXPERIMENTAL RESULTS

3.1 Influence of media thickness on pressure drop

Figure 1 shows the plot of pressure drop developed across the cartridges produced with different media thickness [6]. It will be observed that the cartridge would with the least thickness experiences the maximum pressure drop after a specific time. Or in other words it reaches a higher pressure sooner than the two cartridges wound with greater thickness. There is close relation between pressure drop and the media thickness. Analysis of the pressure drop experienced leads to reasons for its typical behaviour. This includes the concentration of suspended solids in the feed slurry and area available for them to get attached. If the area available for deposition is large then chances of rise in pressure drop with time may comparatively be less and is clarified in figure 2.

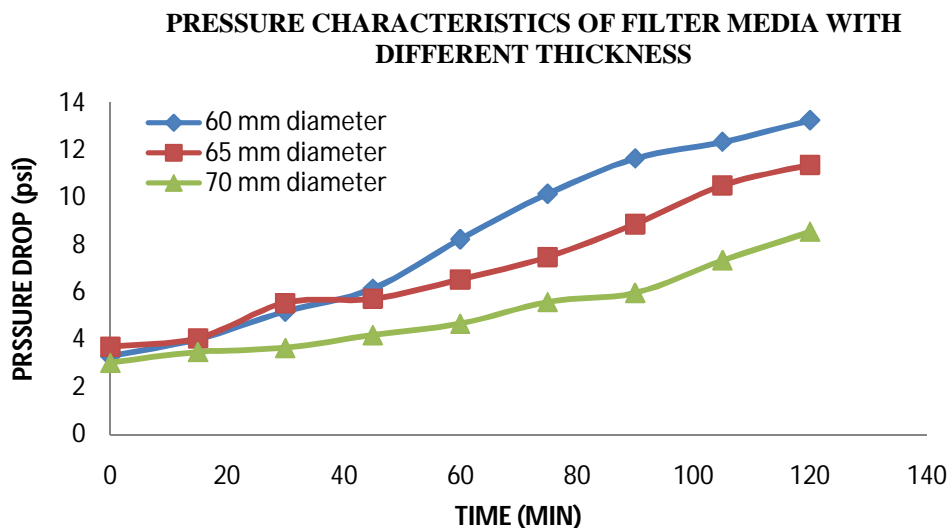


Figure 1 Pressure characteristics of filter media produced with different thickness [6]

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

String wound filters are depth filters and hence the suspended particles that can get deposited on a surface/ get trapped inside the filter matrix/ yarn structure during their passage through it. Figure 2 shows a plot where an arbitrary value of pressure drop range lying between 8.2 psi and 9 psi is considered. The cartridge with least media thickness reaches pressure drop of 8.24 psi at approximately 60 minutes (one hour). To reach 8.5 psi, it might take few minutes because the pressure drop after fifteen more minutes is 10.15 psi that is approximately 2 psi higher. The media with intermediate value of thickness (65 mm) reaches 8.88 psi after 90 minutes. This is approximately 30 minutes later than the media with least thickness. Media with maximum thickness (70 mm) takes 120 minutes to reach pressure drop of 8.55 psi, thus the explanation given earlier is justified. It will be seen that to reach similar pressure drop values, the time taken by filter media with maximum thickness is more than the other two thicknesses considered.

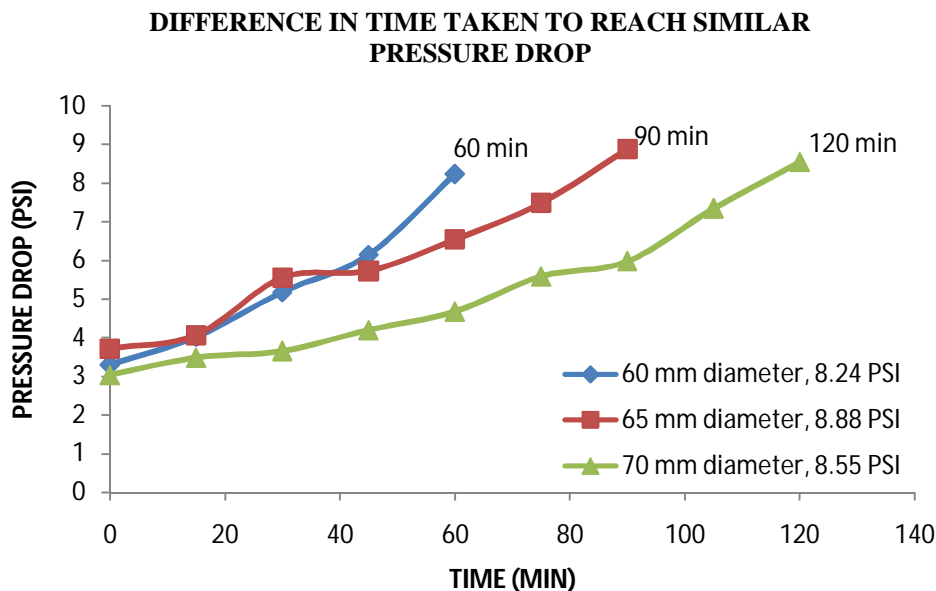


Figure 2 Difference in the time taken to reach similar pressure conditions

Researchers have conducted filter test trials on wound cartridges acquired from different manufacturers till terminal pressure drop of 40 psi was reached and have reported the results. They have stated 'that increased performance with little loss of life or solid retention capacity could be achieved by terminating element life at pressure differential of 20-25 psi' [3]. They also have performed filter tests at two different flow rates and have found that decreasing the flow rate resulted in improved life of the wound filters. When pressure drop values were plotted in MATLAB, it was found that exponential fit was best suited for the data set. Exponential fit gives two options and curves where plotted with each as explained in the following text.

General model Exp1:

$$f(x) = a \cdot \exp(b \cdot x)$$

Equation 1

where $f(x)$ is dependent on x

Coefficients (with 95% confidence bounds):

$$a = 4.065 (3.115, 5.016), \quad b = 0.01054 (0.008045, 0.01304)$$

Goodness of fit:-

$$\text{SSE: } 5.834, \text{ R-square: } 0.9484, \text{ Adjusted R-square: } 0.941, \text{ RMSE: } 0.9129$$

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

Figure 3 is a plot of pressure drop and time created in MATLAB where in the curve represents exponential fit following the equation 1; the cross points indicate the actual values. It will be observed that most of the experimental values do not lie close to those obtained by this equation.

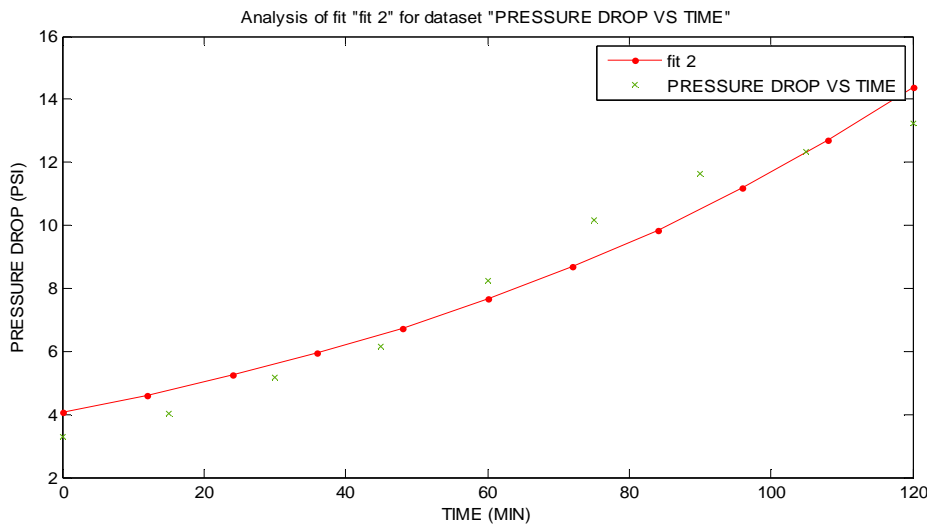


Figure 3 Plot of pressure drop and time for filter sample with least diameter with Exp 1 fit

Figure 3 shows the exponential fit and data fit do not coincide exactly and therefore needs to be improved so that at least few points of the experimental data lie close/on the curve. Hence when the same data set was checked for the other fit, the result was better as is shown in the equation 2.

General model Exp2:

$$f(x) = a * \exp(b * x) + c * \exp(d * x)$$

Equation 2

Coefficients (with 95% confidence bounds):

$$a = 4.847e+004 \ (-3.398e+014, 3.398e+014), \ b = 0.02364 \ (-1443, 1443), \ c = -4.847e+004 \ (-3.398e+014, 3.398e+014), \ d = 0.02364 \ (-1443, 1443)$$

Goodness of fit:

$$\text{SSE: } 0.5659, \text{ R-square: } 0.995, \text{ Adjusted R-square: } 0.992, \text{ RMSE: } 0.3364$$

Figure 4 is plot of experimental data versus the data obtained using equation 2. The crossed points represent experimental data set while the curve is based on exponential equation 2. It is brought to notice that now several points can be seen close to the curve and few on the curve itself. This leads to the assumption that the equation 2 gives better fit than equation 1. The equation 2 can be rewritten in the following form

$$y = a * e^{b * x} + c * e^{d * x}$$

Equation 3,

Where y stands for dependent variable pressure drop (psi), x stands for the independent variable time (minutes) and a, b, c and d are constants.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

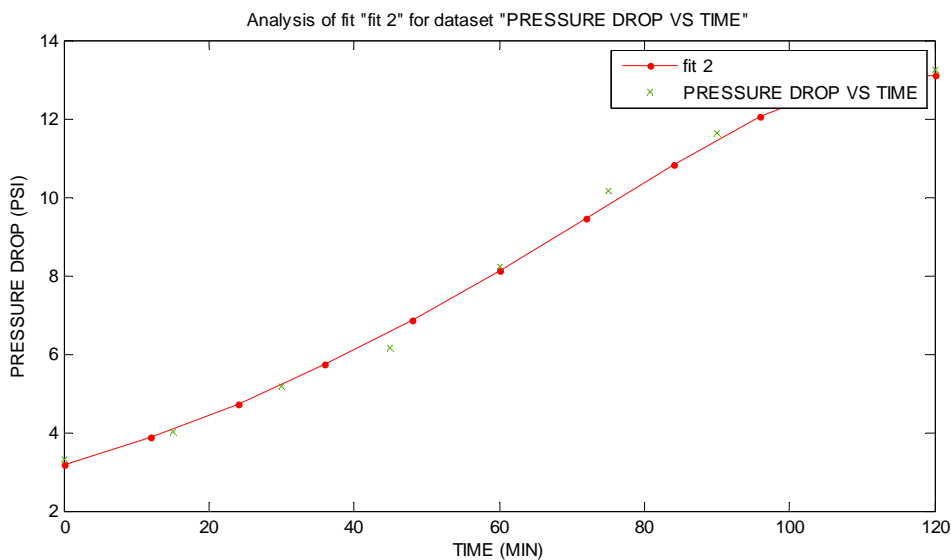


Figure 4 Plot of pressure drop and time for filter sample with least diameter with Exp 2 fit

Using equation 3, for each of the media thickness, the time taken to reach a pressure drop of 25 psi was found. On substituting the values of constants equation 3 can be further simplified as follows:

$$y = 3.553e^{0.012x}, R^2 \text{ value is } 0.966 \text{ for media thickness of } 60 \text{ mm diameter,} \quad \text{Equation 4,}$$

$$y = 3.756e^{0.009x}, R^2 \text{ value is } 0.985 \text{ for media thickness of } 65 \text{ mm diameter,} \quad \text{Equation 5,}$$

$$y = 2.935e^{0.008x}, R^2 \text{ value is } 0.987 \text{ for media thickness of } 70 \text{ mm diameter} \quad \text{Equation 6,}$$

Equations 4, 5 and 6 can be solved to find time taken (x) by the wound filters of different media thickness to reach same pressure drop of 25 psi.

For media thickness of 60 mm, 65 mm and 70 mm, the time found out comes to be 162.59 minutes, 210.6 minutes and 267.77 minutes. Suppose a flow rate of 600 L/hr is considered, then media having thickness of 60 mm, 65 mm and 70 mm will be able to filter approximately 1625.9 litres, 2106 litres and 2677.7 litres of water before they start giving problems and have to be replaced. Researchers have considered 40 psi as the terminal pressure but beyond 25 psi, the rise in pressure drop is approximately 20 psi per 5 minutes [3]. Thus the time found in this case (up to 25 psi) can be considered as the fruitful time as after that, there is rather rapid rise in pressure drop.

3.2 Influence of media thickness on retention efficiency:

From the particle analysis of the filtrate samples drawn at regular intervals, it was possible to obtain the retention efficiency of media having different outer diameters as shown in table 1.

It is revealed from the same table that the smallest average particle size of the distribution is 6.25 µm. The retention efficiency of 70 mm is better than filters with lower thickness values except for average particle diameter of 6.25 µm. The micron ratings are listed in their decreasing order of merit 56 µm (70 mm), 68 µm (65 mm) and 94 µm (70 mm). Thus changing the media thickness resulted in significant change in the micron rating of the wound filters.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

Table 1 Calculated value of retention efficiencies for wound cartridges from differently spun yarn

Part. size μm	Retention efficiency % Media thickness		
	60 mm	65 mm	70 mm
93.75	100	100	100
81.25	55.32	100	100
68.75	55.32	100	86.95
56.25	55.32	55.06	80.42
43.75	70.96	67.64	73.57
31.25	29.2	36.86	40.46
18.75	70.96	53.4	57.17
6.25	47.02	47.89	-13.51

IV. CONCLUSION

The thickness of media is found to influence the pressure drop developed. A filter with smaller diameter will reach similar pressure drop sooner than a filter with greater diameter. Due to greater thickness, the life of media can be increased. Using MATLAB the best fit was determined and the time take for each filter to reach 25 psi was calculated. Beyond 25 psi the test is expected to reach terminal pressure rather rapidly. Higher media thickness results in better retention of particles as the resistive layers increase that in turn leads to better micron rating and reduced pressure drop.

REFERENCES

- [1] Kanade, P. S., and Bhattacharya, S. S., "Designing a Cartridge Winder with Electronic Control", Journal of Engineered Fibers and Fabrics, Vol. 9, No. 2, pp. 112-119, 2014.
- [2] Williams, C. J, "Testing the performance of spool-wound cartridge filters", Filtration & Separation, vol. 32, no. 2, pp 165, 1992.
- [3] Williams, C. J, and Edyvean, R. G. J., "Testing cartridge filters in aqueous media: Interpreting the results – The pitfalls and problems. Part – I: Evaluating the performance methods", Filtration & Separation, vol. 32, no. 2, pp 157, 1995.
- [4] ASTM F 795 – 88, "Standard practice for determining the performance of a filter medium employing a single-pass, constant rate, liquid test", Dec 1988 (964)
- [5] ASTM F 796 – 88, "Standard practice for determining the performance of a filter medium employing a single-pass, constant pressure, liquid test", Dec 1988 (970)
- [6] Bhattacharya, S. S., and Kanade, P. S., "Influence of winding parameters on performance of string wound filter cartridge - Part-II", Filtration Journal, Vol.13, No. 4, pp 222-231, 2014.