PAPER • OPEN ACCESS

Comparison on Filtration Performance of Metallic Wire Mesh Filter at Different Temperatures

To cite this article: Juan Li *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **490** 052033

IOP Conf. Series: Materials Science and Engineering **490** (2019) 052033 doi:10.1088/1757-899X/490/5/052033

Comparison on Filtration Performance of Metallic Wire Mesh Filter at Different Temperatures

Juan Li*, Xiaochun Wang, Chenggang Liu

School of Environmental Science and Engineering, Suzhou University of Science and Technology, Jiangsu, China

*Corresponding author e-mail: lijuan@mail.usts.edu.cn

Abstract. Metallic wire mesh filter is characterized by corrosion resistance, high strength and plasticity, stability under high pressure difference, favourable regeneration performance and long lifetime, which can be used to purify cryogenic liquid. In order to research its filtration performance at different temperatures and to discuss the filtration mechanism at cryogenic temperature, experiments were carried out to purify liquid nitrogen, and filtration performance was compared with two kinds of wire mesh filter in literatures. Emphasis was laid on the effect of filtration medium. The results show that filtration pressure drop is proportional to fluid speed at cryogenic temperature, which coincides with the condition at atmospheric temperature. However, at the same fluid speed, the higher the temperature, the lower the pressure drop due to thermal expansion and the permeability increase of wire mesh filter medium at high temperature. Furthermore, filtration efficiency increases with filtration speed and such trend is more obvious at later stage at cryogenic temperature, while it is not obvious at high temperature due to the larger porosity of filter cake at high temperature which has no significant effect on filtration efficiency.

1. Introduction

In recent decades, the application of rigid metallic micro-porous wire mesh material attains huge success not only in aerospace field, but also in separation, recovery, purification and filtration in civilian industry. Especially in solid-liquid filtration, such material is used as filtration medium to capture solid particles on the surface while the liquid purified flows through the medium. Metallic wire mesh filter is characterized especially by cryogenic toughness and stability under high pressure difference, which makes it suitable for solid-liquid filtration at cryogenic liquid[1]. After a certain time of filtration, solid particles deposit above the external surface to generate a filtration cake, which increases pressure drop. When pressure drop achieves the preset value, regular regeneration is required to remove filter cake, so as to recover the filtration ability of the medium and repeat the filtration and regeneration process[2].

Filtration performance is mainly determined by pressure drop and efficiency. Filtration slurry flowing through the filter and solid particles which are captured on filter surface and block pores both result in filtration pressure drop. While filtration efficiency is defined as particle captured on filter surface divided by the initial total amount in slurry Factors affecting pressure drop and efficiency include filtration slurry speed and viscosity, solid particle concentration in feed slurry, filter pore size, filtration pressure, filter cake properties such as particle size diameter distribution, its compressibility, thickness and area[3].

Study on filtration performance of metallic wire mesh filter at atmospheric and high temperatures has been made widely and deeply by many researchers, such as the application in air purification and ventilation as well as in vehicle exhaust clean-up. However, filtration experiments and data are few at cryogenic temperature, most filtration study is aimed at ceramic medium[4]. Therefore, purification of liquid nitrogen at 77K was carried out by metallic wire mesh filter in this paper, and filtration performance including pressure drop and efficiency were compared with that at atmospheric and high temperatures in two literatures respectively, so as to further discuss the filtration mechanism at cryogenic temperature.

2. Experimental Research

2.1. Experiment Scheme

Schematic diagram and structural parameters of metallic wire mesh filter are shown in Figure 1 and Table 1 respectively. Feed slurry was composed of liquid nitrogen and solid carbon dioxide particles. Slurry speed flowing through filter was $5.22\times10^{-6}m^3/s$ (corresponding to 200L/min of nitrogen gas at normal temperature), while CO_2 gas flow was maintained at 2L/min. According to the filtration area of $640cm^2$, slurry speed on filter surface is $8.16\times10^{-5}m/s$ and volumetric concentration of CO_2 particles in feed slurry is 0.619%.

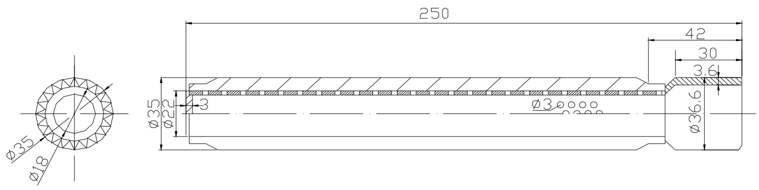

Figure.1 Schematic diagram of metallic wire-mesh filter (unit: mm)

Table 1. Structural parameters of metallic wire mesh filter

Parameters	Data
Nominal Pore Size	0.5μm
Number of Wrinkles	24
Height of Wrinkles	6.5mm
Filtration Area	$640cm^2$
Number of Filtration Layers	2
Thickness of Filtration Medium	3mm

2.2. Experimental Devices and Process

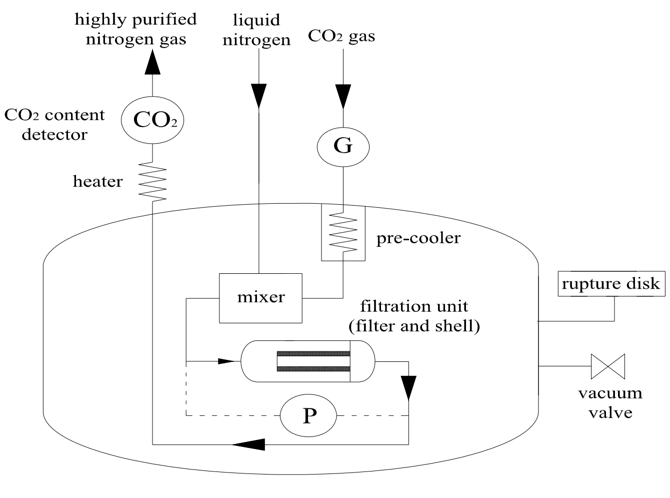

Figure 2. Experimental diagram of filtration system

Experimental diagram of filtration system is shown in Figure 2. Liquid nitrogen and pre-cooled CO_2 gas were mixed to generate feed slurry which flow through the filtration unit. CO_2 particles were captured on wire mesh surface while liquid nitrogen highly purified was heated to atmospheric temperature. Gas flow meter G was used to measure nitrogen gas flow, CO_2 concentration detector was used to measure CO_2 concentration in nitrogen gas. Pressure difference transmitter P was used to measure pressure drop. The whole experimental tank was vacuumized through vacuum valve, so as to achieve thermal insulation.

3. Results and Discussions

3.1. The Filtration Performance at Cryogenic Temperature

Figure 3 and 4 show the change of pressure drop and filtration efficiency with time respectively. Volumetric concentration of CO_2 in filtrate was 10~50ppm, which verified the feasibility of filter. It can be seen that pressure drop maintained constant basically in initial 5 minutes without large fluctuation. Then, it rose sharply, that is because solid CO_2 particles were captured but its distribution on filter surface was not uniform at initial stage, particle piles were connected continuously to generate filter cake gradually. With increase of filter cake thickness, filtration was achieved mainly by its screening effect, resistance is more and more higher until the maximum allowable pressure drop was achieved. Similarly, filtration efficiency was stable in initial 5 minutes. With increase of pressure drop, filtration efficiency changed obviously, the reason is the same as that in pressure drop curve.

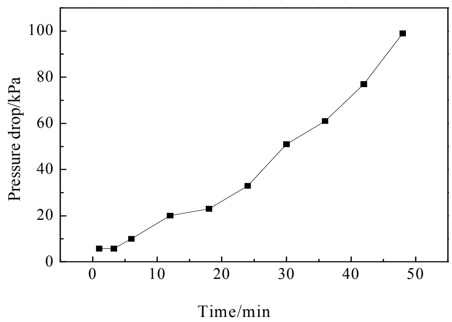

Figure 3. Change of pressure drop with time

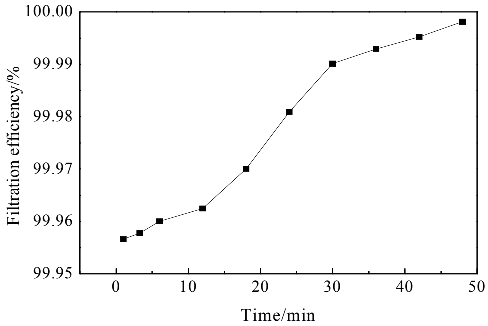

Figure 4. Change of filtration efficiency with time

3.2. Comparison of Filtration Performance at Different Temperatures

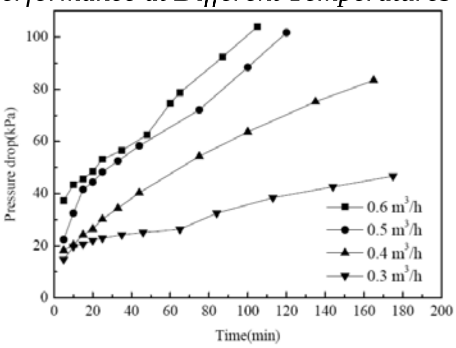

Figure 5. Change of pressure drop with time at atmospheric temperature

IOP Conf. Series: Materials Science and Engineering **490** (2019) 052033 doi:10.1088/1757-899X/490/5/052033

For filtration process at atmospheric temperature, filtration performance test for sintered metallic wire mesh with size of Φ40mm×1000mm and absolute filtration precision of 10μm was carried out, as shown in reference [5]. The suspension was prepared by 425-mesh talcum powder, its concentration was 1g/L, filtration tests were carried out at the speed of 0.3m^3/h, 0.4m^3/h, 0.5m^3/h, 0.6m^3/h respectively. Pressure drop change trend was shown in Figure 5. pressure drop is larger at larger slurry speed, which is the same at that at cryogenic temperature. However, pressure drop increased rapidly in initial 20~30min, while it increased almost linearly at later stage. That is because solid particle concentration in slurry was higher, once the particles were captured on filtration layer, they played the role of filtration medium and continuous filter cake layer was generated in the end.

For filtration process at high temperature, metallic fiber wire mesh filter element was used to carry out filtration test in reference [6]. Characteristic parameters of the element are shown in Table 2. During the test, electrical heater with power of 60kW was used to preheat the gas. In order to maintain uniform temperature distribution in filtration element, electrical heating wall was installed at external side of filtration shell. Filtration temperature can achieve 600℃. Slurry speed was 1.0~2.5m/min. Figure 6 show filtration pressure drop change, in which pressure drop is mainly related to gas flow speed and its dynamic viscosity. It is found that the pressure drop value is proportional to gas flowing rate, which coincides with the situation both at cryogenic and atmospheric temperature. However, at the same gas flow rate, pressure is lower at higher temperature, that is because thermal expansion of filtration medium at high temperature resulted in increase of porosity and permeability.

Table 2. Characteristic parameters of metallic fiber wire mesh filter element

Characteristics	Data
Fibre Diameter	40μm/70μm
Thickness of Filtration Medium	0.15mm
Length of Filtration Medium	1500mm
Diameter of Filtration Medium	150mm
Porosity	37%
Permeability	240 L/min·dm^2

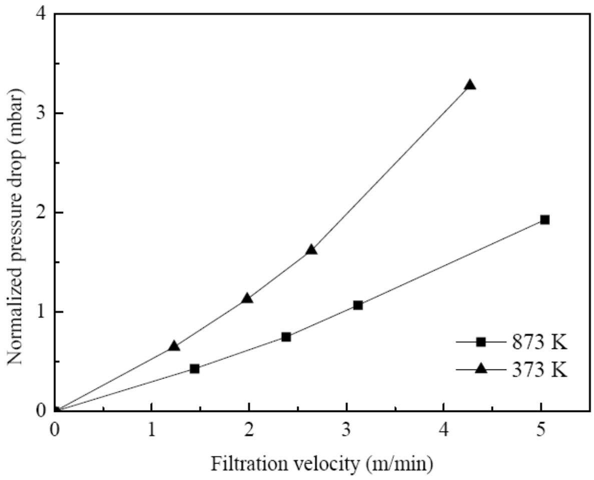

Figure 6. Normalized pressure drop curves at high temperatures

In general, compared with filtration process at normal and higher temperatures, as for the similar kind of filtration media and contamination particles, pressure drop at the condition of cryogenic temperature is lower in a theoretical manner. Firstly, the viscosity of routine liquid is lower at cryogenic temperature. Secondly, the porosity value of wire mesh filter is lower on the account of cold shrink, while more solid particles may penetrate into the depth of wire mesh filter at higher temperature. At lower temperature, solid particles that have not penetrated stay inside the filtration medium. All such effects result in higher pressure drop value and the shorter filtration time at the lower temperature.

4. Conclusion

This paper has researched and compared the filtration performance of metallic wire mesh filter at different temperatures. Pressure drops are plotted during the whole filtration process. For filtration at cryogenic temperature a test rig is established, liquid nitrogen at 77K and solid CO_2 particles are mixed to generate feed slurry which flow through the filter medium. Pressure difference transmitter, concentration detector and gas mass flow meter are used to measure pressure drop, CO_2 concentration in nitrogen gas and its mass flow respectively. The results show that pressure drop maintained constant in initial 5 minutes and then increased linearly due to formation of filter cake. Filtration efficiency is high and has the same trend.

For filtration processes and results at atmospheric and high temperatures, data in two literatures are referred respectively. The results show that pressure drop vale at normal temperature is much higher than the value at cryogenic temperature due to filtration performance of different filters, particle characteristics as well as the higher feeding slurry flow at normal temperature. At cryogenic temperature, filtration efficiency increases with filtration speed gradually especially at later stage, while at high temperature, such trend is not so obvious, that is because diffusion has very significant effect on filtration at high temperature, porosity of filter cake is larger which has less effect on filtration efficiency.

Acknowledgments

This work was financially supported by National Natural Science Foundation for Youths of Jiangsu Province (No. BK20170382).

References

[1] J. Li, Y. M. Shi, R. S. Wang, et al. Analysis of the performance of a sintered stainless steel wire mesh filter for cryogenic liquid purification. Cryogenics, 2009, 49(1): 27-33.
[2] H. Sehaqui, P. Spera, A. Huch, et al. Nanoparticles capture on cellulose nanofiber depth filters. Carbohydrate Polymers, 2018, 201, 482-489.
[3] T. J. Phelps, A. V. Palumbo, B. L. Bischoff, et al. Micron-pore-sized metallic filter tube membranes for filtration of particulates and water purification. Journal of Microbiological Methods, 2008, 74(1), 10-16.
[4] J. Huang, G. Huang, C. J. An, et al. Performance of ceramic disk filter coated with nano ZnO for removing Escherichia coil from water in small rural and remote communities of developing regions. Environmental Pollution, 2018, 238: 52-62.
[5] P. X. Luan, X. W. Liang. Experimental research of the filtering performance of sintering wiremesh filtering element. China Petroleum Machinery, 2003, 31(7): 3-5.
[6] W. Peukert, M. Goetzinger. Understanding particle interactions from a microscopic view of particulate interfaces. Particuology, 2005, 3(1-2): 14-18.