STUDY OF POLYPROPYLENE (PP) CARTRIDGE FILTER CHARACTERISTICS AND DEVELOPMENT OF LIQUID FILTRATION SYSTEM TEST RIG

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ABSTRACT

The function of cartridge filter is to separate substance or particle from liquid. Cartridge filter is a media to filtrate substance that flow with liquid. Cartridge filter in this project focus for water filtration system that usually used at houses and small scale industry. Volume flow rate relate with pressure of the water that flow through pipe system. Cartridge filter function as a media that reduced pressure from the water flow and call pressure drop. Sediment sand particles function as particles that flow with the water and will filtrate with cartridge filter. Sediment sand make contact on the surface of cartridge filter depend on the volume flow rate of water. Cartridge will clogged because of sediment sand clog on the surface of cartridge filter when tried to enter the cartridge filter. This situation make filtration system has different pressure on the entrance and the exit of cartridge housing. Different pressure call pressure drop represent the pressure drop of the cartridge. From the pressure drop can relate with volume flow rate and determined life span and maximum condition of the cartridge filter. Maximum clogging condition happen because of pressure of cartridge filter does not increase anymore and cartridge filter has fully clogged with sediment sand.

ABSTRAK

Fungsi penapis kartrij adalah untuk memisahkan bahan atau zarah-zarah yang mengalir bersama cecair. Penapis kartrij yang difokuskan dalam projek ini adalah penapis kartrij biasanya digunakan untuk system penapisan air di rumah dan industry-industri kecil. Tekanan air yang mengalir di dalam paip adalah berkait rapat dengan kadar aliran isispadu. Penapis kartrij boleh menurunkan atau mengurangkan kadar tekanan air yang mengalir melalui paip. Zara-zarah pasir digunakan sebagai bahan ujian untuk menguji tahap ketahanan penapis kartrij. Zarah-zarah pasir dimasukkan kedalam system pengujian penapisan yang telah dibina. Pasir yang telah dimasukkan akan terlekat dan tersumbat disebabkan size liang penapis kartrij yang terlalu kecil. Keadaan ini akan menyebabkan perbezaan tekanan antara tekanan sebelum memasuki penapis cartridge dengan tekanan keluar daripada penapis kartrij. Perbezaan tekanan ini akan meningkat dan sampai satu tahap akan malar dan tidak meningkan lagi. Keadaan ini menunjukkan, penapis kartrij telah tersumbat dan perbezaan tekanan pada keadaan ini adalah pada tahap tertinggi. Daripada perbezaan tekanan penapis kartrij ini, graf perbezaan tekanan melawan kadar aliran isipadu dapat dibentuk. Daripada graf ini, dapat mengetahui jangka hayat dan keadaan tersumbat tertinggi bagi penuras kartrij.

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LIST OF SYMBOLS

μm	Micron meter
gpm	Gallon per minute
in	inch
m	meter
mm	millimeter
kg/m³	kilogram permeter cube
m/s	meter persecond
m/s²	meter persecond square
m³/s	meter cube persecond
l/s	liter persecond
l/min	liter perminute
mg/l	milligram perliter
MPa	MegaPascal
kPa	kilopascal
psi	pound per square inch
°C	Degree Celsius
°F	Degree Fahrenheit
%	Percent
ΔP	Pressure drop
H	Head
V̇	Volume flow rate
A	Area
kW	kilowatt
f	friction factor
L	length of pipe
D	pipe diameter
K_L	constant for minor losses
u	liquid velocity
g	gravity acceleration

Re	Reynolds number
ϵ	surface roughness
SG_{water}	specific gravity of water
h_L	head loss
R^2	coefficient of determination

LIST OF ABBREVIATIONS

PP	Polypropylene
Re	Reynolds number
avg	average
atm	atmospheric
PVC	Polyvinyl chloride
C-W	Colebrook - White

CHAPTER 1

INTRODUCTION

1.1 Project background

Filtration is commonly the mechanical or physical operation which is used for the separation of solids from liquid by interposing a medium through which only the fluid can pass. Oversize solids in the fluid are retained, but the separation is not complete, solids will be contaminated with some fluid and filtrate will contain fine particles, depending on the pore size and filter thickness. By using filtration, water treatment and sewage treatment in which undesirable constituents are removed by adsorption into the filter medium.

The function of the filtration is using a surface filter medium to remove a volume of solids from a liquid requires that the medium should contain uniform pores smaller than the smallest particle to be removed. It should also be strong enough and possess a sufficient area to hold the required volume of solids. If a depth-type medium is used, the medium must contain an infinite number of small, irregular, continuous passages which give the solids a difficulties path to travel through(Products 2006). A depth medium of proper density will stop essentially all solids above a specified size a depth medium of proper density will stop. The medium selected must withstand the required maximum allowable pressure drop and provide a margin of safety to cover both inadequate maintenance and line pressure surges commonly found in the system as a result of stop and starts.

The general application of liquid filtration is to remove solids that may damage the aesthetic appearance of a product such as solid in paint, bleach, liquid soap, vinegar and plastic resin for use in plastic extrusion products. A second application is removing solids which could affect chemical reaction of a product such as catalyst fine in a refining process. Third application is removing solids that could damage operating equipment such as abrasive contaminant in hydraulic and lubricating oils. Fourth application is removing solids that could affect a finished production item such as contaminant in grinding and cutting oil of production equipment. The fifth or the last application is removing solids that could in some way affect the health of operating personnel such as radioactive waste in the primary coolant system on boiling water reactors and clean up water reactor system.

Test rig is test equipment and system that can test something. Development test rig used to take data, make experiment and to analyze something. When there has something to measure and want to collect data, test rig must be developed. In this project, test rig developed to test cartridge filter type. When installing one of cartridge filter type and run the experiment procedure, data can be collected and ready to analyze. Before developing a test rig, parameters want to use and the material selection must be cleared. The specification of the pump, friction loss of pipe use and estimation pressure inside the pipe system must be cleared and determined.

Many types of filter have on the market, from lost cost filter until the high cost filter. For the high cost filter, the quality must be much better compared to low cost filter. Filter application is to filter liquid and separate any substance that comes with the liquid. These application same like cartridge filter, that has a different pore size with different types of cartridge filter that function to filter any substance comes along with the liquid. There are also has high cost and low cost cartridge filter. Same goes to cartridge filter for high cost cartridge, the material use more quality compares to low cost cartridge filter. Low cost cartridge filter is compatibility used in houses and small scale industry because of the quality not too bad and the cost is compatible.

Filtration type use on this project is cartridge filtration system. Cartridge filter is a low cost filtration system and easy to use and suitable for houses. It is easy to replace the cartridge with a new one, once the cartridge cannot use anymore. It can separate any particle from water that flow through the cartridge. This application happen when water with particle flow enters the cartridge filter and cartridge with a specific micron rating will filter water. Particle with larger micron size than the micron rating of cartridge cannot go through the cartridge filter. When many particle micron sizes stuck at cartridge filter, it will be clogged and pressure drop will increase. Water pressure flow through the system will also decrease.

1.2 Problem Statement

Nowadays, water filter was very famous among Malaysian especially who stay in the urban area. Because of many pollution and bacteria that can affect health, people that stay in town or city really concern about the quality of the water. Nowadays, water contaminations in Malaysia are in serious condition especially in town and city areas. So, the best alternative to get quality, clean and healthiest water is by using a water filter. Water supply from water sources has sediment like sand, to avoid this sediment flow with water through pipe supply to people house. Cartridge filter is an effective device to filtrate water that will flow and supply through the people's house.

Many types of liquid filtration existed and mean also much type of filter system consumables which is filters available in the mass market. Cartridge filters are one of the most used and applied at normal household and in the small scale industries. The main problem with the filters available at the local stores does not have enough information provided such as pressure drop vs. volume flow rate graph and nominal pressure drop compared with costly high industry grade filters which is inconsiderable for low cost small scale industry. Small scale industries such as food industries need clean and good quality of water to produce products. Because of small scale industries, compatible filter used is low cost cartridge filter that can filter water come from water sources and can block sediment particle inside the water flow.

1.3 Objectives

The main objectives of this project are to design, fabricate and analyze polypropylene (PP) cartridge filter using liquid filtration system test rig. The additional objective is to determine whether nominal or maximum pressure drop, volume flow rate for polypropylene (PP) sediment filtration cartridge and classify the filter according the pressure drop and micron rating. The other objective is to determine the specific indication or characteristics of the maximum clogging condition of the cartridge filter.

1.4 Scopes

Develop system test rig that includes pump, control valve, tank, cartridge filter, cartridge cover, pipe, pressure meter and flow rate meter to get the result of pressure drop and volume flow rate for sediment filtration. Project analysis focusing on the cartridge water filter that usually used on the outside of the house. To install these types of cartridge on the system test rig and run the experiment. From the experiment show the result such as the pressure drop, water flow rate, cleanliness of the water after filtration and effect of the cartridge with dust flow through the water.

The cartridges use in this experiment is 2- Tier PP Sediment cartridge filter with 2 different pore sizes which is 1 μm and 5 μm. These cartridge filters will be tested on a filtration system test rig with 3 different volume flow rate for both cartridge filters. The result shows the pattern graph of the relation between pressure drop and volume flow rate. From the graph can measure and analyze the nominal and maximum pressure drop of the sediment filtration cartridge. Specific indication or characteristics of the maximum clogging condition of cartridge filter will be determined.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Water from surface sources is often contaminated by microbes, whereas groundwater is normally safer, but even groundwater can be contaminated by harmful chemicals from human activities or from the natural environment. Rainwater captured by a rooftop harvesting system or with small catchment dams is relatively safe, provided that the first water is allowed to flow to waste when the rainy season starts(Treatment, n d). The amounts of water have been treated. This can be estimated by assuming that each person will need a minimum of 20 to 50 litters of water a day for drinking, cooking, laundry and personal hygiene.

A community should be consulted when choosing a water treatment system and should be made aware of the costs associated with the technology. In particular, community members should be made aware of the behavioral or cultural changes needed to make the system effective over the long-term and thus be acceptable to them. Communities may also need to be educated about protecting water sources from animal or human contamination, and mobilized(Treatment, n d). All the positive effects of a water treatment system could be affected if the water is not drawn, stored and transported carefully and hygienically. Usually, people used boiling, household slow sand filter and domestic chlorination for treating water at household. For the community water treatment system,the methods used are storage andsedimentation, up-flow roughing filter, slow sand filtration and chlorination in piped water-supply systems.

2.2 Filtration Equipment

The types of equipment used to achieve these separations are relatively few in broad classes, although extremely varied in physical embodiment. These broad classes are:

i. For suspending solids separation:
   – Screens and strainers
   – Deep bed filters
   – Cartridge filters
   – Microfiltrationmembranes

ii. For oil droplet separation:
   – Coalescing filters

iii. For dissolved material removal:
   – RO, NF and UF membranes

The deep bed filter is probably most important in terms of volumes of water filtered, whereas the membranes are the vital component for final product purity(Ken Sutherland, 2008).

2.2.1 Screens and strainers

The coarsest water filtration is undertaken by strainers, either the in-lineor larger units. The in-line units can often be blown clear of collecting solids, while the larger ones run continuously, with collected solids washed or scraped off the collecting surface. The filtration medium is usually a perforated metal plate or a piece of wire mesh, in the form of a cylinder forthe in-line units, or a large plate or wire screen for the continuous strainers.

The straining function, which may be required to remove large objects accumulated in a sewer flow, is usually performed in screens. The screens used for large water flows

may have arrays of vertical bars, with moving scrapers, or circular arrays of wire mesh, rotating through screening and washing zones, and often designed specifically for the channels in a waterworks.

The normal way of filtering effluent streams of fresh or waste water has been to use a screen as a roughing filter, often followed by a micro strainer, which takes the form of a rotating drum, closed at one end, rotating about a horizontal or nearly horizontal axis. The open end fits into a wall that partitions the contaminated liquid from the filtrate. The feed suspension enters the inside of the drum, at the bottom, and the filtrate flows by gravity to the outside of the drum. Sprays on the top of the rotating drum wash through the drum and discharge the solids into a trough running parallel to the axis of the drum, containing a screw conveyor. The drum is usually covered with a woven monofilament fabric or wire mesh with an aperture size of 25 μm, although particles as fine as 3 μm can be collected because a cake is allowed to build up. This is a very effective prefilterfor high flow conditions(Ken Sutherland, 2008).

2.2.2 Deep bed filters

Among the most widely used filters for clarifying high flows of water entering treatment works is the deep bed or sand filter. This has a relatively deep bed of granular material as its filter medium, with the feed flowing through the full depth of the material. The deep bed filter has been the basic means of treating fresh water to render it safe to drink for over 100 years.

The gravity filter exists in two main types such as the slow filter, characterized by a low water flow rate and a finer grade of granular material, and the rapid filter, with water flow rates 5-7 times higher, and using a coarser material. The main difference between the two types is, however, in their mode of operation. The slow sand filter works by a straining action, achieved by a shallow layer of organic material on the top of the bed, which contains biological matter. This layer has both a filtering and a biological destruction part to play in the water cleaning process. By contrast, the rapid sand filter aims for a truly deep

bed action, with contaminant solids adsorbed onto the bed material for most of its depth. Both are capable of giving treats water that is free of solid particles above 0.5 µm.

The slow version has its water flow downwards through the bed of sand. For a new bed, time must be allowed for the biological layer to form. Once established, however, the slow sand bed can operate satisfactorily for considerable periods of time for a week or even months before the flow rate drops too far. Then the top layer must be scraped off the bed, and removed to another container for cleaning.The rapid filter was originally developed with liquid flow downwards through the bed of granules. It must be cleaned much more frequently than the slow filter, perhaps as often as daily. It is cleaned by reversing the water flow using clean filtrate, at a much faster rate than the processing flow, so as to expand and fluidizethe bed completely, so that trapped solids are dislodged into the wash water. The backwashingflow is usually augmented with air scouring at the base of the bed, or hydraulic jets on the surface. Backwash lasts only a few minutes and uses 1% to 5% of the throughput.

After the backwash, the fully expanded bed sinks back to its compact form, with all its particles settling at velocities dictated by their size and density. The result is a stratified bed, with the coarsest particles at the bottom, and the finest at the top. This is the opposite of what is needed for a down flow filter, which should have the raw water meeting the coarsest particles first and the finest last. The obvious change in upwards flow risked the expansion of the bed in the direction of the flow, and the consequent release of trapped solids into the filtrate, and it was not until the Imodium filter of the 1940s that up flow became possible, with an open grid of parallel bars just below the surface of the bed to restrain the unwanted expansion.

A major development was the multimedia filter, which uses two or more different materials of markedly different density as well as different sizes. Materials such as anthracite, sand and garnet are graded such that the light (anthracite) has the coarsest grains and the densest (garnet) the finest. Then in the resettling, the density factor is greater than the size factor, and the finer particles sink to the bottom. A downwards flow of raw water

then reaches the coarsest layer first, as it should(Ken Sutherland, 2008). A modern version of this design is the Spruce filter, which has four layers of different solids, the bottom one, magnetite, being positively charged. An effluent quality of 3 mg/l and less than 0.2 μm is claimed.Other modern versions are the pressurized bed, and the moving bed, which allows continuous operation, by having the bed of sand or other materials move downwards through the filter. The dirty solids are carried from the base of the bed by a jet of air to a wash zone above the filter, to be washed clean of trapped solids and then returned to the top of the bed in the filter.

2.2.3 Cartridge filters

The cartridge filter uses a replaceable filter element, generally cylindrical in shape and longwith respect to its diameter, which operates by filtering a fluid from the outside of the cartridge to its inside. It normally comprises a central open-structured core, on which is placed the filter medium, and is contained in a cylindrical housing. The medium can be a thin flat sheet, or, much more likely, a pleated sheet, to maximize the filtration area, or a thicker layer of bonded granules or fibers for depth filtration applications(Ken Sutherland, 2008). Cartridges are made to a set of generally accepted standard dimensions, so as to be interchangeable as to source.

Individually, the cartridge filter has a relatively low liquid capacity, and it would need to be used in multiple-unit batteries to reach the kinds of flow rates being covered by this article. However they can be fitted with a wide range of filter media, and so can be selected to match almost any filtration task.

2.2.4 Microfiltrationmembranes

An important modern development in terms of filter media has been that of the micro filtering membrane, with an open structure enabling operation at relatively low Tran’s membrane pressures. These are available with cut points down to 0.1 μm or below, thus enabling use for removing pathogenic species from drinking water.

As with the cartridge filter, unit capacities may be low, requiring their use in arrays of modules, but the MF membrane is becoming a very valuable tool in most kinds of water filtration(Ken Sutherland, 2008).

2.2.5 Coalescing filter

In a coalescing filter, liquid droplets of one liquid phase suspended in another liquid, with which they are completely immiscible, are caused to combine to form larger drops, and so to become separated from the other liquid. Most coalesces take the form of cylindrical vessels whose interiors are full of some kind of plastic or wire mesh, with which the dispersed droplets collide, and are captured, to merge with other neighboring droplets, and so grow in size. The mesh should preferentially be wetted by the dispersed phase. Eventually the captured drops become so large that they fall from the mesh and form a separate layer. A coalescing filter may also affect some separation of solid particles as well.

2.2.6 Diffusion membranes

The membranes used for reverse osmosis, Nano filtration and ultrafiltration work, not by true filtration, but by diffusion of the relatively pure liquid through the body of the membrane material, under relatively high applied pressures. Reverse osmosis has become a key process in the desalination of salty water to produce drinking water. Ultrafiltrationis becoming a key preliminary stage for reverse osmosis, but also an important water purification stage in its own right, giving guaranteed purity of drinking and process waters.

This is a rapidly developing field, with new polymers, and consequently new membranes, appearing annually, enabling a good match to be made between water purification needs and membrane capabilities(Ken Sutherland, 2008).

2.3 Pump selection

Pumps are the fluid moving machineries which increase the mechanical energy of the fluids to be displaced. The energy increase may be used to increase the velocity, the pressure or the elevation of the fluids. A large number of pumps, differing widely in principle and mechanical construction, have been developed to meet a wide variety of operating conditions. For a selection of pumps for a specific application requires the knowledge of operating conditions of the system and applicability of different available pumps. Friction loss in the pipe is the minor loss that not much effect of the pressure in the pipe system. Major and minor friction loss data need to find the requirement of pump want to use. The specification of the must full filled the requirement of the system to make sure the experiment runs smoothly. The pump has many types such as horizontal centrifugal pump, jet pump, axial flow propeller pumps and deep well vertical turbine pump.

2.3.1 Type of pump

Horizontal centrifugal pumps are frequently used if the source of water is a surface supply, such as a lake, stream, canal or pond, or a shallow well. A shallow well, as opposed to a deep well, is one in which the water level in the well is high enough to permit the vacuum at the pump to lift the water and keep it flowing at an acceptable rate. As the name implies, horizontal centrifugal pumps normally have a horizontal shaft. This type of pump is usually subdivided into two groups, single suction which is end suction and double suction which often called split case. Either of these may be single or multistage; that is, they may have only one impeller or they may have two or more impellers(Bankston & Baker, 1994). These impellers are so constructed that the water, in passing through the pump, is conducted from the discharge of one impeller to the suction of the second; thus, the total head is that developed by a single impeller multiplied by the number of impellers in the pump.

A jet pump is often used for very low capacity requirements which are5 to 20 gpm, such as a home water system. This pump consists of a small centrifugal pump located at

ground level connected to a jet installed below the water level in the well. By circulating part of the water from the pump back through the jet, water is forced up to the impeller in the pump, and a continuous flow at reasonable pressure is provided.Jet pumps are designed for home water systems, and their capacities are seldom adequate for aqua cultural purposes. Also, the jet pump requires about twice the horsepower that a submersible requires delivering the same amount of water from the same depth.

Axial flow propeller pumps are designed to operate efficiently for aqua cultural, irrigation or drainage pumping at lower head and higher volume the more than 500 gpm. Their efficiency is high, especially when the total head is in the range of 8 to 20 feet. The pumping element of an axial flow propeller pump consists mainly of a revolving propeller in a stationary bowl which contains the vanes above and below the propeller(Bankston & Baker, 1994). Water enters the pump through the intake bell. It is discharged into the distributor section and then out the discharge elbow. Flowing in essentially a straight line along the pump axis keeps friction and turbulence to a minimum. The propeller of an axial flow pump must be submerged in the source of water. One of the advantages of this pump is that it will handle some debris.

Deep well vertical turbine pumps, the most widely used pump is a vertical centrifugal, commonly referred to as a deep well turbine. Basically, this is a centrifugal pump designed to be installed in a well. It will not handle debris. It consists of four major components which is bowl assembly, column and shaft assembly, discharge assembly and the driver. Because of the limited diameter of its impellers, each impeller develops a rather low head, and it is necessary in the average application to stack several impellers in series one above the other with each in its own bowl or diffuser housing. This is called staging. Thus, a four-stage bowl assemblycontains four impellers, allattached to a common shaftthrough the separate housing orbowls. The bowl shaft is attachedto the line shaft through the centerof the pump column pipe andmust be long enough to locate thebowl assembly below the level ofthe water in the well when pumpingat required capacity.

2.4 Type of cartridge filter

2.4.1 String wound polypropylene filter cartridge:

- Characteristics: These elements are made in various sizes, from 4 to 80 inches long and in different micron rating from 1 to 150 microns. The typical honeycomb structure of the filter body gives it a considerable capacity for accumulating impurities present in the fluid being filtered. These filters can be produced in different yarns, according to the application they are designed for polypropylene, rayon, cotton, nylon, and glass fiber.

- Features:
  - Exceptionally high structural strength.
  - Fits all standard housings.
  - Low pressure drop, high dirt holding capacity and long service life.

- Applicable fields:
  - Electronic industry: pre-filter for ultra-pure water
  - Food & beverage industry: filter of mineral water, wines and fruit juice.
  - Medicine industry: filter of drug liquid, gases.
  - Chemical industry: filter of organic solvent.
  - Petroleum industry: filter for oil-field flooding.

- Specification:
  - Filter Media: polypropylene, cotton, glass fiber, rayon, nylonMicron Retention Rating (Nominal) : 1, 5, 10, 20, 30, 50, 75, 100, 150 µm
  - Nominal Length: 5 in,10in, 20 in, 30 in, 40 in,50 in, 60",70",80"
  - Diameter: OD 2 in (50mm) , 2.2 in (55mm) , 2.5 in(63mm) ID 1.1 in (28mm), 1.18 in (30mm)
  - Maximum Operating Temperature: 250 °F(120°C)