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CHEMICAL AND THERMAL STABILITY OF NONWOVEN FILTRATION MEDIA IN FLUID POWER APPLICATIONS

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ABSTRACT

There are many fluids used in hydraulic systems but they can be broken down into three categories; petroleum based oils, fire resistant fluids and biodegradable fluids. Nonwoven filtration media are widely used in fluid power applications. Many different fluids are used under a wide range of operating conditions. Nonwoven filtration media are thermally bonded or resin bonded with polymers that are susceptible to thermal and chemical attack. The polymers can swell, fracture and/or soften which may change the filtration performance. The change in filtration performance can be gradual or sudden based on the concentration, exposure time, temperature and additives. This paper evaluated different wetlaid microglass filtration media for compatibility with a range of hydraulic fluids at different temperatures.

INTRODUCTION

There are a wide range of industries that use non-woven media for liquid filtration applications. They range from food and beverage, biotech, pharmaceutical, potable water, hydraulic oils, fuels, solvents, acids and bases. Each application has a different contaminant that must be removed. There are many different types of nonwoven media that can be used for these applications. The media vary by materials of construction, processing method and performance characteristics. They can be classified into two distinct types based on their method of formation. The first method is a dry laid process, which includes carded, needled, spunbond and meltblown media. The second process uses a wet laid formation, which is generally done on a paper machine with cellulose, polymeric or glass fibers. It is common for media to be produced with one or more of the different fiber types. Micro fiberglass media can be produced with the broadest range of filtration capability and efficiencies due to the wide range of fibers available. Micro fiberglass media are typically held together with polymeric binders, which vary, in their chemical and thermal stability.

Cellulose based media are generally lower cost with poor retention characteristics and low dirt holding capacity. Cellulose fibers are coarse and flat which produces a dense, two-dimensional structure with high-pressure drop. The addition of synthetic polymeric fibers to a cellulose sheet will significantly improve the filtration performance by opening up the structure and adding finer cylindrical fibers to the matrix which do not surface load as readily. Wetlaid media produced with 100% synthetic or glass fibers will generally result in a very three-dimensional sheet with lower pressure drop and higher dirt holding capacity. Figures 1-4 show four different types of wetlaid media.

Figure 1. Wetlaid Media @ 100x

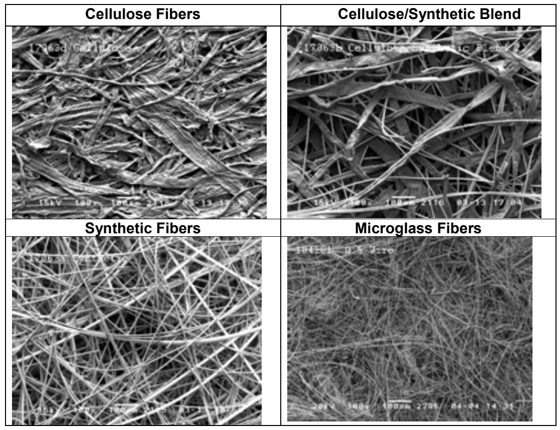
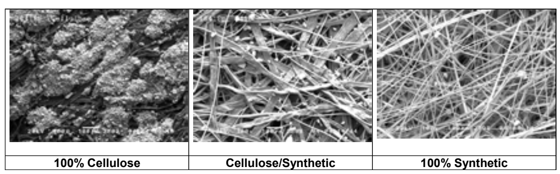


Figure 2 shows a surface filter and depth filters after being challenged with the same level of contamination. The cellulose surface filter loads all the dirt on the surface while the 100% synthetic wetlaid retained all the dirt within the structure. The cellulose/synthetic blend is more of a depth filter but retains some surface filtration characteristics.

Figure 2 – Surface vs. Depth Filter Media



BINDER SYSTEMS

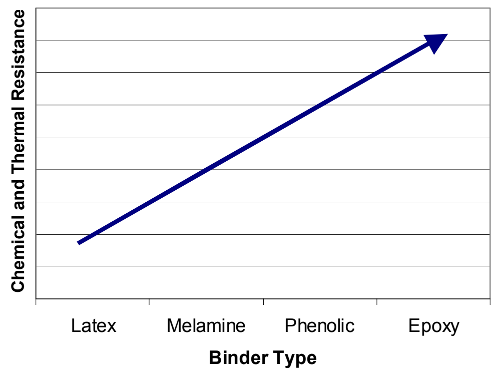
Nonwoven liquid filtration media are thermally or resin bonded and use polymers that are susceptible to thermal and chemical attack. The polymers can swell, fracture and/or soften which may change the filtration performance. The change in filtration performance can be gradual or sudden based on the concentration, exposure time, temperature and additives.

Thermoplastic binders used in resin bonded systems are often generically called latex but there are many different types with a range of chemical and thermal resistances. In general thermoplastic binders are good film formers and flow and are good at coating fibers or webs. They are flexible but soften when exposed to heat, which can be an advantageous or a disadvantage depending on the application. Many thermoplastic binders add crosslinking polymers to improve their chemical and thermal stability. When thermoplastic resins are crosslinked they may have a crosslinking bond every 50 to 100 carbon molecules.

Thermoset binders are used in applications that require higher thermal and chemical resistance. These polymers undergo a chemical change to produce a network or thermoset polymer. Thermoset binders are highly crosslinked, which produces a glassy or crystalline structure with no Tg. Thermosets will not soften or flow in the presence of heat. They can not be dissolved or continuously deformed because they will begin to decompose at lower concentrations and temperatures.

Wetlaid media typically contain latex type binders, which do not have broad chemical and thermal compatibility. Applications that require improved chemical compatibility use thermoset binders such as phenolics, melamines or epoxies. Phenolic binders are generally added in a post coat and cure step. The biggest downside to phenolic binders is flammability and waste disposal. Melamine and epoxy based binder systems can be applied in-line on a wetlaid process but are generally more costly than phenolics. Figure 3 shows the relative chemical and thermal compatibility of various wetlaid binders.

Figure 3 – Binder Compatibility



HYDRAULIC FLUIDS

There are many fluids used in hydraulic systems but they can be broken down into three categories; petroleum based oils, fire resistant fluids and biodegradable fluids. Petroleum based fluids are the most common. They are widely used due to their low cost, good lubricity and low toxicity. They are not generally used straight but are combined with corrosion, rust, foaming and wear inhibiting agents. There are generally two different types of fire resistant hydraulic fluids: phosphate esters and fluids with a high water content.

Phosphate esters are widely used in aerospace applications due to their good fire resistance and their ability to work over a wide range of temperatures. Phosphate esters are aggressive fluids that attack many polymers. High water based fluids come in three different types: oil in water emulsions, water in oil emulsions and water glycol. The oil in water emulsions typically contain 95% water and 5% oil with oil droplets dispersed throughout the water. The water in oil emulsions are between 40% and 60% water dispersed in oil. Due to their high oil content the fire resistance of these fluids is lower than the other types. Water glycol fluids typically contain 40% water and 60% glycol. This fluid is widely used since it has excellent fire resistance and can be used can be used at lower temperatures because of the antifreeze properties of the glycol.

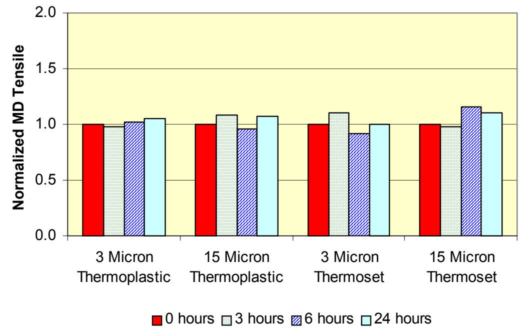
Biodegradable fluids are increasing in use, especially in Europe, due to concerns about the environmental impact of leaks and spills. The two most widely used biodegradable hydraulic fluids used are synthetic based diesters and vegetable based oils.

CHEMICAL AND THERMAL COMPATIBILITY

Wetlaid microglass media that is typically used in hydraulic filtration applications were tested for thermal and chemical compatibility. Thermoplastic and a thermoset resin bonded media with efficiencies at Beta 200 = 3 μm(c) and 15 μm(c) were tested. All the media had similar basis weight, thickness and binder content. Three samples of each media were tested for each condition.

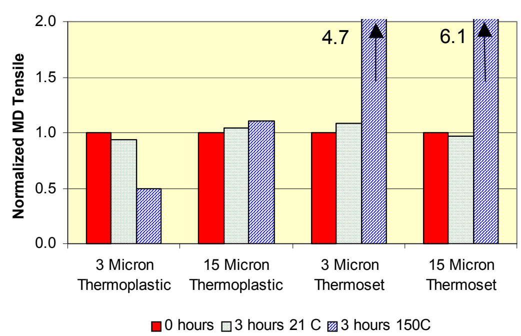
Dry media samples at each efficiency and with each binder system were exposed to 150°C air for 0, 3, 6 and 24 hours. Machine direction tensile strength measurements were made at each time interval for each sample type and are listed in figure 4. Due to differences in starting tensile values, all numbers were normalized for comparison. All of the media samples tested were thermally stable at 150°C for exposure of 24 hours or less. Analysis of the binder content showed that there was no measurable loss.

Figure 4. 150°C Air Exposure



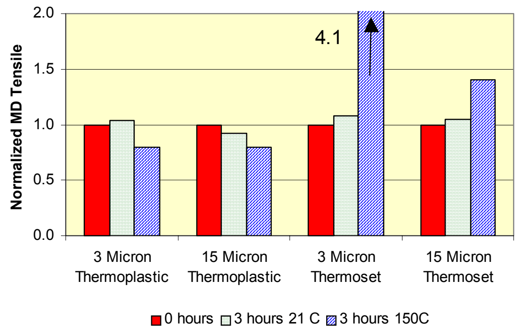
Media samples at each efficiency and with each binder system were soaked in a petroleum based hydraulic fluid for less than 1 minute to wet out the samples and for 3 hours at room temperature and 150°C. Each sample was sandwiched between two absorbent pads for 10 minutes to remove excess fluid. Machine direction wet tensile strength measurements were made at each condition for each sample type. The results are listed in figure 5. Due to differences in starting tensile values, all numbers were normalized for comparison. All of the samples tested at room temperature showed no statistically significant change in wet tensile strength. The latex binder samples, soaked at elevated temperature, had at best a slight improvement and at worst, a fifty-percent reduction in wet tensile strength. In contrast, the thermoset binder samples soaked at elevated temperature had, on average, a 5x improvement in wet tensile strength. The improvement in wet tensile strength is not due to temperature effects alone because no improvement was measured with samples exposed to hot air.

Figure 5. 150°C Petroleum Based Hydraulic Fluid



Media samples at each efficiency and with each binder system were soaked in a phosphate ester based hydraulic fluid for less than 1 minute to wet out the samples and for 3 hours at room temperature and 150°C. Each sample was sandwiched between two absorbent pads for 10 minutes to remove excess fluid. Machine direction wet tensile strength measurements were made at each condition for each sample type. The results are listed in figure 6. Due to differences in starting tensile values, all numbers were normalized for comparison. All of the samples tested at room temperature showed no statistically significant change in wet tensile strength. The latex binder samples, soaked at elevated temperature, had on average a 20% reduction in wet tensile strength. The thermoset binder samples soaked under the same conditions showed between a 40% and a 400% improvement in wet tensile strength.

Figure 6. 150°C Phosphate Ester

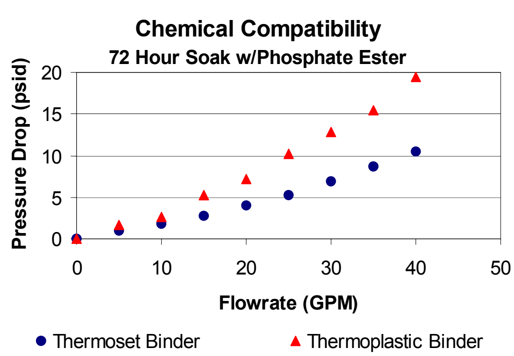


Reduction in strength is only one measurement of a hydraulic fluid's effect on the nonwoven filtration media. Media swelling and pressure drop increase is another important criteria. Micro fiberglass based wetlaid nonwoven filter media was tested for compatibility with a range of hydraulic fluids according to ISO 2943. A brief overview of the test method is listed below.

The filter is tested for fabrication integrity and failure of the element to exhibit a minimum bubble point, which is designated by the manufacturer, will eliminate that unit from testing. The element is rinsed in the test fluid to remove any previous test fluid. The filter is immersed in the desired test fluid for at least 72 hours. The immersion should be continuous and at a temperature at least 15C above the highest recommended operating temperature. The elevated temperature is used to accelerate a long life test at standard operating temperatures.

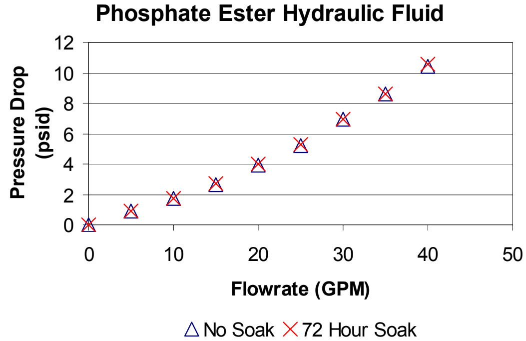
Six filters were produced with micro fiberglass based hydraulic filter media. Three of the filters contained media that used a thermoplastic binder system and three filters contained media with a thermoset binder. All six filters were soaked in phosphate ester at elevated temperatures for 72 hours and tested. Figure 7 is a plot of the pressure drop over a wide range of flowrates.

Figure 7



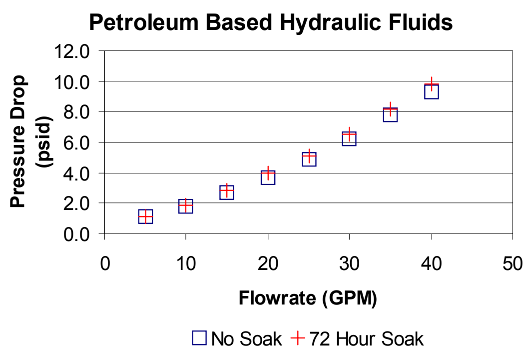
The thermoplastic binder exhibited on average an eighty-one percent higher pressure drop compared to the thermoset binder. Three additional filters with the same thermoset binder were tested using phosphate ester based hydraulic fluid but were not presoaked in the fluid at elevated temperature. Figure 8 compares the pressure drop of the filters at long and short exposure times.

Figure 8



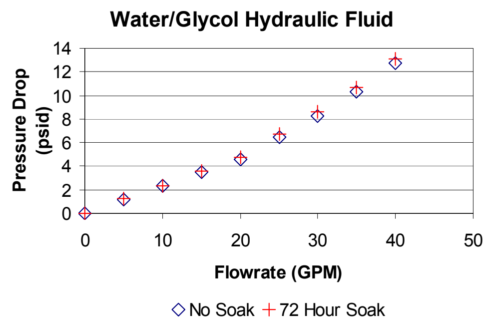
The average increase in pressure drop between the two sets of filters was 1.2%. That compares to a 5.1% increase in average pressure drop for filters soaked in a standard petroleum based hydraulic fluid at elevated temperature and filters with a short exposure during the test. Figure 9 compares the pressure drop increase of the two sets of filters with a standard petroleum based hydraulic fluid.

Figure 9



Water glycol based hydraulic fluids also present a compatibility problem with many types of media. A set of filters with the same thermoset binder was tested for pressure drop increase with and without prolonged exposure to a water glycol based hydraulic fluid. The average increase in pressure drop between the two sets of filters was three percent. Figure 10 is a plot of the average pressure drop increase over a range of flowrates with the water glycol based hydraulic fluid.

Figure 10



CONCLUSION

Wetlaid microglass media is typically used in hydraulic filtration. There are many different applications where many aggressive fluids and high temperatures are used. Hydraulic filter elements require media with broad chemical and thermal compatibility. Resin bonded wetlaid microglass media typically uses thermoplastic binders, which soften and flow when exposed to heat and tend to swell when exposed to aggressive fluids. This can cause the media to weaken which may result in filter integrity failures or to swell causing higher pressure drops.

Wetlaid microglass media produced with thermoset binders are chemically and thermally stable and show increasing media strength and no pressure drop increase with exposure time and temperature.

CONTACT

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