Filtration for Rotary Pumps
Introduction

Filtration used to protect rotary, positive displacement pumps is an important element for maximizing pump life and minimizing maintenance expense. Many systems using rotary pumps require a level of liquid cleanliness far different than the pump itself. For example, the loading of crude oil and fuel oils aboard tankers has virtually no solids limitations while turbomachinery lubrication or servo hydraulic systems may mandate system filtration in the 2 to 10 micron (millionths of a meter) range. This article will address filtration provisions intended to protect the rotary, positive displacement pump rather than the variety of systems these pumps serve.

Clearances

Rotary, positive displacement pumps include a great variety of designs, chief among which are gear, vane and screw pumps. Running clearances within these pumps can range from less than 0.001 inches (0.025 mm) to perhaps as much as 0.010 inches (0.254 mm) depending on pump size and pressure rating. Running clearances are those necessary gaps or spaces between stationary and rotating parts and between adjacent rotating pump components, figure 1. Single screw pumps literally have zero running clearances due to a slight, deliberate interference fit between the metallic rotor and the elastomeric stator. The clearance regions of rotary pumps are the most susceptible to damage and abrasion from solids, contaminants and foreign material. Internal slip flow (volumetric inefficiency) carries the liquid borne debris towards pump running clearances. This debris can cause jamming or breaking of pumping elements, scoring of clearance surfaces and abrasive erosion of clearance components. Jamming or breakage is catastrophic in nature and will normally cause immediate system shutdown with its attendant outage costs as well as extensive repair time and cost. Scoring and abrasion of clearance surfaces will usually reduce the pump output flow by allowing increased slip through increased clearances. This is usually detected as a loss in system discharge pressure due to the loss of pump flow rate. While more gradual, it still requires shutdown, albeit planned, and the expense to overhaul the pump.

Filtration

Filtration refers to the deliberate addition of components to the liquid system to remove undesirable solids. The term “filter” is more frequently applied to a component in the discharge side of the pump system and intended to protect downstream equipment. At least one installation of a 400 gpm (91 m³/h) high speed rotary lube oil pump was inspected after 60,000 hours operation and required only new gaskets, shaft seal and ball bearing during reassembly. This provides ample evidence that systems that stay clean can provide extraordinarily long pump life. Some recirculating liquid systems will have a return line filter that removes contaminants as the liquid is returned to its source before being pumped again back into the system. Return line filters are relatively inexpensive and very effective but limited to systems that can accommodate the backpressure imposed by the presence of such a device (see figure 2). Lubrication systems with gravity oil return to the reservoir normally do not provide enough pressure to effectively use a return line filter. On the inlet side of the pump, filtration devices are usually called “strainers”. The name implies a...
nuts, bolts, washers), weld rod stubs, unremoved port dust guards, lacing wire, rags, tools, lunch pails and a nearly endless list of things that would never be expected in a pumping system. In addition to such initial contaminant, many systems must accommodate ongoing levels of contaminant such as sand and carbonates found in transporting crude oil, highly abrasive dust ingress in hydraulic and lubrication systems associated with mining and ore handling machinery, not to mention sewage pumping, a subject requiring its own unique solutions to solids handling. Figure 3 illustrates particle size comparison with common items.

<table>
<thead>
<tr>
<th>Square Mesh (per inch)</th>
<th>Wire Diameter (inch)</th>
<th>Opening Size (INCH)</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.016</td>
<td>0.034</td>
<td>46.2%</td>
</tr>
<tr>
<td>40</td>
<td>0.010</td>
<td>0.015</td>
<td>36.0%</td>
</tr>
<tr>
<td>60</td>
<td>0.0075</td>
<td>0.0092</td>
<td>30.3%</td>
</tr>
<tr>
<td>80</td>
<td>0.0055</td>
<td>0.0070</td>
<td>31.4%</td>
</tr>
<tr>
<td>100</td>
<td>0.0045</td>
<td>0.0055</td>
<td>30.3%</td>
</tr>
</tbody>
</table>

For the same mesh size, larger diameter wire will decrease the open area and opening size. Conversely, smaller diameter wire will increase the open area and opening size. Opening size, pressure drop and contaminant holding capacity must all be considered together as none can be separated from the others. Fine strainers will clog faster and need more frequent cleaning unless they are very large (and expensive). On the other hand, neglecting pressure drop, they provide the maximum protection for the pump.

Contaminant

System contamination has many forms, comes in many sizes and can range from catastrophic to negligible in its impact. Fabrication debris is frequently the most serious source of contamination in new systems. Weld bead, slag and spatter, pipe scale, rust, machining chips, etc. all provide opportunities for pump failures or rapid wear outs. Other debris left from inattentive workmanship can be a danger to pumps as well such as extra flange fasteners (nuts, bolts, washers), weld rod stubs, unremoved port dust guards, lacing wire, rags, tools, lunch pails and a nearly endless list of things that would never be expected in a pumping system. In addition to such initial contaminant, many systems must accommodate ongoing levels of contaminant such as sand and carbonates found in transporting crude oil, highly abrasive dust ingress in hydraulic and lubrication systems associated with mining and ore handling machinery, not to mention sewage pumping, a subject requiring its own unique solutions to solids handling. Figure 3 illustrates particle size comparison with common items. The table below provides some hardness comparisons for common materials and gives a feel for how destructive some contaminants can be:

<table>
<thead>
<tr>
<th>Material</th>
<th>Knoop Hardness Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>163</td>
</tr>
<tr>
<td>Heat Treated Steel</td>
<td>360</td>
</tr>
<tr>
<td>Nickel</td>
<td>537</td>
</tr>
<tr>
<td>Sand</td>
<td>710</td>
</tr>
<tr>
<td>Chromium</td>
<td>935</td>
</tr>
<tr>
<td>Tungsten Carbide</td>
<td>1880</td>
</tr>
<tr>
<td>Diamond</td>
<td>7000</td>
</tr>
</tbody>
</table>
Strainer Types

There are numerous strainer designs available from many vendors. They range from a simple cone strainer, made from wire mesh cloth, that is trapped between flanges, to duplex, self cleaning, automated strainers. Many can be equipped with magnetic devices to attract and retain ferrous particles. The cone strainer shown in figure 4 is intended as a temporary device used to catch fabrication debris. It will not retain much quantity of contaminant, is awkward to service but is quite inexpensive. Cone strainers must be removed after initial system cleaning to prevent later plugging and collapse.

Submerged and simplex strainers, figure 5, and “Y” type strainers are intended for permanent installation. They are designed to allow ready access to the strainer element for cleaning or replacement. They do, however, require that the pumping system be shut down while the strainer is serviced. Their cost is moderate and they should be considered the minimum pump protection required for a reasonably well designed system. Some simplex strainers are available with manual or motor driven scrapper blades allowing a degree of strainer cleaning to be provided without interrupting pump operations. This self cleaning feature can be automated via timers or pressure switches such that minimal human intervention is needed.

Duplex strainers, figure 6, are more versatile, albeit more expensive, in that they allow transfer of flow from one strainer element to another without interruption of pump operations. One element can be cleaned or replaced while the system continues to operate. This strainer type is especially appropriate for systems whose operation is critical to a process or service and pump system outages must be minimized.

* Photos courtesy of Jamison Products, LP.
Strainer Pressure Drop

As with any strainer, the pressure loss across it should be measured and monitored or, preferably, alarmed. This is due to the fact that as a strainer does its job, contaminants accumulate in the strainer and gradually close off the open flow area. This area reduction leads to increasing pressure drop across the strainer. Excessive pressure loss in this area will reduce the pressure available to the pump (NPIPA) and cause cavitation with its attendant damage. In the worst case, the pressure difference across the strainer will cause the strainer element to collapse and be carried into the pump. This inevitably causes a complete and extensive failure of the pump. Always monitor or alarm the pressure loss across suction (inlet) side strainers.

Strainer Recommendations

If not impossible, it is at least economically impractical to prevent ALL contaminant from reaching a pump (see figure 7). Unfortunately, there is also no realistic strainer size that can be relied upon to prevent all pump wear from taking place. The practical nature of pump inlet side strainer protection dictates a compromise between what is affordable and practical vs what would be ideal.

For example, high viscosity liquids such as bunker fuels or asphalts will inherently cause more pressure loss through any strainer. This, in turn, reduces the pressure available to the pump inlet, itself a problem if allowed to fall too low. Consequently, viscous liquids will dictate relatively large strainer element openings for economic reasons. There is always the risk that one or more particles small enough to pass through such a strainer will cause damage. It is currently a risk that most pump users will have to live with as no practical alternatives exist. By the same token, low viscosity liquids allow the use of much finer strainer elements and thus better protection for the pump. Aside from contaminant large enough to do immediate damage, a high viscosity pump can generally afford more wear (increase in running clearances) before significant flow reduction occurs. On the other hand, the same degree of wear in a low viscosity pump will cause significant flow loss. Fortunately, these factors work in the general favor of the pump user.

Strainers should be selected in consultation with the pump supplier recognizing that no strainer system will be perfect.

Figure 7: Pump Rotor Damage Caused by Hard Contaminant

The list below can be used as a check sheet for the principle parameters regarding strainers:

1. Type (Cone, Simplex, “Y”, Duplex, etc.)
2. Materials of construction
3. Flow rating (at maximum liquid viscosity)
4. Port sizes and ratings (if applicable)
5. Strainer pressure rating (overall)
6. Strainer element opening size
   As a guideline, the following sizes can be used as a starting point for determining the appropriate strainer design:
   - Diluent < 5 cSt 60 mesh
   - Crude oil < 10 cSt 40 mesh
   - Crude oil < 20 cSt 20 mesh
   - Crude oil < 200 cSt 1/8" perforations
   - Crude oil < 500 cSt 3/16" perforations
   - Crude oil > 500 cSt 1/4" perforations
7. Strainer element open area (recommend 30 to 40% open area)
8. Design pressure drop when clean (at maximum liquid viscosity)
9. Maximum allowable pressure drop across a dirty, contaminated strainer.
   Caution: The inlet pressure to the pump must never be allowed to fall below the NPIPR required.
10. Applicable codes
11. Optional features
12. Cost

Conclusion

The objective of using an inlet strainer is to provide the pump with reasonable protection against likely contaminant hazards at an affordable cost while sizing and instrumenting such strainers so they provide their protection in a reliable manner over the long term.
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