Does Your Manifold Have Worm Holes?

Manifold Erosion Due to Cavitation

Cavitation is the formation of small bubbles in a liquid due to low pressures. The bubbles are dissolved gasses and liquid vapor.

Cavitation is caused by low pressures that result from high velocities when the fluid takes a pressure drop. For instance, when a fluid takes a pressure drop of 3000 psi (200 bar) across an orifice or a metering edge, the velocity reaches trans-sonic, if not supersonic, velocities. If one applied Bernoulli's theorem to these conditions, you would expect the pressure at the point of metering to approach a hard vacuum. This type of cavitation is very difficult to prevent.

Cavitation in and of itself does not cause any damage; it is the collapse of the bubbles that can be destructive. When the bubbles collapse, there is a shock wave generated that contains so much energy it can rip electrons loose from the fluid's molecules. This is apparent in the blue light given off; evidence of a phenomenon called sonoluminescence, or sound-generated light. The blue color of the light indicates that the temperatures involved are an order of magnitude higher than the surface of the sun. If the bubble happens to be close to a surface when it collapses, the shock wave will do damage at a molecular level, eroding material.

The key phrase in the preceding paragraph is "If the bubble happens to be close to a surface when it collapse.s" If there is sufficient pressure downstream of the metering edge, the bubble will collapse close to where it was formed (inside the cartridge valve) and will not do any damage. If the bubble collapses outside the cartridge, close to the manifold wall, material can begin to erode.

Most people visualize the phenomenon of cavitation erosion as high speed jets of oil blasting material away, similar to sand blasting. This is not the case. The bubbles are generated by high velocity but the damage is done by the collapse of the bubble. The damaged area is irregular in shape and may even turn corners.

The natural inclination is to open up the tank area of the cavity with an undercut to move the surface away from the high speed jets. Unfortunately, this lowers the downstream pressure and makes matters worse. In fact, the correct path to take is to leave the cavity as is and reduce the size of the tank passage.

Cavitation Observations

- The rule of thumb is that if you have a cavity-erosion problem, adding 5% backpressure will probably stop the erosion and 10% is a sure thing. The percentage is of the total drop across the valve. If there is a 3000-psi (200 bar) drop across the valve, a backpressure of 150 psi (10 bar), or 5% will prevent erosion.
- Switching a manifold from aluminum to ductile iron will reduce the rate of erosion by a factor of 10.
- Sun valves that are the most likely to cause erosion are balanced piston valves that modulate from the nose (port 1) to the side (port 2). These include pilot-operated relief valves and priority flow controls.

- Sun direct-acting reliefs (RD**), sequences (SC**), and pilot operated, balanced poppet reliefs (RP*S, RV*S, and RP*T) do not erode cavities because the actual metering of the fluid occurs inside the valve (the valve creates its own backpressure). Switching to one of these valves is easy as they use the same cavities and have the same flow paths as the balanced piston versions.
- Using a vented relief to load and unload a pump is a very common application, but it presents some potential problems. When the vent is blocked to bring the pump back up to pressure, the valve modulates the full pump flow from minimum up to existing system pressure. If the conditions are there for cavitation, each cycle can cause erosion. Adding downstream pressure can prevent problems, as can Sun's balanced poppet valves, the RV*S family.
- Most hydraulic systems are not designed to spill oil over a relief valve on a continuous basis. Often there is something wrong, such as a pump compensator that is set above the system relief.
- The solution for cavity erosion with the priority flow controls (FR** and FV**) is back pressure.
- The presence of cavitation is characterized by white noise. If you can eliminate the noise, you will eliminate the cavitation.
- Dissolved air in the fluid probably exacerbates cavitation erosion.
- High temperatures raise the vapor pressure and increase the likelihood of cavitation. When a fluid takes a pressure drop of 3000 psi (200 bar) its temperature increases by about 24°F (14°C). A normal fluid temperature of 160°F (70°C) becomes a somewhat high 184°F (84°C) immediately downstream of the valve. This is not due to the cavitation; it is just conservation of energy.
- If you seriously want to convert hydraulic power into heat, you need to allow for cavitation. The trick to making it work is to take the pressure drop in two or more stages.
- High specific gravity fluids such as water or phosphate esters can cause severe cavitation erosion damage to valves but do not seem to cause as much damage to manifolds. Once again, limiting pressure drop will lessen the problem.

Cavitation erosion is not exclusive to Sun Hydraulics. It is a natural phenomenon caused by what happens when a fluid experiences a large velocity increase. One does not need a screw-in cartridge valve to demonstrate this; a simple orifice or leak path will do.

Sun has a fixture that we use to demonstrate cavitation and its results; white noise, sonoluminescence and cavity erosion. We had a customer that was using all the excess horsepower of a machine to generate heat with the hydraulic system. The result was that the aluminum manifold would erode in a matter of hours. One of our engineers, Dick Clark, had a fixture built that has a clear plastic section around the discharge side of a relief valve. With this fixture, you can clearly see the erosion happening and hear the noise. The demonstration is quite graphic as you realize the material between you and the oil is being eaten away. One of the customers likened it to looking down the barrel of a loaded shotgun. As you increase backpressure, the stream of bubbles retreats back into the valve and the white noise goes away.

The same engineer, Dick Clark, used to quip that he had never seen a good electric crane or a hydraulic light bulb. I was reading a ***Discover*** magazine on an airplane and there was an article about sonoluminescence. The article described how the scientists created a bubble and then collapsed it with an acoustic transducer. The result was a flash of blue light. I made the connection to cavitation erosion. The next day I came into work and had the lab crew set up the cavitation fixture. When the lights were turned off the eerie blue light became very visible. We had our hydraulic light bulb! It takes about 20 hp (15 kW) to generate a feeble glow. The sonoluminescence demonstration is very popular, every one wants to see it and we have shown it to hundreds of people.

In summary, adding backpressure will stop or prevent cavity erosion. Changing manifold material from aluminum to ductile iron will greatly lessen the rate of erosion. Switching to a different design of valve will stop erosion.

For a video demonstration of sonoluminescence, Click Here!