Hydrocyclones for Separation Of Solids From Machine Tool Coolant

By Polytech-Filtration

Overview

A hydrocyclone uses a swirling flow of fluid to accelerate the separation of solid contaminants which would otherwise settle out of the fluid naturally, but over a much longer period of time. Contaminated coolant is pumped into the hydrocyclone feed connection tangentially to the hydrocyclone inside wall creating a swirling flow where the heavier particles move to the outside wall due centrifugal forces. At the bottom of hydrocyclone a restrictive "underflow" nozzle allows a portion of the flow, containing the heaviest concentration of solid contaminants to exit the hydrocyclone. The remaining flow reverses direction and exits the top of the hydrocyclone via the "overflow" connection.

Hydrocyclones have a fixed flow capacity. Systems are configured with multiple hydrocyclones to meet specific flow capacity requirements.

Advantages

- Greatly accelerates the natural settling rate of solid contaminants allowing faster turn over of coolant and smaller system size and coolant capacity than a comparable settling tank with or without a dragout type sludge conveyor.
- Best separation of granular solid contaminants.
- No filter media consumption.
- Capable of separating more than 3 pounds per hour of solid contaminants per gallon per minute coolant flow.
- Hydrocyclones have no moving parts for reliable low maintenance operation.
- Continuous flow minimizes machine operator involvement.
- At equilibrium solid contaminant concentration, hydrocyclones separate solids at the rate they are introduced to the coolant system.
- Hydrocyclones aerate fluid minimizing odors and acid production from anaerobic bacteria that feed on tramp oils in coolant.
- Multiple hydrocyclones can be run in parallel to proved required flow capacity.

Disadvantages

- Hydrocyclones are not effective on oil due to the viscosity.
- Low separation efficiency on very small particles.
- Low separation efficiency on flaky or stringy particles.
- Entrained air vortex aggravates foaming problems.
- Equilibrium solid contaminant concentration level may exceed process and/or fluid maintenance requirements.

- Hydrocyclones are subject to abrasive wear over time and need periodic maintenance.
- Large or stringy solid contaminants may clog the underflow nozzle, increasing internal wear and bypassing all contaminants to the clean side.
- Feed pumps work in contaminated fluid and may wear over time.
- Particle size separation efficiency varies with hydrocyclone size and is fixed in any particular design.

How it Works

High efficiency hydrocyclones generally have a conical shaped main body that tapers in from top to bottom. Contaminated coolant is pumped into the hydrocyclone main body via a tangential entry which creates a swirling flow around the outside perimeter. As the swirling flow travels down the length of the main body, the conical shape increases the speed of rotation and increases the inertia of the heavier particles which concentrate at the perimeter. At the bottom of the hydrocyclone, a restrictive (underflow) discharge nozzle allows only a small portion of the liquid to exit. This liquid is the portion along the outside wall of the hydrocyclone containing the greatest concentration of solid contaminants. The flow is still rotating rapidly as it exits the nozzle providing the characteristic conical underflow spray.

The rest of the fluid, unable to exit the underflow nozzle forms an inner vortex that reverses direction and flow towards the top of the hydrocyclone. At the very top of the main body, a vortex finder (a short tube centered in the hydrocyclone) provides a flow path to the hydrocyclone discharge that minimizes inner vortex interference with the tangential entry flow. The center of the inner vortex is well below atmospheric pressure so an axial center core of air is drawn into the hydrocyclone. This air core introduces a lot of air and can cause a great deal of foaming in the coolant if there is any tendency to foam.

An underflow discharge without the characteristic conical shape may be the result of clogging, internal bypassing or inadequate pressure drop across the hydrocyclone and will result in very poor separation performance.

On machine tool coolant systems, the underflow is directed to a either a hopper with an overflow that returns excess coolant to the system or a dragout settling tank where the solids can settle out for ultimate removal.

The separation efficiency for particle sizes varies with the size of the hydrocyclone. However, the flow capacity and tendency to clog varies as well. Most hydrocyclones are a compromise between the improved small particle separation efficiency of smaller hydrocyclones and the cost of ganging small hydrocyclones to meet specific flow capacity requirements and the need for trouble free operation.

In closed loop coolant filtration or separation system, the coolant will reach an equilibrium where the concentration of contaminants stabilize and the rate of contaminant input equals the rate of contaminant removal. The efficiency of the separation device for any given particle size determines the concentration of those particles in the coolant at the equilibrium level. In some applications, the level of contaminants present at this equilibrium level will be acceptable, producing good surface finishes, reasonable abrasive life and consistent coolant condition. In others it is simply confusing as contaminant particle size distribution testing measures the same level of contamination in the clean tank as in the dirty tank, despite the fact that the swarf trolley is continually filling with solids.

In some cases, the separation efficiency is so low that contaminant levels build to unacceptable levels. One application that falls into this category is cast iron grinding, where very small, low density carbon particles are produced from the iron. Hydrocyclones can't touch the carbon particles due to their small size and low density, so they concentrate until the coolant becomes black mud.

On large systems, the added cost for sidestream or kidney loop polishing filtration to keep the concentration of fines below a trouble threshold may be well justified in media savings over full media filtration and extended coolant life over separation alone.

While the attraction of a media free coolant system is undeniable, improved grinding capabilities, new abrasives, materials evolution and increasing finish requirements often push coolant clarity requirements beyond the equilibrium clarity capabilities of hydrocyclone separation systems.

Experience with similar applications is the best guide when considering new applications.