HYDRAULIC FLUID FLOW AND PRESSURE THEORY

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COMPRESSIBILITY

For simple hydraulic design it can be assumed oil is incompressible, however the compressibility and density of oil is a factor in sophisticated hydraulic components. Bulk modulas is a measure of incompressibility. The higher the bulk modulas the less compressible or stiffer the fluid.

Mathematically the bulk modulas is defined by $\beta = -V(\frac{\triangle P}{\triangle V})$ where: β = bulk modulas (psi)
V = original volume (in.^{3})
$\triangle P$ = change in pressure (psi)
$\triangle V$ = change in volume (in.^{3})

The bulk modulas of an oil changes somewhat with pressure and temperature, but within the operating ranges in most fluid power systems, this factor can be neglected. A typical value for oil is 250,000 psi.

EXAMPLE:

A 10-in.^{3} sample of oil is compressed in a cylinder until its pressure is increased from 100 to 2000 psi. If the bulk modulas equals 250,000 psi. find the change of volume of the oil.

SOLUTION: To solve for $\triangle V$, we have: $\triangle V = -V(\frac{\triangle P}{\beta}) = -10\ (\frac{1900}{250{,}000}) = -0.076$ in.^{3}

This represents only a 0.76% decrease in volume, which shows that the oil is highly incompressible.

PRESSURE WAVES

Another important consequence of the compressibility of fluids is that disturbances introduced at some point in the fluid propagate at a finite velocity. Fore example, if a fluid is flowing in a pipe and a valve at the outlet is suddenly closed (thereby creating a localized disturbance) the effect of the valve closure is not felt instantaneously upstream. If takes a finite time for the increased pressure created by the valve closure to propagate to an upstream location. The speed of sound or the speed of a pressure wave in oil is approximately 4200 feet per second. The speed of sound varies with temperature and density. The following are typical wave speeds for comparative purposes only:

SPEED OF SOUND IN OIL	**4200 FEET PER SECOND**
SPEED OF SOUND IN WATER	**4780 FEET PER SECOND**
SPEED OF SOUND IN AIR	**1200 FEET PER SECOND**
SPEED OF LIGHT	**186,000 MILES PER SECOND**