CAUSES AND CONSEQUENCES OF PRESSURE LOSS IN PIPES

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Changes in flow path area where a fluid may be accelerated and/or decelerated such as restriction orifices, pipe reducers and expanders, venturi meters etc. will result in some pressure lost. There are two components to the pressure loss/gain through an area change, the permanent pressure loss and the change due to acceleration. As the name suggests the permanent pressure loss is not recoverable, and like the pressure loss through ordinary fittings such as a pipe elbow, it is lost to friction, eddies, and noise. Pressure changes due to acceleration are reversible, for example in a system where the pipe area decreases, some potential energy in the form of pressure is converted to kinetic energy as the fluid is accelerated in the smaller pipe, reducing the fluid pressure in this pipe. In a perfect system if the fluid then entered a larger pipe and decelerated the kinetic energy of the fluid would be converted back into pressure [1, 2, 3, 4, 5, 6, 7].

The degree of permanent pressure lost through a pipe size change is dependent on the geometry of the size change. Generally the more abrupt the change the higher the losses, while more gradual changes result in much lower pressure drops[8].

When the development of gas turbines started, before Second World War, the idea was to use them for electric power generation, but with low power output and low thermal efficiency they were not competitive. Instead, gas turbines played an important role in developing military aircrafts, from propeller-driven to jet engine driven, at the end of Second World War. The use of gas turbines for power generation was small until the end of the 20th century, when they had reached high enough power output and thermal efficiency to compete with other power generation solutions[9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24].

The gas turbine in its simplest form can be seen in Figure 1, it consists of three main components; a compressor, combustion chamber and turbine, which are connected by a shaft. Air is being compressed in the compressor before it enters the combustion chamber, where fuel is injected and the mixture ignites. The hot working fluid then expands in the turbine, providing power, which is used to drive the compressor and either a generator, producing electricity, or for example a pump, providing mechanical work.

To achieve a higher power output from the turbine, and hence a higher efficiency, one important thing is the temperature after the combustion chamber. A higher temperature will give a higher power output, but the materials in the turbine is limiting. Therefore, to be able to increase the temperatures even further than the materials can manage, cooling of the components is crucial.[25, 26, 27, 28, 29, 30]

Fluid mechanics To understand the pressure drop in the cooling and secondary air system components, and how it is defined, some basic fluid mechanics need to be presented. Pressure and pressure losses The total pressure is defined as the pressure, or force per unit area, a flowing fluid which is brought to rest exerts on a face perpendicular to the flow direction, and can be divided into a static and dynamic pressure. The static pressure is the momentum associated with motions of the molecules at a point in a fluid flow, while the dynamic pressure represents the kinetic energy of the fluid [31, 32, 33, 34, 35, 36, 37, 38, 39, 40].

How do you calculate the pressure drop?

One way to calculate it is using the Darcy-Weisbach equation, which is: $\Delta Pf = f * (L/D) * (\rho v^2/2)$ where ΔPf is the frictional pressure drop, f is the friction factor, L is the pipe length, D is the pipe diameter, ρ is the fluid density, and v is the fluid velocity. Simply put, pressure drop is the difference in total pressure between two points in a fluid-carrying network. When a liquid material enters one end of a piping system, and leaves the other, pressure drop, or pressure loss, will occur.

How do you calculate pressure drop in a horizontal pipe?

Pressure Drop Formula

ΔP=Head loss in a pipe (ft)

L = Pipe length (ft)

〖 ϑ〗^2= Velocity of the fluid flow rate inside the pipe (ft/second)

D= Pipe internal diameter (ft)

= Pipe roughness / Pipe friction factor {f = [1.14 + 2 log10(D/e)]-2} and then iteratively f = {-2*log10[((e/D)/3.7)+(2.51/(Re*(f1/2))]}-2. [4]

The pressure drop in a pipe arises from friction between the fluid and the pipe wall, changes in flow direction, blockages, and alterations in pipe diameter. Pressure drop can be calculated using the Darcy-Weisbach formula. In a pipeline system consisting of multiple pipes, valves, and fittings, the total pressure drop is the sum of the pressure drops in each component [41, 42, 43, 44, 45, 46, 47, 48, 49, 50].

The pressure drop equation (Darcy Weisbach formula) is given by,

ΔP= f (Lϑ^2)/D2g

Example

Determine the pressure drop of water in a 100 m long pipe having a diameter of 0.1 m. Take the friction factor as 0.03 and flow velocity as 30 m/s.

L = 100 m

D = 0.1 m

f = 0.03

V = 30 m/s

ρ = 1000 kg/m3

Substituting these values in the above equation, the pressure drop = 13.5 MPa, which is quite significant. This would require strong, high-quality equipment to withstand the pressure and maintain efficient operation. It also means the pump must generate a pressure significantly above 13.5 MPa to maintain the desired water flow rate. This requires high energy consumption and increases operational costs. Therefore, it is essential to consider pressure drop when designing and operating the system[51, 52, 53, 54, 55, 56, 57].

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