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DESIGNING OF SUSTAINABLE CRYOGENIC DELIVERY SETUP FOR MACHINING

Objective:
To design a sustainable cryogenic fluid delivery setup for machining

Methodology:
Method used to design delivery pipe is using a steady flow energy equation.
Steady flow energy equation consider effect of both pressure and temperature of fluid.
First point was taken at the exit of cylinder and second point was taken at end of the pipe.
Suitable nozzle have to selected to get desired outlet velocity.

Total friction losses $H = h_{l(Pipe)} + h_{l(Fittings)} + h_{l(Entry\ and\ exit\ losses)}$

Friction loss in pipe $h_{l(pipe)} = \frac{f_d L V^2}{2gd}$

Friction loss in Pipe fittings $h_{l(Pipe\ fitting)} = \frac{kV^2}{2g}$

Losses at entry and exit $h_{l(Entry\ and\ exit\ losses)} = \frac{kV^2}{2g}$

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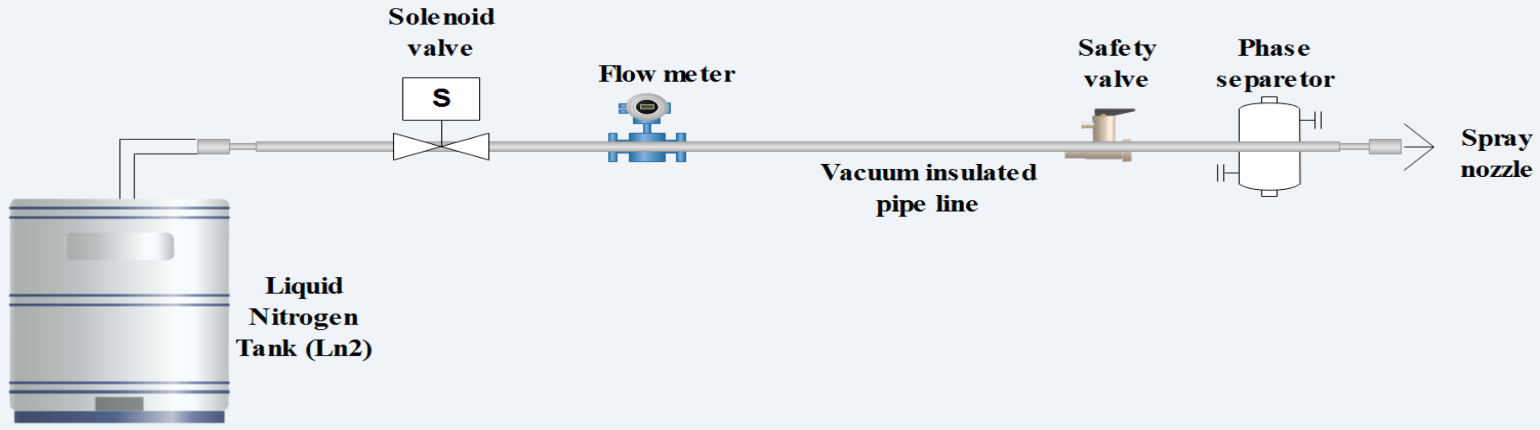
Abstract
The aim of this study is to design a sustainable cryogenic delivery setup for machining. Main concern, while designing the system, is safety, desired flow rate and phase change. Safety concern can be overcome by placing a safety valve in the line, desired flow rate can be achieved by choosing suitable pipe diameter and nozzle dimension, and for phase change, phase separator and vacuum insulated pipe is used. Pipe diameter is designed using steady flow energy equation. At the end, a schematic of proposed system is also provided.

Assumption

- Perfect insulation is assumed, no phase change of cryogenic fluid while flowing through pipe.



Designing of delivery setup by using steady flow energy equation:

POINT-1, Pressure = 15 bar, Temperature= -196°C (@ cylinder outlet)

- Properties of liquid nitrogen at this point Specific enthalpy = -121.144 KJ/Kg, density = 808.396 Kg/m^3.
- POINT-2, Pressure = 1 bar, Temperature= -19°C (@nozzle outlet).
- Properties of liquid nitrogen at this point Specific enthalpy(h) = 91 KJ/Kg, Density = 808.396 Kg/m^3.
- Steady flow energy equation $h_1 + \frac{v^2{}_1}{2} = h_2 + \frac{v^2{}_2}{2} + Q$
- (Assumption - temperature is decreased by 6 degree centigrade due to heat flow and other losses, which can be calculated by given equations in table).
- Applying steady flow energy equation between these points ($V_1 = 0$ at inlet)
- Outlet velocity $V_2 = 20.62$.
- Diameter corresponding to flow rate of 0.7 liter/min, by continuity equation Q = AV, D = 0.8 mm.
- Considering factor of safety for high expansion ratio of liquid nitrogen approx. diameter D = 10 mm.
- Contraction nozzle dimension - inlet diameter = 10 mm and outlet diameter = 3 mm. Final velocity at the exit of the nozzle will be 1.65 m/s
- Desirable flow rate and outlet nozzle velocity can be obtained by choosing suitable nozzle diameter.

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