Tutorial

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Ex.17: Using the Bingham plastic and power-law models, determine the various pressure drops, nozzle velocity and nozzle sizes for a section of **12.25** in (**311**mm) hole. Two pumps are used to provide **700** gpm (**2650** l/min). **The Data:**

- Plastic viscosity = **12** cp, Yield point = **12** lb/100 ft^2 Mud weight = **8.8** lb/gal
- Drillpipe (ID = **4.276** in, OD = **5** in, length = **6480** ft)
- Drill collars (ID = **2.875** in, OD = **8** in, length = **620** ft (**189** m))
- Last casing was **13.375** in with an ID of **12.565** in. **13.375** in casing was set at **2550** ft.
- The two pumps are to be operated at a maximum standpipe pressure of **2200** psi.
- Assume a surface equipment type of **4**.

Power law model:

Surface losses

- ΔP_s or $P_1 = E \times \rho^{0.8} \times Q^{1.8} \times PV^{0.2}$
- ΔP_s or $P_1 = 4.2 \times 10^{-5} \times 8.8^{0.8} \times 700^{1.8} \times 12^{0.2} =$ **52 psi**
- $\theta_{600} = 2 \times PV + YP = 2 \times 12 + 12 = 36$

- θ_{300} = PV + YP = 12 + 12 = 24

- $n = 3.32 \log \frac{\theta_{600}}{\theta_{300}}$

- $n = 3.32 \log \frac{36}{24} = 0.584$

- $k = \frac{\theta_{300}}{511^{n}}$

- $k = \frac{24}{511^{0.585}} = 0.628$

Pipe losses

Pressure losses inside drill pipe $\acute{V}=\frac{24.5\times Q}{D^2}=\frac{24.5\times 700}{(4.276)^2}=937.97\ \text{ft/min}$

- $V_c=\left(\frac{5.82\times 10^4\times K}{\rho}\right)^{\left(\frac{1}{2-n}\right)}\left(\frac{1.6\times(3n+1)}{D\times 4n}\right)^{\left(\frac{n}{2-n}\right)}=\left(\frac{5.82\times 10^4\times 0.628}{8.8}\right)^{\left(\frac{1}{2-0.584}\right)}\left(\frac{1.6\times(3\times 0.584+1)}{4.276\times 4\times 0.584}\right)^{\left(\frac{0.584}{2-0.584}\right)}$

$=256\ \text{ft/min}$

- Since $\acute{V}>V_c$, flow is turbulent and pressure drop inside drill pipe is calculated from:

- $P=\frac{8.91\times 10^{-5}\times\rho^{0.8}\times Q^{1.8}\times PV^{0.2}\times L}{(D)^{4.8}}=\frac{8.91\times 10^{-5}\times 8.8^{0.8}\times 700^{1.8}\times 12^{0.2}\times 6480}{(4.276)^{4.8}}=\mathbf{668.45\ psi}$

Pressure losses inside drill collars

- $\acute{V} = \frac{24.5 \times Q}{D^2} = \frac{24.5 \times 700}{(2.875)^2} = 2074.85 \text{ ft/min}$

- $V_c = \left(\frac{5.82 \times 10^4 \times K}{\rho}\right)^{\left(\frac{1}{2-n}\right)} \left(\frac{1.6 \times (3n+1)}{D \times 4n}\right)^{\left(\frac{n}{2-n}\right)} = \left(\frac{5.82 \times 10^4 \times 0.628}{8.8}\right)^{\left(\frac{1}{2-0.584}\right)} \left(\frac{1.6 \times (3 \times 0.584 + 1)}{2.875 \times 4 \times 0.584}\right)^{\left(\frac{0.584}{2-0.584}\right)}$

$= 301.8 \text{ ft/min}$

- Since $\acute{V} > V_c$, flow is turbulent and pressure loss inside drill collars P_3 is determined from:

- $P_3 = \frac{8.91 \times 10^{-5} \times \rho^{0.8} \times Q^{1.8} \times PV^{0.2} \times L}{(D)^{4.8}} = \frac{8.91 \times 10^{-5} \times 8.8^{0.8} \times 700^{1.8} \times 12^{0.2} \times 620}{(2.875)^{4.8}} = \mathbf{429.93 \text{ psi}}$

Annular pressure losses /Pressure losses around drill collars

- $\acute{V} = \frac{24.5 \times Q}{D_{oh}^2 - OD_{dc}^2} = \frac{24.5 \times 700}{12.25^2 - 8^2} = 199.27 \text{ ft/min}$

- $V_c = \left(\frac{3.878 \times 10^4 \times K}{\rho}\right)^{\left(\frac{1}{2-n}\right)} \left(\frac{2.4 \times (2n+1)}{(D_{oh} - OD_{dc}) \times 3n}\right)^{\left(\frac{n}{2-n}\right)} = \left(\frac{3.878 \times 10^4 \times 0.628}{8.8}\right)^{\left(\frac{1}{2-0.584}\right)} \left(\frac{2.4 \times (2 \times 0.584 + 1)}{(12.25 - 8) \times 3 \times 0.584}\right)^{\left(\frac{0.584}{2-0.584}\right)}$

$= 232.6 \text{ ft/min}$

- Since $V_c > \acute{V}$, flow is laminar and pressure loss around drill collars is calculated from:

- $P_4 = \left(\frac{KL}{300 D_e}\right) \left(\frac{2.4 \acute{V} \times (3n+1)}{D_e \times 3n}\right)^n = \left(\frac{0.628 \times 620}{300(12.25 - 8)}\right) \left(\frac{2.4 \times 199 \times (3 \times 0.584 + 1)}{(12.25 - 8) \times 3 \times 0.584}\right)^{0.584} = \mathbf{6.3\ psi}$

Open hole section- Around Drillpipe

- $\acute{V} = \frac{24.5 \times Q}{D_{oh}^2 - OD_{dp}^2} = \frac{24.5 \times 700}{12.25^2 - 5^2} = 137.13 \text{ ft/min}$

- $V_c = \left(\frac{3.878 \times 10^4 \times K}{\rho}\right)^{\left(\frac{1}{2-n}\right)} \left(\frac{2.4 \times (2n+1)}{(D_{oh} - OD_{dp}) \times 3n}\right)^{\left(\frac{n}{2-n}\right)} = \left(\frac{3.878 \times 10^4 \times 0.628}{8.8}\right)^{\left(\frac{1}{2-0.584}\right)} \left(\frac{2.4 \times (2 \times 0.584 + 1)}{(12.25 - 5) \times 3 \times 0.584}\right)^{\left(\frac{0.584}{2-0.584}\right)} = 229.6 \text{ f/min}$
- Since $V_c > \acute{V}$, flow is laminar and the pressure loss around the drillpipe in the open-hole section is determined from:
- $P_5 = \left(\frac{KL}{300 D_e}\right) \left(\frac{2.4 \acute{V} \times (3n+1)}{D_e \times 3n}\right)^n = \left(\frac{0.628 \times 3930}{300(12.25 - 5)}\right) \left(\frac{2.4 \times 137 \times (3 \times 0.584 + 1)}{(12.25 - 5) \times 3 \times 0.584}\right)^{0.584} = \mathbf{13.76 \text{ psi}}$
- (Where L = 6480 - 2550 = 3930 ft, and L = length of drillpipe in the open-hole section).

Pressure losses around drillpipe: Cased hole section

- $\acute{V} = \frac{24.5\times Q}{D_c^2 - OD_{dp}^2} = \frac{24.5\times 700}{12.565^2 - 5^2} = 129\ ft/min$

- $V_c = \left(\frac{3.878\times 10^4\times K}{\rho}\right)^{\left(\frac{1}{2-n}\right)}\left(\frac{2.4\times(2n+1)}{D_e\times 3n}\right)^{\left(\frac{n}{2-n}\right)} = \left(\frac{3.878\times 10^4\times K}{\rho}\right)^{\left(\frac{1}{2-n}\right)}\left(\frac{2.4\times(2n+1)}{(D_c - OD_{dp})\times 3n}\right)^{\left(\frac{n}{2-n}\right)}$

- $V_c = \left(\frac{3.878\times 10^4\times 0.628}{8.8}\right)^{\left(\frac{1}{2-0.584}\right)}\left(\frac{2.4\times(2\times 0.584+1)}{(12.565-5)\times 3\times 0.584}\right)^{\left(\frac{0.584}{2-0.584}\right)} = 183.38\ ft/min$

- Since $V_c > \acute{V}$, flow is laminar and the pressure loss around the drillpipe in the cased hole is determined from:

- $P_6 = \left(\frac{KL}{300D_e}\right)\left(\frac{2.4\acute{V}\times(3n+1)}{D_e\times 3n}\right)^n = \left(\frac{0.628\times 2550}{300(12.565-5)}\right)\left(\frac{2.4\times 129\times(3\times 0.584+1)}{(12.565-5)\times 3\times 0.584}\right)^{0.584} = \mathbf{8\ psi}$

Pressure drops across bit

- Total pressure loss in circulating system, except bit.
- $P_{Total} = P_1 + P_2 + P_3 + P_4 + P_5 + P_6$
- =52 + 668.45 + 429.93 +8+ 13.76+6.3 =1178.44 psi
- Therefore, pressure drop available for bit (P_{bit})
- P_{bit} =2200 -1164.85 = **1021.56 psi**

Determine nozzle velocity (ft/s)

- $V_n = 33.36\sqrt{\frac{P_{bit}}{\rho}}$

- $V_n = 33.36\sqrt{\frac{1021.56}{8.8}} = 359.43\ ft/s$

Determine total area of nozzles (in^2)

- $A_n = \frac{0.32 * Q}{V_n}$

- $A_n = \frac{0.32 * 700}{359.43} = 0.623 \text{ in}^2$
- Nozzle size (in multiples of (1/32)
- $d_n = 32\sqrt{\frac{4 * A_n}{3 * \pi}}$
- $d_n = 32\sqrt{\frac{4 * 0.623}{3 * \pi}} = 16.46$
- Hence, select 1 nozzles of size 17 and 2 of size 16.

B.H.C.P.

- B.H.C.P. = $0.052\rho D + \Delta P_{ap} + \Delta P_{ac}$
- = 0.052*8.8*7100 + 21.76 + 6.3 = **3277 psi**
- $\mathrm{E.C.D.} = \mathrm{IMW} + \frac{\Delta_{ap}+\Delta_{ac}}{0.052\times D}$
- $\mathrm{E.C.D.} = 8.8 + \frac{21.76+6.3}{0.052\times 7100} = \mathbf{8.876\ lb\ /\ gal}$

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