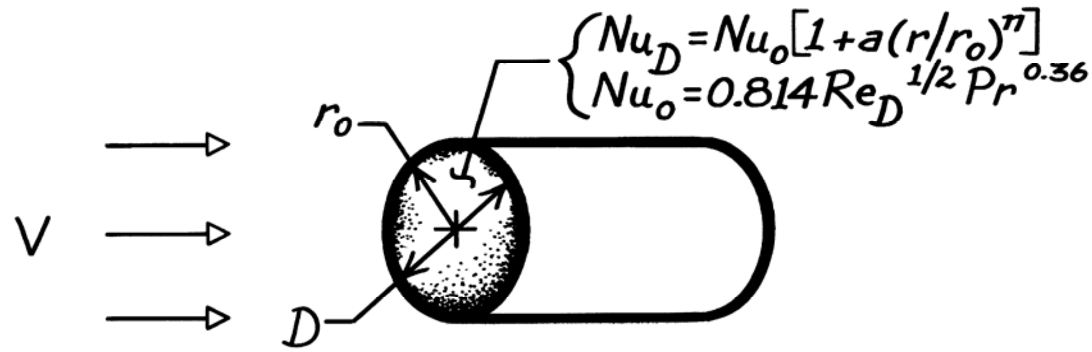
PROBLEM 6.14

KNOWN: Radial distribution of local convection coefficient for flow normal to a circular disk.

FIND: Expression for average Nusselt number.

SCHEMATIC:



ASSUMPTIONS: Constant properties.

ANALYSIS: The average convection coefficient is

$$\bar{h} = \frac{1}{A_s}\int_{A_s} h dA_s$$

$$\bar{h} = \frac{1}{\pi r_o^2}\int_0^{r_o} \frac{k}{D} Nu_o\left[1 + a\left(r/r_o\right)^n\right] 2\pi\, rdr$$

$$\bar{h} = \frac{kNu_o}{r_o^3}\left[\frac{r^2}{2} + \frac{ar^{n+2}}{(n+2)r_o^n}\right]_0^{r_o}$$

where Nu_o is the Nusselt number at the stagnation point (r = 0). Hence,

$$\overline{Nu}_D = \frac{\bar{h}D}{k} = 2Nu_o\left[\frac{(r/r_o)^2}{2} + \frac{a}{(n+2)}\left(\frac{r}{r_o}\right)^{n+2}\right]_0^{r_o}$$

$$\overline{Nu}_D = Nu_o\left[1 + 2a/(n+2)\right]$$

$$\overline{Nu}_D = \left[1 + 2a/(n+2)\right] 0.814 Re_D^{1/2} Pr^{0.36}.$$ <

COMMENTS: The increase in h(r) with r may be explained in terms of the sharp turn which the boundary layer flow must make around the edge of the disk. The boundary layer accelerates and its thickness decreases as it makes the turn, causing the local convection coefficient to increase.