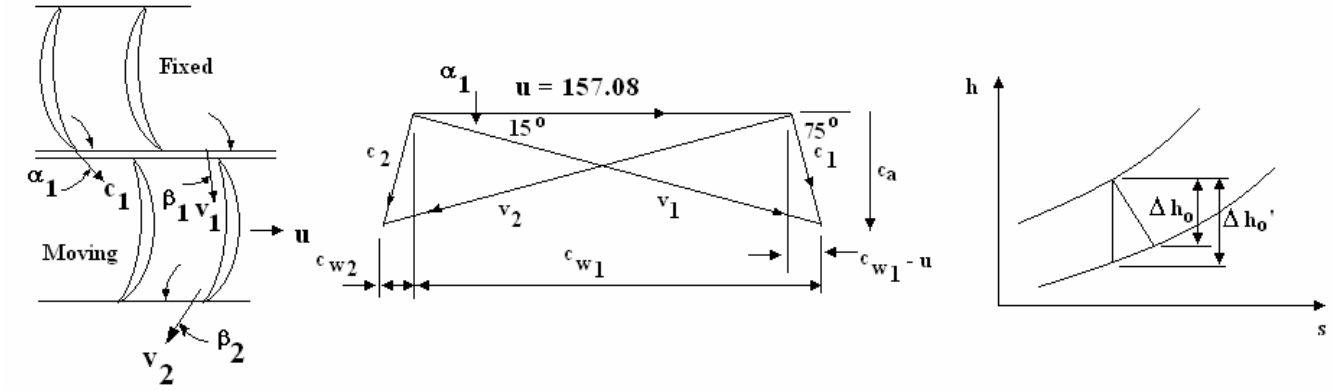
THERMODYNAMICS 201 2003

Q.7 Fifteen successive stages of an axial-flow reaction steam turbine have blades with constant inlet and outlet angles of 15° and 75° respectively. The mean diameter of the blade rows is 1.0 m and the speed of rotation is 50 rev/s. The axial velocity is constant throughout the stages. The steam inlet conditions to the turbine are 15 bar and 300°C and the outlet pressure is 0.24 bar.

Determine:
(a) all relevant blade and steam velocities and sketch the velocity diagram
(b) the specific enthalpy drop per stage
(c) the overall efficiency of the turbine.

If there is a reheat factor between each turbine stage of 1.03 determine the stage efficiency.
Note. As there is constant axial velocity and all blades are of the same geometry kinetic energy can be ignored.



$u = \pi ND = \pi \times 50 \times 1 = 157.08$ m/s
$\tan\alpha_1 = c_a/c_{w1}$
$c_{w1}\tan 15 = (c_{w1} - u)\tan 75 \quad 0.269\, c_{w1} = 3.732(c_{w1} - 157.08)$
$0.269\, c_{w1} = 3.732 c_{w1} - 586.23$
$586.23 = 3.463\, c_{w1}$
$c_{w1} = 169.28$ m/s
$c_{w2} = c_{w1} - u = 169.28 - 157.08 = 12.2$ m/s
$c_a = c_{w2}\tan\beta_2 = 12.2 \tan 75 = 45.55$ m/s
$\Delta c_w = 169.28 + 12.2 = 181.5$ m/s

Stage enthalpy change $\Delta h_s = u\, \Delta c_w = 157.08 \times 181.5 = 28507$ J/kg
For 15 stages $\Delta h_o = 15 \times 28.507 = 427.6$ kJ/k

$h_1 = 3039$ kJ/kg $\quad s_1 = 6.919$ kJ/kg K
$s_1 = s_2 = s_f + x_{sfg}$ at 0.24 bar
$6.919 = 0.882 + 6.962\, x \quad x = 0.867$
$h_2 = h_f + h_{sfg}$ at 0.24 bar
$h_2 = 268 + (2348)(0.867) = 2304$ kJ/kg
Ideal enthalpy drop = 3039 – 2304 = 735 kJ/kg
Overall Efficiency $\eta_o = 427.6/735 = 58.2\%$
$\eta_o = \eta_s \times$ Reheat Factor
$0.582 = \eta_s \times 1.03$
$\eta_s = 0.565$ or 56.5 %