Tutorial on Radial Turbines

- A small inward flow radial turbine comprising of a ring of nozzle blades, a radial vaned rotor and an axial diffuser, operates with a total-total efficiency of 90 %. At turbine entry, the stagnation pressure and temperature of the gas is 400 kPa and 1140 K, respectively. The flow leaving the turbine is diffused to a pressure of 100 kPa and has negligible final velocity. Given that the flow is just choked at the nozzle exit, determine the impeller peripheral speed and the flow outlet angle from the nozzles. Assume that the inlet tangential velocity is equal to the blade speed and that the exit tangential velocity is zero.

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Since $C_{w2}=U_2$ and $C_{w3}=0$

$\Delta w=h_{01}-h_{03}=U_2^2$

The total to static efficiency, $\eta_{tt}=(h_{01}-h_{04})/(h_{01}-h_{04ss})$

$=U_2^2/\{c_p\ T_{01}(1-(T_{04ss}/T_{01}))\}$

Substituting and simplifying, **U_2=587.4 m/s**

$M_2=C_2/a_2=(U_2/a_2)\ \mathrm{cosec}\ \alpha_2$; given that $M_2=1$ and $h_{01}=h_{02}$

$C_pT_{01} = C_p\ T_2 + ½\ C_2^2 = C_p\ T_2 + ½\ U_2^2\mathrm{cosec}^2\alpha_2$

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Therefore, $T_2/T_{01} = 1 - ½(\gamma-1)\ (U_2/a_{01})^2 \mathrm{cosec}^2\alpha_2$

Where, $c_p/T_{01} = \gamma R T_{01}/(\gamma-1) = a_{01}{}^2/(\gamma-1)$

Also, $T_2/T_{01} = (a_2/a_{01})^2 = U_2{}^2 \mathrm{cosec}^2\alpha_2\ /(M_2 a_{01})^2$

Combining the above equations,

$\sin\alpha_2 = (U_2/a_{01})(½(\gamma-1) + 1/M_2{}^2)^{½}$

Substituting, $\boldsymbol{\alpha_2 = 73.88^o}$