Unified Engineering Spring 2008
Thermodynamics & Propulsion Z. S. Spakovszky

(Add a short summary of the concepts you are using to solve the problem)

Problem T12

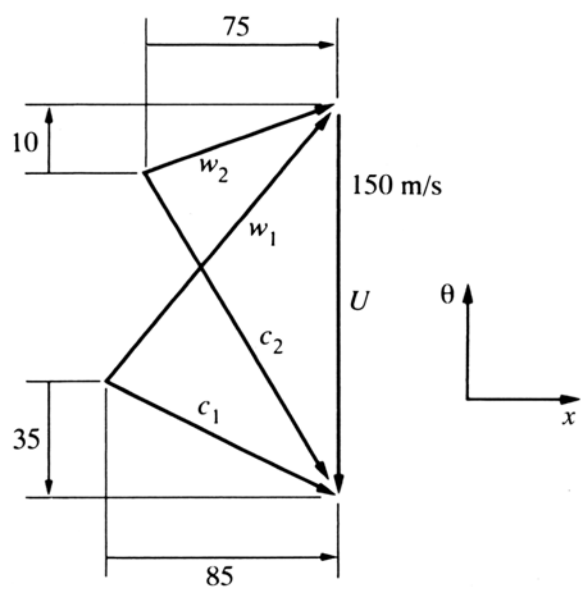
At a certain operating condition the velocity triangles for an axial compressor stage are as shown in the figure below. The subscripts 1 and 2 denote entrance to the rotor and stator, respectively. Station 3 is at the exit of the stator. The stage is designed such that the absolute velocity vector at the exit of the stator, c_3, is equivalent to the absolute velocity vector entering the rotor, c_1. This is called a repeating stage. The stagnation temperature and pressure at the entrance to the rotor are 340 K and 185 kPa. Neglect frictional effects and assume air to be an ideal gas with constant specific heats, γ = 1.4 and R = 287 J/kg-K.

a) Draw an *h*-*s* diagram and sketch the static and the stagnation states through the compressor stage (label all stations and indicate the work transfer where applicable).

b) Determine the specific compressor shaft work.

c) Find the stagnation and static temperatures at stations 1, 2, and 3.

d) Find the stagnation and static pressures at stations 1, 2, and 3.



(Add a short summary of the concepts you are using to solve the problem)

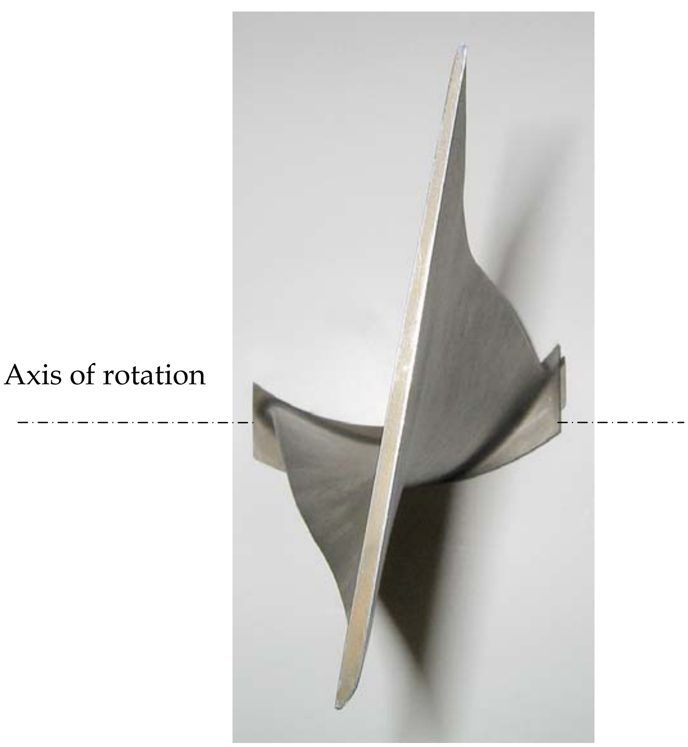
Problem T13

Consider the last stage of a low-pressure steam turbine. I have such a turbine rotor blade in my office (see pictures below) and we wish to estimate its performance. You are asked to reconstruct the velocity triangles near the hub using the blade geometry shown in the picture. The following assumptions can be made. The steam power plant operates in Europe where the frequency of the alternating current is 50 Hz (the turbine thus rotates at 50 Hz). In the relative frame at the tip, the flow leaves the rotor blade at the speed of sound. Downstream of the rotor the flow in the absolute frame has zero swirl at all radial stations. The axial velocity can be assumed constant throughout, that is $c_{x1}(r) = c_{x2}(r) = c_x$. At exit conditions the speed of sound of steam is 470 m/s and the density of steam is 0.59 kg/m^3 respectively.

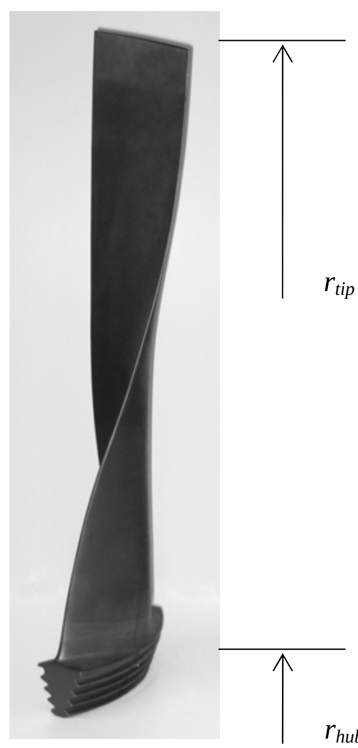
a) Consider the flow in the rotor frame leaving the blade tip (use the photo to estimate the blade tip angle). Determine the blade tip radius r_{tip} and the axial velocity c_x.

b) Draw the velocity triangles at the hub section (use the photo to estimate the blade metal angles). Determine the blade hub radius r_{hub} and the steam mass flow through the stage.

c) Find the shaft power of the turbine stage (you can assume that the specific shaft work is constant along the blade span).



Top view – flow is from left to right



Side view