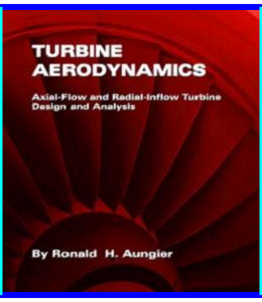
TURBOMACHINERY
AERODYNAMICS
CONSULTING

Industrial Compressor & Turbine Design, Performance Analysis, Application and Troubleshooting



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Subject: Geometry required for a radial-inflow turbine aerodynamic performance analysis using Program *RIFT*.

Reference: Aungier, R. H., ***Turbine Aerodynamics: Axial-Flow and Radial-Inflow Turbine Design and Analysis*** (ASME Press, New York, 2006).

The geometry specifications required for a radial-inflow turbine stage aerodynamic performance analysis with Program *RIFT* are described in the following pages. Supply geometry only for those components that are actually included in the stage. Any geometry not known must be estimated, which may compromise the prediction accuracy. Usually an inlet volute is the first component in the stage. However, the analysis can be started with a general inlet station instead. This can be useful when analyzing a component by itself.

I. Specify the Units Used for the Input Data

Length __________ Pressure __________

II. Inlet Station Geometry (if not starting the analysis with a volute)

The basic geometry for the inlet station is the passage radius, passage width and flow angle with respect to the tangential direction (if not supplying inlet volute geometry).

Mean radius -- ______________

Passage width -- ______________

Flow angle with tangent -- ______________

II. Inlet Volute Geometry

The basic geometry for the inlet volute is illustrated on figure 1. Data are supplied at the inlet, mean and discharge stations. For a conventional scroll-type volute, the data at the mean station can be omitted. For a conventional collector or plenum type, (circumferentially uniform area) the mean station data will be identical to the inlet station values. Other variations can also be modeled. The discharge (station 3) is the axisymmetric annular passage through which all of the flow exits the volute.

Volute rms Surface finish ------------------------------------ ______________

Inlet Area, A_1 -- ______________

Inlet mean radius, r_1 --- ______________

(Optional) mean area, A_2 -------------------------------------- ______________

(Optional) mean radius, r_2 ------------------------------------ ______________

Discharge radius r_3 -- ______________

Discharge passage width b_3 ------------------------------------ ______________

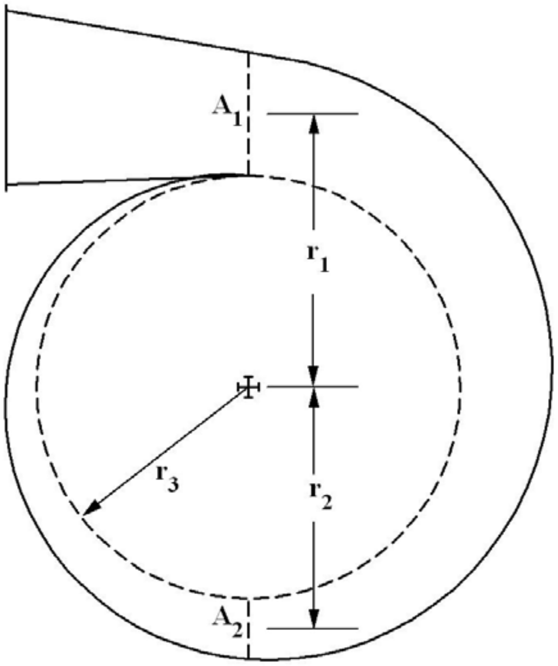

Figure 1: Volute Geometry

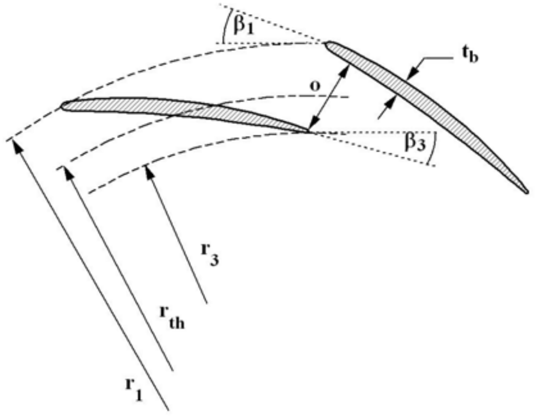

Figure 2: Nozzle Geometry

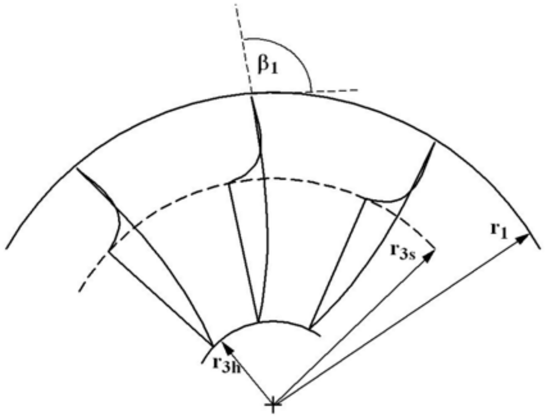

Figure 3: Front View of Impeller

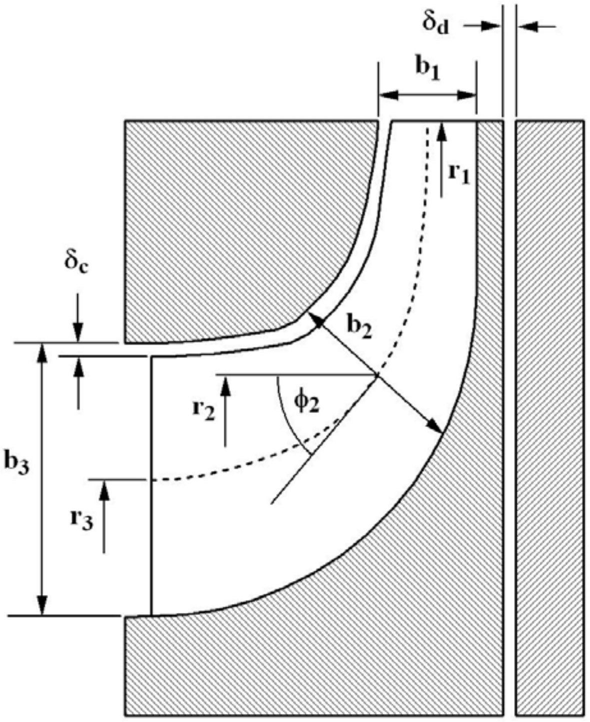

Figure 4: Side View of Impeller

III. Nozzle Row Geometry

The basic geometry for the nozzle row is illustrated on figure 2. Nozzle rows are usually simple radial passages as illustrated in the figure, but that is not a necessary restriction. Hence, the axial coordinate, z, and the radial coordinate, r, are supplied for the mean streamline at stations 1 through 3, where station 2 is approximately mid-way between the stations 1 and 3. The mean streamline lies mid-way between the two end-wall surfaces and the origin used for the axial coordinate is arbitrary. Similarly, the passage width, b, blade thickness, t_b, and blade camberline angles with tangent, β, are supplied at all three stations. Finally, the number of blades, the throat radius, r_{th}, and throat passage width, o, is required.

Nozzle rms Surface finish ------------------------------------ ____________

The number of nozzle blades ---------------------------------- ____________

Inlet axial coordinate, z_1 ------------------------------------ ____________

Inlet radius, r_1 -- ____________

Inlet passage width, b_1 --------------------------------------- ____________

Inlet passage blade angle, β_1 --------------------------------- ____________

Inlet blade thickness, t_{b1} ------------------------------------ ____________

Mean axial coordinate, z_2 ------------------------------------- ____________

Mean radius, r_2 --- ____________

Mean passage width, b_2 -- ____________

Mean passage blade angle, β_2 ---------------------------------- ____________

Mean blade thickness, t_{b2} ------------------------------------- ____________

Exit axial coordinate, z_3 ------------------------------------- ____________

Exit radius, r_3 -- ____________

Exit passage width, b_3 -- ____________

Exit passage blade angle, β_3 ---------------------------------- ____________

Exit blade thickness, t_{b3} -------------------------------------- ____________

Throat radius, r_{th} --- ____________

Throat width, o, -- ____________

IV. Impeller Geometry

Figures 3 and 4 illustrate the geometry required for an impeller (rotor row). The only subtle point requiring caution relates to angle conventions used. Blade angles are measured from tangent from the direction of rotation and in the upstream direction as illustrated on figure 3. Note that this is opposite to the convention for nozzle blades. Generally all blade angles will be ≤ 90 degrees, with the exception of the tip angle for backward leaning impeller blades as shown on figure 3. Similar to the nozzle row, blade and passage data are supplied on the mean streamline at inlet, mid-passage and exit, denoted by subscripts 1, 2 and 3, respectively. Again, the origin used for axial coordinates is optional. The curved passage normally encountered in the impeller requires one additional parameter to be entered relative to the nozzle row. This is the slope angle, φ, illustrated in figure 4. This is the angle between the axial direction and a tangent to the mean streamline, again measured in the flow direction. Hence, φ is normally negative or zero. Data concerning the disk and housing are also required to allow dick-friction losses to be modeled. Finally, splitter blades can be included by specifying the number of splitter blades per each full-length blade and the fractional meridional length of the splitters relative to the full-length blades (enter zero for both if there are no splitter blades). The data required for the impeller are:

Impeller internal rms surface finish ------------------------- ____________

Disk-housing (external) rms surface finish ------------------- ____________

The number of full-length blades ----------------------------- ____________

The number of splitter blades per full-length blade ---------- ____________

Fractional meridional length of splitter blades -------------- ____________

Inlet axial coordinate, z_2 ------------------------------------ ____________

Inlet radius, r_1 -- ____________

Inlet passage width, b_1 --------------------------------------- ____________

Inlet passage blade angle, β_1 --------------------------------- ____________

Inlet blade thickness, t_{b1} ------------------------------------ ____________

Inlet slope angle, φ_1 --- ____________

Mean axial coordinate, z_2 ------------------------------------- ____________

Mean radius, r_2 --- ____________

Mean passage width, b_2 -- ____________

Mean passage blade angle, β_2 ---------------------------------- ____________

Mean blade thickness, t_{b2} ------------------------------------- ____________

Mean slope angle, φ_2 -- ____________

Exit axial coordinate, z_3 ------------------------------------- ____________

Exit radius, r_3 --- ____________

Exit passage width, b_3 -- ____________

Exit passage blade angle, β_3 ---------------------------------- ____________

Exit blade thickness, t_{b3} -------------------------------------- ____________

Exit slope angle, φ_3 -- ____________

Exit passage width, b_3 -- ____________

Throat (blade-to-blade) opening ------------------------------- ____________

Throat (hub-to-shroud) passage width -------------------------- ____________

Ratio of disk Radius-to-inlet radius -------------------------- ____________

Disk clearance, δ_d --- ____________

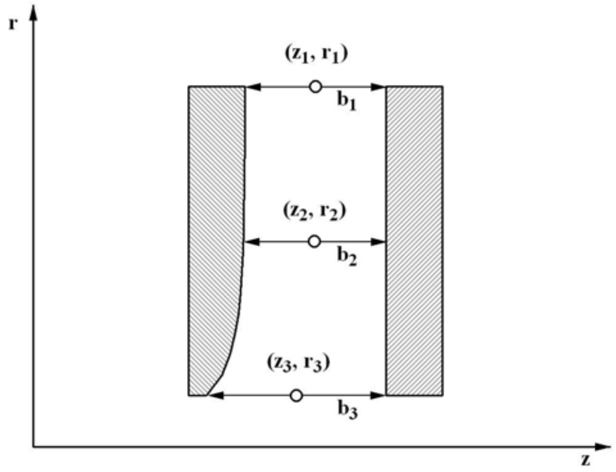

Figure 5: Vaneless Passage Geometry

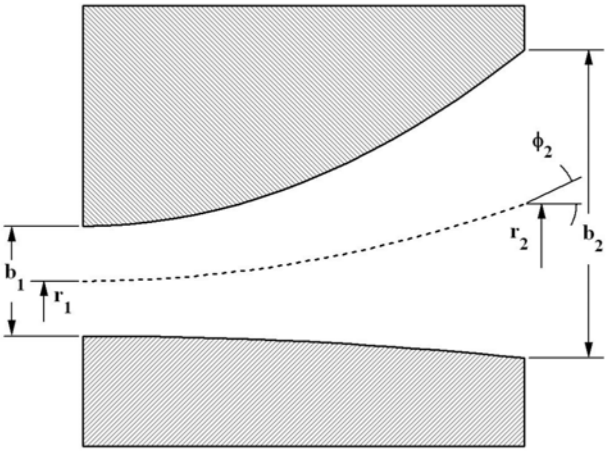

Figure 6: Exhaust Diffuser Geometry

V. Vaneless Passage Geometry

The stage will normally contain one or more vaneless passages between the major components. Figure 5 illustrates the geometry supplied, again at inlet, mid-passage and exit stations on a mean streamline mid-way between the end-walls. The axial coordinate, z, radius, r, and the passage width, b, are required at all three stations. The origin used for z is arbitrary. The rms surface finish and the location of the passage (e.g., upstream of the nozzle, between the nozzle and impeller, etc.) also are specified. Here provision is made for up to three vaneless passages, which should be more than sufficient for most cases, although more can be used. Use only as many as are required for your stage.

`Location:`

`Passage rms surface finish ------------------------------------`

Position	Axial Coordinate	Radius	Passage Width
Inlet			
Mid-Passage			
Discharge			

`Location:`

`Passage rms surface finish ------------------------------------`

Position	Axial Coordinate	Radius	Passage Width
Inlet			
Mid-Passage			
Discharge			

`Location:`

`Passage rms surface finish ------------------------------------`

Position	Axial Coordinate	Radius	Passage Width
Inlet			
Mid-Passage			
Discharge			

VI Exhaust Diffuser Geometry

The exhaust diffuser geometry is illustrated in figure 6. Data are supplied at the inlet and discharge stations on a mean streamline mid-way between the two end walls. The slope angle, φ, is illustrated in figure 6 at the discharge (it is zero at the inlet for that case. Like the impeller, it is the angle between the axial direction and a tangent to the mean streamline, again measured in the flow direction. For exhaust diffusers, φ is normally positive or zero. The origin for the axial coordinate, z, is arbitrary.

Inlet axial coordinate, z_2 ------------------------------------ ____________

Inlet radius, r_1 -- ____________

Inlet passage width, b_1 --------------------------------------- ____________

Inlet slope angle, φ_1 --- ____________

Exit axial coordinate, z_2 ------------------------------------- ____________

Exit radius, r_2 --- ____________

Exit passage width, b_2 -- ____________

Exit slope angle, φ_2 -- ____________

VII Total Pressure Loss

This is a fictitious component that can be inserted at any location to model losses in non-standard components, such as inter-stage piping etc. Here, provision is made for up to three losses, but more can be accommodated. The loss model allows specification of loss coefficients independently for the tangential and meridional components of the upstream velocity pressure and/or a specified total pressure drop. You also need to specify the location (e.g., upstream of the volute, at the end of the stage, etc.) .If α is the flow angle with tangent and $P_v = P_t - P$ is the corresponding velocity pressure, the loss data specification is (enter zero for portions not used):.

$P_{t,new} = P_t -$ __________ $\times P_v \sin^2\alpha -$ __________ $\times P_v \cos^2\alpha -$ __________

Location: ____

$P_{t,new} = P_t -$ __________ $\times P_v \sin^2\alpha -$ __________ $\times P_v \cos^2\alpha -$ __________

Location: ____

$P_{t,new} = P_t -$ __________ $\times P_v \sin^2\alpha -$ __________ $\times P_v \cos^2\alpha -$ __________

Location: ____