Turbomachinery CAD CWM PART 3

RADIAL FLOW WATER TURBINE

Exercise 2 - Design, Manufacture and Testing of a Runner for Given Operating Point Conditions

Design

This part of the exercise is concerned with the solid modelling of a *runner* with designed optimum inlet and outlet blade angles for a given operating point condition defined in terms of water head *H*, shaft rotational speed *N*, fluid throughput *Q*, and guide-vane setting α_0. The runner is located at the centre of the turbine volute (Drg.No. TC000). It has ten blades that are supported on a base disc which is shaped to direct the flow out axially. There is a closing plate on top of the runner to contain the flow within the blades. The blade geometry is classed as radial with a simple two-dimensional profile (Drg.No. RU001).

Determining the Blade Profile

A simple blade shape, with respect to the fluid dynamics of a radial flow system, is that of a logarithmic spiral. This can be further simplified by adopting a circular arc construction, with the all-important inlet blade angle β_1 and outlet angle β_2 as defined in (fig.4.1).

To calculate the blade inlet and outlet angles, for given guide-vane angle α_0, runner speed *N (rps)*, energy head *H (m* H_2O*)*, and volumetric flow rate *Q* (m^3/s), proceed as follows (noting that 1 *m* H_2O = 0.0981 *bar*, and 1 *l/s* = 0.001 m^3/s).

i) Inlet velocity diagram

Calculate the runner inlet peripheral velocity u_1, from the radius $r_1 = 39.8mm$ and the runner speed *N*. Reduce u_1 to a specific velocity U_1 by dividing by $\sqrt{gH}$

Calculate the runner inlet radial velocity v_{r1}, from the annular area of the volute at inlet, i.e. from the breadth $h = 7mm$ and the diameter $d_1 = 79.6mm$, and the volumetric flow rate *Q*. Reduce v_{r1} to a specific velocity V_{r1} by dividing by $\sqrt{gH}$

Assume the fluid inlet velocity angle $\alpha_1 \approx \alpha_0$. You are encouraged to construct the velocity diagram to determine β_1, as shown in (fig.4.2a) – create a new sketch in SolidWorks for this. If necessary, check by calculation for accuracy.

ii) Outlet velocity diagram

Calculate the runner outlet peripheral velocity u_2, from the radius $r_2 = 21.3mm$

and the runner speed *N*. Reduce u_2 to a specific velocity U_2 by dividing by $\sqrt{gH}$

Calculate the runner outlet radial velocity v_{r2}, from the annular area of the volute at outlet, i.e. from the breadth *h = 10mm (approximate height at flow exit from blade)* and the diameter $d_2 = 42.6mm$, and the volumetric flow rate *Q*. Reduce v_{r2} to a specific velocity V_{r2} by dividing by $\sqrt{gH}$

Assume that the outlet specific velocity V_2 has a radial component V_{r2} defined by an isosceles triangle with U_2. Construct the velocity triangle according to this approximation to determine β_2, as shown in (fig.4.2b also see fig A7). (i.e. Assume $U_2 = W_2$)

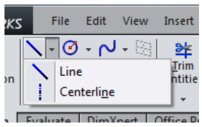
Constructing the Runner Geometry

Create a new part in SolidWorks and Save it as Runner_XX (where XX is the Nominal inlet blade angle β_1).

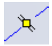
Use the Revolved-Boss/Base command to make the Ø79.6 base disc for the runner, with a Ø 12mm by 10mm high spigot and R7 fillet (see Drawing RU001). Create the sketch on the Right Plane. Follow the good practice, for part manufacture **CNC machine datum** purposes, to locate the centre of the disc accurately, at the (x, y) origin.

Use the Hole Wizard to create the central thread using the settings – **Hole Type - Straight Tap, Standard ISO, Type - Tapped Hole, M6, Through All**.

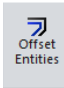
Create a sketch on the spigot face of the disc for the blade profile. Remember that an extrusion is made from a closed profile sketch of <u>solid</u> lines. Use construction lines for any geometry that is created to aid the construction, and not required as part of the extrusion. Solid lines can easily be converted to construction lines – select the line and tick the ‘for construction’ box in the options tab. If you know that you wish to create a construction line, you can use the centreline command (accessed with the drop-down arrow under the line command).



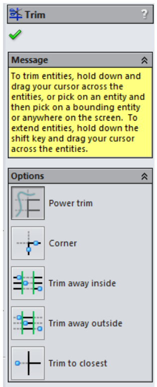
Refer to Fig 4.3 for details and annotation of the construction geometry.

Draw a circular outline of the runner for which $\mathbf{r_1 = 39.8mm}$ and $\mathbf{r_2 = 21.3mm}$ using solid lines. It is important to locate the centre of the circles accurately on the surface of the runner disc, at the (x, y) origin. Create a horizontal centre line through the left-hand side of the circles (i.e. a construction line – use the Centreline command). From point **A** on the circumference of the inner circle draw a line to point **P** of length $\mathbf{r_1}$ and angle $\mathbf{(\beta_1+\beta_2)}$ **-** initially create a construction line of about the right length at the approximate angle. Use the Smart Dimension command to create the length dimension for **AP** and edit the length. For the angle dimension select the line **AP** (it will appear to be creating a new length dimension), then select the horizontal line inboard of **A** – you should now have an angular dimension that you can edit to the correct value. Draw a construction line from the origin at **O** to point **P**. At the bisector **G** of line **OP** draw a perpendicular line **GH** (The length to **H** is not important. You may have to lengthen it if you cannot generate an intersection at **C** in the next stage). As you create the line move the cursor along line **OP**, a symbol should appear to indicate the centre of the line. 

Locate the start of the line at this point, and then look for the perpendicular symbol to locate the other end (at **H**). The centre of the blade profile arc will lie along this line. This is located at the point of intersection of line **GH** and a line drawn from point **A** at an angle **(π-β_1)** with line **AP**, (i.e. at an absolute angle **(π+β_2)**). Create this line (using a construction line) and use Smart Dimension to set the angle β_2.



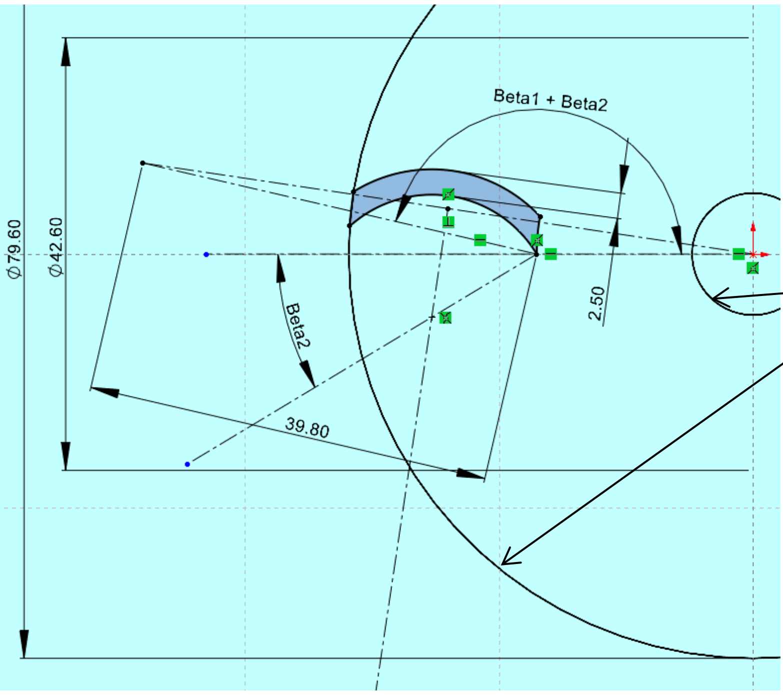
Draw a circle passing through **A** with centre at **C** (use a solid line).
To create the blade thickness of 2.5mm use the offset command.
Type in 2.5 for the offset distance and select the circle (radius **AC**). Make sure that the new circle is on the correct side of the original circle with the preview, and if not then tick the reverse box.



Use the Trim Entities command to trim away all of the unwanted solid arcs -

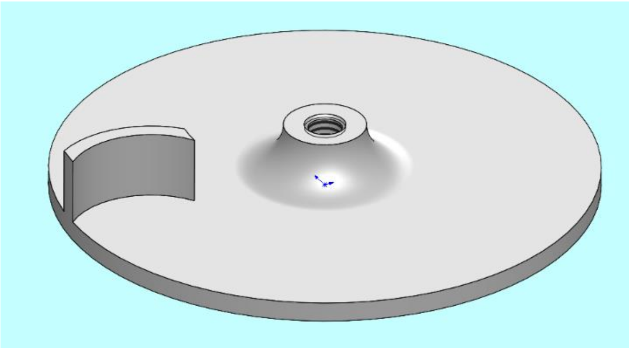
Select the PowerTrim tool, from the Options tab.

To remove unwanted curve sections, you need to drag the cursor across them. <u>Click the mouse at a location away from the curve - keep holding the mouse button down and drag the cursor through the unwanted part of the geometry</u> to leave the 'closed' contour shown (i.e. the runner blade profile, made from 4 separate curves).



Note that in this image the runner disc is shown in 'wireframe' display for clarity (the two circles are diameter 79.6 and 12 mm).

Exit the sketch and extrude the runner blade profile to 10mm height, making sure that it extends from the base disc (rather than extruding into it).



Finally, you need to copy the blade around the disc. Use the circular pattern icon (the icon is found by clicking the "pull-down" arrow ▼ below the 'Linear Pattern' icon).

Go to the View menu, Hide/Show, and select Temporary Axes – this will make it easier to select the axis for the pattern. With the Circular pattern form open, select the blue centreline at the origin of the part (this is the primary axis of the disc) as the 'Pattern Axis' (the upper box in the Direction 1 form).

Tick the equal spacing box. The angle should be 360°, and number of instances is 10. Select the previously created blade from the tree list as the 'Features to Pattern'. Select the Full or Partial Preview button and check that it looks OK. Accept with the green tick.
Save the part.

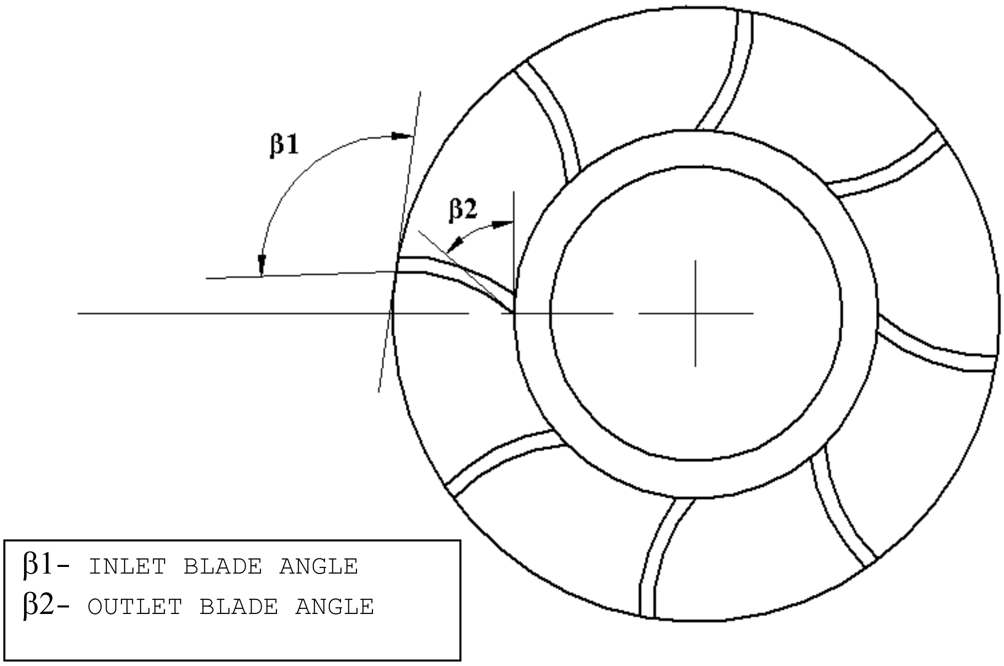


Fig 4.1 Typical blade angle definition

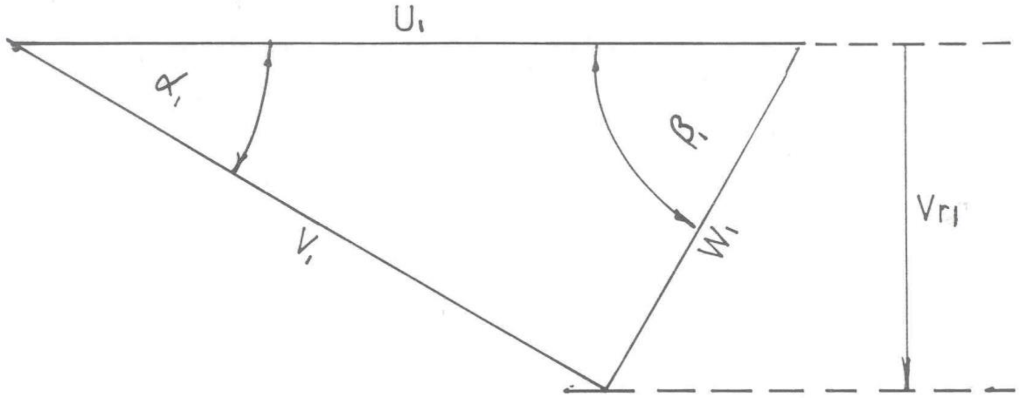


Fig 4.2a

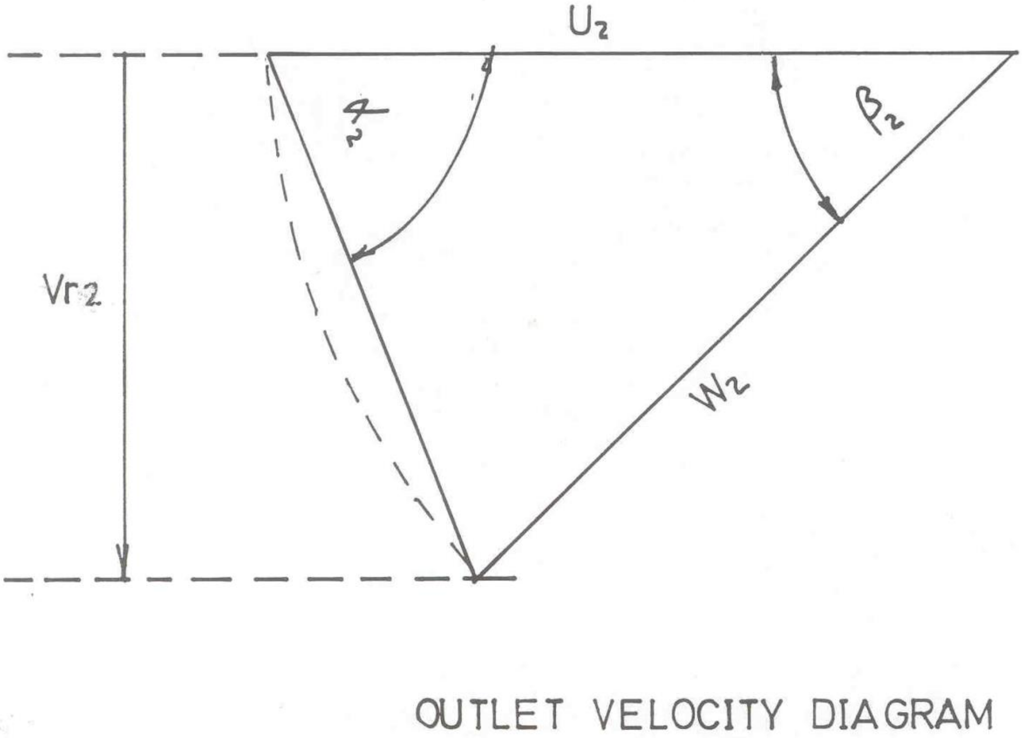


Fig 4.2b

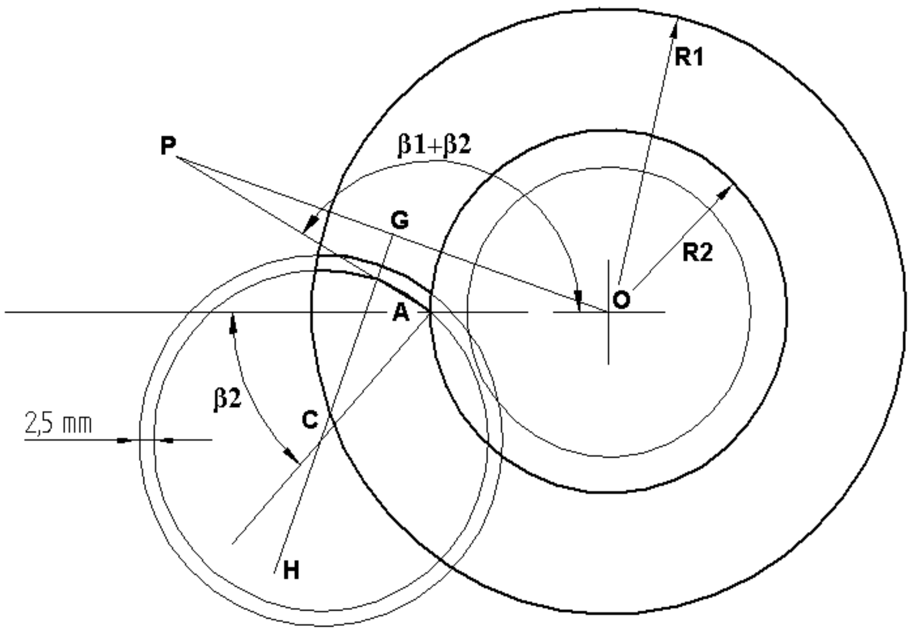
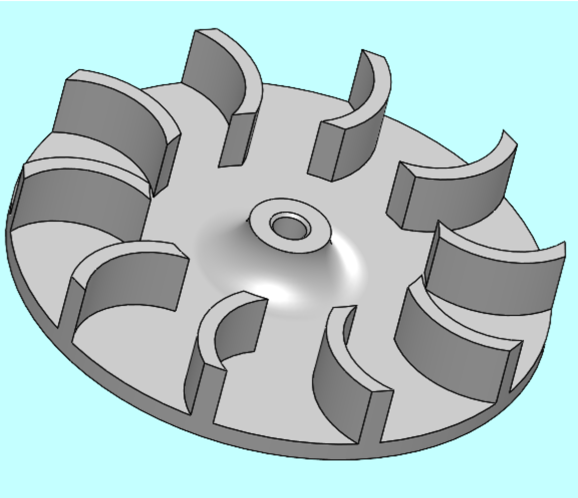
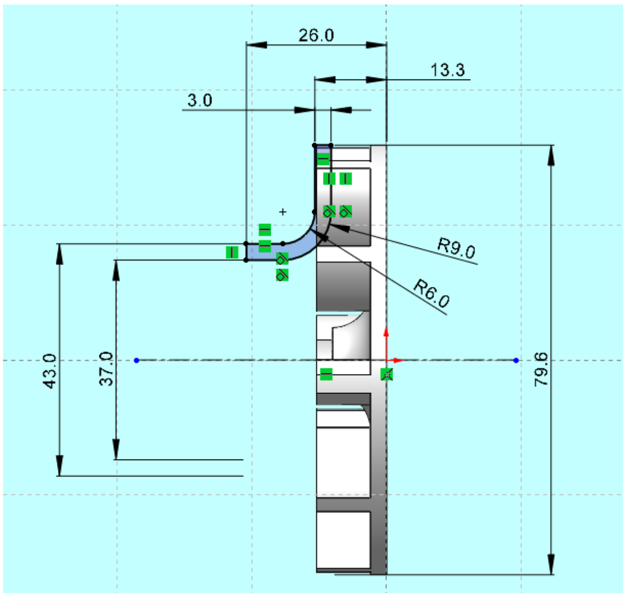


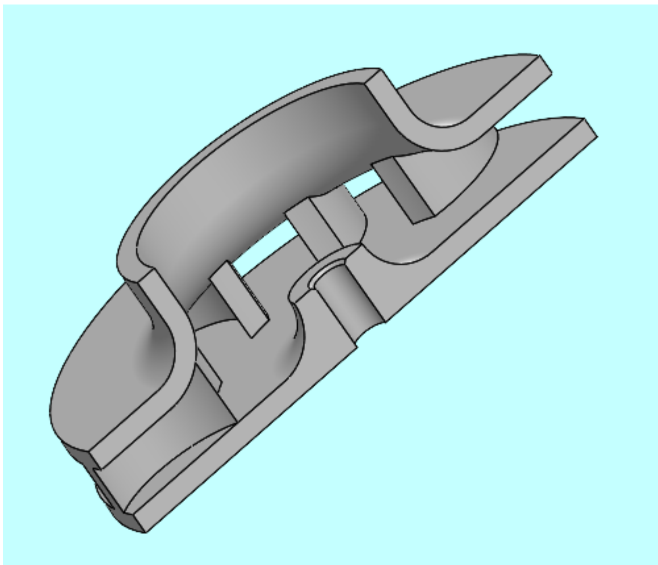
Fig 4.3 Blade profile construction



The final step is to create the closing plate on top of the blades. Create a Revolved-Boss/Base on the Right plane, by sketching the profile (see drawing RU001). Include a centreline through the origin, which will be used as the revolve axis. Dimensions placed from the centreline to a radius can be made into diameters by placing the value to the opposite side of the centreline during creation (as shown in fig 4.5).

Fig 4.4 Extruded blades patterned in the Turbine Runner





Figs 4.5 & 4.6 Closing plate sketch for Revolved Boss/Base, and sectioned view of completed Runner