AXIAL PUMP

Theorectical and tutorial

Axial flow pumps or propeller pumps allow fluid to enter the impeller axially.

They discharge fluid nearly axially, pumping the liquid in a direction that is parallel to the pump shaft. An axial flow pump is also called a propeller pump because the impeller works much like the propeller of a boat. The propeller is driven by a motor that is either sealed directly in the pump body or by a drive shaft that enters the pump tube from the side.

Axial flow pumps use the propelling action of the impellers vanes on the liquid to develop pressure.

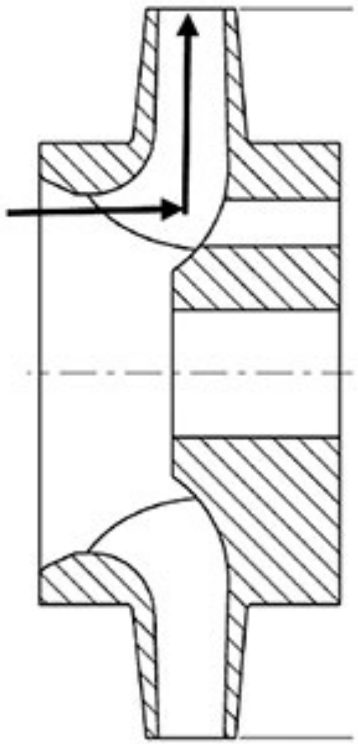
Axial flow pumps are frequently used in industrial settings as circulation pumps that work in conjunction with sewage digester or evaporators. Axial flow pumps are also used in the heat recovery systems, nuclear reactor water circulation, and high volume mixing applications, axial flow pumps can also be used as a liquid pump for ballast control in marine application.

Axial flow pumps use the propeller action to draw water into the pump by suction. An axial flow pump can be designed as a suction pump that draws water in through one end and discharges it out the top of the pump. However, axial flow pumps are not typically used for suction lift application.

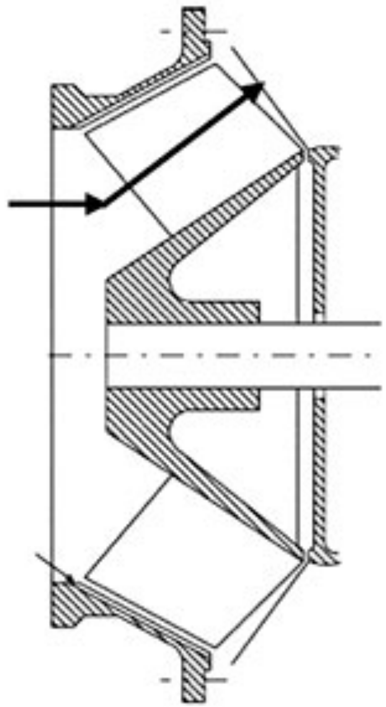
Axial flow pumps used for pumping clear water or storm water may also be submersible. A submersible pump that uses an axial flow design is common in irrigation and drainage application. Axial flow pumps may also be used as a sump pump in some industrial applications to circulate slurries or wastewater or to drain storm water from sump pits or waste storage lagoons.

Axial flow pumps are typically used in high flow rate, low lift application. A mixed flow pump similar to a turbine pump may be used as a well pump provided the well is not too deep.

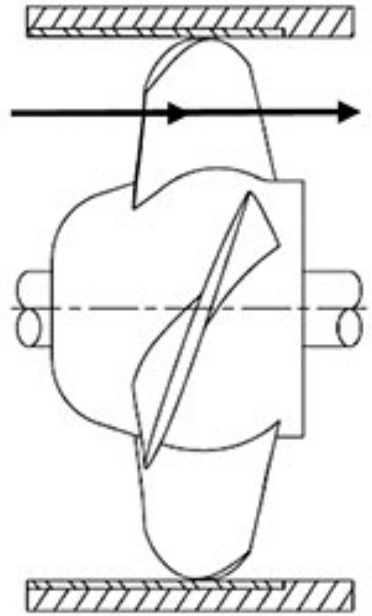
Radial flow



Mixed flow



Axial flow

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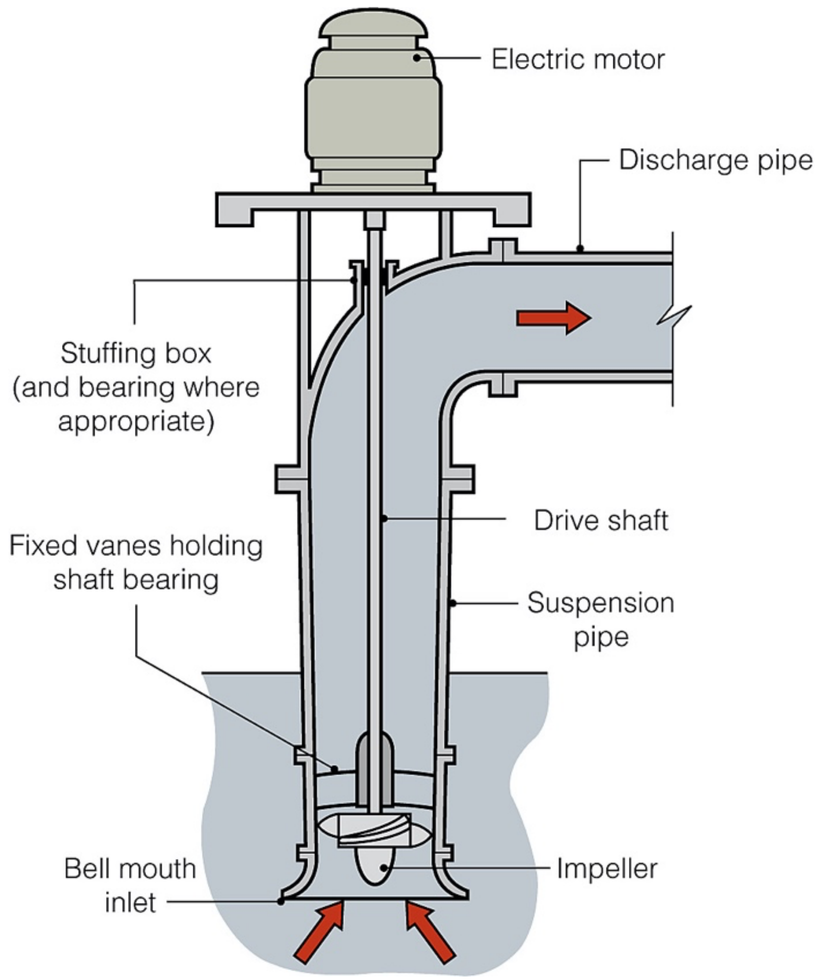
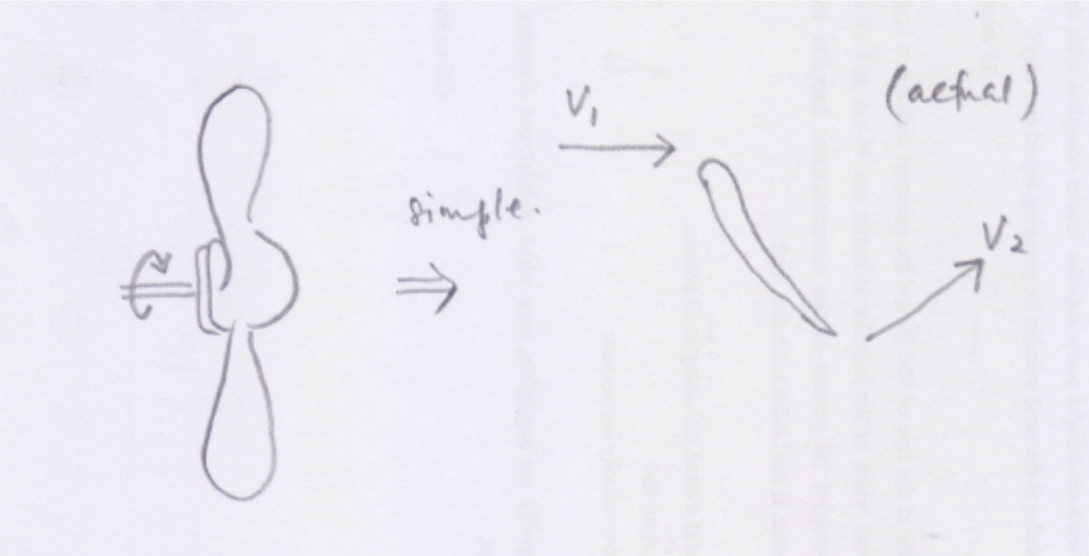
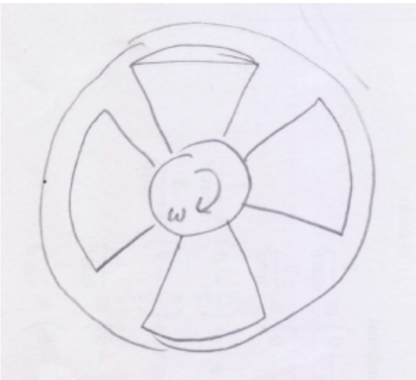

Electric motor
Discharge pipe
Stuffing box
(and bearing where
appropriate)
Drive shaft
Fixed vanes holding
shaft bearing
Suspension
pipe
Bell mouth
inlet
Impeller

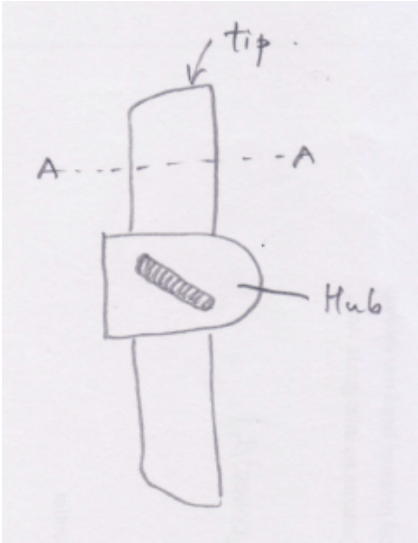
Axial pump or propeller pump



Pandangan depan

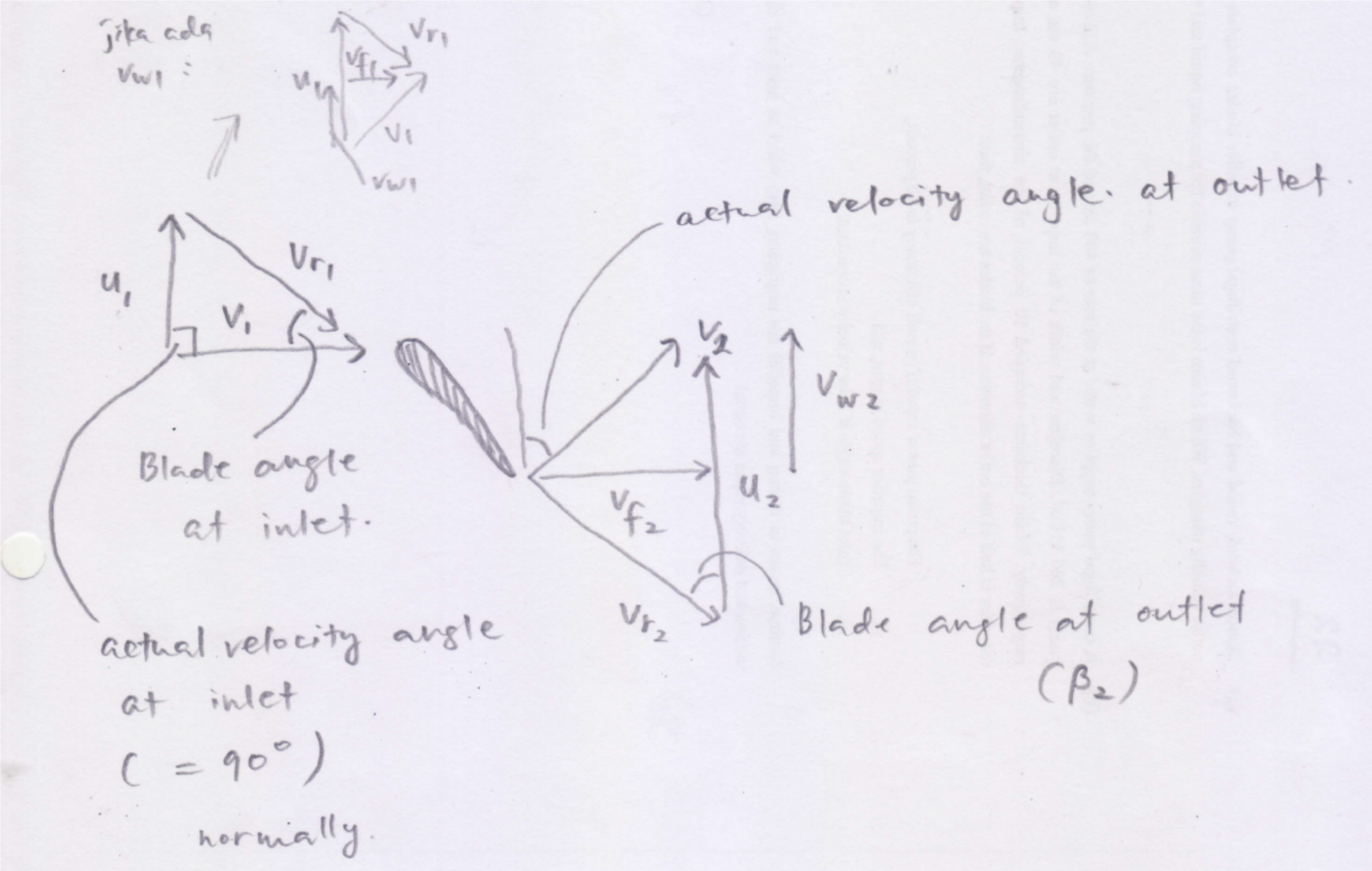


Side view



Top view for cross-sectional A-A

Velocity triangles



Velocity

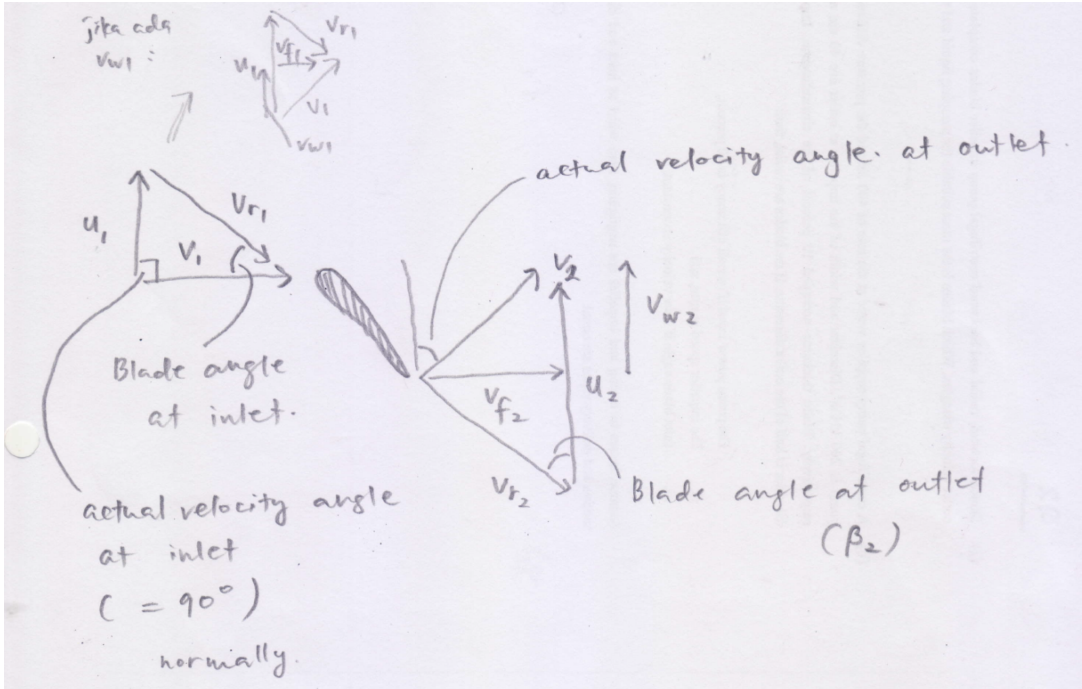
$$v_1 = v_f$$

$$v_{w1} = 0$$

$$u_1 = u_2 = u_3 = r\omega$$

$$v_{f1} = v_{f2} = v_f$$

$$\dot{m} = \rho A v = \rho\pi({R_2}^2 - {R_1}^2)v_f$$



Euler head for axial pump

$$H_E = \frac{1}{g}(u_2 v_{w2} - u_1 v_{w1})$$

Assume that $v_{w1} = 0$

$$H_E = \frac{1}{g}(u_2 v_{w2}) = \frac{1}{g} u_2 \left(u_2 - \frac{v_{f2}}{\tan B_2}\right)$$

Efficiency of axial pump

$$\eta_{overall} = \frac{P_{out}}{P_{in}} = \frac{\rho g Q H_m}{P_{in}}$$

$$\eta_{mano} = \frac{P_{out}}{P_{in}} = \frac{\rho g Q H_m}{\rho g Q H_E} = \frac{H_m}{\frac{1}{g} u_2 v_{w2}} = \frac{g H_m}{u_2 v_{w2}}$$

Example

An axial flow fan has a hub diameter 1.5 m and a tip diameter of 2.0 m. It rotates at 18 rad/s when handling 5.0 m^3/s of air, develops a theoretical head equivalent to 17 mm of water. Determine the blade outlet and inlet angles at the hub and at the tip. Assume that the velocity of flow in independent of radius and the energy transfer per unit length blade is constant. Take the density of air as 1.2 kg/m^3.

Solution

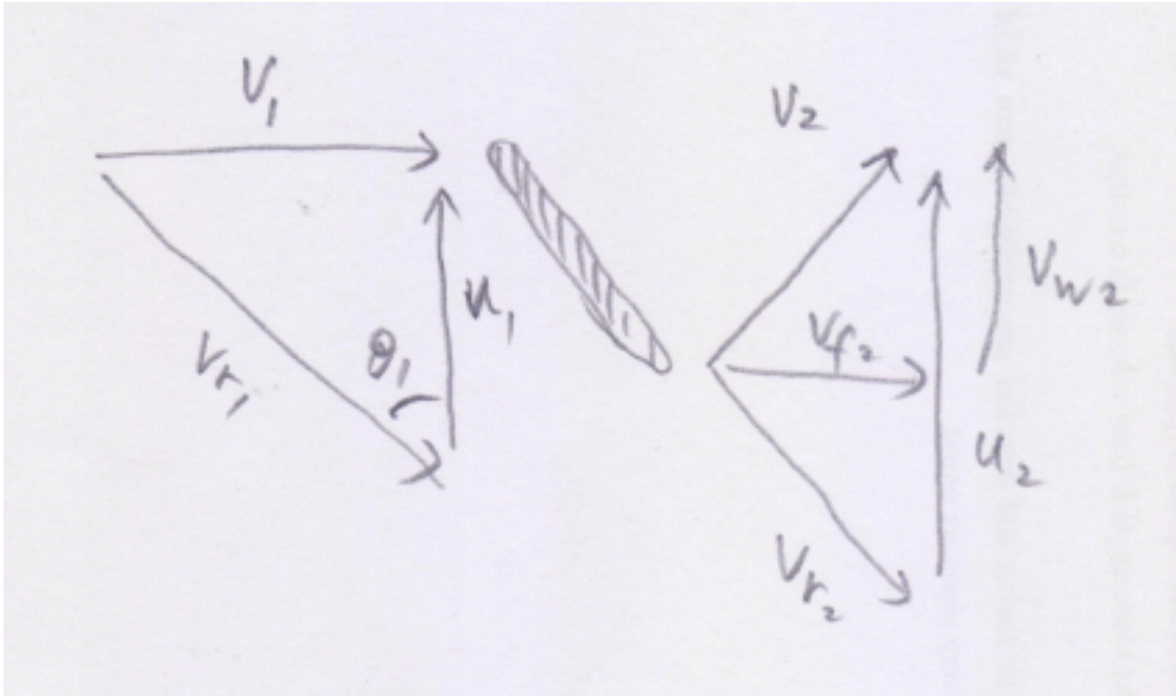
$$d_{hub} = 1.5\ m$$

$$d_{tip} = 2.0\ m$$

$$\omega = 18\ rad/s$$

$$Q = 5.0\ m^3/s$$

$$H_{theory} = 17\ mm\ \ of\ water$$



At inlet

$$\tan\theta_1 = \frac{v_1}{u_1}$$

$$v_1 = v_f = \frac{Q}{A} = \frac{Q}{\pi\left(R_{tip}{}^2 - R_{hub}{}^2\right)} = \frac{5.0}{\pi(1^2 - 0.75^2)} = 3.64 \quad m/s$$

At inlet hub

$$u_{1-hub} = r\omega = \frac{1.5}{2} \times 18 = 13.5 \quad m/s$$

$$\tan\theta_{1-hub} = \frac{v_1}{u_1} = \frac{3.64}{13.5} = 0.2696$$

$$\theta_{1-hub} = 15.08°$$

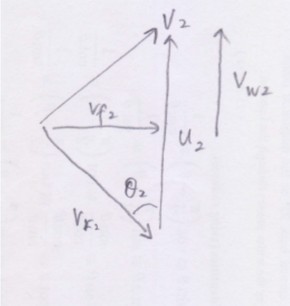
At inlet tip

$$u_{1-tip} = r\omega = \frac{2.0}{2} \times 18 = 18.0 \quad m/s$$

$$\tan\theta_{1-tip} = \frac{3.64}{18} = 0.202$$

$$\theta_{1-tip} = 11.43°$$

At outlet



$$\tan\theta_2 = \frac{v_{f2}}{u_2 - v_{w2}}$$

$$v_{f2} = v_{f1} = 3.64 \quad m/s$$

$$u_{2-hub} = r\omega = \frac{1.5}{2} \times 18 = 13.5 \quad m/s$$

$$u_{2-tip} = r\omega = \frac{2.0}{2} \times 18 = 18.0 \quad m/s$$

$v_{w2} = \ ?$

$$H_E = \frac{1}{g} u_2 v_{W2} = H_{theoretical} = 17\ mm\ (water)$$

$$\rho_{air} g h_{air} = \rho_{water} g h_{water}$$

$$h_{air} = \frac{\rho_w g (0.017)}{\rho_{air} g} = 14.17\ m$$

$$H_E = \frac{1}{g} u_2 v_{w2}$$

$$14.17 = \frac{1}{g} u_2 v_{w2}$$

$$v_{w2} = \frac{14.17g}{u_2}$$

At outlet hub

$$v_{f2} = 3.64\ m/s$$

$$u_{2-hub} = 13.5\ m/s$$

$$v_{w2-hub} = \frac{14.17g}{13.5} = 10.3\ \ m/s$$

$$\tan\theta_{2-hub} = \frac{3.64}{13.5 - 10.3}$$

$$\theta_{2-hub} = 48.7°$$

At outlet tip

$$v_{f2} = 3.64\ m/s$$

$$u_{2-tip} = 18\ m/s$$

$$v_{w2tip} = \frac{14.17g}{18} = 7.72\quad m/s$$

$$\tan\theta_{2-tip} = \frac{3.64}{18 - 7.72}$$

$$\theta_{2-tip} = 19.5°$$

Example

An axial flow pump operates at 500 rpm. The outer diameter of the impeller is 750 mm and the hub diameter is 400 mm. At the mean blade radius, the inlet blade angle is 12^o and the outlet blade angle is 15^o, both measured with respect to the impeller rotation axis. Sketch the corresponding velocity diagrams at inlet and outlet. The hydraulic efficiency is 87% and overall is 70%. Then, calculate:

1. The head generated by the pump
2. The rate of flow through the pump
3. The shaft power consumed by the pump

Solution

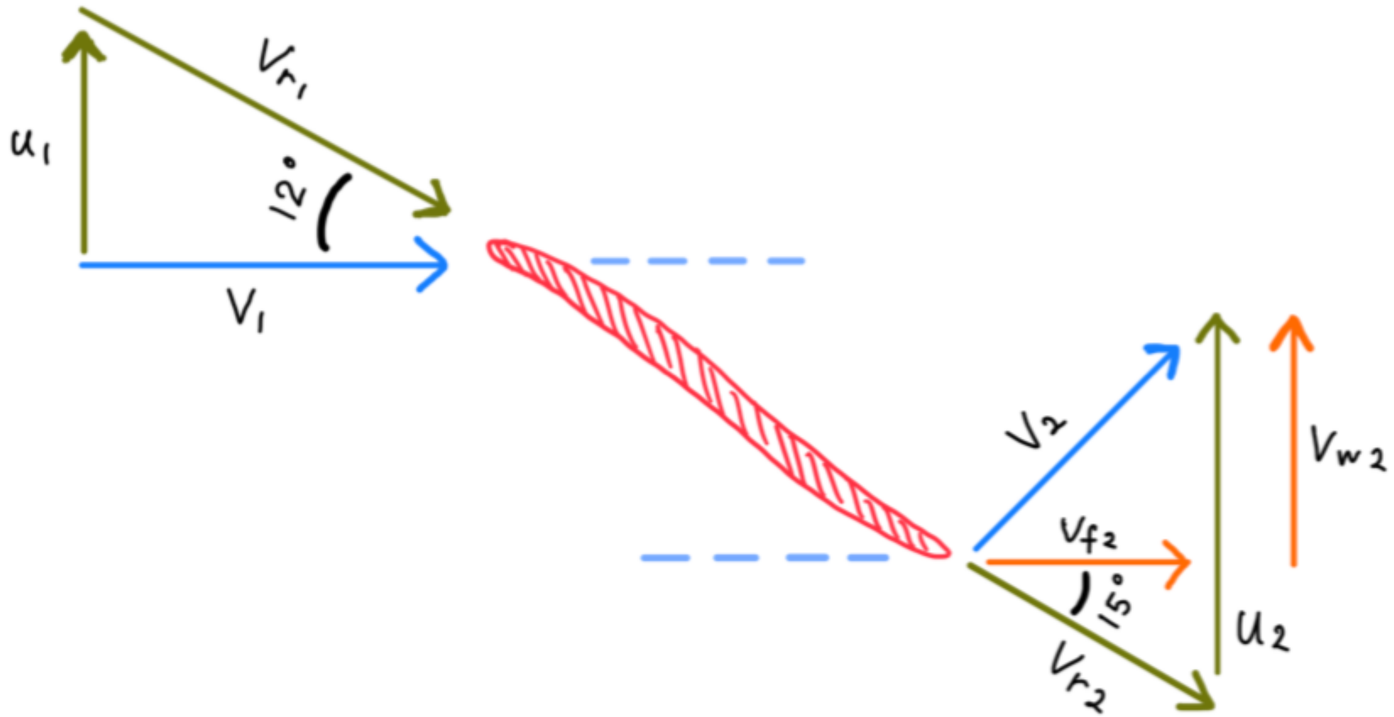
$$N = 500\ rpm$$

$$d_{tip} = 0.75\ m$$

$$d_{hub} = 0.40\ m$$

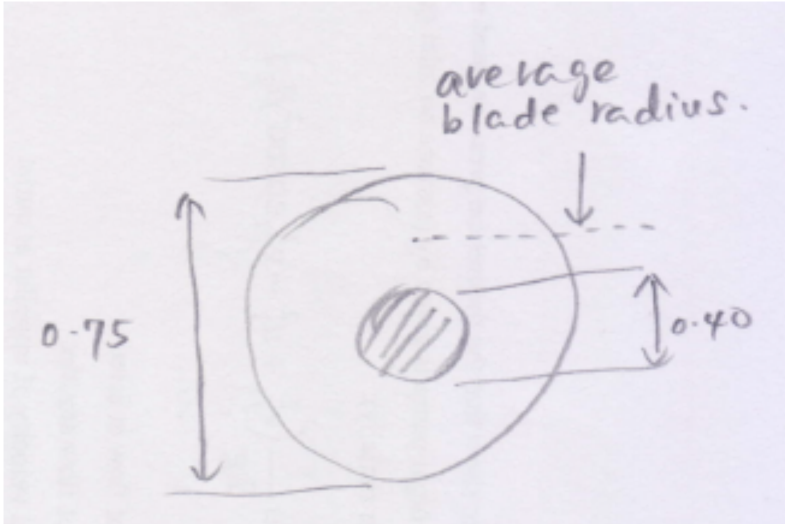
$$\theta_{inlet} = 12°$$

$$\theta_{outlet} = 15°$$



Average diameter

$$\frac{0.75}{2} - \frac{0.40}{2} = 0.175$$



$$r_{average} = 0.20 + \frac{0.175}{2} = 0.2875\, m$$

$$average\ diameter = 0.575\, m$$

$$u = \frac{\pi DN}{60} = \frac{\pi(0.575)(500)}{60} = 15.06\ \ m/s$$

At inlet

$$\tan 12° = \frac{u_1}{v_1}$$

$$v_1 = (15.06)(\tan 12°) = 3.20 \quad (m/s) = v_{f2}$$

At outlet

$$v_{f2} = v_1 = 3.20\ m/s$$

$$u_2 = u = 15.06\ m/s$$

$$\tan 15° = \frac{u_2 - v_{w2}}{v_{f2}} \quad \Longrightarrow \quad v_{w2} = 14.20 \quad m/s$$

$${v_2}^2 = {v_f}^2 + {v_{w2}}^2$$

$$v_2 = 14.56 \quad m/s$$

(a) Head generated by the pump

$$\eta_h = \frac{P_{out}}{P_{in}} = \frac{H_m}{H_E}$$

$$H_m = H_E \times \eta_h = (0.87)\frac{1}{g}(u_2 v_{w2}) = \frac{0.87}{g}(15.06)(14.20)$$

$$H_m = 18.965 \;\; m$$

(b) Flow rate

$$Q = Av_f = \pi({r_2}^2 - {r_1}^2)(3.20) = 1.01 \;\; m^3/s$$

(c) Shaft power

$$\eta_o = \frac{P_{out}}{P_{in}}$$

$$P_{in} = \frac{P_{out}}{\eta_o} = \frac{\rho g Q H_m}{0.7} = 268.4 \quad kW$$