

Fluid Machinery & Steam Generator

Francis turbine

- Area of flow $A_{f1} = K \pi d_1 b_1$
- Discharge through the runner $Q = A_{f1} V_{f1}$
- Hydraulic power $[HP = \rho g Q H]_{\text{wh}}$
- Runner power when v_{w1} is in direction of u_1
 $R.P = \frac{\rho g Q}{\rho} [v_{w1} u_1 - v_{w2} u_2]$
- Runner power when v_{w1} is in opposite direction of u_2
 $R.P = \frac{\rho g Q}{\rho} [v_{w1} u_1 + v_{w2} u_2]$
- Hydraulic efficiency $\eta_h = \frac{R.P}{HP} = \frac{v_{w1} u_1}{gH}$ L-R-L-R
- Mechanical efficiency $\eta_{mech} = \frac{S.P}{R.P}$ M-S-E-S
- Overall efficiency $\eta_o = \eta_h \times \eta_{mech}$ O-S-L-R
- Volumetric efficiency $\eta_{vol} = \frac{Q}{Q + \Delta Q}$
 where ΔQ = leakage loss
 Q = discharge entering the turbine
- Degree of reaction (R) : $R = 1 - \frac{v_2^2 - v_1^2}{2 v_{w1} u_1}$
- Efficiency of draft tube $\eta_d = \frac{\frac{v_1^2 - v_2^2}{2g}}{\frac{v_1^2 - v_2^2}{2g} + h_f}$
- Pelton wheel**
- Power available at inlet of vanes = $\frac{\rho Q v^2}{2}$
- Runner power $R.P = \frac{\rho Q v^2}{\rho} [v_{w1} - v_{w2}] u$
- $(\eta_h)_{max} = \frac{1 - k \cos \alpha}{2}$
- Blade efficiency $\eta_{b, max} = \frac{v_1^2 - v_2^2}{v_1^2}$
- Specific speed of Turbine $N_s = \frac{N \sqrt{P}}{H^{5/4}}$

Model relationships for turbine / Cp

Capacity or flow coeff. velocity coeff.

$$\left[\frac{Q}{ND^3} \right]_1 = \left[\frac{Q}{ND^3} \right]_2 \quad \left[\frac{C_H}{N^2 D^2} \right]_1 = \left[\frac{C_H}{N^2 D^2} \right]_2$$

Power coeff.

$$\left[\frac{P}{N^3 D^5} \right]_1 = \left[\frac{P}{N^3 D^5} \right]_2$$

Brayton cycle or Joule cycle:- [G.M.P.P]

$$\eta = 1 - \frac{1}{(r_p)^{\frac{\gamma}{\gamma-1}}} \quad T_2 = T_4 = \sqrt{T_{max} \cdot T_{min}}$$

$$(r_p)_{optimum} = \left(\frac{T_{max}}{T_{min}} \right)^{\frac{\gamma}{\gamma-1}}$$

$$(r_p)_{optimum} = \sqrt{(r_p)_{max}} \quad (r_p)_{max} = \left(\frac{T_{max}}{T_{min}} \right)^{\frac{\gamma}{\gamma-1}}$$

$$\text{Back work Ratio} = \frac{W_c}{W_T}$$

$$\text{Work Ratio} = \frac{W_{net}}{W_T} = \frac{W_T - W_c}{W_T} \quad 1 - \frac{W_c}{W_T}$$

Rankine vapour power cycle (or) steam power cycle

$$\text{Specific steam consumption } SSC = \frac{3600}{W_{net}} \frac{\text{kg}}{\text{kwhr}}$$

$$\eta_{Rankine} = 1 - \frac{Q_{out}}{Q_{in}} = 1 - \frac{T_c}{T_h} = \frac{W_{net}}{Q_c} = \frac{Q_2 - Q_1}{Q_1} \quad \frac{kJ}{kJ}$$

For regeneration in Rankine cycle

$$W_1 = (1-x)(h_1 - h_2) + (1-y)(h_1 - h_2)$$

$$W_2 = (1-x)(h_1 - h_2) + 1(h_1 - h_2)$$

$$W_{net} = W_1 - W_2$$

$$Q_2 = 1(h_2 - h_3)$$

Applying conservation of energy

Mechanical Engineering Formula

Jiyuan Zhang



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Table of Contents Mechanical Engineering Formula

1. Understanding the eBook Mechanical Engineering Formula
 - The Rise of Digital Reading Mechanical Engineering Formula
 - Advantages of eBooks Over Traditional Books
2. Identifying Mechanical Engineering Formula
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Mechanical Engineering Formula
 - User-Friendly Interface
4. Exploring eBook Recommendations from Mechanical Engineering Formula
 - Personalized Recommendations
 - Mechanical Engineering Formula User Reviews and Ratings
 - Mechanical Engineering Formula and Bestseller Lists

5. Accessing Mechanical Engineering Formula Free and Paid eBooks
 - Mechanical Engineering Formula Public Domain eBooks
 - Mechanical Engineering Formula eBook Subscription Services
 - Mechanical Engineering Formula Budget-Friendly Options
6. Navigating Mechanical Engineering Formula eBook Formats
 - ePub, PDF, MOBI, and More
 - Mechanical Engineering Formula Compatibility with Devices
 - Mechanical Engineering Formula Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Mechanical Engineering Formula
 - Highlighting and Note-Taking Mechanical Engineering Formula
 - Interactive Elements Mechanical Engineering Formula
8. Staying Engaged with Mechanical Engineering Formula
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Mechanical Engineering Formula
9. Balancing eBooks and Physical Books Mechanical Engineering Formula
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Mechanical Engineering Formula
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Mechanical Engineering Formula
 - Setting Reading Goals Mechanical Engineering Formula
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Mechanical Engineering Formula
 - Fact-Checking eBook Content of Mechanical Engineering Formula
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
- Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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