Gas Turbine Power Calculation

Problem Statement

The working fluid flows through a gas turbine at a constant rate of 11 kg/s. It enters the turbine with:

- Velocity: $c_1 = 110$ m/s
- Specific enthalpy: $h_1 = 2050$ kJ/kg

The fluid exits with:

- Velocity: $c_2 = 55$ m/s
- Specific enthalpy: $h_2 = 1550$ kJ/kg

The heat lost to the surroundings during the process is:

- $q = -45$ kJ/kg

Calculate the power developed by the gas turbine.

Solution

The power developed by the turbine can be calculated using the **steady-flow energy equation**:

$$\dot{W} = \dot{m}\left[(h_1 - h_2) + \frac{c_1^2 - c_2^2}{2} + q\right]$$

where:

- $\dot{W}$ = Power developed (kW)

- $\dot{m}$ = Mass flow rate (kg/s)
- h_1 and h_2 = Specific enthalpies at the inlet and outlet (kJ/kg)
- c_1 and c_2 = Velocities at the inlet and outlet (m/s)
- q = Heat transfer per unit mass (kJ/kg)

Given Data

$$\dot{m} = 11\,\text{kg/s}, \quad h_1 = 2050\,\text{kJ/kg}, \quad h_2 = 1550\,\text{kJ/kg}$$

$$c_1 = 110\,\text{m/s}, \quad c_2 = 55\,\text{m/s}, \quad q = -45\,\text{kJ/kg}$$

Step 1: Calculate the Change in Kinetic Energy

The change in kinetic energy per unit mass is given by:

$$\frac{c_1^2 - c_2^2}{2} = \frac{110^2 - 55^2}{2 \cdot 1000}\,\text{kJ/kg}$$

$$= \frac{12100 - 3025}{2000} = \frac{9085}{2000} = 4.5425\,\text{kJ/kg}$$

Step 2: Substitute into the Energy Equation

Substitute the values into the energy equation:

$$\dot{W} = 11\,[(2050 - 1550) + 4.5425 + (-45)]$$

$$\dot{W} = 11\,[500 + 4.5425 - 45]$$

$$\dot{W} = 11 \times 459.5425 = 5054.9675\,\text{kW}$$

Final Answer

The power developed by the gas turbine is:

$$\boxed{\dot{W} \approx 5055\,\text{kW}}$$