

Thermodynamics
Professor Anand T N C
Department of Mechanical Engineering
Indian Institute of Technology, Madras
Tutorial Problem - Part 2

(Refer Slide Time: 0:16)

- Problem solving methodology
 - (i) Are there one or more systems/control volumes?
 - (ii) Identify work/heat flow/ forces
 - (iii) What do we know about initial state?
 - (iv) What is TD model: Property relation: Ideal gas? Steam?
 - (v) What do we know about process? Something constant? Process relation?
 - (vi) What do we know about final state?
 - (vii) Does sketching on a p-v (etc) diagram help?
 - (viii) Use conservation of energy, mass etc.
 - (ix) Is trial and error necessary?



Problem solving methodology

1. Identify system(s)/control volume(s)
2. Identify work or heat interactions or forces acting on the system or control volume
3. Collect the information regarding the initial state of the system or control volume
4. Collect the information regarding the process the system is undergoing. Obtain the information regarding property relations.
5. Collect the information regarding the final state of the system or control volume.
6. Draw state diagrams (p-V, p-T, etc.) if it helps.
7. Use conservation laws, e.g., conservation of mass, energy, etc.
8. Is trial and error necessary?

We may have to go through these steps more than once.

(Refer Slide Time: 4:25)

Q2) A DC electrical motor is used to operate a hoist mechanism in a crane. The motor is supplied with 300 V and 10 amp from a DC source for a period of 2 min. The torque provided by the motor to the hoist shaft is 250 Nm at 50 rpm. The hoist mechanism lifts a mass of 2.5 tonnes through a height of 5m. Calculate the work interaction for the DC source, motor, hoist, and the mass.

Figure 1

Solution of the problem given in Fig. 1:

The battery does work on the motor. The motor does work on the hoist. The hoist does work on the mass. If we consider the motor and the hoist as separate systems, both are receiving work as well as doing work. If we consider the battery as a system, it is doing work. If we consider the mass as a system, work is being done on the system.

Work interaction for the battery: $W_{battery} = Vit = 300 \times 10 \times 120 = 360 \text{ kJ}$

The motor does work on the hoist and receives work from the battery.

Work interaction for the motor: $W_{motor} = -W_{battery} + W_{motor-hoist} = -360 \text{ kJ} + T\theta = -360 \text{ kJ} + T(2\pi Nt) = -360 \text{ kJ} + (2\pi NT)t = -360 + 2 \times 3.1415 \times \left(\frac{50}{60}\right) \times 250 \times 120 \times 0.001 = -360 \text{ kJ} + 157 \text{ kJ} = -203 \text{ kJ}$

The work interaction for the motor is negative. It means that work is being done on the motor. There are friction losses in the motor. Some of the work it receives from the battery through the work interaction is dissipated as heat energy because of frictional losses.

The hoist does work on the mass and receives work from the motor.

$$\text{Work interaction for the hoist: } W_{hoist} = -W_{motor-hoist} + W_{hoist-mass} = -157 \text{ kJ} + mgh = -157 + 2500 \times 9.81 \times 5 = -157 + 122.6 = -34.4 \text{ kJ}$$

The work interaction for the hoist is negative. The hoist has friction losses. Some work it receives from the motor gets dissipated as heat loss because of friction.

Work is done on the mass.

$$\text{Work interaction for the mass: } W_{mass} = -mgh = -122.6 \text{ kJ}$$

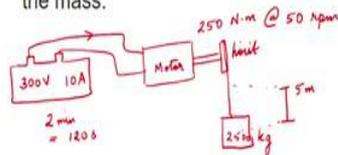
Sum of work interactions for all the components should be zero.

$$W_{battery} + W_{motor} + W_{hoist} + W_{mass} = 360 \text{ kJ} + (-203 \text{ kJ}) + (-34.4 \text{ kJ}) + (-122.6 \text{ kJ}) = 0 \text{ kJ}$$

(Refer Slide Time: 10:21)



Q2) A DC electrical motor is used to operate a hoist mechanism in a crane. The motor is supplied with 300 V and 10 amp from a DC source for a period of 2 min. The torque provided by the motor to the hoist shaft is 250 Nm at 50 rpm. The hoist mechanism lifts a mass of 2.5 tonnes through a height of 5m. Calculate the work interaction for the DC source, motor, hoist, and the mass.



$$\begin{aligned} W_{batt} &= V \times I \times t \\ &= 300 \text{ V} \times 10 \text{ A} \times 120 \\ &= 360000 \text{ J} = 360 \text{ kJ} \\ W_{motor} &= -W_{batt} + W_{hoist} \\ &= -360 \text{ kJ} + T\theta \\ &= -360 \text{ kJ} + 250 \text{ Nm} \times 717 \end{aligned}$$



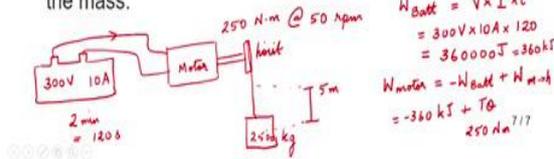
$$\begin{aligned}
 W_{m \rightarrow h} &= T\theta \\
 &= 250 \text{ N} \cdot \text{m} \times \theta \\
 &= P \times t \\
 &= 1308.9 \times 120 \text{ s} \\
 &= 157 \text{ kJ}
 \end{aligned}$$

$$\begin{aligned}
 N &= 50 \text{ rpm} \\
 N &= \frac{50}{60} \text{ rps} \\
 P &= 2 \text{ kN} \cdot \text{T} \\
 &= 2 \text{ k} \times \frac{50}{60} \times 250 \\
 P &= 1308.9 \text{ W}
 \end{aligned}$$



(Refer Slide Time: 12:31)

Q2) A DC electrical motor is used to operate a hoist mechanism in a crane. The motor is supplied with 300 V and 10 amp from a DC source for a period of 2 min. The torque provided by the motor to the hoist shaft is 250 Nm at 50 rpm. The hoist mechanism lifts a mass of 2.5 tonnes through a height of 5m. Calculate the work interaction for the DC source, motor, hoist, and the mass.



$$\begin{aligned}
 W_{\text{source}} &= V \times I \times t \\
 &= 300 \text{ V} \times 10 \text{ A} \times 120 \\
 &= 360000 \text{ J} = 360 \text{ kJ} \\
 W_{\text{motor}} &= -W_{\text{source}} + W_{m \rightarrow h} \\
 &= -360 \text{ kJ} + T\theta \\
 &= -360 \text{ kJ} + 250 \text{ Nm} \times 717
 \end{aligned}$$



$$\begin{aligned}
 W_{m \rightarrow h} &= T\theta \\
 &= 250 \text{ N} \cdot \text{m} \times \theta \\
 &= P \times t \\
 &= 1308.9 \times 120 \text{ s} \\
 &= 157 \text{ kJ}
 \end{aligned}$$

$$\begin{aligned}
 N &= 50 \text{ rpm} \\
 N &= \frac{50}{60} \text{ rps} \\
 P &= 2 \text{ kN} \cdot \text{T} \\
 &= 2 \text{ k} \times \frac{50}{60} \times 250 \\
 P &= 1308.9 \text{ W}
 \end{aligned}$$

$$\begin{aligned}
 W_{\text{motor}} &= -360 + 157 \text{ kJ} \\
 &= -203 \text{ kJ}
 \end{aligned}$$

$$\begin{aligned}
 W_{\text{hoist}} &= -T\theta + mgh \\
 &= -P t + mgh \\
 &= -157 \text{ kJ} + 2500 \times 9.81 \times 5 \\
 &= -157 \text{ kJ} + 122.6 \\
 &= -34.4 \text{ kJ}
 \end{aligned}$$

$$\begin{aligned}
 W_{\text{mass}} &= -mgh \\
 &= -2500 \times 9.81 \times 5 \\
 &= -122.6 \text{ kJ}
 \end{aligned}$$



(Refer Slide Time: 17:30)



$$\begin{aligned}W_{\text{spring}} &= T\theta \\ &= 250 \text{ N} \times \theta \\ &= P \times t \\ &= 1808.9 \times 1200 \\ &= 157 \text{ kJ}\end{aligned}$$

$$\begin{aligned}W_{\text{motor}} &= -360 + 157 \text{ kJ} \\ &= -203 \text{ kJ}\end{aligned}$$

$$\begin{aligned}W_{\text{inert}} &= -T\theta + mgh \\ &= -Pt + mgh \\ &= -157 \text{ kJ} + 2500 \times 9.81 \times 5 \\ &= -157 \text{ kJ} + 122.6 \\ &= -34.4 \text{ kJ}\end{aligned}$$

$$\begin{aligned}W_{\text{mass}} &= -mgh \\ &= -2500 \times 9.81 \times 5 \\ &= -122.6 \text{ kJ}\end{aligned}$$

$$\begin{aligned}N &= 50 \text{ rpm} \\ N &= \frac{50}{60} \text{ rps} \\ P &= 2KN \cdot T \\ &= 2K \times \frac{50}{60} \times 250 \\ P &= 1308.9 \text{ W}\end{aligned}$$

	kJ
W_{spring}	360
W_{motor}	-203
W_{inert}	-34.4
W_{mass}	-122.6
	<hr/>
	0

