Manipal Institute of Technology, Manipal

Department of Mechanical and Industrial Engineering

Scheme of Evaluation and Answer Key - BME/ BMES [MIE 1071/ MIE 1072]

Mid Term Examination – 06/03/2025

6. A boiler generates 225 kg of 15% wet steam at a temperature of 230°C. This steam is subsequently heated in a superheater to achieve a degree of superheat of 85°C. Prior to entering the superheater, the steam loses approximately 15% of its heat. The superheated steam is then used to run a turbine, during which it loses 353.15 MJ of heat.

   a) Total heat supplied to feed water in the boiler

   b) Dryness fraction of steam at the entry of super heater

   c) Total heat supplied in the super heater.

   d) Quality of the steam at the exit of the turbine

   The temperature of the feedwater entering the boiler is found to be 28°C

Marks – (5) Note: Deduct 0.5 mark from total marks obtained if units not written

P = 28 bar

From the steam tables –

hf = 990.5 kJ/kg; hfg = 1811.5 kJ/kg; hg = 2802 kJ/kg

0.5 mark

Solution

hp = 117.236 kJ/kg

hq = 2530.275 kJ/kg (enthalpy at exit of boiler)

hr = 2150.733 kJ/kg (enthalpy at entry of superheater)

hs = 2993.25 kJ/kg (enthalpy at exit of superheater)

ht = 1423.68 kJ/kg (enthalpy at exit of turbine)

2.5 marks

Thus,

a) Total heat supplied to feed water in the boiler – 2413.039 kJ/kg or 542.933 MJ

b) Dryness fraction of steam at the entry of super heater – x = 0.64

c) Total heat supplied in the super heater – 842.52 kJ/kg or 189.566 MJ

d) Quality of the steam at the exit of the turbine – Wet steam – x = 0.2391

2 marks

7. A manufacturing company is considering the installation of a coal-fired boiler for its process heating requirements, constrained by investment limits. The required steam generation capacity is 4000 kg per hour at a pressure of 0.64 MPa and a temperature of 250ºC. The feed water is sourced from a nearby river at an average temperature of 25ºC. The coal consumption is 800 kg/h, with a calorific value of 24 MJ/kg. Evaluate the enhancement in boiler efficiency when the following accessories are implemented:

i) an Economizer that increases the feed water temperature to 65ºC and reduces coal consumption by 15%.

ii) an air Preheater that reduces coal consumption by 18%.

iii) both air preheater and economizer, resulting in a combined effect of reducing coal consumption by 24% and preheating the feed water temperature by 30ºC

Marks – (5) Note: Deduct 0.5 mark from total marks obtained if units not written

From the steam tables; P = 6.4 bar

Tsat = 161.4 ºC; hf = 681.5 kJ/kg; hfg = 2076.7 kJ/kg; hg = 2758.2 kJ/kg — ***1 mark***

Solution

hw = 104.675 kJ/kg

hs = 2957.55 kJ/kg — ***1 mark***

η = 59.43 %

Case 1

hw = 272.155 kJ/kg

mf = 680 kg

η = 65.81 %

Improvement in efficiency – 6.38 % (Absolute terms) — ***1 mark***

Case 2

mf = 656 kg

η = 72.48 %

Improvement in efficiency – 13.04 % (Absolute terms) — ***1 mark***

Case 3

mf = 608 kg

hw = 230.285 kJ/kg

η = 74.76 %

Improvement in efficiency – 15.33 % (Absolute terms)

1 mark

8. A large industrial fan, used for ventilation in a manufacturing facility, is driven by a motor running at 1800 rpm. To achieve the desired airflow, the fan operates with a speed reduction ratio of 2.5. The motor and fan are connected by a belt drive, with the larger pulley measuring 500 mm in diameter, causing the pulleys to rotate in opposite directions. The system is designed to transmit 40 kW of power, with a coefficient of friction of 0.28 between the belt and pulley surface. The center distance between the pulleys is fixed at 1.8 meters. Considering that the permissible tension in the belt is limited to 27 N/mm of belt width, determine the belt specifications required for this system. Additionally, calculate the initial tension needed when the drive is stationary.

Marks – (5) **Note:** Deduct 0.5 mark from total marks obtained if units not written

Solution

D1 = 200 mm – ***0.5 mark***

V = 1130.97 m/min – ***0.5 mark***

θ = 3.53 rad – ***1 mark***

T1/T2 = 2.69 – ***0.5 mark***

T2 = 1255.66 N

T1 = 3377.74 N – ***1 mark***

b = 125.1 ≈126 mm – ***0.5 mark***

L = 4.767 m – ***0.5 mark***

T0 = 2316.69 N – ***0.5 mark***

9. A gear box for a machine tool is to be designed, the motor of which runs at 4000 rpm. Following are the gears available. Build a compound gear train and calculate out the least possible speed for the machine spindle in such a way that the driver and driven shafts are parallel to each other. The entire gear train consists of five shafts. Sketch the arrangement and list the criteria in building the gear train.

Gear	Type	Module (mm)	No. of teeth
A	Spur	2	92
B	Spur	2	40
C	Helical	2	104
D	Helical	2	40
E	Bevel	2	116
F	Bevel	2	30
G	Spur	3	30
H	Spur	3	75
I	Helical	3	72
J	Helical	3	30
K	Bevel	3	20
L	Bevel	3	68

Marks – (4)

Solution

Calculate velocity ratios

A & B – 0.43; C & D – 0.384; E & F – 0.258; G & H – 0.4; I & J – 0.416; K & L – 0.294 – ***1 mark***

Gears chosen based on velocity ratios

C, D, G, H, K, L, E & F – ***0.5 mark***

Velocity Ratio – 0.0117

Velocity of output shaft – 46.8 rpm – ***0.5 mark***

Sketch – ***1 mark*** Note: deduct 0.5 mark if bevel gear representation is inapt

Conditions – Same type of gear, matching module, least number of teeth on driver and the greatest number of teeth on driven, two pairs of bevel gear – ***1 mark***

10. Give reasons for the following:

1. Generating “super-heated steam” in a boiler is practically not possible
2. Belt drives are known as “non positive drive”
3. It is not recommended to use a gear train for power transmission from the engine to the rear wheel in a motorcycle.

Marks - (1 x 3 = 3 marks)

1. Generating “super-heated steam” in a boiler is practically not possible

   In a boiler drum, water is always in contact with the steam, due to which steam generated contains suspended water molecules. Therefore, generating superheated steam has to be done externally in a superheater, as it is not possible within the boiler.

2. Belt drives are known as “non positive drive”

   Belt drives are known as a non-positive drive since it is practically not possible to maintain the estimated velocity ratio because of slip and creep

3. It is not recommended to use a gear train for power transmission from the engine to the rear wheel in a motorcycle.

   A gear train for power transmission from the engine to the rear wheel is not recommended due to the large center distance between the engine shaft and rear wheel, which can make the machine bulky and impractical.

11. Machines in a group drive need to be stopped and started at will. Suggest the type of pulley for the said requirement and hence explain its construction and working with a simple schematic representation.

Marks (3)

Suggesting Fast and Loose Pulley – ***0.5 mark***

Sketch – ***1.5 marks*** (if driver pulley is not wide – deduct 0.5 mark; if too wide gap between fast and loose pulley – deduct 0.5 mark)

Explanation – ***1 mark***