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higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

T1310(**E**)(A2)T
APRIL EXAMINATION

NATIONAL CERTIFICATE

POWER MACHINES N6

(8190046)

2 April 2015 (Y-Paper)
13:00–16:00

This question paper consists of 6 pages and a formula sheet of 6 pages.

DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE
POWER MACHINES N6
TIME: 3 HOURS
MARKS: 100

NOTE: If you answer more than the required questions, only the required questions will be marked. All work you do not want to be marked, must be clearly crossed out.

INSTRUCTIONS AND INFORMATION

1. Answer FIVE questions.
2. Read ALL the questions carefully.
3. Number the answers according to the numbering system used in this question paper.
4. Write neatly and legibly.

Answer FIVE of the seven questions.

QUESTION 1

A double acting, two-stage air compressor delivers 3 kg of air per minute at a pressure of 1,5 MPa. The intake conditions are 98 kPa and 28 °C. The compression and expansion index for both stages is 1,3. The volumetric efficiencies based on inlet conditions are 92% for the low pressure cylinder and 90% for the high pressure cylinder. The compressor rotates at 240 r/min. Intercooling at 360 kPa is complete and the temperature after intercooling is 87°C. Mechanical efficiency is 85%.

Take R for gas as 0,288kJ/kg.K and Cp as 1,005 kJ/kg.K.

Calculate:

1.1 The power required to drive the compressor in kW (7)

1.2 The diameter of the low pressure cylinder if the stroke is 1,5 times the diameter (7)

1.3 The heat transfer during compression in the first stage (6)
[20]

QUESTION 2

A boiler plant comprises of an economiser, evaporator, superheater and air heater. The feed water entering and leaving the economiser has a temperature of 44 °C and 175 °C respectively. The air for combustion is heated from 15 °C to 150 °C. The steam pressure is 300 kPa. At the entrance to the superheater the dryness fraction is 0,98
At the superheater outlet the temperature of the steam is 250 °C. The calorific value of the fuel burned is 31800kJ/kg. The air fuel ratio is 20 : 1. The steam is generated at the rate of 9,5 kg of fuel burned.

Take Cp for air as 1,005 kJ/kg.K and for flue gases as 1,045 kJ/kg.K

Calculate:

2.1 The heat transfer affected in each component per kg fuel burned (10)

2.2 The plant efficiency (4)

2.3 The temperature of the flue gases leaving the plant (6)
[20]

QUESTION 3

An internal combustion engine on the diesel cycle principle has a clearance volume of 0,00041 m³, a piston diameter of 180 mm and the stroke length of 250 mm. Fuel is cut off at 20 mm after TDC on the return stroke. The pressure and temperature after polytropic expansion is 400 kPa and 1 150 K. The compression and expansion index is 1,35 and 1,28 respectively.

Take R as 0,288 kJ/kg.K

Calculate:

3.1 The swept volume and cylinder volume in m³ (4)

3.2 The volume after constant pressure heat addition in m³ (3)

3.3 The lowest and highest pressure in kPa (4)

3.4 The work done in kJ/cycle (5)

3.5 The indicated power of the engine in kW if it operates on the 2-stroke principle at 330 r/min with 4 cylinders. (4)

[20]

QUESTION 4

In a trial on a six cylinder, four-stroke engine a Morse test was carried out. When running at full load and all cylinders working, the brake power was 56 kW. The measured brake power when each cylinder was cut out in turn and the load reduced to bring the engine back to its original speed was as follows:

Cylinder Number	1	2	3	4	5	6
Brake Power(kW)	44,2	44	43,9	44,3	44,1	43,7

The following are further recordings taken:

Indicated specific fuel consumption	=	0,26 kg/kWh
Heat value of the fuel	=	42 MJ/kg
Air fuel ratio by mass	=	15,2: 1
Exhaust gas temperature	=	400 °C
Specific heat capacity of exhaust gas	=	1,1 kJ/kg.K
Cooling water temperature rise	=	38 °C
Cooling water flow rate	=	34 kg/min
Specific heat capacity of water	=	4,187 kJ/kg.K
Normal air temperature	=	18 °C

Calculate:

4.1 The mechanical efficiency (7)

4.2 The mass of fuel used in kg/min (2)

4.3 The mass of exhaust gas in kg/min (2)

4.4 The heat lost to the exhaust gases in kJ/min (2)

4.5 The heat lost to the cooling water in kJ/min (2)

4.6 Draw up a heat balance in kJ/min and as percentage to determine percentage heat lost to radiation. Assume that the heat lost to friction is absorbed by the cooling water. (5)

[20]

QUESTION 5

Steam expands through a convergent divergent nozzle at a rate of 5 kg/s to the exit where the isentropic dryness factor is 0,94 and the diameter is 72,2 mm.

At the entrance the superheated steam has a pressure of 1 500 kPa and a temperature of 250 °C and the velocity is negligible.

At the throat the steam has a pressure of 820 kPa, a velocity of 500 m/s and a specific heat capacity of 2,56 kJ/kg.K with an index of 1,31.

The specific volume of dry saturated steam at the exit pressure is 0, 6684 m^3/kg. The isentropic dryness factor is 98,95% of the actual dryness factor.

Calculate:

5.1 The specific enthalpy and temperature of the steam at the throat (6)

5.2 The specific volume, the area in mm^2 and diameter in mm at the throat (6)

5.3 The actual dryness factor, the specific volume, the area in mm^2, the velocity in m/s and the specific actual enthalpy at the exit (8)

[20]

QUESTION 6

A velocity compounded impulse turbine has two rows of moving blades with a row of fixed blades between them. The nozzle delivers steam at 660 m/s and at an angle of 17° with the plane of rotation of the wheel. The first row of moving blades has an outlet angle of 18° and the second row has an outlet angle of 36°. The row of fixed blades has an outlet angle of 22°. The mean radius of the blade wheel is 155 mm and it rotates at 4 000 r/min. The steam flow rate is 80 kg/min and its velocity is reduced by 10% over all the blades.

6.1 Use a scale of 1 mm = 5 m/s and construct velocity diagrams for the turbine and indicate the lengths of all the lines as well as the magnitude on the diagrams. (10)

6.2 Determine the following from the velocity diagrams:

6.2.1 The axial thrust on the shaft in N (2)

6.2.2 The total force applied on the blades in the direction of the wheel in N (2)

6.2.3 The power developed by the turbine in kW (2)

6.2.4 The blading efficiency (3)

6.2.5 The average blade velocity in m/s (1)

[20]

QUESTION 7

In an ammonia vapour compression refrigerator, the pressure in the evaporator is 276 kPa and the ammonia at entry to the evaporator is 0,12 dry while at the exit is 0,91 dry. During compression the work done per kg of ammonia is 170 kJ. The rate of ammonia circulation is 5,6 kg/min.

Assume the compressor is single-acting, runs at 120 r/min with a volumetric efficiency of 80%.

Properties of ammonia at 276 kPa are:

Latent heat (hfg) = 1 340 kJ/kg
Specific volume = 0,44 m^3/kg

Calculate:

7.1 The actual coefficient of performance (COP) (6)

7.2 The volume of vapour entering the compressor per minute (7)

7.3 The diameter of the cylinder and stroke if the stroke and the diameter are the same. (7)

[20]

TOTAL: 100

POWER MACHINES N6

FORMULA SHEET

Any applicable formula may also be used.

GENERAL

$$P_aV_a = mRT_a$$

$$R = Cp - Cv$$

$$\gamma = \frac{Cp}{Cv}$$

$$PV = c$$

$$PV^n = c$$

$$PV^\gamma = c$$

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{n-1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}$$

$$\Delta U = m \, . \, Cv \, . \, \Delta T$$

$$Q = \Delta U + Wd$$

$$\Delta s = m\left(Cv \, . \ln \frac{P_2}{P_1} + Cp \, . \ln \frac{V_2}{V_1}\right)$$

$$\Delta s = m \, . \, Cv \, . \ln \frac{P_2}{P_1}$$

$$\Delta s = m \, . \, Cp \, . \ln \frac{V_2}{V_1}$$

$$\Delta s = m \, . \, R \, . \ln \frac{P_1}{P_2}$$

$$Q = m \, . \, Cp \, . \, \Delta T$$

$$Q = m \, . \, Cv \, . \, \Delta T$$

$$S_{su} = S_g + Cp \, . \ln \frac{T_{su}}{T_s}$$

$$S_{fg} = S_g - S_f$$

$$S = S_f + xS_{fg}$$

$$h_{su} = h_g + Cp\,(t_{su} - t_s)$$

GENERAL

$$h_{ws} = h_f + xh_{fg}$$

$$V_{ws} = xV_g$$

$$V_{su} = \frac{\frac{n-1}{n}(h_{su} - 1941)}{P_{su}}$$

$$r = \frac{V_s + V_c}{V_c}$$

$$V_s = \frac{\pi}{4} d^2 \times L$$

$$P_2 = \sqrt{P_1 \times P_3}$$

$$r_{ps} = \sqrt[x]{\frac{P_{x+1}}{P_1}}$$

Different formulae for

work done (Wd)

$$= P \times \Delta V$$

$$= P_1 V_1 \ln \frac{V_2}{V_1}$$

$$= \frac{P_1V_1 - P_2V_2}{n-1}$$

$$= \frac{P_1V_1 - P_2V_2}{\gamma - 1}$$

$$= m \,.\, Cp \,.\, \Delta T$$

$$= \frac{xn}{n-1} P_1V_e \left[\left(\frac{P_{x+1}}{P_1} \right)^{\frac{n-1}{xn}} - 1 \right]$$

$$= \frac{xn}{n-1} mRT_1 \left[(r_{ps})^{\frac{n-1}{n}} - 1 \right]$$

GENERAL

Different formulae for work done (Wd)

= *area of PV-diagram*

= *work done first stage + work done second stage + ...*

$$Wd_{nett} = Wd_t - Wd_c$$

$$Wd_{nett} = Q_{nett}$$

Different formulae for air standard efficiencies (ASE)

$$= 1 - \left(\frac{1}{r}\right)^{\gamma - 1}$$

$$= 1 - \frac{r_p r_c^{\gamma - 1}}{r_v^{\gamma - 1}\left[(r_p - 1) + \gamma^{r_p}\,(r_c - 1)\right]}$$

$$= \frac{\text{heat added} - \text{heat rejected}}{\text{heat added}} = 1 - \frac{\beta^{\gamma} - 1}{r^{\gamma - 1} \times \gamma(\beta - 1)}$$

Different volumetric efficiencies, θ_{vol}

$$= \frac{\text{Volume of air taken in}}{\text{Swept volume}}$$

$$= \frac{\text{Volume of free air}}{\text{Swept volume}}$$

$$= 1 - \frac{V_c}{V_s}\left[\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}} - 1\right]$$

GENERAL

Different thermal efficiencies, $0_{therm.}$

$$= \frac{Wd}{heat\ supplied}$$

$$\eta_{brake\ therm.} = \frac{BP}{m_{f/s} \times CV}$$

$$\eta_{ind.\ therm.} = \frac{IP}{m_{f/s} \times CV}$$

$$\eta_{therm.} = \frac{m_s\ (hs - hw)}{m_f \times CV}$$

$$\eta_c = \frac{T_2' - T_1}{T_2 - T_1}$$

$$\eta_t = \frac{T_3 - T_4}{T_3 - T_4'}$$

$$\eta_{mech.} = \frac{BP}{IP}$$

Indicated efficiency ratio

$$= \frac{\eta_{ind.\ therm.}}{ASE}$$

Brake efficiency ratio

$$= \frac{\eta_{brake\ therm.}}{ASE}$$

$$BP = 2\pi \frac{TN}{60}$$

$$T = F \times r$$

$$BP = P_{brake\ mean}\ LANE$$

$$IP = P_{ind.\ mean}\ LANE$$

$$ISFC = \frac{m_{f/h}}{IP}$$

$$BSFC = \frac{m_{f/h}}{BP}$$

$$COP = \frac{T_1}{T_2 - T_1}$$

$$COP = \frac{RE}{Wd}$$

$$P = m\ .\ U\ .\ \Delta Vw$$

$$F_{ax} = m\ .\ \Delta V_f$$

GENERAL

$$\eta_{dia.} = \frac{2 . U . \Delta Vw}{V_1^2}$$

$$P_c = P_1\left(\frac{2}{\gamma+1}\right)^{\frac{\gamma}{\gamma-1}}$$

$$T_c = T_1\left(\frac{2}{\gamma+1}\right)$$

$$C_c = \sqrt{2\times10^3\ (h_1 - h_c) + C_1^2}$$

$$C_2 = \sqrt{2\times10^3\ (h_1 - h_2) + C_1^2}$$

$$C_c = \sqrt{2\times10^3 \times C_p\ (T_1 - T_c) + C_1^2}$$

$$C_2 = \sqrt{2\times10^3 \times C_p\ (T_1 - T_2) + C_1^2}$$

$$A_c = \frac{mV_c}{C_c} \qquad A_2 = \frac{mV_2}{C_2}$$

$$\eta = \frac{h_1 - h_c}{h_1 - h_c'} \qquad \eta = \frac{T_1 - T_c}{T_1 - T_c'}$$

$$\eta = \frac{h_c - h_2}{h_c - h_2'} \qquad \eta = \frac{T_c - T_2}{T_c - T_2'}$$

$$\eta = \frac{h_1 - h_2}{h_1 - h_2'} \qquad \eta = \frac{T_1 - T_2}{T_1 - T_2'}$$

$$EE = \frac{m_s\ (h_s - h_w)}{m_f \times 2\,257}$$

$$\eta_{iso.} = \frac{Wd_{iso.}}{Wd_{poly.}}$$

$$\eta_{rank.} = \frac{Wd}{Q}$$

$$\eta_{Carn.} = 1 - \frac{T_2}{T_1}$$

$$h = u + pV$$

$$gZ_1 + U_1 + P_1V_1 + \frac{C_1^2}{2} + Q =$$

$$gZ_2 + U_2 + P_2V_2 + \frac{C_2^2}{2} + Wd$$