UTHM
Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
(ONLINE)
SEMESTER II
SESSION 2019/2020

COURSE NAME	:	TURBOMACHINERY
COURSE CODE	:	BDE 40303
PROGRAMME	:	BDD
EXAMINATION DATE	:	JULY 2020
DURATION	:	3 HOURS
INSTRUCTIONS	:	ANSWER **ONLY FIVE (5)** FROM **SIX (6)** QUESTIONS **OPEN BOOK EXAMINATION**

THIS QUESTION PAPER CONSISTS OF **SIX (6)** PAGES

Q1 (a) The flow rate of a liquid which is discharged by a pump is given by Q and the head is given by H. The specific gravity of the liquid which has a standard unit of $kg/m^2.s^2$, is denoted by SG. Using dimensional analysis, find the expression for pumping power (P) for this machine.

(8 marks)

(b) An axial pump has a rotor diameter of 32 cm. The pump discharges water (ρ_{water} = 1000 kg/m^3) at a rate of 2.5 m^3/min while rotating at 1450 RPM. The energy input to the pump is 120 J/kg and the overall efficiency is 78%. If a scale model of this pump has a rotor diameter of 22 cm and rotates at 2900 RPM, calculate:

(i) flow rate of water in the model pump;
(ii) change in total pressure from the model pump; and
(iii) input power to the model pump.

(12 marks)

Q2 (a) An axial flow compressor is designed to operate with constant axial velocity component. For this compressor:

(i) show that the speed ratio (U/c_x) can be expressed as:

$$\frac{U}{c_x} = \tan\alpha_1 + \tan\beta_1 = \tan\alpha_2 + \tan\beta_2$$

(ii) show that for a 50% degree of reaction, the gas angles are:

$$\alpha_1 = \beta_2 \text{ and } \alpha_2 = \beta_1$$

where, α_1 and β_1 are inlet absolute flow and blade angles respectively and α_2 and β_2 are exit absolute flow and blade angles respectively.

(6 marks)

(b) An axial flow compressor operates based on the following data:

Parameter	Value
Blade speed at mean blade radius, U_m	185 m/s
Blade speed at blade tip, U_t	240 m/s
Stagnation temperature rise, ΔT_0	15 K
Axial absolute velocity component, c_x	140 m/s
Work done factor, λ	0.85
Degree of reaction at mean radius, Λ	50%

For a free vortex design condition, determine:
(i) whirl component at mean rotor inlet;
(ii) gas angles α_1, α_2, β_1 and β_2 at mean radius;
(iii) whirl component at rotor exit; and
(iv) gas angles at blade tip.

(14 marks)

Q3 **Figure Q3** shows the characteristic map of a centrifugal compressor. The map presents the performance parameters which are normalized by design values, namely pressure ratio (PR/PR_{Design}), pseudo-dimensionless mass flow (MFP/MFP_{Design}) and pseudo-dimensionless speed ($\overline{N}/\overline{N}_{Design}$). The design point is also marked on the compressor map. At 80% design speed ($\overline{N}/\overline{N}_{Design}$= 0.8), the compressor operates at the following conditions:

Parameter	Value
Rotational speed, N	12,000 RPM
Mass flow rate, $\dot{m}$	11.5 kg/s
Pressure ratio, PR	2.45
Normalized pressure ratio, PR/PR_{Design}	0.7
Stagnation inlet temperature, T_{01}	298 K
Stagnation inlet pressure, P_{01}	101 kPa

Using the map and the given data, evaluate the following quantities for the compressor:
(i) design pseudo-dimensionless speed in $RPM/\sqrt{K}$;
(ii) design pressure ratio;
(iii) design mass flow rate in kg/s;
(iv) choking mass flow rate at design speed in kg/s; and
(v) pressure ratio at surge point for 70% design speed.

(20 marks)

Q4 (a) Define and briefly describe the following terms for axial flow turbines:
(i) Normal stage;
(ii) Degree of reaction; and
(iii) Blade loading.

(6 marks)

(b) In a normal stage axial flow turbine, gas enters at a constant axial velocity of 250 m/s. The mean blade velocity is 350 m/s and the mass flow rate of gas is 15 kg/s. The nozzle exit angle is 63° while the stage exit swirl (rotor exit) angle is 9°. For this turbine, determine:
(i) rotor inlet absolute velocity;
(ii) rotor inlet swirl component;
(iii) rotor exit swirl component;
(iv) inlet and exit blade angles;
(v) turbine power output; and
(vi) degree of reaction.

(14 marks)

Q5 The operating data of a nozzle type inward flow gas turbine is given as follows:

Parameter	Value
Rotational speed, N	25,500 RPM
Stagnation pressure at nozzle inlet, P_{01}	705 kPa
Stagnation temperature at nozzle inlet, T_{01}	1080 K
Static pressure at nozzle exit, P_2	515 kPa
Static temperature at nozzle exit, T_2	1000 K
Static pressure at rotor exit, P_3	360 kPa
Static temperature at rotor exit, T_3	923 K
Stagnation temperature at rotor exit, T_{03}	925 K
Specific heat ratio of gas, γ	1.33
Heat capacity of gas, C_p	1147 J/kg.K

For this turbine, evaluate the following performance;
(i) total-to-static efficiency;
(ii) specific work of impeller;
(iii) diameter of impeller; and
(iv) total-to-total efficiency.

(20 marks)

Q6 A Pelton wheel is operating at 14 m/s bucket velocity with water (ρ_{water} = 1000 kg/m^3) being supplied at a rate of 0.82 m^3/s and a head of 45 m. The water jet is deflected in the bucket by 160°. Taking the velocity coefficient (C_v) to be 0.98 and neglecting the losses in the bucket, determine:

(i) jet velocity;
(ii) tangential velocity component at bucket exit;
(iii) power developed by turbine; and
(iv) efficiency of turbine.

(20 marks)

– END OF QUESTIONS –

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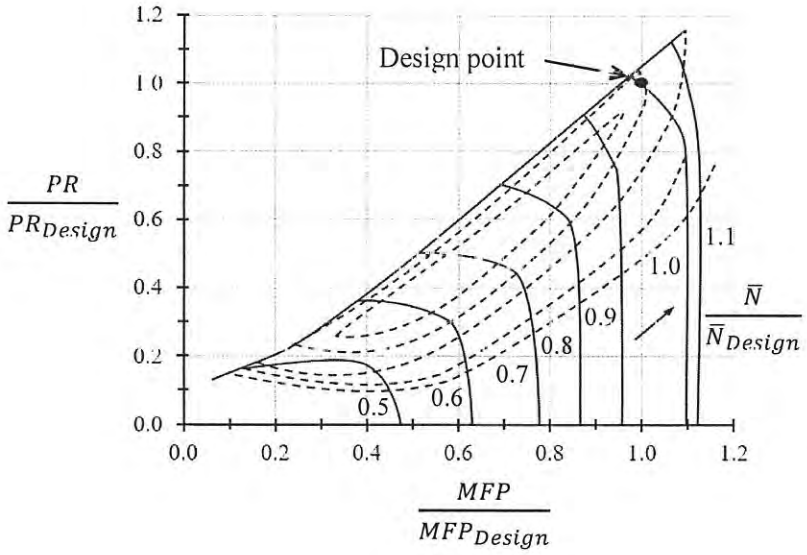

Figure Q3