Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2018/2019

COURSE NAME	:	TURBOMACHINERY
COURSE CODE	:	BDE 40303
PROGRAMME	:	BDD
EXAMINATION DATE	:	JUNE 2019 / JULY 2019
DURATION	:	3 HOURS
INSTRUCTIONS	:	ANSWER **ONLY FIVE (5)** FROM **SIX (6)** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **FOUR (4)** PAGES

Q1 (a) The discharge pressure Δp of a centrifugal pump is a function of flow rate Q, rotational speed N, fluid density ρ, fluid viscosity μ, and impeller diameter D. Using the Buckingham-π method of dimensional analysis, determine the dimensionless parameters that characterise the performance of this machine and express the parameters related to discharge pressure in the form of the head coefficient.

(8 marks)

(b) A centrifugal pump operating at 1000 rpm is delivering 18.2 m^3/hr of water at 10.5 bar gauge pressure. The pump requires 6 kW of shaft power at design point. If the pump is operating at 1500 rpm, determine:

(i) flow rate;
(ii) discharge pressure;
(iii) head; and
(iv) shaft power.

(12 marks)

Q2 A 915mm blade diameter single-stage axial flow gas turbine has inlet total pressure and temperature of 5.0 bar and 1100K respectively. The turbine is rotating at an angular speed of 765 rad/s with 15 kg/s mass flow rate. The axial velocity is 250 m/s and is constant throughout the stage. The rotor is designed with 63° inlet flow angle and 9° exit swirl angle. The total-to-static efficiency of the turbine is 0.85. For C_p =1.147 kJ/kg.K, determine:

(i) relative flow angle at rotor inlet;
(ii) relative flow angle at stage exit;
(iii) absolute flow velocity at exit;
(iv) power output;
(v) degree of reaction; and
(vi) isentropic static temperature at turbine exit.

(20 marks)

Q3 An axial flow gas compressor has a tip and hub diameters of 95cm and 85cm respectively. The absolute flow makes an angles of 28° at the inlet and 56° at the exit. The relative flow angles at rotor inlet and exit are 56° and 28° respectively. The compressor operates at 5000 rpm with air density of 1.2 kg/m^3. For this compressor, determine:

(i) axial velocity;
(ii) mass flow rate;
(iii) power required by the compressor;
(iv) flow angles at the hub assuming free vortex condition; and
(v) degree of reaction at rotor hub.

(20 marks)

Q4 (a) Compare and explain the advantages and disadvantages of radial flow gas turbines with axial flow gas turbines in terms of efficiency, pressure ratio, multi-staging capability and application.

(8 marks)

(b) An inward flow radial gas turbine operating at 30,500 rpm blade rotational speed has the specifications shown below:

Rotor inlet tip diameter	92 mm
Rotor exit tip diameter	64 mm
Rotor exit hub diameter	26 mm
Exit to spouting speed ratio (C_3/C_0)	0.447
Ideal velocity ratio (U_2/C_0)	0.707
Gas density at rotor exit	1.75 kg/m^3

For this turbine, determine:

(i) rotor exit flow area and rotor disc area;
(ii) dimensionless specific speed;
(iii) volume flow rate of gas at rotor exit; and
(iv) turbine power output.

(12 marks)

Q5 (a) A centrifugal compressor operates at 20000 rpm with gas entering the compressor at a stagnation temperature and pressure of 35 °C and 1.0 bar respectively. The flow enters the compressor axially and the rotor exit diameter is 58 cm. The pressure ratio between the blade inlet and exit is 3.5. The radial velocity component at the blade exit is 120 m/s and the isentropic efficiency of the compressor is 80%. The flow between the blade inlet and exit is assumed to be isentropic with the specific heat ratio of $\gamma = 1.4$ and specific heat of $C_p = 1.004$ kJ/kgK. For this machine:

(i) sketch the velocity triangle at the blade exit and label accordingly the velocity components and flow angles;
(ii) calculate actual temperature rise in rotor;
(iii) calculate the slip velocity; and
(iv) determine the slip factor.

(10 marks)

(b) The specification data for a centrifugal air compressor is given below:

Blade tip diameter, D	1 m
Rotational speed, N	5945 rpm
Mass flow rate of air, $\dot{m}$	28 kg/s
Static pressure ratio, (p_3/p_1)	2.2
Atmospheric pressure, p_1	1 bar
Atmospheric temperature, T_1	25° C
Slip factor	0.90

The specific heat and specific heat ratio is given as C_p = 1.005 kJ/kgK and γ = 1.4 respectively. Based on the given specification and neglecting the power input factor, determine:

(i) the adiabatic efficiency;
(ii) the exit air temperature; and
(iii) the required power input.

(10 marks)

Q6 A Pelton wheel type turbine in a hydro power station produces 1260 kW of power under a head of 610 m. The friction loss between the reservoir and the nozzle is equivalent to 46 m head. The bucket of the wheel deflects the jet through 165° angle and the relative water velocity is reduced by 10% due to friction. The bucket to jet velocity ratio is 0.46. The bucket diameter is 890 mm and the turbine operates with two nozzles with a nozzle velocity coefficient of 0.98. If the actual hydraulic efficiency of the turbine is 90% of the theoretical efficiency, sketch the turbine velocity diagram and calculate:

(i) theoretical hydraulic efficiency;
(ii) actual hydraulic efficiency;
(iii) rotational speed of the wheel;
(iv) mass flow rate of water through one nozzle; and
(v) nozzle diameter.

(20 marks)

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