Department of Mechanical Engineering
IIT Kharagpur

Nontraditional Manufacturing Processes: Mf30604

End Sem. Examination: Spring 2017-18 **Time: 3 hours** **Full marks: 100**

Attempt All Questions of Part-A and Part-B

Part – A (50 marks)

1. Answer the following in brief (5x5=25)

i. Name different nontraditional machining processes in which material removal mechanism is thermal. Describe briefly with a schematic diagram the construction and operating principle of a machine which utilizes photons for machining. How is material removed while cutting metal sheets by this machine?

ii. Among different nontraditional machines which one will you prefer to make a square groove in a glass plate? Describe briefly the construction of the machine with a schematic diagram. What are process parameters that determine the material removal rate?

iii. Name the nontraditional machining process which can produce the minimum feature size with highest resolution and also image it? What is the basic mechanism of material removal in this process and on what factors machining rate depends?

iv. What is the main difference between the conventional forming and high energy rate forming? Name the different methods of HERF? Explain the basic principle of electromagnetic forming of a stainless steel sheet having low electrical conductivity?

v. What is the role of magnetic field in magnetron sputtering process? Why is the step coverage better in magnetron sputtering process of coating than that in thermal evaporation process? What are the factors that influence the quality of film deposited?

2. a. Derive an expression for the material removal rate of a **brittle** material in abrasive jet machining. (5)

b. A workpiece has a 10 μm thick **ceramic** coating on its surface. The strength of coating is 4 Gpa. This coating is to be removed by abrasive jet having average grit diameter of 50 μm and grit density of 4000 kg/m^3. If the10 μm thick coating is to be removed in a single impact of grit **what should be its velocity**? Estimate the AJ mass flow rate to remove ceramic coating over a 10 cm x10 cm area in one minute machining time. (3+4=7)

3. i. A fiber laser beam has the following characteristics:
Wavelength = 1.06μm, M^2 =30, Beam diameter = 16 mm, Laser power = 2 kW.

The laser beam is to be focused to a spot of diameter 500 μm with the help of a convex lens on a steel plate for cutting. What should be the focal length of lens?

The sheet thickness is 5 mm and the severance energy for O_2 assisted laser cutting of steel is 8 J/mm^2. What will be the maximum cutting speed?
What is the role of O_2 in this cutting process? **(3+2+1=6)**

ii. Full penetration butt welding of two 6 mm thick titanium plates is to be done at 3 m/min speed with an electron beam focused to 600 μm diameter spot at the plate surface. What will be the e-beam power required to perform the welding and what will be the actual weld-bead width? During the welding process ~5% material is evaporated and the e- beam power coupling efficiency including conduction loss is 0.1.
The thermo-physical properties of aluminum are given as the following:
Density = 4510 kg m^{-3}, Latent heat of fusion= 437 kJ kg^{-1}, Latent heat of vaporization =9000 kJ kg^{-1}, Specific heat = 520 J kg^{-1} K^{-1}, Melting temperature =1670°C, Boiling temperature = 3260°C, Thermal conductivity =19 W m^{-1}K^{-1}
You may assume constant properties over the whole temperature range. **[7]**

Part – B (50 marks)

4(a) Explain the functions of servo reference voltage and servo sensitivity in relation to maintaining the inter-electrode gap in EDM.

4(b) Explain with simple diagram how the effect of variation of electrolyte temperature (between exit and entry side) in the inter-electrode gap is taken care of during designing for tool in ECM.

4(c) The composition (% by weight) of Nimonic 75 alloy is given in the table below:

Element	Ni	Cr	Fe	Ti	Si	Mn	Cu
% presence by weight	72	20	5	0.5	1	1	0.5
Atomic weight	58.7	52	56	48	28	54	63
Valency	2, 3	2, 3, 4	2, 3	3, 4	4	2, 4, 6,7	1, 2
Density (g/cm^3)	8.9	7.2	7.9	4.5	2.3	7.4	9

Calculate **the time required** to electrochemically machine a square block (area = 20 mm x 20 mm) of this alloy to a depth of 5 mm when a current of 2000 A is used. Use the lowest valency of dissolution for each element. Faraday's constant= 96500 coulombs.
(3+3+4 = 10 Marks)

5.(a) What are the reasons for developing a hybrid manufacturing process?

5.(b) How are the hybrid processes classified?

5.(c) Write short notes on the following two hybrid processes highlighting process mechanism with schematic diagrams and their advantages in terms of process capabilities..

i. Abrasive electro-discharge grinding (AEDG)

ii. Laser assisted chemical etching

(1+1+2x4 = 10 Marks)

6(a) Highlight two application areas where electrochemical honing process may be useful.

6(a) With a neat diagram **explain the different interaction phases** of the rotating grinding wheel with moving job and corresponding material removal mechanisms during electro-chemical grinding (ECG) process.

6(c) In a photochemical blanking operation a rectangular slit 300 micron width was attempted to be made on a copper-beryllium sheet of 200 micron thickness by selectively exposing only the top surface with a mask. It resulted in a tapered slit for which the dimension at the top was more than the dimension at the bottom.
Suggest some change in the approach while continuing with the same process so that a near-vertical slit could be obtained. (Use suitable diagram for explanation)

(2+6+2 = 10 Marks)

7(a) Prove that buckling strength to weight ratio of an Euler column increases if its linear dimensions are scaled down.

7(b) With the help of diagram explain the process sequences for a optical lithography process on a silicon wafer.

7(c) Why is an X-ray source more suitable for high resolution lithography?

(3+6+1 = 10 Marks)

8(a) What type of power supply one should use for electro-chemical-discharge machining (ECDM) and why?

8(b) Why is the manufacture of the micro-electrode tools essentially carried out **in situ** in a micro-EDM set up itself?

8(c) Explain with a schematic diagram the way a micro-tool (for subsequent use micro-EDMing operation) can be fabricated in-situ in a micro-EDM set up by wire electrodischarge grinding (WEDG) process?

8(d) What are the possible sources of stray capacitance in a micro-EDM set up?

(3+2+4+1 = 10 Marks)

**** *End of question paper* *****