Sample Final Exam (ME 363, Spring 2023, Purdue University, West Lafayette IN, USA)

1. (10 points)

   The tensile strength of a part produced by powder metallurgy can be empirically related to porosity as follows:

   $$UTS = UTS_0 e^{-nP}$$

   where P is the volume fraction of pores in solid, UTS_0 is the tensile strength at zero porosity, and the exponent ranges between 4 and 7 (assume to be 4 in this case). A fully dense ceramic has the properties of UTS_0=140 MPa, E_0= 310 GPA and density of 4000 kg/m^3.

   (a) After compaction, it reaches 80% of the density of the solid material. If the linear shrinkage is 5% during sintering, determine the density.
   (b) Determine the UTS and modulus of elasticity of this material after sintering.

2. (10 points) For a plastic composite, the reinforcement material is carbon fibers (assumed strength: 2400 MPa; elastic modulus: 290 GPa) and the matrix is epoxy (strength: 120 MPa; elastic modulus: 100 GPa). The elastic modulus of the composite is 170 GPa.
   (2.1) What is the volume fraction of the carbon fibers in the composite? What is the fraction of the load supported by the matrix (assuming the composite is in a cylindrical shape under one-dimensional tensile load)?
   (2.2) If the one-dimensional tensile load starts from 0 and continues increasing slowly, does the stress on the fiber or the stress on the matrix reach their corresponding strength first? Please explain why.

3. (13 points) A metal workpiece in the cylindrical shape (where the original diameter is 60 mm and original height is 55 mm) is hot upset to a smaller height by a hydraulic press that operates at v = 75 mm/s. (It is assumed that m = 0.12, C = 115 MPa, and the sliding friction can be neglected). If the maximum press force the hydraulic press can apply is 600 kN, then please determine the smallest height, h_{min}, to which the workpiece can be upset to. (Write your result in the unit of mm).

4. (13 points)

   A continuous hot rolling mill has three stands. The dimensions of the starting slab are 3.0 in. in thickness, 15.0 in. in width, and 10 ft in length. The final thickness is to be 1 in. The roll diameter at each stand is 36 in. It is observed that the speed of the slab entering stand 1 is 240 ft/min. Assuming no widening of the slab occurs during the rolling sequence and percent reduction in thickness is to be equal at all stands, answer the following questions.

   (a) Determine the percent reduction per roll station.
   (b) What is the thickness of the plate exiting at stand 1 and 2?
   (c) What is the length and speed of the final strip exiting stand 3?
   (d) Determine the rotational speed of roll #1, assuming that the roll tangential velocity is equal to the average of entering and exit velocities for each station.

5. (12 points)

   A blanking operation will be used to create a round disk of 20 mm in diameter from a strip of 2.1 mm thick 7075 aluminum.

   (a) Determine the force required to perform this blanking.
   (b) Determine the appropriate punch and die diameters. Assume that the clearance of 0.07t is needed between the punch and die for this operation, where t is the thickness of the 7075 aluminum.

6. (12 points) A cylindrical metal rod, which has an original diameter of 12 mm is hot-drawn through a die to a final diameter of 9 mm, and the friction coefficient is assumed to be 0.13, and the die angle is 14° It is assumed that for the metal material, C = 200 MPa & m =0.12. If the maximum drawing force that can be applied by the equipment is 10 kN, what is the maximum drawing velocity in the unit of mm/s (i.e. the maximum velocity of the drawn material after it passes through the die)?

7. (30 points) Multiple choice problems (In real exam you will have 10 multiple choice problems). (Only one answer exists for each problem).

7.1 Which of the following is NOT the typical advantage of powder metallurgy?
(a) Production of complex parts (b) reduction of material waste (c) high strength (d) high production rates

7.2 Which of the following manufacturing processes has to be carried out by putting the workpiece in vacuum:
(a) Laser machining. (b) Chemical machining. (c) Electron beam machining. (d) Plasma arc cutting

References:

Textbook: *Manufacturing Engineering and Technology*, by Serope Kalpakjian and Steven Schmid, Prentice Hall, 6th edition.

Lecture notes of ME 363, by Prof. Yung C. Shin, Purdue University, West Lafayette, IN.