MEC-E7006 Advanced Production Technologies **5.4.2018**

Exam questions

1. A modern Selective Laser Sintering (SLS) machine with a CO_2-laser power of 70 W (λ = 10.6 µm; good beam quality M^2=1) is used to fuse PA 2200 powder at a sintering temperature of 170 °C. The density of this material is 930 kg/m^3 and the specific heat amounts to 2.35 J/(g*K).

   Assume that the laser is focused with a 30 cm focal length lens and the beam size, coming to the lens, is 1 cm. Additionally, the following process parameters are known: a scan speed of v_s = 3 m/s and a required layer thickness of 100 µm.

   - Calculate the spot size of the laser
   - Calculate the additional energy required to sinter a straight line for 10 s, considering that the machine was already pre-heated to 150 °C.
   - The goal is to print a single solid cube with a volume of 40 cm^3. For this reason, a hatch spacing (distance between the scan lines, needed only for the xy-plane) of 80 % of the beam diameter is applied. For each new horizontal layer, a recoating time of 3 s must be added. The scanning pattern is of your own choice. How long will the print take?

2. What are the ISO/ASTM approved Additive Manufacturing process categories? Provide a brief description of each method.

3. (a) Calculate the total cost per part for the case where 10 parts are made in one build using material extrusion process. The height of the parts is 60 mm and layer thickness is 0,2 mm. Assume average layer cross section to be 2,4 cm2, extrusion line separation to be 0,8 mm and extrusion speed to be 7,5 cm/s. The wait between extrusion stopping and starting in a new layer is 2 s. Assume preparation time and warm-up time to be 15 min together and cool-down and part removal time to be 15 min together. Weight of each part is about 30 g and material cost is 40 €/kg. Material extrusion equipment cost is 50000 and it is amortized in 5 years. Expected usage is 2500 h in a year. (b) Calculate breakeven quantity between additive manufacturing and injection molding if the injection molding tool is assumed to cost 3 k€ and the production cost for each part is 0,3 € in injection molding.

$$t_L = \frac{A_c}{v_{ext}\, s_{line}} + t_s \qquad d = \frac{4\lambda M^2 f}{\pi D}$$

$$V = d\, h\, v_s\, \Delta t \qquad E = C_h\, \rho\, V\, \Delta T$$

$$t_B = \sum t_L \qquad N_B = \frac{C_{CT}}{C_{AMP} - C_{CP}}$$