GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Quarter 1996

-- WORK TWO OF THE THREE QUESTIONS --

MANUFACTURING
EXAM AREA

Assigned Number **(DO NOT SIGN YOUR NAME)**

-- Please sign your name on the back of this page --

Problem #1

Consider the rolling of threads for a bolt using a two-roller die (see Figure 1). The diameter of the stock material is "d", the minor diameter of the thread is 0.8*d, and the threads have a thread angle of α degrees (α is typically 60°) (see Figure 2). The material being rolled can be modeled as strain hardening with $\sigma = K\varepsilon^n$. The roller dies have diameters of "D" and rotate at angular velocity "ω".

Determine the forces and power needed to carry out this operation.

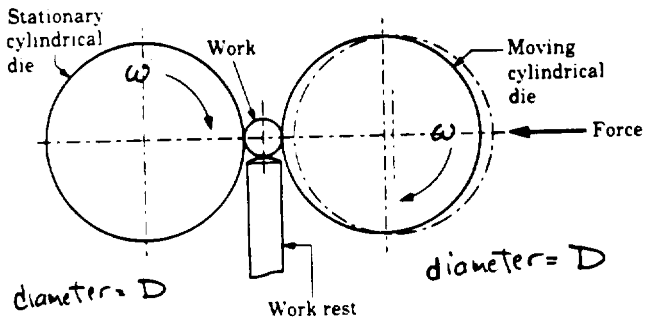

Figure 1: Thread rolling with a two-roller die.

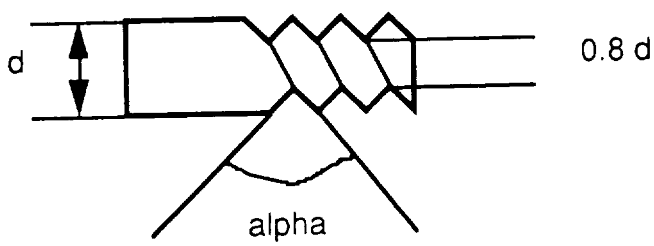

Figure 2: Thread geometry.

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Problem #2

A planing process is being used to machine a 300 mm x 300 mm x 25 mm flat mild steel block as shown in Figure 3. A single point high speed steel cutting tool with a rake angle $\alpha = 10^\circ$ is being used. Other parameters of the cutting process are as follows: cutting speed $V = 2$ m/s, undeformed chip thickness $t = 0.25$ mm, width of cut per pass $w = 2.5$ mm, cutting ratio $r_c = 0.3$. The length of contact between the chip and tool rake face $l_f = 0.75$ mm and the coefficient of friction between the tool and chip is known to be 1.07. The cutting and thrust forces are measured during each pass with a cutting force dynamometer and found to be as follows: $F_c = 890$ N and $F_t = 667$ N.

Do the following:

a) Calculate the total power and the material removal rate for a pass.

b) If it is given that the compressive yield strength of the tool material is 500 MPa, can the cutting tool fail by plastic deformation under the cutting conditions specified in the problem? Show appropriate calculations in support of your answer.

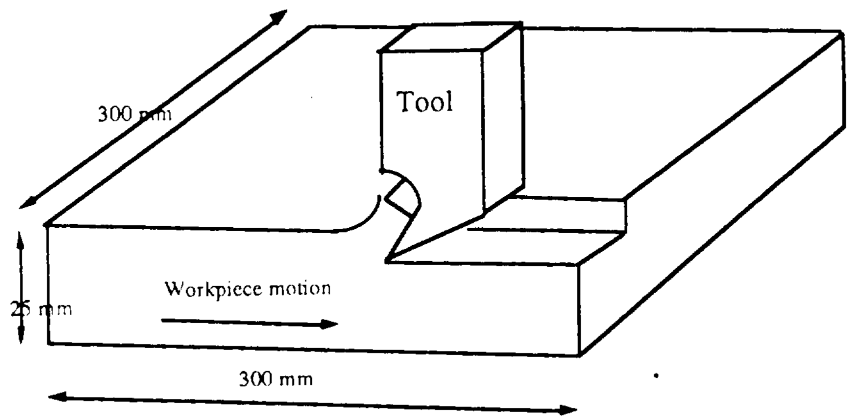

Figure 3: Cutting Geometry

Problem #3

A manufacturer of large earth moving equipment has hired you as a consultant to help them with the design and manufacture of hemispherical bearings for their front end loaders. In particular, the company is having significant problems with defects in the bearings and is also interested in improving the economics of the process. In the current process, the hemispherical bearings of constant thickness, h, are sand cast in a concave down configuration with the sprue and runner configuration as shown in Figure 4. Post casting, the bearings are machined to achieve the net shape and lubrication channels are machined in circular overlapping patterns on the internal surface to distribute oil. The bearing material is a high melting point bronze alloy known to dissolve significant water vapor and atmospheric gases while in the melt state. Further the bronze has a substantially lower gas solubility below the melt temperature. Some of the relevant parameters known for the casting systems are bearing radius 10 cm, bearing thickness 1 cm, density of green sand 1515 kg/m^3, sand specific heat 800 J/kg K, sand thermal conductivity 0.27 W/m K, sand hemispherical emissivity 0.9, sand porosity 18%, sand green strength 5 MPa, sand moisture content 15%, flask dimensions 40x40x30 cm, bronze melting point 1093° C solidus, 1066 °C liquidus, bronze density 8.8 g/cm^3, bronze specific heat 389 J/kg K, bronze thermal conductivity 259 W/m K, bronze hemispherical emissivity 0.5, bronze modulus 110 GPa.

For the existing process:

a) List the casting defects you might expect and the physical rationale for why these defects occur in the given system.

b) Using a sketch, suggest a mold redesign to eliminate the defects discussed in a).

c) For this sand casting process, list the major process steps that contribute to the overall cycle time of the process. Do not discuss.

d) Outline the steps that you would use to estimate the mold filling time.

e) Based on an order of magnitude, one-dimensional heat transfer analysis, estimate the solidification time for the part.

f) Discuss the microstructure that you would expect with the current process.

g) Given you results in c), d) and e), discuss the steps to be taken to reduce the manufacturing costs with this process.

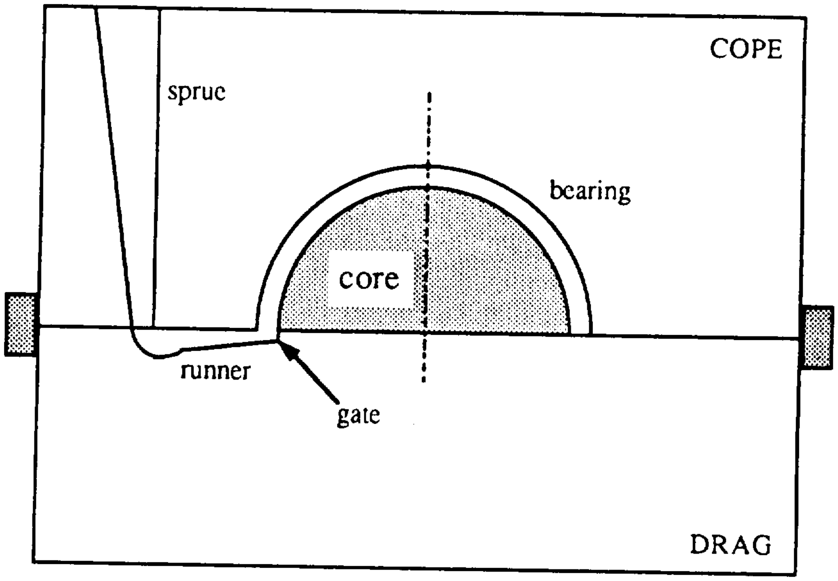

Figure 4: Bearing Casting