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Chapter 7: Machining – HINTS

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Exercise 7.1 Look around your house and find one or more examples of machined parts or products. Try to find examples of integral machining, and machining as a secondary process.

Hint 7.1: all kinds of possibilities. As always, an Internet search can help (search terms e.g. "machining of metals" or "machining of castings"), but make sure to get your hands on actual parts and products.

Exercise 7.2 Sketch an imaginary, small cube of material loaded by a shear force F in N. How is the shear stress τ in N/m^2 defined?

Hint 7.2: consider that tensile stress is perpendicular to the area on which it is working, while shear stress is parallel to it.

Exercise 7.3 Why can we assume that for isotropic materials, shear strength rises with yield strength? And why not if the material is anisotropic?

Hint 7.3: consider the mechanism of yielding in metals, and whether this varies with direction. Then think about a material which has much higher strength in one axis than at right angles to this axis (e.g. wood). Is the failure mechanism going to be the same for every direction of loading?

Exercise 7.4 Judging from Table 7.1, which of the listed materials is easiest to machine, and which is the most difficult? Explain why.

Hint 7.4: at this stage, assume strength is the driving criterion.

Exercise 7.5 How does the strain-to-failure affect the machining process, apart from the chip length? Hint: remember the definition of the total plastic deformation energy in tension (in J/m^3) (see also Chapter 4).

Hint 7.5: be sure to distinguish between *force* and *power*.

Exercise 7.6 What do you think happens to the machining force that drives the cutting tool forward if we double the cutting depth?

Hint 7.6: simple question, simple answer.

Exercise 7.7 Sheet metal manufacturing processes such as blanking and punching also operate by exceeding the material's shear strength. Still, there is a key difference with machining, apart from the shape of the ingoing material. What is that?

Hint 7.7: the key word here is 'shape', relating to the production waste.

Exercise 7.8   Which material from Table 7.1 will show the largest springback during machining? Hint: first find the machining force components, and then apply Hooke's Law.

Hint 7.8: you should find that materials with a high ratio of strength over stiffness will be the ones showing most springback.

Exercise 7.9   Briefly revisit Exercise 7.4. What is your answer now?

Hint 7.9: strength, stiffness and strain-to-failure all come in; and don't forget about cost.

Exercise 7.10   Do you think that an alloy that is well-suited to sheet metal forming will also be well-suited to machining? Why, or why not?

Hint 7.10: for simplicity, assume single-curved sheet metal forming here (where strain-to-failure also plays a certain role).

Exercise 7.11   Assume we use a milling machine (see also Section 7.6) with a 12 kW capacity to make a steel mould, removing 4 cm^3/s. If the specific heat of steel equals 470 J/(kg.K), how much hotter will the chips then get? Hint: you will also need the density of steel.

Hint 7.11: if your answer is not in the range of 500-800°C you have not done a good job.

Exercise 7.12   Apart from its contour angle and strength, which other tool properties can you think of that are relevant to machining?

Hint 7.12: the next section will give a clue, but common sense should be sufficient.

Exercise 7.13   A workpiece made of aluminium 6082 (as in Table 7.1) has dimensions L = 300 mm and W = H = 30 mm, and is machined as in Figure 7.3(a). What is the downward force component F_v needed to cause a deflection δ = 0.1 mm? What then is the typical accompanying component F_h? Given a tool width of 5 mm, what cutting depth can we then use? Will this be productive, do you think?

Hint 7.13: first use the formula for the deflection to determine the force (downward, vertical component). From this, find the horizontal component. Assume that the stress that must be imposed is 50-60% of the yield stress (this is actually a conservative estimate). Finally, note that the area over which the horizontal force component is working, is equal to the tool width times cutting depth. Another hint: observe your units!

Exercise 7.14   Now suppose that we have the same cutting geometry, but with the workpiece fully supported, as in Figure 7.3(b). If we assume that the same tool forces from the last Exercise are applied by the tool, explain why the deflection of the surface will be orders of magnitude smaller in this case.

Hint 7.14: find a valid equation for the relationship between the downward force component, the geometry (you will need to assume an effective surface area *A* over which the force is working) and the stiffness.

Exercise 7.15   Suppose we want to machine a thin-walled box-like shape out of a solid block of material (much like the iBook unibody). What do you recommend: first machining the walls to their approximate thickness and then finishing them, or finishing them directly?

Hint 7.15: take into account that resistance to bending goes with the third power of thickness.

Exercise 7.16   Dimensional inaccuracies can have several other causes than the elastic deformations of tool and part. Name at least two. What can we do to minimize their effect? And are these measures related to design or to manufacturing?

Hint 7.16: for one of the causes, 'internal stresses' is the keyword. For the other(s), just use your common sense, or re-read the text carefully to find the answer.

Exercise 7.17   How exactly does the strategy of first using large tools and high machining forces, then smaller tools and low machining forces, affect the geometrical tolerances? What is the consequence in terms of cost?

Hint 7.17: the answer should become apparent upon re-reading Section 7.4 (and 7.5).

Exercise 7.18   For a high speed machined, thin-walled metal electronics housing, what do you recommend: first finishing the inside, then the outside – or the other way around? Why?

Hint 7.18: consider whether both sides need an equal quality of finish.

Exercise 7.19   Take a close look at your product samples (see Exercise 7.1). Which quality issues can you spot, in terms of roughness, burrs or lay?

Hint 7.19: all kinds of possibilities – just take a close look.

Exercise 7.20   Even when clamped in the chuck and centred on the other end, the workpiece will still bend under the machining force, if the cutting tool is operating somewhere in between – so, we get comparatively large deflections for small forces. How can we solve this problem?

Hint 7.20: one way to rephrase the question is "how can we balance out any bending force on the workpiece?"

Exercise 7.21   Look around in a local workshop or find detailed illustrations of these six kinds of drills on the Internet. What are the key differences (e.g. how many cutting surfaces do they possess)?

Hint 7.21: a regular image search should do; be sure to add the word 'bit' to your search team (e.g. "jobber drill bit").

Exercise 7.22   Suppose we use a triaxial milling machine equipped with an end mill (with 10 mm diameter) to hollow out a rectangular block. What is the minimum internal radius of the hollowed-out block?

Hint 7.22: do you think the radius could somehow be smaller than half the diameter of 10 mm?

Exercise 7.23   Think of a shape that can be made on a CNC-operated milling machine with four or five axes, using a standard end mill only, that can <u>not</u> be made on a triaxial machine, without re-clamping the product (at least not with acceptable productivity).

Hint 7.23: if you imagine (or sketch) the situations well, you should have little difficulty here.

Exercise 7.24   Why is a ball nose mill needed for double-curved shapes? And why do such shapes require CNC operation over at least three axes? Explain.

Hint 7.24: just imagine a fairly complex, double-curved product, say, a rubber duck. Now imagine the (steel) mould it is moulded in. How would you make this mould if you only had a slab mill and an end mill?

Exercise 7.25   Look back at one of the product examples you found (see Exercise 7.1). Consider which metal and method were involved, and then draw up three design guidelines for this combination. How do you see these rules reflected in your product?

Hint 7.25: think back to the manufacturing triangle: which shapes (= function) can be made with high accuracy (= quality) and quickly (= cost), and which shapes cannot? Similarly, which materials allow fast, accurate machining, and which ones do not? As always, do not give 'manufacturing' rules (e.g. "use the right tool for the material" refers to manufacturing, not to design).