CHAPTER 2

STRENGTH

CHAPTER OUTLINE

CHAPTER SUMMARY

In Chapter 2 you will be introduced to the concept of design with tradeoffs. Specifically, the tradeoff between strength and weight. You will also be introduced to a few concepts that will help you design a strong part.

2.1) INTRODUCTION

Designing components for product assemblies (e.g. casing for a smart phone, latch for a car door, bracket for a camera, etc…) is an exercise in finding the optimum solution to a multidimensional problem. For example, a component needs to be stiff and strong enough in order not to deflect or break. Yet, it must be lightweight in order to maximize performance (e.g. vehicle acceleration) and minimize transportation cost (e.g. it must be brought in by truck to the assembly plant). If the customer interfaces with the part, then that component needs to be aesthetically pleasing with nice surfaces to the touch. It must also be designed to minimize the manufacturing costs (there are some features that add high costs of manufacturing, but which are not needed or are transparent to the customer). These are only few of the conflicting requirements that engineers deal with continually in design work. Other requirements that should not be overlooked are ecology, human health, safety, recyclability and water consumption among many others.

2.2) STRENGTH VERSUS WEIGHT

The principles of design related to maximizing the strength to weight ratio is premised on techniques that minimize the amount of material present in a part. However, the reduction of material has to be balanced by the need to maintain structural integrity and rigidity. The science related to that is beyond the scope of this introductory chapter, yet the following are general guidelines that you will find helpful when designing a lightweight but strong product.

2.2.1) Stress concentrations

A load that is applied to an actual part will cause stresses to develop. The tangible manifestation of stress is deformation or strain. The concept of stress and strain is beyond this scope, however an intuitive understanding can be developed by referring to everyday experiences. Almost everyone has at one time witnessed a part that was loaded past its ability and broke as a result. Take for example a tire swing connected to a tree branch. As a person gets on the swing, the branch experiences a bending stress which manifests visually in bending deformation. The amount of deformation is related to the magnitude of the load. The tree branch analogy works very well to illustrate the concept of stress concentration due to geometric irregularities. The connection between the tree branch and the tree truck is rounded with a smooth transition, and that is precisely to avoid additional mechanical stresses. Another example is given in Figure 2.2-1 which shows two bellcrank designs that have shape changes. The bellcrank on the left is more likely to fail under the same load as the one on the right because of stress concentration. Notice that the inside corner of the bellcrank on the left is very sharp and the inside corner of the bellcrank on the right is more rounded.

Another factor to consider when removing material to minimize weight is to avoid removing materials near the outer surfaces and to leave enough of a wall thickness to maintain structural integrity. Figure 2.2-2 shows a bellcrank that has failed at a place where the wall thickness was too small to support the stress concentrations that developed around the abrupt change in cross-sectional area.

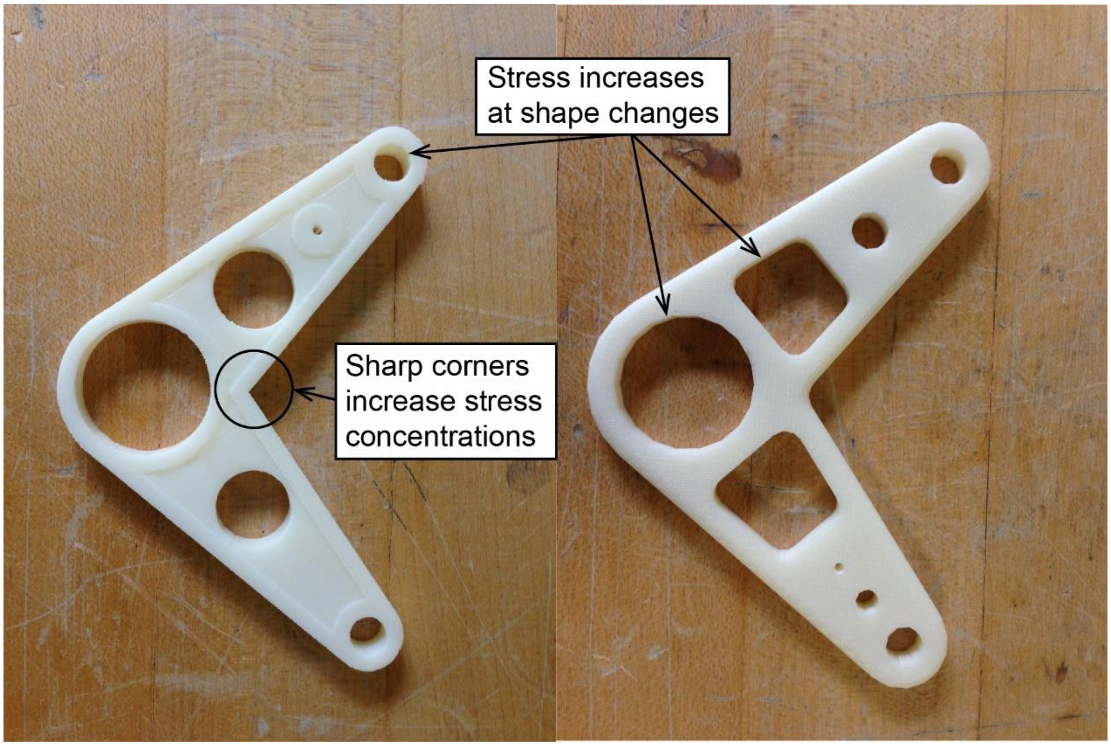

Figure 2.2-1: Stress concentrations

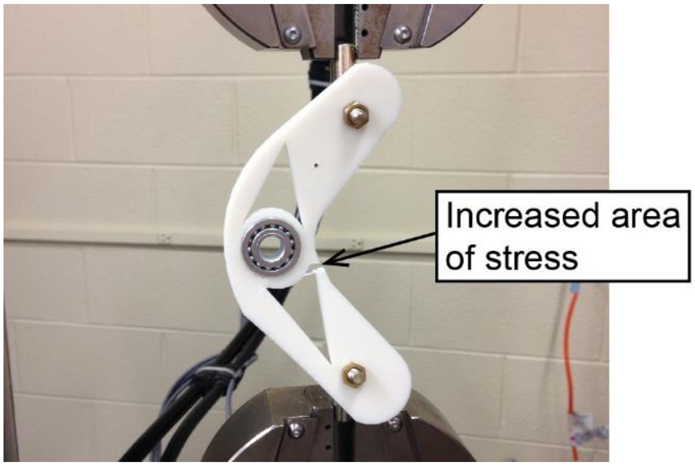

Figure 2.2-2: Stress concentrations failure

2.2.2) Bending stiffness

The stiffness of a part depends on the type of material your part is made of. For example, you know from experience that metal is stiffer than plastic. But, there is more to the story. Try this, take a ruler and lay it flat on a table with half of it hanging off. Now take your finger and press down on the end that is off the table. Note how flexible the ruler is. Now flip the ruler on its edge and repeat the process. The ruler is much stiffer on its edge. The ruler didn't change material. It just changed shape. So, stiffness depends on both material and shape.