MEEM 3501
Product Realization I
HO2: Design and Manufacturing Overview

Let us begin by considering what the terms "design" and "manufacture" mean. In other words, how can we define these terms. Webster's definition of design includes "to conceive or draw the plans for." This is typically what one thinks of when hearing the word design, but as engineers, we should consider, explicitly, a component of this definition that may or may not be successfully implied, depending on who is interpreting the definition. The same is true for Webster's definition of manufacture, which includes "to make from raw materials by hand or machinery." There is an implicit attention to how the object is made. We will include this consideration explicitly also.

The remainder of this section is a thought exercise. Assume for this exercise that someone is paying you to design and manufacture a product. First, evaluate this assumption. Contradictory to the assumption is the fact that some of us may design and manufacture "products" for fun in a recreational role. However, the assumption is a safe one when considering the business world in which we act, or will act, as engineers. In the business world, engineers design and manufacture things for a reason. This is the key. There must be some reason to design and manufacture a product. When producing a product for this reason, there is a reward. Recreationally, the reward would be personal enjoyment. In the business world, or even your personal life, the reward is monetary. Think for a moment; can you expect to be monetarily rewarded for producing a product that has no use, or inhibitingly limited use? Of course not. But it has been done in the past. Determination of usefulness is an issue on its own. The focus here will be on the normally implicit parts of the definitions of design and manufacture rather than the customer-driven concept of usefulness.

Alternate Definitions of Design and Manufacturing

The first point in identifying the implicit characteristic of the design definition is related to the usefulness issue. That is, there must be a need, which suggests usefulness, for which you can design a product to satisfy. The Webster's definition can be modified to explicitly include the notion of satisfying a need — "to conceive or draw the plans <u>to satisfy a need</u>." To go one step further, where does the need come from? Of concern to engineers and their employers in the business world is selling products to customers. The customer has a need. Therefore, this can also be explicitly included in a definition of design — "to conceive or draw the plans <u>to satisfy a customer need</u>." This will be our "Definition of Design." At all times it is very important to keep in mind that your decisions and actions during product design must focus ultimately on **satisfying a customer need**.

The next consideration is that of using the design. Is the design itself useful in satisfying the customer need? Recall that the design consists of "drawing the plans for." The plans must be executed through manufacturing to obtain the physical product. Recall that Webster's definition of manufacture includes "to make from raw materials by hand or machinery." The act of making is the execution of the design, which consists of plans that, when executed, result in a product. Typically, these plans include (1) the product geometry, including its shape, size and appearance, and (2) the materials from which the product should be made. The geometry and materials serve as design details or physical specifications which will assure that the product meets the need, which includes specifications as to functional performance. Therefore, let the notion of specifications be explicitly included in our "Definition of Manufacture": "to make <u>to some physical specifications</u> from raw materials by hand or machinery."

Note at this point that the definition of design indicates that plans are drawn up. If executing these plans results in a physical, useful product, then the plans must include the instructions for how to manufacture the product. However, these instructions are not traditionally considered as part of the product design. It will be discussed later how a design should not only specify the physical (geometry and material) specifications, but also the instructions for how to bring the raw materials to the useful physical form of a final product. This implies that manufacturing engineering, in its traditional definition of determining how to make things, is in fact one in the same with design engineering.

Design and Manufacturing Engineering Practice

It is clear that in product development, which includes not only the design of a product, but also its successful manufacture, a customer need must be satisfied. As mentioned, the focus in this course will not be on determining the customer need. The focus will be on developing products that satisfy a pre-defined need, which includes a function that must be performed by the product as well as specifications as to how the function is achieved, i.e., what level of performance is required in terms of speed, repetitions, lifetime, etc. Achieving the goal of developing a successful product relies heavily upon design engineering and manufacturing engineering, among others.

Traditional Practice — Over-the-Wall Engineering

Given a need and its associated specifications, the next step is to design the product. Obviously, the product cannot be manufactured until it is designed, i.e., until the product plans are drawn up. So, it makes sense to design the product, then manufacture it. However, does it make sense to first design the product, then *plan* its manufacture? This would be a serial approach to product planning (design) and manufacturing planning. This is old practice. It is often termed “over-the-wall engineering” since the design engineers plan the product so that it meets the need and then throw these plans over the wall to the manufacturing engineers who must then find a way to make the product to the design specifications. This is how American companies operated until the mid 1980’s and some companies still ten years later and beyond.

Contemporary Practice — Simultaneous Engineering

To be globally competitive, a company must consider how a product will be manufactured *simultaneously* with considering how it must be designed to function. This is a parallel, concurrent, or simultaneous approach to engineering a product. This may make perfect sense to you. However, it was not until recent years that American companies began to embrace and employ the concept. If this is not obvious, the following points and the following section may help.

- Considering how a product is manufactured while designing the product for function can lead to designs that are more *easily* manufactured.
- Considering how a product is manufactured while designing the product for function can avoid designs that are *impossible* to manufacture.
- How a product is manufactured directly affects whether or not it will function properly.

A Radical Thought

The following concept was introduced earlier: manufacturing and design engineering are <u>one in the same</u>. It turns out that the idea of simultaneous engineering as an interaction between design and manufacturing engineers is better accepted than having individuals who excel in both areas. Two reasons for this are:

1. The simultaneous engineering concept maintains the separation of detailed product design and detailed manufacturing planning, which is the way industry is set up — design engineers and manufacturing engineers.

2. Unfortunately, we as humans have a limited capacity for excellence. Therefore, we excel in design engineering or manufacturing engineering.

So ideally, these two engineers should be <u>one in the same</u>. As you will discover through comparing the actual performance of your ideally designed and manufactured products to their anticipated performance, we do not live in an ideal world.

Another concept that was introduced earlier is that a design is incomplete if it does not include the instructions for its manufacture. If a product design is considered complete only if it includes the instructions for its manufacture, then how the product is manufactured must, of course, be considered during the design — simultaneous engineering. However, simultaneous engineering, as defined above, does not explicitly state that the manufacturing plans must be part of the design, only that manufacturing plans must be considered during design. The impracticality, whether through industrial organization or human capabilities, of employing individuals who are experts in both design and manufacturing engineering does not preclude the goal of including as part of a product design its manufacturing instructions. These manufacturing instructions can be realized through interaction between design and manufacturing engineers working simultaneously on the product development problem. Therefore, as much as possible, strive toward a complete design as defined as "plans", which include manufacturing plans.

Conclusion

Under a simultaneous engineering framework, the design engineers, who are experts in designing products for function, have a general understanding of manufacturing so they can communicate with manufacturing engineers, who are experts in how to manufacture products and have a general understanding of design so they can communicate with design engineers. After your MTU undergraduate experience, you should have general knowledge in both design engineering and manufacturing engineering. If you continue, through elective courses and/or graduate school, you will become more of an expert in one of these areas. It will not be until you practice as an engineer that you will become notably proficient as one of these types of engineers. Still, to be competitive in the current and future global marketplace, an engineer labeled with one expertise must have general knowledge of the other engineering area so the critical and necessary communication can be maintained. This communication is necessary to assure a <u>complete</u> design — one that includes complete plans/instructions for manufacturing the product.

Design and Manufacturing Engineering Resources

The acts of designing a product and planning its manufacture have much in common. In particular, the engineering tools available for analysis purposes are identical. The frameworks under which they are applied are essentially the same also. The difference is the problem to which they are applied. The problems considered in design and manufacturing engineering can be categorized. Others have categorized these areas in similar ways. The following categories are offered in an attempt to get everyone thinking in a similar direction.

First, the *tools* available include many that have been, or should have been, learned in preceding courses along with some new ones. For example, low-level tools learned in other courses include Mathematics (Geometry, Algebra, Trigonometry, Calculus), Constitutive Laws (Elasticity, Plasticity, Damping, Fatigue, Combined Stress), and Conservation of (Energy, Momentum, Mass). These *"Great Ideas"* of Mechanical Engineering have been applied under different *frameworks* such as Heat Transfer, Fluid Mechanics, Solid Mechanics, Dynamics, and Materials Processing. Design and manufacturing engineering are higher-level frameworks under which these tools or great ideas and lower-level frameworks are applied in a coordinated fashion. Therefore, besides learning a few new concepts and equations, design and manufacturing primarily involves learning how to select and coordinate the appropriate tools. This includes *understanding* (1) the individual, fundamental *concepts* of these lower-level tools and frameworks, and (2) how the individual lower-level tools and frameworks interact to solve a bigger, *real-life* problem.

Finally, many design problems can be categorized based on function or purpose of the *components* within the category. These categories are:

1. Power/Energy Conversion
2. Power/Energy Transmission
3. Transmission Support
4. Frames
5. Joints

The manufacturing problems are categorized based on function or purpose of the *processes* within the category. These categories are:

1. Solidification
2. Deformation
3. Removal
4. Surface Treatment
5. Joining / Assembly

Note the common thread of “join”. Joining processes are employed to manufacture joints which are essentially components that hold two other components together. The other categories are self-explanatory. These will be covered in more detail later. What is important to understand is that most any function can be achieved with a combination of components from these categories and that most any product can be manufactured using a combination of manufacturing processes from these categories, in fact a combination of any <u>one</u> of 1-4 along with 5.

Summary

There are general constraints in product design and manufacturing. The first and foremost is that the product must satisfy a need. The second is that there is a set of tools for analysis, and categories of components and processes to select from, but the convenience of selection comes at a cost — the savings realized in the engineering stage by selecting a <u>standard</u> component or process <u>may not</u> result in a savings in the end (i.e., production), likewise, the additional cost realized in the engineering stage that is associated with developing a <u>special</u> component or process <u>may</u> result in a savings in the end.

The concept of simultaneous engineering was discussed. A radical concept of manufacturing engineering being one in the same with design engineering has the potential for being a utopia, but is not acceptable, even in current industrial organizations, and likely unachievable in practice. As an alternative, experts in one area (design/manufacturing) must have general knowledge of the complementary area (manufacturing/design) to accommodate the interdisciplinary communication needed to simultaneously design a product for function and plan its manufacture. This simultaneous design and manufacturing planning results in a complete product design or plan — physical (geometry and material) specifications and instructions for achieving them.

If you have truly been successful in other courses, as measured by understanding the concepts rather than memorizing equations and example problem solutions, learning design and manufacturing engineering should be very straightforward. If you have weaknesses in understanding material from other courses, then having real-life situations in which they can be applied should reinforce and improve your understanding of the underlying concepts. In summary, there is much to learn, but you are not starting from scratch — your current knowledge is the foundation which, if a little weak now, will be greatly strengthened through practice.