Reverse Engineering and Engineering Design
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Design, above all else, defines the difference between an engineering education and a science education. Design represents the bridge between theory and reality. It is the process by which our ideas enter and influence the world around us. Design distinguishes us as engineers. Little agreement exists over how to teach design to undergraduate engineering students. Yet it must be done. One approach is teaching students a structured, problem-solving method that may be used to tackle open-ended design problems. While this approach is widely used, the specifics of the various ways engineering design is taught vary substantially. Reverse engineering is a process by which an existing product is predicted, observed, disassembled, analyzed, tested, experienced, and documented in terms of its functionality, form, physical principles, manufacturability, and assemblability. It is an in-depth study and analysis of an existing product to recreate the design decisions and information developed by the original design team. The intent is to fully understand and represent the existing product and realize that considerable effort and ingenuity goes into the design of every engineered system. Reverse engineering can significantly impact design education as it provides concrete experiences for students as they learn design methods. It allows the engineering student to witness a physical creation that is the result of a design process they are being asked to learn. Students are shown the culmination of the design process and then allowed to work backwards through the steps to achieve a greater understanding. Allowing students to work with a physical product while learning design also eases the transition from analytical courses to the open-ended nature of design courses. Balance between theory and practice is the key that will ultimately serve the best interests of the students.

Reverse Engineering Steps

Engineering Design generally starts with a need, formulates a design, creates documentation so that the design can be manufactured, and then produces the item. *Reverse Engineering* is an in-depth study and analysis of an existing product to recreate the design decisions and information developed by the original design team. This includes the methods of manufacture, materials, manufacturing cost, product requirements and important engineering analyses used during the design of the product.

Reverse Engineering is an important first step in the design process because it establishes a starting point. It helps create an understanding of the problem and can be a valuable source of ideas for new designs. For example, two existing designs or elements can be combined in a way which results in an innovative (and patentable) design. Companies regularly buy and reverse engineer their competitors' products. It is an accepted (and expected) part of design and problem solving. Reverse Engineering is also a way to benchmark a competitor's product.

Steps in Reverse Engineering a Product:

- Investigation, Prediction and Hypothesis
  - Investigate and examine the product treating it as a black box. Use and experience the product over its operating range. Develop a statement of global need/function. Gather and organize customer needs. Compare the product to its competition in a

qualitative manner. Develop a process description or activity diagram for the product. Predict how the product works (i.e., fulfills the customer needs). Conceptualize both black box and more refined models of the product's functionality and physical principles, without taking the product apart.

- Product Disassembly
  - Create a plan for disassembly. Perform a *structured tear down* of the product. Note everything of interest, both inside and outside the product. Take careful notes and make freehand sketches of the parts with dimensions and tolerances. From the information gathered create an exploded view of the product and a bill of materials naming all the parts. Determine how the parts are assembled and create an assembly tree.
  - Perform a *functional analysis* of the product. Document the actual product function and compare it to the prediction. Construct a morphological matrix using the parts and their corresponding functions. Investigate function sharing throughout the device. Determine the *performance specifications* for the product. Develop QFD matrices for the product and use the results to suggest design changes that should be made in the product.
  - Determine the *materials* used in the design, and, more importantly, why they were used.
  - Determine the *manufacturing methods* used, and, more importantly, why each was chosen.
  - Determine *costs*: cost of raw material, cost of fabrication, cost of tooling, cost of labor to assemble, test, and pack.
  - Determine how the mechanical, electronic, and control components are *combined* in the product and if they are combined in an *optimum* way.
  - Determine the important *physical principles* and *modeling relationships* necessary to both the *engineering analysis* of the design and the *assessment* of the impact of design changes that might be made in a re-engineering of the product.
  - Study applicable *standards* and determine which elements of the product are directly influenced by the standards.
  - *Evaluate* the product with respect to *performance, quality, and cost*. How well does it perform? What benefits does it provide to the customer? Perform a *marketing competitive analysis* to determine how the current product compares with similar products on the market. What are the product's strengths? What are the product's weaknesses? Is the product easy to use? Durability? Maintenance? Environmental issues?
  - *Make recommendations*. Is there an opportunity to design a superior product by either creating a more innovative concept for meeting the customer's needs or by doing a better job of designing the engineering details? Could you use new technology? Could you use new materials? Could you....?