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Curriculum Development on Computer-Aided Design and Additive Manufacturing

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Jennifer Curtis - Dr. Michael P. Davis

Abstract

The discipline of computer-aided design is a modern phenomenon driving the rapidly improving technological world of today. Additive manufacturing is not new, but the progress made in the past two decades has increased the examination made by academics and industry experts significantly. One method of this phenomenon is known as 3D printing. This future technology enables businesses to cut costs, reduces time to market, produces stronger and lighter parts, improves efficiency, and solves a myriad of other challenges. This very beneficial and essential process is needed for students to have an understanding of the technology in the 21st-century global economy. Figure 1 shows a rudimentary flow chart expressing the design process from the conception phase through to model finalization.

Introduction

Additive manufacturing in the form of 3D printing entails an understanding of an entire code base similar to that witnessed by CNC technicians. Available software converts 3D models into machine-readable code, with different software packages interpreting 3D models differently as the required steps and a basic machine are shown in figure 2. This abstraction between physical and computer-based modeling allows for numerous inconsistencies and potential errors when attempting a software crossover. An in-depth understanding of the way a 3D model becomes instructions for a 3D printer can aid engineers in controlling the number of variations and flaws in a rapidly prototyped design, effectively leading to an output adhering to the tolerances and requirements of the specific project.

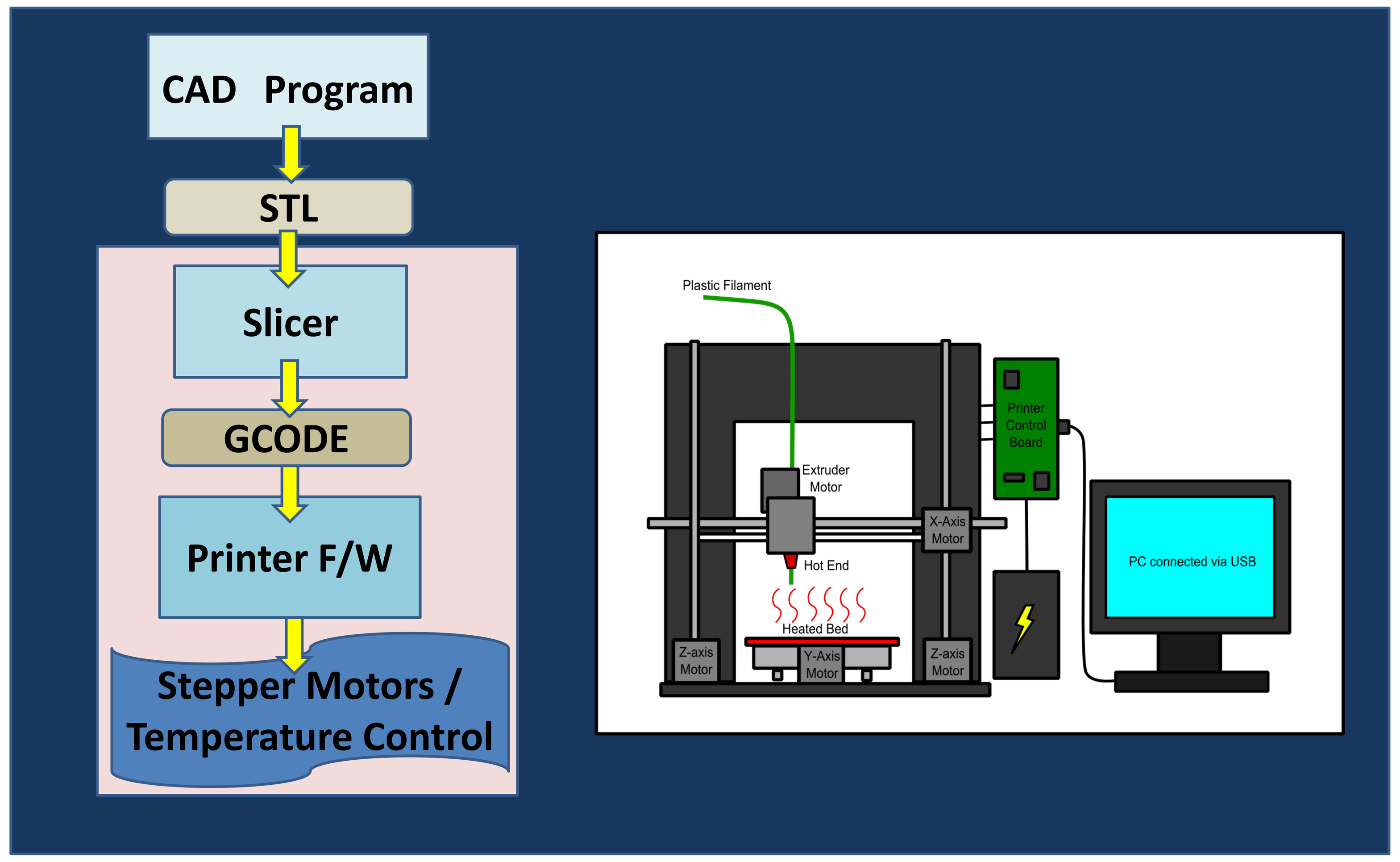


Figure 2. 3D Printer Guide and Model

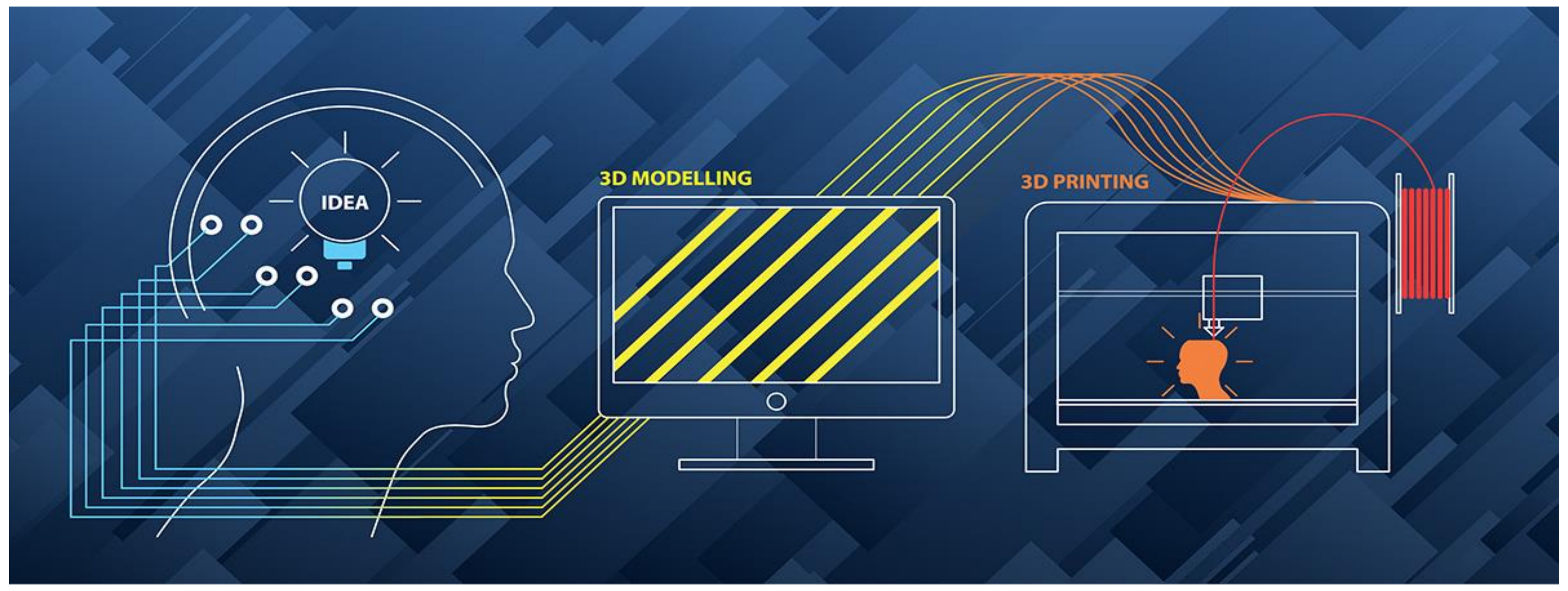


Figure 1. 3D modeling process

3D Printing Concepts

A basic introduction of 3D printing will allow the students to have a more robust understanding of how the structure of a model can be transformed. Depending on the use of the part, strength, cost, and appearance can be altered by the infill density and pattern. For simplification shown in figure 3, the models will be provided as a teaching tool for future students. To successfully design and print a model, considerations of the material used, and the machine used for printing must be analyzed. A more in-depth look into the basic features of 3D printing listed are needed for creating and designing successful prototype's:

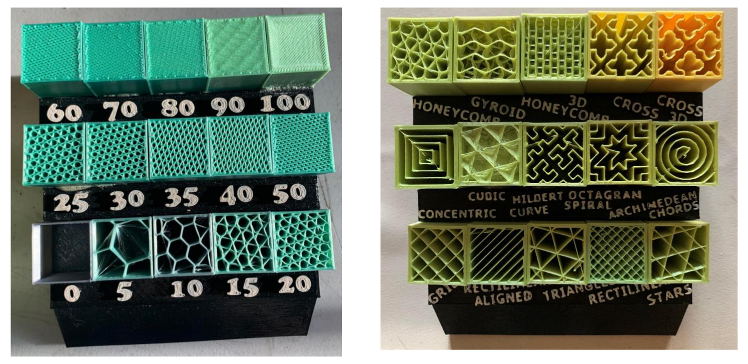


Figure 3. 3D density infill and pattern options

- Brim, Skirt, and Raft
- Layer Height
- Temperature
- Material Properties
- Bed Adhesion
- Nozzle Aspects
- Material Properties
- G-Code
- Slicing
- Print Orientation
- Support Structures
- Bed Calibration
- Print Speed

Discussion

By adding 3D printing to the class will direct students to appreciate CAD as more of a design tool than merely a tool to generate required images for presentations. The 3D printed wrench module is meant to teach the students how to use the printers and the CAD software, but also how to design a working model using additive manufacturing practices. The goal is that this would allow students to strengthen their understanding of the importance of rapid prototyping.

Curriculum Adaption

To highlight the importance of 3D computer-aided design and additive manufacturing, a design-related lab described in figures 4, 5, and 6. This is used to introduce critical concepts while further motivating students to embrace the engineering thought process and curriculum. This allows students to have a real-life design come to life by designing and redesigning a wrench with specified constraints.

Design

- Max Normal Stress Theory

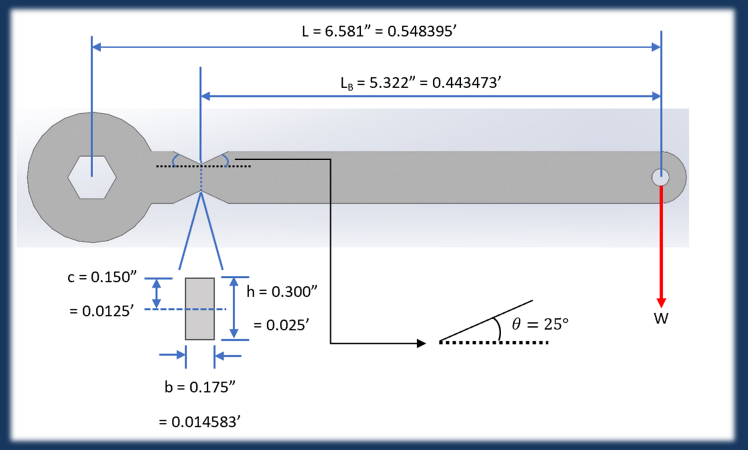
$$\sigma_{max} = \frac{S_y}{n}$$

- Max Shear Stress Theory

$$\tau_{max} = \frac{(\sigma_1 - \sigma_3)}{2} = \frac{(\sigma_{p,max} - \sigma_{p,min})}{2}$$
$$\tau_{max} = \frac{S_y}{n}$$

- Distortion Energy Theorem

$$\sigma' = \left[\frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_1 - \sigma_3)^2}{2}\right]^{1/2}$$
$$\sigma' = \frac{S_y}{n}$$



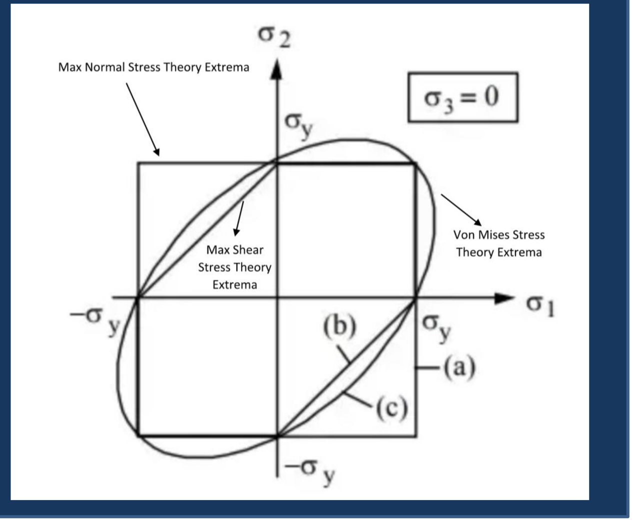
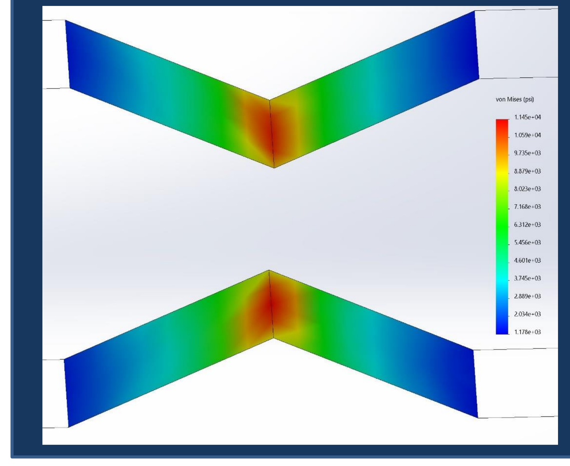


Figure 4. Design process using failure theories

Analysis



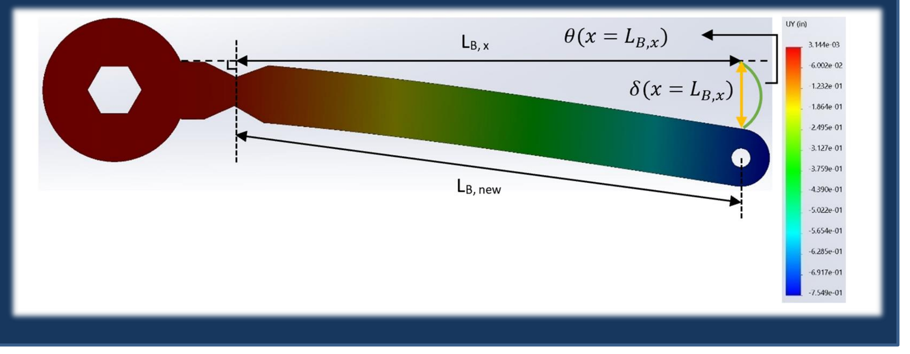


Figure 5. Simulation Analysis of breaking point using SolidWorks

Manufacture

Experimental Testing

Re-Design

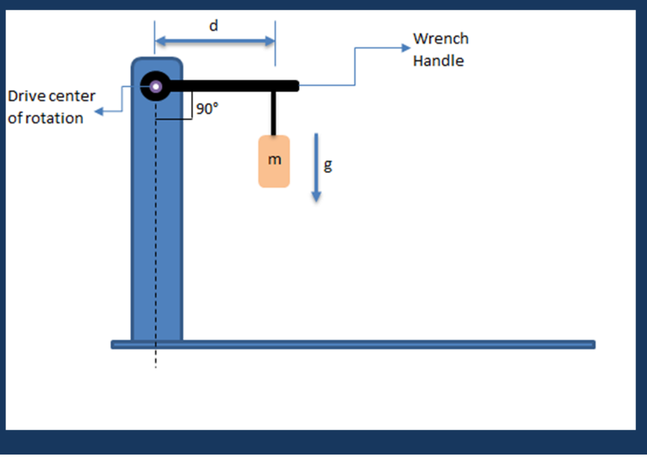


Figure 6. Experimental Testing

Results

The wrench is designed with an identifiable breaking point where the amount of weight held at failure is compared to the software simulations. Each 3D printing plastic material has a yield and break range that can be used to define the desired torque assigned.