Session 3286

Engineering Design Graphics: From Table-driven parametric design to RPT

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Abstract:

This paper describes a project for students in a first semester Freshman Engineering Design Graphics course. The students use 3-D software to design a part and modify the design by changing parameters in a design table that is exported to a spreadsheet. A number of different designs are sent to two different rapid prototyping (RPT) design firms that build the parts and give the cost of building each part. A silicon mold is made and a quick cast prototype is poured. Students learn how to manipulate design parameters, evaluate “what if” scenarios in the design and relate cost to design.

Introduction:

In recent years the engineering design process has changed as the tools and methods for the engineer continue to improve. The traditional design process is linear in that one phase is often dependent upon the completion of the previous step. Today the design process is concurrent with iterations continuing to occur much later in the design cycle than was possible with the traditional design process.

The integration of rapid prototyping technology into the Engineering Design Graphics (EDG) curriculum is expensive and beyond the resources of this two-year college engineering program. The college instead sought partnership with local companies in order to add RPT to the EDG curriculum. The presentation will discuss how to facilitate industry support and expand the EDG experience to incorporate rapid prototyping and quick cast prototypes. An RPT model would serve as the positive for creating a mold and eventually a usable part. The models required for the project were; (many) isometric sketches of the design, 3D parametric models created with SolidWorks 2000, clay models, a stereo lithography model and a urethane model cast from a silicon mold.

The Engineering Design Graphics course described in this paper was developed to prepare the two-year engineering student for continued study at a four-year engineering school. The new engineer must now possess the skills necessary to shorten the design cycle and competitively run the “time to market” race. An understanding of the Design Process and skills such as; graphics skills both manual sketching and 3D computer modeling skills, design skills where design intent is understood and applied to the design
from the beginning, prototyping skills and presentation skills. It is that set of skills that makes the framework for Engineering Design Graphics (EDG).

Design Process:

Engineering design is the act of creating the specifications for a product or process that best satisfies the design criteria. The design process starts with a clear understanding of the problem to be solved and the criteria by which the design will be judged. The students were introduced to several design issues to identify and determine specific design constraints. These collaborative student centered discussions provided a basis for brainstorming, teamwork, considering alternative ideas and limiting the range of acceptable design options i.e., design constraints. Similar roundtable discussions and activities continued as the students realized that the heart of the design process is a repetitive iterative loop: generate the design idea, evaluate it against the criteria, refine the idea, test it again (fig. 1), and so on until the design idea becomes the solution.

![Design Process](image)

Design Process Fig. 1

Graphic Skills:

Sketching and visualization skills were developed using learning activities that included isometric grid sketch paper and pencils. Orthographics, isometrics, visualization and standard drafting conventions were discussed and demonstrated, as students would perform appropriate learning tasks improving their skills and usage of the graphic language. For such topics as sectioning, auxiliaries, detailing and assembly, 3D parametric modeling using SolidWorks was integrated into the curriculum. Solid Works is a feature based parametric solid modeler. This provided the EDG experience with a powerful easy to use design tool that also facilitated the instructor with a means to
thoroughly and quickly discuss and demonstrate the more complex issues of orthographic projection. In order to provide a variety of configurations of the CAD model for final design consideration, a design table (Fig. 2) was created. A design table allows you to build multiple configurations of parts or assemblies by specifying parameters in an embedded Microsoft Excel worksheet.

<table>
<thead>
<tr>
<th>Height@Sketch1</th>
<th>Depth@Depth</th>
<th>Width@Sketch1</th>
<th>Outside corners@Fillet1</th>
</tr>
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<tbody>
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</tr>
<tr>
<td>Conf 4</td>
<td>8</td>
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<td>4</td>
</tr>
</tbody>
</table>

**Design Table Fig. 2**

**Rapid Prototyping:**

Stereo lithography (SLA) uses laser-hardened resins to form the model (fig. 3). The system software controls a focused laser beam in a pool of light sensitive polymer. The laser hardens each layer in the shape of the cross section or slice of the part. As successive layers are hardened, they submerge slightly into the resin pool and the next layer is hardened on top of them. The cost of this technology may be as much as $350,000. By developing industry partnerships we were able to bring state of the art technology into the classroom. These relationships were formed with a win-win attitude between the companies and the college. The college will benefit in several ways; we use the industry site for field trips, we bring current RPT technology into the classroom. These individuals also serve on our advisory committee and a curriculum development industrial steering committee. Our students often get Coop placement and full time employment. The companies win as well by; continuing to improve the local workforce, having access to potential employees with the skills that the industry needs, and having an active roll in local education.

SLA Fig. 3

Clay Fig. 4
Student Project:

Two major design projects were assigned. For the purpose of this paper the focus will be on one project, which required the students to design an electrical plug for the elderly or handicapped. Project requirements include; a list of design constraints, needs statement, ideation freehand sketches (isometric and orthographic) as well as iterative sketches, clay models (fig. 4), 3D parametric models to include three different configurations driven by a design table (spreadsheet), detailed drawings generated from the 3D modeling software, an SLA prototype a silicon mold, a part cast from the mold and a power point presentation (PPT).

By creating a CAD model of the part we then generated stereo lithography or STL files for the stereo lithography process. Actual costs of the SLA parts (Fig. 5) were provided by the industry partner. Cost per SLA is determined by volume and surface area. In some cases rough tooling costs were provided. This gave the students real quantitative data to assist in redesign. A digital camera and scanner are used to create image files of the sketches, models, field trips and detail drawings. These images are then inserted into the PPT. Presentation. The presentation is to be used by the students at the end of the semester in a seminar. This seminar is open to the entire campus while some engineering and technology classes are required to attend.

![Image](image.png)

V = .8385 cu. In.
S = 8.6398 sq. in.
Cost = $221.65

Cost of SLA Fig. 5

The EDG course is 3-credits, fifteen-weeks and meets twice a week for a total of 5 hours. The course has five units of study:

1. Design Process and Sketching
2. Orthographics-Drafting Standards
3. Parametric Modeling
4. Rapid Prototyping
5. Documentation

These units are concurrent in that concepts from multiple units are being covered simultaneously in class. While the Design Process is handled more as a lecture situation, the Sketching, Orthographics and Drafting Standards units are taught using paper, pencils
and SolidWorks 2000. The software creates orthographic drawings automatically. The use of the 3D software shortened the learning curve of understanding orthographic projection. Design intent is introduced very early during the ideation-sketching phase. Therefore while learning more advanced functionality of SolidWorks, the student is sensitive to the design intent of the project at hand. Rapid prototyping is studied and discussed. A field trip to one of the RPT sites was made and students received SLA parts of their designs. After the project is designed and the students have an SLA model, a silicon mold is made and a urethane usable part is cast. A digital camera is used to capture sketches, clay model, SLA model and urethane model. These image files are used in the power point presentation, which serves as an electronic portfolio as well as a summarization and conclusion to the EDG experience.

**Conclusion:**

This was the first year that the EDG course was taught in this manner. Student interest was high and evaluations were excellent. Test scores and the final presentation proved that the students had understood and applied the learned skills to assigned design projects. The students were able to see how cost to design is considered very early in the design process and how the tools available to the engineer make iterations possible. The relationship of the college and the industry partners has been enhanced through this experience as we both look forward to continue to bring RPT into the EDG curriculum.

**Acknowledgements:**

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**Bibliography:**