AC 2004-145: USE OF CAMBRIDGE ENGINEERING SELECTOR IN A MATERIALS/MANUFACTURING COURSE

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Use of Cambridge Engineering Selector in a Materials/Manufacturing Course

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Abstract

During the 1998-1999 academic year, Mechanical Engineering at Texas A&M University decided to combine a materials course that included a laboratory and a manufacturing course that contained a laboratory. As part of this activity, we decided to increase the design activity and material selection within the new course. Starting in fall 2002, we made a copy of a materials selection program, CES-4™ (Granta Design Limited) available to each student taking the course. A number of activities were devised to help the students become familiar with the program. The culminating activity was for each laboratory group to design a children's playground. They were to select the materials and the manufacturing processes for a playground that could handle 20 to 40 children from the ages of 2 or 3 to about 12 to 13 years old at one time. The Parks and Recreation Departments of both communities wanted the equipment to last 20 to 25 years with minimum maintenance. The application of the CES-4™ program to the design will be discussed and examples will be shown.

Keywords:

Materials, materials selection, manufacturing, design

Prerequisite Knowledge:

Introductory materials course, engineering math, mechanics of materials

Objectives:

To develop the materials selection and design capability of junior mechanical engineering students.

Equipment and Materials:

CES-4 Software and suitable computer, multiple disk copying machine

Introduction

Selection of materials and manufacturing processes are important concepts that faculty would like engineering students to be able to understand and use. There have been a variety of methods developed to help do this. ASM International has published books that help.[1, 2, & 3] Several textbooks have collected data on materials and their properties.[4 & 5] One of the most complete is Callister's text, Material Science and Engineering where the author has collected a range of data on approximately 70 materials.[6] The CD that comes with the text is searchable. M. F. Ashby developed a series of selection charts some years ago where he demonstrated that a wide range of materials properties could be collected and plotted on the same abscissa and ordinate.[7] Using the idea of these Ashby charts, a company Granta Design, Ltd., has developed a software package, Cambridge Engineering Selector (CES), which includes a wide range of data on materials, manufacturing processes, and shapes for approximately 3000 engineering materials. The program is very powerful, and is potentially useful for students in mechanical engineering.

The objective of this paper will be to describe the use of the CES-4 software in a junior level materials and manufacturing course. During the course, students' practice using the software through several homework assignments and team projects. These will be discussed.

Procedure:

The Company, Granta Design, Ltd., has an educational arrangement that makes it very reasonable for a university or college to obtain access to the software for their students' use. Mechanical Engineering Texas A&M University purchased a site license for 250 students, and made enough copies so that each student in MEEN 360 received an individual copy that could be installed on their personal computer. The software has an internal clock that does not allow the program to run after one year from date of installation. The CES-4 package has an exceptional collection of data on each of the materials listed in the program. See Table 1 for an example of the properties available for cartridge brass (deep drawing) where more than 30 properties are listed. The units may be set to any of several different systems that are available.

Table 1. Example of data available from CES-4.[8]

Brass: deep-drawing/cartridge brass, CuZn28, soft (wrought) (UNS C25600)

General

Tradenames

SPRING WIRE BRASS, American manufacture (USA); HELMET METAL, English manufacture (UK); NEUSTADT, German manufacture (Germany); ANGSBURG, Manufacturer unknown (); LYON'S GOLD, English manufacture (UK); COMMON TOMBAC, French manufacture (France); PRYM 225, Prymetall GmbH & Co. KG (GERMANY); WIELAND-M28, Wieland-Werke AG (GERMANY); ;

Designation

Copper Alloy: CuZn28 (UNS C25600)

Density		0.3063	-	0.3125	lb/in^3
Energy Content		1.083e+004	-	1.3e+004	kcal/lb
Price		0.8736	-	0.9199	USD/lb
Recycle Fraction	*	0.4	-	0.5	

Composition

Composition (Summary)

Cu/28Zn

Base	Cu (Copper)	
Cu (Copper)	72	%
Zn (Zinc)	28	%

Mechanical

Bulk Modulus	*	17.07	-	18.01	10^6 psi
Compressive Strength		15.95	-	17.4	ksi
Elongation		50	-	52	%
Elastic Limit		15.95	-	17.4	ksi
Endurance Limit	*	21.9	-	22.63	ksi
Fracture Toughness	*	64.07	-	66.52	ksi.in^1/2
Hardness - Vickers		63	-	72	HV
Loss Coefficient	*	2.78e-004	-	3.31e-004	
Modulus of Rupture		15.95	-	17.4	ksi
Poisson's Ratio		0.34	-	0.35	
Shape Factor		30			
Shear Modulus	*	5.845	-	6.179	10^6 psi
Tensile Strength		45.69	-	47.86	ksi
Young's Modulus		15.81	-	16.68	10^6 psi

Thermal

Maximum Service Temperature		846	-	864	°R
Melting Point		2214	-	2241	°R
Minimum Service Temperature		0			°R
Specific Heat	*	0.09066	-	0.09114	BTU/lb.F
Thermal Conductivity		69.33	-	72.8	BTU.ft/h.ft^2.F
Thermal Expansion		9.944	-	10.61	µstrain/°F

Electrical

Resistivity	5.89	-	6.46	µohm.cm

Optical

Transparency	Opaque

Environmental Resistance

Flammability	Very Good
Fresh Water	Very Good
Organic Solvents	Very Good
Oxidation at 500C	Average
Sea Water	Very Good
Strong Acid	Poor
Strong Alkalis	Very Good
UV	Very Good
Wear	Very Good
Weak Acid	Good
Weak Alkalis	Very Good

Notes

Typical Uses

Deep-drawn items including cartridge cases & heat exhangers (fresh clean water); cold-headed parts; hardware.

Other Notes

(s)=soft; (1/2 h)=half hard; (h)=hard; (xh)=extra hard; (hr) = hot rolled; (w)=soln heat-trtd; (wh)=soln heat-trtd & work hdnd; (wp)=soln heat-trtd & precip hdnd; (whp)=precip hdnd after cold-wkng; (wph)=work hdnd after precip hdng.

Reference Sources

Data compiled from multiple sources. See links to the References table.

Links

Reference
Shape
Structural Sections
Supplier
ProcessUniverse

Assignment 1

The first assignment, shown below, asked the students to select the maximum and minimum properties for a number of attributes. For the specific modulus and strength, the students had to use the software included in CES-4 to divide that particular property by the material's density. Additionally, they were to plot a figure using the software. Interestingly, several students found a much more efficient method of doing it than I had.

MEEN 360, F2002
Cambridge Engineering Selector
Pair or Individual Activity, Due: ______________
Names ___________________________ & ______________________

1. Use the Cambridge Engineering Selector to find information on the materials that satisfy the following attributes. There should be a set of answers for each attribute; they are independent of each other. Attributes Endurance Limit, Price, Seawater, Specific Modulus, and Specific Strength will have only two categories maximum and minimum (no intermediate category).

Attribute	Maximum	Minimum
Density		
Melting Point		
Fracture Toughness		
Thermal Expansion		
Endurance Limit		
Maximum Service Temperature		

Price		
Seawater[1]	Excellent	Very Poor
Specific Modulus		
Specific Strength		

2. Tensile strength, σ_{TS}, vs K_{1C} Show the entire plot. From the plot show all materials with σ_{TS} > 150,000 psi with a K_{1C} > 35 ksi $in^{1/2}$.

The activity may be done in pairs to make it easier to work through the questions and help each other. You certainly may work individually if you want to. The program contains a process and shape selector in addition to the materials selector. We will use the manufacturing selection component next time.

Assignment 2

The second assignment, shown below, provided the students with several different scenarios, and they were to select the material or process or shape that best fit the particular requirements listed. This activity required them to use the process and shape universes in addition to the material universe.

MEEN 360
CES HW 2
Name(s) ________________________ & _________________________

Answer the following three material selection questions.

1. Select material(s) with these particular attributes:
   - a minimum elongation of 10%
   - a maximum service temperature of between 900 and 1025 R
   - very good oxidation resistance at 500 °C
   - a maximum cost of $5/lb

List number of materials

   - if for the same conditions as listed above, you want the maximum density to 0.28 lb/in^3, then which materials remain in the running?
2. Using the Process Universe and Surface Treatment, which process would be selected under the conditions listed below?
   - curve surface coverage, average
   - coating thickness normal, 1to 5 mils
   - component area, restricted
   - Processing temperature, minimum 600°R
   - Surface roughness, very smooth
   - Corrosion protection, aqueous, yes
   - Friction control, yes
3. Try Processing Universe- Shaping
   - hole diameter in 1000 mil
   - mass range, maximum 10 lb
   - section thickness, maximum 3000 mil
   - quality factor of 5
   - Tolerance, 10 mil maximum
   - Economic batch size, 2 lb max
   - Production rate, 0.001/s
   - Primary process characteristics, Yes
   - Secondary, No

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[1] For this attribute include five materials that are excellent and 5 that are very poor in seawater.

Assignment 3

This was the first of two semester projects, which they did using their laboratory groups. The use of CES was not required, but only suggested. As often is the case, those students who had a person in their group that was motivated to use the software did, those that did not chose not to.

MEEN 360, Fall 2002
PROJECT # 1
Due 18Oct02

Each laboratory group will select a small appliance, for example- coffee pot, hair dryer, iron, etc. (there should be at least 6 parts in the appliance), and answer the following questions concerning the item your group selected.

1. Take the appliance apart, and describe how you did it. Be sure to include sketches of all the parts and the assembly (an exploded assembly).

2. Identify the materials that make up the appliance. (CES may be helpful)

3. Determine the functional requirements for each part. (See design flow chart handed out with our syllabus.)

4. Describe the manufacturing process(es) that were used to make the individual parts.

5. Reassemble the entire appliance. Describe the procedure.

6. What recommendations would you make to improve the appliance with regard to ease of operation, ergonomics, appearance, safety, etc.?

Reporting Procedure:

Each group will turn one typed report with the above information included. The drawings may be hand drawn or computer generated, and should demonstrate good engineering practice. (ENGR 111/112)

Assignment 4

The fourth assignment, given below, was the second and final project for the semester. I gave the assignment out later in the semester, and so the students' complaint was that there was insufficient time to do it properly. They had a valid complaint, and next time I will give the project out earlier. However, there was a range in the quality of the final product. Several were simply terrific, while others appeared to have been tossed together while meeting at the kitchen table the night before. Generally speaking, I was pleased with the results, and most of the groups made a serious effort to use the CES-4 software, and I think it really enhanced their report and analysis. The grade distribution is shown in Table 2, and at least from the grades the distribution in quality may be observed.

MEEN 360
Project 2, Fall 2002
Lab Group Project

Problem Statement:

You have been asked to select materials and manufacturing processes for the components that make up a children's playground. It is to be built in an area similar (climate wise) to Bryan/College Station. The playground should be able to handle upwards of 20 to 40 children from the ages of 2 or 3 to about 12 to 13 years old at one time. The Parks and Recreation Departments of both communities would like the equipment to last 20 to 25 years with a minimum of maintenance.

1. Use the design format that we introduced this fall.
2. Select the materials and manufacturing process for the equipment.
3. For one of the particular playground items (slide, tube, etc.) perform a thorough design.
    a. Loads, fatigue life, safety, corrosion, detailed manufacturing steps, assembly procedures, etc.
4. If you would like to speak directly with a park's person, the director of the Bryan Parks and Recreation Department, David Schmitz, has agreed to be a contact person, Ph. No. 209-5201, e-mail: dschmitz@ci.bryan.tx.us. In fact, he is a certified playground specialist. In addition, College Station Parks and Recreation also has a person who is willing to be a point of contact his name is Pete Vanecek, Ph. No. 764-3412, e-mail: pvanecek@ci.college-station.tx.us.
5. There are a number of attractive playgrounds in the two towns: Tanglewood, Central Park, Villa West, Astin, Bee Creek, etc.

Due Date: 4:00 pm, last day of classes 9/10 Dec. 02

Assignment 5

This assignment was given as a take home portion of the final examination. It required the students to use basic mechanics of materials to help find the property that needed to be minimized to help in the final selection. I selected these two from the accompanying text, not realizing that they were on the CES website. Students that found the website had an easy time

MEEN 360
Final Exam- Take Home Component
Name ____

Students are to work the exam by themselves. You may discuss ideas with classmates, but you may not copy someone else's work. The exam will be turned in at the beginning of the final exam, Monday 16 Dec. 02 at 8 am.

1. Credit for inventing the rowed boat seems to belong to the Egyptians. Boats with oars appear in carved relief on monuments built in Egypt between 3300 and 3000 BCE (Before the Common Era), Boats, before steam power, could be propelled by poling, by sail, and by oar. Oars gave more control that the other two, and their military 0potential was well understood by the Romans, the Vikings, American Indians, and Venetians. Select candidate materials for an oar. Two other constraints are: toughness needs > $1 kJ/m^2$ and cost needs < \$100/kg.

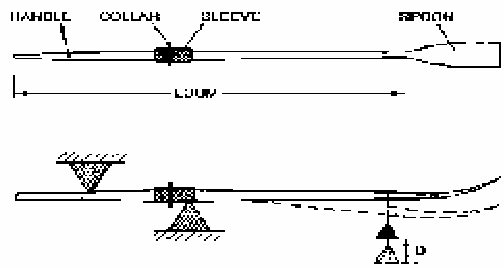

Figure 2.1 Oars are designed on stiffness, measured in the way shown in the lower figure: and they must be light.

MEEN 360
Final Exam- Take Home Component
Name ____

Students are to work the exam by themselves. You may discuss ideas with classmates, but you may not copy someone else's work. The exam will be turned in at the beginning of the final exam, Wednesday 18 Dec. 02 at 8 am.

1. Luigi Tavolino, furniture designer, conceives of a lightweight table of daring simplicity: a flat sheet of toughened glass supported on slender, unbraced, cylindrical legs, see Figure 4.1. The legs must be solid (to make them thin) and as light as possible (to make the table easier to move). They must support the tabletop and whatever is place upon it without buckling. What materials would you recommend?

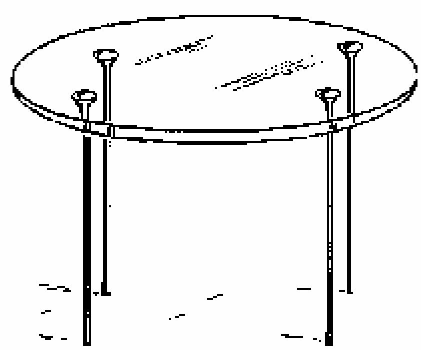

Figure 4.1 A light-weight table with slender cylindrical legs. Lightness and slenderness are independent design objectives, both constrained by the requirement that the legs must not buckle when the table is loaded.

The legs need to have adequate toughness. A useful rule of thumb is that

$$G_c = (K_{1C})^2/E \geq 1 \text{ kJ/m}^2$$

for adequate toughness.

while those who tried it on their own struggled. I was moderately satisfied with the results. The grades for two projects and the take home exam are given in Table 2. There were about 90 students in the class. I had two sections: one MWF and the other TTh, one of the above was used in each section.

Table 2. Grades for the two projects and the take home final.

Grades	Project 1	Project 2	Take Home Final
Average	83.9	80	77.3
Standard Deviation	11.5	16.1	16
Maximum	95	100	100
Minimum	66	53	25

Comments:

The CES-4 materials and processes selection software was used in a junior level materials and manufacturing processes course. The results were satisfactory; students who took the next course which required the use of the software felt as if they had been helped by the use of it in the class describe in this paper. Anecdotally, faculty in follow on design courses reported on students using the software in their class. From my standpoint, I appreciated the tremendous amount of information that is available on a wide range of materials. Several of the assignments need to be made more rigorous so that the students are encouraged to use the process and shape universes more and at a higher level.

Acknowledgements:

I would like to acknowledge the Department of Mechanical Engineering for providing us the resources to purchase the software, for the students who actively participated in the course and used the software, and for Granta Design, Ltd working with universities to help make the software available.

[1] ASM Handbook, Vol. 20, Materials Selection and Design, ASM International, Metals Park, OH 1997.
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[7] Ashby, M. F., Materials Selection in Engineering Design, Pergamon Press, Inc., Elmsford, NY, 1992.
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