Syllabus – Design with Aluminum

Part 1: Course Information

Description

Design with Aluminum is an introductory course focusing on students' learning of basics of engineering design, properties, manufacturing processes, design aspects and design guidelines along with several real life examples and applications of aluminum alloy materials commonly used in automotive and other applications. The topics will be covered using 'Blended learning' and 'Flipped class room' approaches. Being an introductory course, only basics of engineering design, mechanical and physical properties, mechanics (stress-strain relationships), and manufacturing processes as applied to body design are introduced. Where applicable, a comparison between steel and aluminum is presented and discussed. The lecture handouts, together with homework assignments, course projects, and exams are designed to train the targeted students in community colleges with basic math, CAD and mechanics experience, for associate degrees and/or certificate programs. A list of few important references is provided at the end of each course module.

This course is designed to meet over a period of 7 weeks (or more), 2 meetings per week, and 2 hours per meeting.

Prerequisites Entry level knowledge of mechanical properties of materials, stress and strength considerations, and manufacturing processes; Basic math skills (example: Excel) and basic CAD skills will also help in solving simple examples.

Reference Books

- Lecture handouts will be distributed one week in advance
- Body Structures by European Aluminum Association, 2013
- Design with Aluminum by European Aluminum Association, 2011
- Specifications for aluminum by Aluminum Association, 1967
- Various SAE and other conferences papers will be provided for reference

Tools to be used *Hand calculator and/or Excel math tool for simple calculations (moderate use); NX or similar CAD tools (minimal use)*

Part 2: Course Learning Outcomes (CLOs)

The course learning outcomes that the students would have achieved:

1. Develop motivational and self-teaching techniques (in a blended learning environment) by reading lecture handouts ahead of time in preparation for class room discussions (sometimes called "*Flipped class room*");
2. Understand the basics of engineering design, design methodology and design process, Design for X (design for manufacture and assembly, design for functional performance, design for reliability, design for sustainability and life cycle assessment);
3. Understand the benefits and limitations of Steel versus Aluminum along with some applications of aluminum for light-weighting technologies;
4. Understand the concepts of stress, strain, Hooke's Law; material properties - density, Young's modulus, stiffness, rigidity, resilience, toughness of engineering materials, and how they are related to each other;
5. Apply knowledge in statics and mechanics of materials in material selection (using Ashby charts) and design of members subjected to axial, bending and torsion loads;
6. Understand the major metallurgical differences, different types of aluminum alloys (such as 5000, 6000 series), and applications of aluminum;
7. Understand the traditional and non-traditional manufacturing processes (such as Machining, Bulk Forming, Casting, Forging, Foam, Hydroforming, Roll-forming, 3D Printing, etc.) of Aluminum Materials;
8. Develop a basic knowledge of aluminum extrusions, applications, and the best practices;
9. Develop an understanding of failure of aluminum due to galvanic corrosion and protection of aluminum joints against such defects;
10. Develop an overall basic knowledge of price of aluminum alloy, weight savings, scrap value;
11. Develop a basic knowledge and confidence of aluminum applications and design guidelines in automobile industry (using cast, extrusions, and stamped parts for car body structures, etc.);
12. Develop an understanding and ability to redesign a steel part using aluminum materials in a view to design products using aluminum, or other best choice of materials;
13. Perform simple research on selection of manufacturing techniques (casting, forging, etc.) of real parts or real life applications using aluminum, and communicate them effectively to the class in the form of presentation;
14. Communicate effectively with aluminum designers, CAE analysts, manufacturing engineers and suppliers at work.

Part 3: Course Topics and Roadmap

Topics covered:

1. Engineering Design
    a. Introduction and course overview
    b. Design methodology
    c. Design for manufacture and assembly
    d. Design for functional performance
    e. Design optimization of cost versus maintenance
    f. Design for sustainability
    g. Life cycle assessment
    h. References

2. Material considerations
    a. Ashby material selection guidelines
    b. Steel versus aluminum – benefits and limitations
    c. Design with aluminum – current trends and real life examples
    d. References

3. Basic mechanical physical properties of aluminum
    a. Stress and strain considerations
    b. Rigidity and stiffness
    c. Resilience and toughness
    d. Stiffness to weight ratio
    e. Aluminum alloys – major metallurgical differences and applications
    f. References

4. Products and manufacturing methods of aluminum with real life automotive and other industrial applications
    a. Machining
    b. Bulk deformation processes
        i. Casting and Molding
        ii. Forging
        iii. Extrusion
        iv. Drawing
        v. Rolling – conventional and roll forming
        vi. Sheet metal forming
        vii. hydroforming
        viii. Foam technology
    c. 3D printing technologies
    d. References

5. Design for Functional Performance
    a. Galvanic corrosion
    b. Fastener protection

   c. Non-conductive barrier material
   d. Mixed material designs
   e. References

6. Design for Cost Optimization
   a. Price of aluminum alloy
   b. Weight savings
   c. Secondary cost savings
   d. Integration of multiple part designs in to a single product
   e. Aluminum scrap value
   f. Aluminum extrusions
   g. Design guidelines for aluminum extrusions
   h. Hydroforming process
   i. References

7. Characteristics of Extruded Products
   a. Basic types of extruded shapes, open, semi-closed and closed
   b. Variation of material thickness in cross sections
   c. Extrusion of inner and outer webs and fins
   d. Role of hollow profiles for joining extrusions
   e. High volume aluminum alloys – 6060 and 6063
   f. Bumper beams in special 7xxx-series alloys
   g. Design guidelines
   h. References

8. Rolled Aluminum Products
   a. Rolled products as plate, sheet, foil or welded tubes
   b. Special alloys and tempers
   c. References

9. Car body structures
   a. Body design concepts
   b. Body design with aluminum
   c. References

Roadmap

The following roadmap is recommended for instructors (Note: The highlighted Handout(s) are given one week in advance for discussion in the following week):

Week	• Lecture Topics • CLOs	Main Topics, Concepts and Calculations	• Course Materials, • Homework & Projects
1	• Course overview • Homework policies, Sample HW Template • Introduction to Engineering Design • 1, 2, 11	• Course Topics • HW policies and grading rubric • Design Theory and Methodology • Design for 'X' (X → manufacture, assembly, functional performance, cost optimization, and sustainability) • Life Cycle Assessment • Plans for Next Class	• Handout #0 • HW Policies and Format • HW Grading rubric • Handout #1 • HW1 • Handout #2 • Handout #3
2	• Material Considerations • Basic Mechanical and Physical Properties - 1 • 3, 4, 5, 6	• Stress-strain Curve • Elastic Modulus, Rigidity Modulus, Stiffness in axial, bending and torsion • Ashby Material Selection Procedure • Aluminum applications, Pros and Cons • Plans for Next Class	• Handout #2 • Handout #3 • HW2 • Go over the scope of Project 1 • Handout #4

3	• Basic Mechanical and Physical Properties - 2
	• 3, 4, 5, 6
	• Products and Manufacturing Methods of Aluminum - 1
	• 3, 4, 6, 7
		• Practice Examples Using Ashby Charts
		• Machining Operations
		• Bulk Deformation Processes:
		  ○ Casting
		  ○ Forging
		  ○ Extrusion
		  ○ Drawing
		  ○ Rolling
		• Plans for Next Class
			• Handout #3 (continued)
			• Handout #4
			• HW3
			• Handout #5

4	• Products and Manufacturing Methods of Aluminum - 2
	• 3, 4, 6, 7, 8
	• Design for Functional Performance
	• 1, 9
		• Bulk Deformation Processes:
		  ○ Sheet Metal and Roll Forming
		  ○ Hydro Forming
		  ○ Foam Technologies
		  ○ 3D Printing Technologies
		• Galvanic Corrosion and Protection Methods
		• Use of Non-conductive Material
		• Design of Mixed Materials
		• Plans for Next Class
			• Handout #4
			• Handout #5
			• HW4
			• Go over the scope of Project 2
			• Handout #6
			• Handout #7

5	• Design for cost Optimization
	• 1, 10
	• Characteristics of Extruded Products
	• 6, 7, 8, 11, 12, 13
		• Primary and Secondary Cost Savings of Aluminum Alloys
		• Integration of Multiple Parts Using DFMA
		• Aluminum Scrap Value
		• Aluminum Extrusions
		  ○ Types of Extruded Parts
		  ○ Extrusion using Various Design Features
		  ○ Applications of Extruded Products
		  ○ Design Guidelines
		• Plans for Next Class
			• Handout #6
			• Handout #7
			• HW5
			• Project 1
			• Handout #8
			• Handout #9

6	• Rolled Aluminum Products
	• 6, 7, 11, 12, 13
	• Car Body Structures – 1
	• 6, 7, 11, 12, 13
		• Aluminum Rolled Products
		  ○ Different Shapes
		  ○ Applications
		  ○ Heat Treatment
		• Car Body Structures
		  ○ Design Concepts
		  ○ Types of Body Structures
		• Final Project Guidelines and Communication
		• Plans for Next Class
			• Handout #8
			• Handout #9
			• Project 2

7	• Car Body Structures – 2
	• 6, 7, 11, 12, 13
	• Design Guidelines & Communication
	• 11, 12, 13, 14
		• Car Body Structures
		  ○ Examples of Different Car Bodies
		  ○ Advantages and Disadvantages of Various Body Structure Designs
		• Course Wrap-up
			• Handout #9 (continued)
			• Project 2 (continued)
			• Final Exam

Part 4: Grading and Assessment

HW Assignments

Homework is assigned related to *some of the topics* described above. Suggested format and template for submission of HW is given. Grading rubric is provided.

Course Projects

Course projects are to be assigned. The first one is about the aluminum manufacturing processes, after Topic 4, around midterm time frame. The second one is the final project about design of an aluminum car body structure. This covers all important course topics, and will be assigned during Week 6 of the term.

Computer Usage

MS Excel, MS Office and some CAD software would be used.

Grading Scheme (Grading rubric is given in the class)

- Homework (5) 50%
- Pre Exam (1) 10%
- Final Exam (1) 10%
- Course Projects (2) 30%

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