Joining Aluminum to Aluminum and Dissimilar Materials – a New Course Development for Designers and Technicians

Azadeh Sheidaei, Ph.D, Assistant Professor
Yaomin Dong, Ph.D, Associate Professor
Javad Baqersad, Ph.D, Assistant Professor
Craig Hoff, Ph.D, Professor
Department of Mechanical Engineering, Kettering University

Abstract

Aluminum is replacing steel for its strength to weight ratio, equal or better stiffness and toughness properties, durability and manufacturability considerations. It has other major benefits such as corrosion resistance, fuel economy in vehicles, sustainability, enhanced image and maintenance advantage. Aluminum components can be joined among themselves and with other materials using numerous methods. The selection of an adequate joining technique depends on the material combination to be joined, the required joint characteristics, and the boundary conditions given by design and engineering as well as production engineering and, last but not least, economic considerations. The course learning outcomes (CLOs) of programs at research universities and community colleges are very different. This paper presents a new course, "Joining Aluminum to Aluminum and Dissimilar Materials" that focuses on student learning outcomes for community college students, future designers, and technicians. The course was developed for the Center for Advanced Automotive Technology (CAAT), which is funded by the National Science Foundation. One of its missions is to create a curriculum that meets the needs of educating people in new technology developments in the automotive industry. The material developed in this course contains the course syllabus, course learning objectives, course materials, homework assignments, term projects and tests.

Keywords

Aluminum, joining, design, dissimilar material, manufacturing

1. Introduction

Joining is one of the most important manufacturing processs in the auto industry. Although resistance spot welding is a standard joining technique for steel car bodies, it causes some problems it is used for aluminum. Subsequently, by the growing application of lightweight aluminium in cars, this brings a significant challenge for both automobile manufacturer and the supplier of the aluminium materials and components. One solution to this problem is using non-heat involving joining techniques like mechanical joining and adhesive bonding.This course contains different joining methods for aluminum to aluminum and dissimilar materials.

2. Course Content

2.1 The course learning objectives (CLOs)

The course learning objectives of the proposed course "**Joining Aluminum to Aluminum and Dissimilar Materials"** can be described as follows:

Upon completion of the course, students will be able to

(1) Understand the various joining techniques related to aluminum materials;
(2) Gain a basic knowledge of aluminum joining, applications, and the best practices;
(3) Develop a basic knowledge and confidence of aluminum joining applications and design guidelines in automobile industry;
(4) Develop an understanding and ability to redesign a product using aluminum materials with the best choice of joining techniques;
(5) Perform simple research on selection of joining techniques of real parts or real life applications using aluminum, and communicate them effectively to the class in the form of presentation;
(6) Can communicate effectively with aluminum designers, CAE analysts, manufacturing engineers and suppliers at work;
(7) Demonstrate effective communication and teamwork skills through technical presentations and reports in course projects.

To demonstrate the effectiveness of the curriculum, assessment questions are developed for pre- and post- course offering survey, as indicated below:

Pre and Post Course Offering Survey Questions

Please answer the following questions by choosing one of the following:

5-Strongly Agree, 4-Agree, 3-Disagree, 2-Strongly Disagree, 1-N/A

(1) I have the general knowledge of joining.
(2) I have the knowledge of aluminum welding.
(3) I have the knowledge of mechanical joining.
(4) I have the knowledge of adhesive bonding
(5) I have the knowledge of hybrid joining techniques
(6) I have the knowledge of joining dissimilar materials
(7) I have the knowledge of traditional manufacturing processes (such as machining, stamping, casting).
(8) I have the knowledge of joining methods (such as welding, mechanical joining, adhesive bonding, hybrid joining).
(9) I know the Pros and Cons of different joining methods.
(10) I have a good understanding on application of different joining methods.

(11) Overall, I am able to design and develop products with the best choice of joining methods.

As a pilot course offering, this course, with a smaller class size, is planned with faculty member(s), potential future instructor(s) sitting in to be trained. Feedback for this pilot offering will be studied and all necessary adjustments will be made to improve the curriculum.

2.2 Course Outline

(1) Introduction to Joining
(2) Overview of Aluminum welding
(3) Mechanical joining
(4) Adhesive bonding
(5) Hybrid joining techniques
(6) Joining dissimilar materials

3. Course Project

A course project is designed to assess the students' learning outcomes. In this project, a connecting rod in an automotive windshield wiper system[1] is used for the students to use the best joining methods to join the base rod and two ball sockets, as shown in Figure 1. Dimensions of the connecting rod assembly are given in Figure 2. The connecting rod is under cyclic tension and compression during the wiping operation. Therefore the joining strength, cost effectiveness in mass production, reliability, and environmental robustness of the products are to be considered. There are two scenarios to be considered:

(1) Joining the base rod to ball sockets, all made of aluminum 6061.
(2) Joining base rod (aluminum 6061) to sockets of 30% glass-filled nylon 66.

The project deliverables include detailed drawings, descriptions of joining processes in both cases.

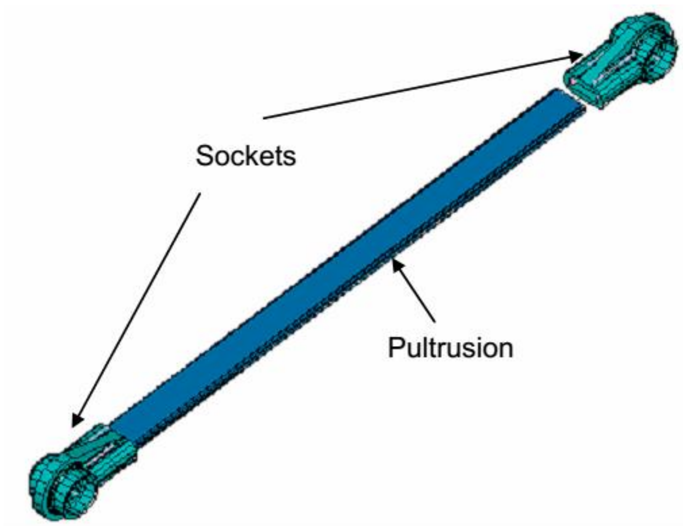

Figure 1 Connecting rod assembly

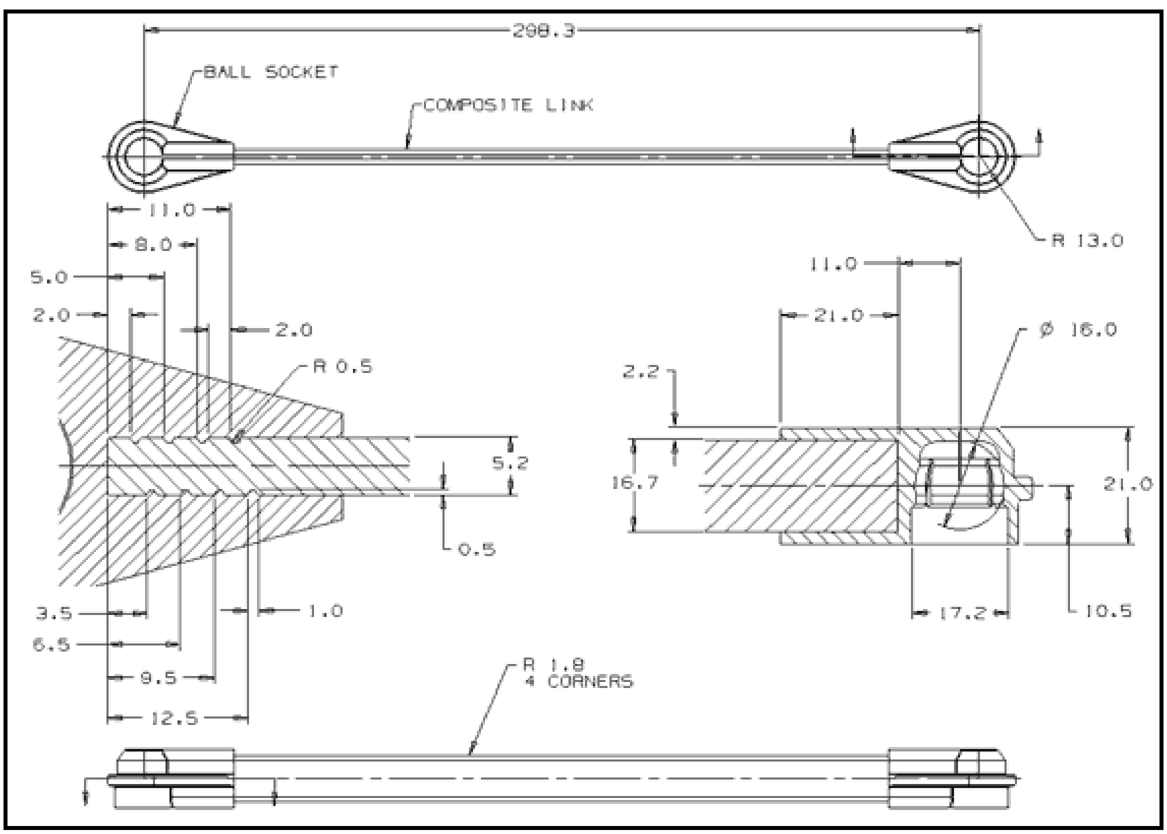

Figure 2 Connecting rod drawing [dong et al, 2016]

4. Assessment Techniques and Tools

Assessment is planned before and after the course offering in order to assess the effectiveness of the students' learning as well as the course materials. The process education methodology by PacificCrest is used for assessment[2]. The SII is a method of assessment articulated by Pacific Crest which requires the assessor to focus on three main items: strengths, areas for improvement, and insights gained. "Strengths" identifies the ways in which a performance was commendable and of high quality. Each strength should include a statement as to why that particular strength was considered important and how the strength was produced. "Areas for improvement" identify the changes that can be made in the future to improve performance. "Improvements" should include the issues that caused any problems and mention how those changes can be implemented most effectively. "Insights" identify new and significant discoveries that were gained concerning the performance area.

The following SII questions will be used for additional post-course assessment to facilitate continuous improvement:

(1) What are the three strengths of this course? Please explain.
(2) What are the top three things that you have learned?
(3) What are the three improvements for this course that would help you learn better?
(4) How can these improvements be made?
(5) What action plans can be put in place to help yourself learn more?
(6) What have you learned about your own learning process?
(7) Is there anything else you would like the instructor to know about the class?

5. Roadmap

To make the course "transferable" to any institutions, the following roadmap (Table 1) is recommended for instructors:

Table 1 Roadmap

Week	• **Lecture Topics** • **CLOs**	**Main Concepts, Terms, and Applications**	• **Course Materials,** • **Quizzes & Projects**
1	• Introduction to Joining • 1, 2, 3	• Main joining techniques and their different characteristics • Mechanical fastening systems • Advantages and disadvantages of the discussed joining techniques • Design of a joining area especially for the particular joining technique • Hybrid joining methods	• Handout #1 • Quiz 1 • Project

		• Suitability of different joining methods for different demands	
2	• Overview of aluminum welding • 4, 5	• Arc welding • Beam welding • Electric resistance welding • Brazing • Solid state welding	• Handout #2 • Quiz 2 • Project
3	• Mechanical Joining • 4, 5, 6	• Mechanical joining without additional fastener • Mechanical joining with an additional fastener • Special Mechanical Joints	• Handout #3 • Quiz 3 • Project
4	• Adhesive Bonding • 5, 6	• Design aspects for adhesive bong • Adhesive selection • Surface pre-treatment for adhesive bonding • Factors influencing the strength of adhesive joints	• Handout #4 • Quiz 4 • Project
5	• Hybrid Joining Techniques • 4, 5, 6, 7	• Main hybrid joining techniques • Application criteria • Production considerations	• Handout #5 • Quiz 5 • Project

Reference books are

- The Aluminum Automotive Manual by European Aluminum Association, 2015 http://www.european-aluminum.eu/aam/
- Aluminum Auto-Body Joining by G. N. Bullen, SAE International, ISBN 978-0-7680-8252-4, 2015
- Various SAE and other conference paper will be provided for reference
- Siemens NX User Manuals

6. Conclusions

A new course in Joining Aluminum to Aluminum and Dissimilar Materials for community college students, future designers and technicians. The project was sponsored by the Center for Advanced Automotive Technology (CAAT) which is funded by the National Science Foundation and located at Macomb Community College (MCC) in Warren, Michigan. One of the missions of CAAT is to create curriculum that meets the needs of educating people in new technology developments in the automotive industry. The material developed in this course contains course the syllabus, course learning objectives, course materials, homework assignments, term projects and tests. The course covers Introduction to Joining, Overview of Aluminum welding, Mechanical joining, Adhesive bonding, Hybrid joining techniques, Joining dissimilar materials. A course project has also been developed to apply knowledge learned in the course to design a joint to join Fiber-Reinforced Composite parts. An assessment was performed before and after the course to assess how effectively students learning outcomes are achieved. The authors are still waiting for the post-offering assessment results in order to assess the students learning outcomes. This course has been offered at MCC in fall semester that ended by the end of 2016. The course materials are available online and can be found at CAAT website (http://autocaat.org/webforms/ResourceDetail.aspx?id=4152).

7. Acknowledgements

The authors would like to thank the Center for Advanced Automotive Technology (CAAT), which is funded by the National Science Foundation (NSF Grant No. 1400593), for funding the development project presented in this paper.

8. References

1. Dong, Y., et al., How to Join Fiber-Reinforced Composite Parts: An Experimental Investigation, in Joining Technologies for Composites and Dissimilar Materials, Volume 10. 2017, Springer. p. 1-9.
2. Crest, P., Teaching Institute Handbook. 2006, Sponsored by Kettering University Center for Excellence in Teaching and Learning (CETL).

Azadeh Sheidaei

Dr. Azadeh Sheidaei is an Assistant Professor of Mechanical Engineering at Kettering University. She received her Master and Ph.D in Mechanical Engineering from Michigan State University. She published 11 ISI journal papers and 12 conference papers which have been cited over 190 times. She is teaching core undergraduate courses in solid mechanics in the ME department at Kettering University. Sheidaei is a member of the American Society of Composite (ASC) and a reviewer for journals of Materials Science and Engineering B, Fuel cell, Computational material science and Int. J. of Vehicle Design (IJVD). Sheidaei has received several research and educational grants from NSF, CAAT and KEEN within the last year.

Yaomin Dong

Dr . Yaomin Dong is Associate Professor of Mechanical Engineering at Kettering University. He received his Ph.D. in Mechanical Engineering at the University of Kentucky , USA in 1998. He has 10 years of R&D experience in automotive industry and holds multiple patents. His areas of expertise include automotive windshield wiper systems, engineering materials, metal forming processes, mechanics and simulation with composite materials, computer aided engineering, and finite element analysis.

Javad Baqersad

Dr. Javad Baqersad is an Assistant Professor of Mechanical Engineering at Kettering University and the director of Experimental Mechanics Laboratory. His main research area is focused on structural dynamics, vehicle dynamics, and vibrations. He has more than 10 years of academic and industry experience. He has published more than 40 conference papers and journal articles. He is a reviewer for many scientific journals and is currently the associated technical editor for Experimental Techniques Journal.

Craig Hoff

Dr. Craig Hoff, P.E., is Professor of Mechanical Engineering, and Dean of College of Engineering at Kettering University. He received his Ph.D. in Mechanical Engineering at University of Michigan–Ann Arbor. He has over 30 years of experience in higher education where he teaches energy systems and automotive engineering courses. He is the faculty adviser to the university's Formula SAE team. He’s conducted numerous applied research projects for industry in the area of advanced automotive powertrains. Through his involvement with the FSAE team and industry projects he's had considerable experience with composites and and other lightweighting methods.