AC 2009-857: A METHODOLOGY FOR TEAM TEACHING A COURSE WITH INDUSTRIAL EXPERTS

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A Methodology for Team Teaching a Course with Industrial Experts

One way of bringing experience into the classroom is for faculty to partner with engineers in the field. The advantages to the students, the faculty and even the collaborating industrial partners are numerous, however preparation time for such endeavors often can be limited and the logistics complex. To ease the development of this type of experiential learning, a process for such collaborations is needed. In this paper, a template for a team taught course where university faculty partner with practicing engineers is provided. Using this template, a methodology that includes best practices, guidelines, and activities is developed which can be used by faculty to more easily integrate practice into their classroom. A checklist for selecting appropriate industrial projects with the collaborating partners is also included. To illustrate the usage of this methodology, a case study of a course partnership between industrial experts and Kettering University Mechanical Engineering faculty is provided.

Introduction

Team teaching is, by definition [1], "a method of coordinated classroom instruction involving a team of teachers working together with a single group of students". The team teaching approach has been around for years and is a strategy used at many different levels in many schools. A strong team includes a variety of different teaching styles, and personal chemistry between the team members is arguably one of the most important indicators of success.

One method of team teaching is to have faculty raise comments from the floor during presentations. Lindauer [2] chose to formalize faculty interaction by employing a discussant format, wherein each of the faculty was assured of ten minutes at the end of the other's lecture. The advantages of the discussant format have proved to be numerous and have addressed matters of both form and substance. Relative to more ad hoc team teaching approaches, the discussant format disciplines faculty by encouraging them to prioritize comments and limit the pursuit of tangential issues. The format also proves valuable in reviving student interest toward the end of class sessions. Changing faculty members an hour into the lecture revitalizes the class, enabling key points to be conveyed more effectively. Because discussant comments are prepared during the lecture instead of beforehand, they possess a dynamic quality.

Robinson and Schaible [3] suggested that the optimum team size is two members. The complexity of a team size beyond this inhibits good collaboration. The teammates should agree from the start that the first time teaching together is a trial run and there should be no hard feelings if the chemistry isn't right.

A case study where three professors decided to integrate their teaching and the content of three separate courses into one period of time is documented by Bakken et al [4]. This work provided an example of integrated curricula for teacher education and the team members came from different disciplines. They used several collaborative or cooperative teaching approaches. First, each of them taught in their specific discipline, in traditional team teaching. Two or three teachers led discussions and presented information together. And, sometimes, when one of them was teaching, another would join in to clarify or add another view.

Gray and Halbert proposed an approach called teaching with a student [5]. This model is less expensive, involves less conflict, conserves faculty time, and leads to a more student-centered classroom. The professor in charge of course design shares the daily delivery and delegates most of the administrative duties to the "student teacher."

The team teaching methodology used can determine the effectiveness of the instruction. El-Sayed [6] rates the effect of several different team teaching models on course delivery, including interactive course dialogue, transitions/integration, and efficient use of faculty time.

From the literature, the advantages of team teaching include:

- Courses can reflect real-life engineering challenges.
- Courses can be interdisciplinary by engaging professors with unique expertise.
- Students are able to see the professors interact in the classroom. Such an interaction constantly leads to new insights about the disciplines involved because each professor models the behavior of an individual from his discipline.
- During the problem solving process, it is beneficial for students to see the professors as learners as well as teachers, and demonstrate that learning is a lifelong endeavor.
- The level of classroom discussion and interaction is improved. This interaction is beneficial for students who might have trouble articulating their questions or may lack the confidence to question the professor who is the expert.
- Students have the opportunity to see that faculty members from different disciplinary areas and departments really do have consistent educational and intellectual goals.
- It is beneficial and refreshing for students to see different teaching styles in the same classroom, and helps them develop their own methods for their reports and presentations.
- Students have good models of team work when they see professors working together through collaborative teaching.
- Working with new people and learning more about another discipline is very stimulating for both the faculty members and students and their enthusiasm makes the classes more interesting.
- Team teaching gets faculty members into other places to get better acquainted with colleagues they often have little contact with.
- It is beneficial for companies to have many different solutions to their engineering problems at very low or even no cost. Very often the students look at the projects from very fresh perspectives and might lead to innovative solutions.

- Companies can find future recruits by this kind of interaction with students, and students also have the opportunity to see if the companies and products fit their interests in the future.
- Interacting with academia is a chance for the industrial experts to have a respite from the normal day to day work pattern.
- Industrial experts are provided with the philanthropic opportunity to leave a legacy to the next generation.

Certainly there are a lot of challenges in the team teaching model:

- The class schedules of the universities may be very different from that of the current product development/launch in the companies. Therefore the conflict of priorities in educational institutes and industrial companies will have to be resolved and agreed upon.
- Students might be confused when they don't know which professor to ask specific questions.
- It is expensive to pay more than one professors to teach one class.
- It would be difficult for all parties involved if the professors weren't compatible, and faculty should never be forced into something like team teaching.
- Class projects will be more "on the fly" instead of thoroughly prefabricated.

The Need to Team up with Industrial Experts

Kettering University offers one of the largest co-operative educational programs in the United States. Our students rotate their academic and work terms every three months. They conduct research through their co-op projects leading to graduation thesis. It is very important to bring the real life projects and industrial experts to the classroom in order to stimulate the students' skills of creative thinking, problem solving, and therefore achieve the educational outcomes. It is a common practice and easy to do to invite guest speakers to the classrooms for certain topics. Yet it involves much more work to have a true team teaching approach. The main theme of this paper is to develop an understanding of team teaching with industrial experts and provide practical recommendations that other faculty can use to build upon for use in their own courses.

The process for team teaching involves the following steps:

- Define course learning outcomes
- Choose topic/theme
- Choose teaching team
- Choose industrial partners
- Outline matching/mapped activities
- Choose project with input from industrial partners
- Choose guest lecturers
- Provide field trip for immersion learning at industrial sight
- Design assessments
- Timeline for development

Table 1 shows the template of the team teaching course outline, where the weekly topics are tabulated. This template can be modified based upon the instructor's course and type of project. It is best geared for use in courses beyond the freshman year when the students have enough background for more sophisticated team projects.

Table 1 Template of Team Teaching Course Outline

Week	First class period	Second class period
1	Introduction to class with prof(s) /Selection of project teams	Overview of industrial process with expert(s)/presentation of project
2	Lecture 1, assignment 1	Lecture 2, assignment 2
3	Guest lecture- topic 1	Progress report/pres. on projects
4	Lecture 3, assignment 3	Lecture 4, assignment 4
5	Lecture 5, assignment 5	Assessment/exam 1
6	Guest lecture- topic 2	Lecture 6, assignment 6
7	Lecture 7, assignment 7	Lecture 8, assignment 8
8	Lecture 9, assignment 9	Progress report/pres. on projects
9	Field trip to industrial site, written reflection	Lecture 10, assignment 10, continue to work on project
10	Lecture 8, assignment 8	Assessment/exam 2
11-14	Lecture 9, assignment 9, project	Lecture 10, assignment 10, project
Final week	Final presentation with experts	Final exam

Best Practices

In order to provide some of the wisdom that comes from experience, the following recommendations are provided. Working with projects that are based in industry creates challenges, however the rewards in student learning are worth the extra effort. Having clear mutual expectations and communication are keys to success.

- Underestimate the time requirements.
- There will always be fires, so plan for this.
- Keep open communication, when in doubt ask for approval.
- Remember that the frustrations that the students encounter is not unlike situations that they will encounter in industry - do not underestimate the value of this learning.
- Remain positive and do your best, some things will work and some won't.
- Make the development of the team a top priority. Don't just assume the team will work well together.
- Set clear goals for the team that all members agree upon, and then ensure its activities lead to those goals.
- Communicate clearly and honestly to survive and grow stronger from conflict.
- Honor individual and team success through administrative support.
- Assume responsibility for assigned roles.
- Be prepared for team discussions and work

Guidelines for Guest Lectures

Guest lecturers from industry are largely unfamiliar with academia and the mindset of students. In this case the professor is the expert and must be the facilitator. The professor must communicate how to best interact with students and the level of content needed for each class period. Most individuals from industry will greatly appreciate this guidance as they wish to make a positive contribution. Often the industrial experts have limited time but greatly look forward to the opportunity to contribute.

- Provide time estimate and orientation for guest lecturers - be a coach.
- Attend all class sessions with guest lecturers.
- Help the experts to understand how your students learn best.
- Be approachable and seek regular feedback from students.
- Communicate the background and experience of the students

Suggested Additional Active Learning Activities

In addition to the activities outlined in the template, several active learning techniques can contribute to student learning and are synergistic. Activities where the students can participate in the preparation, presentation, or grading work well due to the spontaneous nature of these type of courses. Students can take ownership of their learning and often have ideas that provide superior knowledge construction. Following is a list of possible additional activities.

- Written briefs on topics or pre reading.
- Presentations on research papers.
- Ask students to write quiz questions based upon guest lecturers topics.
- Have students set the performance criteria and expectations for grading.
- Present projects.

Check List for Team Teaching with Industrial Experts

The following is a recommended check list of discussion items. These issues should be discussed before beginning to teach together in order to make the team more efficient right from the start. Some of these decisions are straight forward and others will take some time for instructors new to this methodology to build sufficient experience.

- Scope?
- IT requirements?
- Approval timeline?
- Able to get information in a timely manner?
- Confidentiality?
- Background of the students in class/appropriate challenge?
- Materials, books, supplies?
- Role assignments?
- Who provide what, how to get it?

- Who should teach what?
- What content should be taught separately?
- What content should be taught jointly?
- How will we grade the students' work?
- Who grades which papers?
- What grading system?

Case Study

Automotive windshield wiper systems design is chosen as a case study example to illustrate the team teaching approach discussed in this work. The design process of a typical windshield wiper system will be presented by the industrial expert, including the wiper arms and blades, wiper linkage mechanism, frame, pivot housing, etc. A very common safety problem is the snow load causing system failures in the wiper systems. The solutions to snow load problems will be one of the main tasks in the students' project. Supervised jointly by the faculty members and engineers from industry, different project teams will perform their own designs approved by the teaching team.

Windshield Wiper Systems **- Industrial Experts and Faculty**

Automotive windshield wiper systems, in conjunction with washer systems, are used in vehicles to remove contaminants such as rain, sleet, snow, and dirt from the windshield. As shown in Figure 1, a typical wiper system consists of an electric motor, a linkage to transform the rotational motion from the motor to oscillatory motion, and a pair of wiper arms and blades. The areas of the windshield that must be wiped by the wiper system are mandated by the federal motor vehicle safety standards FMVSS 104[7].

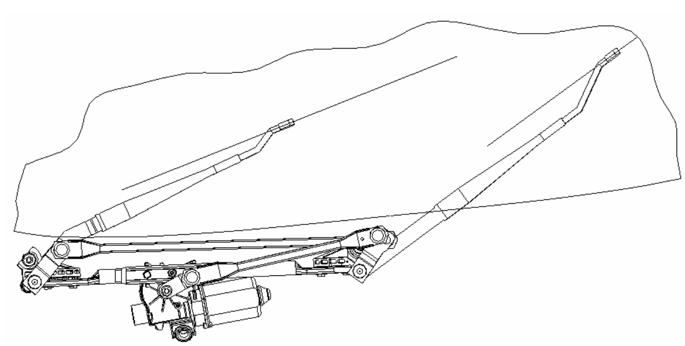

FIGURE 1 – A TYPICAL WIPER SYSTEM

The design of a typical wiper system starts with the technical specifications of the OEM car maker. Given a particular application platform, the geometry of the windshield glass is known. Based on the wiping pattern requirement (Figure 2) dictated by FMVSS 104, the lengths of the wiper blades and wiping angles can be determined. Then based on wiping speed and blade-glass frictional loads, the wiper arms and blades can be designed. The linkage mechanism can be designed based on the kinematics, structural strength, wiping angle, and system packaging requirements. The electric motor can be chosen according to the energy required by the wiper system.

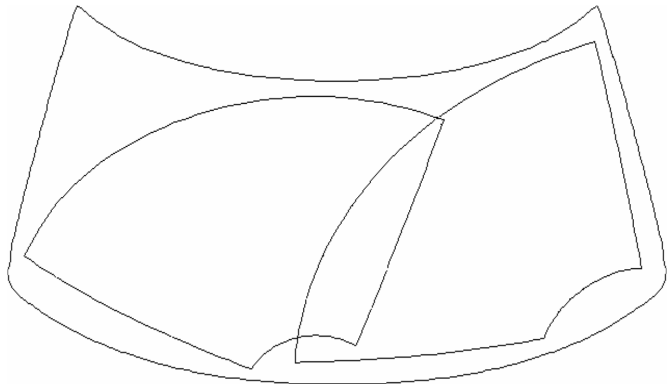

FIGURE 2 – WIPING PATTERN

***Design and Analysis of Windshield Wiper Systems* - Industrial Experts**

A typical wiper arm and blade structure is shown in Figure 3, and stress analysis of the wiper arm is depicted in Figure 8 [8].

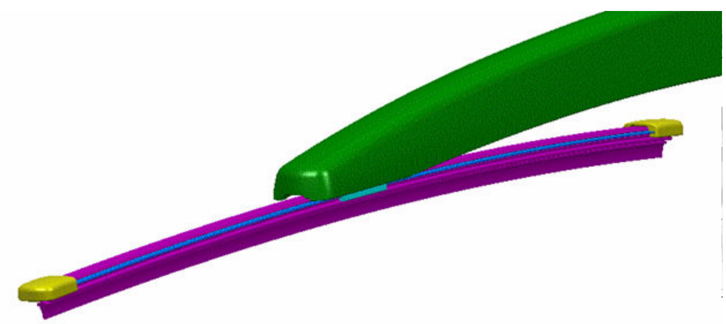

FIGURE 3 –ARM AND BLADE ASSEMBLY

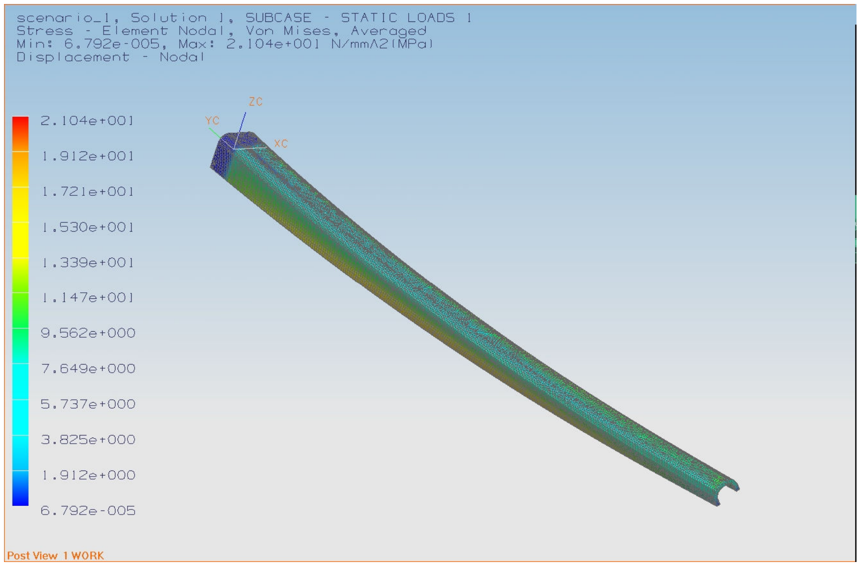

FIGURE 4 – ARM STRESS DISTRIBUTION BY FEA

The wiper arm and the lever are mounted on the pivot shaft that is located in the pivot housing assembly (Figure 5). The pivot housing assembly includes grommet, retainer, washer, O-ring, bearings, spring washers, pivot shaft, lever and ball stud.

The pivot shaft is the most critical component in the pivot shaft assembly, because the wiper arm and blade assembly is mounted on the top and the lever is in connected in the middle. If the pivot shaft fails, the whole wiper system will lose its performance, even its function. Figure 6 shows the stress and displacement distributions. Given the same material properties as the wiper arm, it is seen that this design is safe.

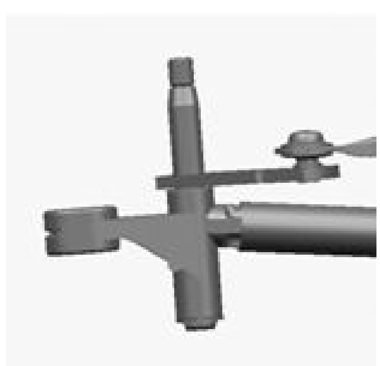

FIGURE 5 – FRAME AND PIVOT HOUSING ASSEMBLY

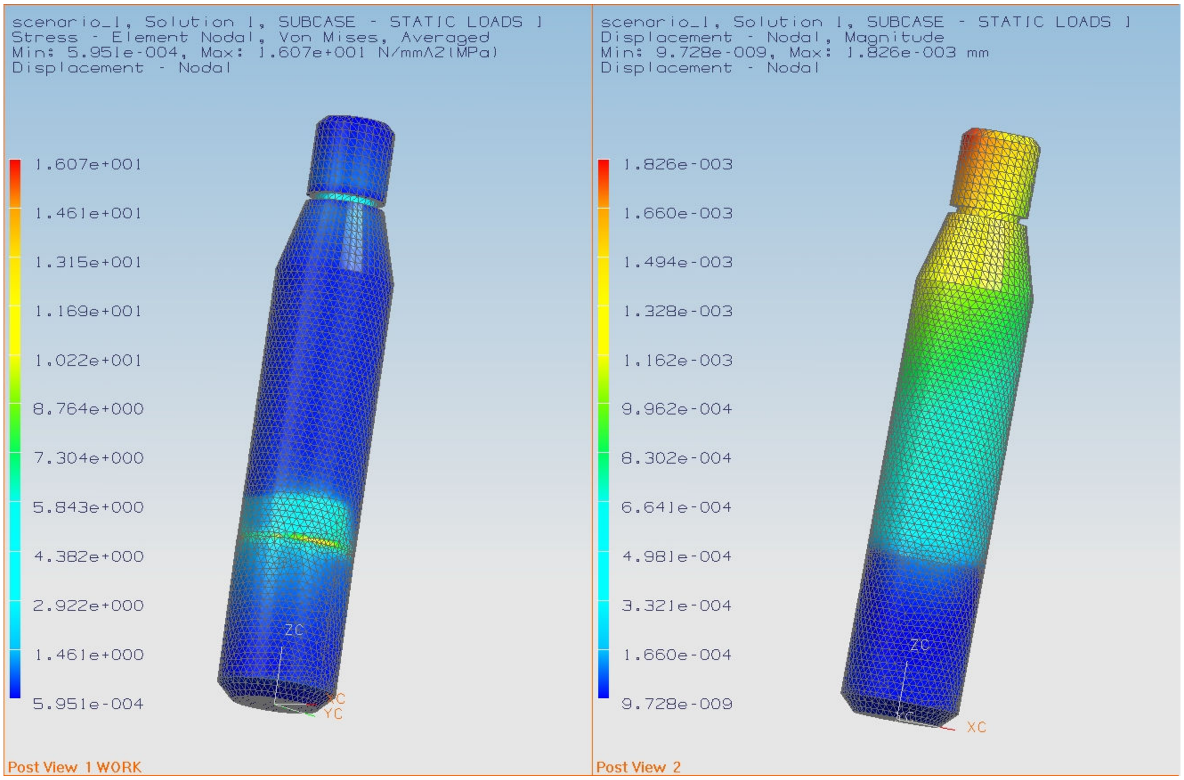

FIGURE 7 – PIVOT SHAFT STRESS AND DEFORMATION BY FEA

***Flexible Linkage for Overload Protection* – Faculty Member and Industrial Expert**

Snow and ice often build up on the windshield glass in the winter, as shown in Figure 8. The snow/ice stack can literally block the wiper arms/blades, and therefore the wiper system load will significantly increase. Such an excessive load, often referred as snow load, will cause either fatigue or catastrophic system failure. Figure 8 shows a broken rocker arm.

FIGURE 8 – WINDSHIELD WIPERS UNDER SNOW LOAD THAT BREAKS A ROCKER ARM

Figure 9 depicts a proposed solution. In this illustration the hatched area represents snow/ice pack above the cowl screen, which restricts the normal motion of the system. Once the arms have contacted the restriction, the loading in the system increases as the motor torque approaches the motor's stall torque. However, once the critical load is reached in the connecting rod, the rod will buckle limiting any further increase in system loading and allowing the crank to rotate through the reversal position. In the illustration, the connecting rod is shown in the post-buckled configuration.

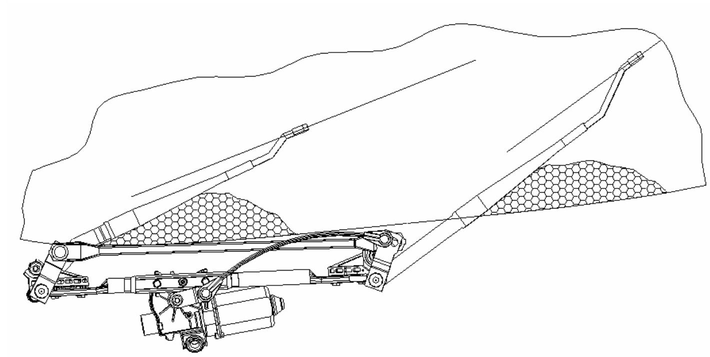

FIGURE 9 – WINDSHIELD WIPERS WITH A FLEXIBLE LINKAGE

Figure 10 depicts the connecting rod of length L, cross sectional area A, and cross section moment of inertia I. The elastic modulus of the material is denoted as E. The ends of the rod are free to rotate due to the socket-ball joints. External compressive load P is applied at the centroid of the cross section.

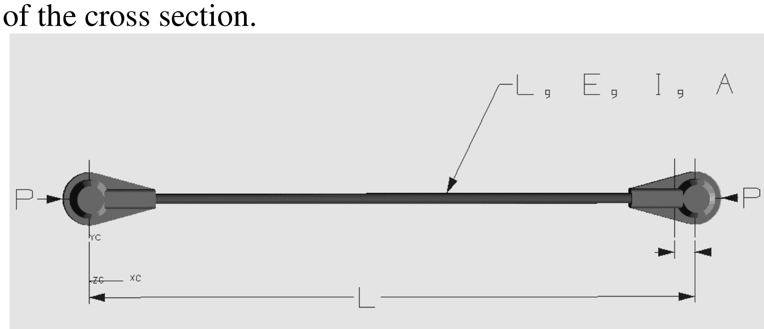

FIGURE 10 –A FLEXIBLE LINKAGE

As the load is increased and assuming that the elastic limit of the material is not reached, a critical point is encountered at which the rod deforms laterally. In this configuration the rod supports the load via bending. The applied load at which this transition occurs is referred to as the critical load Pcr. The critical load can be determined for a given cross section, column length, and material from [9]

$$P_{cr} = \frac{\pi^2 \cdot EI}{L^2}$$

The wiper linkage mechanism can therefore be designed with the flexible connecting rod. The spherical sockets at both ends of the linkage are over-molded plastic parts to provide for ball-socket joints [7]. The composite material is selected per following specification:

Resin Specification: Thermoset Polyester (21% by weight)
Fiber Specification: 113 Yield E-glass Roving (75% by weight)
Filler content (4% by weight)

Monotonic mechanical properties of the materials are:

Elastic Modulus: 43 GPa (6.2 Mpsi)
Ultimate Strength: 1140 MPa (165 ksi)
Strain at Fracture: 2.6%
Specific Gravity: 1.92

The flexible connecting rod undergoes a maximum tensile load of 1000 N at motor stall. The stress and deformation are calculated by FEA as shown in Figure 11.

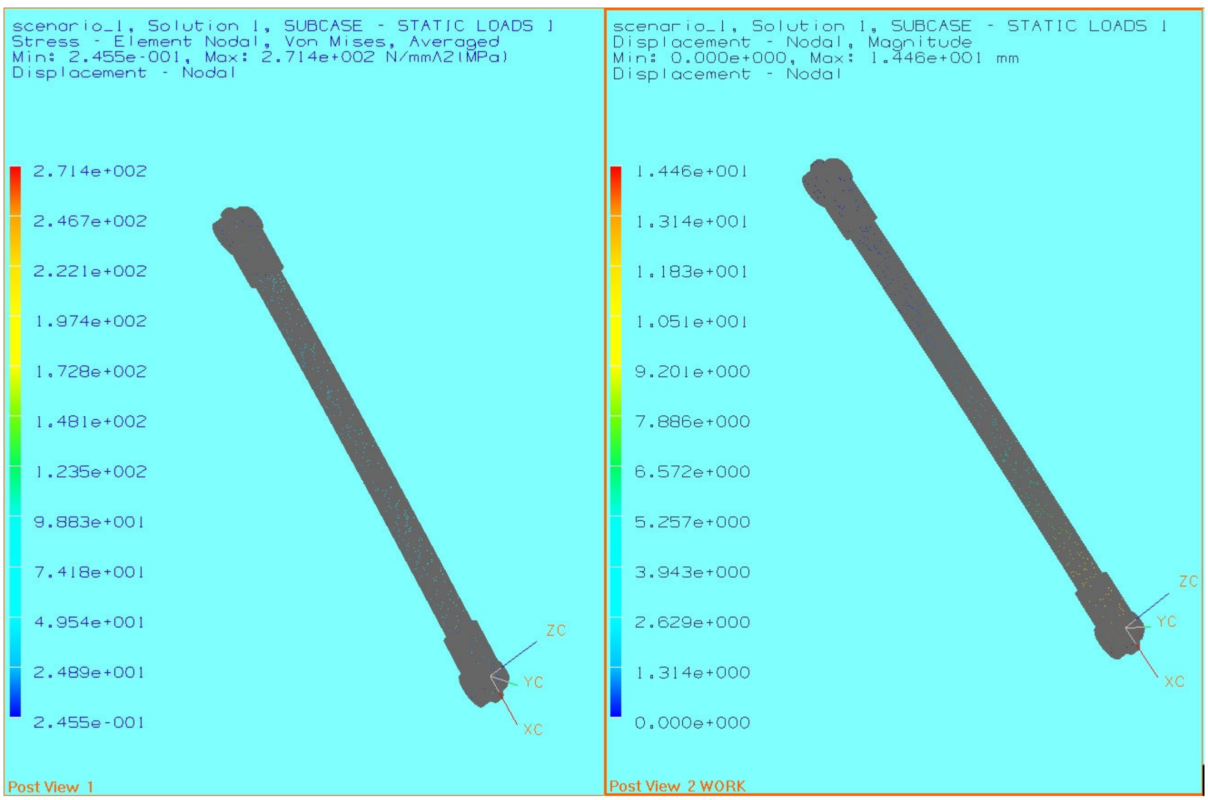

FIGURE 11 – LINKAGE STRESS AND DEFORMATION BY FEA

Conclusions

A team teaching strategy to bring industrial experts into the classroom is proposed. To facilitate the development of this type of collaborative learning, a template for such team teaching is provided. Using this template, a methodology that includes best practices, guidelines, and activities is developed which can be used by faculty to more easily integrate practice into their classroom. A checklist for selecting appropriate industrial projects with the collaborating partners is also included. To illustrate the usage of this methodology, a case study of a course partnership between industrial experts and Kettering University Mechanical Engineering faculty is provided. This case study involves an automotive wiper system design. A typical failure of the wiper systems is caused by the snow load. Through the novel use of the composite material properties, the wiper system is protected from loading extremes, and its durability is enhanced. Such a collaborative course teaching approach not only solves an industrial problem, but also stimulates the critical thinking and team work between faculty, field engineers, and students.

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