AC 2011-2872: AN INDUSTRY-UNIVERSITY PARTNERSHIP CASE STUDY

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Abstract

At many universities, senior undergraduate mechanical engineers work in teams on industry-sponsored capstone design projects. These projects provide an excellent opportunity for students to synthesize their courses, work with the more realistic deadlines and expectations of industry, and interact with company representatives. It also give industrial partners a chance to become educational partners with the university, preview potential new hires, and complete some non-critical projects at low cost.

This paper presents a case study of a successful six-year partnership between the Automotive Bumper Project committee of the American Iron & Steel Institute (AISI) and a mechanical engineering department. The AISI Bumper Project has sponsored seven senior capstone design projects and three master's projects, providing excellent educational opportunities for twenty-five students. The projects ranged from specific vehicle bumper designs to building and testing a high-energy pendulum impact tester.

The university benefited from this long-term relationship by gaining relevant student projects, supporting graduate students, and retaining a connection with industry. The industry consortium benefited by encouraging the study of topics of interest (steel design, impact analysis) at the undergraduate level, receiving 'outside-the-box' design concepts, and learning how bumpers may be affected by future trends. The costs on both sides were kept low, enabling most of the funds to go directly toward hardware so the students could build and test their designs.

Introduction

Partnerships between universities and industry take many forms. At one extreme, a large corporation or consortium of smaller companies may sign a formal agreement for a body of ongoing research activities with a particular university. The Ford-MIT alliance is an example of this sort of partnership. [1] At the other extreme, a single company may choose to sponsor a single student or small group to develop a design. Many schools operate such a sponsorship system for their capstone design courses. [2] In between, there are many different levels of cooperation.

This paper discusses collaboration between an industry consortium and a mechanical engineering department that involved several different types of work over a six-year period. Initially, the consortium provided a project for inclusion in a single-quarter senior design course. Later, they funded a number of full-year capstone design projects. In addition, several projects were expanded into master's theses. One project was handled as applied research for a faculty member. The on-going relationship was maintained through the efforts of key contacts in each organization. In this paper, the projects, successes, challenges, and key success factors will be presented.

The American Iron & Steel Institute (AISI) is an industrial consortium of steel producers and associated companies set up to "influence public policy, educate and shape public opinion in support of a strong, sustainable U.S. and North American steel industry committed to manufacturing products that meet society's needs." [3] The AISI is broken into divisions focused on different industries. Within the Automotive division, the Bumper Project group consists of steel producers, bumper manufacturers, and OEM representatives. Among their many tasks, this group selects and sponsors projects that further the objectives of the AISI, that is, that encourage the use of steel in bumper systems.

Working with a consortium (as opposed to an individual company) offers several benefits for industry-university collaboration. First, because the consortium can only engage in pre-competitive work (to avoid collusion), the projects proposed are typically not on the critical path for any company. In addition, because data is shared between competing companies, it has already been screened for confidentiality. In most cases, not even a non-disclosure agreement (NDA) is required. Intellectual property, of course, still remains a contentious issue and must be handled on a case-by-case basis unless a more formal, long-term agreement is developed.

Projects

As discussed above, many schools have research relationships with specific companies or consortia. Many also have relationships with repeat sponsors for capstone design projects. The university-industry relationship described herein consists of a combination of these. Although no long-term agreement was in place between the consortium and the university, the AISI Bumper Project has sponsored twelve projects over a six year period in the mechanical engineering department. Seven of these were year-long senior design (capstone) projects, three were master's theses, and two were applied research projects involving undergraduate and graduate student assistants. Given the 2000+ mile distance between the consortium and the university, and the fact that no consortium member has yet visited campus, this is a rather remarkable body of work. This section provides a brief summary of the specific funded projects.

Vehicle Compatibility (8 students) – The first set of funded projects developed designs for truck bumper systems to reduce the risk of injury to passenger car occupants in front-end collisions. The projects included developing both geometric changes (to bring truck bumpers in-line with cars) and structural changes (to 'soften' the blow of a truck on a car). The real challenge was to accomplish these changes while maintaining the 'tough' image and performance of a truck. The project started as a paper study with four students in a design class, and then grew into senior projects for four additional students working in a team. The first class project team's report has been posted on AISI's http://autosteel.org website [4]. In this report, the students documented their ideation results (over 20 concepts developed), their analysis (using FEA and hand calculations) and additional details on the final three selected concepts. An example of their results is shown in Figure 1, where the existing (straight) frame rails are supplemented with a new lower bumper supported by an integrated torsion bar. Reinforcements were also proposed for the frame rail system. The second team built physical and numerical prototypes to prove-out the concepts. [5]

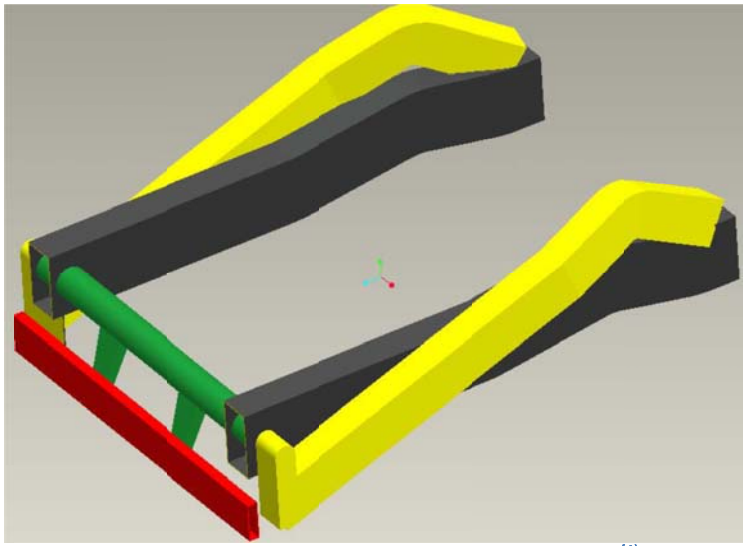

Figure 1: Bumper compatibility torsion bar concept [4]

Pedestrian Bumper Systems (5 students) – The second set of projects related to the design of bumpers to reduce injuries sustained by pedestrians in the event of a collision. This was inspired in part by new legislation in place in Europe. The work started as an applied research patent survey (with an undergraduate research assistant) and then became a funded master's thesis. Additional alternatives were investigated in a follow-on senior project with a team of three undergraduates. The patent survey work was documented in an SAE paper [6], and the master's thesis [7] and senior project [8] results were recorded in final reports.

Bumper Test System (8 students) – In order to support the on-going series of bumper impact studies, AISI funded several project teams to design, implement, and refine a bumper impact test pendulum at the university. Additional funds for shared instrumentation were provided by the ME department. The goals of this system were to simulate head-on impact between 1500-kg vehicles at speeds up to 8 km/h while simultaneously recording deflection and impact force. The first team, consisting of a senior project team of three undergraduates [9] and one masters student [10], designed, built, and tested the main system (Figure 2). A second masters' student completed a Reliability and Repeatability study on the system. The following year, a new three-member senior project team refined the system to reach its maximum potential. The final system met the goals and has been used to perform final impact testing on two subsequent bumper projects.

Global Adaptable Bumper System (7 students) – Vehicle bumper impact standards vary considerably between major global markets. In order to better meet the challenges of designing for this variability, the AISI bumper group suggested work on an 'adaptable' bumper system that could be readily modified for each market. As a first stage in this process, three senior project students studied the most severe standard for low-speed impact, the Insurance Institute for Highway Safety's low-speed impact protocol. Since the IIHS protocol had just changed, the students looked at previously well-performing bumper systems and predicted how they would fair under the new standard. They used these predictions to propose a new design that would perform well in those conditions. [11]

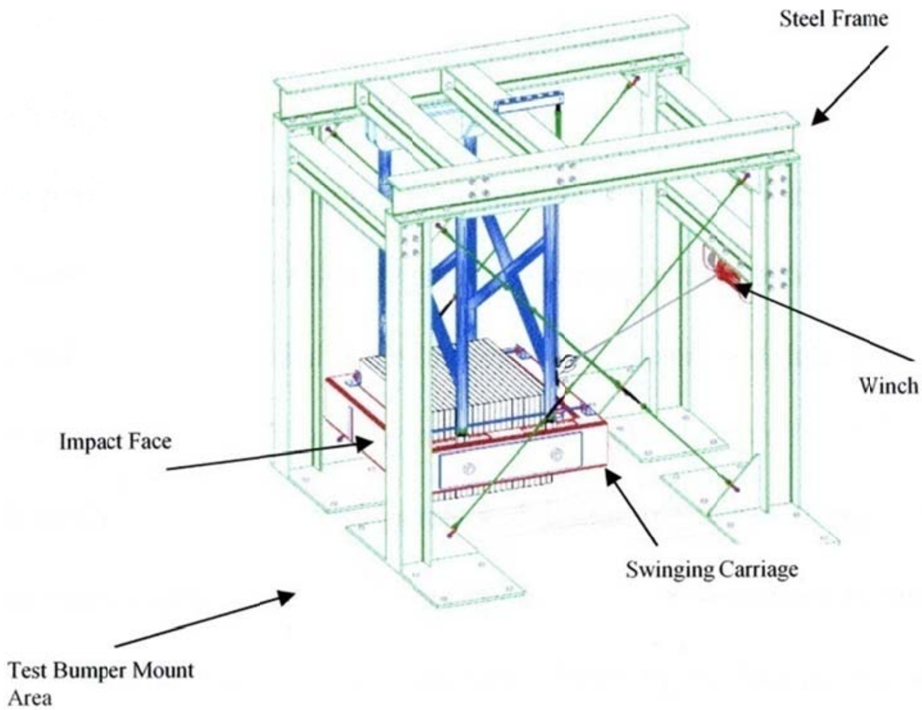

Figure 2: Bumper impact test system

Following completion of the IIHS and pedestrian bumper senior projects, a master's student was sponsored to develop the 'adaptable' bumper system. This project, however, was unsuccessful. After the student left, the project was completed by a senior project team of three students [(12)]. This team reviewed current bumpers and integrated the best features into a design that could be easily adapted for the different requirements in the major global vehicle markets. Their final design [(12)] also included an innovative steel energy-absorber that could reduce lower limb injury to pedestrians in the event of impact up to 25 mph, shown in Figure 3.

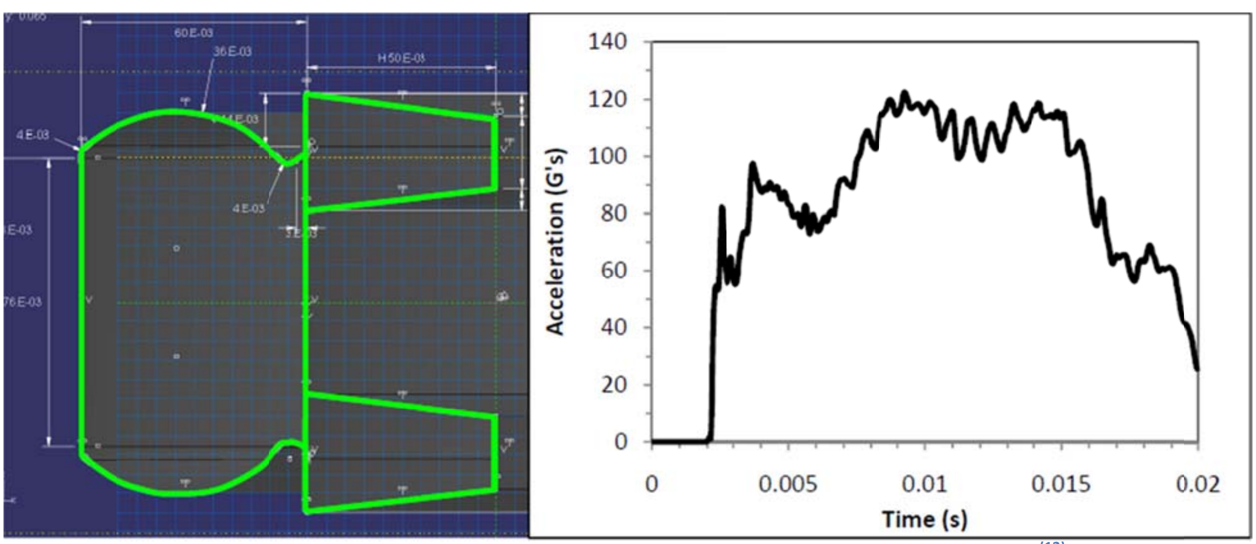

Figure 3: Best-in-class global bumper proposal with steel pedestrian energy absorber [(12)]

Results

A series of projects in four major areas were completed by twenty-one undergraduate and four graduate students over a six-year period. In addition to developing team-building skills on an open-ended project, the students learned to use material from earlier classes on ever more complicated problems. They also were able to practice aspects of lifelong learning: Teaching themselves about topics that had not been covered in classes (e.g., impact, biomechanics, finite element analysis).

The senior design project process is similar to that carried out at most universities' capstone courses: All projects started with the students defining the problem based on discussions with the customer and research into the topic area (of which none of them were previously familiar). After obtaining sponsor/customer agreement on the objectives, the students proceeded to further investigate existing solutions and develop their own, 'fresh-eyes,' concepts to meet the project needs. These concepts were then evaluated and a single direction was developed into a final design through extensive analysis. This final design was then prototyped and tested in one or more impact events. Students typically needed to create the impact test setup themselves (at least until the impact tester became available).

Over the course of this relationship, there have been a number of benefits afforded to the project sponsors (AISI Bumper Project). First of all, the student projects provided a means of completing pre-competitive research into alternative designs for specific conditions. This research was performed at very low cost to the individual consortium members (approximately $5000, including materials, for each of the projects). In addition, by engaging students in the process, the sponsors got a completely unbiased (by prior work, failures, management perspective, historical experience, etc) set of design alternatives to consider for future designs. While none of the resulting designs could be considered ready for production, the design concepts, testing results, and analysis documented in the final report provided a starting point for each consortium member to develop into their own ideas on future products. Finally, by working with a single faculty member as the point contact, the sponsors were able to jointly formulate a cohesive set of projects that built up a more complete body of knowledge over time.

The university also experienced a number of benefits from this relationship. The major benefit, of course, is the real-world projects and sponsor interactions afforded to the students. The educational value of this is immense. In addition, by having a number of projects submitted over an extended period of time, both parties knew what to expect, and the entire process was greatly simplified. The university also benefited from the on-going interaction between the lead faculty member and the consortium member. This interaction, and the association with the individual projects, kept the faculty member connected to industry and engaged in the discipline.

Success Factors

The main goal of this paper is to present the critical success factors and limitations of on-going university-industry collaboration, based on the specific case herein. So, what makes for a successful collaboration?

The first critical success factor is shared goals. At a teaching-focused university, whatever else goes on must come second to undergraduate education. For an on-going relationship to be a success, the industrial partners must also have that as one of their primary objectives. This sounds like altruism, and it is! If industrial partners wish to have a seat at the table with universities, they must be willing to put their needs second to the needs of the students.

However, there must also be secondary shared goals. Most importantly, the industrial partner is would like a 'fresh-eyes' approach to a problem. To enable this, the university partner must be focused on helping the students achieve a solution to the problem, and provide details about their solution and its alternatives back to the consortium. The university partner is likely interested in remaining active professionally and possibly in publicizing the results of the partnership. The industrial partners must be aware of these interests and flexible about publication.

Working with a consortium has helped with managing shared goals. Since the consortium members share costs, they already anticipate that they will need to compromise on any project objectives. Since the work is pre-competitive, publication and intellectual property are typically not issues. And, since a consortium has public-policy objectives, supporting engineering education is beneficial to their broader purpose.

A second critical success factor is personal relationships. As with any partnership, the people matter. It is important to have a single (or a few) point(s) of contact in each organization. That way, they can get to know each other and learn what to expect as the relationship progresses. Continuity of these individuals is also important, as that allows more efficient work and enables relationship building. Although personalities can make a difference, as long as the points of contact are focused on the shared goals, the individual personalities are not critical.

A third critical success factor is appropriate projects. The university contact must be willing to work through the needs of the industrial sponsor to identify appropriate projects for university work. Based on experience, the right venue (sponsored research, graduate thesis, or senior design) for each process should be selected. The projects should have the right scope and timing for student work. Due to the nature of academic schedules, time-critical projects should be avoided. In the case of a consortium, distilling the goals into an appropriate format for the university will probably become the university contact's responsibility. For example, in the present work, each project proposal was written by the author and edited and approved by the AISI Bumper Project members.

It is worth discussing project scope a little more. Most faculty are good at estimating the level of difficulty of a problem, and so identifying projects that are either too hard or too easy for senior undergraduates. After all, we do this all the time when we write exams! However, experience appears to be an essential ingredient to correctly estimate level of effort, time, and money required to complete a senior design project. An approach that has worked well in this relationship has three stages, and starts 3-6 months before the project is scheduled to start. Collaboratively, the consortium members discuss areas of common interest. These are shared with the faculty contact, who then drafts reasonably-scoped project proposals. These proposals are then shared with a faculty member with more experience in the senior design class to confirm the scope. Finally, the proposals are returned to the consortium and one or more are selected for submission.

A fourth critical success factor is funding. This is a two-way street. Given that the primary shared goal is education and project success is secondary, the industrial sponsor will not be able to provide as much funding as for a full research project. At the same time, the university must not get greedy. Although it is easy to view funds as a revenue stream, that viewpoint nearly always conflicts with the primary goal of education. For the present relationship, funds for each project were kept under $10,000 (and in most cases less than $5000), allowing the focus to remain on education.

The final critical success factor observed in this relationship was commitment. Each project needs to have a sponsor representative. This individual must be willing to spend time working with the university teams, providing historical insights and guidelines. This on-going commitment of time may last more than a year for a single project. In the present partnership, most of the sponsor representatives were members of the AISI Bumper Project who volunteered their time (THANK YOU!) for a specific project. In some cases, however, where an industrial representative could not be found, the author, as the university's key contact, acted as the sponsor's local representative. The time commitment for these tasks is non-negligible, and must be factored into the costs of the project.

It is worth noting that legal contracts were NOT, in general, a part of the relationship. As a result, for this series of projects, there were certainly not a critical success factor. Because of the interpersonal relationships, shared goals, and successes, no contract was needed to develop and maintain the series of projects. Small contracts were signed when larger dollar amounts were needed (for instance, to fund faculty or graduate student work). However, these were limited in scope and flexible in implementation. Intellectual property (IP) was not an issue as the consortium was willing to accept the university's default policy, which essentially states that the university retains all IP. Perhaps this would have become a concern if more funds were provided … in which case it would be a good example of policy getting in the way of student learning!

Challenges & Limitations

As with any partnership, balancing the shared goals is always a challenge. Despite the commitment to education, an industrial sponsor is always looking for tangible outcomes from the project. Fortunately, this is not necessarily in conflict with engineering education. The students need to know that they are responsible for delivering something at the end of their work. This sense of responsibility is important to their education. However, sometimes the pressure from the sponsor becomes too high to be beneficial to the students and the faculty representative must step in and remind everyone of the primary goal (education).

Project success is occasionally a challenge. In the described relationship, several of the teams struggled to achieve successful projects. While this is not unusual in the open-ended design experience at a university, it is sometimes difficult for the sponsors to adjust to. Both partners need to be flexible with the final results. Some students, some teams, perform better than others on specific projects. Another benefit of keeping costs low is that the sponsor can choose to resubmit the project at a later date in an attempt to obtain better results. This occurred twice in the present relationship, and the following projects produced much better results.

As mentioned in the critical success factors, time is another challenge for this type of relationship. Both the industry representatives and the faculty contact must invest considerable time in defining projects, working with student teams, and evaluating results. The benefits of this work are better learning experiences for the students and better project results for the sponsors. However, finding the time to make this happen is always a challenge. Universities and companies can help by recognizing this time commitment and rewarding those who participate.

Conclusions

This paper presented the activities, accomplishments, and key success factors of a six-year informal relationship between an industrial consortium and its university partner. The relationship provided educational opportunities for twenty-five undergraduate and graduate students working on nine different projects. In nearly all cases, the students were able to work directly with industrial sponsors and perform preliminary research, detailed analysis, and build and test prototypes.

Major factors contributing to the success of this relationship include shared goals (especially focused on students' education), time commitments of key contacts, appropriate project selection, and limited costs.

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