Training and Recruiting High-Quality Next Generation through Industry Partnered Competitions

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Abstract
Communication between students and industry in engineering programs is typically very limited if existent at all. A new competition with a new model has emerged where students interact directly with foundries as part of the process. This article describes that process along with the benefits for students and companies involved.

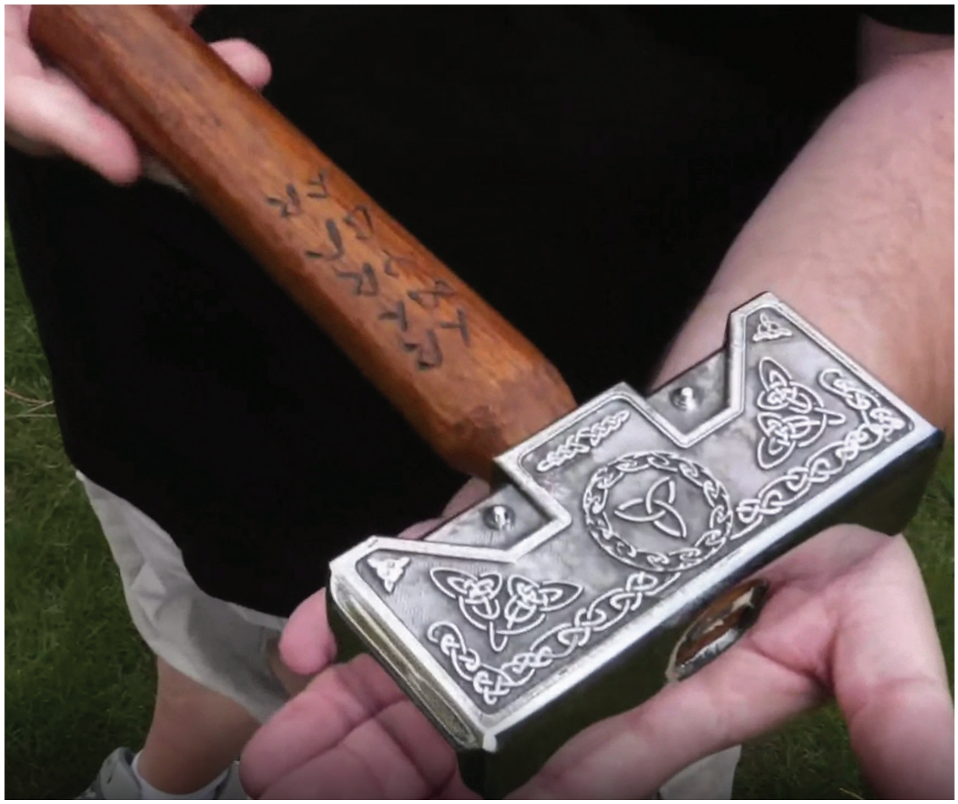

Figure 1: Thor's Hammer Competition Entry

Introduction
This partnered competition consists of student teams working with a company to develop and execute the contest entry. While student competitions have existed for a while, industry generally is on the sidelines, typically as sponsors or providing advice. Otherwise industry involvement has been low. A new competition (well, 4 years old) has used a new model that requires the integration of the student team working with a specific company in industry. This competition is particularly of interest to Investment Casters, as this has been the casting process of choice for student teams.

Cast In Steel (CIS)
Cast in Steel is a competition that challenges university students to use modern casting and design tools to creatively design and produce a designated functioning artifact. These artifacts are historical in nature but they allow for engineering design, design for manufacturing, tooling production, production and finishing. The artifacts have to be functional as they will be tested for performance. Other judging criteria include Artistry, Quality of Engineering Processes and Report (Including testing videos), Team Effectiveness, etc. Past artifacts have included:

- 2019: Viking Axe
- 2020: Bowie Knife
- 2021: Thor's Hammer (**Figure 1**)
- 2022: Celtic Sword
- 2023: African Spear Point

General Process
The student team is paired up with a foundry that will provide expertise and eventually produce the article in question. Typically, the students will come up with a design for their article and material selection. They will then work with the foundry exploring capabilities of the process vis-à-vis their article, available options for alloys (that is, what does the foundry actually pour), requirements for tooling, etc. Then they will develop the process with the assistance of the foundry, produce 3D printed patterns (or molds), the foundry will typically assemble the final tree/pattern and create the mold, pour the casting and sometimes heat treat the casting. This is then given to the students to finish. Depending on the capabilities available to the foundry, they may also perform NDT, dimensional inspection, etc. but these are not essential. The detailed process described following is an idealized process, which as foundries we are aware it does not flow this easily,

especially when working with students.

The students are rated on the effectiveness of their design vis-à-vis performance tests, artistry, and historical accuracy. The competition provides significant flexibility by only establishing certain boundaries such as maximum length and weight. Otherwise, the designs are wide open. With regards to performance, as an example, swords are required to cut articles and retain their sharp edge. The tests performed are dependent on the article produced.

The students are expected to perform significant research and justify their design on a historical basis. For instance, for the Viking axe, while there is significant variability there must be a line that connects the submitted design with original artifacts. Then, the artistry and aesthetic component comes into play. The students can choose from many options to make the artifact stand out with the overall design (see **Figure 2**) even if it is an artistic deviation from the original historical artifacts. In other instances, the students can incorporate other features such as those shown in **Figure 3** in the Viking Axe. In this case, the runes incorporated have a historical connection.

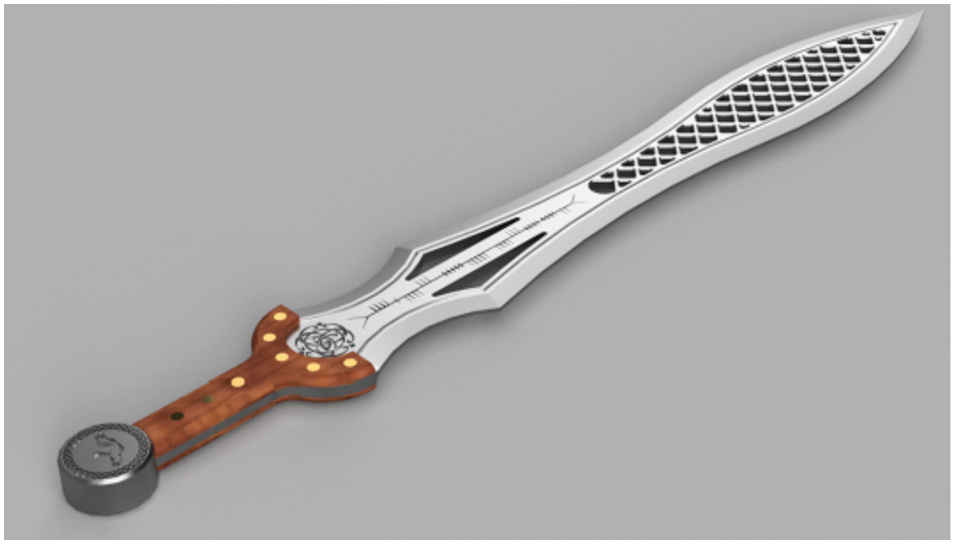

Figure 2: Celtic Sword showing an aesthetic choice in the grid pattern within the blade

Figure 3: Viking Axe with runes incorporated in the blade and handle as artistic elements.

The design of the artifact has to incorporate the fact that the geometry must be cast. While some secondary processes are allowed (grinding for sharpening, polishing, or finishing within the hole for handle fitting) the bulk of the geometry is meant to be cast. This is where the interaction with foundries begins. Students will often design parts that are not castable. This can be due to inexperience (some contestants have not taken casting courses yet) or because they do not fully grasp the details of what will make a successful casting. At this point the foundry will provide feedback to the students so they can modify their design to eliminate uncastable features, modify the design so they become castable, and learn more about the process on other items where they can incorporate features assumed as not being castable. This entry design process takes many forms, but in general it includes CAD design, communication with the foundry, casting filling and solidification simulation, if possible site visits to the foundry by the team.

As part of the design process an alloy must be selected. Here the students will typically research possible alloys that will meet the function based on their research. Sometimes, they will have alloys that are not commonly cast (such as 1060 steel), or under optimize by over emphasizing criteria. For instance 316/CF8M stainless steel for corrosion resistance, but it does not really hold an edge. This is another area where working with the foundry exposes students to the reality of industry. First off, what suitable alloys does the foundry pour? This typically simplifies the conversation, and the student learn. For a sword, a martensitic of PH stainless was often a common choice.

Once a design is finalized then the production process is designed. Investment casting has been heavily favored by teams because of the ability to produce intricate decorative detail but also, in the case of swords, the ability to produce a thin casting. (**Figure 4**) It is worth mentioning that other processes have been used, primarily sand-based processes as will be described later.

Given the limited production runs, at a maximum about seven parts, one article for entry, one for the foundry, one for the school, and one for each team member (~4), permanent tooling is not used. Rather, 3D printed tooling is used. For investment casting the patterns are printed in available equipment with significant input from the foundry as to what will make a successful pattern. The 3D printing has taken many routes: Students' home printers, school printers, companies printers, and even company partners printers (at the

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request of the company to support the project at the discretion of the foundry). Information such as internal density, surface thickness, materials, etc. is the type of experience that the foundry will typically have that will help the students. Best practice has the students learning how to use the equipment and setting parameters for successful printing way before the patterns are to be printed.

Then the foundry typically takes over to use the patterns, assemble trees and produce molds. Then pouring, cutting, gate grinding and blasting take place. Some foundries will help with heat treatment if possible, some with edge grinding, but often the student team will have to find solutions to these issues if the foundry can't provide them.

Then the students have a rough casting and they work to finish it with polishing, fitting handles, additional decoration, etc. as the contest piece will require. The students will need to submit a detailed and professional report along with a testing video. The report will include team processes (organization, team responsibilities), design decisions, quality metrics, etc. The report is now limited to 30 pages due to the lengthy reports previously submitted.

The entries are then sent to the SFSA who coordinate and sponsor the contest. The entries are judged in several categories such as quality of engineering report, artistry, historical accuracy, etc. by an panel of industry experts. Then, the performance test has recently been done at the AFS Casting Congress, **Figure 5**, (many schools send students there anyways) and the final awards are given.

In the past typical processes have been investment casting with and 3D printed expendable pattern, patterns for sand casting, and 3D printed sand molds.

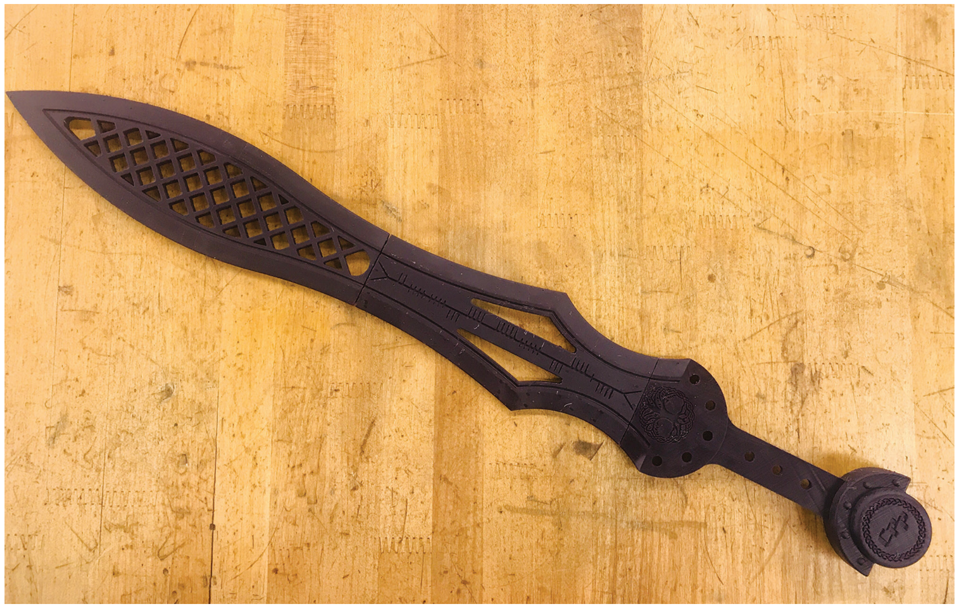

Figure 4: 3D printed pattern

Challenges

Typical challenges have generally been due to the students' inexperience with real product development processes as well as communication. Among these, unrealistic expectations including improper or incomplete communication of expectations. This has gone both ways. For the students, they often do not coordinate well enough by not providing sufficient detail. From the foundry end, they assume that students understand 'obvious' things (obvious to people in industry, that is) so they forget to go the extra level of detail. Other simple things such as lead time or translated 'you can't expect the casting the next day after handing in a 3D pattern'; timely responses to inquiries by the foundry (that is, answer even if it is just an acknowledgment of the communication); formal communication and information sharing (not just texting). Other challenges, as discussed, over optimistic designs with features that are uncastable (too thin, too small, etc.).

Deadline meeting is a challenge that exists for the students. Many for the first time are faced with an open-ended project, with many internal deadlines which they often have to set and meet in coordination with their teammates. In addition, the have external deadlines, when does the foundry need your designs for review and patterns for production to allow them time to complete their tasks. This is one of the greatest contributions to the students development: project planning and execution.

Other challenges are team related. The first one is how to form teams. At Cal Poly Pomona we form teams that include upperclassmen and lowerclassmen, as well as students with casting experience (through work or classes) with newcomers, and students with experience in the contest with those without experience in the competition. Other schools may use other methods.

Other team related issues have to do with team processes. Lack of effective communication internally and with the foundry, unclear responsibility assignments, unclear expectations, missing internal deadlines, etc. One large problem is endless iteration of designs, that is they do not freeze the design at a proper time to move on to the next stages. Not taking advantage of processes that can be done in parallel and making them sequential, for instance, report writing while other activities are taking place. Not fully reviewing and learning the competition instructions and rules and sharing them with foundry partners.

Students will normally learn the importance of professionalism. After missing some meetings, or not showing up to the foundry as expected, or missing deadlines the foundry will typically report this to the faculty advisor to the team. Then, clear and forceful explanations are given, proper apologies are made (including a significant step up in performance as the only real proof of apology) and generally things work out. In the end, we work with industry to develop the students in all areas, not just technical knowledge.

Student Perspective

What do the students get out of this? Meeting with industry and making contacts while getting closer to real world experience. Said another way, realizing reality: true capabilities, not textbook, what lead times are and why, expectations from industry, professionalism, soft skill development and understanding of its importance, project management experience, professional communication, teamwork and leadership, etc. Also, excitement and fun; professional networking; learn by doing; learn stuff not in class. Research – how to do practical research to address immediate problems; technical skill development (alloy selection, design, new processes, simulation, gating design, patternmaking, 3D printing, heat treatment, materials testing, NDT, etc.).

Foundry Perspective

Why should a foundry participate? Fun. It is fun working with students despite occasional frustrations. In addition, it is very personally rewarding to see their growth through the process by helping educate students with a real world project and show the realities of working in/with industry. Other tangible benefits include exposing the next generation to casting; become actively engaged with the university for projects, guest speakers; screening for hiring; development of alternative solutions and selection processes; showcasing company and capabilities; etc. One common situation is that students, through their inexperience, sometimes question some things in the foundry which leads the foundry to learn and/or improve their processes in some areas.

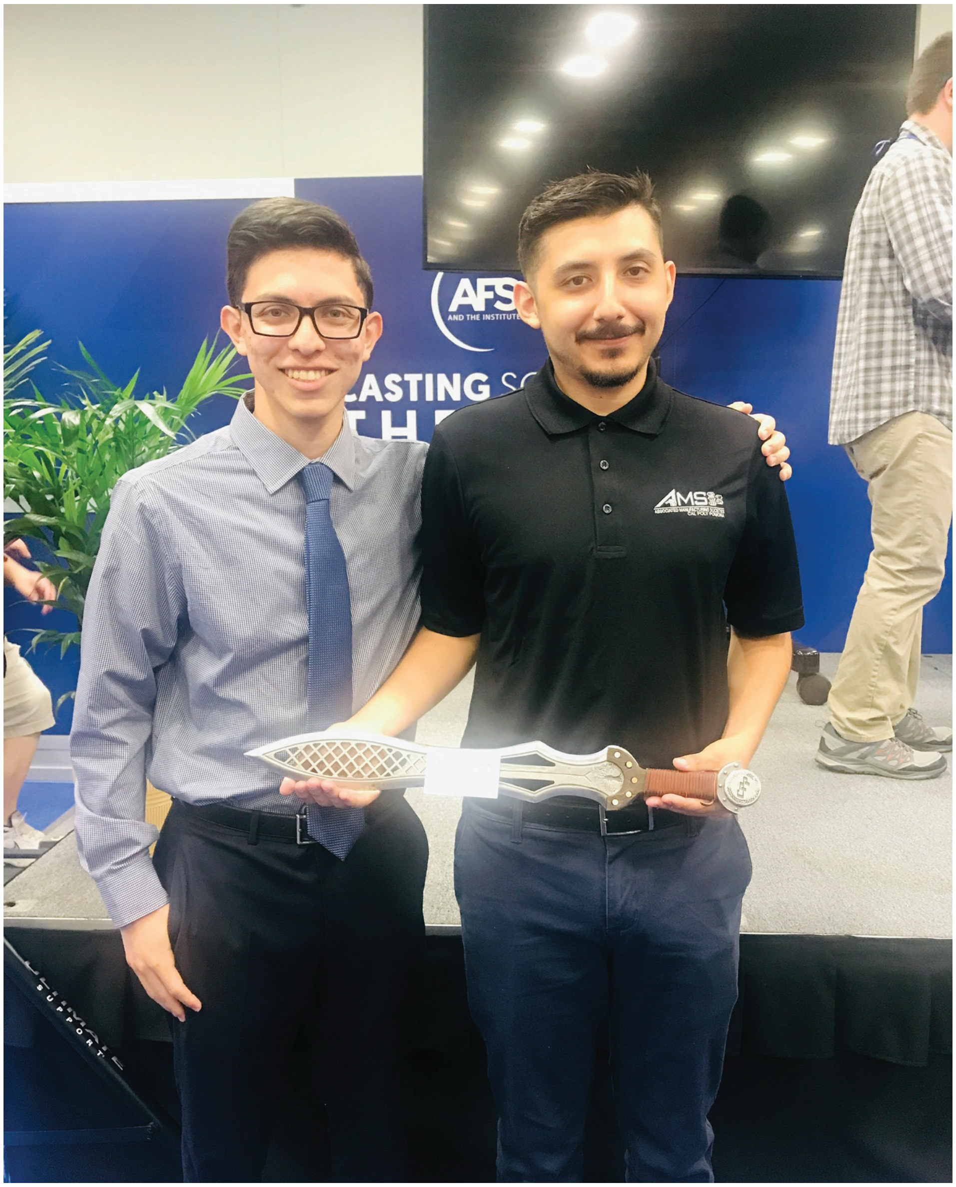

Figure 5: Students at AFS Casting Congress Competition and Final Judging

How Can A Foundry Participate If Interested?

Contact SFSA and/or the authors. If you have a local school that could be involved and you would like to work with them, introduce them to the contest. Currently, schools with four year engineering degrees have participated. However, this is a competition that is designed to be as open as possible and I believe that other student participants would be welcome, such as community college students.

There is even work to see how to make versions of this competition available to high schools. At this time it is envisioned that the competition would be significantly different, but with the same objective: get students interested in metal casting through a compelling, fun and interesting project.

Conclusion

The Cast In Steel competition allows students to design and manufacture an interesting and fun competition item. The competition is challenging at a technical, performance and artistic level. The students work directly with a foundry which provides benefits to both parties.