Session 2793

Development of a Crawfish Processing Machine in a Capstone Design Course

Michael Larson, Donal Collins, Melanie Landry

Department of Mechanical Engineering, Tulane University, LA 70118

Abstract

This paper describes how an entrepreneurial focus can be brought to a capstone design course in mechanical engineering. During the 2000-2001 academic year, senior undergraduates in the Department of Mechanical Engineering at Tulane University were divided into teams to prototype, test, refine and manufacture a new product under the direction of faculty and graduate students who created the concept of an industrial-scale crawfish peeling machine. The graduate students and undergraduates worked together to employ a structured design methodology in a course which satisfies many of the ABET 2000 objectives and gives the students a window on the process of developing intellectual property and bringing it to the marketplace.

I. Introduction

The motivation behind this design effort is a direct result of Louisiana losing its position as the leading producer of crawfish tailmeat. While thousands of people still work in the state to produce millions of pounds of tailmeat, recent years have seen a less expensive Chinese product being imported into the U.S. resulting in a loss of market share and jobs for Louisiana companies. This project seeks to design machinery to aid producers in becoming internationally competitive once again. Mechanizing the industry represents a significant innovation over the present hand-peeling done by processors -- no machinery is currently used to facilitate tailmeat removal due to a lack of industrially suitable designs.

The Chinese processors are able to sell a high-quality product at much lower prices. (In May of 1997, a tariff was placed on Chinese crawfish products because of unfair trade practices. Application of the "Anti-dumping" law has raised the price of the Chinese product almost to the $6 to $9 per pound price range that Louisiana processors typically charge [4]. Before passing of this tariff, Chinese tailmeat sold for $3 to $6 per pound, a dramatic discount compared to Louisiana products. Simply examining the labels that are printed on the tailmeat product sold in the local New Orleans grocery stores reveals that many still opt to sell only the Chinese products due to the cost differential, even since passage of the tariff.

By 1995 U.S. imports of crawfish had grown to $9.1 million. U.S. exports had decreased by 43% since 1996 when the Chinese entered the market. State officials estimate that Louisiana lost 3,000 jobs because of the loss of market share to the Chinese product [4]. While many local observers view these developments as constituting a major economic cloud, it is possible that this competition could prove to have a silver lining. The cheaper product has penetrated new markets; major restaurant franchises have added crawfish dishes to their menus nationwide. The total volume of crawfish sales worldwide is many times greater today than it was prior to the Chinese entering the market. It follows, then, that should local crawfish producers find a way to be a major player in this new larger market, they stand to increase sales significantly. The only way for Louisiana processors to gain price competitiveness, however, is by reducing production costs. Various studies have been performed to determine the economic feasibility of processing crawfish. Most conclude *that for the local industry to survive in the future, peeling machinery must be developed* [3].

One of the major factors contributing to the large price differential of the foreign and domestic products is the cost of labor. In the U.S., labor costs account for up to 50% of total costs to the processor. Reports written as long ago as 27 years [1] and as recent as three years [2] both conclude that the introduction of a cost-reducing peeling machine would contribute significantly to Louisiana's ability to regain a competitive position in the market for crawfish tailmeat. There are several reasons why a machine could greatly benefit the local industry. First, it could reduce the cost of producing tailmeat. A machine would likely require between a fifth to a third of the amount of labor to produce output comparable to current levels of output. Second, it could offset the critical shortage of labor which is experienced in some areas of the state. Conversations with the owner of the largest peeling facility in Louisiana reveal that he cannot find enough peelers to handle the supply of crawfish during the peek season. According to a DAE survey of only 19 local processors, labor shortages amount to over $2 million in lost sales each year [2]. Across the state the figure is sure to be much higher. Third, output capacity could be greatly increased by the use of a machine. At peak production, machines could outperform by many times the rate at which people can turn out the product, generating greater revenue.

II. Industry Background

Today there are some 80 crawfish processing facilities in Louisiana which boil, peel and package crawfish tailmeat, either frozen or fresh, for the consumer market. These originally "mom & pop" operations have developed into international businesses grossing millions of dollars per year. All of these currently employ hand peelers to remove tailmeat from the crawfish exoskeleton. In a recent survey of 19 Louisiana processors, owners indicated that if there were a peeling machine available that they would process 29% more crawfish than current production (from 1.11 million pounds to 1.43 million pounds total for the 19 respondents [2].) Most of the owners based this increase on projections of what production could be using the current techniques if they could hire enough labor during the peak harvest months. If a machine were available that increased processing speed and decreased labor costs, it would open up more of the market to these producers. We have made personal contact with some of these owners and all are enthusiastic over the prospect of having machines to aid production.

Historically, the challenge of mechanizing the process of removing the tailmeat from boiled crawfish has seemingly been undertaken by comparatively few people. This could be due in part to the local nature of the crawfish industry. A possible hindrance to the development of a machine may have been the development of the automated shrimp peeling machine in the 1940's (which, incidentally fuelled the rapid expansion of the shrimp peeling industry). Many, as evidenced by archival newspaper stories and U.S. patents, have mistakenly believed that the techniques so successfully used to peel shrimp could be used to peel crawfish. However, this is not the case since the exoskeletons of the two species are held to the tailmeat by very different mechanisms. While the shrimp exoskeleton is attached to the body at the base of the tail and otherwise rests limply atop the body, the crawfish exoskeleton is more of an extension of the crawfish body; it is a continuously attached shell (similar to a human fingernail) which grows harder over time and is periodically shed. Industrial shrimp peeling devices containing mechanical rollers exploit the difference in coefficients of friction between the shell and the rollers and between the meat and the rollers. This is what allows the meat to pass through a bed of rollers while the shells float upward as the two are separated in a water bath. Such a method proves unsuccessful when attempted with crawfish.

III. Course Synopsis

Mechanical Design I & II are sequential 4 credit courses offering an introduction to manufacturing processes. The laboratory attempts to simulate a "real world" engineering environment that presents its students with a product specification and requires them to prepare a preliminary proposal, form a project team and develop and construct a suitable design subject to performance and economic constraints. Beginning with the concept development process and continuing on through competitive benchmarking, patent searches and concluding with the product development, students are given a full design and manufacturing experience with an entrepreneurial bent. This experience, conducted in the relative security of an academic setting, is invaluable for budding professional engineers.

The class primarily consists of mechanical engineering seniors and is considered the culmination of the mechanical engineering educative experience. Required weekly reports and monthly presentations to both classmates and supervising faculty and graduate students are the vehicle which keeps the students on track in applying a structured design methodology and facilitates team member communications.

The students participating in the first half of this two semester endeavor were divided into three groups to attack this particular design problem. The first group is undertaking the refinement of a fully automated peeler patented by a faculty member and graduate student [5]. That prototype, which exhibits the efficiency, longevity and suitability for industrial applications, is an effective demonstration platform for potential investors. A second group is responsible for the design of a sorting machine to withdraw specimens from a large volume container and align them according to the specific requirements of a peeling device. The third group is seeking alternative peeling methods, primarily in the form of using a pressure differential to separate attachment membranes. The entire effort involved support and funding from academia, the state of Louisiana and private industry. The university's Technology Development Office is also playing an important role in intellectual property protection (one patent has already been secured) and is actively pursuing commercial development and implementation.

The responsibilities borne by the students involved in this program were shown to provide them with experience in teamwork, "hands on" skills, effective communication, and open ended problem solving that are essential components of the Accreditation Board of Engineering and Technology (ABET) program guidelines. Familiarity with concurrent engineering, component vendor interactions, and the construction of a tangible engineering system (from concept generation to production) were three items emphasized during the term. The perceived "real" nature of the problem and potential for commercial development was highly influential in maintaining student focus and motivation, which can, in the authors' experience, easily be lost when design projects are perceived to be "made-up" academic exercises.

IV. Design Process

The students spent time getting feedback from crawfish producers to ascertain the specific performance criteria that would make a crawfish peeling machine attractive to industry. It is clear that there is a place in the market for devices which: (1) would automate the peeling process and greatly increase the rate of production, and (2) would facilitate the manual peeling process by reducing the incidence of injuries while boosting productions rates (the repetitive hand motion involved in the peeling process can cause inflammation of the tendons in the wrists leading to carpal tunnel syndrome).

Preliminary patent searches conducted during design courses from previous years yielded nine patents for devices that claim to be "crawfish peeling machinery." Each patent utilizes one of three principles in order to peel the crawfish: (1) two rollers act to squeeze from the tail end to force the tailmeat out, (2) blades act to incise the exoskeleton in order to ease removal of tailmeat, or (3) a fluid (air or water) is injected into the base of the tail in order to force the tailmeat out. While each of these methods has merits, the designs described in patent documentation were deficient in that none were well-suited to industrial application. The machines described would require virtually the same amount of labor as is currently employed to achieve only slightly improved peeling rates. Hence, no processing plants have utilized machinery (aside from grading equipment to separate crawfish by size) to facilitate the peeling process.

By the spring of 2000, a team of Tulane faculty and graduate students was able to design, patent (#6,042,465) and construct an initial prototype that demonstrated the feasibility of automated peeling undertaking. The task designated to the aforementioned first group for the fall semester of 2000 was to refine and fully automate the design partially displayed in Figure 1 in order to prepare the for industrial grade performance and working conditions.

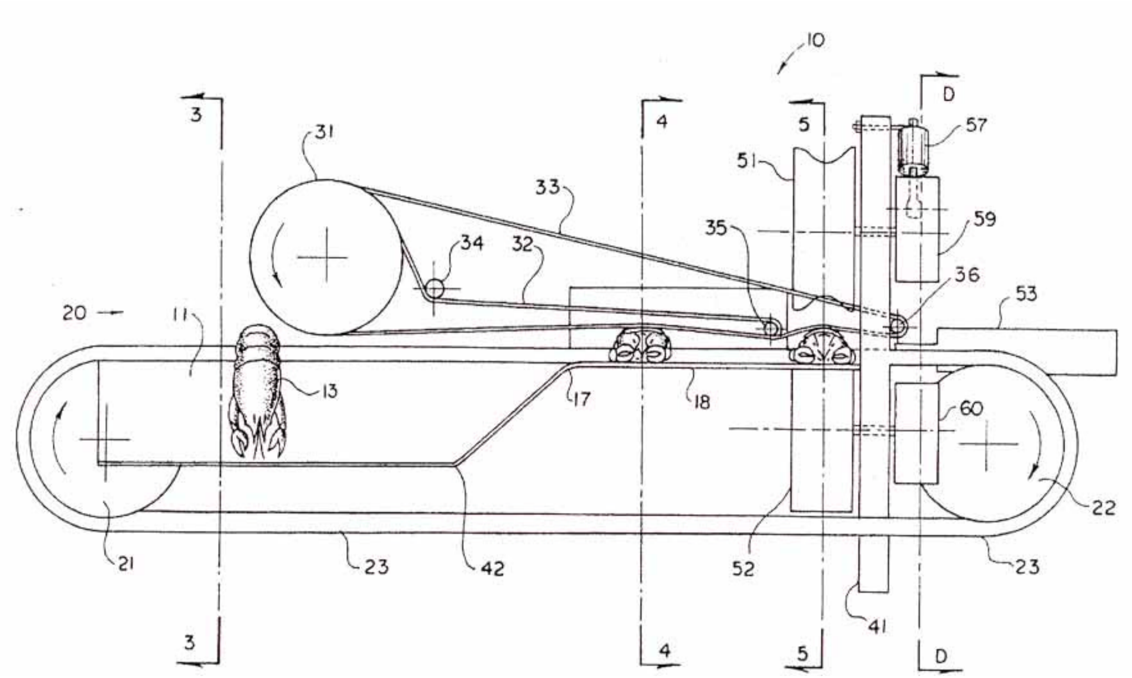

Figure 1 The automated device patented by Tulane faculty and students.

The prototype, whose sequences are required to be manually dictated by an overseer, performed at a rate of one crawfish per second. Specimens were transported on belts (23, 32 and 33) driven by electric motors coupled to pulleys 21 and 31 to the location indicated by vertical plane 5. There a pneumatic ram (57) extended a contoured pulley to secure the crawfish, in synchrony with the rotation of pulley 52, equipped with an imbedded air injection needle, to puncture the soft tail underbelly. Pneumatic ram (52) was then used to separate the tail from the rest of the body. A blast of air through the aforementioned needle then successfully forced the tail meat from its shell. The two pulleys securing the specimen are then driven by electric motors 59 and 60 in opposite orientations to remove the remaining shell exoskeleton.

Students involved in this portion of the design phase first sought to increase the robustness and longevity of the system by opting for stainless steel components with "wet down" electric motors in order to withstand the effects of the high moisture working conditions. Similar hardware specifications (electric motor rpm, pneumatic pressure, etc) were incorporated in the design overhaul to maintain the performance witnessed in the prototype testing. Industry professionals were then consulted in establishing control systems for the 4 motors, 3 pneumatic ram devices. An industrial sponsor provided a Programmable Logic Control (PLC) device for executing the necessary actions of transporting specimens to the extraction sight and subsequently removing the crawfish tailmeat. Low-pressure jets were added to automatically clean, at timed intervals, those areas prone to accumulate debris. An optical error alert was also included in the design to cut system power and alert a line operator in the event of a mishandled specimen. Concurrent with the establishment with all of these improvements was the preservation of an aesthetically pleasing machine to enhance market acceptability.

Those involved in the prototype refinement project conducted a great deal of "hands on" engineering, with instruction in welding, milling and lathing operations. Knowledge of these skills is always useful in considering the ability to envision a feasible design that minimizes construction costs in the process of Design For Manufacture (DFM). Research into component selection exposed group members to vendor and manufacturer interactions as well as providing an awareness of budget streamlining. Elements of electrical engineering were required in order to design the control systems to complete the product, forcing the students to think across disciplinary lines. Students also showed improvements in adapting to each other's specific vision for how the device should be constructed and making the appropriate sacrifices in respect of their fellow team members' concepts. Documentation of such concepts was rigorously maintained in light of potential patent applications.

The crawfish sorter team faced the unenviable task of creating a system to align a rather awkward specimen (large front claws and a curled tail following the initial cooking phase) for any number of potential peeling devices. Exploring a multitude of various concepts in concert with the prototype peeling group, they narrowed their focus down to a gravity assist system. The system relied on the center of gravity of each specimen to control its entry to a collector, thereafter entering a small chamber with a rotational axis of freedom that orients the crawfish for transport to a peeling device. Although still in the development phase, the current design shows promise.

The goal of the third design group was to examine various existing methods for peeling or shelling of food products and to create alternative, novel methods that had not been previously considered. A number of different patents were found for removing the outer covering of a variety of food products including fruits, vegetables, nuts, shrimp and of course crawfish. The more interesting patents described methods for using high pressure steam to peel food products. Patent number 5,942,271, entitled Method for the removal of skins from fruits or vegetables by vapor explosion, purports to vaporize the moisture under the skins of food products to remove the outer covering. Patent number 6,056,987, Two-stage process for heating skins of fruit, requires placing the food product on a conveyor belt and preheating it with steam then feeding it into a steam chamber where it is again exposed to high temperature steam which causes the skin to separate from the body upon cooling. Patent number 4,524,681 entitled Methods and apparatus for thermal blast peeling, skinning, or shelling food, also exposes food to superheated steam at an elevated pressure and quickly brings it to atmospheric pressure. This process has in fact produced successful experimental results when attempted with crawfish.

The students developed an embodiment they termed Thermo-Peel that incorporates the principles of thermodynamics to remove the meat from the shell. The Thermo-Peel process flashes the moisture under the shell of the crayfish to vapor, separating the head from the tail and extracting the meat from the shell. This third group's design project also required the completion of a working prototype that again incorporated "hands on" engineering. Frequent correspondence with both the sorting group and industry professionals was necessary in producing an efficient design and reducing prototype costs. Once again documentation for purposes of intellectual property retention was maintained.

V. Conclusion

Implementation of an entrepreneurial focus in Tulane University's mechanical engineering capstone design course, through developing mechanization for the Louisiana crawfish industry, provided an effective vehicle for meeting many of the educational criteria outlined in the ABET 2000 guidelines. At the same time, working on a "real world" project that had clear potential for economic development and community service was a great motivator for the undergraduate students. With the completion of the first half of the two semester course, students displayed greater levels of confidence in "hands on" applications and a much more comfortable atmosphere when attempting to resolve both inter and intra-group design issues. Frequent feedback on group performance by supervisors and the requirements of numerous presentations proved to maintain a highly structured process in addition to enhancing student communication skills and levels of maturity when speaking in front of peers, academic superiors and industry professionals. The opportunity for gaining potential patent rights and product marketability served well in student adherence to professional entrepreneurial conduct and documentation throughout their respective design processes.

Bibliography

1. Fontenot, W. J. *Profitability of Crayfish Peeling Plants in Louisiana*. Louisiana State University (LSU) thesis, 1970.

2. Gillespie, Jeffrey M. *Factors to be Considered in the Crawfish Peeling Machine Development Decision*. DAE Report 705. 1997.

3. Huner, Jay V. *Freshwater Crayfish Aquaculture*. Food Products Press, 1994.

4. McQuaid, "U.S. tariffs on Chinese crawfish set in stone," The Times-Picayune, August 30, 1997, page A-1.

5. *Method and Apparatus for Peeling Crawfish*, US6042465. inventors: Michael C. Larson and Andrew L. Johnston. Issued 3/28/00.

MICHAEL LARSON

Dr. Larson is an associate professor in the Department of Mechanical Engineering at Tulane University. He earned his Ph.D. in applied mechanics at MIT in 1992. He is actively engaged in doing computational and experimental research to design advanced electronic packages. Before attending MIT he spent two and a half years working as a structural engineer performing finite element and damage tolerance analyses for the U.S. Air Force. He has been teaching the Mechanical Engineering Department's design courses for the past eight years.

DONAL COLLINS
Donal Collins is currently a second year graduate student in Tulane University's Department of Mechanical Engineering and will be receiving his degree in May 2001. He received his Bachelors in Mechanical Engineering from Tulane as well in the spring of 1999. A member of ASME, SAE and ASAE, he specializes in off road vehicle dynamics and agricultural equipment development and was privileged to have the opportunity of working for a number of months with Lockheed Martin X-33 engineers on chassis fabrication using composite materials. When the opportunity arises for a reprieve from academia Mr. Collins normally returns home to assist neighboring New England dairy farmers in crop retrieval and suds consumption.

MELANIE A. LANDRY
Melanie A. Landry graduated Magna Cum Laude in Physics from Loyola University, New Orleans, and is currently a graduate student in Mechanical Engineering at Tulane University, New Orleans. She is a member of Sigma Pi Sigma honors physics fraternity, Society of Physics Students and the American Society of Mechanical Engineers. She has done several technical internships at the Corps of Engineers and the Port of New Orleans in the Engineering departments and worked on a project for Lockheed Martin this past summer designing a Thermal Protection System (TPS) for NASA's Reusable Launch Vehicle (RLV).