2006-534: CONVERSION OF AN OBSOLETE MANUALLY OPERATED UNIVERSAL TESTING MACHINE INTO A HYDRAULIC HOT-PRESS WITH COMMUNICATIONS CAPABILITY

Akbar Eslami, Elizabeth City State University

Dr. Akbar Eslami is a professor and chair of the Department of Technology at Elizabeth City State University. He received his Ph.D. in Mechanical Engineering from Old Dominion University. His research interests are in computer aided manufacturing and design, composite materials and automation.

Mehran Elahi, Elizabeth City State University

Dr. Mehran Elahi is an assistant professor in the Department of Technology at Elizabeth City State University . He received his PH.D. in Engineering Science and Mechanics from Virginia Tech. His research interests are in Composite materials and control.

Conversion of an Obsolete Manually Operated Universal Testing Machine into a Hydraulic Hot-Press with Communications Capability

Introduction

The improvement of outdated laboratory equipment is a useful and often overlooked resource that has several advantages. One obvious advantage is that it saves money by adding new capability and reducing capital expense for newer equipment. Another advantage is the honing of skills by the people who make the improvements. Yet a third advantage is the example and inspiration that stimulates others to put forth other ideas for improvement. The importance of constant improvement was expressed by the renowned statistician and quality advocates. W. Edwards Deming one of whose 14 points is "Constantly and forever improve the system of production and service." The concept of constant improvement has been captured by the Japanese in the word *kaizen* and used by them to bring their automotive and other industries to world class status from the ashes of defeat in World War II.

When the need arose for a hot press to mold precision polymer laminates the obvious response was to determine how much a new press would cost. The new press would have to heat the laminates to 175˚C, measure the force necessary to apply pressure of 1.0 MPa, and communicate with a computer that could acquire and store the information for further analysis. A widely used and well developed laboratory press was available that would satisfy the heating requirement but not the force measurement and communication requirements. The cost of the press plus the addition of force measurement and communication capabilities was estimated to cost in excess of $10,000. This was a capital expense that could be reduced by converting and upgrading an existing piece of equipment.

Upon the acquisition of a new computer controlled material testing machine, the existing obsolete hydraulic testing frame was rendered useless. The tester was nearly four decades old with a single non-functioning Bourdon tube pressure gage. So the decision was made to transform the existing manually operated tension and compression materials tester into a hydraulic hot press with symmetric and uniform heating zones and communication capabilities. The expectations were that the improvements of existing equipment were not only cost effective but also would provide the other advantages noted above. The original manually operated hydraulic cylinder and load frame were in good condition and were retained. Once converted, the now-functioning compression hot press was calibrated and characterized according to its temperature range and stability, pressure range and stability, and the geometric and thermal symmetry of the platens. The total cost of conversion of the unit was around $3300.00. The results of the project are reported here.

This case study presents the importance of reconfiguring, reengineering of an outdated, seldom used, material testing frame into more applicable laboratory equipment. This type of transformation trend is based on existing equipment and can be useful in educational institutions, such as those in many third-world countries that do not have the budget or resources to purchase and or maintain new off the shelf laboratory equipments. This budgetary restraint is an ongoing challenge especially for many of the third-world countries which are to transfer their agricultural-based economy to a service and industry-based economy. Many educational and vocational institutions in these countries, with limited teaching and learning resources, have to cope with the existing equipment for the time being. Thus creative transformation approaches such as the one discussed in this paper can prove to be highly beneficial.

Conversion of a Materials Tester

The equipment described here is a molding press which originally was a materials test unit that was acquired in 1976. The equipment is shown in Figure 1. This unit could provide both tension and compression capability. The first step in transforming the equipment was to remove the unnecessary components. Since there is only need for compressive capability in a molding press, the top crossbar and two associated columns were subsequently removed. The large-diameter Bourdon tube gage measured hydraulic pressure from which the force exerted by the hydraulic cylinder was inferred. Because this gage required the operator to read and record the pressure value, and because direct force measurement is preferable to an inferred value, the gage was removed as well. What remained was the hydraulic cylinder and compression load frame with the cabinet.

The hydraulic cylinder was a manually operated single-acting cylinder with a built-in pump and a fluid reservoir surrounding the cylinder. Although removed, the gage indicated that the hydraulic cylinder could generate a force of 89 kN (20,000 lb_f). Careful measurements revealed that the stroke of the hydraulic cylinder pump was 19.8 mm and those 100 strokes displaced the cylinder extension a distance of 38.2 mm. Consequently, the displacement multiplication was estimated to be 38.2/(100x19.8) = 0.01929. Force multiplication is the reciprocal of displacement multiplication or 1/0.01929 = 51.8. Thus, when the cylinder exerts a force of 89 kN the pump is exerting a force of 89/51.8 = 1.72 kN (386 lb_f). The width of the pump plunger was 11.2 mm so the maximum hydraulic pressure was estimated to be $1{,}720/(\pi \times 0.0112^2/4) = 17.5$ MPa (2,538 psi). These values appeared to be in a reasonable range for a hydraulic system. After removing unnecessary components new components were added to achieve three capabilities: direct force measurement; controlled heating of material; communication with a computer. Figure 2 shows the converted hydraulic press with added components.

<u>Load Cell</u> - A compressive Omega load cell [1] with a rated capacity of 45 kN was mounted between the hydraulic cylinder and the lower base (movable). Special rings were made to connect the bottom of the load cell to the hydraulic cylinder and to guide the other end of the load cell to the center of the lower base. The top ring also served to attach a heated platen to the lower base.

<u>Heated Platens</u> - Electrically heated platens[2] were attached to the upper base (fixed) and the lower base. The square shaped platens were 150 mm on a side and 25 mm thick. With platens this size and a 45 kN load cell a pressure as high as 2.0 MPa can be applied to the polymer laminates during molding. This pressure is twice the required 1.0 MPa pressure. Each platen was

heated by two 100 W electric resistance cartridge heaters enabling the platens to reach a temperature of 315˚C. The temperature measurement and control was accomplished using steel sheathed J- Type thermocouples.

Control/Communication - Three Newport digital meters were used to monitor and control processes. One indicator[3] monitors the load cell and it has no load control capability as the hydraulic cylinder is manually operated. However, it does have alarm capability to provide warning when applied force is approaching the rated 45 kN value of the load cell. The other two meters[4] monitor the temperature of each heated platen and exercise self tuning PID control (Proportional-integral-derivative is a common feedback loop component in industrial control applications) over the electric cartridge heaters. All three meters have either RS232 or RS485 serial communication capability. A schematic of the connections among the meters, heaters, relays and load cell is shown in Figure 3. The three meters together with associated fuses, and the main power switch were mounted on a composite panel (carbon fabric and epoxy resin composite panel) made especially for this application.

Testing of Upgraded Press

In order to demonstrate the molding capability of the new hot press, the following steps for making high quality laminates of epoxy resin and fiber glass fabric were carried out.
First, thirteen pieces of 181 style woven fiber glass fabric (plain weave), nominally 150 by 150 mm, were cut. Next, a mixture of 105 Epoxy Resin and 205 Hardener, with a ratio of five to one, was applied manually to fiber glass fabric with an acid brush; plies were stacked and faced with thin steel plates liberally sprayed with high temperature PTFE (polytetrafluoroethylene) release agent dry lubricant. Then, uncured laminate was inserted between Heated Platens, in room temperature, and a laminating force of 13.2 kN (2,960 lb_f) was applied to generate a laminating pressure of 585 kPa (85 psi). Meanwhile, temperature was raised to 80˚C (175˚F) and held for 4 hours to cure the laminates. Finally, after curing, platens were cooled to room temperature and the completed laminate was removed from the press and de-flashed. Physical examination of the fiber glass reinforced polymeric composite laminate indicated that the upgraded press has been able to produce the high quality polymer laminates with smooth surfaces.

Assessment of Students and Project

The Department of Technology uses a capstone project course as an instrument to validate program outcomes, and to document student progress in meeting accreditation criteria. All program students are required to complete a project and demonstrate their teamwork, communication, and problem solving skills in the real world project, which in this case was to transform an obsolete, manually controlled, universal testing machine into a hot press with communication capabilities. This required utilizing load cell, heating platens, and meters to control and monitor the process.

The Capstone Course is designed to be offered in the last semester of the Industrial Technology program. This course provides students with an opportunity to tie together some key learning outcomes from the curriculum and be able to demonstrate some competencies that they have learned during the major. The students are assigned to teams of three to four students and each team has its own single project. Each team has a faculty advisor who provides general technical assistance. Each team is required to prepare a project plan, a design review, construct the project and provide a final report on project and present it to faculty members. Students' presentation should be in both written and oral forms, allowing faculty to assess the students' performance and project. Students are required to send e-mail memos and invite department faculty members to participate in their presentation at the end of the semester. Faculty members use a questionnaire survey that addresses five program outcomes to measure the students' competencies. The faculty members provide the feedback to improve the program curriculum, outcomes and capstone project. These outcomes include scientific knowledge, technical skills, communication skills, computer application and professional and ethical practices.

Conclusion and Further Work

This project provided an opportunity to practice some technical outcomes of the Industrial Technology Program where students were exposed to a hands-on multidisciplinary technology senior project. This approach culminated the student's theoretical knowledge and experimental expertise where students were required to get involved in all phases of the project from design, fabrication, instrumentation, testing, data collection, final analysis and interpretation of results. All aspects of the project were documented along the way and finally were submitted in a report format and presented to faculty members and students at the end of the semester.

Students were also required to use AutoCAD software for drawing upgraded press (Figure 4) and Multisim software to simulate different components of the project, allowing faculty to assess those students' abilities in addition to their knowledge and skills. This project was assigned to a group of three students and students were required to work together on the project, from inception to completion and subsequent presentation and publication thus exposing students to teamwork and communications skills which are required of every successful technology and engineering effort.

This project could be further expanded and improved by addition of a computer interface data acquisition and control capability to automate and control the load and temperature application process. This would require adding a data acquisition unit, data acquisition software platform, and basic programming skills. This is the work that remains to be done and could serve as a capstone course for senior students.

Bibliographic Information

1. Canister Style Compression Load Cells, LC1001 series –range 10K lbs, http://www.omega.com

2. Heated Platens, operation manual, Carver, Inc. 1569 Morris Street, Wabash, IN 46992-0544

3. I series Newport Strain Gauge indicator, operation manual, http://www. newportUS.com/i

4. I series Temperature & Process Controller, operation manual, http://www. newportUS.com/

Figure 1. - Original 30-year-old press fitted to perform mechanical tests of materials. The large-diameter dial gage measured hydraulic pressure from which the mechanical load on the material was inferred.

Figure 2. - Upgraded press with new components including heated platens, load cell, relays and three control/ communication units.

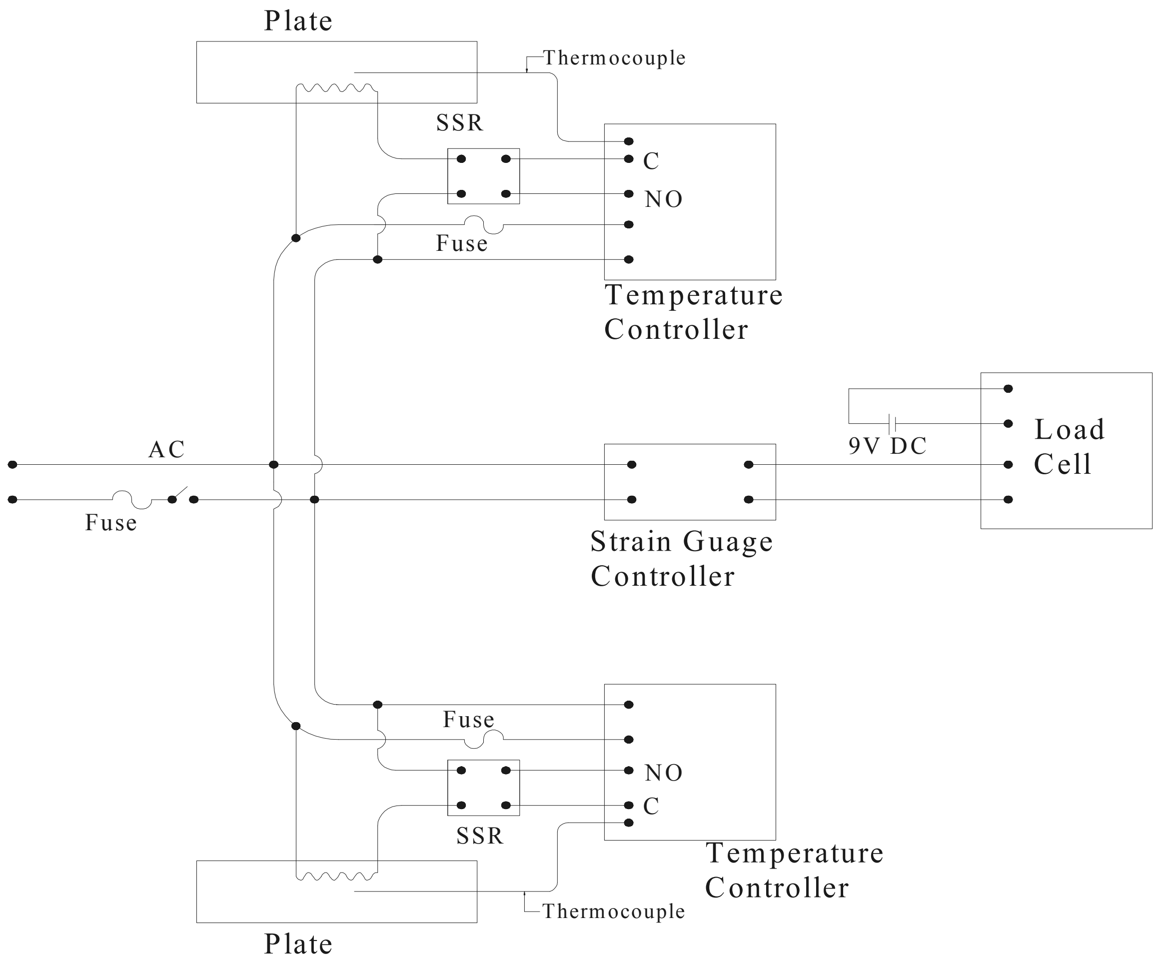

Figure 3. - Schematic of connections among process meters, platen heaters and load cell.

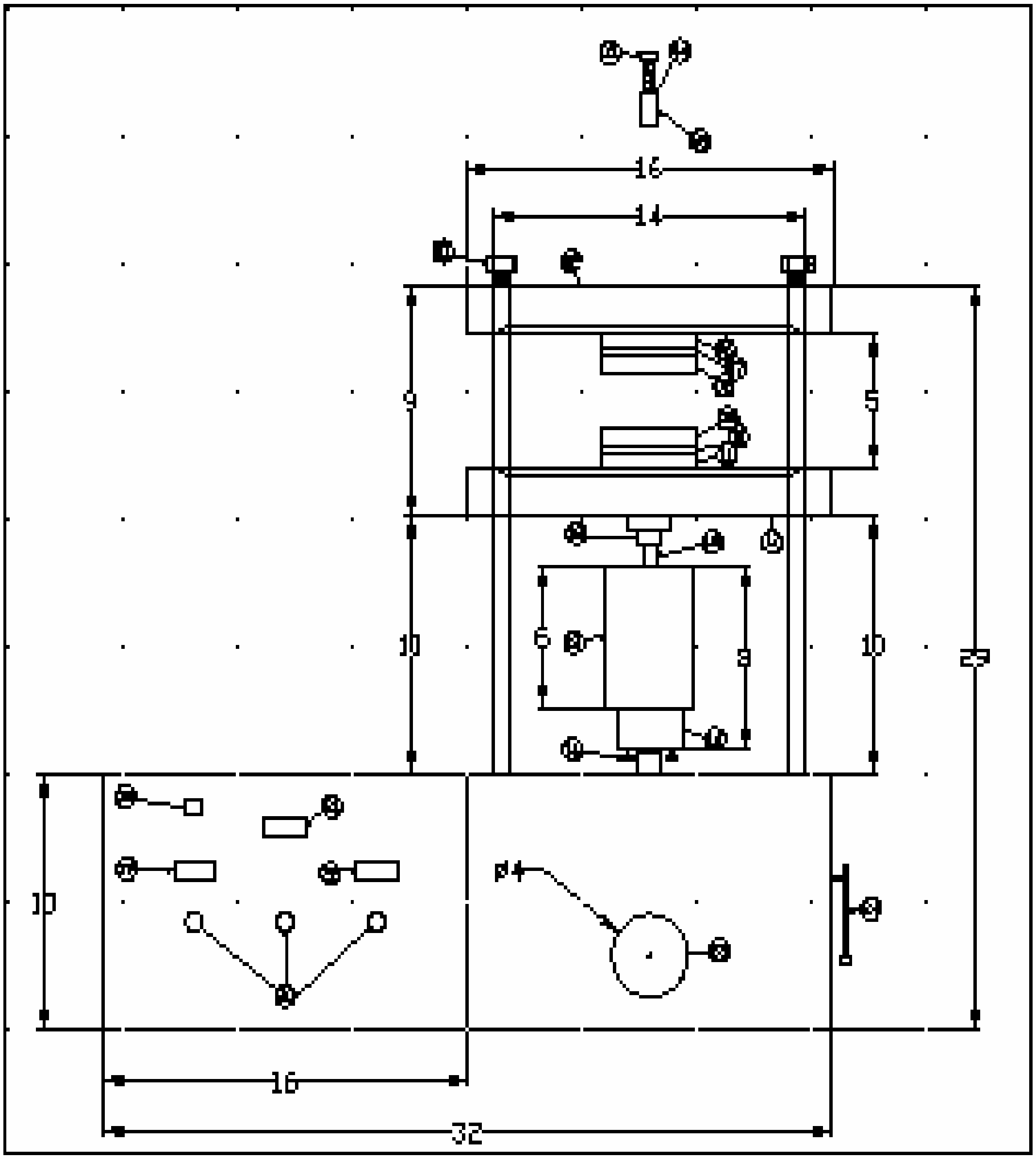

Figure 4. - Computer Aided Drafting of the Upgraded Press.