AC 2011-2366: USING UNDERGRADUATE RESEARCH AS A RECRUITING TOOL FOR GRADUATE STUDY

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Using Undergraduate Research as a Recruiting Tool for Graduate Study

Abstract

This paper focuses on using the undergraduate research experience as a recruiting tool for graduate study. One undergraduate Engineering Technology student researched the machining capability of a laser micro-machining center on piezoelectric materials. With high-precision cuts of 31 to 80 microns wide and 12 to 24 microns deep, the laser provides an outstanding opportunity in the field of transducer design. This student is in the process of completing his ET degree and is currently weighing the possibility of graduate study. Seventeen of the 22 graduate students in this program came through the undergraduate ranks at the same institution. The access to undergraduate research opportunities played a key role in the recruitment effort, and will continue in that vital function.

Introduction

Western Carolina University (WCU) is a comprehensive state university, composed of approximately 9,000 undergraduate and graduate students. With manufacturing comprising roughly 20% of all jobs in the western portion of the state, WCU engages with the region's industry to train engineers and to collaborate with their industrial needs. The Department of Engineering and Technology, coupled with the Center for Rapid Product Realization (Rapid Center), provides the vehicle for accomplishing this engagement effort. Engineering and Technology houses three undergraduate and one masters degree programs. While the graduate program draws students nationally and internationally, many of the students come from the region. The graduate program has grown from six students in the 2004-05 academic year to 22 students in 2009-10. Much of this growth can be attributed to the broad array of technical topics and ability to recruit undergraduates by exposing them to challenging topics that give them a glimpse of masters-level topics. The primary mode for providing this exposure has been the senior capstone project course sequence[1], but additionally, there have been several independent study projects that have shown undergraduate ET students the challenges that lie in the graduate program.

The Rapid Center houses a wide array of high-tech machinery, such as rapid prototyping (Stratasys FDM Titan®, Stratasys Eden 333®, ZCorp Z400®); flexible gaging (Zeiss Contura HTG® Coordinate Measuring Machine, OGP SmartScope Flash 200® Video Measuring System, ADE Phase Shift MicroXAM® surface mapping microscope); computer numerical control machining (HAAS® 2D Laser Cutting Center, four HAAS® milling machines, three HAAS® lathes); CAD/CAM (50 Dell® Model , 21" LCD Monitors, PRO/ENGINEER Wildfire®); and an Oxford Lasers Micro-Machining Center.

The focus of this paper is to highlight an independent study project in which an ET undergraduate student used the Oxford Lasers Micro-Machining Center to explore the micro-machining of piezoelectric materials. Originally discovered in 1880 by Pierre and Jacques Curie, piezoelectric materials were not commercialized until the 1940's, when they found application in sensors. Most piezoelectric accelerometers are made of quartz crystal. When the crystal is subjected to a force, it generates a small electrical charge. That charge is directly proportional to the applied force. Using Newton's Second Law (F=ma), it is very useful to use piezoelectric sensors to measure force and acceleration, opening a wide array of applications.[2,3] Farlow, et al were able to micromachine piezocomposite transducers with kerfs as small as 13 μm, using a copper vapor laser.[4]

Independent Study Research Opportunities

Minerick, et al show that research can be used as a recruiting tool to draw talented high school students to the university ranks.[5] The same can be said for recruiting undergraduates into the graduate ranks. As mentioned above, the undergraduate students at WCU have several opportunities for undergraduate research. The independent study opportunity serves multiple roles to assist both students and faculty members. There are times that students need a course to fulfill a technical elective, which will either broaden their technical exposure in their chosen field or provide more depth in a field where they already have exposure. The faculty member can couple this student need with projects that are appropriately sized to complete in a semester's time. These projects are smaller in scope than that of a graduate student, so they serve as excellent opportunities for a faculty member to start a new direction of research, or supplement an existing one.

In this research, which is explained in more detail later in this paper, the student that conducting the experimentation was a junior in Engineering Technology, three semesters from graduation. He needed a technical course to provide exposure to an area that he had not yet experienced – laser micromachining and piezoelectric materials in this particular case. The format for the project was relatively straightforward: self-guided study supplemented with laboratory assistance from the faculty member and applications engineer. Meetings at approximately two-week intervals provided the opportunity to monitor the progress.

While the computer numerical controlled (CNC) machining portion of the laser micromachining research complemented the courses he took as an undergraduate, the exposure to lasers and piezoelectric materials provided a broader exposure to the field. The ET students in this program are exposed to sensors that use piezoelectric materials, but they do not get the opportunity to machine those materials in the laboratory.

Overview of Laser Machining Center

Acquired from Oxford Lasers in England, the Oxford Lasers Micro-Machining Center (see Figure 1) was introduced for precision machining and part marking of materials ranging from polymers to high-tech super-alloys.

Figure 1: Oxford Laser Micro-Machining and Part Marking System

Several of the key specifications and features include[6]:

- Two lasers are integrated into the machine: a 266-nanometer (nm) and a 532-nm wavelength with the former focusing on softer materials (polymers and softer metals) and the latter for harder materials (ceramics, nickel-based alloys).
- The laser is a diode-pumped solid state laser, using a medium that is solid, rather than a gas, such as CO_2.
- There is five-axis computer numerical control (CNC) for three-dimensional machining.
- Galvo scanning heads allow laser machining inside a square workspace of 50 by 50 mm without using the CNC stages; this allows for much higher-speed machining, since the workpiece remains stationary.

- The beam can be focused to a spot size adjustable between 6 and 24 microns (μm). The CNC axes have a resolution of 0.1 μm, providing the capability of micron-level high-precision machining. A typical human hair is on the order of 50 to 100 μm in diameter.

In the fall of 2006 this laser was the platform for an undergraduate ET student's independent study project. That research project was a design of experiments (DOE) that explored the best machine settings for achieving a quality two-dimensional data matrix.[7] The ET student continued into the masters program and following graduation, landed a successful job with the tire manufacturer Goodyear. An interview with this student revealed several major factors in his decision to attend graduate school: familiarity with the program; a high comfort level with the faculty; the higher probability of more meaningful employment; research assistantships available at the graduate school; and this undergraduate research opportunity. While it is difficult to place a weighting on the significance of this latter factor relative to the others, it proved to be an important reason for this student. His graduate study focused on CNC machining, something that was integral to the research he performed in his independent study project.

Experimental Layout

The entire piezoelectric workpiece (see Figure 2) is approximately 15 mm x 22 mm with a thickness of 0.246 mm (246 μm). The five circles shown on the workpiece are series of concentric circles cut by the laser. The first circle in the upper left corner is a set of 4 concentric circles, while the others are composed of 10 concentric circles each.

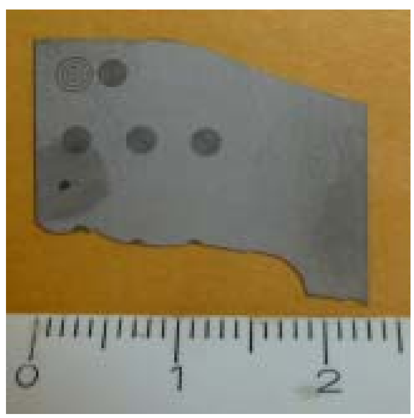

Figure 2: The piezoelectric workpiece

An expanded view of the middle circle on the bottom row is shown in Figure 3. The outer circle is 2.00 mm in diameter with a spacing of 100 μm between each of the 10 concentric circles. Each of the 10 circles was cut by passing the laser along the path six consecutive times in this particular case. Additional depth can be achieved through additional passes.

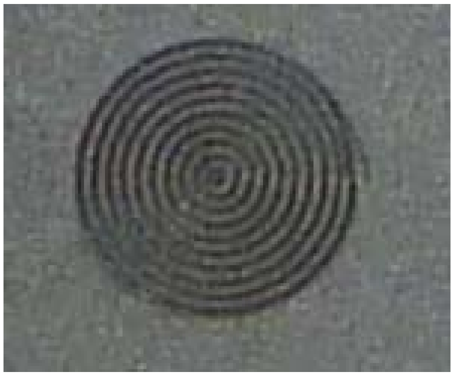

Figure 3: One spot cut on the laser (10 concentric circles)

Following the machining of the workpiece, it was analyzed under an ADE Phase Shift MicroXAM® surface mapping microscope, a surface profiler that uses white light interferometry to surface map the workpiece contour in three dimensions. Figure 4 shows a three-dimensional view of the successive concentric circles with dimensional details in the following figures.

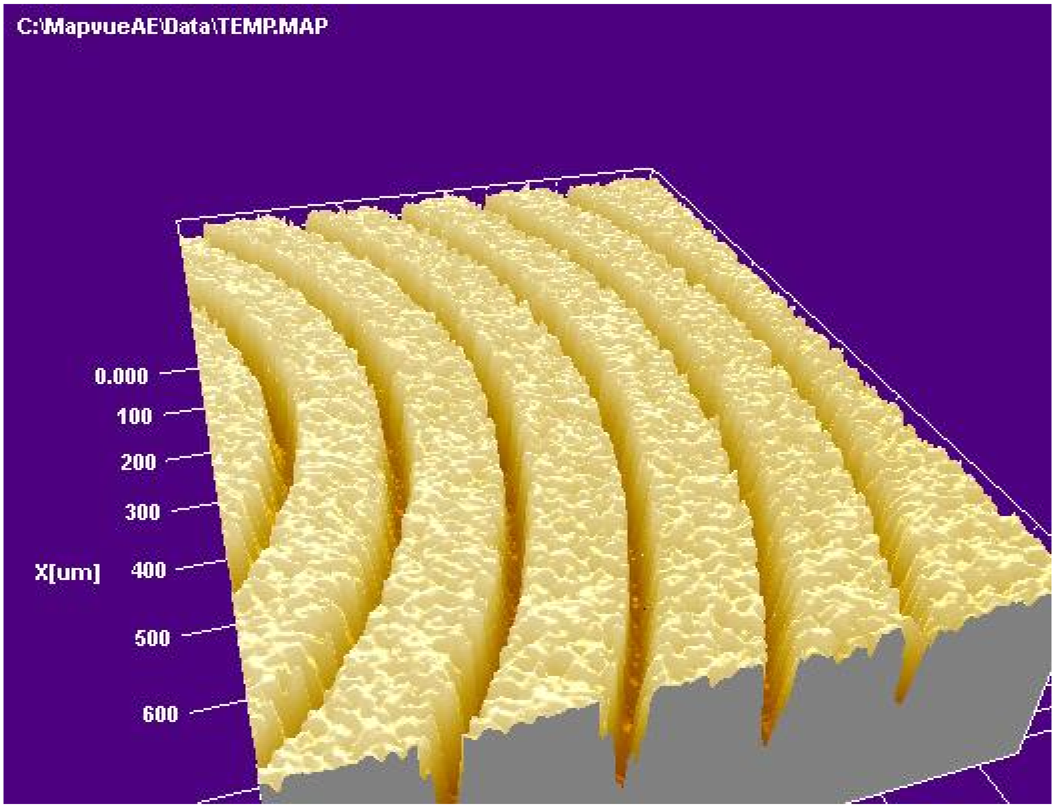

Figure 4: Concentric circles, 3D view

Taking a "virtual slice" through six of those circles produces the profile shown in Figure 5. The six cuts average approximately 12 μm in depth with a slot width of averaging approximately 31 μm.

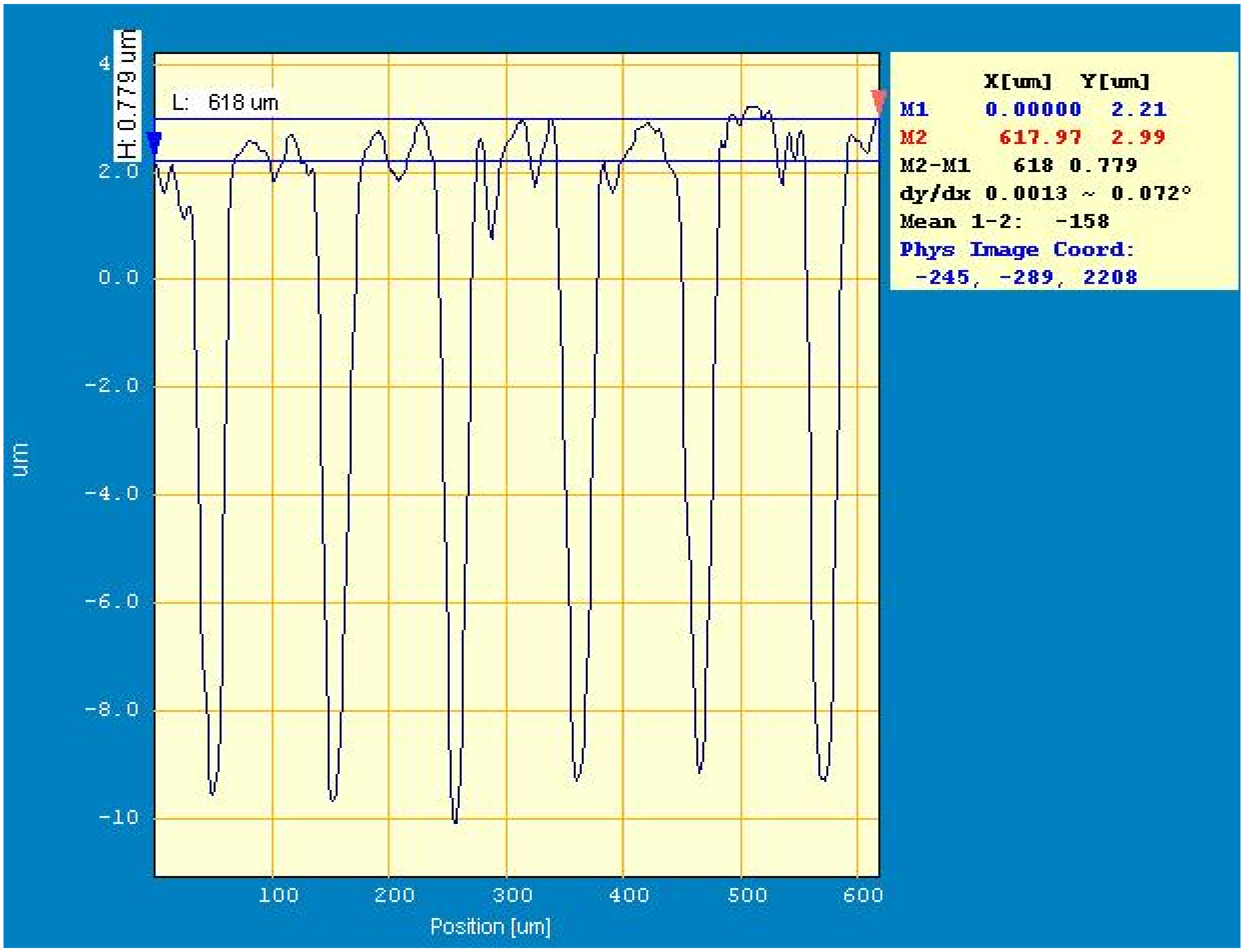

Figure 5: Profile of six adjacent cuts

The other circles shown in Figure 2 were machined using a different number of passes. In the case of the circle on the lower right corner, each of the 10 concentric circles saw nine passes of the laser beam, leading to slot widths (or kerfs) of 80 μm and depths of 24 μm.

Lessons Learned and Future Prospects

This ET undergraduate student spent a semester researching piezoelectric materials and learning how to use this laser micro-machining center. He is still a semester away from deciding whether he will attend graduate school at this university with the recovering economy and potential job prospects leading the list of influencing factors in his decision. An informal survey of current graduate students at this university showed that 40% of responders had conducted an independent study project under the direct supervision of a faculty member.

While the technical results presented here are preliminary in nature, it appears that this laser machining center will be an effective tool in machining piezoelectric materials, maintaining tight tolerances on miniscule features; the implications for micro-sensor design are promising. Additional research, potentially with additional undergraduate students, will focus on detailed quantification of the machining process.

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