

## Rejuvenate An Old Tinius Olsen Machine with Computer Data Acquisition Using Its Existing Hardware and LabVIEW

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### Abstract

Computer data acquisition is more and more widely used in today's undergraduate laboratory courses. To meet this trend, it is necessary to bring computer data acquisition to old laboratory equipment, such as a Tinius Olsen machine. One solution is to go to the equipment's original manufacturer or other vendors for a retrofitting package with computer data acquisition, that usually costs thousands of dollars. The other solution is to achieve computer data acquisition by utilizing the equipment's existing hardware, together with the computer data acquisition hardware and software. This later approach represents zero cost spent specially on the Tinius Olsen machine. This paper presents the procedures to bring computer data acquisition to an old Tinius Olsen machine using its own existing hardware and National Instruments data acquisition hardware and LabVIEW software. A potentiometer that is geared to the dial servo gives the signal for load applied, while an LVDT based extensometer provides the signal for elongation of the specimen. The potentiometer output and the extensometer output were first calibrated against the load and elongation, respectively. These two signals were then hooked up directly to the data acquisition hardware. A LabVIEW program was written to acquire the signals and then generate the stress-strain curve in real time using the built-in calibration equations for load and elongation.

### Introduction

Computer data acquisition is more and more widely used in today's undergraduate laboratory courses. While the newly acquired laboratory equipment likely will have the computer data acquisition built into it, it is the old equipment that presents a challenge to institutions of how to modernize it with computer data acquisition. Going back to the equipment's original manufacturer or other vendors for a retrofitting package with computer data acquisition is one possible solution, which usually costs thousands of dollars. For budget constrained institutions, a better solution is to look at the equipment itself and try to rejuvenate it with the computer data acquisition. Among the commercially available computer data acquisition systems, the hardware and LabVIEW software by National Instruments are widely used. Some educators presented efforts to modernize their equipment with computer data acquisition and LabVIEW for some individual experiments [1, 2, 3], while others implemented it for the whole laboratory course [4, 5, 6].

At the Department of Engineering at Indiana University-Purdue University Fort Wayne, the Tinius Olsen universal testing machine, which was purchased about 30 years ago and is shown in Figure 1, is used in the tension test and strain hardening labs in the laboratory course ME 304 - Mechanics and Materials Laboratory. These two experiments were the two most time consuming



Figure 1: Tinius Olsen Universal Testing Machine

labs as the students needed to record manually the load and elongation data. This paper documents the implementation of the computer data acquisition on this old Tinius Olsen machine with its existing hardware and already acquired National Instruments computer data acquisition hardware and LabVIEW. It requires zero cost from the institution and it also dramatically reduces the length of the labs.

### Load Signal

The original Tinius Olsen machine uses a dial servo, which is connected to the hydraulic system, to indicate the load. Also in the original Tinius Olsen machine, a potentiometer is geared to the load dial servo. This potentiometer ideally gives the voltage signal for the load applied. However, before using this voltage signal, a calibration must be performed. This is done by comparing the voltage output with the load value indicated by the dial. Figure 2 shows the calibration for both loading situation (load value by the dial increases) and the unloading situation (load value by the dial decreases). Linear curve fitting was performed to get the slope of the loading line and unloading line and they are found to be identical. However, as can be seen from Figure 2, there is a shift of the loading line from the unloading line. The vertical distance of the two lines is about  $8.8\text{ mV}$ , while the horizontal distance is about  $270\text{ lbf}$ . This is due to the backlash of the gearing system that connects the potentiometer to the dial servo. This shift will show its effects on the strain-hardening stress-strain curve, as will be discussed later.

The relation to convert the potentiometer voltage output  $V_p$  (mV) to load  $P$  (lbf) can then be

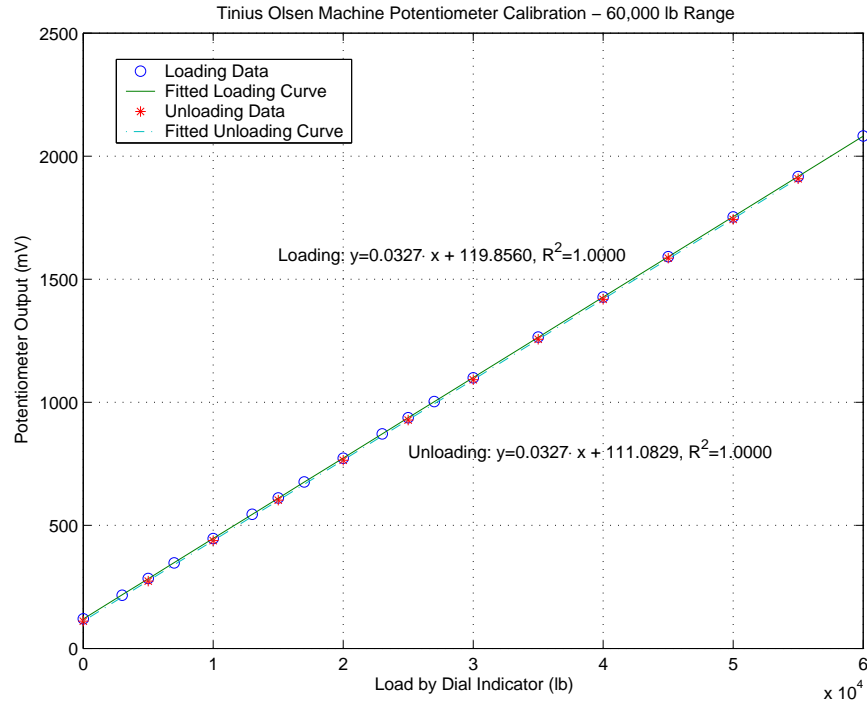


Figure 2: Load Signal

described by the following equation:

$$P = 30.58 \cdot (V_p - V_{p0}) \quad (1)$$

where  $V_{p0}$  is the voltage output when the dial is zeroed.

### Elongation Signal

The original Tinius Olsen machine is also equipped with an electronic extensometer for its electronic recorder. This extensometer is based on a Linear Variable Differential Transformer (LVDT) which operates on AC signal (60Hz). The extensometer AC voltage output was calibrated against the linear elongation using a Starrett Digi-Chek, as shown in Figure 3. The micrometer of the Starrett Digi-Chek has a fine graduation of 0.0001 *in*. In order to ensure proper movement of extensometer arm, the edge of the Digi-Chek moving block is in contact with the extensometer arm just inside of the extensometer knife edge. As a result, the linear movement at the extensometer knife edge is larger than the linear movement of the Digi-Chek moving block. This effect can also be examined by looking at the effective arm length from the pivot point, as shown in Figure 3. The arm length of extensometer in real tension tests is from the pivot point to the knife edge, which is in contact with the specimen. However, the effective arm length in this calibration set up is from the pivot point to the contacting point, which is smaller than the test arm length. According to the dimensions of the extensometer moving arm, this difference is estimated to cause the current extensometer output to be about 3% larger than the output of the same linear movement at the extensometer knife edge. The calibration curves are shown in Figure 4. As can be seen from the figure, there are little differences between the loading and unloading curves, and the extensometer output is linear to the elongation in the measurement range (0 – 0.03 *in*). These general characteristics are typical of the LVDT device.

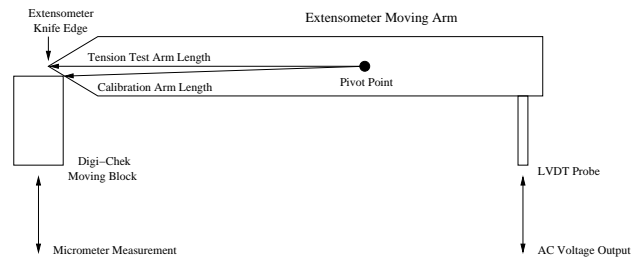


Figure 3: Extensometer Calibration Setup

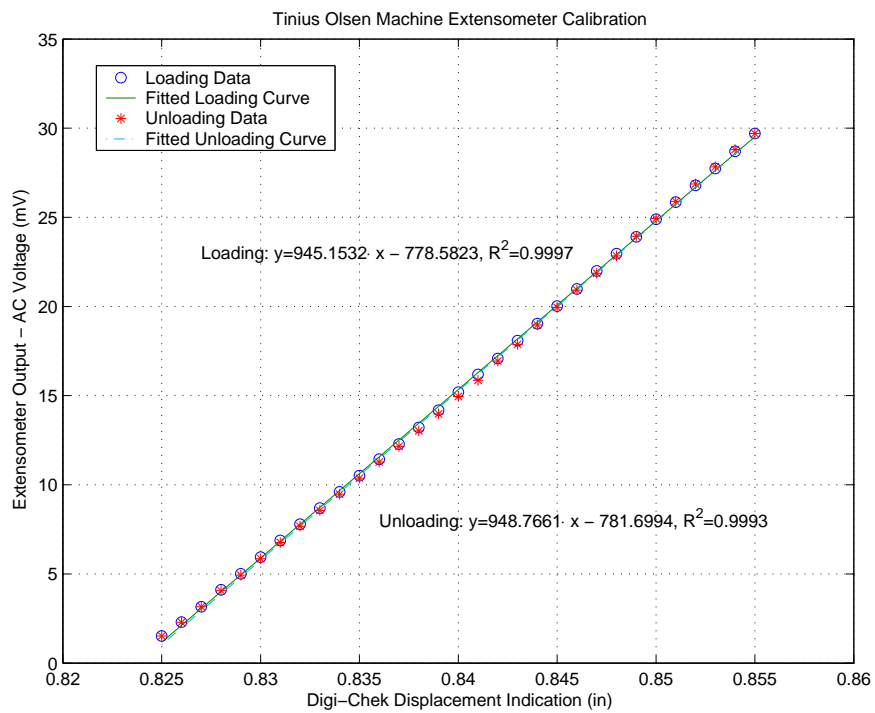


Figure 4: Elongation Signal

The relation to convert the extensometer AC voltage output  $V_e$  (mV) to specimen elongation  $\Delta L$  (in) can then be described by the following equation:

$$\Delta L = 0.001056 \cdot (V_e - V_{e0}) \quad (2)$$

where  $V_{e0}$  is the voltage output when there is no load applied. Note that this equation underestimates the true elongation in real tension tests for the reason discussed above due to the calibration setup.

### Computer Data Acquisition with LabVIEW

The potentiometer and extensometer signals are connected to National Instruments PCI-6024E or DAQpad 6020E data acquisition card through the SCB-68 shielded connector box. A LabVIEW virtual instrument (VI) was developed as shown in Figure 5 for the front panel and in Figure 6 for the block diagram. There are a total of 9 controls at the left side on the front panel. The first three correspond to the physical channels connecting the extensometer and potentiometer. The next two controls are for inputting the factors in Equations (1) and (2). The next two controls are for the dimensions of the specimen, namely the gage length  $L_0$  (in) and diameter  $d_0$  (in). The last two controls are for inputting the initial voltage readings, which can be obtained by running this program for a few seconds after the specimen are inserted into the test machine and the load dial is zeroed. A rather large number of samples (1000 samples or more with a sampling rate of 1000 samples per second or better) are taken at a time to acquire the waveforms of the extensometer and then to output the AC voltage. This is due to the fact that there is no signal conditioning for the extensometer output and there is considerable amount of noise embedded in the very small LVDT output signal, which would distort the linear stress-strain curve. By taking a large number of data points covering over 10 periods, the random noise effect is kept to a minimum in the AC voltage output.

There are four plots generated on the front panel. The first one tracks the potentiometer and extensometer outputs throughout the experiment, which also gives a visual presentation of the relative magnitude between the signals. These two signals are also plotted out individually in the two plots at the bottom. It should be mentioned that the slope of the curve in potentiometer plot represents the loading rate. Students can observe this plot to adjust their loading rate, if it is desired. The bigger plot on the top is the stress-strain plot which plots the stress-strain curve in real time. Both original voltage outputs and stress strain values are also output to a disk file so that the student can use their favorite software such as Matlab or Excel to process the data.

In Figure 5, the front panel is shown for a strain-hardening test of an Aluminum 6061-T6 specimen that was performed with two loading and unloading cycles. The stress-strain curve is plotted in Figure 7 for more details. As can be seen from the figure, there is a shift between the first unloading curve and the second loading curve. Furthermore, the unloading curves do not drop down right away, occurring only after a slight shift back horizontally, and also they do not reduce back to zero stress. The difference in stress between the first unloading curve and the second loading curve, as well as the end stress of the unloading curves, are about 2000 *psi*. This value is comparable to what the shift in load as shown in Figure 2 would cause (270 *lbf* will cause a stress of 1400 *psi* for a specimen with a diameter of 0.5 in). As discussed before, all these are due to the backlash of the gearing system, as the gears need to change moving direction.

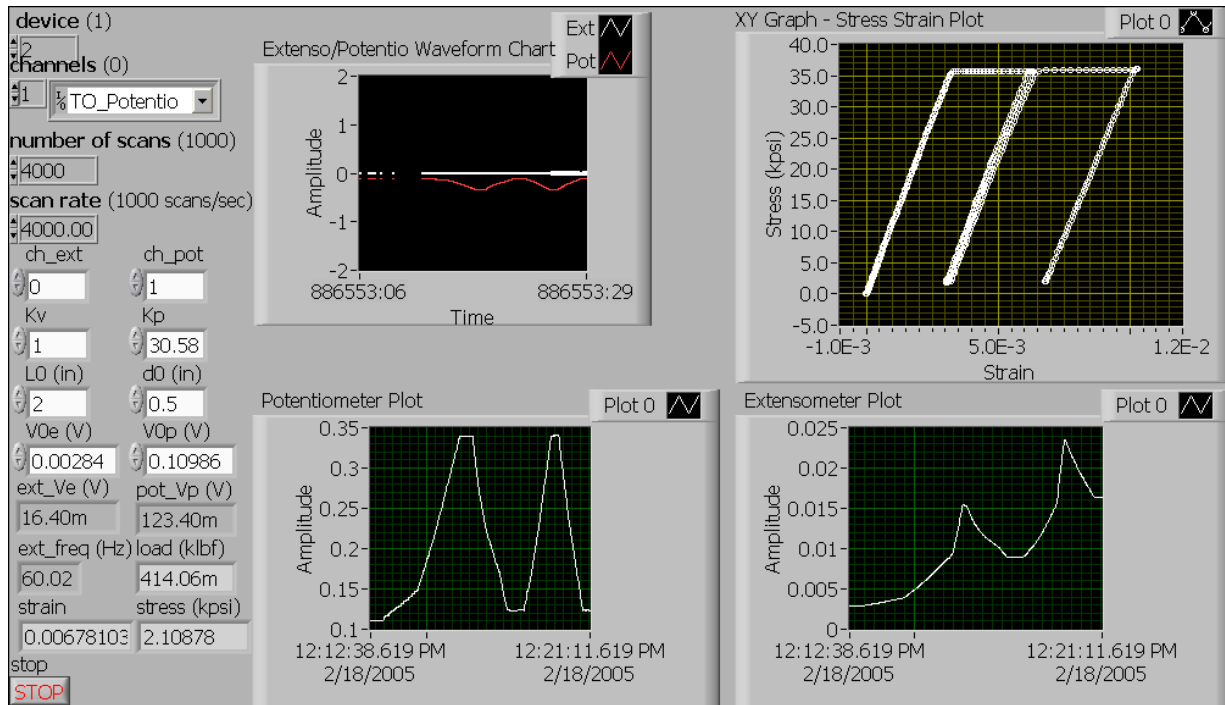


Figure 5: Front Panel of the VI

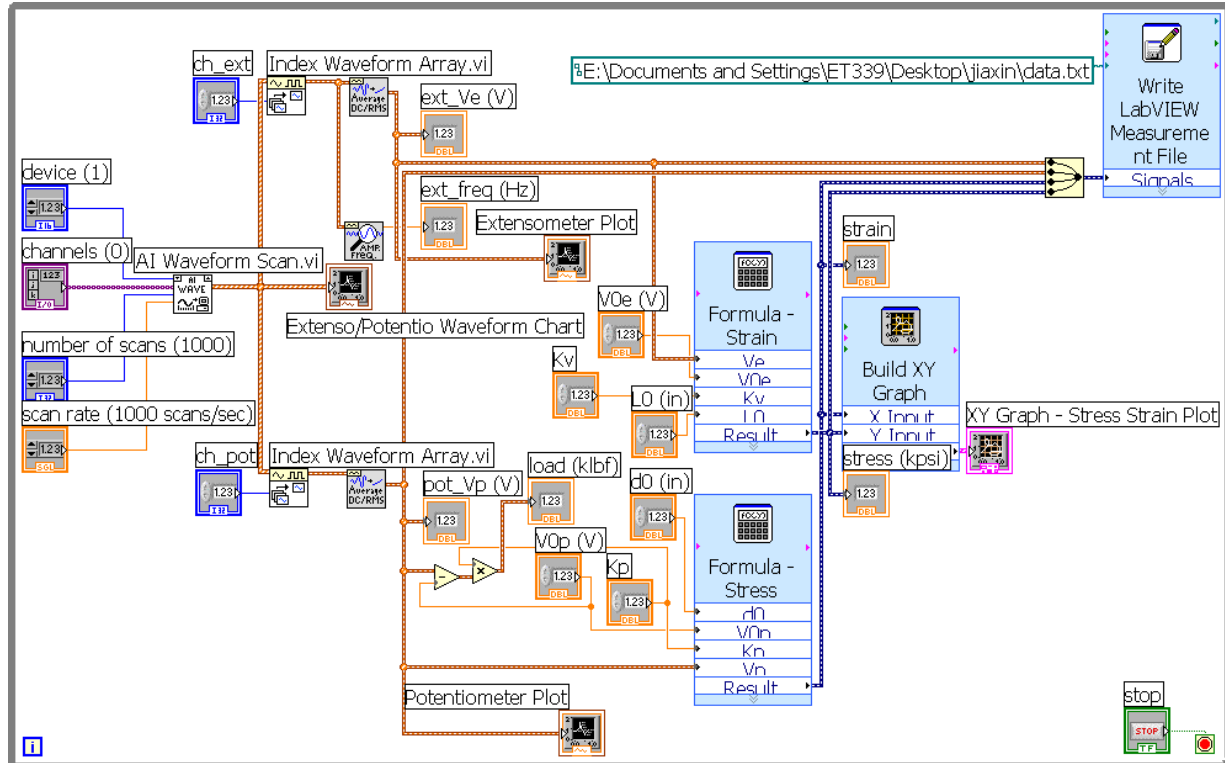


Figure 6: Block Diagram of the VI

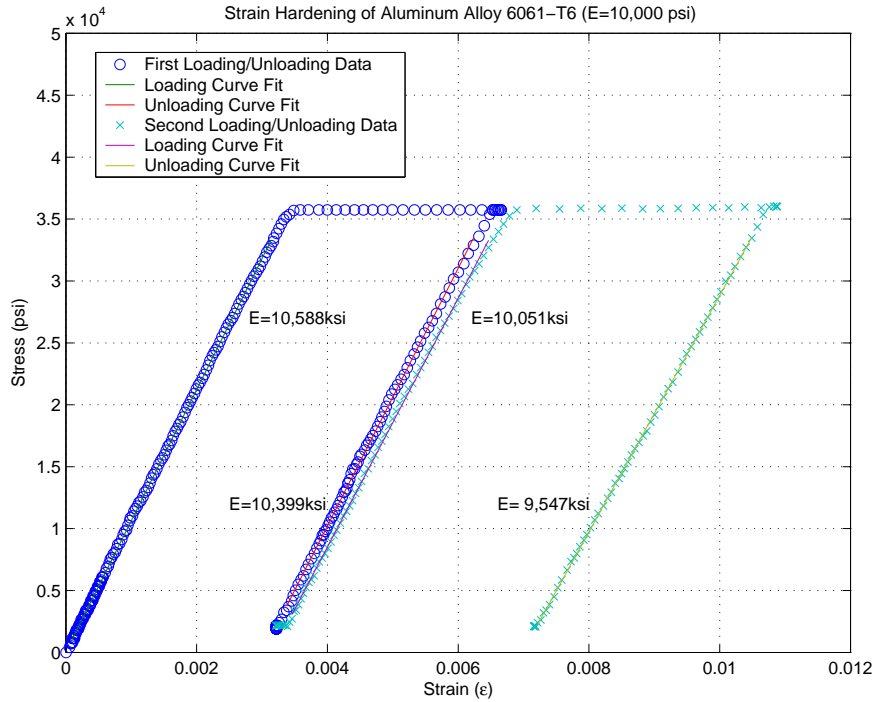


Figure 7: Strain-Hardening Test

However, the shifts of stress-strain curves only occur when loading is changed to unloading or vice versa. In order to determine the material properties such as the Modulus of Elasticity or yield strength, this shift will not cause a problem as only one loading process is needed.

Figure 8 shows the tension test of a 1020HR Steel specimen. The configured computer data acquisition system clearly captures the upper and lower yield points existing for low carbon steels. The slope of the stress-strain curve gives the Modulus of Elasticity for steel. As there is only one loading process, no shift of curves is present. Table 1 provides a comparison of Modulus of Elasticity for the two specimen with published values. The calculated values from curve fitting of experimental results is usually higher and one of the reasons is that Equation (2) of the extensometer calibration tends to give a smaller elongation and thus the strain.

**Cost of Implementation**

The implementation of computer data acquisition to the Tinius Olsen machine presented zero cost. The potentiometer and extensometer were purchased together with the Tinius Olsen machine about 30 years ago, although they were not used until this implementation. A new

Table 1: Comparison of Modulus of Elasticity

Material	Modulus of Elasticity (ksi)	Modulus of Elasticity (ksi)	% Error
	Published	Calculated	
6061-T6 Aluminum	10,000	10,588	5.88%
1020HR Steel	30,000	31,806	6.02%

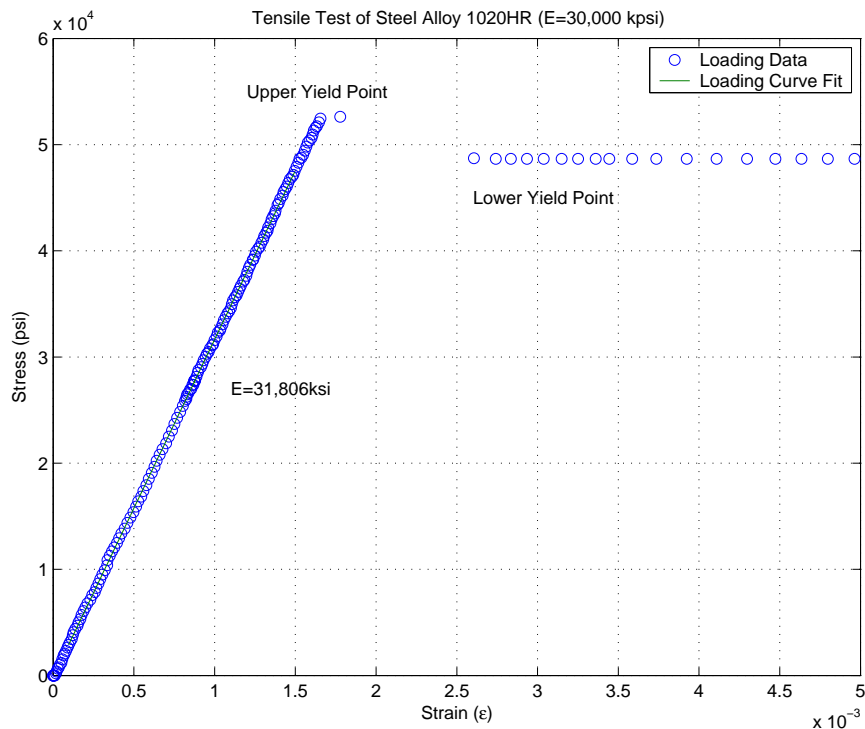


Figure 8: Tension Test of 1020HR Steel

potentiometer usually costs a couple dozen dollars while a new digital extensometer costs around two thousand dollars. The computer data acquisition systems were also pre-existing and were shared among all the mechanical engineering labs. A complete data acquisition hardware system from National Instruments typically costs less than one thousand dollars.

To compare with a retrofitting package which can cost tens of thousands dollars, the computer data acquisition was achieved seamlessly. The only thing that is missing from this implementation is the automatic control of the loading and unloading. However, as indicated before, one can observe the slope of potentiometer plot to have a feel of the loading or unloading rate and then to make any adjustments if necessary.

## Conclusion

In this paper, the procedures to bring computer data acquisition to an old Tinius Olsen machine is presented, using its own existing hardware and National Instruments data acquisition hardware and LabVIEW software. A potentiometer that is geared to the dial servo gives the signal for load applied, while an LVDT based extensometer provides the signal for elongation of the specimen. The potentiometer output and the extensometer output were first calibrated against the load and elongation, respectively. These two signals were then hooked up directly to the data acquisition hardware and a LabVIEW program was written to process the signals and generate the real time stress-strain curve. The data was also stored in a computer file for later processing of the stress-strain curve. Overall, this implementation used pre-existing equipments and presented zero cost to the institution.



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## Biography

JIAXIN ZHAO is an Assistant Professor of Mechanical Engineering at Indiana University-Purdue University Fort Wayne. He received his BS from the University of Science and Technology of China, his MS from the University of Missouri-Rolla, and his PhD from Purdue University-West Lafayette. His research and teaching interests are tribology, machine design, solid mechanics and numerical methods including finite elements and parallel computing.