MECHANICAL ENGINEERING 2000 LABORATORY DEVELOPMENT USING STUDENT DESIGN SUPPORT

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Abstract

The University of Tennessee at Chattanooga Engineering curriculum is being renovated with major emphasis being placed on transforming our well used, traditional laboratories into modern state-of-art facilities where LabVIEW is used for control, data acquisition, analysis, and presentation. Some of these laboratories are being made available on the WEB. This process is taking place in house at UTC with no new fully instrumented laboratory systems being purchased from vendors. This represents a major challenge for the engineering faculty, technical staff, and students who are responsible for this activity. The university receives the most visible reward from this effort as it gains modern laboratory facilities at minimum cost. For example, about $16,000 ($7,000 on the initial purchase in 1980 plus $9,000 in new electronic sensors, controls, data acquisition software, and computers) was spent in providing a fully renovated heat-exchanger laboratory system. This system currently costs about $40,000 when purchased with an equivalent data acquisition-control system. This paper will describe some of the various difficulties and procedures that were considered in renovating-redesigning this system. It will also describe the benefits obtained by student participation.

Introduction

Engineering laboratories have been underfunded and neglected at most universities. These factors have left most engineering programs providing engineering graduates who are not properly prepared to join the modern workforce. If this condition is to be corrected, the university must recognize and accept a new challenge. This challenge can only be met if the engineering faculties take responsibility for renovating their near antique laboratories, purchasing only new sensors, computer systems, and software required to complete the renovation task. Most faculties do not possess the modern skills required to complete this task. Therefore, the universities must provide (1) faculty development funds that enable the faculties to develop the new skills, and (2) extra service compensation and/or release time required for completing the renovations.

When a faculty member who has been actively teaching senior level mechanical engineering labs for many years considers the task of renovating older labs, it may not seem to be a very formidable task provided they have an understanding of the many forms of fundamental instrumentation being used in a lab system as well as the more modern forms of instrumentation that must be added to the older system. In effect the renovation process becomes a form of unique design that most faculty and students will find to offer very serious design challenges.

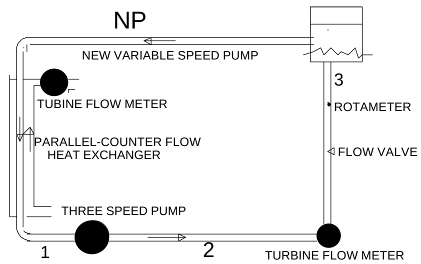
The Challenges of Renovation

In 1986 the university purchased the H950 Water-Water Turbulent Flow Heat Transfer Unit from P. A. Hilton. The system was used as purchased in our senior level heat transfer lab through 1997. The system consisted of a simple tube-in-tube heat exchanger, a thermostatically controlled water heater and piping circuit having a three speed pump, a hook-up to provide city water for the coolant water supply, rotameters for measuring the hot water being circulated in the system and the coolant water supply, a flow control valve in the hot and coolant flow lines, six thermocouple temperature sensors used for measuring the inlet and outlet water temperatures for both water flows and metal surface temperatures separating the two flows at the entrance and exit of the heat exchanger, and a six channel digital temperature indicator. Hilton provided an operators manual describing the fundamental principles of heat transfer with procedures required for obtaining (1) the convective heat transfer coefficients for inside and outside surfaces of the interface tube, (2) the overall heat transfer coefficient for the process, (3) the maximum potential heat transfer rate, (4) the actual heat transfer rate, and (5) the effectiveness of the heat exchanger system. Each of these parameters were computed for several parallel and counter flow steady-state runs in the lab conducted prior to 1997. Spreadsheet computations were completed for each test with comparisons being made between parallel and counterflow arrangements.

The renovation of this system consisted of providing LabVIEW data acquisition for the six temperatures being monitored in the system and the two water flow rates. Each type "K" thermocouple that was connected to the digital thermometer was connected to the data acquisition backplane using shielded, twisted-pair copper wires in order to reduce the influence of random signal noise. On starting up the system, it was found that the temperatures being indicated by the computer data acquisition system were very different from those indicated on the Hilton digital display. On further investigation it was found that the digital display area where the copper extension wires originated was being heated by the power supply for the unit. This provided heated dissimilar metal junctions from that at the other end where the extension copper wires were connected to the backplane. This method of wiring provided thermocouple voltage errors and significant temperature errors that were removed by running type "K" thermocouple wire throughout. In other similar systems where no temperature differences existed within the wiring lengths, copper extension wires were used without significant temperature errors. This learning process is noted when the renovated system is used during each lab.

Turbine flow meters, due to their reduced size and accuracy, were selected for use in measuring the hot and cold water flow rates. The requirement for accurate experimental flow rates provided for increased fluid head losses that are generally associated with flow meters having greater accuracy. In an effort to recover the lost flow capacity resulting from adding the new turbines, the hot water three speed pump selector switch was set such that the pump ran at its highest speed and an in-line boost pump was added to the coolant water supply. The coolant flow rate was reestablished by using the boost pump. But, the hot water circulating capacity in the system was decreased from 150 to 67 grams per second. This reduction in flow rate seriously reduced the Reynolds number operating range for the hot water side of the heat exchanger. The small turbine meter used for measuring the coolant flow rate was added in the discharge line returning to the drain. The turbine meter for the circulating hot water was added in place of a short pipe section just downstream of the pump. The system has been used this past year with these renovations having been completed.

The system is now undergoing further renovations in an effort to reestablish the original maximum flow rate for the hot water side of the system while also providing for computer control of the flow rates in the system and heater control setting that will enable the system to be run over the Web Site at UTC. A computer controlled, variable speed, direct current motor driven centrifugal pump is being added to the hot water circulating system. A fixed speed, centrifugal pump could have been used to boost the flow rate back up with flow control being completed by a computer controlled flow valve. The use of the variable speed pump performs both of these functions in one unit with flow control being performed by computer control. The use of the single variable speed pump also represents major cost and space savings over adding two separate pieces of instrumentation to the system. Front panel space in the fluid flow circuit is very limited as each component is positioned to save space and reduce the overall size of the system. Sites noted by locations 1, 2, and 3 shown below were considered for location of the new pump but rejected due to the location of existing valves and potential for fluid cavitation problems. Site 3 was least desirable as it provided for the pump to add hydraulic head while developing lowest inlet pressures due to large valve and flow meter head losses upstream.



This could have caused cavitation in the hot water supply and loss of pumping capacity. Site 2 was next least desirable for the same reasons. Site 1 was most acceptable as it provided for the hydraulic head to be added then taken out by the turbine flow meter and valve. This represent the optimum pump location. But, no space existed between the exit of the heat exchanger and the pump where this could be readily done. The best option for locating the new pump rested with a one foot section of piping located between the hot water storage tank-heater and the inlet to the heat exchanger. This pipe section is located behind the front panel in the back side of the Hilton unit. This location, noted as site NP above, transports the hottest water with the highest potential for cavitation due to the water's high vapor pressure. The pump inlet pressure at this location is assured of positive gage pressures since the fluid height in the reservoir will provide the required inlet pressure. The consideration of these various fluid mechanics principles related to pump selection/design is important because the renovation designer is limited in space and instrumentation selection while being forced to maintain pre-renovation performance for the post-renovation system. The heater controller provided by Hilton was operated manually. This controller will be replace by an analog or digital controlled unit so inlet water temperature to the heat exchanger can be operated remotely. Having computer control of the flow rates in the heat exchanger and the heater power setting will allow the renovated Hilton system to be operated through our Web Site.

The problems related to renovation design have been discussed for one of ten systems being used in the Senior Mechanical Engineering Laboratory at University of Tennessee at Chattanooga. Similar renovation concerns were addressed for each of the following laboratory systems: transient heat transfer, refrigeration trainer, internal combustion engine enery balances, combustion products and emission factors, natural gas boiler study, stress-strain-deflection of a beam, linear vibrations, rotational balancing, and kinematic analysis of slider-crank and valve train for a 3.5 horsepower Briggs and Stratton engine. A complete description of each of the labs making up the Senior Mechanical Engineering Laboratory exists in recent publications (1,2,3).

Student participation in the process of renovation takes place when they complete the design project phase of the course requirement for the Senior Lab. This four week experience comes at the end of the semester following the completion of the experimental lab component and the study of fundamental instrumentation in the lecture component of the two credit hour lab course. The students find this hands-on phase of the course most rewarding as it enable them to apply basic concepts while transforming an old system the students have used into a modern system. The students accept this course responsibility with vigor and enthusiasm knowing that future students will be using their product. The student design projects have supported renovation of (1) a supersonic, blow-down wind tunnel, (2) the friction factor and flow meter calibration experiments in the fluid mechanics laboratory, (3) computer data acquisition applications for the Tinius-Olsen testing machine and the truss experiment in our strength of materials laboratory along with other efforts like developing LabVIEW applications for use in capstone senior design projects.

In Conclusion

The process of renovation design is most rewarding but very challenging. The faculty and students who have participated in the renovation process described above have developed a broad based understanding of modern instrumentation installation and applications. Students having experienced this process are more capable of meeting the requirements of a modern workforce on graduation. Faculty having been involved become more productive and capable of conducting experimental research and develop teaching skills required for producing engineers for the 2lst century.

References

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