Introducing Fundamental Manufacturing Processes and Manufacturing Organizational and Production Systems by Way of Laboratory Activities

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The rebirth of manufacturing in the United States will not just accidentally happen. Engineering programs must help stimulate the rebirth by educating students in the importance and fundamentals of manufacturing processes, organization and production systems. These concepts continue to gain increasing importance for aiding engineers to help reindustrialize the United States for the twenty-first century. At Trenton State College, in the Department of Engineering, these concepts are being introduced and taught most effectively via the hands-on approach. The department believes that by placing a strong commitment on practical learning experiences, it is better able to teach and reinforce theoretical concepts.

An example of this belief is the engineering department's sophomore level production Systems and Methods course. Numerous course concepts are taught in conjunction with laboratory activities which require students to develop and present manufacturing processes, organizational and production systems solutions utilizing the department's CNC, CAD, plus the polymer and metallic manufacturing facilities.

A few of the laboratory enhanced Production Systems and Methods course concepts are included in the following list: reverse engineering product design and manufacturing, manufacturing costs concepts (direct materials and labor plus overhead) and control, breakeven calculations, routing, flow process charting, Gantt charting, network diagraming, bill of materials development, manufacturing completion probability analysis and packaging design. Additional concepts such as the design and analysis of polymer and metallic welded fabrications and castings, CNC milling, lathe turning and the set-up and analysis of polymer molding (injection, compression, thermo-forming and extrusion blow) experiments are also studied by way of various laboratory activities. All of these concepts are taught in a unique facility housing laboratory size equipment.

FACILITY

Two large materials manufacturing laboratories, one testing room and a lecture area are utilized for the course. One laboratory houses all of the needed polymer production equipment. The equipment includes a polymer welder, a thermoformer, an injection molder, a compression molder and an extrusion blow molder.

A second laboratory provides space for all of the needed metallic production equipment. These items include lathes, manual mills, CNC mills, band saws, drill presses, heat treating ovens and a green sand foundry.

The testing room contains hardness, tensile, impact, compression and flexural testing devices for performing quality assurance checks on polymers, composites and metals. All of the course lectures, demonstrations and lab activity sessions are conducted in these facilities. There is a maximum course student capacity of twenty-four.

COURSE STRUCTURE

Each student receives three credits for the course which meets five hours per week for fourteen weeks. Approximately two hours per week are devoted to lecture/demonstration while the remaining three hours are used by the student to work on laboratory activities. The following narrative explains the structure and content of four of the six laboratory enhanced activity assignments utilized during the course.

LAB 1: REVERSE ENGINEERING PRODUCT DEVELOPMENT AND MANUFACTURING DESIGN ACTIVITY ASSIGNMENT

One specific laboratory example in the course is a problem solving reverse engineering product development and manufacturing design activity that entails the designing of the manufacturing processes sequence and systems of production for each part of a commercial product. It is presented in the following manner. Student groups organize a company and select a commercially mass produced product, (five parts minimum) with all accompanying packaging. As a result of the instructor's lectures and demonstrations , each group must develop an exploded drawing of the product, design a detailed route sheet (includes all processing, storage, transportation, inspections, delays, and combined activities) for each manufactured and purchased part, develop a flow process chart for the manufacturing and packaging of the product, produce a parts list plus a product structure tree and indented bill of materials, develop a production lot size and breakeven chart containing all direct and indirect costs plus the Gantt and network charts for the production of the product.

As a culmination of every individual group's effort, each must present the results of its group's manufacturing and design activity laboratory experience to the class by way of oral and written (includes drawings, sketches, route sheets, bills of materials, parts lists, network and Gantt charts, flow process charts and breakeven charts) reports. The design work is accomplished outside of the class, but the remainder of the project is completed during the course laboratory sessions. Each group of students is evaluated on how well it completes the laboratory activity by comparing the group's results with the original product and production design criteria.

LAB 2: POLYMER AND METALLIC WELDING ASSIGNMENT

The student is given lectures concerning various polymer and metallic welding fabrication techniques. A presentation is provided concerning metallic welding joint design. Each student is required to complete metallic butt joint and double-fillet lap joint design calculations for determining the allowable working stress, recommended metal thickness and weld size for each joint type in service under specific environmental conditions .

This is followed by a hands-on lab to teach the student the correct set-up and operation of polymer hot air and shielded metal arc welding equipment. Now , the student must produce numerous fillet welded polymer tee joints and then analyze each to determine the percent of the acceptable and unacceptable welded areas.

Each student also produces a metallic double-fillet lap joint. The joint is tensile tested (See Figure 1) and the joint's strength, load, allowable stress, load limit of the unwelded stock and maximum joint design load are calculated. Also, the condition and location of the weld break must be analyzed. The student must then prepare a lab report that illustrates and explains all processing calculations, conclusions and recommendations.

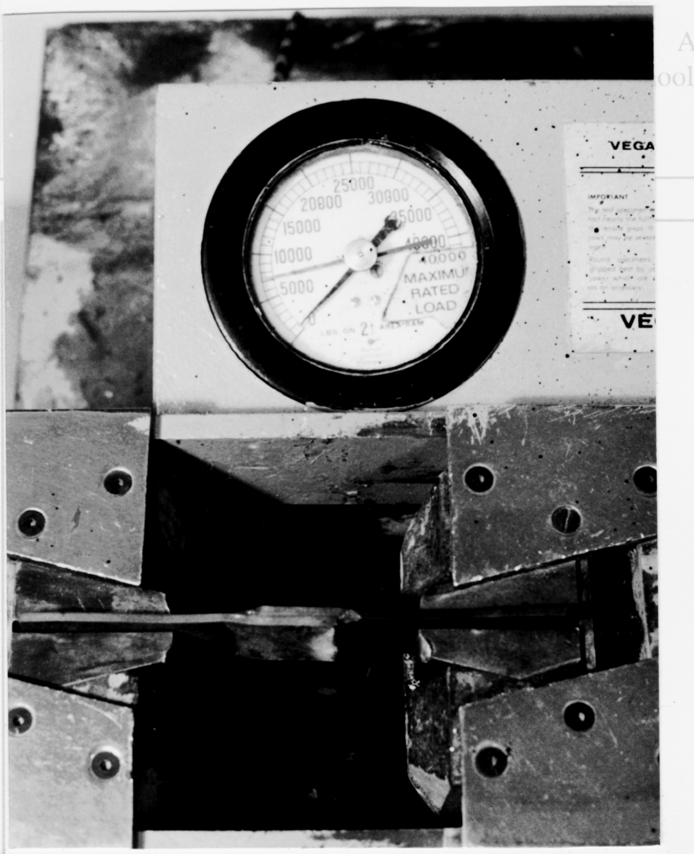

Figure 1. WELD JOINT TENSILE TEST SETUP

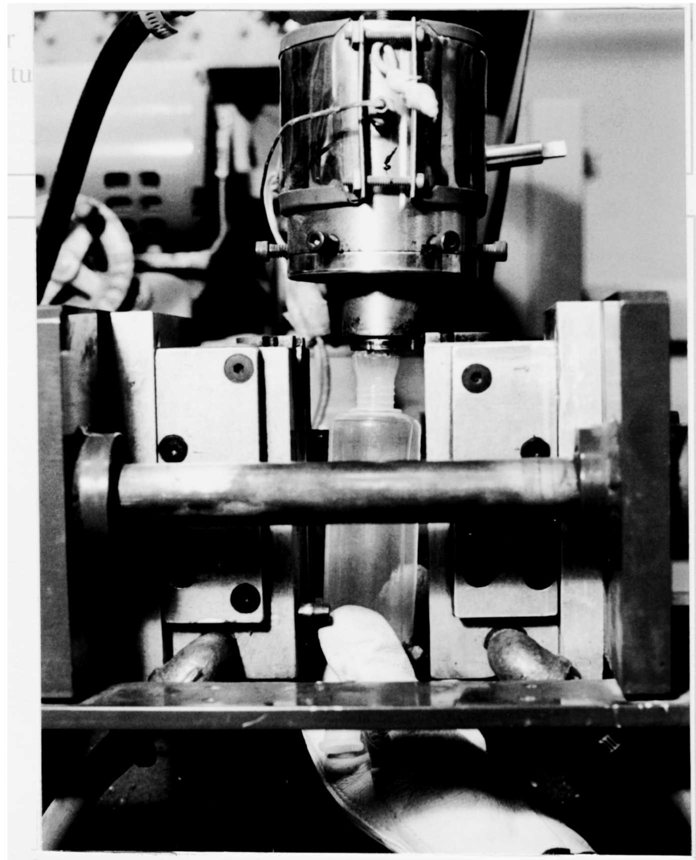

Figure 2. BLOW MOLDER, BOTTLE PRODUCT AND MOLD

LAB 3: POLYMER MANUFACTURING ASSIGNMENT

Lectures/demonstrations concerning plastics injection, compression, extrusion/blow and thermoforming processing and materials are presented. The student is taught how to calculate projected mold surface area, clamp forces, molding pressures and material flow temperatures for compression and injection molding.

Processing sheet depth of draw ratio, part area to sheet area ratio, sheet thinning and forming temperature calculations for thermoforming are taught. Also, extrusion blow molding (See Figure 2) product shrinkage, neck to body diameter ratio, mold clamp pressure and blow air pressure calculations are presented.

At the conclusion of the lectures/demonstrations, the student must produce a lab report explaining terminology related to each polymer manufacturing process. Also, completed calculations with logical conclusions and processing recommendations concerning all of the above mentioned processing variables and adjustments are placed in the report.

LAB 4: WAX MACHINING ASSIGNMENT

The student is taught by way of demonstrations how to operate CNC mills. Appropriate numerical control programminq is taught along with the machining feed, speed, depth of cut and machining time calculation determinations. Now the student is required to complete a program that will allow him/her to CNC mill initials into a rectangular piece of wax. (See Figure 3)

After successfully milling, the student must submit the product and a lab report. The report contains an account of programming and operating problems encountered. Also, calculations with logical conclusions concerning machining speeds, feeds, depths of cuts, production times and estimated product costs at various production times are included in the report. The student is also required to determine pulses, inches, and millimeters per revolution for all drive screws in the mill and conclude how replacing these items along with CNC program changes can influence part production times.

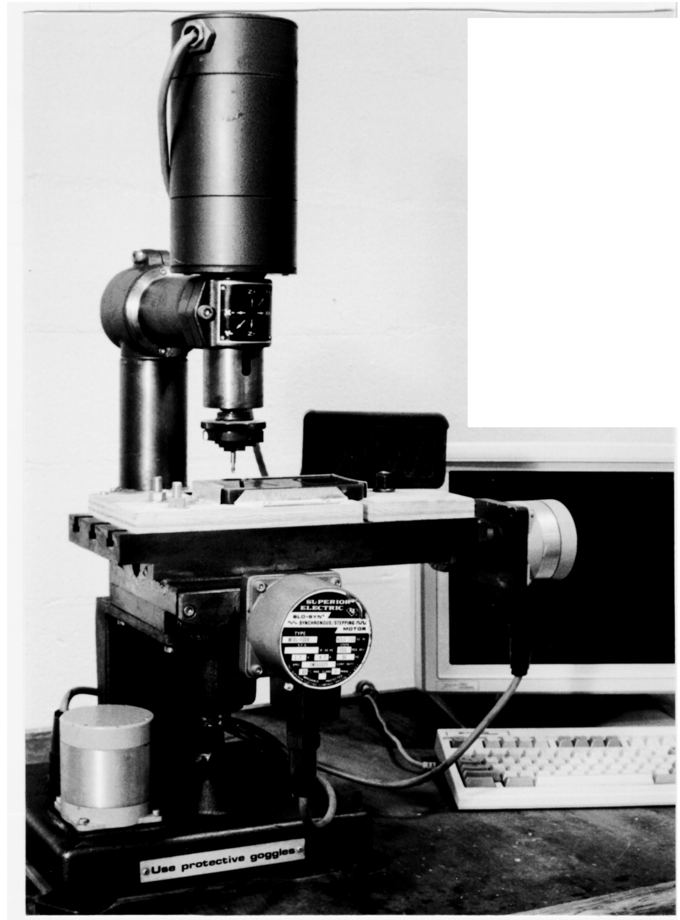

Figure 3.
CNC MILL SETUP WITH RESULTING WAX MILLED PRODUCTS

CONCLUSION

Participation in problem solving activities such as the examples given, the student can more readily learn and apply the theoretical concepts stressed in the Production Systems and Methods course. The theoretical concepts are reinforced and made applicable to actual industrial manufacturing.

Some additional concepts taught in the course would be a variety of the following: corporate organizational structures, production control system modeling, forms of industrial ownership, law in engineering, budgets, cost estimates, manufacturing engineering, loading, scheduling, parts list development, production cost analysis and material handling.

Each laboratory experience or activity is utilized as a tool for teaching and reinforcing student understanding of the course objectives. The unique hands-on, practical laboratory learning method found most effective in the course is designed to assist each student to apply selected production systems and methods in a real world environment.

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