AC 2007-364: PRACTICAL SKILL DEVELOPMENT, ANALYSIS AND TESTING ARE USED TO TEACH THE TOPIC OF HEAT TREATMENT OF AEROSPACE ALUMINUM ALLOYS

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Abstract

Students learn best when they can see the results of their efforts. Students of the Aviation Technology Department at Purdue University enroll in AT308 Manufacturing Processes in their junior year. AT308 is the fourth materials course in a series of five courses offered in the Aeronautical Technology curriculum, and this course is organized as a separate business venture to provide students with an opportunity to learn about the aviation manufacturing industry. The theoretical knowledge in this course is reinforced with practical skill development, which is crucially important for future maintenance professionals in the aviation industry. In the course of study, students are treated like a manufacturing company employs them. They are working in teams and learning how to work together, but are responsible individually. They function as team leads on some job assignments and quality control inspectors on others. By the time students have finished all assignments, they have experienced the whole concept of today's manufacturing and assembly process. Modern industry is a complex mechanism, and students who understand it well and understand how it works have a better chance to find their dream job. For students to be successful, they have to understand the basic concepts, and one of the most important concepts in aerospace manufacturing is heat treatment of aluminum alloys. Students manufacture so called "dog bones", and one aspect of this task is to learn how to use sheet metal equipment and understand the stamping process. However, it is more important for the students to learn the basics of material science, such as load and stress. The aerospace industry needs people who understand the properties of aluminum alloys, and how heat treatment changes those properties. Students test the hardness of original samples and compare them with others after various types of heat treatment have been applied. The manufacturing and testing is supported by theoretical calculations, which are done before the testing. The test results of the samples are recorded by students and analyzed later. Any unusual results are discussed with the whole class.

Introduction

Too often a lack of "real-life" experience lies between the new graduate and his or her dream job. How do we fix this problem? How do we expose undergraduate students to the modern business environment with its full spectrum of complicated components, while still retaining the necessary academic and theoretical background? How do we break this circle where students should acquire knowledge before they start working, but to find a job they have to have some experience? It certainly looks like a "Catch-22".

If someone is dreaming about becoming an aviation maintenance professional, the Aviation Technology Department at Purdue University has an answer. It offers an Aircraft Manufacturing Processes course (AT 308), which is organized as an independent business venture and simulates a real world manufacturing experience for students. During this course students are assigned tasks and job positions they will encounter during their professional career. The students spent a considerable amount of time in the classroom learning theory about heat treatment, loads, strains, and structural joints. The theory is reinforced in the materials laboratory where they manufacture and test several hands-on projects using manual and CNC mills and lathes, and test equipment.

During their freshmen year, students take AT108 and AT166, which are prerequisites for AT308, and are taught sheet metal fabrication and repair, corrosion, heat treatment, aerospace materials, welding, and painting. The topics of AT108 and AT166 are geared towards the FAR Part 147 curriculum. Students enrolling in AT308 have developed basic aircraft materials skills, but all of them still have a lot to learn about structural joint design, the use of CNC equipment, and quality control systems like ISO 9000. American universities, in general, are adding more hands-on engineering projects to their curriculum to attract new students[1]. Hands-on projects are motivating and help sustain students' interest in technology and the curriculum to prevent them from switching to other majors[2]. The need to encourage the study of engineering is becoming more important as globalization and information sharing helps other countries compete with the U.S, and many traditional engineering activities are outsourced.

In the course of study students are given work orders, as if they were an employee of a company. Their manufacturing facility, the laboratory, is equipped with various industrial tools including lathes, milling machines, testers, and other machine equipment. Students are working in teams, learning how to work together, but taking responsibility at the individual level. They will be team leaders on some jobs and quality control inspectors on others. By the time students have completed all assignments, they have been exposed to the whole idea of the process. Modern industry is a complex mechanism, and students who have an understanding of how industry operates have a better chance to find their dream jobs. It also addresses an issue of practical engineering that largely disappeared from the curriculum of most mechanical engineering schools, which offered a mix of high-quality academic and practical experience in the past[3].

During the course students learn how to follow instructions because aviation maintenance is no place to make risky decisions, gamble with parts, procedures, and processes. That is why the philosophy of AT308 emphasizes following process exactly and in specific detail. However, it does not mean that a drawing or process cannot be changed, sometimes in response to errors that occur along the way. A good technician must be able to recognize a mistake or a design flaw when he or she sees one. Given the aviation focus on safety, these skills are fundamental to preventing, rather than reacting, to problems and accidents. Safety is a strong part of the culture in this course, and procedures are designed with this in mind.

Students learn how to deal with a variety of problems. Communication with co-workers, managers or customers is very important, and one of the best ways to understand effective communication is to learn how to work in teams. Prospective employers increasingly demand a more comprehensive understanding of the engineering technology discipline and improved levels of communication skills from graduates[4].

Hands-on projects combined with classroom knowledge

During the semester 13 different work orders are assigned, which cover different aspects of the industrial environment. The manufacture of parts and assemblies is the first step in the process. The most complicated part to manufacture is a vacuum port that is used in a composite laboratory for a vacuum bag project. It requires time, effort, and skill to make them; and saws, lathes and milling machines are used in the manufacturing process. All manufactured parts are

inspected by the students, and because they work in teams they will inspect each others' work to develop experience with and knowledge of quality assurance.

Secondly, students assemble sheet metal parts together using rivets. Riveted structural joints are widely used in the aviation industry, and future aircraft maintenance technicians have to know how to repair a failed joint. However, it is more important to know why a joint fails, and it is very important to start with the basics[5]. Students first make the structural joint test pieces, then calculate the strength of riveted joints, and finally, test the test pieces using a tensile tester. Students are then able to compare their calculations and predictions with the actual results and gain experience with failure prediction and statistical methods.

This experience gives students direct feedback about how different loads and different material thicknesses affect a structural joint, and it reinforces the classroom theory. Students experience the difference between failures of a material itself versus shear failure of the rivets. In the current industry environment, it is important that future maintenance professionals have both sound hands-on skills, and a solid understanding of engineering fundamentals. North America may be losing manufacturing jobs, but most U.S. manufacturing companies claim they have serious problems finding qualified candidates for the highly technical positions in modern manufacturing[6].

Figure 1: Testing of structural riveted joints on tension.

The third component of the course is testing. As was mentioned before, students test several structural riveted joints on tension, and hardness testing of several samples of aluminum strips is performed to learn about the effects of heat treatment. "Dog bones" samples are relatively simple to make, but the effects of the property changes of aluminum alloy after heat treatment is not so easy to explain. Students learn about different types of heat treatment, but most importantly, they also discover what happens if different processes are used. Students develop the ability to gather

quality data and analyze it with statistical tools, skills that will benefit both them and their future employers[7].

Students learn how heat treatment changes properties of aluminum

One and probably the most important objective of the course is to learn about properties of the metals, in general, and how they could be changed by different types of heat treatment. Students have to understand different tempers of aluminum and how to find this information in reference materials.

As was mentioned before, the students manufacture so called "dog bones" samples from 2024-T3 aluminum sheets. This task by itself teaches the students how to use a sheer and how to operate a press. Each student will make seven samples. The second step is to change the properties of six samples by annealing them and by using different heat treatment methods. One sample per student is left unchanged to establish a baseline.

Figure 2: "Dog bone" samples before and after testing.

Annealed "dog bones" are placed in a different environment. One sample per student is left as is under room temperature conditions, another is artificially aged (precipitation heat treatment), and a third one is placed in a freezer. By doing this, students learn that annealed aluminum is a stable temper and would not change at all. They already should know this from their lectures, but for some of them this is still a surprise!

The second group of the samples is going through natural and artificial aging processes according to reference material. One sample per student is placed in the freezer to slow down the aging. There is also a small trick of which students are not aware. The artificial aging temperature is outside of the required temperature range, which would affect final properties of those samples. This was done to make students think about the importance to follow proper processes, because mistakes like that could happen in real life and could be costly to any company. After all, an improper application of heat can significantly damage a component either metallurgically or structurally. In addition, the energy sources involved in heating, a high-voltage electrical supply, fuel gas, etc., can endanger workers if not handled properly. Even without such failures, a poorly executed heat-treatment project can cause scheduling delays and higher-than-necessary fabricating costs[8].

After the heat treatment is complete, the students perform necessary calculations to predict ultimate force needed to break the samples. Then hardness tests are performed using a Brinell tester. The following step is most loved by the students: samples are placed in a tensile tester and pulled apart. All students are asked to do analysis of the test data. For some students it is still a surprising fact that calculations and the data are really close. However, not following artificial aging parameters creates some confusion. This is a perfect time to discuss the issue during recitation period.

Teamwork pays off here as well. It does not take long for the students to figure out that the annealing process went correctly, because other "dog bone" samples fell exactly inside expected range of data. So, the problem is with the next step, which is artificially aging. The goal is achieved: students realized that something went wrong, and they were able to find the root cause of the problem.

Critical thinking is one and probably the most important aspect of a college education. No one knows everything, but students should be able to realize that a problem exists if they see unexpected results. Unfortunately, there are too many so called professionals, who rely blindly on test data with no or very little understanding of basic principals of engineering.

Figure 3: "Dog bone" sample in the tester.

Theoretical calculations will sink deeper into the minds when people see the end result. AT308, Inc. delivers exactly what is needed: learning by validation of the theoretical side of the course. There is another way to learn. The Franklin W. Olin College of Engineering in Needham, Massachusetts offers a different approach to engineering education. Guizzo reverses the "theory first, practice later" model and gets students involved in hands-on engineering projects from the very start[9]. The course topics in AT308 are supported by practical hands-on projects that demand time and effort to complete. Students are forced to be organized, and are exposed to many sides of the industrial environment. During the course they learn to follow process sheets and apply a variety of manufacturing processes, while using a variety of industrial equipment - all the time working in teams!

Many human resource management textbooks discuss the topic of effective communication in the workplace, and it sounds almost ridiculous to even mention it as a problem in our highly connected and technological society. Almost everyone has a phone, email, instant messaging, or other form of communication at his or her fingertips. However, lack of communication causes most of the problems in the industrial environment. The price of those problems could be devastating in the aviation industry. In this course, students experience these difficulties while working in teams, and acquiring the new language of manufacturing. Predictably, they learn how to address conflicts in a professional manner, when problems occur. They also learn how to find an answer to any problem collectively. Strong communication skills are critical to professional success[10].

Conclusions

The College of Technology at Purdue University provides students with a sound understanding of both theoretical knowledge and hands-on experience. The right combination of both is what makes it a perfect place to study, and AT308 is no exception to the rule. Upon completion of this course, students have a much better grounding in the theoretical knowledge, which they first hear and see during lectures. They understand heat treatment and different tempers of aviation grade aluminum. They also realize the importance of following heat treatment processes to get consistent properties of the materials. The well-equipped laboratory provides a place to apply the theory and develop their skills. It becomes more than just paper knowledge - it is something they can touch, make, assemble, and test. Experience is the best teacher. This is what students experience during their "employment" in AT308, Inc.

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