The Place of Welding in Engineering Education

Shows that a technical program about welding belongs in every engineering program that involves metals

By HOWARD B. CARY*

To some the word "welding" connotates a shower of sparks and smoke in a back alley shop where a mechanic is attaching a trailer hitch to a new car. Unfortunately, many engineering educators have this impression of welding and, when the word is mentioned, it is suggested that it does not belong in the same sentence with the words, "engineering" and "education".

Welding is much more than a method of joining pieces of metal. It is a design concept. It is the only way we can make large monolithic metal structures. It is a manufacturing method. It is a fantastic cost-savings system and, of course, is the most economical way to permanently join metals.

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Welding is encountered everywhere, from the most common items to the most exotic. Our modern day automobile would not be possible at prices we could afford without welding. We would have trouble feeding the world since most agricultural equipment is manufactured by welding. It would be difficult for us to build earthen dams, highway projects, etc., without the all-welded heavy construction equipment. Welding pioneered in the construction of tractors, bulldozers, scrapers, rollers, etc.

Our energy problems would be more difficult without welding. The modern draglines used for coal mining are welded. It is doubtful that we could import liquid natural gas if it were not for welding. We would have difficulty moving people without the all-welded transit bus and the welded hydrofoil for high speed water transportation. We would have trouble moving the goods to markets since railroad rolling stock depends on welding for tough durable equipment. We would not have nuclear power or fossil power without welding. Finally, we would never have gotten to the moon without welding.

These few examples should remind us that welding in one form or another is present in all engineered structures made of metal. Perhaps these examples are convincing proof that welding is important for engineers, particularly student engineers.

"Concern here is with a technical program about welding ...."

In discussing this information with engineering educators, too often the response is, "but we do have welding in our curriculum." More often than not, however, the welding in the curriculum is a vocational skill training program. This is not what I have in mind ; my interest is not in teaching engineers how to weld.

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This type of program belongs in the vocational school, the trade school, some place other than in engineering education.

Concern here is with a technical program about welding, about the different types of welding processes, how to design for welding, the cost of welding, how to ensure quality welds, the metallurgy of welding, the physics of welding, the electricity and chemistry of welding, how codes and standards relate to welding, how welding as a design function competes with other design systems, and if the weldment is properly designed to produce the least costly engineered structure.

A program of this type belongs in every engineering program that involves metals. The structural engineer needs it because all high rise buildings, storage tanks, long span bridges and other engineered structures are welded. They may be field assembled by bolting, but the parts so assembled have been shop welded.

The marine engineering student needs a background in welding. All ocean-going ships are welded ; river barges are welded. In fact, welding was pioneered in the shipbuilding industry. The mechanical engineer must understand welding ; power generating equipment, reactors, boilers, tanks, vessels of all types and power piping are all welded and more and more machinery is welded. The chemical engineer soon learns that every piece of equipment—autoclaves, digestors, cracking stills, etc.—are welded and that welding relates to corrosion which represents the greatest problem of chemical equipment. The industrial or manufacturing engineer needs to know about welding, since welding is one of the widest used manufacturing processes in existence.

The quality control engineer must understand welding since it creates his major challenge for quality. A metallurgical engineer must know welding, the different processess and different techniques, since the metallurgy of welding is far different from classical metallurgy. The aerospace engineer needs to understand welding since the trend in aircraft is towards welding and spacecraft are almost entirely welded. We could go on—mining engineers, petroleum engineers, electrical engineers, automotive engineers, etc. Hopefully, the point has been made.

"There are new technologies that need inclusion in the engineering education program."

What should we have in such a program ? This is perhaps its most difficult aspect, and there are problems to be faced. There are new technologies that need inclusion in the engineering education program. It is difficult to drop programs already included, and many educators feel that welding is so specialized that it deserves scant attention. So the question is, "How can we include welding technical subjects in an already crowded program ?"

The following subjects should be addressed and hopefully included in a technical welding program :

- The different welding processes, their applications, advantages and limitations.
- The relationship to physics and chemistry of the different welding processes. (They are all built on the basics that engineers should know.)
- The relationship of physical properties of metals and gases to welding including heat input, heat output, conductivity, expansion, contraction and their effects on welding.
- The monolithic characteristics of weldments and the stress strain loading at notches or changes of section affecting the life of the part.
- The effect of welding on metals previously work hardened or heat treated.
- Specifications (relating to structures) such as building codes, the Pressure Vessel Code, piping codes, API tank codes, ABS marine code, etc.
- How to specify welding, the process, the filler metals required, and the quality expected.
- How to specify the welds, the quality expected and how it can be assured.
- The relationship of people involved, the qualifitions of procedures, the qualification of welders, the qualifications of other personnel and effects on enc product.

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All of these topics are interrelated. They are based on engineering requirements, and they need engineering judgments. Knowledge of welding greatly increases the accuracy of engineering judgments that must be made.

We have a five-day lecture/demonstration short course entitled, "Welding for Engineers and Supervisors." This is a very popular course attended by many people who are sponsored by their employers. We find there are two types of people attending—supervisors in industrial plants who have good records, but have no knowledge of welding which they are expected to supervise ; and young engineers recently out of school who suddenly find that everything around them is welded but they are ill-equipped to deal with welding.

In talks with many of these young engineers, it is obvious that they have a need to know about welding. It is also obvious that they do not have a need to know how to weld. They find themselves in an industrial environment where about everything they work with is welded and often times the products or services they render use welding, yet they have no technical background on the subject. They have a need to know and by not providing them this type of knowledge in college we are not properly preparing them for the world of work. Let us consider a few illustrations—not to scare one, but to stress the importance that welding technology has to engineers.

". . . an all-welded ship is a monolithic structure whose stress pattern is changing continually. . . . "

Many are familiar with the Liberty Ship failure problem during World War II. Almost a thousand ships sustained some type of structural casualty during the war. Eight ships were lost at sea, four others broke in two, numerous lives were lost.

A very extensive inquiry was conducted and concluded that the failures in welded ships were caused by notches and abrupt changes of section and by the use of steel that was notch sensitive at the operating temperatures. In this regard, an all-welded ship is a monolithic structure whose stress pattern is changing continually while at sea and whose stresses at critical points were many times greater than expected by the designers. Have we explained this to our students ? I am afraid not.

There is also the trailing rear axle assembly of an automobile model currently on the streets of America. Fatigue tests and road tests of this assembly made prior to introduction of the model produced cracks at specific locations in almost every design that was proposed. It is to be noted that this is a welded assembly subjected to torque loading, some impact loading, and service temperatures ranging from the lowest to the highest atmospheric temperatures. It presented an all-too-familiar welding problem and I was asked to suggest a solution.

"a failure of our educational system . . . not providing welding technology in engineering programs"

At a meeting with the designers I asked who was familiar with the ship fracture study during World War II. Not a one. The designs are entirely different, but the problem is very similar. We have a monolithic welded structure different from the box section of ship hull. In this case, a channel member has parts attached and holes or cut-outs and it is continuously under changing stress and temperatures. The failures were occurring precisely where they would be expected—that is, at the change of section—yet no one had the answer. To me, not providing welding technology in engineering programs represented a failure of our educational system.

"losses . . . could be avoided with better knowledge among designers of the technology of welding"

As another example, consider the petrochemical plant that goes up in flames. This type of disorder happens all too often. Petroleum and chemical engineers are always able to reconstruct the facts that lead up to such a disaster. In many cases this can be traced to the use of improper material or the specifying of improper welding materials. These losses are tremendous and could be avoided with better knowledge among designers of the technology of welding.

Such examples are all too commonplace. Engineers are accused of not knowing their business. We have examples of bridge failures due to design details that create notches. We hear of chemical process vessels that last only a few weeks. Many more examples could be provided, but these should be sufficient. The hope here is that engineering educators recognize the importance of welding as a technical engineering subject and, most fo all, the hope is that they do something about it.