Introductory Overview

George A. Alers
Rockwell International

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INTRODUCTORY OVERVIEW

George A. Alers
Science Center, Rockwell International
Thousand Oaks, California 91360

As previously mentioned, the ARPA program is divided into three parts. The major part devoted to defect characterization will be discussed tomorrow. The other parts are the subject of today's program and involve some major NDT problems that are not directly associated with defect characterization in a solid. They have to do with the problem of adhesive bonds, the problem of measuring residual stress and some new techniques that show great promise for failure prediction. The solution of these problems not only requires improvements in our understanding of the physical phenomena involved but they also require translation into a device for use in the field. During today's program, we will cover the four distinct areas of: 1) adhesives and composites, 2) new measurements and techniques, 3) internal stress, and 4) acoustic emission. I will begin by going over the program, pointing out the connections between each of the talks and introducing some of the ideas that tie the subjects together.

The first several talks are concerned with the very important problem of adhesives and composites. Polymers are steadily moving into more and more structural applications, especially in the aerospace industry, because weight and ease of fabrication are assuming greater importance. The adhesive bond is a method of joining metals that is very efficient because it provides the maximum amount of strength for the least amount of weight. Composites, of course, are the ultimate in structural efficiency because the strong fibers can be put in the direction of the loads thereby taking strength away from where it is not needed and putting it where it is needed. Unfortunately, these very efficient materials have not seen broad acceptance because we do not have nondestructive test techniques that will show that the completed part is reliable. We do not have a way of non-destructively testing an adhesively bonded part to assure that the bulk adhesive is at the strength level that it is supposed to be and that it is properly stuck to the metal. Without these kinds of tests, the part has to be terribly overdesigned. In fact, standard practice appears to involve making an adhesive joint to the best of our ability and then boring a hole in it to bolt the members together.

Later in the meeting we will discuss the inspection of new materials. Not only are the composite and the polymer on the horizon as new structural materials, but ceramic materials with their high temperature capabilities will certainly need to be inspected for flaws. Here, the minute size of the critical defect will tax all of the tools that we are developing today and we shall see how important it will be to provide defect characterization capabilities at unusually high frequencies and their application to some old problems such as the measurement of internal stress. There are a lot of black magic and witchcraft methods of processing that extend the fatigue life of a part by putting compressive internal stresses into the surface. Shot peening is the most common, but one must use the right size shot, driven at the right speed for the right length of time before the fatigue life of a metal part is extended. The only available method to insure use so far has been to use x-ray techniques for measuring the stresses in the surface. Unfortunately, the measurement technique is very subtle to use and very easily misinterpreted. There are many other places where residual stresses play an important role on an atomic level; the internal stresses between dislocations and between precipitates control deformation on a microscopic scale. These, in turn, determine the yield strength and the ultimate strength of a metal part. There has always been a dream among nondestructive testing workers to invent a little black box that could be used to give a meter reading of the ultimate strength or the yield strength of a metal. It is my opinion that this ultimate aim will be achieved by some of the work that is being done with nonlinear acoustics as we will hear about later.

Then, there is the field of acoustic emission. Everywhere in nondestructive testing we hear about acoustic emission as the greatest technique now being developed. We have seen it in the testing of very large objects where it is economically impossible to go over every cubic inch of the structure looking for flaws. Acoustic emission has the very powerful capability of locating the flaw by detecting the direction from which the noises come. Once located, some of the defect characterization techniques can be used to assess its criticality and a decision can be made concerning the safety of the entire structure. Unfortunately, after acoustic emission has been used for awhile, a lot of the chief engineers who were in charge of building giant structures began to view the technique with skepticism and used a line from Macbeth to describe their feelings that acoustic emission "is a tale told by an idiot; full of sound and fury but signifying nothing." It is our objective in the advanced NDE field to give some respectability to acoustic emission by learning to understand how it is that the noises are made and how to interpret them so that we can recognize the true flaws and be able to predict better how to use the technique.

Now that I have summarized the problems and payoffs that face us, I would like to go back and go over each area to tell you about our authors and how their work ties together in today’s session.

In composites, the basic geometry is either a sandwich structure consisting of metal plates glued together with an adhesive, or fibers embedded in an epoxy matrix. There are always likely to be gross defects, such as disbanded areas, bubbles and porosity and there may be a subtle lack of adhesion at
the joint between the polymer and the metal or between the epoxy and the fiber that ruins the adhesive strength of the interface and thus deprives the whole part of its strength. These adhesion effects may be on a very small scale, perhaps even on an atomic scale, and thus they will be very difficult to see. There may also be a chemical deficiency in the bulk of the epoxy or adhesive that causes a reduction in its cohesive strength. Our work today is to understand not only how these large defects that are relatively easily seen by x-rays and ultrasonics affect the strength of the part, but also to look at the subtle defects at the interface or in the chemistry of the adhesive itself to see how they play a role in the strength of the part.

Our first speaker, Bill Bascon, from the Naval Research Lab, will set the stage by talking about the role of gross defects as deduced from the fracture mechanics of this kind of layered structure. Then we will turn to one of the main problems with adhesive bonds and polymeric materials, which is the failure of the interface and thus deprives the whole part of its strength. These adhesion problems exist, today's program should show that we are on the verge of having field-applicable techniques for measuring the cohesive strength of a bond. Also, we have got some pretty promising leads for the adhesive strength of that interface between the polymer and the metal. It will take another year's work to provide the statistical basis to prove that these statements are true, but I think we have come from no tests at all to some very specific tests for some specific features of the adhesive bonds.

In the composites area, it was only a few years ago that it was said, "water ruins composites" and everybody had a different idea of how and why this happened. Over the past two years, we and other laboratories have figured out where the water goes, why it does what it does when it gets there, and have even found some physical properties that can be used to measure, in a nondestructive way, that the water has been there or is still there or that the strength has been degraded.

In the area of ceramics, our program is very new and we are using some of the output of the measurement of residual stresses to reflect the stresses that may be in a ferromagnetic material.

I am really most excited about the area of acoustic emission, which has been around for years. During the last two years, there has been a major thrust in the theoretical aspects of what generates the noise and what are its characteristics. We have coupled experimental and theoretical investigations that are already giving us information about what to look for in the frequency spectrum to tell the difference between a crack and a broken precipitate. It won't be too long into the future when we can tell the difference between a crack and the dropping of a wrench on top of a pressure vessel.
MR. MAX WILLIAMS (University of Pittsburgh): Thank you very much. The chair here is very encouraged by the fact that we also have a mechanical device in case the electronics fall apart.

Thank you very much, George Alers. As the next item on the program, we have Bill Bascom from the Navy who will discuss the Durability of Composites and Adhesives.