QUALITY CONTROL OF REINFORCED PLASTICS STRUCTURES

By

Robert W. Matlock

Zenith Aircraft
Gardena, Calif.

The members of the engineering profession who become involved with the design or production of sandwich structures are invariably faced with the difficult problems of quality control. The word "difficult" is used because several years' search by many engineers has still failed to result in any solution which is either considered to be good, or has been adopted as standard practice.

The present methods of quality control consist of the control of the processes of fabrication and the fabrication and testing of sample test coupons. It is usually quite apparent to all concerned -- the fabricator, the inspector, and the engineer -- that these methods are no real solution to the problem, but are make-shift methods which are "better than nothing" or "a step in the right direction".

The author has no quarrel with process control, and in fact recognizes that this type of control is the foundation upon which the structural use of plastics must be built. If for no other reason, careful process control must be maintained to prevent ultimate rejection of fabricated parts. However, the nature of the steps followed in the fabrication of a sandwich structure are not of the type of which it can be said if steps a + b + c + ... n are correctly performed, then the part is correctly fabricated, and therefore, structurally sound. Although the reasoning may be correct in theory, it is simply not true in fact. There are too many variable factors. The limits of what is correct and not correct are too narrow and undefined. The biggest reason of all is, of course, the human element.

The attempt to achieve quality control by the fabrication and testing of sample panels or coupons is considered to be both impractical and dangerous. It is, furthermore, a great source of irritation to those involved in the fabrication of sandwich structures. Again, however, it is not proposed that sample panels and testing be eliminated as a method of quality control. It is an excellent method of checking process control, and should be used as such.

If the present methods of quality control are not satisfactory, then what is the solution? Is there a solution? To these questions can be added a third question. Is there a solution available now, today?

To answer the above questions let us first put our finger directly on the problem by deciding what we wish to accomplish by quality control. We want the part to have a nice appearance, we want it to fit properly, and we want it to perform satisfactorily in service. Since appearance and fit are matters for known and common inspection methods, this aspect will not be further considered here. In the case of performance we must assume that if the part is structurally sound under the loading conditions for which it was designed, then it will perform in a satisfactory manner. To insure this, the actual part must be tested by either equivalent loads, or subjected to equivalent or greater stresses. This is the only sure method of proving that each and every sandwich structure will meet the above requirement of quality.

It appears, therefore, from all of the preceeding discussion that quality control should consist of process control, the fabrication and testing of sample coupons, and of final testing of the finished part. The use of testing as a method of insuring reliability is not common, probably because of the large anticipated costs. However, this is not necessarily true. New developments and new methods appear to be changing this situation. It is felt, therefore, that testing should be made full partner of the previously used methods, thus forming a team of great value and reliability. In the following sections, each method is discussed in greater detail.

Process Control

The term "process control" is used to include control over the basic materials entering the part, and the physical steps followed in its fabrication. This portion of quality control should never be relaxed, even though the finished parts are to be 100% proof loaded. The reason for this is obvious, in that only through adequate control during the fabrication stage can rejection, scrappage, or rework be avoided in the finished part. From an economic standpoint alone, process control during fabrication is a practical requirement

As an example of the quality control measures used by the Zenith Plastics Co. in the fabrication of reinforced plastics sandwiches for radomes and similar structural and semi-structural applications, the following measures are taken to control material quality:

1. Only certified materials are purchased.
2. Glass cloth is inspected for nominal thickness, contamination or dirt, broken fibers, or any other visual defects.
3. Each drum of resin is sampled and tested in the laboratory for gel time and viscosity.
4. Impregnated cloth is tested for resin content.
5. Sample laminates are made into standard tensile test specimens for a check on the combined materials.

In addition to the control for material quality, a rigorous inspection procedure of each step of the fabrication process is followed. As a final check on complete cure the Barcol hardness is taken.

A process similar to that above may easily be developed for other types of sandwich constructions. Although the materials and processes used in metal sandwich constructions, for example, are entirely different, it is quite clear that similar steps may be followed, and suitable controls established

Sample Panels

The extent to which materials and process engineers have relied on sample panel fabrication and testing as a quality control measure is disturbing. It is strongly suspected that the popularity of this method is largely due to the fact that it offers an obvious and palusible method of quality control, and that for the same reasons its defects have been disregarded. A little serious thoughe, however, will indicate at least three major faults.

The primary fault lies in the cost. Although the parts in themselves may be relatively small, it is a well known fact in the industry that the labor costs involved in making a small part are nearly as great as required for a large part. When one considers the general high cost of plastic sandwiches, it is apparent that the cost of sample panels is not inconsiderable. In addition to the cost of the sample itself must be added the cost of testing and the cost of recording and submitting the test results. In addition to all of these costs must be added one more item, and a very important item it is, the complication and interruption of regular production work. Although this last item is difficult to analyze, it is obviously one of considerable importance.

It may be concluded, therefore, that if sample panels and testing are used as a quality control measure, required by a specification, they do not come free. Although the charges for this work may not be listed as a separate and distinct item, it is quite apparent that the charges will be most probably buried in the cost of the parts.

The second point in the case against the test sample is its unreliability in determining whether the production part is sound. Even though the test sample be fabricated at exactly the same time by exactly the same personnel and of exactly the same materials as the finished part, let no one be so naive as to believe that human nature is such that identical care will always be given. Let it be remembered that if the production department makes the samples, and they should, it is the same department which is responsible for the prompt acceptance of the related parts. If anything is to be right, it will undoubtedly be the samples.

Probably the most annoying aspect of test samples is what happens when a test sample fails? Does this mean the part or parts are unsatisfactory? Not necessarily. It means only that the test sample was not good, and that the parts are suspect.

Perhaps the worst case is that in which the test panel passes with colors flying. In this case it might be concluded that the part is satisfactory, a very dangerous assumption indeed.

The third fault is very basic and goes directly to the heart of the matter. As the samples must necessarily be fabricated by the production personnel, it removes the function of quality control from the hands of the inspection department and places it where it should not be -- in the production department. Although it may be logically argued that inspection could supervise the fabrication of the samples, this is not a practical solution. It places the inspector in the role of a policeman with the task of preventing dishonesty, rather than of maintaining quality control.

It is apparent from the previous discussion that the writer has little respect for the method of determining part quality by the fabrication and testing of sample panels. It is argued, however, that the use of sample panels should not be eliminated. It is suggested that their use be limited to a check and statistical control of the quality control process itself, and that they have no relation at all to a specific part. If for no other reason, it is good psychology to run a few test samples through the shop along with the day's production. If there is a gradual deterioration or a radical change in the processes used, it will most likely become apparent through the samples. As long as the results are not taken too seriously, good or bad, and the number of samples made is small, it is felt that only good can come from their use.

In connection with the use of test samples for quality control, it is a source of great wonder to the author that a very close source for good quality control measures has been overlooked. In every plastics shop may be found a considerable number of rejected parts or assemblies. Many of these are rejected for reasons other than structural faults, and provide a great source of test specimens which are not subject to the taint of special care in preparation. It is extremely helpful and advantageous for the structural laboratory to avail themselves to this source of free samples.

In addition to the rejects, it is suggested that consideration be given to removing an occasional production part for test purposes. It may be a surprising fact that a production part may be less expensive than a test sample. In the case of some of the extremely large radomes made by Zenith Plastics Co. this is obviously not the case, but it may be very true for a production run of small parts. In any event the value of a production part for test purposes will be greater than that of several test specimens.

Static Testing

Out of all the thought and discussion that has been expended on the effort to achieve quality control, it is amazing that there has been so little attention given to static testing. It is quite obvious that there is no other approach so direct as that of proof loading each and every part. From the standpoint of the stress engineer this is the ultimate in quality control, a method which proves without doubt that the structure will sustain the loads it was designed to carry. And it is, after all, the stress engineer who is most interested in quality control. It is he who assumes the responsibility for the structural integrity of the part, and it is he who must be satisfied.

Perhaps the reason that static testing has not received greater consideration is that the cost is expected to be high. This may or may not be true. If quality control is put on a dollar-and-cents basis, and it should be, then value is the function which should be considered the determining factor. A small amount of quality control for a small price is no greater value than a great amount of quality control for a larger price.

Furthermore, it is extremely doubtful that comparative cost studies of quality control methods have ever been made. Taking again the case of the sample panels, it is estimated that the cost of fabricating samples, preparing the specimens, and testing, will in many cases be greater than that of attaching a structure to a jig, applying load, and removing the structure. It is assumed, of course, that consideration has been given to the element of time in the design of the jig to facilitate mounting and removal, and in applying the load.

The Zenith Plastics Co. is currently static testing four separate radomes for one of its customers as a routine procedure. That the method of quality control by static testing is regarded as being practical and successful may be deduced from the facts that (1) these static tests began with one radome in 1948, which is still being tested on a statistical basis, and (2) none of these radomes has ever failed or given trouble in service except from accidental damage.

Of the four radomes mentioned above, two are tested on a statistical basis. On the remaining two, each unit is tested. The former two radomes may be described as being large. Of the latter two, one may be called very large and the other extremely large. It may be of considerable interest to show the cost of the static test in relation to the cost of the part. The table below is prepared for this purpose.

Radome No.	Size	Test Cost/Part Cost
1	8' x 9'	.067
2	8' x 9'	.050
3	9' x 15'	.031
4	30' x 20'	.005

The above tests are carried to yield (1.15 limit) load. The jigs were designed for destruction tests on the first units as well as for the proof testing. Consequently, the structure of the jigs is considerably stronger and more expensive than would be required for proof load only. In addition, approximately 95% of the equipment and jiggery used for Radome #3 is also used for Radome #4. It is also available for similar tests on other radomes if required, thus further reducing the cost of additional testing as its utility is increased.

It is sincerely believed that the test costs shown above are not really indicative of what can be done in this direction. Nearly all experience in the field of design of static test fixtures has been pointed toward an ultimate load test fixture. In these cases, speed of installation and removal, and the quick application of load are not problems to be given serious consideration. With an increase in experience in designing and using proof-testing jigs, it is quite apparent that methods of attachment for quick installation and removal of the part will be developed. This is also true of the problem of quickly applying and removing load. The bolt, the nut, and the shot bag can be made as obsolete as the Model "T".