WELDING FOR AEROSPACE APPLICATION

A PANEL DISCUSSION

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A Panel Discussion of Pertinent Problems

The panel was composed of Messrs. Russell Meredith, Engineering Division, S&ID, North American Aviation, Downey, California; Robert Hackman, Staff Engineer, Development Labs, Linde Company, Newark, New Jersey; Frank Wallace, Welding Engineer, Pratt-Whitney Aircraft, East Hartford, Connecticut; P. G. Parks, Welding Development Branch, MSFC, NASA, Huntsville, Alabama; and G. O. Hoglund, Alcoa Process Development Labs, Aluminum Company of America, New Kensington, Pennsylvania.

Selected questions from the attached questionnaire were discussed.

QUESTION: Why is there only a limited amount of aluminum being welded with the MIG process in the aerospace industry?

Meredith - Welding in the horizontal position, joint configuration and distortion are problematic. We had a problem with horizontal welding with MIG getting full penetration without scarfing is the best I can say at the moment. I see beautiful welding done with the MIG process at Douglas. I think in our case this is the reasoning and we did quite a bit of work to start with. We thought this was the route to go, much faster, lots of advantages. I don't think the excessive porosity you get has anything to do with the problem.

Wilson - Would someone on the floor like to take a few minutes and comment on this?

Saperstein (DAC)- I think here we are not really talking about MIG vs. TIG, we're talking about details, the process equipment. The main cause of porosity in aluminum is hydrogen. The main source of hydrogen in aluminum welding is water. I think we have demonstrated to ourselves that by controlling very carefully the water or H_2 potential in the arc atmosphere, you can virtually eliminate the porosity problem. One of the reasons that industry has experienced less porosity in TIG welds than in MIG welds is basically because of the design of the torches. If you bother to take apart any MIG torch that's made today, you will find cork gaskets, rubber "O" rings, and other sealing techniques that I think everyone will agree are far from being good. It takes less than 0.007 cc of water to leak into a shielding gas with a dew point of -80° to cause intolerable porosity. This is an abnormally small amount of water. DAC has gone about eliminating, in all cases, the water potential in the arc atmosphere from the gas bottle used, the transfer lines, the torch design, and the exit dew point of the shielding gas; If at all possible doing this while the torch is being operated. And as a result of these preventive measures that have been taken, we have little problem with hydrogen and water. As I mentioned, it is not the process, but the tool used in the process and in some cases a lack of knowledge as to what is the cause of the problem.

Meredith - I'd like to comment just a little more on this. Actually there are two parts to this why TIG is the desirable process to use. I think porosity differences can be eliminated, but the hydrodynamic head of molten metal you are trying to hold up on the side in horizontal welding is the big problem.

Saperstein - We are doing some square butt welding now in the horizontal position with MIG. It is working satisfactorily, but we are not working with thicknesses that you are talking about. We are welding 3/8".

Meredith - You are not getting excessive sagging?

Saperstein - No. And a lot of this goes in the process of development; details of changing the process to get what you need.

Parks - I'd like to make a comment from observation on the application of the TIG process as it is presently being used and the MIG process as it is

being used by some of the other contractors of MSFC. I think it is much simpler to use the TIG process. Consequently it seems to be that the controls to produce the quality weld required is more easily produced by the TIG process than the MIG. I think people being fundamentally lazy, prefer to use the TIG process in some area than the superior MIG process. As the thickness of the material decreases, the MIG process has a definite place for superior quality welds as compared to those produced by the TIG process. But it is more difficult to control because you are introducing more variables. I have seen evidence from the Boeing people of quality MIG welding on the Y-Ring sections. I think there are some 30 lbs of deposit per joint, and with 3 joints there are some 90 lbs. of metal deposited in the vertical-up position. They have produced rings with 3 joints with as few as 4 repairs.

Saperstein - This torch design problem that I mentioned is something I believe the torch manufacturers should do something about. We have very exotic power supplies, but in some cases we are still dealing with very archaic welding torches.

Wilson - You equipment manufacturers - this is something that you can consider. The second question - cleaning techniques used or recommended for DC straight polarity process.

Parks - Square butt joint welding of 2219 alloy does give a superior joint from the standpoint of distortion, no joint preparation, and higher degree of efficiency. Mainly we have demonstrated that we can penetrate using the buried arc technique. I would say that where we can apply this I would use the process. That eliminates joint preparation and some of the variable required by the MIG process. I would qualify the last sentence of the question - In all positions; position has a teriffic effect on the results, the downhand position produces good results from quality standpoint; vertical-up, excellent results. Horizontal welding is something else. We do find that we can expect a lower quality than we find in the other positions. Again this is related to material thickness and the application of the process. I suspect that an investigation of the MIG process might prove superior in lighter gage material, ¼" and below. Precleaning as necessary to weld soundness, I will start with a question. How clean is clean and what level of cleanliness is required to produce a good weld? I'll answer that by saying I don't know. We do find that the 2219 alloy is super sensitive to contamination but simple contamination is a finger print. It's amazing what a finger print at the butting surface will result in; porosity, cracks, or just about anything. It is that sensitive to cleanliness. Consequently, we have to have parts surgically clean, or as clean as possible. But relating porosity to time, temperature, humidity; I don't think we have all the answers. The parts and pieces must be surgically clean and I can't define surgical cleanliness.

Wilson - Any comments from the floor on recommended cleaning procedures?

Lemmond - I have a question in addition to this cleanliness. Have you run tests to find out just how long you can allow a surface to remain in the atmosphere without forming an excess layer of oxide?

Wilson - First we must define atmosphere and what you mean by it and second we have found problems with delays of only 12 hrs.,yet we have gone as long as 7 days and produced a good weld. Gets into the 3rd question really, environmental control of dust, draft, temperature, etc.

Hoglund - In reference to oxide buildups on aluminum - if the air is clean, the oxide formed after you do your preliminary scraping, or wire brushing, will stay pretty constant. But if you strive to attain the conditions here at NASA which are much cleaner than ours, you will find dust or water on the surface. Other contamination can occur in 5 minutes during a dust storm or you might not have it for a week. So the local conditions determine the answer to your problem as I see it.

Wilson - Isn't humidity quite a factor too? Because it can vary from day to day - say from 90% to 20% or so the same day?

Hoglund - There seems to be a relationship. If the oxides present in aluminum are free of moisture it apparently doesn't affect it. How do you measure surface oxides? If it contains hydrogen, the oxide coating is heavy; yet it contains hydrogen; you are in trouble. It may be as simple as that but we certainly haven't been able to prove it.

I know one time we had to bake the surface. By just plain preheating at 250^{o} made all the difference in the world between sound welds and unsound welds. That preliminary baking had a tremendous effect on porosity and apparently moisture that was absorbed on the surface.

Platz - We have had a lot of comments but I don't think we have really answered the last question as to what cleaning techniques or procedures are recommended.

Parks - The cleaning procedure at MSFC - We have established what we call a countdown in preparation to welding some of the large assemblies - bulkhead, Y-Ring, cylinder, etc. Preparatory to the countdown as we approach the critical time of the cleaning, the cleaning is accomplished by manually scraping the part and washing with alcohol. You have seen the old-fashioned scrappers, there is no steel wool or buffing used.

Platz - This leads to my next question with your so called tongue and groove type joints. It seems to me that this is a rather difficult type joint to try to draw file. We know that the butting faces are prepared by milling. If you accomplish a very good degree of cleaning or clean base metals, and if you weld within a reasonable length of time, you haven't picked up enough oxide to present a problem. One other comment, in a vertical or downhand position weld-- If we had to do this in a horizontal position we would find some other means of holding those parts in alignement.

Meredith - We draw file and scrape the same way, but we have found that this wiping is a problem. The scraping method in our experience is the most satisfactory method, more so than chemical etching or wire brushing. Wire brushing is the poorest. There are other places where chem etching or wire brushing is adequate and much cheaper.

Question - To what extent are welding processes controlled rather than welders being certified for the production of welding?

Wallace - First, I'd like to kick around the word certified. When we talk of certification at United Aircraft, we think in terms of the total process which includes the welder. I am assuming that the requestor had in mind machine welding. This morning it was discussed that semi-automatic welding was a machine that has certain program controls built into it.

It seems to me that it is completely necessary to fulfill this certification by determining first of all the conditions under which the materials in question are to be welded; now I'm talking about process selection, and in a completely all embracing welding development program which now results from this process selection. So it follows logically that once the process and controls are selected and the demonstration completed that this is the route to follow, the people who have been capable of doing this sort of thing or accomplishing this development program should in effect dictate by some mechanism such as process routing sheets which are very explicit and detailed including pictures and isometrics as the case may be so that the word certification or qualification become one. The operator or welder become one. We like to think of a program before giving it to manufacturing as having a complete and thorough shakedown where the welding engineer, his technical people, or technicians at an operating level can at any time de-bug the process before it goes into production by virtually understanding it from having worked with it from its beginning. He should be able to put his finger directly on a problem. Certification is a nebulous thing at this point.

Atkins - Are you saying that development documentation are replacing our old concept of shipyard qualification?

Wallace - I believe this to be the case. In our business of building a conventional air craft engine - You gentlemen in the aerospace or rocketry business know that you don't just walk up to a particular problem which is a design that must be consumated by welding and say that you are going to do this and that. It just doesn't happen. More often than not, you only have one or two tries. After that it's too late. We were discussing this the other day when we were talking about mutilation of weldments as a means of satisfying some quality standard. In reality you produce an inferior product. This is unnecessary if enough preplanning went into the effort before striking the arc to make a particular component.

Seamans - We talked about certification of welders and procedures. What do you think of certification of equipment per se?

Wallace - I tried to cover that by saying that I don't necessarily believe in a mechanism called a certification document to satisfy some QA person because you are working to a spec that has a lot of words written into it. If you have done a good job of analyzing parameters that are necessary to build this component we are talking about, this in itself is automatic certification. You are not going to use a piece of equipment that is inferior to start with. If you have a real costly product that you are going to make, aren't you going to know how to intelligently apply this piece of equipment to do this particular job?

Hutchinson - Will you have problems of repeatability or the thing breaking down somewhere along the line?

Wallace - I presuppose that you are talking about the kind of equipment that is applicable to the amount of money the component you are building costs. If on the other hand you are talking of a job shop operation that involves quality welding, then someone discussed here the need for instrumentation as a means of "in process" control. This perhaps can be construed to be a form of certification.

Hutchinson - There are specifications imposed on the contractor requiring certification of both operators and equipment.

Wallace - Yes, I am a victim of some of those contracts, and I for one know that you must follow the line, but I don't necessarily agree with this.

Weck - It may interest you to know the scheme used in England. This is not the certification scheme, but any equipment manufacturer has to put a new piece of equipment into our labs. We test it and inspect it to the limits of what it is designed to do. The manufacturer then receives the confidential report from us which will reveal all the weaknesses we have discovered in the equipment and subsequently they can carry out certifications of their own. The advantage of this is that we have not an axe to grind. We can do the testing of equipment in a completely disinterested manner whereas if the testing is done at the manufacturers, you always have people involved who themselves were engaged in the development, design, and construction of the equipment.

Hutchinson - At MSFC what certifications do you require?

Wilson - We write the specs. We certify the equipment in manufacturing development and establish the requirements to meet all requirements established by our engineering people. We certify our equipment and people by a performance test which shows at least for that day there are no problems.

Atkins - I don't know of any spec that does not require certification so i don't think you have any choice.

Wallace - My first thought is that a contractor would take a good hard look at the first part he produces by a process, properly tooled, properly engineered, and would decide that here is where we are going to take off from, that this is the base line. I did not mean to imply that there should not be in-process control as you go on. But what better evidence could one want than the first part being successful.

Hoglund - Operator performance qualification is a waste of time, money, and effort and it doesn't contribute to your quality. It is a personnel problem more than a QA problem. All personnel problems are headaches. I'm not talking about performance qualification; I'm talking about the operator and welder. I don't think it adds anything to the picture and we don't answer it by operator qualification. We should start a little action to eliminate this operator qualification.

Wallace - If we look back over the years at the time these specs became mandatory industrically, it was during the war years when there were no standards for a qualified operator. That was some 20 years ago and I think now that they are obsolete as far as operators and equipment are concerned. I know that we have argued for some years as to the unnecessary expense of certifying an operator to a MIL Spec when we still have to train him for a specific job.

Mortimer - We at Boeing were satisfactory with our certification by establishing production conditions. Use production tools and settings and then run your weld to these settings, section your parts for physical and mechanical properties; if you keep these settings, repeatability is very successful.

Wilson - Lets go to another area and leave certification requirements.

Ingram - At the conclusion of the meeting, I'd like to comment on this area about a plan we have been trying to initiate and I hope to get about 30 of you people to participate.

Hackman - Question No. 5 is directed at the development of controls to correct for variables that may occur during the welding process. This is a personal point of view now and not the company's: It's nice to try to control things but first you have to understand them. There are a great deal of things that are not understood about the MIG and TIG welding process, particularly the MIG process. Example: under a step function change in the MIG, it may take upwards of 12 cycles for the system to re-establish equilibrium. This is without regard to the control. This is the self-regulation characteristic---12 cycles. You can do all you want in the way of control and power supply, but you can't beat it. You can put in all relays that you want or take all out that you want, this will effect about 6 to 8 cycles of the response. It does not determine the final readout or level out time. If you accept this, then obviously you are looking for a very quick change or correction to a system. You are not going to get it out of current or voltage; in fact we don't know what you can get it out of. Secondly, it is quite possible to have a MIG arc operating with a good set of recording meters, something that really responds. The arc can visible change lanes in amounts quite easy to see and yet the best voltmeter in the world will not indicate any change because at the point you picked it up, there was no change. This, we believe, is the result of emission change in the wire. There are ways of stabilizing this. If we get the whole system pure enough, the ultimate in shielding gas purity and delivery to the system, you will have a system so unstable, you cannot operate. It requires impurites to make a stable arc. This is a basic law of physics.

Wilson - Any comments from the floor?

Miller - We have done some work in this field and have found that seam welds in the refractory alloys can be tied to the expansion that takes place in the weld. I might comment here even though MIG & TIG are my fields, I know enough about resistance welding to know that it is far more amienable to this type feed back control. And this doesn't mean that you can't get feed back out of MIG or TIG.

Jackson - This X-ray method that Dr. McMasters was talking about yesterday might prove effective on this program.

Meredith- How do you use that process where there is tooling involved?

Jackson - Bob said that was step 2 that we haven't come to yet. You have got to get the tooling out of the way and you have to bring this scanning device within 3/4" of the back of the weld.

Miller Electric - Bob, wouldn't you agree that all of us are attempting to do some development work in the development of programmable controls, however, we all are encountering what you just pointed out. So that the appropriate variables will produce quality welds under varying conditions. Very often we get requests for specs on building welding equipment.

Hackman - It is possible to meet the exact intent or exactly what is down in black and white in a spec for a piece of equipment that may not weld--it's true. The spec does not point out that it also must weld. This is what you judge a machine by, does it or does it not make the product. When you are sometimes groping for response times that are significant, you hope to attach numbers to them that are also meaningful. It is possible to ask for response that is well beyond the system response. I'm sure the builder can build it, but it is possible to build it to where the reliability will go the other way. You want to be careful not to specify things that are really not needed.

__?__ - Isn't it possible that with transistorized circuits we might get a system that could respond within the 12 cycles? There are appearances beyond the horizon that may correct that.

Hackman - Probably any commercial power supply available will meet this requirement, but we have to look at the complete system. The arc is part of the system and it has certain dynamic response characteristics to it. From a metallurgical standpoint that weld is cooling and solidifying and the rate of this is dictated to a large extent not only by power supply heat input but heat transfer away from the weld. That is, what are the heat transfer characteristics? We should not overlook the other components of the system.

Hoglund - The development of programmable controls implies to me a weld process in which changes of certain welding variables will be required. Regardless of how many cycles it takes to accomplish the task. This is one of the design factors that determine whether a piece can be programmed.

Meredith - I think what we are trying to determine is what is actually happening while the weld is being made. You want to be able to make these corrections during the weld and not after the fact. The point that I wanted to make is that these variables are getting attention.

Wilson - I want to combine questions 6 & 15. What is your opinion of the need for the porosity standards now used for the aerospace industry?

Meredith - I would put a note on the side of #15 saying that we need a MIL or NASA standard. Everybody has their own porosity standards. I'm sure that we can live with a lot more porosity than we have. The X-ray people are going to read the X-rays as they want regardless of the spec. I feel that the only porosity problem we have is loss of cross sectional area. If you have a build-up of the weld, you can live with a lot more porosity than if you shave it off.

Seamans - I guess this depends a lot on where porosity lies.

___?___ We can concur with what Dr. Weck said yesterday about aluminum magnesium welds and I don't think it changes too much with alloys. Such things as porosity do not affect strength but anything which gives you a notch and the incipient cracks at the surface.

Tignor - At the Martin Company we are degrading the weld nugget in order to get a satisfactory radiographic conception. We have found that the porosity level in a weld that has been heat treated is not the same as one that has not. Which is for our own good, because when you go back and repair them,you have to go through another heat treat cycle.

Hoglund - One place where porosity distribution is an important factor from a practical standpoint is in the electrode. Nobody has come up with a test for an electrode, so we don't have a test for this porosity distribution you get with it.

Saperstein - What are the aluminum suppliers doing about reducing hydrogen in aluminum?

Hoglund - The materials are fluxed and manufactured to control costs. If the hydrogen in commercial products is too great, we don't know about it and are controlling it according to good commercial practices. I hesitate to say that porosity in welds comes from gas in the metal; it may come from gas on the surface of metal or electrode.

Atkins - If you have a pore, it does not mean that you have gas. In casting you have got shrinkage and this can result in a pore without gas.

Hoglund - Are you encountering porosity in EB welding or are you getting porosity in something else in attempting an EB weld?

Meredith - I think it is porosity. 88% of the porosity is caused by H_2, not other gases.

Saperstein - The porosity problem is aggravated due to the fact that you are working in a vacuum. The size of the pore is inversely proportional to the difference of a partial pressure of hydrogen and the partial pressure of the atmosphere above the molten material.

Hoglund - What you are saying is then that there is gas in the base metal.

Brooks - To add a little ancient history to this picture--several companies back in the 40's were doing some work on the effect of H_2 in aluminum. Some progress was made in the degassing methods and this was cleaned up rather well. In recent years I have not run across this high porosity that existed in the late 40's and early 50's.

Atkins - In EB welding, gas in the metal may be a very important factor, but this hasn't been studied. If this is the case we are in a bad spot. Because to get it any less than it is presently a real tough proposition.

Hackman - I think it is possible to trap inert gas and this might be the problem in an active metal like titanium, anything will react during a weld except an inert gas. So you have to assume that any pores will be caused by an inert gas. On other metals when we have suspected that gases were included in the base metal, we run a vacuum melt of the material prior to the EB weld or whatever other type weld we want to make. Wouldn't this be a very simple test to apply to aluminum?

Wilson - Not on aluminum alloys. That would not apply.

Brooks - To clarify a few things about gas in aluminum---The first problem, and we are doing everything possible to correct it, is the gas on the surface of the metal. The greatest source of moisture when butting two surfaces is right in the middle. You may come to the conclusion then that the gas is coming from the metal when it actually is from the surface.

Meredith - But running bead-on-plate, the spherical pores show up.

Atkins - What about the group that was formed to establish standardizations of aluminum? (To Mr. Ingram)

Ingram - We have endeavored to establish working committees that would be divided in part. I finally received the data in July and we had a starting a committee to evaluate it. We forwarded a letter to Julian Kobler and about three weeks ago he called me. We agreed to get together and establish other factors and get the committee into operation. I'm going to ask you people now as to how many of you are really willing to work on a working committee. Once we have correlated some of this information that is so necessary, there is a group in the AWS who have been working on drawing standards and they have a wealth of information.

Wilson - What is the potential in using plasma for joining?

Hackman - The process as far as my company is concerned is coming out of the development stage. There is equipment out which is being used in production. This is being used almost entirely on two applications; the welding of refractory metal compacts in order to make electrodes for the final refining process and for the welding of stainless steel primarily on tube mills. Here, we are probably more concerned with aluminum. I wish that some of the results we get with stainless could be achieved with aluminum, but so far this has not been the case. It would be a lot of advantage to have a process that would weld the bulkhead to the Y-ring in less than 7½ hours. Potentially, at least, Plasma has this. The difficulty is that the surface conditions leave something to be desired if it is a single pass weld, adding filler metal then perhaps you don't care. We have to work quite a short nozzle to work distances compared to what we can use in other metals. Its got potential, but on aluminum its not around the corner.